Chemical Reactions and Equations - Chapter Outline

Special class

Sushmita • Mar 16, 2022

FUNCTIONAL GROUPS POLLS

CARBON AND ITS COMPOUNDS

CHEMISTRY 101



Sushmita Sharma

- DELHI UNIVERSITY

- Author of Chemistry Textbooks
- PLUS VERIFIED EDUCATOR
- Masters Research Project from Hindu College, DU

SUSHIO





Sushmita

Follow

Expert in CBSE Class 10

Author of Gateway to Science Chemistry 9 & 10 M.Sc. Research Project - Hindu College, DU BSc (Hons) Chemistry - Gargi College DU CODE-SUSH10

2M Watch mins

914K Watch mins (last 30 days)

11K Followers

471 Dedications

Join with us in Telegram

FOR HOMEWORK AND CLASS NOTES CLICK ON:

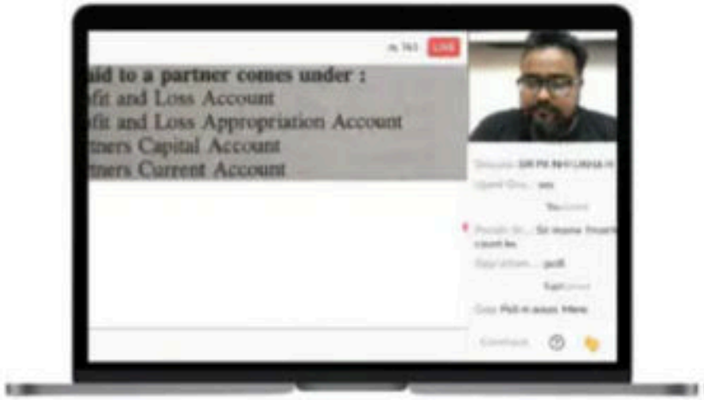
- HTTP://TINYURL.COM/JEEADVMATH

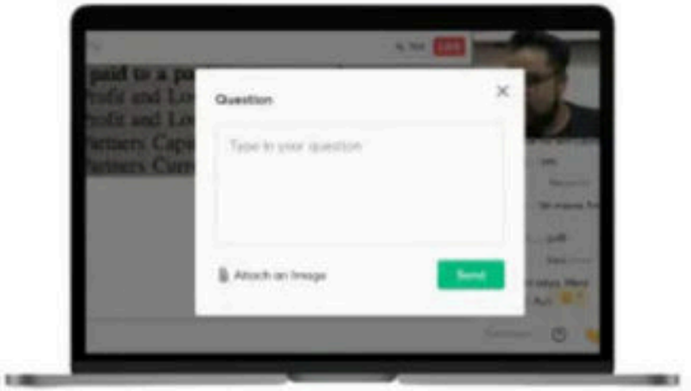
TELEGRAM CHANNEL

- HTTPS://T.ME/SUSHMITASHARMA_UNACADEMY

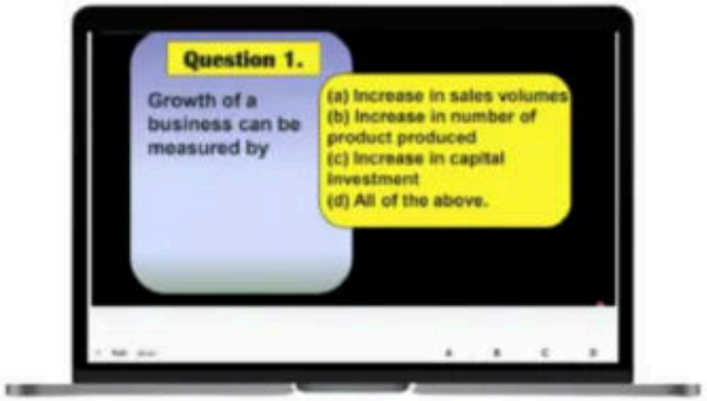


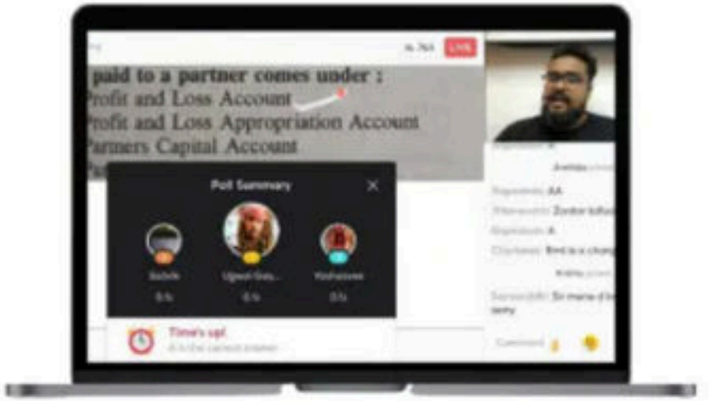
UNACADEMY FREE SPECIAL CLASS FEATURES



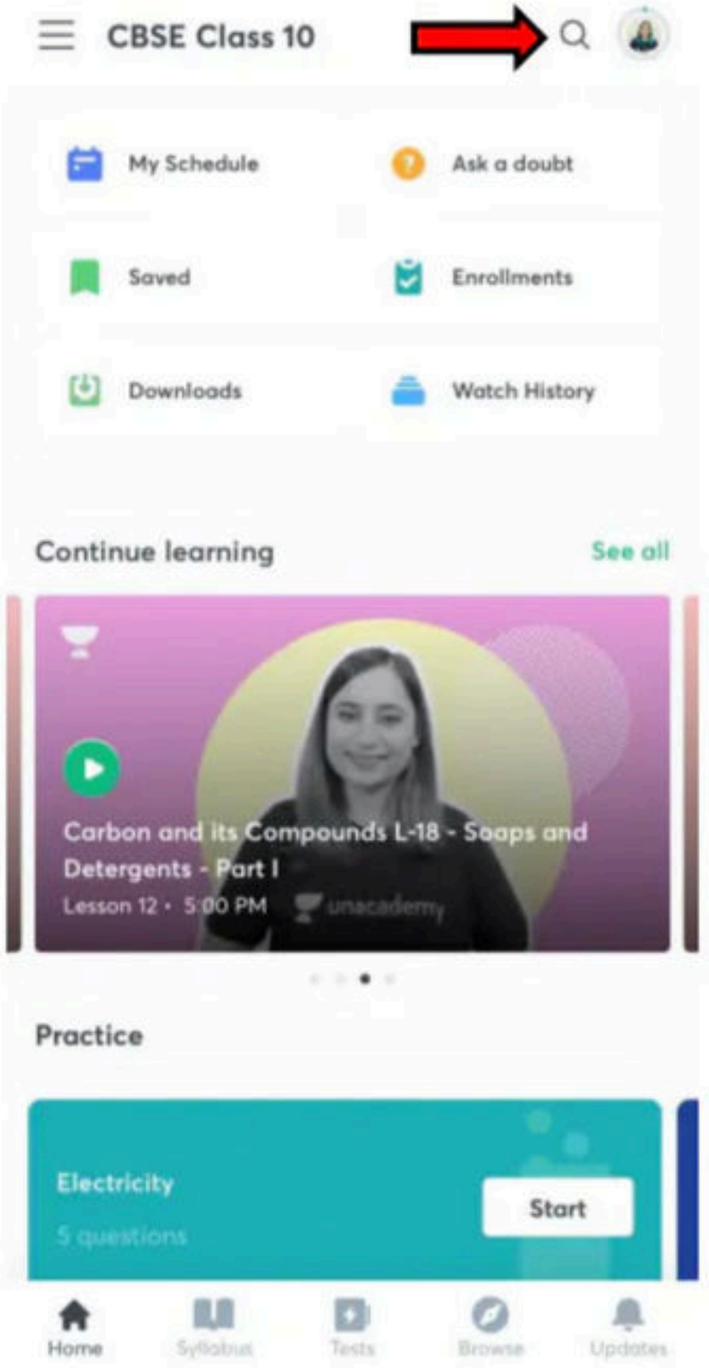


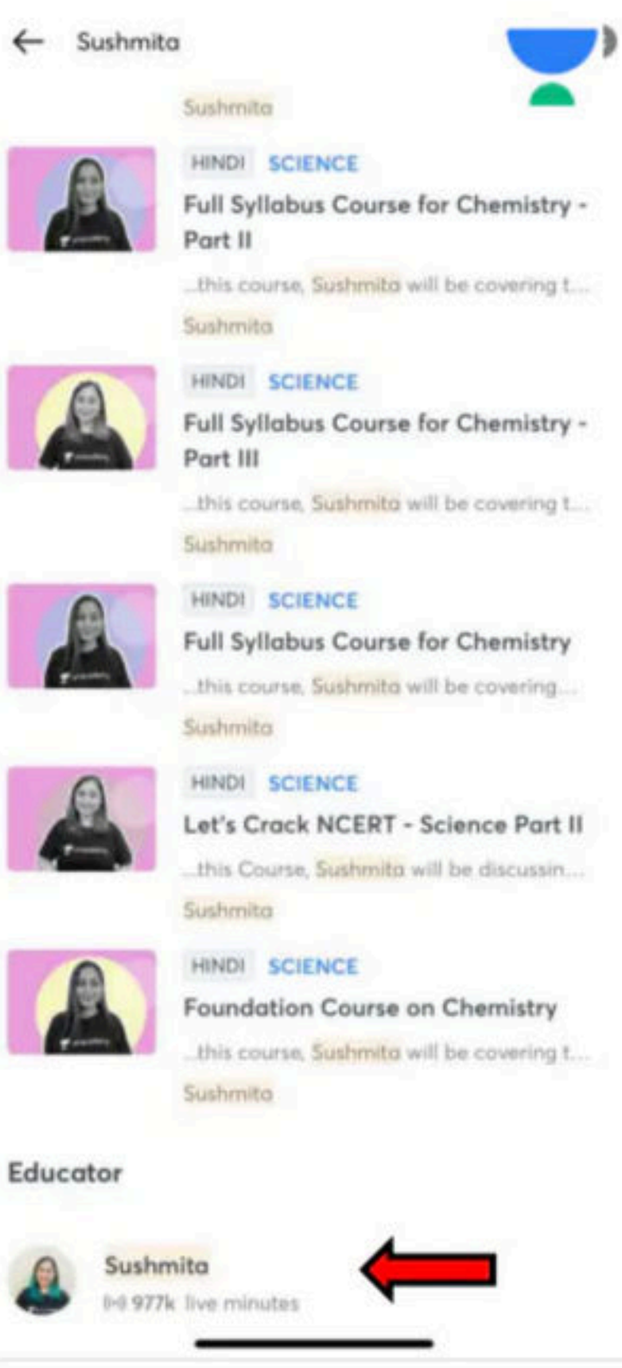
- LIVE REAL-TIME INTERACTION USING CHAT AND EMOJIS!
- ASK QUESTIONS USING THE QUESTIONS TAB

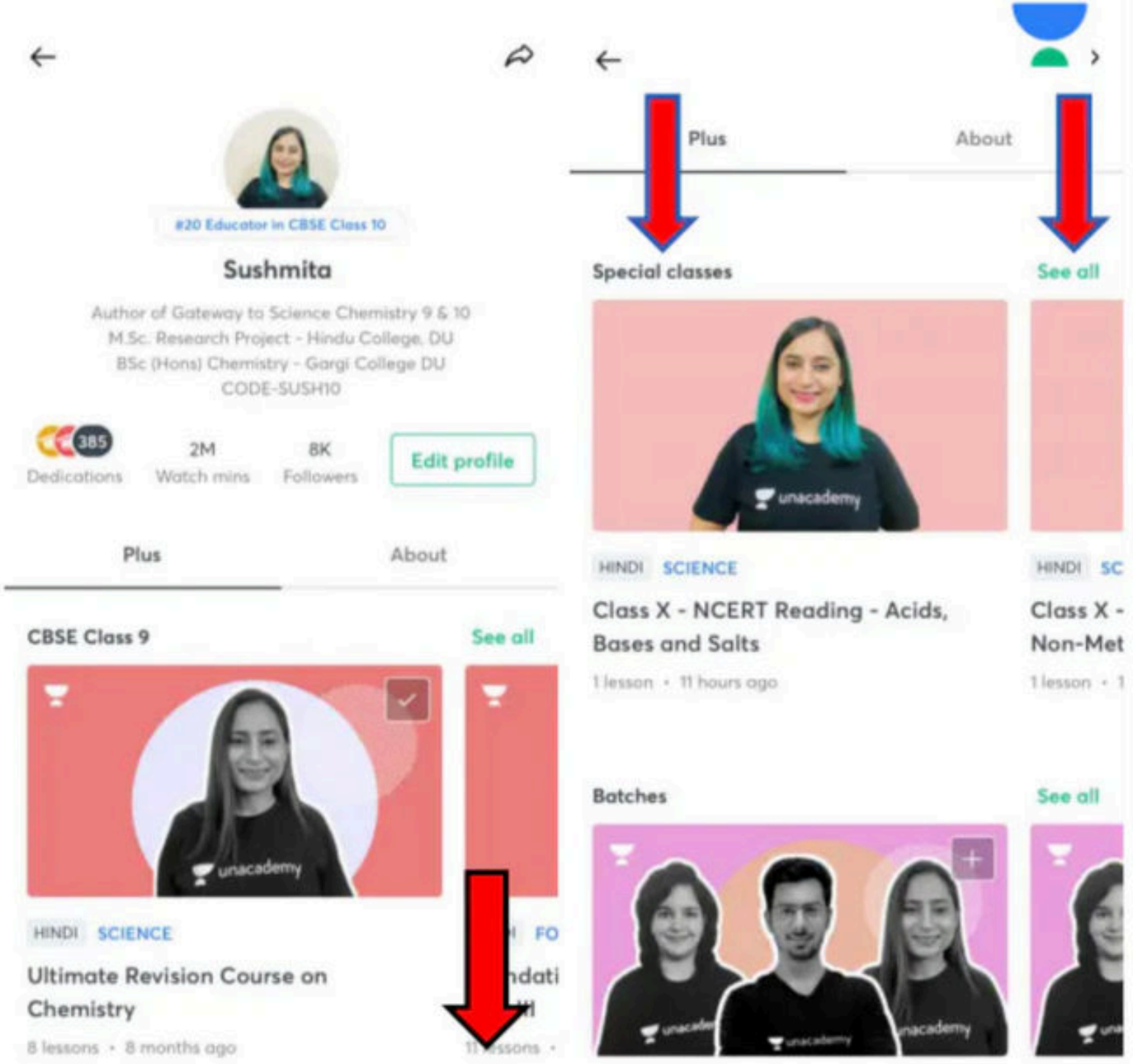




- LIVE POLL OPTIONS FOR QUIZ
- POLL LEADERBOARD - COMPETE WITH YOUR FRIENDS!


CBSE Class 10
My Schedule
Ask a doubt
Saved
Enrollments
Downloads
Watch History
Continue learning
See all
Carbon and its Compounds L-18 - Soaps and Detergents - Part I
Lesson 12 • 5:00 PM
unacademy
Practice
Electricity
5 questions
Start
Home
Syllabus
Tests
Browse
Updates


Sushmita
Sushmita
HINDI SCIENCE
Full Syllabus Course for Chemistry - Part II
...this course, Sushmita will be covering t...
Sushmita
HINDI SCIENCE
Full Syllabus Course for Chemistry - Part III
...this course, Sushmita will be covering t...
Sushmita
HINDI SCIENCE
Full Syllabus Course for Chemistry
...this course, Sushmita will be covering...
Sushmita
HINDI SCIENCE
Let's Crack NCERT - Science Part II
...this Course, Sushmita will be discussin...
Sushmita
HINDI SCIENCE
Foundation Course on Chemistry
...this course, Sushmita will be covering t...
Sushmita
Educator
Sushmita
977k live minutes


#20 Educator in CBSE Class 10
Sushmita
Author of Gateway to Science Chemistry 9 & 10
M.Sc. Research Project - Hindu College, DU
BSc (Hons) Chemistry - Gargi College DU
CODE-SUSH10
385
Dedications
2M
Watch mins
8K
Followers
Edit profile
Plus
About
CBSE Class 9
See all
HINDI
SCIENCE
Ultimate Revision Course on Chemistry
8 lessons • 8 months ago
Plus
About
Special classes
See all
HINDI
SCIENCE
Class X - NCERT Reading - Acids, Bases and Salts
1 lesson • 11 hours ago
Batches
See all

Class 10 - Mission Term II

File Edit View Insert Format Data Tools Extensions Help Last edit was yesterday at 22:59

Share

A1 S.No.

S.No.	DATE	TIME	TOPIC	LINK
1	03-03-2022	20:15	Class 10 - Mission Term II - Flying Start	https://unacademy.com/class/class-10-mission-term-ii-flying-start/HJR6ZDWX
2	04-03-2022	20:15	MISSION TERM II - Versatile Nature of Carbon	https://unacademy.com/class/mission-term-ii-versatile-nature-of-carbon/GZLD0HGK
3	05-03-2022	20:15	Class 10 - Mission Term II - COVALENT BONDING L-1	https://unacademy.com/class/class-10-mission-term-ii-covalent-bonding-l-1/NB1A4E3H
4	06-03-2022	20:15	Class 10 - Mission Term II - COVALENT BONDING L-2 (e- dot)	https://unacademy.com/class/class-10-mission-term-ii-covalent-bonding-l-2-e-dot/END2LY65
5	07-03-2022	20:15	Class 10 - Mission Term II - HYDROCARBONS L-1	https://unacademy.com/class/class-10-mission-term-ii-hydrocarbons-l-1/NATN6HGE
6	08-03-2022	20:15	Class 10 - Mission Term II - HYDROCARBONS	https://unacademy.com/class/class-10-mission-term-ii-hydrocarbons/4A1PCGOJ
7	09-03-2022	20:15		
8	10-03-2022	20:15		
9	11-03-2022	20:15		
10	12-03-2022	20:15		
11	13-03-2022	20:15		
12	14-03-2022	20:15		
13	15-03-2022	20:15		
14	16-03-2022	20:15		
15	17-03-2022	20:15		
16	18-03-2022	20:15		

Sheet1

Explore

ANDROID APP AND WEB

LIVE TEST

unacademy

UNACADEMY COMBAT

CBSE MEGA COMBAT Class 9 and 10

13 March 2022, 11 AM

30 Questions | 45 Minutes

Dont miss your shot at winning Rewards worth ₹1 Crore*



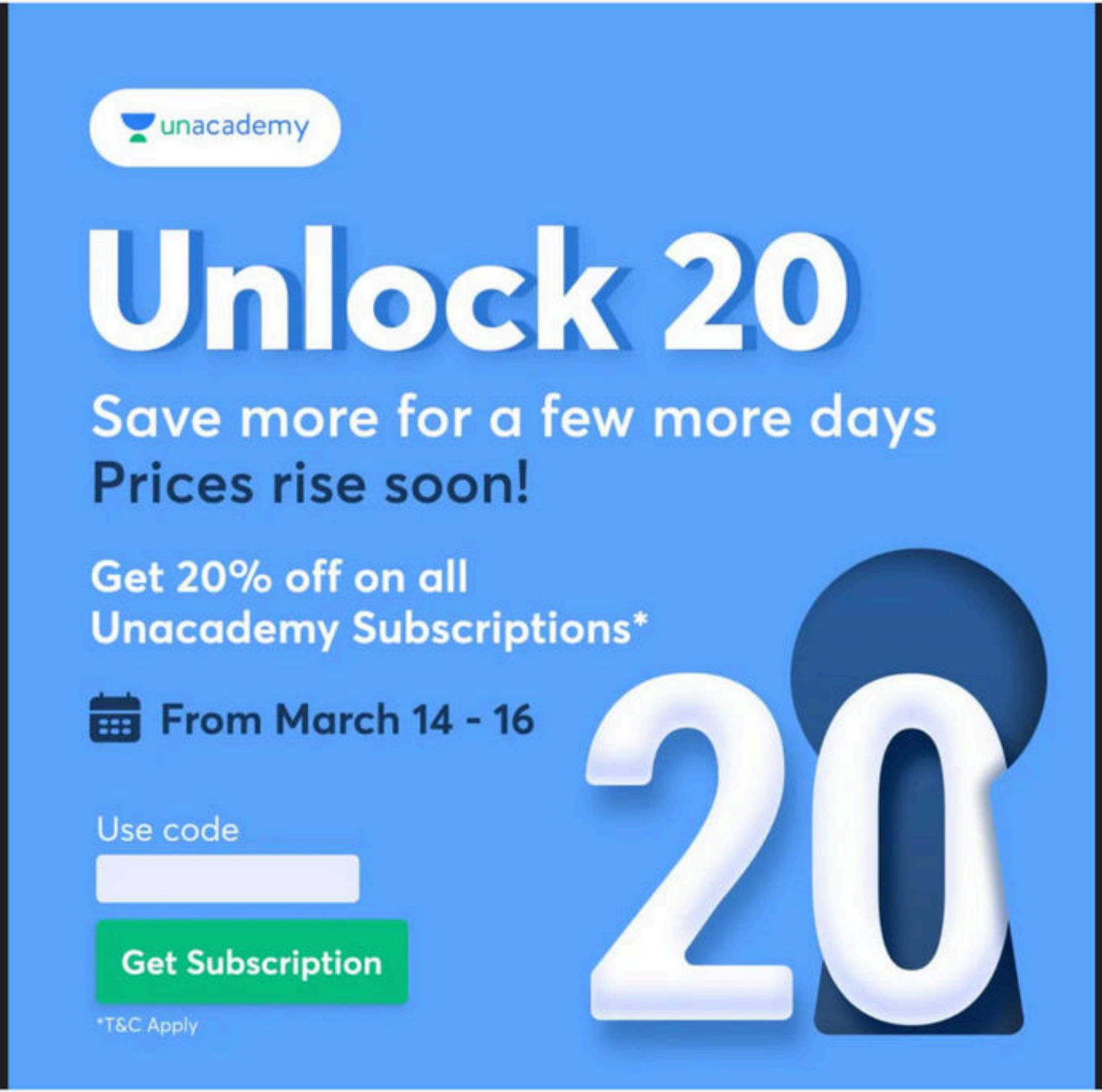
Samsung Mobile | JBL Speaker | Boat Smartwatch | Boat Earpods | Amazon Vouchers

Lucky winners can win amazing gadgets and gift vouchers*

Enroll Now

Use Code _____

*Terms and conditions apply


unacademy
Unlock 20
Save more for a few more days
Prices rise soon!
Get 20% off on all
Unacademy Subscriptions*
From March 14 - 16
Use code
Get Subscription
*T&C Apply
20

Strictly according to the NCERT Textbook and the latest syllabus & examination pattern prescribed by the Central Board of Secondary Education (CBSE), New Delhi

Gateway to Science

Chemistry

With Video Lectures

For Class 10



By

Dr Chand Seth
Former Associate Professor
Department of Chemistry
Hindu College, University of Delhi

Edited By

Akanksha Singh
M.Sc., B.Ed.

Sushmita Sharma
M.Sc., B.Ed.

Pallavi Kaushik
M.Sc., B.Ed.



Scan, Watch & Learn

Scan the QR Code given alongside the topic to watch the video through the MERIT BOX Android Mobile App.

GOYAL BROTHERS PRAKASHAN

GOYAL BROTHERS PRAKASHAN
EDUCATIONAL PUBLISHERS

Sales & Registered Office :
11/1903, Chuna Mandi, Paharganj, New Delhi - 110055
Post Box : 5720, Phones : 43551877 & 43561877
E-mail : info@goyal-books.com
Website : www.goyal-books.com

Administrative Office :
D-231, Sector 63, Noida-201301 (U.P.)
Phone : 0120-4655555

Showrooms :

Ahmedabad : Y-10, Dev Castle Complex Opp. Radhekrishan Villa, Jaymala-Govindwadi Road Isanpur, Ahmedabad-382 443 (Gujarat) **Tel : 09925004030**

Chennai : No. 50/39 Ground Floor, Five Furlong Road Guindy, Chennai-600 032 (Tamil Nadu) **Tel : 044-22552776, Fax : 044-22552767**

Guwahati : Bishop Plaza, Col. J. Ali Road, Lakhtokia, Guwahati – 781001 (Assam), **Phone : 0361-2735337**

Hyderabad : F-7/8/41, First Floor, Agarwal Chambers, 5-9-1121, King Kothi Road, Hyderabad - 500001 **Tele-fax : 23211332**

Kochi : **Fair Heavens, H.No.522783/A, Shine Road, Vytilla, Ernakulam-682019 (Kerala) Phone : 0484-2305288**

Kolkata : No. 203, 2nd Floor, Fomra Towers, 84-A, Acharya Jagdish Chandra Bose Road, Kolkata - 700014 **Phone : 033-22262683**

Bengaluru : 1681/5/4, Ground Floor, 3rd Main Ramamohanapuram, Bengaluru - 560 021, **Phone : 080-23320655**

Bhopal : Plot No. 203, Zone-II, M.P. Nagar, Bhopal-462 011 (M.P.), **Tele-fax : 0755-4271371**

Lucknow : B-318, Sector-B, Mahanagar, Opposite P.A.C Main Gate, Lucknow - 226 006, **Phone : 0522-2320841**

Patna : Ravi Kiran Apartment, Flat No. 2-A, Second floor, Near Water Pumping Station, Pani Tanki Lane, Pirmohani, Patna – 800003

Nagpur : Thakkar Villa House No. 436 Joshirwadi, Sitabuldi, Nagpur - 440012, **Phone :** 9823655077

Disclaimer

Due care and diligence has been taken while writing, editing and printing the book. Neither the author nor the publishers of the book hold any responsibility for any mistakes that may have inadvertently crept in.

To buy our books online log on to www.goyal-books.com

STEPS TO ACCESS FREE ONLINE TEST PACKAGE AND ONLINE SUPPORT

Visit our website www.study.goyalsonline.com or download "Merit Box" (Android App) from Play Store.

A. For website usage
- Click on 'Register Now'.
- Follow the on-screen instructions for registration.

USE CODE: 9789389749571

B. For 'Merit Box' users
- Register with your Mobile Number & Email ID
- Open Q-R Scanner and scan the Q-R Code to subscribe free package.

Q-R Code

For any queries, please reach us at elearning@goyal-books.com

© Reserved

First Edition : 2020
Price : ₹345.00

Published & Printed by
Roshan Lal Goyal for Goyal Brothers Prakashan, New Delhi

PREFACE

Gateway to Science—Chemistry for **Class X** has been written strictly according to the latest syllabus and examination pattern prescribed by the **Central Board of Secondary Education (CBSE)**. While preparing the book, our aim has been to promote understanding of the basic principles of chemistry, and at the same time, retain the excitement of the students.

This student-friendly book teaches Chemistry in such an interesting and comprehensive manner that even an average student will have no difficulty in grasping the fundamental concepts of the subject.

The most important feature of this book is the ample practice of variety of questions which are necessary to assess the learning abilities of the students.

Salient features of the book are:

- Strictly according to the latest **CBSE** syllabus and examination pattern
- **Clear**, **simple** and **easy** language
- Topic-wise **Video Lectures** as a support for effective learning
- **Attractive illustrations/pictures** that help the learners to further clarify the concept
- **Concepts** supplemented by suitable day-to-day examples
- A large number of **chemical reactions** described along with **experimental observations**
- **Periodic Table** showing mass number and atomic number of various elements along with the list of actual names of the elements
- **SAMPLE PROBLEMS** with their solutions as asked in the examination
- Highlighted **important terms** and **definitions**
- **Key Points** at the end of each chapter
- Interesting and informative text under **DID YOU KNOW?**
- Well-designed **exercises** to assess conceptual, reasoning skill and application-based learning as per the latest recommendations of the CBSE board
- Exhaustive questions for each chapter categorised into:
  - (i) Multiple-choice questions
  - (ii) Assertion and Reason
  - (iii) Very short answer type questions
  - (iv) Short answer type questions
  - (v) Long answer type questions
  - (vi) Passage-based questions
  - (vii) Higher Order Thinking Skills (HOTS) questions

We hope that the book will provide a meaningful way of learning the subject, thereby making the whole process of understanding chemistry a joyful experience. It is also hoped that the book will meet the requirements of both the students and the teachers.

Suggestions and constructive criticism for the improvement of the book shall be highly appreciated.

—Author



CONTENTS

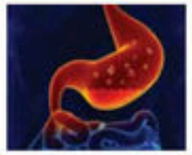
1 Chemical Reactions and Equations ... 1 - 41

u Chemical reactions u Characteristics of chemical reactions u Chemical equations u Balancing chemical equations u Types of chemical reactions • Combination reactions • Decomposition reactions • Displacement reactions • Double displacement reactions – Precipitation reactions – Neutralisation reactions • Oxidation and reduction reactions u Oxidation and reduction reactions in everyday life



2. Acids, Bases and Salts ... 42 - 87

u Acid-base indicators u Acids • Properties of acids u What do all acids have in common u Bases • Properties of bases u Common factor of acids and bases u How strong are acid or base solutions u Universal indicator u Importance of pH in everyday life u Salts u Common salt-a raw material for chemicals u Sodium hydroxide-Chlor-Alkali process u Bleaching powder [$CaOCl_2$] u Baking soda [$NaHCO_3$] u Washing soda [$Na_2CO_3.10H_2O$] u Plaster of Paris [$(CaSO_4)_2.H_2O$] u Water of crystallisation



3. Metals and Non-Metals ... 88 - 136

u Metals • Physical properties of metals u Non-metals • Physical properties of non-metals u How do metals and non-metals react chemically? u Formation of ionic compounds • Properties of ionic compounds u Formation of covalent bond • Properties of covalent compounds u Chemical properties of metals u Chemical properties of non-metals u Extraction of metals • Extraction of metals near the top of metal reactivity series • Extraction of metals in the middle of reactivity series • Extraction of metals low in reactivity series u Corrosion of metals u Alloys



4. Carbon and its Compounds ... 137 - 182

u Occurrence of carbon u Covalent bonding in carbon compounds u Versatile nature of carbon u Allotropes of carbon u Organic compounds u Kinds of formulae of organic compounds u Hydrocarbons • Saturated hydrocarbons • Unsaturated hydrocarbons • Cyclic hydrocarbons u Nomenclature of organic compounds u Isomers u Homologous series u Functional groups • Haloalkanes • Alcohol • Aldelydes • Ketones • Carboxylic acids u Chemical properties of carbon compounds • Combustion of carbon and its compounds • Oxidation of carbon compounds • Substitution reactions of organic compounds • Addition reactions of organic compounds u Important carbon compounds • Ethanol • Ethanoic acid u Soaps and detergents



5. Periodic Classification of Elements ... 183 - 212

u Early attempts at classification of elements • Dobereiner's triads • Newlands' law of octaves • Mendeleev's periodic table u Modern periodic table – long form of the periodic table u Position of hydrogen in the periodic table u Periodicity in the periodic table u Trends in properties • Atomic size • Metallic character • Non-metallic character • Chemical reactivity u Merits of the long form of the periodic table



CBSE Sample Question Paper ... 213 - 220

Chemistry IX

Sushmita Sharma



1 Chemical Reactions and Equations

INSIDE THE CHAPTER

1.1 Chemical reactions
1.2 Characteristics of chemical reactions
1.3 Chemical equations
1.4 Balancing chemical equations
1.5 Types of chemical reactions
- Combination reactions
- Decomposition reactions
- Displacement reactions
- Double displacement reactions
  - Precipitation reactions
  - Neutralisation reactions
- Oxidation and reduction reactions

1.6 Oxidation and reduction reactions in everyday life

UVG0JWA891

INTRODUCTION

A large number of changes take place in our daily life. They may be physical change or chemical change. In **physical change**, substances undergo change in state and shape, but do not undergo any change that **modifies their** chemical composition. For example, melting of ice is a physical change. In **chemical change**, the composition of substance alters and new substances with entirely different properties are formed. For example, burning of wood is a chemical change. These chemical changes occur as a result of chemical reactions.



Fig. 1.1: Melting of ice is a physical change



Fig. 1.2: Burning of wood is a chemical change

1.1 CHEMICAL REACTIONS

Chemical reaction is a process during which one or more substances undergo a chemical change, with the absorption or release of energy, so as to form one or more new substances.

A rearrangement of atoms takes place such that a new substance formed have completely different properties. The existing bonds are broken to form new bonds.

During a chemical reaction, only a rearrangement of elements takes place. The elements present in the reaction do not change into different elements. **The substances which take part in a chemical reaction are called *reactants* and the substances formed after the reaction, the new substances formed are called *products*.**

For example, Hydrogen + Oxygen → Water

Reactants → Products

Chemical reactions are not only carried out in science laboratories, a large number of reactions keep on occurring around us in our daily life. Some of the examples are **burning of fuels, fermentation of grapes, formation of curd from milk, cooking of food, digestion of food in our bodies, process of respiration and rusting of iron**. In a chemical reaction, the amount of reactants keeps on decreasing, whereas that of products keeps on increasing with time, until the reaction is over.

5:05

45 mins

30 mins

1. Punctuality
2. Regularity
3. Google Sheet
4. Consistency
5. Doubts

75 mins

6. Discipline

$$Mg + O_2 \xrightarrow{\text{burn}} MgO + \text{heat} + \text{light}$$

Food

unacademy

▲ 1 • Asked by Prince Kum...

Mam when we add quick lime into water then water starts boiling ? Ye kaise hota hai Mam

$$CaO_{(s)} + H_2O_{(\ell)} \downarrow$$

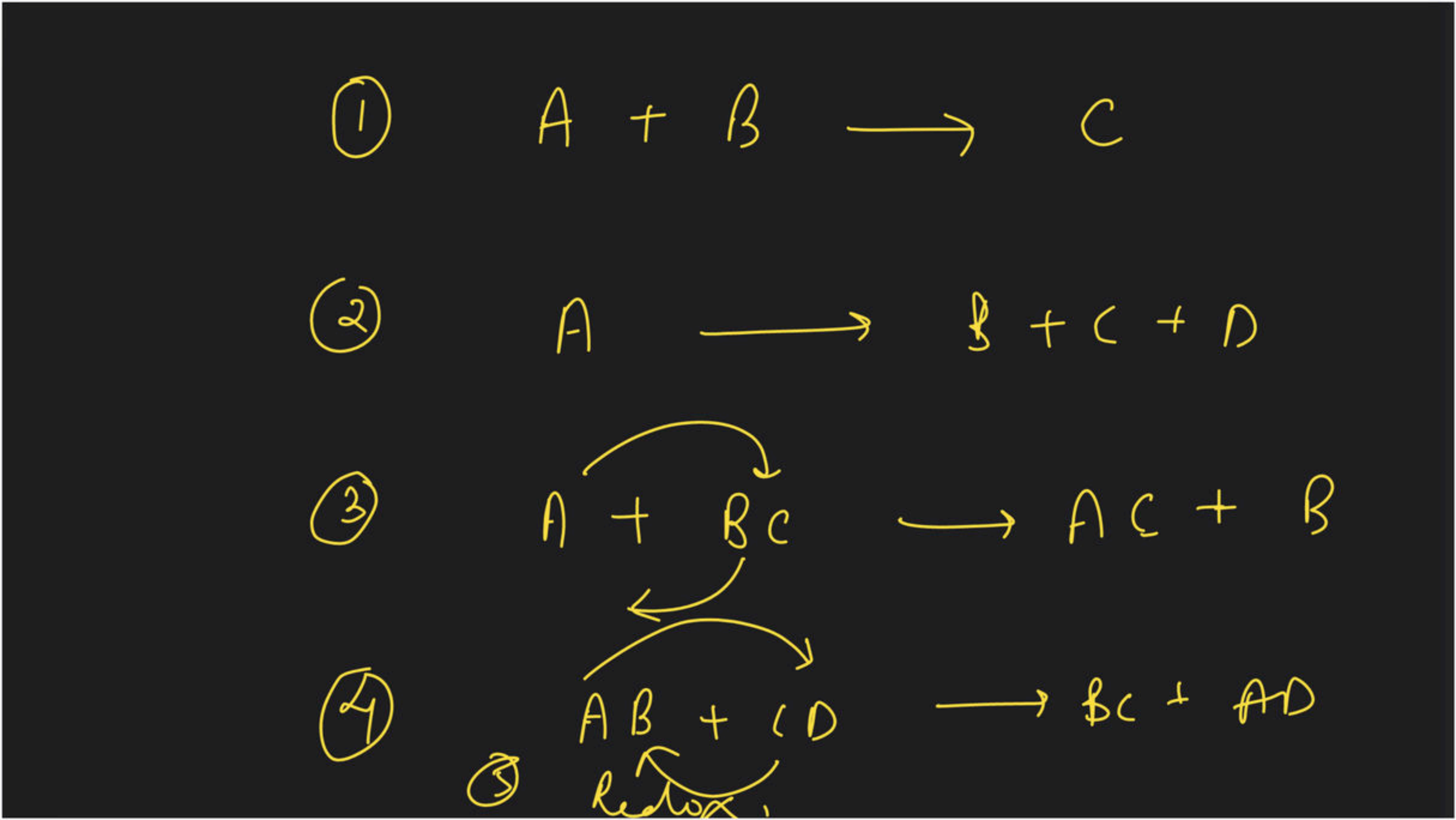
$$\checkmark Ca(OH)_2 + \text{heat} \checkmark$$

unacademy

▲ 1 • Asked by Adityapand...

mam 6 am no class because running pe jata hu mam




1
A + B ⟶ C
2
A ⟶ B + C + D
3
A + BC ⟶ AC + B
4
AB + CD ⟶ BC + AD
5

$$2\,Mg\,(s) + O_2\,(g) \rightarrow 2\,MgO\,(s) + \text{heat} + \text{light}$$

dazzling white light

$$Mg + O_2 \longrightarrow MgO$$

$$2Mg + \overset{\checkmark}{O}_2 \longrightarrow 2Mg\tilde{O}$$

5 characteristics ⟶

1. Change in colour
2. Change in state
3. Change in temperature
4. Formation of a precipitate
5. Evolution of a gas.



dil. H_2SO_4

$$Zn(s) + H_2SO_4\ (aq) \rightarrow ZnSO_4\ (aq)$$



$$ZnSO_4\ (aq) + H_2\ (g)$$

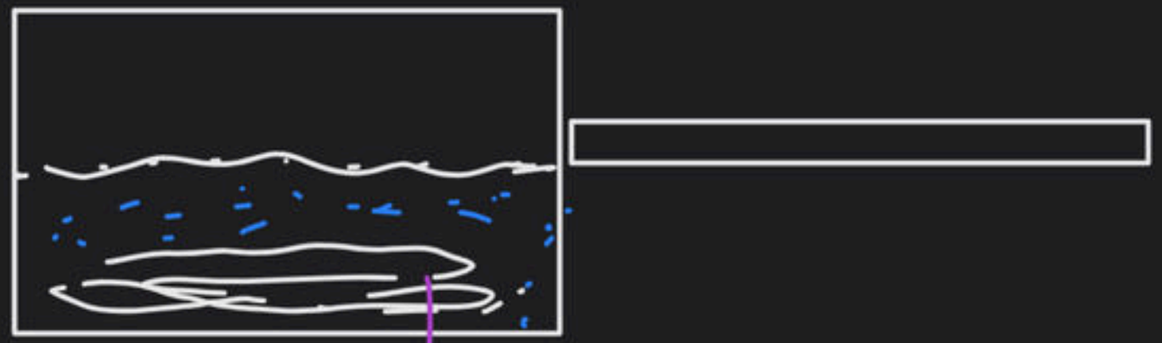


precipitate

$$A + B \longrightarrow C + D$$

A: water soluble

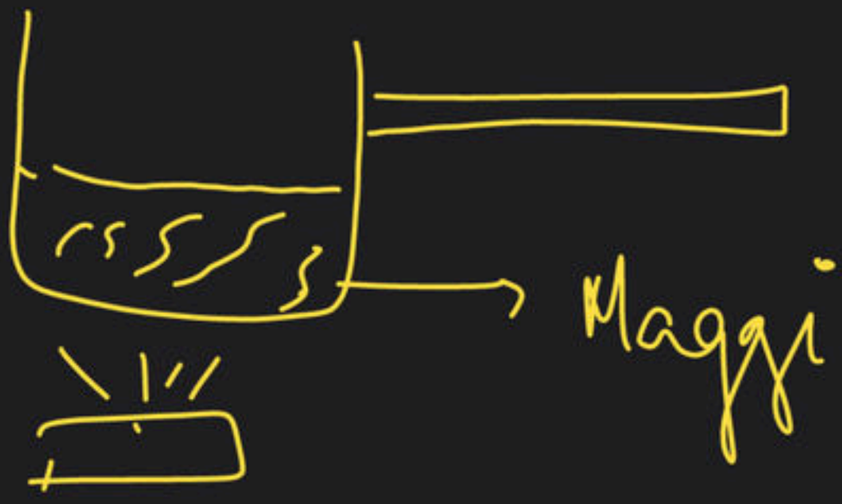
C: insoluble in water

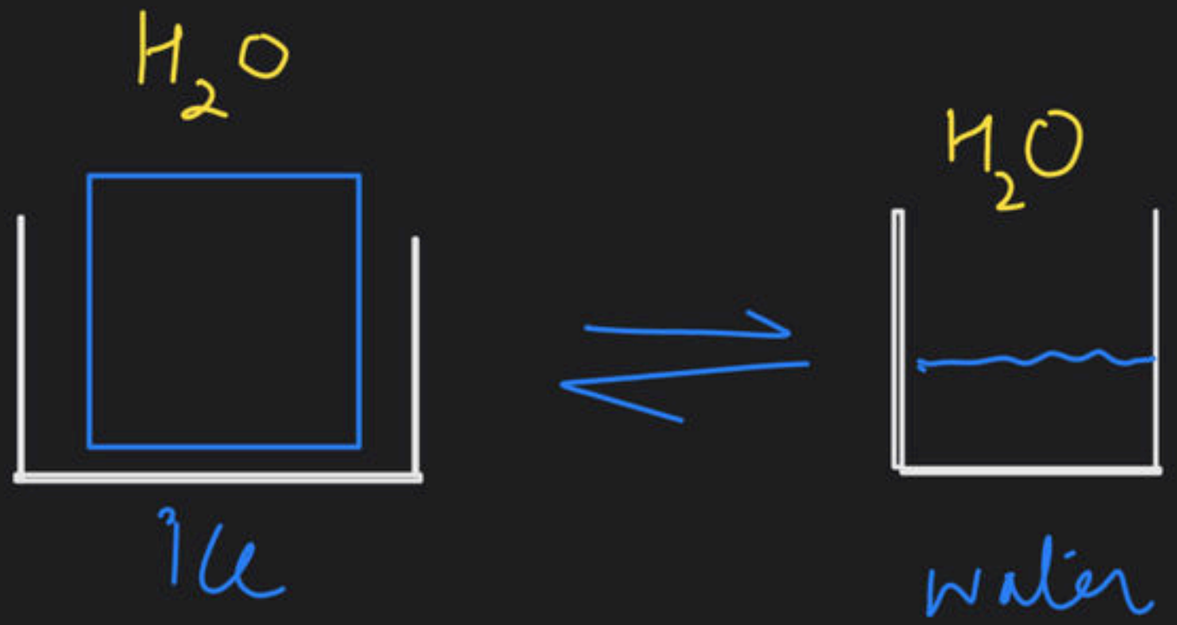


Precipitate

Milk

Colloid


Maggi



Reversible / Physical changes

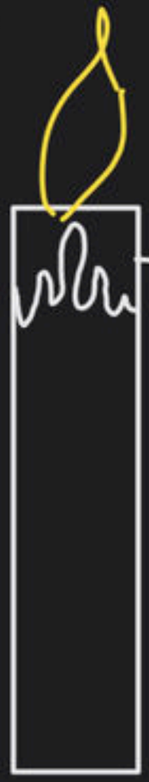
$$\underset{\text{(Carbon)}}{C} + O_{2(g)} \xrightarrow{\text{burn}} CO_{2(g)} + \text{heat}$$

Paper $\xrightarrow{\text{burn}}$ Ash

Chemical changes (irreversible)

Chemical change ✓

Burning of wax

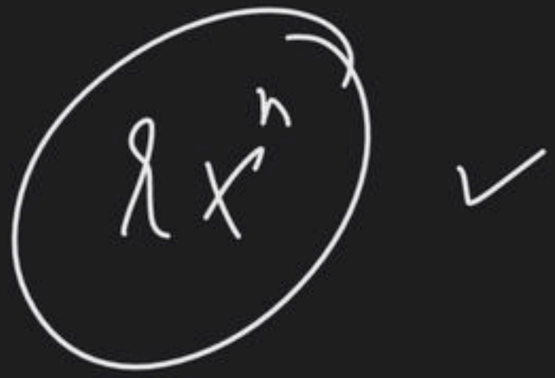


$$\text{Wax} \xrightarrow[O_2]{\text{burn}} CO_2 + \text{steam} + \text{heat} + \text{light}$$

$(H_2O(g))$

→ Melting of wax (physical change)

Chemical change = chemical rx^r



In higher classes you will also study about the rate of chemical reactions, which depends on the following parameters :

1. Temperature
2. Pressure
3. Concentration of the reactants
3. Physical states of the reactants
5. Catalysts used

The most common example of a chemical reaction is burning of magnesium wire/ribbon in air. Magnesium is a silvery white metal and is available in a laboratory in the form of a ribbon/wire. 'Burning in air' basically means that we are carrying out the reaction of any substances by heating in the presence of oxygen gas present in the air. Here, magnesium combines with oxygen on heating to form magnesium oxide.

$$\underset{\text{(Ribbon)}}{\text{Magnesium}} + \underset{\text{(From air)}}{\text{Oxygen}} \xrightarrow{\text{Heat}} \underset{\text{(White powder)}}{\text{Magnesium oxide}}$$

This is a chemical reaction, the two reactants (magnesium and oxygen) react to form only one product (magnesium oxide) that has entirely different properties from those of the reactants.

The magnesium ribbon available in laboratories usually has a coating of 'magnesium oxide' on its surface, which is formed due to the slow action of oxygen at room temperature on it. This layer is removed before burning because it does not let the reaction occur. It is cleaned with the help of a sand paper.



Fig. 1.3: Magnesium ribbon



Fig. 1.4: Magnesium ribbon being burnt in air

The experiment can be performed as follows :

1. Take 5 cm long magnesium ribbon and clean it by rubbing its surface with sand paper.
2. Hold the magnesium ribbon with the help of a pair of tongs and heat the other end over a burner.

We notice that the ribbon burns with a **dazzling white flame**. Hold the burning magnesium ribbon over a watch glass so that the magnesium oxide being formed is collected.

1.2 CHARACTERISTICS OF CHEMICAL REACTIONS

BBSE40HO3M

The conversion of reactants into products in a chemical reaction is accompanied by some features (in most of the reactions) which can be observed. These features (or changes) are known as characteristics of chemical reactions. Before we study about writing chemical equations, let us study the characteristics of a chemical reaction. **The important characteristics of chemical reactions are :**

(i) Change in colour (ii) Change in state (iii) Change in temperature
(iv) Formation of a precipitate (v) Evolution of a gas

Any one of these general characteristics can tell us whether a chemical reaction has taken place or not.

I. Change in Colour

Some chemical reactions are characterised by a change in colour. For example, when citric acid reacts with potassium permanganate solution (purple), the solution loses its colour gradually and becomes colourless. So, this chemical reaction is characterised by a change in colour from purple to colourless. We can perform the reaction between citric acid and potassium permanganate solution as follows (lemon juice is source of citric acid).

(i) Take 10 mL dilute potassium permaganate solution in a test tube. It is purple in colour.

(ii) Add citric acid or lemon juice to it dropwise with the help of a dropper and shake the test-tube simultaneously.



Fig. 1.5: Potassium Permanganate (purple in colour) turning into a colourless solution after reaction with citric acid

(iii) The purple colour of potassium permanganate solution goes on fading and ultimately the solution becomes colourless.

Similarly, when sulphur dioxide gas is passed through acidified potassium dichromate solution, the orange coloured potassium dichromate solution becomes green (see Fig 1.6(b)). Thus, this chemical reaction is also characterised by a change in colour from orange to green.

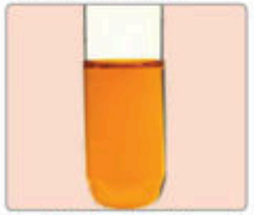


Fig. 1.6(a): Potassium dichromate (orange solution)



Fig. 1.6(b): After passing SO_2 gas, the orange solution of potassium dichromate changes to green

II. Change in State

Some chemical reactions are characterised by a change in state. Burning of a candle is an example of this characteristic. When wax is burned, water and carbon dioxide are formed. Wax is a solid, water is a liquid whereas carbon dioxide is a gas. So during the combustion reaction of wax, the physical state changes from solid to liquid and then gaseous state.



Fig. 1.7: Burning of solid wax produces water (liquid) and carbon dioxide (gas)

III. Change in Temperature

Before we study this characteristic, we must know that calcium hydroxide is known as 'slaked lime' and calcium oxide is known as quicklime. Let us see how temperature changes occur in a chemical reaction of quicklime with water. When we add water to calcium oxide (quicklime), slaked lime is formed and a lot of heat energy is produced due to which the reaction mixture becomes hot. This reaction is an ***exothermic reaction (heat producing reaction).*** This reaction can be performed by following these simple steps.

(i) Take 10 g of quicklime in a hard-glass beaker.
(ii) Slowly add water to it.
(iii) Touch the beaker carefully, it feels quite hot because of the rise in temperature.

The chemical reaction between zinc granules and dilute sulphuric acid and the chemical reaction in which carbon burns in air to form carbon dioxide (combustion of carbon), also releases a lot of heat.

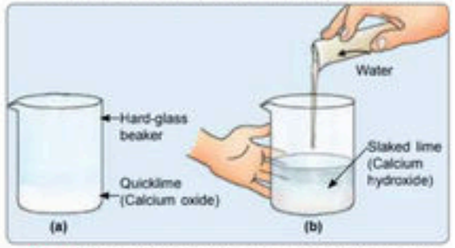


Fig. 1.8: Calcium oxide reacts with water to form calcium hydroxide and a lot of heat is released



Fig. 1.9: Coal burns in air to form carbon dioxide and heat energy is released

Let us now see an example in which heat energy is absorbed. When barium hydroxide [$Ba(OH)_2$] is added to ammonium chloride (NH_4Cl) (taken in a test-tube) and stirred with a glass rod, barium chloride, ammonia and water are formed as a result of the reaction. A lot of heat energy is absorbed during this reaction and the temperature of reaction mixture falls. It is an ***endothermic reaction***, hence decrease in temperature is the characteristic of this reaction.

IV. Formation of a Precipitate



Fig. 1.10: When solutions of lead nitrate and potassium iodide are mixed, a yellow precipitate of lead iodide is formed.

Precipitate is an insoluble substance formed as a product of a chemical reaction, which separates out of the solution. Some chemical reactions are characterised by the formation of a precipitate. For example, when potassium iodide solution is added to a solution of lead nitrate, a yellow precipitate of lead iodide is formed. Here, both the reactant solutions are colourless.

The formation of a yellow precipitate of lead iodide can be easily noticed. Hence it is a characteristic of this reaction. We can carry out this chemical reaction as follows :

(i) Take 10 mL lead nitrate solution in a test-tube.

(ii) Add potassium iodide solution to it.

(iii) A yellow precipitate of lead iodide is formed at once.

(iv) The solution becomes yellow, hence a change in colour is also seen.

In the reaction of lead nitrate and potassium iodide, we used two solutions (liquid) as reactants and obtained lead iodide (solid) as a precipitate. Hence, this reaction also shows change in state.

Similarly when dilute sulphuric acid is added to barium chloride solution (taken in a test-tube) a white precipitate of barium sulphate is formed. Thus, the formation of a white precipitate of barium sulphate is characteristic of this reaction which is easily noticeable.

V. Evolution of a Gas

Let us study a simple example to understand the concept in which gas is evolved during a chemical reaction. When zinc granules react with dilute sulphuric acid, bubbles are produced. These bubbles are of hydrogen gas. We can also use dilute hydrochloric acid in place of dilute sulphuric acid.

We can perform the reaction as follows :

(i) Take 2–3 zinc granules in a conical flask (or a test-tube).

(ii) Add dilute sulphuric acid over the zinc granules.

(iii) The bubbles of hydrogen gas being formed near the zinc granules can be easily noticed.

(iv) On touching conical flask with our hand, we find that it is hot. So, a change in temperature also occurs in this chemical reaction along with the evolution of gas.

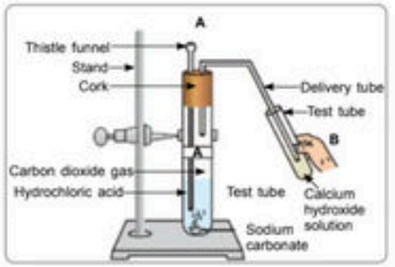


Fig. 1.11: Sodium carbonate solution reacts with hydrochloric acid to produce carbon dioxide gas. This carbon dioxide gas is passed in calcium hydroxide solution.



Fig. 1.12: Dilute sulphuric acid reacts with zinc to produce hydrogen gas. The gas evolves and escapes in the form of bubbles

Similarly when dilute hydrochloric acid is poured over sodium carbonate in a test-tube, carbon dioxide gas is evolved. So, this reaction is characterised by the evolution of carbon dioxide gas.

$$\underset{\text{Hydrochloric acid}}{2HCl(aq)} + \underset{\text{Sodium carbonate}}{Na_2CO_3(s)} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Water}}{H_2O(l)}$$

We have observed all the five characteristics of chemical reaction. We have also studied them in detail for some of the chemical reactions with those more than one characteristics. For example, the chemical reaction between zinc granules and dilute sulphuric acid that we just saw in the last characteristic (evolution of gas) shows two characteristics : evolution of a gas and change in temperature.

Also the chemical reaction between potassium iodide solution and lead nitrate solution shows two characteristics : formation of a precipitate and change in colour.

Assess Yourself – 1

1. What is the difference between a physical change and a chemical change? Explain using examples.
2. What happens to the concentration of reactants during the course of a reaction?
3. Write one example each (reaction) for the following :
   (i) Formation of a precipitate (ii) Evolution of a gas (iii) Change in colour (iv) Change in temperature
4. What do you observe when magnesium ribbon is burnt in air?
5. Burning of a candle is an example of _____ change.
6. What are the two changes that you notice when water is added to quicklime?
7. Write the various forms in which energy is evolved or absorbed during a chemical reaction.
8. What happens when potassium iodide solution is added to a solution of lead nitrate?
9. What are the energy changes that you notice in the reaction of burning of magnesium ribbon?

TZ4V3XKME25

1.3 CHEMICAL EQUATIONS

The description of a chemical reaction *"When magnesium ribbon is heated in air (oxygen), it catches fire and burns to form magnesium oxide."* In the form of a sentence is quite long. It can be done in a shorter way. The simplest way is to write the chemical reaction in the form of a word equation.

The word equation for the above reaction would be :

$$\underbrace{\text{Magnesium + Oxygen}}_{\text{Reactants}} \xrightarrow{\text{heat}} \underbrace{\text{Magnesium oxide}}_{\text{Products}} \quad \ldots(1)$$

A **chemical equation** that represents a chemical reaction briefly in words is called a **word equation**.

The substance/substances, which take/takes part in a chemical reaction is/are called **reactants**. They are always written on the ***left-hand*** side in a chemical equation.

The new substance/substances formed as a result of a chemical reaction are called **products**. They are always written on the ***right-hand*** side in a chemical equation.

- A plus sign (+) is placed in between the reactants or the products, if their number is more than two.
- An arrow (⟶) is put between the reactants and the products. The sign of the arrow (⟶) is read ***"to yield." The arrow points in the direction in which the reaction proceeds.***
- The symbol "Δ" or "heat" is written above the arrow to indicate that the reactants are to be heated.

Writing a Chemical Equation

It is possible to make chemical equations more concise and useful, if we write them using chemical symbols and formulae.

A chemical equation is a statement that describes a chemical reaction in terms of symbols and formulae.

Therefore, equation (1) can be written more concisely by writing symbols and formulae of the reactants and products.

$$Mg + O_2 \longrightarrow MgO \quad \ldots(2)$$

The chemical equation is made concise by using symbols and formulae. Such a chemical equation is called a skeletal equation or an unbalanced equation.

A chemical equation expressed in symbols and formulae, such that the number of atoms of different elements towards the side of reactants is not equal to the number of atoms of the same elements towards the side of products, is called a skeletal equation or an unbalanced equation.

If you notice the reaction of burning of magnesium ribbon, you will see that the number of Mg atoms is same on both sides of the equation while the number of oxygen atoms is not same. This violates the law of conservation of mass which states that, **"the total mass of the reactants is always equal to the total mass of the products."** The equation needs to be balanced, which means that the number of atoms of each element must be same on the reactant and the product side to make the skeletal equation more meaningful. We have to balance the atoms of each element, so that their number is same on the side of reactants as well as products. The equation so formed will be known as **balanced chemical equation**.

A chemical equation in which the number of each element is same on the side of reactants and products, is called a balanced chemical equation.

In the skeletal equation;

$$Mg + O_2 \longrightarrow MgO$$

If, we multiply **Mg** on the side of reactants with **2** and **MgO** on the side of products with **2**, the equation gets balanced.

$$2Mg + O_2 \longrightarrow 2MgO \qquad \text{[Balanced chemical equation]}$$

Pre-knowledge for Writing a Balanced Chemical Equation

Following knowledge is necessary before one proceeds to write a balanced chemical equation.

1. Whether any kind of chemical reaction takes place between the reactants or not.
2. The product/products formed during the chemical reaction.
3. The correct symbols and formulae of all the reactants and the products.

Let us see another example.

Hydrogen reacts with oxygen to form water.

$$H_2 + O_2 \longrightarrow H_2O$$

The number of hydrogen atoms and oxygen atoms in the reactants as well as product are

	In reactants	In product
No. of H atoms	2	2
No. of O atoms	2	1

In this equation, the number of hydrogen atoms is equal in reactants and product, but the number of oxygen atoms is unequal. There are 2 oxygen atoms on the left side but only 1 oxygen atom on the right side. This is a simple equation and can be balanced by Hit and Trial Method. We multiply H_2O by 2 and write $2H_2O$, so that :

$$H_2 + O_2 \longrightarrow 2H_2O$$

Let us count the number of various atoms on both the sides again :

	In reactants	In product
No. of H atoms	2	4
No. of O atoms	2	2

Now the number of oxygen atoms is equal, but the number of hydrogen atoms has now become unequal. To have 4 hydrogen atoms on the left side, we multiply H_2 by 2 and write $2H_2$, so that :

$$2H_2 + O_2 \longrightarrow 2H_2O$$

Let us count the number of various atoms on both the sides once again.

	In reactants	In product
No. of H atoms	4	4
No. of O atoms	2	2

Now we can see that this chemical equation contains an equal number of atoms of hydrogen and oxygen on both the sides of the equation. So, this is a balanced equation and follows law of conservation of mass.



Making Chemical Equations More Informative

SB275C9W38

In the above mentioned chemical equation, you obtained only a balanced raw equation. It does not tell us about the physical states of the reactants and products, the temperature changes during the reaction and other necessary conditions. An equation will only be helpful when it provides all the necessary information.

The chemical equation can be made more informative in the following three ways :

1. By indicating the physical states of reactants and products.
2. By indicating heat involve in the reaction.
3. By indicating the conditions under which the reaction takes place.

1. Indicating the Physical States of Reactants and Products in an Equation.

There are four physical states for the reactants and products of a chemical reaction : solid, liquid, aqueous solution and gas.

Solid state is indicated by the symbol (*s*).

Liquid state is indicated by the symbol (*l*).

Aqueous solution (solution made in water) is indicated by the symbol (*aq*).

Gaseous state is indicated by the symbol (*g*).

The physical states of the reactants and products are indicated by putting these state symbols just after their symbols or formulae in the equation.



Fig. 1.13: Dilute sulphuric acid is an aqueous solution



Fig. 1.14: Zinc granules are solid

For Example

Zinc metal reacts with dilute sulphuric acid to form zinc sulphate solution and hydrogen gas. This can be written as :

$$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$$

Here, zinc metal is a solid, so we write $Zn(s)$

Dilute sulphuric acid is an aqueous solution, so we write $H_2SO_4(aq)$

Zinc sulphate is also an aqueous solution, so we write $ZnSO_4(aq)$

And, hydrogen is a gas, so we write $H_2(g)$.

The above equation can now be written as :

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$$

This equation tells us the physical states of all the reactants and products.

In some cases, an insoluble solid product (precipitate) is formed during the reaction. The insoluble product is a solid substance, so its physical state is indicated in the equation by the symbol (s). For example, when calcium hydroxide solution reacts with carbon dioxide gas, a white precipitate of calcium carbonate and water are formed. The following chemical equation with state symbols of the reactants and products shows the reaction between quicklime and carbon dioxide gas.

$$\underset{\substack{\text{Calcium hydroxide}\\\text{(Lime water)}}}{Ca(OH)_2(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \longrightarrow \underset{\substack{\text{Calcium carbonate}\\\text{(White ppt.)}}}{CaCO_3(s)} + \underset{\text{Water}}{H_2O(l)}$$

In this reaction, we have written 'ppt' under calcium carbonate, indicating that it has been formed as a product and it separates out of the solution due to its insolubility.

2. Indicating Heat Involve in an Equation

(a) Those reactions in which heat is evolved are known as exothermic reactions.

Example: Burning of carbon in air.

When carbon burns in air, it forms carbon dioxide gas. A lot of energy is produced in the reaction. Hence this is an exothermic reaction.

$$C(s) + O_2(g) \longrightarrow CO_2(g) + \text{Energy}$$

An exothermic reaction is indicated by writing "+ Heat" or "+ Heat energy" or just "+ Energy" on the product side of an equation. Our body works with the help of energy. We get this energy from the food. During digestion, food is broken down into simpler substances. The foods like bread, rice and potatoes contain mainly starch (carbohydrate). During digestion, starch (carbohydrate) is broken down into a simple carbohydrate called glucose. This glucose undergoes slow combustion by combining with oxygen to produce energy. This process is called respiration. In addition to other functions, this energy is also responsible for maintaining our body temperature.

During respiration, glucose combines with oxygen to form carbon dioxide and water. A lot of energy is also produced in this reaction.

$$\underset{\text{Glucose}}{C_6H_{12}O_6(aq)} + \underset{\text{Oxygen}}{6O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{6CO_2(g)} + \underset{\text{Water}}{6H_2O(l)} + \text{Energy}$$

Hence, respiration is an exothermic process. Another example that we see in our daily life is combustion of natural gas. It is used as a fuel in our vehicles.



Fig. 1.15: Methane gas used in our households in cylinders, burns in the presence of air to produce heat energy and some light energy.

Natural gas is mainly methane (CH_4). When natural gas burns in the oxygen of air, it forms carbon dioxide and water vapour. A large amount of heat energy is also produced. The chemical equation can be written as:

$$\underset{\text{Methane (Natural gas)}}{CH_4(g)} + \underset{\text{Oxygen (From air)}}{2O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Steam}}{2H_2O(g)} + \text{Heat energy}$$

The burning of natural gas is also an exothermic reaction. All the combustion reactions are exothermic reactions. For example, combustion of fuels such as wood, coal, kerosene, petrol and diesel are all exothermic reactions.

(b) Those reactions in which heat is absorbed are known as endothermic reations. There are many such reactions. For example, all the decomposition reactions require energy (in the form of heat, light or electricity) to take place. So, all the decomposition reactions are endothermic reactions.

For Example, calcium carbonate decomposes to form calcium oxide and carbon dioxide on heating :

$$\underset{\text{Calcium carbonate}}{CaCO_3(s)} + \text{Heat energy} \longrightarrow \underset{\text{Calcium oxide}}{CaO(s)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

Hence, the decomposition of calcium carbonate is endothermic reaction. Photosynthesis is also an example of endothermic reaction. This is because sunlight energy is absorbed during the process of photosynthesis by green plants. It is used by plants to produce food. Another example, when nitrogen and oxygen are heated to a temperature of about 3000°C they combine to form nitrogen monoxide and a lot of heat is absorbed in this reaction :

$$\underset{\text{Nitrogen}}{N_2(g)} + \underset{\text{Oxygen}}{O_2(g)} + \underset{(3000°C)}{\text{Heat}} \longrightarrow \underset{\text{Nitrogen monoxide}}{2NO(g)}$$

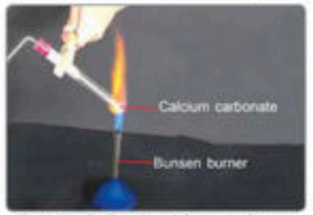


Fig. 1.16: On heating, calcium carbonate decomposes to form calcium oxide and carbon dioxide gas

An endothermic reaction is usually indicated by writing "+ Heat" or "+ Heat energy" or just "+ Energy" on the reactants side of an equation. Another example of endothermic reaction can be electrolysis reactions. Consider the electrolysis of water. Here, water molecules use the electrical energy to dissociate and produce H_2 (gas) and O_2 (gas).

$$2H_2O(l) + \text{Electrical energy} \longrightarrow 2H_2(g) + O_2(g)$$

3. Indicating the Conditions Under which the Reaction Takes Place

If heat is required for a reaction to take place, then the heat sign delta (Δ) is put over the arrow of the equation. If the reaction takes place in the presence of a catalyst, then the symbol or formula of the catalyst is also written above or below the arrow sign in the equation.

For Example : Carbon monoxide and hydrogen gas react to form methanol but this only occurs under certain conditions. Let us see the details.

The mixture of carbon monoxide and hydrogen gases are compressed to 300 atmospheres pressure and then passed over a catalyst (a mixture of zinc oxide and chromium oxide). This mixture is heated to a temperature of 300°C. So the chemical equation for the reaction involved in the production of methanol can be written as :

$$\underset{\text{Carbon monoxide}}{CO(g)} + \underset{\text{Hydrogen}}{2H_2(g)} \xrightarrow[ZnO + CrO_3]{300\text{ atm, }300^\circ C} \underset{\text{Methanol (Methyl alcohol)}}{CH_3OH(l)}$$

Conditions :
Temperature : 300°C
Pressure : 300 atm
Catalyst : ZnO and CrO_3

During photosynthesis, carbon dioxide combines with water in the presence of 'sunlight' and 'chlorophyll' to make food (glucose) and oxygen gas is released. So, we can write a chemical equation for photosynthesis as follows :

$$\underset{\text{Carbon dioxide}}{6CO_2(g)} + \underset{\text{Water}}{6H_2O(l)} \xrightarrow[\text{Chlorophyll}]{\text{Sunlight}} \underset{\text{Glucose}}{C_6H_{12}O_6(aq)} + \underset{\text{Oxygen}}{6O_2(g)}$$

Conditions :
Sunlight and chlorophyll

Note: Formation of precipitate (ppt.) is indicated by downward arrow (↓), and formation of a gas(g) is indicated by an upward arrow (↑).

NXEWCOFMLD

1.4 BALANCING CHEMICAL EQUATIONS

The steps mentioned below are very important and must be followed in order to write a balanced and informative chemical equation.

I. Write the word equation for the chemical equation.
II. Write the equation now with the help of chemical symbols and formulae for elements and compounds respectively for both reactants and products.
III. Balance the chemical equation with the help of hit and trial method.
IV. Make the equation more informative by indicating the physical states of all the reactants and products, the necessary conditions and the energy changes.

Information Conveyed by a Balanced Chemical Equation

Let us take the example of a balanced chemical equation given below :

$$CuO(s) + CO(g) \xrightarrow[250 - 400^\circ C]{\Delta} Cu(s) + CO_2(g)$$

1. A balanced chemical equation tells us about the substances that react and the products formed by the chemical reaction. In the above equation, copper oxide reacts with carbon monoxide to form copper and carbon dioxide.
2. It also tells us about the symbols and formulae of all the substances involved in a chemical reaction.
3. It tells about the number of atoms or molecules of all substances involved in the chemical reaction. In the above equation, one mole of copper oxide reacts with one mole of carbon monoxide to form one mole of copper and one mole of carbon dioxide.
4. It indicates the masses of all substances involved in a chemical reaction.

The above equation tells that 79.54 g of copper oxide, react with 28 g of carbon monoxide to form 63.54 g of copper and 44 g of carbon dioxide. [The masses are calculated by adding atomic masses of elements in a molecule]. It justifies the law of conservation of mass.

Mass of reactants = 79.54 + 28 = 107.54 g

Mass of products = 63.54 + 44 = 107.54 g

5. It also tells us about the physical states of the reactants and products that is CuO and Cu in solid state whereas CO and CO_2 in gaseous state.
6. It tells the necessary conditions that are required to facilitate in carrying out the reaction. The reaction is carried out at temperature in between 250°C and 450°C.

SAMPLE PROBLEMS

1. On adding aqueous solution of sodium hydroxide to an aqueous solution of copper sulphate, copper hydroxide is formed as a precipitate and sodium sulphate remains in the solution. Write this information in the form of a chemical equation.

Ans. In this reaction copper sulphate reacts with sodium hydroxide to form copper hydroxide and sodium sulphate. This can be written in the form of a word-equation as :

Copper sulphate + Sodium hydroxide ⟶ Copper hydroxide + Sodium sulphate

The chemical formula for all the compounds are

Formula of copper sulphate is $CuSO_4$

Formula of sodium hydroxide is NaOH

Formula of copper hydroxide is $Cu(OH)_2$

Formula of sodium sulphate is Na_2SO_4

Putting these formulae in the word-equation, we get :

$$CuSO_4 + NaOH \longrightarrow Cu(OH)_2 + Na_2SO_4$$

The number of various types of atoms in reactants as well as products are as follows :

	In reactants	In products
No. of Cu atoms	1	1
No. of S atoms	1	1
No. of O atoms	5	6
No. of Na atoms	1	2
No. of H atoms	1	2

We find that the numbers of oxygen atoms, sodium atoms and hydrogen atoms are not equal. Let us take the oxygen atoms first. To have 6 oxygen atoms on the left side, we multiply NaOH by 2 and write 2NaOH. Thus,

$$CuSO_4 + 2NaOH \longrightarrow Cu(OH)_2 + Na_2SO_4$$

Let us count the number of various types of atoms on both the sides once again.

	In reactants	In products
No. of Cu atoms	1	1
No. of S atoms	1	1
No. of O atoms	6	6
No. of Na atoms	2	2
No. of H atoms	2	2

This equation contains an equal number of all the atoms on both the sides, so we can say that this is a balanced equation.

Now, to make this reaction more informative, we will indicate the physical states of the reactants and products.



Copper sulphate is an aqueous solution, so we write $CuSO_4(aq)$
Sodium hydroxide is also an aqueous solution, so we write $NaOH(aq)$
Copper hydroxide is formed as a precipitate (solid), so we write $Cu(OH)_2(s)$ or $Cu(OH)_2$(ppt)
Sodium sulphate is in solution, so we write $Na_2SO_4(aq)$
So the equation can finally be written as:

$$CuSO_4(aq) + 2NaOH(aq) \longrightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$$

2. Write a balanced equation for the following reaction :
Methane burns in oxygen to form carbon dioxide and water.

Ans. Word equation for this reaction can be written as :
Methane + Oxygen ⟶ Carbon dioxide + Water
Writing the formula for all the reactants and products :
Formula of methane is CH_4
Formula of oxygen is O_2
Formula of carbon dioxide is CO_2
And, Formula of water is H_2O
Substituting the formulae of all the substances in the above word equation, we get :

$$CH_4 + O_2 \longrightarrow CO_2 + H_2O$$

The numbers of various atoms in reactants and products are :

	In reactants	In products
No. of C atoms	1	1
No. of H atoms	4	2
No. of O atoms	2	3

We can see that the number of hydrogen atoms and oxygen atoms is not equal we multiply H_2O by 2 and write $2H_2O$. The equation now becomes :

$$CH_4 + O_2 \longrightarrow CO_2 + 2H_2O$$

Counting the number of various atoms on both the sides again, we get :

	In reactants	In products
No. of C atoms	1	1
No. of H atoms	4	4
No. of O atoms	2	4

Only the number of oxygen atoms is unequal now. We multiply O_2 by 2 and write $2O_2$:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

To make it more informative, we can write the states of all the elements and compounds.
CH_4 (methane) is a gas so we write $CH_4(g)$
O_2 (oxygen) is a gas so we write $O_2(g)$
CO_2 (carbon dioxide) is a gas so we write $CO_2(g)$
When methane burns in oxygen, water vapour is formed, so we write $H_2O(g)$. Also, a lot of heat is released during this reaction, it is exothermic in nature. So, on writing the equation, finally we obtain :

$$CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(g) + \text{Heat Energy}$$

We indicated the evolution of heat by writing 'heat' on the product side.



3. Write the balanced chemical equations for the following chemical reactions.

(i) Hydrogen + Chlorine ⟶ Hydrogen chloride

(ii) Barium chloride + Aluminium sulphate ⟶ Barium sulphate + Aluminium chloride

(iii) Sodium + Water ⟶ Sodium hydroxide + Hydrogen [NCERT]

Ans. (i) Formula of Hydrogen is H_2

Formula of Chlorine is Cl_2

(Because hydrogen and chlorine react in gaseous phase, and they exist in molecules in gaseous state)

Formula of hydrogen chloride is HCl.

Substituting the formulae in the word equation,

$$H_2 + Cl_2 \longrightarrow HCl$$

We can see that neither hydrogen nor chlorine is balanced in the equation. By multiplying HCl by 2, we can obtain a balanced chemical equation.

$$H_2 + Cl_2 \longrightarrow 2HCl$$

Now, we have the balanced equation for this reaction. We will now state the physical states of the reactants and products. All the three are gases in this reaction. So, the final equation will be

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g).$$

(ii) Formulae for all the reactants and products given in the above word equation are :

Barium chloride ⟶ $BaCl_2$

Aluminium sulphate ⟶ $Al_2(SO_4)_3$

Barium sulphate ⟶ $BaSO_4$

Aluminium chloride ⟶ $AlCl_3$

Here, you have to keep in mind that sulphate (SO_4^{2-}) is a radical and can be balanced as a unit. We do not need to balance sulphur and oxygen one by one. It can be balanced at once.

Substituting the formulae in the word equation,

$$BaCl_2 + Al_2(SO_4)_3 \longrightarrow AlCl_3 + BaSO_4$$

We can notice that only the number of barium atoms is same on both the sides. So, we will start balancing Aluminium first. Multiply $AlCl_3$ by 2.

We can now see that the number of aluminium atoms is same on both the sides. Now for balancing chlorine, we multiply $BaCl_2$ by 3.

$$3BaCl_2 + Al_2(SO_4)_3 \longrightarrow 2AlCl_3 + BaSO_4$$

Now, we are only left with barium and sulphate ions.

To balance these two, we multiply $BaSO_4$ by 3.

$$3BaCl_2 + Al_2(SO_4)_3 \longrightarrow 2AlCl_3 + 3BaSO_4$$

Now, we have a balanced chemical equation. Next step is to indicate the physical states. $BaCl_2$, $Al_2(SO_4)_3$ and $AlCl_3$ are aqueous solutions, so we write '(aq)' and $BaSO_4$ is a precipitate, so we write '(ppt)' and '(s)'.

$$BaCl_2(aq) + Al_2(SO_4)_3(aq) \longrightarrow 2AlCl_3(aq) + \underset{\text{(ppt)}}{3BaSO_4(s)}$$

This is the final balanced equation for this reaction.

(iii) Here, sodium reacts with water to form sodium hydroxide and hydrogen.

Word equation for this reaction is,

Sodium + Water ⟶ Sodium hydroxide + Hydrogen

Substituting the symbols and formulae in the word equation,

$$Na + H_2O \longrightarrow NaOH + H_2$$



This equation has two H atoms on the left side but three H atoms on the right side. So, we multiply H_2O by 2 and NaOH also by 2 so as to have an equal number of H atoms (4 each) on both the sides :

$$Na + 2H_2O \longrightarrow 2NaOH + H_2$$

Now we have one Na atom on left side but two Na atoms on the right side. So, we multiply Na by 2. Now we obtain the following equation :

$$2Na + 2H_2O \longrightarrow 2NaOH + H_2$$

This equation contains an equal number of sodium, hydrogen and oxygen atoms on both the sides. It means that this is a balanced equation. Now mentioning the states of all the reactants and products.

Sodium is a solid (s), water is a liquid (*l*), sodium hydroxide is an aqueous solution (*aq*) whereas hydrogen is a gas (*g*). So, we can write the above chemical equation with state symbols as follows :

$$2Na(s) + 2H_2O(l) \longrightarrow 2NaOH(aq) + H_2(g)$$

4. Write a balanced chemical equation with state symbols for the following reaction:
Heated iron metal reacts with steam to form iron (II, III) oxide, (Fe_3O_4) and hydrogen.

Note: Before we answer this question we should know about the oxides of iron metal. Iron (Fe) forms two main oxides :

(i) **Iron (II) oxide, FeO.** This is called iron (II) oxide because the valency of iron in it is two. The common name of iron (II) oxide, FeO, is ferrous oxide.

(ii) **Iron (III) oxide, Fe_2O_3.** This is called iron (III) oxide because the valency of iron in it is three. The common name of iron (III) oxide, Fe_2O_3, is **ferric oxide**.

Fe_3O_4 is the third oxide of iron. Actually Fe_3O_4 is a mixture of iron (II) oxide FeO and iron (III) oxide, Fe_2O_3. So, Fe_3O_4 is called iron (II, III) oxide ($Fe_3O_4 = FeO + Fe_2O_3$). The common name of Fe_3O_4 is magnetic iron oxide.

Ans. Word equation for this reaction is :

$$\text{Iron} + \text{Steam} \longrightarrow \text{Iron (II, III) oxide} + \text{Hydrogen}$$

Now, Symbol of iron is Fe
Formula of steam is H_2O
Formula of iron (II, III) oxide is Fe_3O_4
Formula of hydrogen is H_2

Writing the symbols and formulae of all substances in the above word equation,

$$Fe + H_2O \longrightarrow Fe_3O_4 + H_2$$

We can see that we have unequal number of iron atoms on reactant and product side. So to balance the number of Fe atoms, we multiply Fe by 3.

$$3Fe + H_2O \longrightarrow Fe_3O_4 + H_2$$

Now the number of iron atoms is equal on both sides and the number of hydrogen atoms is also equal, the number of oxygen atoms is not equal. We multiply H_2O by 4 and write it as 4 H_2O. This will give us :

$$3Fe + 4H_2O \longrightarrow Fe_3O_4 + H_2$$

We can see that the number of hydrogen atoms is now unequal. Now, to get 8 hydrogen atoms on the right side, we multiply H_2 by 4. This gives us the following equation :

$$3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2$$

The above chemical equation contains an equal number of Fe, H and O atoms in the reactants and products, so we have obtained a balanced chemical equation now.

Iron (Fe) is a solid, steam (H_2O) is a gas, iron (II, III) oxide (Fe_3O_4) is a solid and hydrogen (H_2) is a gas.

So, we can write the above chemical equation as follows :

$$3Fe(s) + 4H_2O(g) \longrightarrow Fe_3O_4(s) + 4H_2(g)$$



5. Translate the following statement into chemical equation and then balance the equation :
Hydrogen gas combines with nitrogen to form ammonia. [NCERT]

Ans. Word equation for this reaction is :

Hydrogen + Nitrogen ⟶ Ammonia

Substituting the formula of elements and compounds.

Or $H_2 + N_2 \longrightarrow NH_3$

This equation has two H atoms on the left side but three H atoms on the right side. So, we multiply H_2 by 3 and NH_3 by 2 so that each side has 6H atoms:

$$3H_2 + N_2 \longrightarrow 2NH_3$$

Now, this equation contains an equal number of hydrogen atoms and nitrogen atoms on both the sides, so this is a balanced chemical equation.

We will now mention the physical states of all the reactants and products. Hydrogen, nitrogen and ammonia, are all gases, so we can write the above equation with state symbols as follows :

$$3H_2(g) + N_2(g) \longrightarrow 2NH_3(g)$$

6. Lead nitrate crystals on strong heating decompose to form lead monoxide, nitrogen dioxide gas and oxygen gas. The reaction can be written in the form of the chemical equation as under :

$$Pb(NO_3)_2 \longrightarrow PbO + NO_2 + O_2$$ [Skeletal equation]

Ans. We have the skeletal equation.

$$Pb(NO_3)_2 \longrightarrow PbO + NO_2 + O_2$$

We can see that nitrogen and oxygen have unequal number of atoms on the reactant and product side, so we multiply NO_2 by 2.

$$Pb(NO_3)_2 \longrightarrow PbO + 2NO_2 + O_2$$

Now we have equal nitrogen atoms but oxygen and lead are still unbalanced. We multiply $Pb(NO_3)_2$ and PbO by 2.

$$2Pb(NO_3)_2 \longrightarrow 2PbO + 2NO_2 + O_2$$

Now, we have unbalanced N atoms and unbalanced O atoms again. Multiplying NO_2 by 4, we obtain,

$$2Pb(NO_3)_2 \longrightarrow 2PbO + 4NO_2 + O_2$$

We can see that all the atoms are equal on both the sides. We will now indicate the physical states for all the reactants and products. Also, for heating, we write delta (Δ) above the arrow.

Lead nitrate is a solid, lead monoxide is a solid, oxygen and nitrogen dioxide are gases. So, the final balanced equation will be :

$$2Pb(NO_3)_2(s) \xrightarrow{\Delta} 2PbO(s) + 4NO_2(g) + O_2(g)$$

Exercise–1 (A)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

1. A chemical reaction is characterised by:

(A) a change in state
(B) formation of new products
(C) evolution or absorption of energy
(D) all the above.

2. Which one amongst the following is a complete balanced equation?

(A) $2Al(s) + 3H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3$ (l) $+ 3H_2(g)$
(B) $2Al(s) + 3H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3$ $(l) + 3H_2(g)$



(C) $2Al(s) + 3H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3\ (aq) + 3H_2(g)$
(D) $2Al(s) + 3H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3\ (aq) + 3H_2(g)$ + Heat

3. Regarding balanced chemical equation which one of the following is incorrect?
(A) It tells about the rate of reaction.
(B) It tells the ratio of masses of the reactants and products.
(C) It saves time and space in expressing a chemical reaction.
(D) It tells the physical states of the reactants and products.

4. Which one of the following processes involves chemical reactions?
(A) Storing of oxygen gas under pressure in a gas cylinder
(B) Liquefaction of air
(C) Keeping petrol in a china dish in the open
(D) Heating copper wire in presence of air at high temperature [HOTS]

5. Which of the following is not an endothermic reaction?
(A) $CaCO_3 \longrightarrow CaO + CO_2$
(B) $2H_2O \longrightarrow 2H_2 + O_2$
(C) $6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$
(D) $C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O$

6. The chemical equations are balanced to satisfy one of the following laws in chemical reactions. This law is known as :
(A) law of conservation of momentum
(B) law of conservation of mass
(C) law of conservation of motion
(D) law of conservation of magnetism

7. The chemical reaction between quicklime and water is characterised by :
(A) evolution of hydrogen gas (B) absorption of heat
(C) change in temperature of mixture (D) change in colour of the product

8. What will you add to a solution of lead nitrate so as to obtain a yellow precipitate?
(A) Potassium iodide (B) Potassium nitride
(C) Barium sulphate (D) Potassium chloride

9. An acid that decolourises purple coloured potassium permanganate solution is :
(A) sulphuric acid (B) oxalic acid
(C) acetic acid (D) citric acid

10. Which of the following does not involve a chemical reaction?
(A) digestion of food in our body (B) burning of fuels
(C) burning of candle wax when heated (D) melting of ice

Ans: 1. (D) 2. (D) 3. (A) 4. (D) 5. (D) 6. (B)
7. (C) 8. (A) 9. (D) 10. (D)

II. VERY SHORT ANSWER TYPE QUESTIONS

1. What do you understand by the term chemical equation?
2. How is a balanced chemical equation different from a skeletal equation?
3. Why should a magnesium ribbon be cleaned before burning it in air?
4. Write a balanced chemical equation for the statement given below.
Ammonia gas reacts with oxygen in the presence of platinum at 900°C to form nitric oxide gas and steam.
5. Balance the following equation : $Pb(NO_3)_2(s) \xrightarrow{heat} PbO(s) + NO_2(g) + O_2(g)$
6. Why is respiration considered an exothermic reaction?
7. Balance the following equation :

$$Mg + O_2 \longrightarrow MgO$$

8. Is photosynthesis an endothermic reaction? Explain.
9. Translate the following statements into balanced chemical equations :
   (a) Phosphorus burns in oxygen to give phosphorus pentoxide.
   (b) Aluminum metal replaces iron from ferric oxide, Fe_2O_3, giving aluminum oxide and iron.
   (c) Barium chloride reacts with zinc sulphate to give zinc chloride and barium sulphate.
10. How will you indicate the following in a chemical reaction?
   (a) Formation of a precipitate (b) Evolution of heat (c) Aqueous solution
11. Classify the following into process endothermic and exothermic reactions :
   (a) Reaction between zinc and dilute sulphuric acid (b) Respiration
   (c) Photosynthesis (d) Reaction between magnesium and oxygen
12. Translate the following statement into a balanced chemical equation :
   "Barium chloride reacts with aluminium sulphate to give aluminum chloride and barium sulphate."

III. SHORT ANSWER TYPE QUESTIONS

1. (i) What do you understand by the :
   (a) reactants and (b) products?
   (ii) What does the symbol (⟶) represent in a chemical equation?
2. Write fully balanced chemical equations and state the physical condition and physical state of the reactants and products in the following chemical reactions :
   (i) Iron metal dissolves in copper sulphate solution, with the formation of iron sulphate and copper.
   (ii) Magnesium when heated in an atmosphere of nitrogen, catches fire and forms a compound magnesium nitride.
   (iii) Sodium sulphate solution reacts with barium chloride solution to form sodium chloride solution and precipitate of barium sulphate.
   (iv) When solution of chlorine in water is exposed to sunlight, it forms hydrochloric acid and oxygen gas.
   (v) Acetylene gas reacts with oxygen on burning to form carbon dioxide gas and water.
3. Balance the following equations :
   (i) $Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$
   (ii) $ZnCO_3(s) + HNO_3(aq) \longrightarrow Zn(NO_3)_2(aq) + H_2O(l) + CO_2(g)$
   (iii) $Cu(NO_3)_2(s) \longrightarrow CuO(s) + NO_2(g) + O_2(g)$
   (iv) $Al(OH)_3(s) + H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + H_2O(l)$
   (v) $Cu(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l) + SO_2(g)$
   (vi) $Fe(s) + H_2O(g) \longrightarrow Fe_3O_4(s) + H_2(g)$
   (vii) $FeSO_4(s) \longrightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$
   (viii) $MnO_2(s) + HCl(aq) \longrightarrow MnCl_2(aq) + Cl_2(g) + H_2O(l)$
   (ix) $C_6H_6(l) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$
   (x) $C_4H_{10}(g) + O_2(g) \longrightarrow CO_2(g) + H_2O(l)$
   (xi) $FeS_2(s) + O_2(g) \longrightarrow Fe_2O_3(s) + SO_2(g)$
4. What are the various ways by which a chemical equation can be made more informative? State with examples.
5. Write the balanced chemical equation for the following statements :
   (i) Aluminium burns in chlorine to form aluminium chloride ($AlCl_3$).
   (ii) Magnesium burns in air to form magnesium oxide.
   (iii) Potassium metal reacts with water to give potassium hydroxide and hydrogen gas.
6. Balance the following reactions and provide the necessary information to make it more informative.
   (i) $Zn + HCl \longrightarrow ZnCl_2 + H_2$
   (ii) $MnO_2 + HCl \longrightarrow MnCl_2 + Cl_2 + H_2O$
7. What happens to potassium chlorate on heating? What kind of reaction do you observe? Explain.
8. On burning magnesium in carbon dioxide, it forms magnesium oxide and carbon. Write the balanced chemical equation for this reaction.



9. Write a balanced chemical equation for the following indicating the heat changes :
   (i) Photosynthesis (ii) Addition of water to quicklime
   (iii) Reaction of sodium hydroxide with hydrochloric acid (iv) Formation of ammonia
10. Carbon monoxide reacts with hydrogen under certain conditions to form methanol (CH_3OH). Write a balanced chemical equation for this reaction indicating the necessary information.
11. 2 g of silver chloride is taken in a china dish which is placed in sunlight for some time. What will be your observation in this case? Write the chemical reaction involved in the form of a balanced chemical equation. Identify the type of chemical reaction.

IV. LONG ANSWER TYPE QUESTIONS

1. An unbalanced chemical equation is no equation. Explain the statement with suitable examples.
2. Correct the formulae and balance the following equations :
   (i) $K(s) + H_2O(l) \longrightarrow KOH(aq) + H(g)$ (ii) $Mg_3N_2(s) + H_2O(l) \longrightarrow MgOH(s) + NH_3(g)$
   (iii) $NH_4Cl(s) + Ca(OH)(s) \longrightarrow CaCl(s) + NH_3(g) + H_2O(l)$ (iv) $H_2O(l) + Cl(g) \longrightarrow HCl(aq) + O(g)$
   (v) $CaOH(aq) + CO_2(g) \longrightarrow CaCO_3(s) + H_2O(l)$.
3. State the various characteristics of chemical reactions.
4. What happens when a candle is burnt? What kind of a change do you witness? What is the characteristic of this change?

1.5 TYPES OF CHEMICAL REACTIONS

HDEUOPXQ78

So far, we have learnt the following aspects during a chemical reaction :

(i) The atoms taking part in a chemical reaction are neither created nor destroyed.

(ii) Atoms of one element do not change into atoms of another element.

In fact, the concept of chemical reactions involve breaking and making of bonds between the atoms of different elements to produce new products. You will learn more about the chemical bonds in this chapters ahead. Most of the chemical reactions are classified in the following different types :

1. Combination reactions 2. Decomposition reactions 3. Displacement reactions
4. Double displacement reactions 5. Oxidation and reduction reactions

I. Combination Reactions

Definition: *When two elements or compounds react chemically, to form a single new compound, then the chemical reaction that takes place is called a* ***combination reaction*** *or a* ***composition reaction***.



Example: Magnesium reacts chemically with oxygen present in air on heating and burns to form magnesium oxide with the evolution of a large amount of heat and light.

$$2Mg(s) + O_2(g) \xrightarrow{\Delta} 2MgO(s) + \text{Heat}$$

If you consider the above reaction carefully, you will notice that two elements (magnesium and oxygen) combine chemically to form a single product, that is, magnesium oxide.

Similarly, calcium oxide reacts vigorously with water to form calcium hydroxide (slaked lime), with the release of a large amount of heat energy.

$$\underset{\text{Quicklime}}{CaO(s)} + H_2O(l) \longrightarrow \underset{\text{Slaked lime}}{Ca(OH)_2(aq)} + \text{Heat}$$

In the above reaction also, we see that two compounds (calcium oxide and water), combine chemically to form a single product, that is, calcium hydroxide.

Let us see the procedure and observations of this reaction.

Procedure:

- Take a beaker and place a few pieces of quicklime (calcium oxide) in it.
- Slowly add water in the beaker.
- Observe the changes taking place in the beaker.
- Touch the beaker from outside to check whether its content is hot or cold.

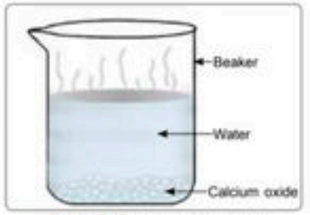


Fig. 1.17: Calcium oxide reacts with water to form slaked lime

Observations:

You will observe that solid calcium oxide pieces start crumbling with a hissing sound to form a powdery mass. The white powdery mass rapidly mixes with water. It appears, as if the contents of the mixture are boiling. Water vapour is seen above the surface of water. The beaker and its content becomes very hot.

Similarly, an element and a compound can react chemically to form a single product. **Such reactions in which two elements or compounds react to form a single product is called chemical combination reaction or chemical composition reaction.**

Note: In the last example, we stated that calcium oxide (quicklime), reacts with water to form calcium hydroxide (slaked lime), with the release of heat energy.

Calcium hydroxide is sparingly soluble in water. A suspension of calcium hydroxide in water is used for whitewashing the walls. When the walls are whitewashed, calcium hydroxide slowly reacts with the carbon dioxide present in air to form a thin layer of calcium carbonate.

$$\underset{\text{Calcium hydroxide}}{Ca(OH)_2(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \longrightarrow \underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{water}}{H_2O(l)}$$

The calcium carbonate so formed gives a white shine to the walls. It is interesting to note that chemical formula of chalk and marble is $CaCO_3$.

Examples of chemical combination reaction when two elements react.

(i) 2 moles of hydrogen gas react with one mole of oxygen gas on electric sparking to form water, with the release of a large amount of heat energy.

$$\underset{\text{Hydrogen}}{2H_2(g)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Water}}{2H_2O(l)} + \text{Heat}$$


Fig. 1.18: Oxygen and hydrogen combine to form water in an oxy-hydrogen flame

(ii) Coal (carbon) burns in air on heating to form carbon dioxide gas with the release of a large amount of heat energy.

$$\underset{\text{Carbon}}{C(s)} + \underset{\text{Oxygen}}{O_2(g)} \xrightarrow{\text{heat}} \underset{\text{Carbon dioxide}}{CO_2(g)} + \text{heat}$$

(iii) Sulphur burns in air on heating to form sulphur dioxide gas with the release of a large amount of heat energy.

$$\underset{\text{Sulphur}}{S(s)} + \underset{\text{Oxygen}}{O_2(g)} \xrightarrow{\text{heat}} \underset{\text{Sulphur dioxide}}{SO_2(g)} + \text{heat}$$

Mostly all the combination reactions are exothermic reactions. We have one example of endothermic combination reaction as well. Nitrogen and oxygen gases are heated to 3000°C. They combine to form nitrogen monoxide and a lot of heat is absorbed in this reaction.

$$\underset{\text{Nitrogen}}{N_2(g)} + \underset{\text{Oxygen}}{O_2(g)} \xrightarrow[3000^\circ C]{\text{heat}} \underset{\text{Nitrogen monoxide}}{2NO(g)}$$

Examples of chemical combination reaction when one element and one compound react.

(i) Carbon monoxide gas burns in oxygen to form carbon dioxide with the release of a large amount of heat energy.

$$\underset{\text{Carbon monoxide}}{2CO(g)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{2CO_2(g)} + \text{Heat}$$

(ii) Sulphur dioxide gas reacts with oxygen in the presence of platinised asbestos (used as catalyst) to form sulphur trioxide gas with the release of a large amount of heat energy.

$$\underset{\text{Sulphur dioxide}}{2SO_2(g)} + \underset{\text{Oxygen}}{O_2(g)} \xrightarrow[450°C]{Pt} \underset{\text{Sulphur trioxide}}{2SO_3(g)} + \text{Heat}$$

(iii) Nitrogen reacts with hydrogen in the presence of iron and nickel at 450°C to form ammonia gas. This reaction releases large amount of heat energy.

$$\underset{\text{Nitrogen}}{N_2(g)} + \underset{\text{Hydrogen}}{3H_2(g)} \xrightarrow[450°C]{Fe + Ni} \underset{\text{Ammonia}}{2NH_3(g)} + \text{Heat}$$

(iv) Formation of methanol is an endothermic combination reaction.

$$\underset{\text{Carbon monoxide}}{CO(g)} + \underset{\text{Hydrogen}}{2H_2(g)} \xrightarrow[ZnO + CrO_3]{300 \text{ Atm} : 300°C} \underset{\text{(Methanol)}}{CH_3OH}$$

(v) Hydrogen combines with chlorine to form hydrogen chloride.

$$\underset{\text{Hydrogen}}{H_2(g)} + \underset{\text{Chlorine}}{Cl_2(g)} \longrightarrow \underset{\text{Hydrogen chloride}}{2HCl(g)}$$

(vi) Iron powder and sulphur are heated together to form iron sulphide.

$$\underset{\text{Iron}}{Fe(s)} + \underset{\text{Sulphur}}{S(s)} \longrightarrow \underset{\text{Iron sulphide}}{FeS(s)}$$

(vii) Sodium metal burns in chlorine gas atmosphere to form sodium chloride.

$$\underset{\text{Sodium}}{2Na(s)} + \underset{\text{Chlorine}}{Cl_2(g)} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl(s)}$$

Examples of chemical combination reaction when two compounds react.

(i) Carbon dioxide gas reacts with water to form carbonic acid and the reaction mixture gets warm.

$$\underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Carbonic acid}}{H_2CO_3(aq)} + \text{Heat}$$

(ii) Sulphur trioxide gas dissolves in water to form sulphuric acid and releases large amount of heat energy.

$$\underset{\text{Sulphur trioxide}}{SO_3(g)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Sulphuric acid}}{H_2SO_4(aq)} + \text{Heat}$$

(iii) Sodium oxide dissolves in water to form sodium hydroxide and releases large amount of heat energy.

$$\underset{\text{Sodium oxide}}{Na_2O(s)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \text{Heat}$$

(iv) Ammonia reacts with hydrogen chloride gas to form ammonium chloride.

$$\underset{\text{Ammonia}}{NH_3(g)} + \underset{\text{Hydrogen chloride}}{HCl(g)} \longrightarrow \underset{\text{Ammonium chloride}}{NH_4Cl(s)}$$

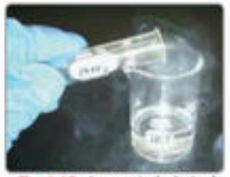


Fig. 1.19: Ammonia (solution) and hydrochloric acid react with each other to form ammonium chloride

In the above chemical combination reactions, one thing is common, that is, all the reactions proceed with the evolution of heat energy. Such chemical reactions are called exothermic reactions.

Definition: *A chemical reaction that proceeds with the release (evolution) of heat energy is called an* ***exothermic reaction****.*

You can see that most of these reactions are exothermic in nature.

Note: The reactions discussed below are not the examples of chemical combination reactions. Nevertheless, heat energy is always released when these reactions take place, and hence, they are exothermic reactions.

Burning of Natural Gas

Natural gas consists of mainly methane (70%), rest being ethane, propane, ethylene and hydrogen. All these gases burn in air (oxygen), with the liberation of heat energy.

$$\underset{\text{Methane}}{CH_4(g)} + \underset{\text{Oxygen}}{2O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Water}}{2H_2O(l)} + \text{Heat}$$

$$2C_2H_6(g) + 7O_2(g) \longrightarrow 4CO_2(g) + 6H_2O(l) + \text{Heat}$$
Ethane — Oxygen — Carbon dioxide — Water

$$C_3H_8(g) + 5O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(l) + \text{Heat}$$
Propane — Oxygen — Carbon dioxide — Water

$$C_2H_4(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 2H_2O(l) + \text{Heat}$$
Ethylene — Oxygen — Carbon dioxide — Water

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l) + \text{Heat}$$
Hydrogen — Oxygen — Water

Respiration in living beings

Respiration is an exothermic process. All living beings need heat energy in order to survive and carry out various activities.

During digestion, the food is broken down into simple substances, the end product being glucose. The glucose so formed, enters the bloodstream through the intestine. In the blood, oxygen carrying red blood corpuscles supply oxygen to glucose, which in turn gets oxidised to form carbon dioxide gas, water and heat energy. It is this heat energy that keeps the body of living beings warm.

DID YOU KNOW?

Natural gas is used as a household fuel. It is directly piped to the houses. Compressed natural gas (CNG) is used as fuel in CNG buses, as it is a non-polluting fuel. It is also used in gas based thermal power houses for generating electricity.



Fig. 1.20: Burning of natural gas in a gas stove

$$C_6H_{12}O_6(aq) + 6O_2(g) \longrightarrow 6CO_2(aq) + 6H_2O(l) + \text{Heat energy}$$
Glucose — Oxygen — Carbon dioxide — Water

Much the same way, when animal dung or waste vegetable matter rots, it produces heat energy.

C2HUT08LG9

II. Decomposition Reactions or Decombination Reactions

Definition: *When a chemical compound decomposes on heating or absorbing some kind of energy, so as to form two or more substances (elements or compounds), then the chemical reaction that takes place is called a* ***decomposition reaction*** *or a* ***decombination reaction****.*

$$\text{(A)—(B)} \longrightarrow \text{(A)} + \text{(B)}$$
Compound — (A and B could be elements or compounds)

Decomposition reaction is the reverse of composition reaction. Decomposition reactions are carried out by applying heat, light or electricity.

For Example: When potassium chlorate ($KClO_3$) is heated in the presence of manganese dioxide catalyst, it decomposes to form potassium chloride and oxygen gas. Look at the following reaction equation :

$$2KClO_3(s) \xrightarrow[MnO_2]{\Delta} 2KCl(s) + 3O_2(g)$$
Potassium chlorate — Potassium chloride — Oxygen

Here delta (Δ) represents heat and MnO_2 is the catalyst.

You can see that here one reactant is dissociating/decomposing to produce two products on heating. This reaction is used for producing oxygen gas in the laboratory.

Let us see a few more examples.

Hydrated ferrous sulphate crystal on heating produce steamy fumes, which condense on the cooler parts of the test tube and also produces a powdery mass. It decomposes to produce ferric oxide, sulphur dioxide gas, sulphur trioxide gas and water. We can see that we had only one reactant and obtained four different products.

$$2FeSO_4.7H_2O(s) \xrightarrow{\Delta} Fe_2O_3(s) + SO_2(g) + SO_3(g) + 14H_2O(g)$$
Hydrated ferrous sulphate — Ferric oxide — Sulphur dioxide — Sulphur trioxide — Steam

The ferric oxide is in the form of **brownish black** residue. The smell is due to sulphur dioxide gas. The steamy fumes are due to the liberation of water of crystallisation in the form of steam.

Procedure :

- Take 2 g of ferrous sulphate crystals (light green in colour) in a dry hard glass test tube.
- Hold the test tube with a test tube holder and heat it over the flame of a bunsen burner or spirit lamp for some time.
- Observe all the changes taking place in the test tube. Smell the gas evolved, if any.

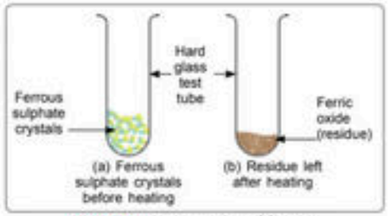


Fig. 1.21: Decomposition of ferrous sulphate crystals on heating



Fig. 1.22 : Heating ferrous sulphate in a boiling tube and smelling the odour

Observations:

(i) The green-coloured ferrous sulphate starts crumbling to form a powdery mass and gives out steamy fumes, which condense on the cooler parts of the test tube.

(ii) On further heating, the powdery mass changes into a deep brownish black mass.

(iii) A colourless gas is evolved that smells like burning sulphur and causes coughing.

Note: The above reaction is called thermal decomposition, because the chemical reaction is brought about by the absorption of heat energy.

Definition: *When a chemical compound decomposes on heating, so as to form two or more substances (elements or compounds), then the chemical reaction is called a* ***thermal decomposition reaction****.*

Next example is the thermal decomposition of lead nitrate.

In this reaction, a single reactant (lead nitrate crystals), breaks down to form different products, that is, lead monoxide, nitrogen dioxide and oxygen as shown in the equation below :

$$\underset{\text{Lead nitrate}}{2Pb(NO_3)_2(s)} \xrightarrow{\Delta} \underset{\text{Lead monoxide}}{2PbO(s)} + \underset{\text{Nitrogen dioxide}}{4NO_2(g)} + \underset{\text{Oxygen}}{O_2(g)}$$

In the above reaction, the residue (lead monoxide) is reddish brown when hot and yellow when cold. Nitrogen dioxide gas is reddish brown in colour.

The above reaction is an example of thermal decomposition as it takes place with the absorption of heat energy.

Procedure:

- Take 2 g of lead nitrate crystals (white in colour) in a hard glass test tube.
- Hold the test tube with a test tube holder and heat it over a bunsen burner flame or spirit lamp as shown in Fig. 1.23 for a few minutes.
- Observe all the changes taking place in the test tube.
- Hold a glowing wooden splint near the mouth of the test tube when the gas is coming out of it freely.
- Allow the test tube to cool. Observe any changes taking place in the colour of the residue.

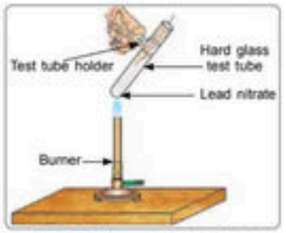


Fig. 1.23: Decomposition of lead nitrate crystals on heating

Observations:

(i) The crystals of lead nitrate start crumbling to form a white powdery mass, with a decrepitating sound.

(ii) The residue starts changing to reddish brown colour.

(iii) A reddish brown gas is evolved.

(iv) When the glowing wooden splint is held in the reddish brown gas, it bursts into flame, thereby showing the presence of oxygen gas in it.

(v) The hot residue is reddish brown in colour.

(vi) On cooling, this residue changes to pale-yellow colour.

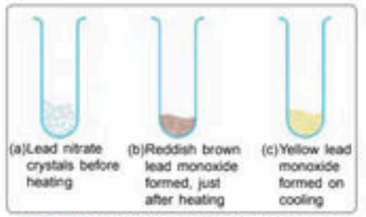


Fig. 1.24: Colour of residue of lead monoxide on heating and after cooling

More examples of thermal decomposition:

1. Mercury (II) oxide (red in colour) on strong heating decomposes into mercury and oxygen

$$\underset{\text{Mercury (II) oxide}}{2HgO(s)} \xrightarrow{\text{heat}} \underset{\text{Mercury}}{2Hg(l)} + \underset{\text{Oxygen}}{O_2(g)}$$

2. Metal hydroxides (except hydroxides of sodium and potassium) decompose on heating to form their respective metal oxides and steam.

$$\textbf{Metal hydroxide} \xrightarrow{\textbf{heat}} \textbf{Metal oxide} + \textbf{Steam}$$

$$\underset{\text{Aluminium hydroxide}}{2Al(OH)_3(s)} \xrightarrow{\text{heat}} \underset{\text{Aluminium oxide}}{Al_2O_3(s)} + \underset{\text{Steam}}{3H_2O(g)}$$

$$\underset{\text{Zinc hydroxide}}{Zn(OH)_2(s)} \xrightarrow{\text{heat}} \underset{\text{Zinc oxide}}{ZnO(s)} + \underset{\text{Steam}}{H_2O(g)}$$

3. Metal carbonates (except carbonates of sodium and potassium) decompose on heating to form their respective metal oxides and carbon dioxide gas.

$$\textbf{Metal carbonate} \xrightarrow{\textbf{heat}} \textbf{Metal oxide} + \textbf{Carbon dioxide gas}$$

$$\underset{\text{Calcium carbonate}}{CaCO_3(s)} \xrightarrow{\text{heat}} \underset{\text{Calcium oxide}}{CaO(s)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

Marble or limestone is naturally occurring form of calcium carbonate.

Note: Thermal decomposition of calcium carbonate (limestone) into calcium oxide and carbon dioxide is an important decomposition reaction for various industries.

Before the discovery of cement, a slurry of quicklime and powdered bricks or sand was used for joining bricks in construction. Even Taj Mahal is made from lime and sand slurry.

These days limestone and clay are baked to form cement, in which an active ingredient is quicklime. Furthermore, slaked lime suspension is used for whitewashing. Slaked lime is an excellent germicide and is spread over open drains, roads, etc.

Another important example of decomposition reaction is the digestion of food. The food that we eat contains complex organic compounds, such as fats, proteins, carbohydrates, etc. These compounds decompose in our digestive system by the action of enzymes to form simple substances, such as glucose and amino acids.

$$\underset{\text{Copper carbonate}}{CuCO_3(s)} \xrightarrow{\text{heat}} \underset{\text{Copper oxide}}{CuO(s)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

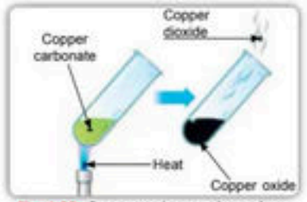


Fig. 1.25: Copper carbonate (green) on heating decomposes to form copper oxide (black) and carbon dioxide gas

Here, all thermal decomposition reactions take place with the absorption of heat energy. Such reactions are called **endothermic reaction**.

Definition: *All chemical reactions that proceed with the absorption of heat energy are called* ***endothermic reactions***.

In addition to thermal decomposition reactions, there are other reactions that proceed only by the absorption of heat energy. Following examples will illustrate the point :

Examples:

1. Carbon dioxide gas reacts with white hot coke to form carbon monoxide with the absorption of heat energy.

$$\underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Coke (white hot)}}{C(s)} \xrightarrow{\text{heat}} \underset{\text{Carbon monoxide}}{2CO}$$

2. Carbon monoxide gas reacts with ferric oxide to form iron and carbon dioxide gas with the absorption of heat energy.

$$\underset{\text{Ferric oxide}}{Fe_2O_3(s)} + \underset{\text{Carbon monoxide}}{3CO(g)} \xrightarrow{\text{heat}} \underset{\text{Iron}}{2Fe(s)} + \underset{\text{Carbon dioxide}}{3CO_2(g)}$$

3. Steam reacts with red hot coke to form a mixture of carbon monoxide and hydrogen, with the absorption of heat energy.

$$\underset{\text{Coke (red hot)}}{C(s)} + \underset{\text{Steam}}{H_2O(g)} \xrightarrow{\text{heat}} \underset{\text{Carbon monoxide}}{CO(g)} + \underset{\text{Hydrogen}}{H_2(g)}$$

4. Take 5 g of barium hydroxide in a test tube. Add 2.5 g of ammonium chloride in it and mix with the help of a glass rod for some time. Touch the side of the test tube with your fingers. You will observe that the test tube is very cold. It is because an endothermic reaction takes place with the absorption of heat energy.

$$\underset{\text{Barium hydroxide}}{Ba(OH)_2} + \underset{\text{Ammonium chloride}}{2NH_4Cl} \xrightarrow{\text{heat}} \underset{\text{Barium chloride}}{BaCl_2} + \underset{\text{Ammonium hydroxide}}{2NH_4OH}$$

(a) Photo-decomposition reactions

Chemical decomposition reactions can be brought about by the absorption of light energy. Such a decomposition reaction is called a ***photo-decomposition reaction***.

Definition: *When a chemical compound decomposes on absorbing light energy, so as to form two or more substances, (elements or compounds), then the reaction that takes place is called a* ***photo-decomposition reaction***.

Let us see the photolysis of silver chloride. It decomposes to form silver metal and chlorine gas. The reaction for this decomposition is :

$$\underset{\text{Silver chloride}}{2AgCl(s)} \xrightarrow{\text{Sunlight}} \underset{\text{Silver}}{2Ag(s)} + \underset{\text{Chlorine}}{Cl_2(g)}$$

The chlorine gas escapes in air and grey silver metal is left in the watch glass. Here, it is useful to know that silver metal has two allotropic forms, i.e., white silver with which you are familiar and grey silver.

Procedure:

- Take about 2 g of silver chloride (white in colour) in a clean watch glass.
- Place the watch glass in bright sunlight for a few minutes.
- Observe any changes taking place in the silver chloride.

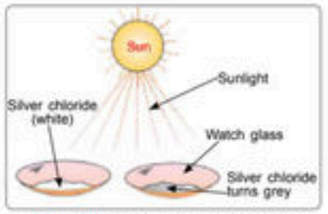


Fig. 1.26: Silver chloride turns grey in sunlight to form silver metal

Observation:

You will observe that silver chloride slowly changes to a deep grey colour. It is because, silver chloride on absorbing light energy undergoes photo-decomposition, and hence, forms silver metal and chlorine.

If the activity is repeated with silver bromide or silver iodide, similar reactions take place. However, rate of reaction is fastest in case of silver iodide and slowest in case of silver chloride.

$$\underset{\text{Silver bromide}}{2AgBr(s)} \xrightarrow{\text{Sunlight}} \underset{\text{Silver}}{2Ag(s)} + \underset{\text{Bromine}}{Br_2(g)}$$

$$\underset{\text{Silver iodide}}{2AgI(s)} \xrightarrow{\text{Sunlight}} \underset{\text{Silver}}{2Ag} + \underset{\text{Iodine}}{I_2(g)}$$

Black and white photographic films are coated with either silver chloride or silver bromide or silver iodide. The iodide films are fastest and chloride films slowest to the exposure of light. When the light falls on these films, silver metal is formed on them depending upon the intensity of light. In such a situation, we say that the film is exposed. The exposed film is finally developed and printed.

(b) Electrolytic-decomposition Reactions

Another kind of decomposition reaction takes place with the absorption of electric energy. Such reactions are called electrolytic-decomposition reactions.

Definition: *Decomposition reactions that take place with the absorption of electric energy are called* ***electrolytic-decomposition reaction.***

Procedure:

- Take a transparent plastic mug. Drill two holes in its base.
- Insert two rubber stoppers each having a single hole in the drilled holes in the plastic mug. The holes in the rubber stoppers should be big enough to allow the carbon rods to pass through them.
- Break two used 1.5 V dry cells and take out the carbon rods from them. Insert the carbon rods through the holes of the rubber stopper as shown in Fig. 1.27.
- Connect the carbon rods to a 6 V battery through connecting wires and a switch (K), with the help of clamps.

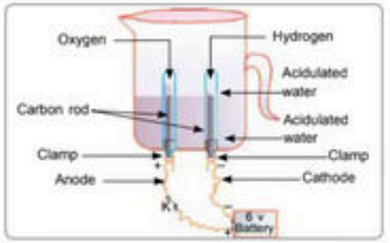


Fig. 1.27: Electrolysis of water

- Half fill the plastic mug with water and to it add a few drops of dilute sulphuric acid. Dilute sulphuric acid makes the water a good conductor of electricity.
- Take two graduated tubes and fill them with acidulated water. By placing the thumb on the mouth of the test tubes, invert each of them in the acidulated water in the plastic mug. Adjust each of the test tube over carbon rods as shown in Fig. 1.27.
- Switch on the electric current from the 6 V battery and leave the apparatus undisturbed for 10 minutes.
- Make your observations carefully.

Observations:

(i) Tiny bubbles of colourless gas are formed at each electrode. These bubbles leave the electrodes and rise up in the test tubes. They collect in the form of colourless gas and in doing so displace water downwards.

(ii) Volume of gas collected at the cathode is twice the volume of the gas collected at the anode because one molecule of water has one atom of oxygen and two atoms of hydrogen.

(iii) The gas collected at the cathode is hydrogen and the gas collected at the anode is oxygen. Their presence can be shown as follows :

(a) Light a candle. Lift the tube in an inverted position from the cathode and bring its mouth near the flame of the candle. You will observe that the gas burns with a "pop" sound and the candle goes off. This is a test for hydrogen gas.

(b) Take a glowing wooden splint. Lift the tube in an inverted position from the anode and introduce a glowing splint in it. You will observe that the splint bursts into flame. This is a test for oxygen.

The electro-decomposition reaction can be expressed as follows.

$$\underset{\text{Acidulated water}}{2H_2O(aq)} \xrightarrow{\text{Electric current}} \underset{\text{Hydrogen (at cathode)}}{2H_2(g)} + \underset{\text{Oxygen (at anode)}}{O_2(g)}$$

More examples of electrolytic-decomposition reaction:

1. Fused (molten) sodium chloride decomposes into sodium and chlorine on the passage of electric current. This reaction is used for the extraction of sodium metal from its ore (rock salt).

$$\underset{\text{Fused sodium chloride}}{2NaCl(l)} \xrightarrow{\text{Electric current}} \underset{\text{Sodium (at cathode)}}{2Na(s)} + \underset{\text{Chlorine gas (at anode)}}{Cl_2(g)}$$

2. Fused (molten) lead bromide decomposes into lead and bromine

$$\underset{\text{Fused lead bromide}}{PbBr_2(l)} \xrightarrow{\text{Electric current}} \underset{\text{Lead (at cathode)}}{Pb(s)} + \underset{\text{Bromine (at anode)}}{Br_2(g)}$$

3. On passing electric current through molten aluminium oxide, it decomposes to give aluminium metal and oxygen gas.

$$2Al_2O_3(l) \xrightarrow{\text{Electric current}} \underset{\text{Aluminum metal}}{4Al(s)} + \underset{\text{Oxygen gas}}{3O_2(g)}$$

SAMPLE PROBLEMS

1. A solution of substance 'X' is used for white washing.

(i) Name the substance 'X' and write its formula.

(ii) Write the reaction of substance 'X' with water.

Ans. (i) The substance 'X' is calcium oxide (quicklime or choona). Its formula is CaO.

(ii) $CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s) + \text{Heat}$

2. Why is double amount of gas collected in one of the test tubes in the electrolysis of water experiment? Name the gas that is collected in double amount.

Ans. H_2 gas is collected in an amount double than that of oxygen gas because one molecule of water (H_2O) contains two hydrogen atoms and one oxygen atom.

III. Displacement Reactions

MZF82LQ0HB

Definition : When a more active element displaces a less active element from its aqueous ionic compound, the reaction that takes place is called a **displacement reaction**.

$$\underset{\text{Compound of less active element A}}{AB} + \underset{\text{More active element C}}{C} \longrightarrow \underset{\text{Compound of more active element}}{CB} + \underset{\text{Less active element is displaced}}{A}$$

Rule for displacement reactions

A metal higher in the metal activity series displaces a metal lower in metal activity series from its ionic compound in aqueous solution.

Amongst the common metals, potassium is the most active and gold the least active. List of metals given below shows their reaction in the decreasing order.

Reactivity Series of Metals

	Potassium	**K**	**(Most reactive metal)**
	Sodium	Na	
	Calcium	Ca	
These metals are more reactive than hydrogen	Magnesium	Mg	
	Aluminium	Al	
	Zinc	Zn	
	Iron	Fe	
	Tin	Sn	
	Lead	Pb	
	[Hydrogen]	**[H]**	
These metals are less reactive than hydrogen	Copper	Cu	
	Mercury	Hg	
	Silver	Ag	
	Gold	Au	**Least reactive metal**

Let us look at the following example :

$$\underset{\text{Copper sulphate}}{CuSO_4(aq)} + \underset{\text{Iron}}{Fe(s)} \longrightarrow \underset{\text{Ferrous sulphate}}{FeSO_4(aq)} + \underset{\text{Copper}}{Cu(s)}$$

In the reaction, the more active metal iron displaces the less active metal copper from its aqueous copper sulphate solution, hence it is a displacement reaction.

No reaction takes place, if copper metal is placed in ferrous sulphate solution, because copper metal is less reactive than iron in the metal activity series.

$$\underset{\text{Ferrous sulphate}}{FeSO_4(aq)} + \underset{\text{Copper}}{Cu(s)} \longrightarrow \text{No reactions}$$

Procedure:

- Take 10 mL each of saturated copper sulphate solution in test tubes A and B. Place the test tubes in a test tube stand.
- Remove test tube B and clamp it in an iron stand.
- Take two iron nails and clean them thoroughly by rubbing with sand paper, so that silver grey surface of iron appears.
- Tie one of the nails with a thread and immerse it in the copper sulphate solution in test tube B. Keep the second nail separately for comparison. Leave the apparatus undisturbed for a day.
- Next day take out the nail from the copper sulphate solution in test tube B.
- Compare this nail with the second nail.
- Compare the colour of copper sulphate solution in test tube B with the colour of copper sulphate solution in test tube A.

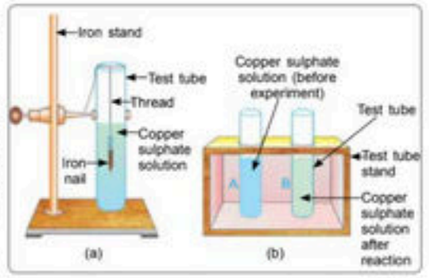


Fig. 1.28: Displacement reaction between iron and copper sulphate solution

Observations:

(i) The nail after the experiment is coated with a reddish brown deposit. This deposit is copper metal that is displaced from the copper sulphate solution.

(ii) The colour of copper sulphate solution in test tube B becomes green while colour of copper sulphate solution in test tube A is blue. This change in colour is due to the displacement of copper ions by the more active metal iron, Fe.

Similarly, metals like lead, zinc, aluminium and magnesium will displace copper from its soluble salt solution as shown by the displacement equations below :

$$\underset{\substack{\text{Copper sulphate}\\\text{(blue)}}}{CuSO_4(aq)} + \underset{\substack{\text{Zinc}\\\text{(Silver white)}}}{Zn(s)} \longrightarrow \underset{\substack{\text{Zinc sulphate}\\\text{(colourless)}}}{ZnSO_4(aq)} + \underset{\substack{\text{Copper}\\\text{(Reddish brown)}}}{Cu(s)}$$

$$\underset{\substack{\text{Copper nitrate}\\\text{(blue)}}}{Cu(NO_3)_2(aq)} + \underset{\substack{\text{Lead}\\\text{(Bluish grey)}}}{Pb(s)} \longrightarrow \underset{\substack{\text{Lead nitrate}\\\text{(colourless)}}}{Pb(NO_3)_2(aq)} + \underset{\substack{\text{Copper}\\\text{(Reddish brown)}}}{Cu(s)}$$

$$\underset{\substack{\text{Copper chloride}\\\text{(blue)}}}{3CuCl_2(aq)} + \underset{\substack{\text{Aluminium}\\\text{(silver white)}}}{2Al(s)} \longrightarrow \underset{\substack{\text{Aluminium}\\\text{chloride (yellow)}}}{2AlCl_3(aq)} + \underset{\substack{\text{Copper}\\\text{(Reddish brown)}}}{3Cu(s)}$$

$$\underset{\substack{\text{Copper chloride}\\\text{(blue)}}}{CuCl_2(aq)} + \underset{\substack{\text{Magnesium}\\\text{(silver white)}}}{Mg(s)} \longrightarrow \underset{\substack{\text{Magnesium chloride}\\\text{(colourless)}}}{MgCl_2(aq)} + \underset{\substack{\text{Copper}\\\text{(Reddish brown)}}}{Cu(s)}$$

In the following reaction, the more active metal zinc displaces the less active hydrogen from dilute sulphuric acid solution.

$$\underset{\text{Zinc}}{Zn(s)} + \underset{\text{Dilute sulphuric acid}}{H_2SO_4(aq)} \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_4(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$



Procedure:

- Place a few pieces of granulated zinc in a conical flask, provided with a rubber stopper and a glass tubing as shown in the figure 1.29.
- Pour dilute sulphuric acid in the flask, so that the granulated zinc pieces are completely immersed.
- Insert the rubber stopper and wait for 2 minutes.

Observations:

- You will observe that tiny bubbles of hydrogen are formed in the reaction mixture. The hydrogen so formed gradually expels out the air in the flask.
- Bring a lighted candle near the open end of the glass tubing. You will observe that hydrogen gas catches fire with a "pop" sound and burns with a pale blue flame.

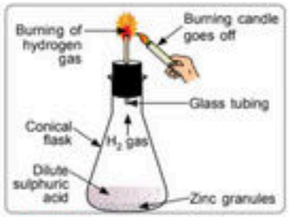


Fig. 1.29: Displacement of hydrogen from dilute sulphuric acid by zinc and combustion of hydrogen

Similarly, metals like, iron, aluminium and magnesium will displace hydrogen from dilute sulphuric acid or dilute hydrochloric acid as shown by the equations given below :

$$\underset{\text{Iron}}{Fe(s)} + \underset{\text{Dilute sulphuric acid}}{H_2SO_4(aq)} \longrightarrow \underset{\text{Ferrous sulphate}}{FeSO_4(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

$$\underset{\text{Aluminium}}{2Al(s)} + \underset{\text{Dilute hydrochloric acid}}{6HCl(aq)} \longrightarrow \underset{\text{Aluminium chloride}}{2AlCl_3(aq)} + \underset{\text{Hydrogen}}{3H_2(g)}$$

$$\underset{\text{Magnesium}}{Mg(s)} + \underset{\text{Dilute hydrochloric acid}}{2HCl(aq)} \longrightarrow \underset{\text{Magnesium chloride}}{MgCl_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

No reaction will take place, if metals like copper, silver or mercury are placed in dilute sulphuric acid, because these metals are less active than hydrogen in a metal activity series.

More examples of displacement reactions:

When a shining strip of copper (reddish in colour) is placed in colourless silver nitrate solution, then silver metal and copper nitrate solution is formed.

$$\underset{\text{Silver nitrate}}{2AgNO_3(aq)} + \underset{\text{Copper metal}}{Cu(s)} \longrightarrow \underset{\text{Copper nitrate}}{Cu(NO_3)_2(aq)} + \underset{\text{Silver metal}}{2Ag(s)}$$

The above reaction takes place, because copper is more reactive than silver in the metal activity series. Copper metal is covered with a deposit of silver and the solution becomes blue on account of the formation of copper nitrate.

Note: No chemical reaction takes place when silver metal is placed in copper nitrate solution. It is because, silver is less reactive than copper in the metal activity series.

Similarly, metals like lead, iron, zinc, aluminium and magnesium will show displacement reactions with silver nitrate solution, because they are more reactive than silver in metal activity series, as illustrated by equations given below :

(i) $$\underset{\substack{\text{Silver nitrate}\\\text{(colourlesss)}}}{2AgNO_3(aq)} + \underset{\substack{\text{Lead metal}\\\text{(Bluish grey)}}}{Pb(s)} \longrightarrow \underset{\substack{\text{Lead nitrate}\\\text{(colourless)}}}{Pb(NO_3)_2(aq)} + \underset{\text{Silver metal}}{2Ag(s)}$$

(ii) $$\underset{\substack{\text{Silver nitrate}\\\text{(colourlesss)}}}{3AgNO_3(aq)} + \underset{\substack{\text{Aluminium metal}\\\text{(silvery white)}}}{Al(s)} \longrightarrow \underset{\substack{\text{Aluminium nitrate}\\\text{(colourless)}}}{Al(NO_3)_3(aq)} + \underset{\text{Silver metal}}{3Ag(s)}$$

(iii) $$\underset{\substack{\text{Silver nitrate}\\\text{(colourlesss)}}}{2AgNO_3(aq)} + \underset{\substack{\text{Copper metal}\\\text{(Red brown)}}}{Cu(s)} \longrightarrow \underset{\substack{\text{Copper nitrate}\\\text{(Blue)}}}{Cu(NO_3)_2(aq)} + \underset{\text{Silver metal}}{2Ag(s)}$$

Let us see a few reactions of metals with water and metal oxides.

- Sodium metal reacts with water to form sodium hydroxide and hydrogen gas is released.

$$\underset{\text{Sodium metal}}{2Na(s)} + \underset{\text{Water}}{2H_2O(l)} \longrightarrow \underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

- On heating, copper oxide reacts with magnesium powder (metal) to form magnesium oxide and copper metal.

$$\underset{\text{Copper oxide}}{CuO(s)} + \underset{\text{Magnesium}}{Mg(s)} \longrightarrow \underset{\text{Magnesium oxide}}{MgO(s)} + \underset{\text{Copper}}{Cu(s)}$$

- On heating iron (III) oxide with aluminium powder, aluminium oxide and iron metal are formed.

$$\underset{\text{Iron (III) oxide (ferric oxide)}}{Fe_2O_3(s)} + \underset{\text{Aluminium}}{2Al(s)} \longrightarrow \underset{\text{Aluminium oxide}}{Al_2O_3(l)} + \underset{\text{Iron metal (molten)}}{2Fe(l)}$$

IV. Double Displacement Reactions

WVECF54DRL

Definition: *A chemical reaction in which two ionic compounds in their aqueous solutions, react by exchanging their ions/radicals, to form two new compounds is called a* ***double displacement reaction****.*



Chemical double displacement reactions can be classified into two kinds.

(a) Precipitation reactions

Definition: *When aqueous solutions of two ionic compounds react by exchanging their ions/radicals, to form two new compounds, such that one of the products formed is an insoluble salt, and hence, forms a precipitate so the double displacement reaction is said to be a precipitation reaction.*

Let us see a few examples. When lead nitrate solution is mixed with potassium iodide solution a yellow precipitate is formed. This reaction is a precipitation reaction and can be expressed as follows :

$$\underset{\text{Lead nitrate (colourless)}}{Pb(NO_3)_2(aq)} + \underset{\text{Potassium iodide (colourless)}}{2KI(aq)} \longrightarrow \underset{\text{Lead iodide (yellow ppt)}}{PbI_2(\downarrow)} + \underset{\text{Potassium nitrate}}{2KNO_3(aq)}$$

In the above reaction, the lead nitrate solution and potassium iodide solution exchanged their ions to form a precipitate of lead iodide and potassium nitrate solution.

Another example is the reaction between sodium sulphate solution and barium chloride solution. It can be represented as follows :

$$\underset{\text{Sodium sulphate}}{Na_2SO_4(aq)} + \underset{\text{Barium chloride}}{BaCl_2(aq)} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl(aq)} + \underset{\text{Barium sulphate (white ppt)}}{BaSO_4(\downarrow)}$$

Procedure:

- Take a clean test tube A and pour 5 mL of sodium sulphate solution in it.
- Take a clean test tube B and pour about 5 mL of barium chloride in it.
- Pour the contents of test tube A in test tube B as shown in Fig. 1.30 and make your observations.

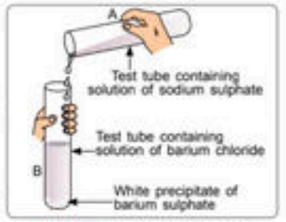


Fig. 1.30: Double displacement reaction between sodium sulphate solution and barium chloride solution

Observations:

You will observe that at once a white precipitate is formed. This white precipitate is due to the formation of insoluble barium sulphate. This is a double displacement reaction.

More examples of double displacement reactions :

1. When colourless, aqueous silver nitrate solution is mixed with colourless, aqueous solution of sodium chloride, it forms a white precipitate of silver chloride.

$$\underset{\text{Silver nitrate (colourless)}}{AgNO_3(aq)} + \underset{\text{Sodium chloride (colourless)}}{NaCl(aq)} \longrightarrow \underset{\text{Silver chloride}}{AgCl(\downarrow)} + \underset{\text{Sodium nitrate}}{NaNO_3(aq)}$$

2. When an aqueous sodium hydroxide solution (colourless), is added to aqueous copper sulphate solution (blue), it forms blue precipitate of copper hydroxide.

$$\underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \underset{\text{Copper sulphate}}{CuSO_4(aq)} \longrightarrow \underset{\text{Sodium sulphate}}{Na_2SO_4(aq)} + \underset{\text{Copper hydroxide (blue ppt)}}{Cu(OH)_2(\downarrow)}$$

3. When hydrogen sulphide gas is passed through copper sulphate solution, a black precipitate of copper sulphate is formed along with sulphuric acid.

$$\underset{\text{Copper sulphate}}{CuSO_4(aq)} + \underset{\text{Hydrogen sulphide}}{H_2S(g)} \longrightarrow \underset{\text{Copper sulphide}}{CuS(s)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq)}$$

4. When aluminium chloride solution reacts with ammonium hydroxide solution, a white precipitate of aluminium hydroxide and a solution of ammonium chloride are formed.

$$\underset{\text{Aluminium chloride}}{AlCl_3(aq)} + \underset{\text{Ammonium hydroxide}}{3NH_4OH(aq)} \longrightarrow \underset{\text{Aluminium hydroxide (ppt)}}{Al(OH)_3(s)} + \underset{\text{Ammonium chloride}}{3NH_4Cl(aq)}$$

(b) Neutralisation reactions

Definition: *When an aqueous solution of an acid reacts with a base (alkali) by exchanging their ions/radicals to form salt and water as the products, the reaction that takes place is called as a* ***neutralisation reaction****.*

Examples:

Acid		Base/Alkali		Salt		Water
$H_2SO_4(aq)$ Sulphuric acid	+	$2NaOH(aq)$ Sodium hydroxide	$\longrightarrow$	$Na_2SO_4(aq)$ Sodium sulphate	+	$2H_2O(l)$ Water
$2HCl(aq)$ Hydrochloric acid	+	$Mg(OH)_2(aq)$ Magnesium hydroxide	$\longrightarrow$	$MgCl_2(aq)$ Magnesium chloride	+	$2H_2O(l)$ Water

Note: Sometimes, a burning sensation is produced in the stomach and food pipe. It is produced due to the excessive production of hydrochloric acid by the walls of the stomach. This condition is called acidity.

When we take antacid tablets, the acidity is considerably reduced. It is because antacid tablets contain magnesium hydroxide and aluminium hydroxide. These hydroxides react with hydrochloric acid, and hence, neutralisation reaction takes place. Thus, the acidity is reduced.

SAMPLE PROBLEMS

1. Why does the colour of copper sulphate change when an iron nail is dipped in it?

Ans. Iron is more reactive than copper, hence it displaces copper from its salt solution. The reaction takes place as follows :

$$\underset{\text{Iron}}{Fe(s)} + \underset{\text{Copper sulphate (blue)}}{CuSO_4(aq)} \longrightarrow \underset{\text{Ferrous sulphate (green)}}{FeSO_4(aq)} + \underset{\text{Reddish brown}}{Cu(s)}$$

As we can notice from the reaction, the blue copper sulphate solution will turn green due to the displacement reaction. Iron will displace copper and form ferrous sulphate solution which is green in colour.

2. Give an example of a double displacement reaction.

Ans. Refer to the reactions given as examples under the heading "Double Displacement Reactions".

3. What happens when dilute hydrochloric acid is added to iron fillings? Tick the correct answer.

(A) Hydrogen gas and iron chloride are produced. (B) Chlorine gas and iron hydroxide are produced.

(C) No reaction takes place. (D) Iron salt and water are produced.

Ans. (A) Hydrogen gas and iron chloride are formed, the reaction equation will be

$$\underset{\text{Iron}}{Fe(s)} + \underset{\text{Hydrochloric acid}}{2HCl(aq)} \longrightarrow \underset{\text{Iron chloride}}{FeCl_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

4. $Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$

The above reaction is an example of :

(A) combination reaction (B) double displacement reaction

(C) decomposition reaction (D) displacement reaction

Ans. (D) Displacement reaction: Here, Aluminium being more reactive, displaces iron from its oxide and forms aluminium oxide.

5. Write the balanced chemical equations for the following and identify the type of reaction in each case :

(a) Barium chloride(*aq*) + Potassium sulphate(*aq*) ⟶ Barium sulphate(*s*) + Potassium chloride(*aq*)

(b) Zinc carbonate(*s*) ⟶ Zinc oxide(*s*) + Carbon dioxide(*g*)

(c) Hydrogen(*g*) + Chlorine(*g*) ⟶ Hydrogen chloride(*g*)

(d) Magnesium(*s*) + Hydrochloric acid(aq) ⟶ Magnesium chloride(*aq*) + Hydrogen(*g*)

Ans. (a) $BaCl_2(aq) + K_2SO_4(aq) \longrightarrow BaSO_4(s) + 2KCl(aq)$ (Double displacement reaction)

(b) $ZnCO_3(s) \longrightarrow ZnO(s) + CO_2(g)$ (Decomposition reaction)

(c) $H_2(g) + Cl_2(g) \longrightarrow 2HCl(g)$ (Combination reaction)

(d) $Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$ (Displacement reaction)

Assess Yourself – 2

1. Identify the type of following reactions, and indicate the heat energy changes, if required.

(i) $Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$ (ii) $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$

(iii) $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$ (iv) $CaCO_3(s) \longrightarrow CaO(s) + CO_2(g)$

(v) $Zn(s) + 2AgNO_3(aq) \longrightarrow Zn(NO_3)_2 + 2Ag(s)$ (vi) $2KClO_3(s) \longrightarrow 2KCl(s) + 3O_2(g)$

(vii) $CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq)$

2. Give an example of decomposition reaction carried out by :

(i) heat (ii) electricity

3. Which of the following is a combination reaction? What is the kind of the other reaction?

(i) $Cl_2(g) + 2KI(aq) \longrightarrow 2KCl(aq) + I_2(g)$ (ii) $2K(s) + Cl_2(g) \longrightarrow 2KCl(s)$

V. Oxidation and Reduction Reactions

IN8W09RMPG

Definitions:

1. **Oxidation:** The oxidation of a substance takes place when :

(i) there is addition of oxygen to a substance,

(ii) there is removal of hydrogen from a substance.

The substance that causes the addition of oxygen or removal of hydrogen is called an **oxidising agent**.

Some common oxidising agents are oxygen (O_2), ozone (O_3), chlorine (Cl_2), hydrogen peroxide (H_2O_2), nitric acid (HNO_3) and sulphuric acid (H_2SO_4).

2. **Reduction:** The reduction of a substance takes place when :

(i) there is addition of hydrogen to a substance,

(ii) there is removal of oxygen from a substance.

The substance that causes the addition of hydrogen or removal of oxygen is called a **reducing agent**.

Some important reducing agents are active metals (Na, K, Ca, Al, Zn), hydrogen (H_2), carbon (C), carbon monoxide (CO), sulphur dioxide (SO_2) and hydrogen sulphide (H_2S).

Let us look at the reaction of copper metal with oxygen (burning of copper in air).

$$\underset{\text{Copper}}{2Cu(s)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Copper oxide}}{2CuO(s)}$$

In this reaction as oxygen is added to copper, therefore, copper is oxidised to copper oxide.

Procedure:

- Take a hard glass tube 50 cm long, 4 cm in diameter and open at both ends. Fix this tube in horizontal position in a laboratory iron stand clamp as shown in Fig. 1.31(a).
- Place 2 g of copper powder (reddish brown in colour) in a small watch glass and then introduce it in the glass tube as shown in Fig. 1.31(a).
- Close both ends of the glass tube with rubber stoppers in which glass tubings are inserted.
- Heat the watch glass strongly for a few minutes.
- Slowly blow in air and record your observations for 10 minutes.

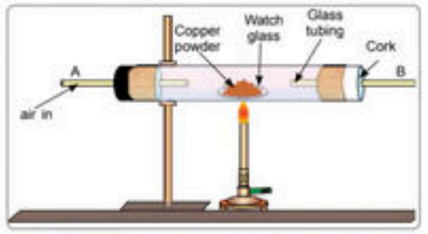


Fig. 1.31(a): Oxidation of copper to copper oxide

Observations:

You will observe that reddish brown coloured copper will slowly change to a black colour. This black substance is copper oxide that is formed when oxygen is added to copper.

Now, go on heating the glass tube and slowly pass hydrogen gas over the black copper oxide for 10 minutes or more as shown in Fig. 1.31(b). Make your observations.

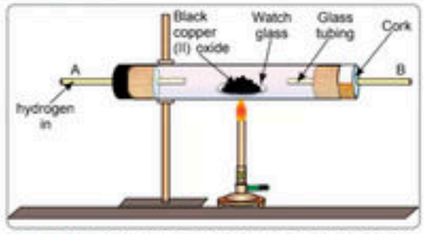


Fig. 1.31(b): Reduction of copper oxide (black) to copper

You will observe that black copper oxide slowly regains its original reddish brown colour.

During this reaction, copper oxide slowly loses its oxygen.

$$\underset{\text{Copper oxide (black)}}{CuO(s)} + \underset{\text{Hydrogen}}{H_2(g)} \longrightarrow \underset{\text{Copper (reddish brown)}}{Cu(s)} + \underset{\text{Water}}{H_2O(l)}$$

In the above reaction, copper oxide is reduced to copper on account of the loss of oxygen.

Note: In any oxidation-reduction reaction, oxidation and reduction take place simultaneously as illustrated below :

$$\overset{\text{Removal of oxygen : Reduction}}{\overbrace{}} \quad \overset{\text{Addition of oxygen : Oxidation}}{\overbrace{}}$$

$$CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$$

In the above reaction :

(i) as copper oxide loses oxygen, therefore its reduction takes place.

(ii) as hydrogen gains oxygen, therefore its oxidation takes place.

So we understand that hydrogen is acting as a reducing agent and copper oxide is acting as an oxidising agent.

The is because hydrogen is gaining the oxygen atom and copper oxide is giving the oxygen required for the oxidation of hydrogen. So we can say, in this reaction,

Substance oxidised : H_2 | Substance reduced : CuO
Oxidising agent : CuO | Reducing agent : H_2

More examples of oxidation and reduction reaction:

(a) $\underset{\text{Manganese dioxide}}{MnO_2(s)} + \underset{\text{Hydrochloric acid}}{4HCl(aq)} \longrightarrow \underset{\text{Manganese chloride}}{MnCl_2(aq)} + \underset{\text{Water}}{2H_2O(l)} + \underset{\text{Chlorine}}{Cl_2(g)}$

In the above reaction:

(i) manganese dioxide loses oxygen, therefore its reduction takes place,

(ii) HCl is oxidised to Cl_2, as it loses hydrogen.

Here, Substance oxidised : HCl | Substance reduced : MnO_2
Oxidising agent : MnO_2 | Reducing agent : HCl

(b) $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$

In the above reaction:

As magnesium gains oxygen, therefore its oxidation takes place,

Here, Substance oxidised : Mg
Oxidising agent : O_2

(c) $\underset{\text{Sodium}}{4Na(s)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Sodium oxide}}{2Na_2O(s)}$

In the above reaction :

As sodium gains oxygen, therefore its oxidation takes place,

Here, Substance oxidised : Na
Oxidising agent : O_2

(d) $H_2S(g) + Br_2(aq) \longrightarrow 2HBr(aq) + S(s)$

In the above reaction:

(i) as H_2S loses hydrogen to bromine, therefore, its oxidation takes place,

(ii) as Br_2 gains hydrogen to form hydrobromic acid, therefore, its reduction takes place.

Here, Substance oxidised : H_2S | Substance reduced : Br_2
Oxidising agent : Br_2 | Reducing agent : H_2S

In the first example, where copper was reacting with oxygen and in the example of reaction of sodium and oxygen, we saw that the metal atoms were simply combining with oxygen. To understand the concept of oxidation reduction in such reactions, we have another concept of oxidation and reduction in terms of metals and non-metals. This concept is :

(i) The addition of a metallic element (or removal of a non-metallic element) is called reduction.

(ii) The addition of a non-metallic element (or removal of a metallic element) is called oxidation.

For example:

$4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$

Here, as sodium (metal) is being added to O_2 gas, hence O_2 gas is being reduced and as sodium is gaining oxygen (non-metal) it is being oxidised.

SAMPLE PROBLEMS

1. Identify the substances that are oxidised and the substances that are reduced in the following reactions:

(i) $4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$

(ii) $CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$

Ans. (i) $4Na(s) + O_2(g) \longrightarrow 2Na_2O(s)$

Substance oxidised : Na

This is because Na is changing into Na_2O. Oxygen is being added to Na metal, hence it is being oxidised.

Substance reduced : O_2

This is because O_2 is changing into Na_2O. A metal atom is being added to O_2, hence it is being reduced.

(ii) Removal of oxygen : Reduction

$$CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$$

Addition of oxygen : Oxidation

Substance oxidised : H_2

Substance reduced : CuO

Note: (Look for the explanation) in the text.

2. Which of the statements about the reaction below are incorrect?

$$2PbO(s) + C(s) \longrightarrow 2Pb(s) + CO_2(g)$$

(A) Lead is getting reduced. (B) Carbon dioxide is getting oxidised.

(C) Carbon is getting oxidised. (D) Lead oxide is getting reduced.

Ans. The incorrect statements are :

(A) Lead is getting reduced. (B) Carbon dioxide is getting oxidized.

Look at the reaction:

Addition of oxygen : oxidation

$$2PbO(s) + C(s) \longrightarrow 2Pb(s) + CO_2(g)$$

Removal of oxygen : reduction

Hence, Substance oxidised : C
Substance reduced : PbO
Oxidising agent : PbO
Reducing agent : C

3. A shiny brown coloured element X on heating in air becomes black in colour. Name the element X and the black coloured compound formed.

Ans. (i) Shiny brown coloured element X is copper metal (Cu).

(ii) The black coloured compound formed is CuO.

When copper atom is heated in air, it forms CuO; the reaction is :

$$\underset{\text{Shiny brown}}{2Cu(s)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Black}}{2CuO(s)}$$

1.6 OXIDATION AND REDUCTION REACTIONS IN EVERYDAY LIFE

CK3M71ZDYJ

Corrosion of Metals

Corrosion of metals is an oxidation process. Corrosion is basically caused by the moist air. If the moist air contains carbon dioxide, hydrogen sulphide, then the process of corrosion gets accelerated. Let us discuss about corrosion of some common metals.

Formation of layers of undesired compounds, such as metallic oxides, metallic hydroxides or metal sulphides on the surface of metals is called ***corrosion of metals***.

In this process, metals are eaten up gradually by the action of air, moisture or a chemical (acid or base). The most common example of corrosion in an everyday life is rusting of iron.

Rusting of Iron

Iron is a metal that is used extensively in making buildings, bridges, rails, machinery and many other articles. However, the problem with iron is that, when it comes in contact with moist air, it slowly reacts with oxygen to form hydrated ferric oxide, a brown powdery substance, commonly called rust. Rust is flaky, non-sticky in nature and hence, easily crumbles from the surface of the metal. Thus, a fresh iron layer is exposed for attack of moist air to form more rust. Rust not only corrodes iron, but weakens the iron structures, thereby causing great economic loss.



Fig. 1.32: Rusting of iron

$$\underset{\text{Iron}}{4Fe(s)} + \underset{\text{Oxygen}}{3O_2(g)} + \underset{\text{Water}}{2xH_2O(l)} \longrightarrow \underset{\text{Hydrated iron (III) oxide (Rust)}}{2Fe_2O_3.xH_2O(s)}$$

Rusting : *The slow conversion of iron into hydrated ferric oxide, in the presence of moisture and air is called rusting.*

Rust : *The flaky, non sticky brown powder formed on the surface of iron, when iron is exposed to moist air is called rust.*

Experiment to show that both air and water are necessary for rusting

In an absolutely clean and dry test tube [Fig. 1.33(a)] place 2 g of anhydrous calcium chloride and then a shining iron nail. Put a stopper on the test tube and place it aside for a week. The anhydrous calcium chloride is used to absorb moisture from the enclosed air. It is seen that the nail does not rust. Thus, we can conclude that ***dry air does not cause rusting***.

Fill three/fourth of another test tube with water [Fig. 1.33(b)] which is already boiled, so that it does not contain any dissolved air. Over the water, pour 1 mL of any oil so as to cut off the atmospheric air. In the water place a shining nail and put a stopper on the test tube. After a week, it is seen that the nail does not rust. Thus, we conclude that ***pure water does not cause rusting***.

Place a shining nail in a test tube [Fig. 1.33(c)] and half fill it with tap water. Stopper the test tube. After a week it is seen that the nail rusts. Thus, we can conclude that ***air and water (moist air) both are necessary for rusting***.

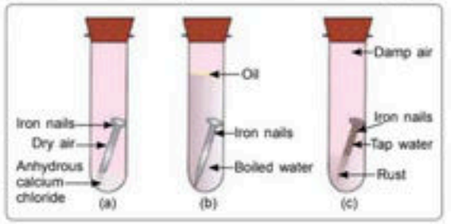


Fig. 1.33: Experiment to show the factors necessary for rusting of iron

Conditions necessary for rusting of iron

Iron rusts, only if its surface comes in contact with (a) oxygen and (b) moisture. If any of the above mentioned conditions is not fulfilled, iron does not rust.

(a) Iron generally rusts in air, because air always contains oxygen gas and moisture.

(b) Iron is found to rust in natural water. It is because, natural water always contains dissolved oxygen.

Prevention of Rusting

DNM80AVOL5

Rusting of iron can be prevented, if moist air is not allowed to come in contact with its surface. Following methods are employed in the prevention of rusting :



Fig. 1.34: Painting of iron articles

1. **By coating with red lead oxide paint (Pb_3O_4) or tar:** The underside of ships, bridges, electric poles, etc., is coated with tar or red lead oxide paint, which does not allow the moist air to come in contact with iron. Thus, rusting is prevented. It is a fairly inexpensive method and is widely used.
2. **By painting:** Articles, such as iron doors, windows, bodies of buses, cars, motorcycles, etc., are first given a coating of red lead oxide, followed by a coat of paint of desired colour. This effectively cuts out the moist air and prevents rusting.

3. **By enamelling:** Enamelling is the process of baking a mixture of silicates on the surface of iron at high temperature. Articles, such as bodies of cooking stoves, refrigerators, cups, plates, wash basins, etc., are enamelled.
4. **By oil and grease:** Moving parts of machines cannot be given a protective layer, because it wears off quickly. These moving parts of the machines are protected from rusting by coating them with a thin layer of oil or grease, which not only prevents them from rusting but also lubricates them.
5. **Plastic coating:** Iron furniture and fixtures are given a thin coating of plastic, which cuts off the moist air and prevents rusting.
6. **By galvanising:** In this process iron sheets are dipped in molten zinc and then passed through heavy rollers, when zinc metal forms a protective layer over iron. The galvanised iron is extensively used in making roofs of sheds, buckets, tubs, iron trunks and suitcases.
7. **By tinning:** In this process iron sheets are dipped in molten tin and then passed through hot and heavy rollers, when tin forms a protective layer over iron. Tinned iron sheets are extensively used for making containers for edible substances, such as fruits, vegetables, meat, etc.
8. **By coating with chromium or nickel electrolytically:** This method is highly expensive, but gives a very bright finish. Chromium or nickel is deposited on iron articles by electroplating. Articles such as, bicycle handles, rims, bumpers of the cars, etc., are coated with nickel or chromium.
9. **By converting iron into stainless steel:** When 12 to 20% chromium is incorporated in iron with 0·1 to 0·7% of carbon, it develops a special property due to which it does not rust in moist air. Such a sample of iron is called **stainless steel**. Stainless steel is used for making surgical instruments, kitchen utensils, cutlery, tools, etc.


Fig. 1.35: Galvanisation of Iron

How galvanised iron is protected from rust?

Zinc is a more active metal than iron in the electrochemical series. Thus, in case of oxidation, zinc will get oxidised first. Rusting of iron is prevented because:

1. Zinc will get oxidised first. Thus, as long as zinc is present, rusting of iron is not possible.
2. Zinc combines with oxygen to form zinc oxide, which is highly sticky in nature. Thus, it forms an impervious layer over the zinc metal and prevents its corrosion and rusting of iron.

Corrosion of Other Metals

X4F9MCVZ6I

1. **Corrosion of copper:** The position of copper in the metal activity series is below hydrogen and hence it is not expected to corrode. However, it is found that when objects made of copper are kept in moist air, containing carbon dioxide for prolonged time, they get coated with a greenish coating. It is because carbon dioxide gas in the presence of moisture and oxygen slowly reacts with copper to form basic copper carbonate [$CuCO_3$. $Cu(OH)_2$], which is green in colour. However, corrosion of copper is a very slow process.
2. **Corrosion of silver:** The position of silver is below copper in the metal activity series and hence it is not expected to corrode in moist air. However, it is found that objects of silver, get coated with a blackish powder in few weeks. It is because air always contains traces of hydrogen sulphide gas. The hydrogen sulphide gas reacts with silver slowly to form silver sulphide, which is black in colour.
3. **Corrosion of gold and titanium:** The objects made from gold or titanium do not corrode, because of their very low position in the metal activity series. It is for the same reason that gold jewellery does not lose its lustre. Similarly, the pipe lines and boilers made from titanium metal do not corrode and hence have a very long life.


Fig. 1.36: Corrosion of copper


Fig. 1.37: Corrosion of silver

Self-protecting Corrosion Resistant Metals

Metals such as ***aluminium*** and ***zinc*** are placed fairly high in the electrochemical series of metals and are expected to corrode in the same way as magnesium. However, it is found that initially a thin layer of oxide is formed on their surfaces, but then the corrosion stops. This is because, their oxides are very sticky in nature and hence, form an impervious layer on the metal surface, which does not allow air and moisture to come in contact with the fresh surface of the metal. Thus, corrosion comes to an end.

Rancidity IL5VDU2BAE

The aerial oxidation of food materials containing fats and oils such that they become stale and start smelling bad is called ***rancidity***.

Any kind of cooked food gets rancid, if kept at room temperature (above 25°C) for 24 hours, provided that it is in contact with air. It is the oxygen in the air that oxidises food and makes it stale. When the fats and oils present in food materials get oxidised, due to the oxygen present in air, the products formed after the oxidation reaction have unpleasant smell and taste. Hence, the foods containing fats and oils change and become stale.

Rancidity can be prevented, these are the ways by which the food can be kept intact.

1. Usually special type of substances (chemicals) called antioxidants are added to food cooked in fats. These antioxidants slow down the oxidation of food and hence, protect it from turning rancid.
2. Alternately the rancidity can be controlled by keeping the food at low temperatures in refrigerators as low temperature slows down the rate of oxidation.
3. The snack manufacturers pack snacks in plastic bags. The air is flushed out from the bags and then dry nitrogen is filled in. This prevents oxygen from coming in contact with packed snacks and they do not get oxidised.
4. Food must be kept in air-tight container, so as ensure limited supply of oxygen.
5. Light also causes rancidity. In absence of light the oxidation of food is slowed down. In presence of light the rancidity occurs at a faster rate. Hence, rancidity can be prevented by keeping food away from light as well.



Fig. 1.38: Cooling slow down the aerial oxidation of food



Fig. 1.39: Dry nitrogen is filled inside these packaged food items



Fig. 1.40: Air tight containers are used to protect food from the fast aerial oxidation

KEY POINTS

- When one or more substances (elements or compounds), undergo a chemical change, with the absorption or release of energy, so as to form one or more products, the changes taking place collectively are called **a chemical reaction**.
- A chemical equation that represents a chemical reaction briefly in words is called a **word equation**.
- The substances that take part in a chemical reaction are called **reactants**.
- The new substances formed as a result of a chemical reaction are called **products**.
- A statement that describes a chemical reaction in terms of symbols and formulae is called **a chemical equation**.
- A chemical equations expressed in symbols and formulae, such that the number of atoms of different elements towards the side of reactants is not equal to number of atoms of same elements towards the side of products is called a **skeletal equation**.
- A chemical equation in which the number of atoms of each element is same on both sides of reactants and products is called a **balanced chemical equation**.

- When two elements or compounds react chemically, to form a single new compound, then the chemical reaction is called a **chemical combination reaction**.
- A chemical reaction that proceeds with the release of heat energy is called an **exothermic reaction**.
- When a chemical compound decomposes on heating or absorbing some kind of energy, so as to form two or more substances (elements or compounds), then the chemical reaction that takes place is called a **chemical decomposition reaction**.
- When a chemical compound decomposes on heating, so as to form two or more substances (elements or compounds), then the reaction is called a **thermal decomposition reaction**.
- Chemical reaction that proceeds with the absorption of heat energy is called an **endothermic reaction**.
- Chemical reaction in which a compound decomposes into simpler substances on the absorption of light energy is called **photo-decomposition reaction**.
- A decomposition reaction that takes place with the absorption of electric energy is called an **electro-decomposition reaction**.
- When a more active element displaces a less active element from its aqueous ionic compound, the reaction that takes place is called a **chemical displacement reaction**.
- A chemical reaction in which two ionic compounds in their aqueous solutions, react by exchanging their ions/radicals, to form two new compounds is called a **chemical double displacement reaction**.
- When the aqueous solutions of two ionic compounds react by exchanging their ions/radicals, to form two or more new compounds, such that one of the products formed is an insoluble salt, and hence forms a precipitate, the reaction is said to be a **precipitation reaction**.
- When an aqueous solution of an acid reacts with a base (alkali) by exchanging their ions/radicals to form salt and water as the products, the reaction that takes place is called a **neutralisation reaction**.
- **Oxidation** of a substance takes place, when it gains oxygen or loses hydrogen.
- **Reduction** of a substance takes place, when it gains hydrogen or loses oxygen.
- Formation of a layer of undesired compounds, such as metallic oxides, metallic hydroxides or metal sulphides on the surface of metals is called **corrosion of metals**.
- The slow conversion of iron into hydrated ferric oxide, in the presence of moisture and air is called **rusting**.
- The flaky, non sticky brown powder formed on the surface of iron, when iron is exposed to moist air is called **rust**.
- The process in which fats and other cooked materials become stale due to aerial oxidation at room temperature is called **rancidity**.

Exercise–1 (B)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

1. Zinc or aluminium do not corrode because :
   (A) They do not react with moist air.
   (B) They react with moist air to form a very thin layer of oxides which is very sticky and hard.
   (C) They are inactive metals.
   (D) They are metalloids.

2. Three beakers labelled as A, B and C each containing 25 mL of water. A small amount of NaOH, anyhydrous $CuSO_4$ and NaCl were added to the beakers A, B and C respectively. It was observed that there was an increase in the temperature of the solutions contained in beakers A and B, whereas in case of beaker C, the temperature of the solution fall. Which one of the following statement(s) is(are) correct?
   (i) In beakers A and B, exothermic process has occurred. (ii) In beakers A and B, endothermic process has occurred.
   (iii) In beaker C exothermic process has occurred. (iv) In beaker C endothermic process has occurred.
   (A) (i) only (B) (ii) only (C) (i) and (iv) (D) (ii) and (iii) [HOTS]

3. Which amongst the following is(are) double displacement reaction?
   (i) $Pb(s) + CuCl_2(aq) \longrightarrow PbCl_2(aq) + Cu(s)$ (ii) $Na_2SO_4(aq) + BaCl_2(aq) \longrightarrow BaSO_4(s) + 2NaCl(aq)$
   (iii) $C(s) + O_2(g) \longrightarrow CO_2(g)$ (iv) $CH_4(g) + 2O_2(g) \longrightarrow CO_2(g) + 2H_2O(l)$ [HOTS]
   (A) (i) and (iv) (B) (ii) only (C) (i) and (ii) (D) (iii) and (iv)

4. Solid calcium oxide reacts vigorously with water to form calcium hydroxide accompanied by liberation of heat. This process is called slaking of lime. Calcium hydroxide dissolves in water to form its solution called lime water. Which amongs the following is(are) true about slaking of lime and the solution formed?
(i) It is an endothermic reaction. (ii) It is an exothermic reaction.
(A) (i) and (ii) (B) (ii) (C) (i) (D) None of the above [HOTS]

5. Which of the following can be decomposed by the action of light?
(A) NaCl (A) KCl (C) AgCl (D) CuCl

6. Consider the following equation of the chemical reaction :

$$2Na(s) + H_2(g) \longrightarrow 2NaH(s)$$

This equation represents :
(A) combination as well as reduction (B) decomposition as well as oxidation reaction
(C) oxidation as well as displacement reaction (D) combination as well as oxidation reaction

7. The process of respiration is :
(A) an oxidation reaction which is endothermic (B) a reduction reaction which is endothermic
(C) a combination reaction which is endothermic (D) an oxidation reaction which is exothermic

8. In order to prevent the spoilage of potato chips, they are packed in plastic bags in an atmosphere of :
(A) Cl_2 (B) H_2 (C) N_2 (D) O_2

9. A white precipitate is obtained by adding dilute sulphuric acid to :
(A) $CuSO_4$ solution (B) NaCl solution (C) $BaCl_2$ solution (D) Na_2SO_4 solution

10. The removal of oxygen from a substance is called :
(A) oxidation (B) corrosion (C) reduction (D) rancidity

11. The removal of hydrogen from a substance is known as :
(A) oxidation (B) calcination (C) reduction (D) hydration

12. One of the following is an endothermic reaction. This is :
(A) reaction of quicklime with water
(B) combination of nitrogen and oxygen to form nitrogen monoxide
(C) combination of glucose and oxygen to form carbon dioxide and water
(D) combination of zinc and sulphuric acid to form zinc sulphate and hydrogen

13. Which of the following is an exothermic reaction?
(A) Process of photosynthesis (B) Decomposition of silver chloride
(C) Electrolysis of water (D) Process of respiration

Ans: 1. (B) 2. (C) 3. (B) 4. (B) 5. (C) 6. (A) 7. (D) 8. (C) 9. (C) 10. (C) 11. (A) 12. (D) 13. (D)

II. ASSERTION (A) AND REASON (R)

For question numbers 1 and 5, two statements are given one labelled *Assertion* (A) and the other labelled *Reason* (R). Select the correct answer to these questions from the codes (i), (ii), (iii) and (iv) as given below.
(i) Both A and R are true and R is the correct explanation of the assertion.
(ii) Both A and R are true but R is not the correct explanation of the assertion.
(iii) A is true but R false.
(iv) A is false but R is true.

1. **Assertion:** Formation of curd from milk is a chemical change.
Reason: The chemical composition of curd is different from the chemical composition of milk.

2. **Assertion:** When dilute sulphuric acid is added to barium chloride solution a white precipitate is formed.
Reason: The formation of a white precipitate of barium sulphate is characteristic of the reaction.

3. **Assertion:** All the combination reactions are exothermic reactions.
Reason: Nitrogen and oxygen are heated at a very high temperature, they combine to form nitrogen monoxide and a lot of heat is absorbed in this reaction.

4. **Assertion:** A chemical process in which a substance gains oxygen or loses hydrogen is called oxidation reaction.
Reason: The substance that causes the addition of oxygen or removal of hydrogen is called reducing agent.



5. **Assertion:** Zinc is less active metal than iron in the metal reactivity series.
Reason: Zinc will get oxidised first. Thus, as long as zinc is present, rusting of iron is not possible.

III. VERY SHORT ANSWER TYPE QUESTIONS

1. What is the mole ratio of hydrogen and oxygen gases liberated during electrolysis of water?
2. Name two gases that can be used for the storage of fresh sample of an oil for a long time.
3. What change in colour is observed when white silver chloride is left exposed to sunlight? State the type of chemical reaction in this change.
4. Why is respiration considered an exothermic process?
5. By adding dilute hydrochloric acid to copper oxide powder, the solution formed is bluish green. Predict the new compound formed that imparts the colour to the solution.
6. In electrolysis of water, why is the volume of oxygen collected over one electrode double than that of the gas collected over other electrode.
7. Why do we store silver chloride in dark coloured bottles? [HOTS]
8. A silver article generally turns black when kept in the open for a few days. The article when rubbed with toothpaste again starts shining.
   (A) Why do silver articles turn black when kept in the open for a few days? Name the phenomenon involved.
   (B) Name the black substance formed and give its chemical formula. [HOTS]
9. A magnesium ribbon is burnt in oxygen to give a white compound X accompanied by emission of light. If the burning ribbon is now placed in an atmosphere of nitrogen, it continues to burn and forms a compound Y.
   (A) Write the chemical formulae of X and Y.
   (B) Write a balanced chemical equation, when X is dissolved in water. [HOTS]
10. A substance X, which is an oxide of a group 2 element, is used intensively in the cement industry. This element is present in bones also. On treatment with water it forms a solution that turns red litmus blue. Identify X and also write the chemical reactions involved. [HOTS]
11. Give one example of chemical decomposition reaction that is carried out by : (i) electric energy, and (ii) heat energy.
12. What is an oxidation reaction? Identify;
    (i) the substance oxidised and (ii) the substance reduced in the following reaction:
    $$ZnO(s) + C(s) \longrightarrow Zn(s) + CO(g)$$
13. What happens chemically, when quicklime is added to water?
14. Zinc and aluminium are very high in the metal activity series, yet they resist corrosion to a great extent. Explain.
15. By writing a chemical equation state two factors that are responsible for the rusting of iron.
16. Brightly polished iron nails are placed in a copper nitrate solution (blue in colour). Describe all that you will observe after one hour.
17. Classify the following reactions into different types :
    (A) $AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$ (B) $CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(aq)$
    (C) $2KClO_3(s) \xrightarrow{\Delta} 2KCl(aq) + 3O_2(g)$ (D) $Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s)$

IV. SHORT ANSWER TYPE QUESTIONS

1. $Fe(s) + ZnSO_4(aq) \longrightarrow FeSO_4(aq) + Zn(s)$
   $Mg(s) + ZnSO_4(aq) \longrightarrow MgSO_4(aq) + Zn(s)$
   Which amongst the above reactions will not proceed and why?
2. Grapes hanging on the plant do not ferment but after being plucked from the plant can be fermented. Under what conditions do these grapes ferment? Is it a chemical or a physical change? [HOTS]
3. An aluminium can is used to store ferrous sulphate solution. It is observed that in a few days holes appear in the can. Explain the observation and write the chemical equation in support of your answer.
4. Ferrous sulphate decomposes with the evolution of a gas having a characteristic odour of burning sulphur. Write the chemical reaction involved and identify the type of reaction.

5. Complete the missing components/variables given as x and y in the following reactions :
(A) $Pb(NO_3)_2(aq) + 2KI(aq) \longrightarrow PbI_2(x) + 2KNO_3(y)$ (B) $Cu(s) + 2AgNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + x(s)$
(C) $Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(x) + H_2(y)$ [HOTS]

6. "Decomposition of ferrous sulphate is an exothermic reaction." Is this statement correct?

7. Identify the reducing agent in the following reactions :
(A) $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(l)$ (B) $H_2O(l) + F_2(g) \longrightarrow HF(g) + HOF(g)$
(C) $Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$

8. On adding a drop of barium chloride solution to an aqueous solution of sodium sulphate, a white precipitate is obtained.
(A) Write a balanced chemical equation of the reaction involved.
(B) What other name can be given to this precipitation reaction?

9. Give an example of a decomposition reaction. Describe an activity to illustrate such a reaction by heating.

10. (A) What is the colour of ferrous sulphate crystals? How does this colour change on heating?
(B) Name the products formed on strongly heating of ferrous sulphate crystals. What type of chemical reaction occurs in this change.

11. (i) What is observed when a solution of potassium iodide is added to a solution of lead nitrate in a test tube?
(ii) What type of reaction is this?
(iii) Write a balanced chemical equation to represent the above reaction.

12. Why is decomposition reaction called the opposite of combination reaction? Explain with examples.

13. In the reaction given below :

$$CuO(s) + H_2(g) \longrightarrow Cu(s) + H_2O(l)$$

Name the following :
(A) substance oxidised (B) substance reduced (C) oxidsing agent (D) reducing agent

14. What happens when a zinc strip is put into a copper sulphate solution? Write the reaction equation. Explain the type of reaction as well.

15. What is 'corrosion'? Explain with the help of examples.

16. What is 'rancidity'? Explain with the help of examples.

17. What is rusting? How can it be prevented?

18. (a) What is a double displacement reaction? Explain with an example.
(b) A small amount of quick lime is added to water in a beaker.
(i) Name and define the type of reaction that has taken place.
(ii) Write balanced chemical equation for the above reaction and give the chemical name of the product formed.
(iii) List two main observations of this reaction.

19. (a) Design an activity to demonstrate the decomposition reaction of lead nitrate.
(b) Draw labelled diagram of the experimental set-up. List two main observations.
(c) Write balanced chemical equation for the reaction stating the physical state of the reactant as well as the products.

20. What is observed after about 1 hour of adding the strips of copper and aluminium separately to ferrous sulphate solution filled in two different beakers? Name the reaction if any change in colour is noticed. Also, write chemical equation for the reaction.

21. A student wants to study a decomposition reaction by taking ferrous sulphate crystals. Write two precautions he must observe while performing the experiment.

22. Silver articles become black when kept in open for some time, whereas copper vessels lose their shiny brown surfaces and gain a green coat when kept in open. Name the substances present in air with which these metals react and write the name of the products formed.

23. Identify the type of reactions taking place in each of the following cases and write the balanced chemical equation for the reactions.
(a) Zinc reacts with silver nitrate to produce zinc nitrate and silver.
(b) Potassium iodide reacts with lead nitrate to produce potassium nitrate and lead iodide.

24. What is an oxidising agent? What happens when an oxidising agent is added to propanol? Explain with the help of a chemical equation.



25. Name the products formed when ethane burns in air. Write the balanced chemical equation for the reaction showing the types of energies liberated.

26. When potassium iodide solution is added to a solution of lead (II) nitrate in a test tube, a precipitate is formed.
    (a) What is the colour of this precipitate? Name the compound precipitated.
    (b) Write the balanced chemical equation for this reaction.
    (c) List two types of reactions in which this reaction can be placed.

V. LONG ANSWER TYPE QUESTIONS

1. Give examples of articles made from iron, which are protected from rusting by :
    (i) Red lead paint (ii) Paint (iii) Enamelling (iv) Plastic coating (v) Tinning
    (vi) Electroplating (vii) Tarring (viii) Alloying (ix) Oiling or greasing

2. Give one example in case of the following reactions :
    (i) When a more active metal displaces a less active metal from its aqueous salt solution.
    (ii) When an active metal displaces hydrogen from dilute sulphuric acid.
    (iii) When two elements react to form a compound.
    (iv) When an element and a compound react to form another compound.
    (v) When two compounds react to form another compound.

3. (i) On heating colourless (white) powder of lead (II) nitrate in a boiling tube, lead monoxide (yellow), oxygen gas and a brown gas X is formed.
    (a) Write a balanced chemical equation of the reaction.
    (b) Identify the brown gas X evolved.
    (c) Identify the type of reaction.
    (ii) Give the characteristic test for the following gases.
    (a) CO_2 (b) SO_2 (c) O_2 (d) H_2 [HOTS]

4. Identify the oxidising agent (oxidant) in the following reactions
    (a) $Pb_3O_4(s) + 8HCl(aq) \longrightarrow 3PbCl_2(aq) + Cl_2(g) + 4H_2O(l)$ (b) $2Mg(s) + O_2(g) \longrightarrow 2MgO(s)$
    (c) $CuSO_4(aq) + Zn(s) \longrightarrow Cu(s) + ZnSO_4(aq)$ (d) $V_2O_5(s) + 5Ca(s) \longrightarrow 2V(s) + 5CaO(s)$
    (e) $3Fe(s) + 4H_2O(g) \longrightarrow Fe_3O_4(s) + 4H_2(g)$ [HOTS]

5. State various methods of preventing rancidity of food.

6. What happens when an aqueous solution of sodium sulphate reacts with an aqueous solution of barium chloride? What is the characteristic of this reaction? Explain.

7. (i) During the reaction of some metals with dilute hydrochloric acid, following observations were made.
    (a) Silver metal does not show any change.
    (b) The temperature of the reaction mixture rises when aluminium (Al) is added.
    (c) The reaction of sodium metal is found to be highly explosive.
    (d) Some bubbles of a gas are seen when lead (Pb) is reacted with the acid.
    Explain these observations giving suitable reasons.
    (ii) Zinc liberates hydrogen gas when reacted with dilute hydrochloric acid, whereas copper does not. Explain why? [HOTS]

8. What is meant by rusting? With labelled diagrams describe an activity to find out the conditions under which iron rusts.

9. What do you understand by endothermic and exothermic reactions? Give examples to support your answer.

VI. PASSAGE–BASED QUESTIONS

Answer the questions (1–4) on the basis of your understanding of the following paragraphs and the related studied concepts.

When fats and oils are oxidised, they become rancid and their smell and taste change. Usually substances which prevent oxidation (antioxidants) are added to foods containing fats and oil. Keeping food in air tight containers helps to slow down oxidation. Chips manufacturers usually flush bags of chips with gas such as nitrogen to prevent the chips from getting oxidised.

1. What is rancidity?
2. What purpose are antioxidants used far?
3. What is the role of air in the oxidation of food?
4. What is the role of nitrogen gas in packaged food?

2 Acids, Bases and Salts



INSIDE THE CHAPTER

2.1 Acid-base indicators
2.2 Acids
- Properties of acids

2.3 What do all acids have in common
2.4 Bases
- Properties of Bases

2.5 Common factor of acids and bases
2.6 How strong are acid or base solutions
2.7 Universal indicator
2.8 Importance of pH in everyday life
2.9 Salts
2.10 Common salt-a raw material for chemicals
2.11 Sodium hydroxide–Chlor-Alkali process
2.12 Bleaching powder [$CaOCl_2$]
2.13 Baking soda [$NaHCO_3$]
2.14 Washing soda [$Na_2CO_3.10H_2O$]
2.15 Plaster of Paris [$(CaSO_4)_2.H_2O$]
2.16 Water of crystallisation

RDSC9U1E7Z

INTRODUCTION

You have learnt in the previous classes that the food materials that taste sour are due to the presence of acids in them. Conversely, the food materials that taste bitter are due to the presence of bases.

You also know that, if you ever suffered from the problem of acidity after overeating, your mother gave you baking soda solution. Why baking soda solution?

Surely, she did have the knowledge that baking soda solution has the capacity to nullify the effect of the excess acid produced in your stomach.

Conversely, if you have bitter taste in your mouth, you are given lemon juice to nullify the effect of the excess base in your digestive system.



Fig. 2.1: Orange is sour in taste due to the presence of acid



Fig. 2.2: Baking soda is basic in nature

There are millions of compounds on our planet. They all are classified in a number of ways. One way to classify them is based on the property of chemical behaviour.

On the basis of chemical behaviour, all compounds can be classified into the following groups :

- Acids
- Bases
- Salts

Acids and bases are everywhere. Some foods contain acid, like the citric acid in lemons and the lactic acid in dairy products. Cleaning products like bleach and ammonia are bases.

We can recognise acids and bases by an indicator. An indicator is a chemical substance that indicates the nature of substances by means of a sharp change in colour or in odour.

2.1 ACID-BASE INDICATORS

NDTU4XROFQ

In order to know whether the given substance (or compound) is an acid or a base/alkali, certain reagents are used. Such reagents are termed as **Acid-Base indicators** or simply as **indicators**. An indicator gives different colours in acidic and basic solutions.

I. Litmus

Litmus is a natural dye extracted from **lichen**, a plant belonging to the *Thallophyte* division. Litmus solution is prepared by boiling the litmus dye in distilled water and finally filtering the solution. Neutral litmus solution is purple in colour. It is used as an indicator for testing acids and bases. It is red in acids and blue in bases.

The most common indicator used for testing acids and bases is litmus. It can be used in the form of a solution or in the form of paper. It is of two types : **Blue litmus** and **Red litmus**.

(i) An acid changes *blue* litmus to *red*.

(ii) A base (or alkali) changes *red* litmus to *blue*.



Fig. 2.3: Blue and red litmus paper



Fig. 2.4: An acid turns blue litmus paper red



Fig. 2.5: A base turns red litmus paper blue

Let us perform the following activity.

You have been provided with three test tubes. One of them contains distilled water and the other two contain an acidic solution and a basic solution respectively. If you are given strips of red litmus paper only, how will you identify the contents of each test tube.

Solution :

1. Dip a strip of red litmus paper into each of the test tubes. The test tube in which the litmus paper turns blue is a basic solution. Remove this test tube and label it as basic. The remaining two test tubes contain water and acid.
2. Take two red litmus strips and dip them in the already known basic solution, so that they turn blue.
3. Remove the blue litmus strips and place each of them in the remaining two test tubes.
4. The test tube in which the blue strip turns red is acidic and the test tube in which it remains blue is distilled water.

This was the use of the strip form of litmus paper. If you have litmus solution, you follow these simple steps.

- Add 3 drops of the indicator solution into the sample solution with the help of a dropper.
- Observe the colour of the solution.

II. Methyl Orange

Let us study the action of synthetic indicators such as methyl orange (orange in colour). Methyl orange also shows a very significant colour change in acidic and basic solutions.

(i) Methyl orange indicator gives *red* colour in *acid* solution.

(ii) It gives *yellow* **colour** in *basic* solution.



Fig. 2.6: Methyl orange in acidic and basic solutions

III. Phenolphthalein

We have another example of an important synthetic indicator. The neutral colour of phenolphthalein is 'colourless'. Phenolphthalein changes colour in basic solution.

(i) Phenolphthalein indicator remains ***colourless*** in ***acid*** solution.

(ii) It gives ***pink*** colour in ***basic*** solution.



Fig. 2.7: Phenolphthalein in acidic and basic solutions

IV. Natural Indicators (other than litmus)

There are many other natural materials obtained from the plant kingdom, such as *red cabbage leaves, turmeric, coloured petals of plants such as Hydrangea, Petunia* and *Geranium*, these can be used as natural indicators for testing the presence of acids and bases in solution form.

For example, the flowers of Hydrangea plant are usually blue which turn pink in the presence of a base. Turmeric in curry, stains white clothes yellow. When stained cloth is washed with soap, which is basic in nature, the stain turns reddish brown. The reddish brown stain again becomes yellow when rinsed with a lot of fresh water. Why? It is beacuse turmeric acts as an indicator, which changes to reddish brown colour in the presence of base. However, on rinsing with fresh water, the base in the soap is washed off, and hence, turmeric changes to yellow colour.

Red cabbage leaves are also natural indicator. The red cabbage is used as an indicator in the form of its extract. It is red in colour. The red cabbage extract remains red in acidic solutions. It turns green in basic solutions.



Fig. 2.8: Turmeric is a natural indicator



Fig. 2.9: Red cabbage is a natural indicator



Fig. 2.10: Red cabbage extract

V. Olfactory Indicators

It is a substance whose smell varies depending on whether it is mixed with an acidic or basic solution. The change that is shown is that when an acid or a base is added to it, then its own characteristic smell vanishes and hence cannot be detected. *The substances whose smell (or odour) changes in acidic or basic solutions are called* ***olfactory indicators***. Onion and vanilla extracts are olfactory indicators.

(i) Onion has a characteristic pungent smell. If a basic solution is added to onion extract, the smell of onion cannot be detected. An acidic solution does not destroy the smell of onions.

(ii) Vanilla extract has a characteristic pleasant smell. If a basic solution is added to vanilla extract, the characteristic smell of vanilla vanishes. An acidic solution does not destroy the smell of vanilla.

Another acid-base indicator is the 'Universal Indicator'. We will discuss it later in the chapter.



Fig. 2.11: Onion is used as olfactory indicator

VI. Effect of Acids and Bases on the Common Indicators

Let us perform the following activity.

Indicators required • Red litmus solution

- Blue litmus solution
- Phenolphthalein solution
- Methyl orange solution

Chemical required:

- Dilute hydrochloric acid (HCl) solution
- Dilute sulphuric acid (H_2SO_4) solution
- Dilute nitric acid (HNO_3) solution
- Dilute acetic acid (CH_3COOH) solution
- Dilute ammonium hydroxide (NH_4OH) solution
- Dilute sodium hydroxide (NaOH) solution
- Dilute calcium hydroxide [$Ca(OH)_2$] solution
- Dilute magnesium hydroxide [$Mg(OH)_2$] solution

Apparatus required:

- 8 test tubes and 8 droppers

Method:

- Arrange 8 test tubes and label them as HCl, H_2SO_4, HNO_3, CH_3COOH, NH_4OH, NaOH, $Ca(OH)_2$ and $Mg(OH)_2$.
- Pour 2 mL of chemical solution in each of the labelled test tubes and then a drop of blue litmus to all the eight test tubes. Observe the change in colour and record it in the table below.
- Repeat the experiment with, red litmus solution, phenolphthalein and methyl orange. Record your observations.

Sample chemical	Blue litmus solution	Red litmus solution	Phenolphthalein solution	Methyl orange solution
Dilute HCl	Red	Red	Colourless	Red
Dilute H_2SO_4	Red	Red	Colourless	Red
Dilute HNO_3	Red	Red	Colourless	Red
Dilute CH_3COOH	Red	Red	Colourless	Red
Dilute NH_4OH	Blue	Blue	Pink	Yellow
Dilute NaOH	Blue	Blue	Pink	Yellow
Dilute $Ca(OH)_2$	Blue	Blue	Pink	Yellow
Dilute $Mg(OH)_2$	Blue	Blue	Pink	Yellow

Thus, to conclude we can say that indicators can tell us whether the substance is acidic or basic.

SAMPLE PROBLEMS

1. You have been provided with three test tubes. One of them contains distilled water and the other two contain an acidic solution and a basic solution, respectively. If you are given only red litmus paper, how will you identify the contents of each test tube?

Ans. Take three strips of red litmus paper. Put one drop in each of the given solutions on these strips.

- The liquid which turns red litmus into blue is a basic solution.

Divide the blue litmus paper formed here into two parts. Put one drop each of the other two liquids separately on these two pieces of litmus paper.

- The solution which turns blue litmus paper red is acidic solution.
- The solution which does not affect the colour of litmus paper is water.

2. Which one of the following can be used as an acid-base indicator by a visually impaired student?

(A) litmus (B) turmeric (C) vanilla essence (D) petunia leaves

Ans. (C) vanilla essence

EH3A09DVMI

2.2 ACIDS

The word acid is taken from the Latin word **acidus** which means, **'Sour.'** If we cut a lemon and taste it, the lemon has a sour taste. This sour taste of lemon is due to the presence of citric acid in it.

Scientists have proposed a number of theories to categorise substances into acids and bases. The theory that you should know is 'Arrhenius Theory'.

The Swedish chemist Svante Arrhenius published his theory of acids and bases in 1887. This theory gave us good definitions to understand the chemical properties of acids and bases.

Arrhenius Theory of Acids :

*An **acid** is a substance which on dissolution, dissociates in water to produce **hydrogen ions (H^+)**.*

Based on this definition, we can say that Arrhenius acids are soluble in water. We can draw the following conclusion, based on the Arrhenius theory, ***'an acid dissociate in water producing hydrogen ions.'***

Example :

$$\underset{\text{Hydrogen chloride}}{HCl(g)} + \underset{\text{Water}}{H_2O} \longrightarrow \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Chloride ion}}{Cl^-(aq)}$$

'H_3O^{+1} is hydronium ion which is formed when an acid is dissolved in water. H^+ (proton from acid) combines with water to form hydronium ion.

We have already seen the effect of acids on different indicators. Now we will see the strength of acids.

Strong Acids and Weak Acids

All the acids can be divided into two groups : **strong acids** and **weak acids**.

(i) The acids which completely dissociate into ions when dissolved in water are called **strong acids**.

(ii) The acids which partially ionise when dissolved in water are called **weak acids**.

(iii) Hydrochloric acid, sulphuric acid and nitric acid are strong acids.

(iv) Acetic acid (ethanoic acid), formic acid, citric acid, tartaric acid and carbonic acid are weak acids.



Fig. 2.12: Lemon contains citric acid

The organic acids are generally "weak acids" mineral acids are generally "strong acids."

The acids obtained from plants and animals are called **organic acids**. **Acetic acid** is found in vinegar, **citric acid** is present in citrus fruits such as lemon and orange, **lactic acid** is present in curd, **tartaric acid** is present in tamarind and unripe grapes, **oxalic acid** is present in tomatoes and **formic acid** or **methanoic acid** is present in ant sting. Organic acids are ***weak acids***. These acids are safe to eat and drink.



Fig. 2.13: Milk contains lactic acid



Fig. 2.14: Acetic acid is found in vinegar



Fig. 2.15: Tamarind contains tartaric acid



Fig. 2.16: Tomato contains oxalic acid



Fig. 2.17: Ant sting hurts because of the formic acid present in it



Fig. 2.18: Sulphuric acid is mineral acid

The acids synthesised from the minerals of the earth are called **mineral acids**. These are *man-made* acids. **Hydrochloric acid, sulphuric acid** and **nitric acid** are the three most common **mineral acids.** Concentrated mineral acids are very dangerous. They should be handled with care. These acids should never be touched and tasted. If required, use very dilute solutions of these acids.

Phosphoric acid (H_3PO_4) and **carbonic acid** (H_2CO_3) are moderately weak acids.

Note: The solutions of weak acids in water are **poor conducting** due to low concentration of H_3O^+ (or H^+) ions. The solutions of weak acids contain its ions as well as molecules of the acid.

Concentrated and Dilute Acids

Concentrated acids, as the name suggests, contains high amount of the acid dissolved in minimum volume of water. The amount per unit volume is defined as the concentration. The concentration of an acid can be decreased by adding water to it. When water is added to a concentrated acid, a dilute acid is formed. Thus, **a dilute acid contains much more of water in it**.

An acid can be diluted by adding water to it. Generally, it is an exothermic process. However, dilution of an acid must always be done by adding concentrated acid to water, very slowly with continuous stirring.

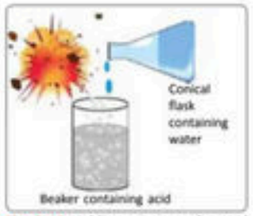


Fig. 2.19: Adding water to the acid for dilution is the wrong procedure and should never be done



Fig. 2.20: Adding acid slowly to water for dilution is the correct procedure

When an acid (concentrated) is added to water, heat is evolved gradually which is absorbed by the water and continuous stirring also assists in better absorption of energy.

If, however, water is added to concentrated acid to dilute it, then a large amount of heat is evolved at once. This heat provides a lot of energy to the water and due to this water gets converted to steam explosively, which can splash the acid on us and can cause acid burns.

Assess Yourself – 1

1. What do you understand by organic and mineral acids?
2. What colour does phenolphthalein show when it is poured into a basic solution?
3. What is the effect of an acid on methyl orange?
4. Litmus is a natural indicator. Name two other natural indicators.
5. Why does a turmeric stain turn red when soap is applied on it?
6. Name the mineral acid present in our stomach. How is acidity cured?

Properties of Acids

1DJAYS5KCL

Here are some characteristic features of acids.

1. **Taste:**
   Acids have a characteristic **sour taste**. All the citrus fruits have sour taste due to the presence of acids.
2. **Action on Indicators:**
   (i) Acids turn blue litmus red.
   (ii) Acids turn methyl orange red.
   (iii) Phenolphthalein remains colourless in acidic solutions.
3. **Corrosive Nature:**
   Acids tend to attack on skin causing severe burns. Acids are harmful for metals as well. They can corrode the metal vessels they are kept in. Acids like sulphuric acid (concentrated) can cut through the cloth. Hence, it is advised to keep them in vessels made up of glass.



Fig. 2.21: Acids are highly corrosive

4. **Dissolution:**
   On dissolving in water all acids dissociate into ions producing H^+ ions (H_3O^+, due to the combination with water molecules). One point to be noted is that strong acids dissociate completely, while weak acids dissociate partially, hence their reaction is shown with a reversible arrow ($\rightleftharpoons$).
   Let us see the dissociation of strong acids.

$$\underset{\text{Hydrogen chloride}}{HCl(g)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Chloride ion}}{Cl^-(aq)}$$

$$\underset{\text{Concentrated sulphuric acid}}{H_2SO_4(aq)} + \underset{\text{Water}}{2H_2O(l)} \longrightarrow \underset{\text{Hydronium ion}}{2H_3O^+} + \underset{\text{Sulphate ion}}{SO_4^{2-}(aq)}$$

Weak acids ionise to very small extent.

For Example :

$$\underset{\text{Acetic acid}}{CH_3COOH(s)} + \underset{\text{Water}}{H_2O(l)} \rightleftharpoons \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Acetate ion}}{CH_3COO^-(aq)}$$

$$\underset{\text{Carbonic acid}}{H_2CO_3(aq)} + \underset{\text{Water}}{H_2O(l)} \rightleftharpoons \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Bicarbonate ion}}{HCO_3^-(aq)}$$

Mixing of water in a concentrated acid is called ***dilution*** *and the product so obtained is called* ***dilute acid.***

Dilution results in lowering the amount of $H^+(aq)$ ions of an acid per unit volume.

For example, if 1 mole of HCl (36.5 g) is dissolved in one litre of water its concentration is 1 mol/L.

However, if 0.1 mole of HCl (3.65 g) is dissolved in one litre of water its concentration is 0.1 mol/L.

Now, amongst HCl solution of 1 mol/L and 0.1 mol/L, the solution with concentration of 0.1 mol/L is dilute solution compared to 1 mol/L solution.

5. Electrical Conductivity:

Hydrochloric acid (HCl), sulphuric acid (H_2SO_4), nitric acid (HNO_3) and perchloric acid ($HClO_4$) are strong acids. The solutions of strong acids in water have high electrical conductivity due to high concentration of hydrogen ion (H^+) in the solution. The solutions of strong acids contain only **ions**.

6. Reaction with Metals:

Metals (such as magnesium, aluminium, zinc and iron) on treatment with dilute mineral acids, displace hydrogen from acids in the form of hydrogen gas. The metals combine with the remaining part of the acid to form a compound called **salt**.

For example :

Metal	+	**Acid**	⟶	**Metal salt**	+	**Hydrogen**
$Zn(s)$	+	$H_2SO_4(aq)$	⟶	$ZnSO_4(aq)$	+	$H_2(g)$
Zinc		Dilute sulphuric acid		Zinc sulphate	+	Hydrogen

Let us perform the following activity :

- Set up the apparatus as shown in Fig. 2.21.

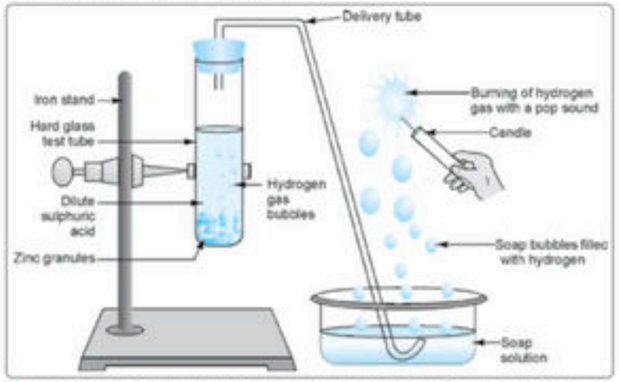


Fig. 2.22: Reaction of zinc granules with dilute sulphuric acid and testing hydrogen gas

- In the hard glass test tube place two or three pieces of granulated zinc.
- Pour 10 mL of dilute sulphuric acid by lifting the rubber cork. Immediately replace the rubber cork.
- You will observe that tiny bubbles of a gas start forming on the surface of zinc granules. These tiny bubbles then form bigger bubbles and rise up the dilute sulphuric acid in the form of a colourless gas.
- In a few moments, bubbles of gas start coming out from the soap solution, in the form of soap bubbles.
- When the first few bubbles escape, bring the flame of a burning candle near one of the soap bubbles.

  You will observe that the soap bubble bursts with a **"pop"** sound and the candle flame goes off. From this observation we can conclude that the gas evolved during the chemical reaction of granulated zinc with dilute sulphuric acid is **hydrogen gas**.
- You can repeat the experiment with dilute hydrochloric acid and acetic acid. You will notice that these acids also produce hydrogen gas.

You will notice that in each case hydrogen gas is evolved. Let us see examples of other metals as well.

$Mg(s)$	+	$H_2SO_4(aq)$	$\longrightarrow$	$MgSO_4(aq)$	+	$H_2(g)$
Magnesium		Dilute sulphuric acid		Magnesium sulphate		Hydrogen
$2Al(s)$	+	$6HCl(aq)$	$\longrightarrow$	$2AlCl_3(aq)$	+	$3H_2(g)$
Aluminium		Dilute hydrochloric acid		Aluminium chloride		Hydrogen
$Fe(s)$	+	$2HCl(aq)$	$\longrightarrow$	$FeCl_2(aq)$	+	$H_2(g)$
Iron		Dilute hydrochloric acid		Ferrous chloride		Hydrogen
$2K(s)$	+	$H_2SO_4(aq)$	$\longrightarrow$	$K_2SO_4(aq)$	+	$H_2(g)$
Potassium		Dilute sulphuric acid		Potassium sulphate		Hydrogen

Dilute mineral acids (HCl, H_2SO_4) or organic acid (CH_3COOH) react with active metals such as magnesium, aluminium, zinc and iron to form their respective salts and hydrogen gas.

Note: Nitric acid (that is also a mineral acid), in dilute or concentrated form does not produce hydrogen gas with metals, except in case of **magnesium** and **manganese**. It is because, nitric acid is a **powerful oxidising agent**. Thus initially the hydrogen displaced by it gets oxidised. So, nitric acid produces nitrogen dioxide or nitric oxide gases when treated with metals.

Less reactive and noble metals such as copper, silver and gold do not displace hydrogen from acids.

LOHYAI2OFW

7. Reaction with Metal Carbonates and Metal Hydrogen Carbonates:

All metal carbonates or metal hydrogen carbonates, react with dilute acids to form their respective salts, water and carbon dioxide gas.

Metal carbonate or Metal hydrogen carbonate + Acid $\longrightarrow$ Metal salt + Water + Carbon dioxide gas

For Example:	$CaCO_3(s)$	+	$2HCl(aq)$	$\longrightarrow$	$CaCl_2(aq)$	+	$H_2O(l)$	+	$CO_2(g)$
	Calcium carbonate		Hydrochloric acid		Calcium chloride		Water		Carbon dioxide
	$Ca(HCO_3)_2(aq)$	+	$H_2SO_4(aq)$	$\longrightarrow$	$CaSO_4(aq)$	+	$2H_2O(l)$	+	$2CO_2(g)$
	Calcium bicarbonate		Sulphuric acid		Calcium sulphate		Water		Carbon dioxide

Let us perform the following activity which is based on the reaction of Na_2CO_3 with HCl (acid)

- Take a hard glass test tube A and place 1 g of sodium carbonate in it.

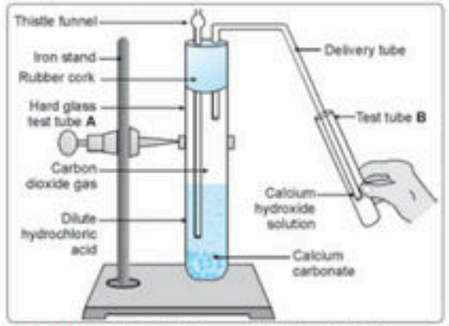


Fig. 2.23: Action of acids on metal carbonates/hydrogen carbonates and testing the carbon dioxide gas with limewater

DID YOU KNOW?

1. Pickles, jams and jellies are stored either in glass vessels or plastic vessels. They are never stored in tin cans for the simple reason that all of them contain organic acids. These acids react with the metals to form harmful salts. Furthermore, they corrode the container.
2. You must have seen people getting their copper or brass cooking vessels coated with tin metal (Kalai). Why do they do so?

   When we cook food in these vessels without the coating of kalai, the organic acids present in the food materials, react with copper and corrode it. Furthermore, the copper salts formed by acids are poisonous in nature.

   The kalai protects the vessels from the action of acids for a while, and hence, prevents food poisoning.

   However, these days quite a number of people use stainless steel cooking vessels, because it is not affected by the acids present in food materials.

- Clamp the hard glass test tube in an iron stand and fix a rubber cork containing a thistle funnel and a delivery tube in its mouth as shown in Fig. 2.23.
- Pour 5 mL of dilute hydrochloric acid from the thistle funnel and observe keenly.
- You will observe that a vigorous reaction takes place with a lot of effervescence and a colourless gas is given off.
- Pass the colourless gas through about 2 mL of limewater contained in test tube B and make your observations.

  You will observe that initially the limewater turns milky. However, as the passage of gas is continued, the milkiness disappears.

  Following reactions take place in the hard glass test tube A and test tube B.

Reaction in test tube A :

$$\underset{\text{Sodium carbonate}}{Na_2CO_3(s)} + \underset{\text{Dilute hydrochloric acid}}{2HCl(aq)} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

Reaction in test tube B :

(i) $$\underset{\text{Limewater}}{Ca(OH)_2(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \longrightarrow \underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{Water}}{H_2O(l)}$$

It is the formation of insoluble calcium carbonate that gets suspended in water, and hence, the limewater turns milky. The milkiness is due to the fact that calcium carbonate is white in colour.

(ii) $$\underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \longrightarrow \underset{\text{Calcium hydrogen carbonate}}{Ca(HCO_3)_2(aq)}$$

Excess of carbon dioxide reacts with insoluble calcium carbonate to form soluble calcium hydrogen carbonate, and hence, the milkiness disappears.

- Now, if the activity is repeated with sodium hydrogen carbonate all the above observations take place. The reaction between sodium hydrogen carbonate and dilute hydrochloric acid is represented as under:

$$\underset{\text{Sodium hydrogen carbonate}}{NaHCO_3(s)} + \underset{\text{Hydrochloric acid}}{HCl(aq)} \longrightarrow \underset{\text{Sodium chloride}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

- Furthermore, if the experiment is repeated with carbonates/hydrogen carbonates of other metals, using hydrochloric acid, nitric acid, sulphuric acid or acetic acid; a metal salt, water and carbon dioxide are formed. Thus, the reaction can be summarised as :

There are a few examples for this kind of reaction.

$$\underset{\text{Zinc carbonate}}{ZnCO_3(s)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq)} \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_4(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

$$\underset{\text{Magnesium carbonate}}{MgCO_3(s)} + \underset{\text{Acetic acid}}{2CH_3COOH(aq)} \longrightarrow \underset{\text{Magnesium acetate}}{(CH_3COO)_2Mg(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

$$\underset{\text{Copper carbonate}}{CuCO_3(s)} + \underset{\text{Nitric acid}}{2HNO_3(aq)} \longrightarrow \underset{\text{Copper nitrate}}{Cu(NO_3)_2(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

$$\underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{Hydrochloric acid}}{2HCl(aq)} \longrightarrow \underset{\text{Calcium chloride}}{CaCl_2(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

$$\underset{\text{Sodium carbonate}}{Na_2CO_3(s)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq)} \longrightarrow \underset{\text{Sodium sulphate}}{Na_2SO_4(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

$$\underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq)} \longrightarrow \underset{\text{Calcium sulphate}}{CaSO_4(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

$$\underset{\text{Sodium hydrogen carbonate}}{NaHCO_3(s)} + \underset{\text{Hydrochloric acid}}{HCl(aq)} \longrightarrow \underset{\text{Sodium chloride}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

8. Reaction with Bases: LDIQK2W.DXN

All metal hydroxides react with dilute acids to form their respective salts and water as the only products.

Such a chemical reaction in which an acid reacts completely with a base to form salt and water as the only products is called ***neutralisation reaction***. In general, neutralisation reaction can be written as :

Acid + Base ⟶ Salt + Water

It has been found that all metal hydroxides (bases) react with all dilute acids to form their respective metallic salts and water as the only products. It is useful to remember that :

(i) Sodium hydroxide and potassium hydroxide are **soluble in water**.

(ii) Calcium hydroxide and magnesium hydroxide are **partially soluble in water**.

(iii) All other metal hydroxides are **insoluble in water**.

Nevertheless, all metallic hydroxides react with acids to form their respective metallic salts and water as shown by the following chemical equations:

Metal hydroxide	+	Acid	⟶	Metal salt	+	Water
$Ca(OH)_2(aq)$ Calcium hydroxide	+	$2HNO_3(aq)$ Nitric acid	⟶	$Ca(NO_3)_2(aq)$ Calcium nitrate	+	$2H_2O(l)$ Water
$Mg(OH)_2(aq)$ Magnesium hydroxide	+	$H_2SO_4(aq)$ Sulphuric acid	⟶	$MgSO_4(aq)$ Magnesium sulphate	+	$2H_2O(l)$ Water
$Al(OH)_3(s)$ Aluminium hydroxide	+	$3HCl(aq)$ Hydrochloric acid	⟶	$AlCl_3(aq)$ Aluminium chloride	+	$3H_2O(l)$ Water
$Zn(OH)_2(s)$ Zinc hydroxide	+	$H_2SO_4(aq)$ Sulphuric acid	⟶	$ZnSO_4(aq)$ Zinc sulphate	+	$2H_2O(l)$ Water
$Fe(OH)_3(s)$ Ferric hydroxide	+	$3HCl(aq)$ Hydrochloric acid	⟶	$FeCl_3(aq)$ Ferric chloride	+	$3H_2O(l)$ Water
$Cu(OH)_2(s)$ Copper hydroxide	+	$2HNO_3(aq)$ Nitric acid	⟶	$Cu(NO_3)_2(aq)$ Copper nitrate	+	$2H_2O(l)$ Water

The following experiment will show us the actual cause of the reaction.

- Take a clean test tube and pour in it 4 mL of dilute sodium hydroxide solution.
- To the solution add 2 drops of phenolphthalein solution and shake the contents of the tube. You will observe the contents of the solution turn pink in colour.
- Now fill a dropper with hydrochloric acid and add few drops of it in the above test tube at a time and stir its contents.
- You will notice that at some point the contents of the test tube become colourless with last two drops of the acid.

  It is because the acid has nullified the effect of the base, sodium hydroxide.

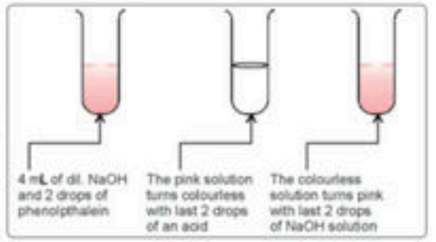


Fig. 2.24: Neutralisation of a base with an acid

- Again add few drops of sodium hydroxide solution to the above test tube.

  You will observe that the pink colour reappears. It is because, sodium hydroxide is present in excess.

The chemical reaction taking place is represented by the following equations.

$$\underset{\text{Sodium hydroxide}}{NaOH(aq)} + \underset{\text{Hydrochloric acid}}{HCl(aq)} \longrightarrow \underset{\text{Sodium chloride}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(l)}$$

You can see from the above equation that an acid reacts with a base (metal hydroxide) to form salt and water.

9. Reaction with Metal Oxides:

All metal oxides react with acids to form metal salt and water as the only products.

Thus, the general reaction between metal oxide and an acid can be written as :

Metal oxide	+	**Acid**	⟶	**Metal salt**	+	**Water**
$CuO(s)$	+	$2HNO_3(aq)$	⟶	$Cu(NO_3)_2(aq)$	+	$H_2O(l)$
Copper (II) oxide		Nitric acid		Copper (II) nitrate		Water

We will now perform a simple activity to witness the reaction of metal oxide with acid.

- Take a beaker and put 1 g of copper oxide (CuO), which is black in colour.
- Add 20 mL of dilute nitric acid in the beaker and stir its contents with a glass rod for few minutes.

  You will notice that black coloured copper oxide completely dissolves and a blue-green solution of copper (II) nitrate is formed.
- If you repeat the experiment with any other metal oxide and an acid, always the metal oxide dissolves to form its salt and water.

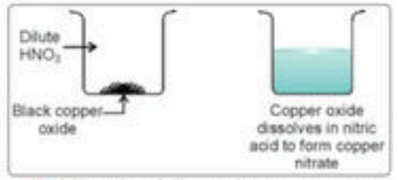


Fig. 2.25: Action of dilute HNO_3 on copper oxide.

The following reactions are few more examples of reactions between metal oxides and acids.

$PbO(s)$	+	$2HNO_3(aq)$	⟶	$Pb(NO_3)_2(aq)$	+	$H_2O(l)$
Lead (II) oxide		Nitric acid		Lead (II) nitrate		Water
$FeO(s)$	+	$2HCl(aq)$	⟶	$FeCl_2(aq)$	+	$H_2O(l)$
Iron (II) oxide		Hydrochloric acid		Iron (II) chloride		Water
$ZnO(s)$	+	$H_2SO_4(aq)$	⟶	$ZnSO_4(aq)$	+	$H_2O(l)$
Zinc oxide		Sulphuric acid		Zinc sulphate		Water
$Al_2O_3(s)$	+	$3H_2SO_4(aq)$	⟶	$Al_2(SO_4)_3(aq)$	+	$3H_2O(l)$
Aluminium oxide		Sulphuric acid		Aluminium sulphate		Water
$MgO(s)$	+	$2HCl(aq)$	⟶	$MgCl_2(aq)$	+	$H_2O(l)$
Magnesium oxide		Hydrochloric acid		Magnesium chloride		Water

Important Note: We have already stated that bases are metal hydroxides, which react with acids to form metal salt and water as the only products.

Now, we have learnt that all metal oxides also react with acids to form metal salt and water as the only products. So, metal oxides should also be bases.

2.3 WHAT DO ALL ACIDS HAVE IN COMMON

MT.J7WZXROH

We have just studied the chemical properties of acids. We saw that, all acids have similar chemical properties. While reacting with metals, acids produce hydrogen gas. So, we can say that hydrogen would be a common factor in all acids. Let us investigate the common factor in all the acids. We have seen that, when acids dissolve in water, they ionise to produce hydronium ions (H_3O^+).

$$\underset{\text{Hydrogen chloride}}{HCl(g)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Chloride ion}}{Cl^-(aq)}$$

When hydrogen chloride ionises in water it produces hydronium ion and chloride ion.

$$\underset{\text{Sulphuric acid}}{H_2SO_4(aq)} + \underset{\text{Water}}{2H_2O(l)} \longrightarrow \underset{\text{Hydronium ion}}{2H_3O^+} + \underset{\text{Sulphate ion}}{SO_4^{2-}(aq)}$$

When sulphuric acid ionises in water it produces hydronium ions and sulphate ion.

$$\underset{\text{Nitric acid}}{HNO_3(l)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Nitrate ion}}{NO_3^-(aq)}$$

$$\underset{\text{Acetic acid}}{CH_3COOH(s)} + \underset{\text{Water}}{H_2O(l)} \rightleftharpoons \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Acetate ion}}{CH_3COO^-(aq)}$$

When nitric acid ionises in water it produces hydronium ion and nitrate ion. Similarly, acetic acid gives hydronium ion and acetate ion, when ionises in water.

Thus, from the above observations, *"we can say that all acids like, HCl, H_2SO_4, HNO_3, CH_3COOH, etc. have hydrogen in common. It is the presence of hydronium ion (H_3O^+) in the aqueous solutions of all the acids which make them behave like an acid."*

Not all Hydrogen-Containing Compounds are Acids

All acids give hydrogen gas as a result of the reaction with metals. This shows that all acids contain hydrogen. But all hydrogen-containing compounds are not categorised as acid. Let us perform the following activity to understand this fact.

Procedure:
- Take 2 mL each of ethanol, glucose solution and dilute sulphuric acid in three separate test tubes.
- Add 2 drops of blue litmus solution to each of these test tubes.
- Observe the colour changes and record your observations.

Observations:

Substance	Colour of Litmus		Conclusion
	Before adding	After adding	
Ethanol	Blue	Blue	No change
Glucose solution	Blue	Blue	No change
Sulphuric acid (dilute)	Blue	Red	Blue litmus turns red

Conclusions: Ethanol (CH_3CH_2OH) and glucose ($C_6H_{12}O_6$) solutions are not acidic in nature while dilute sulphuric acid (H_2SO_4) is acidic in nature. So the conclusion is that not all compounds containing hydrogen are acidic in nature. This happened because ethanol and glucose do not produce $H^+(aq)$ in solutions. So, these compounds do not show acidic character.

FYPJBONTKB

Acids do not Dissociate in the Absence of Water

To understand this fact, let us look at the following activity :

Procedure: In a test tube, take 2 g of sodium chloride and slowly add concentrated sulphuric acid (H_2SO_4) solution. You will notice that a gas is evolving. This gas is hydrogen chloride (HCl). To test the acidic nature of this gas bring (HCl) a dry litmus paper near the mouth of the test tube. You will notice that there is no change in the colour of the blue litmus paper. Now perform the same experiment using a moist litmus paper notice the changes and record you observations.

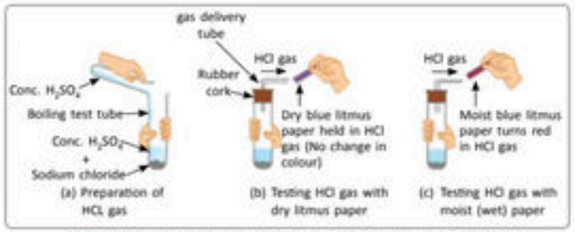


Fig. 2.26: Testing HCl gas with dry litmus and moist litmus paper

Observation : We observe that the dry hydrogen chloride gas (HCl) only turns the moist blue litmus paper to red. This happens because acids dissociate into ions only in the presence of water. So we can say that acids show acidic behaviour only in the presence of water.

Uses of Some Common Acids

Mineral acids are used in industry for different purposes. Some important uses of common acids are :

1. **Sulphuric acid (H_2SO_4):**
   - For manufacture of fertilisers (such as ammonium sulphate), detergents, chemicals, plastics, paints, dyes, synthetic fibres, car batteries and explosives.
   - For refining in petroleum industry.
2. **Nitric acid (HNO_3):**
   - For preparation of fertilisers (such as ammonium nitrate), dyes, drugs and explosives.
   - For the refining of gold and silver.
   - For the cleaning of gold and silver ornaments.
3. **Hydrochloric acid (HCl):**
   - For removing oxide film from steel objects (before the galvanisation process).
   - For removing deposits from inside the boilers. The deposit is called scale deposit and the process is called descaling.
   - For the preparation of chlorides and chlorine gas.
   - Used in dye-stuffs textile, food and leather industries.
   - For cleaning kitchen sink and other sanitary wares.
4. **Acetic acid (CH_3COOH):** Used as table vinegar and for making pickles.
5. **Citric acid ($C_6H_8O_7$):** Used for food preservation.
6. **Carbonic acid (H_2CO_3):** Used for making aerated drinks.
7. **Boric acid (H_3BO_3):** Used as an antiseptic.

SAMPLE PROBLEMS

1. Metal A reacts with dilute sulphuric acid to produce a gas which is seen due to the evolution in the form of bubbles near the metal granules. This gas burns with a popping sound. Write a balanced chemical equation, given that the metal is aluminium.

Ans. The gas that burns with a pop-sound is hydrogen gas. We have been told that the metal is aluminium and the acid is sulphuric acid. Writing the equation for the chemical reaction :

$$2Al(s) + 3H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$$

When aluminium reacts with sulphuric acid, it displaces hydrogen from sulphuric acid and produces a salt, that is, aluminium sulphate and releases hydrogen gas.

2. A solution reacts with crushed egg-shells to give a gas that turns limewater milky. The solution contains
   (A) NaCl (B) HCl (C) LiCl (D) KCl

Ans. The correct answer is (b).
Egg shells contain calcium carbonate. Calcium carbonate when reacts with HCl gives out carbon dioxide gas, which turns limewater milky.

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

3. Why should curd and sour substances not be kept in brass and copper vessels?

Ans. Curd and sour substances contain organic acids. Brass and copper react with these acids slowly and produce poisonous substances. Hence, curd and sour substances are not kept in brass and copper vessels.

4. Which gas is usually liberated when an acid reacts with a metal? Illustrate with an example. How will you test for the presence of this gas?

Ans. Hydrogen gas is liberated when an acid reacts with a metal.

$$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$$

Test for the presence of hydrogen gas: Bring a burning matchstick near the mouth of the inverted gas container (gas jar or boiling tube). The gas in the container burns with a pop sound and a blue flame. This proves that the gas in the container is hydrogen.

5. Metal compound A reacts with dilute hydrochloric acid to produce effervescence. The gas evolved extinguishes a burning candle. Write a balanced chemical equation for the reaction if one of the compounds formed is calcium chloride.

Ans. The compound formed as a product is calcium chloride. So, the given compound 'A' is a salt of calcium.

Since, the given compound produces effervescence with dilute hydrochloric acid, and extinguishes a burning candle, it should be a carbonate. Therefore, the given compound is **calcium carbonate**.

$$CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$$

6. Why do HCl, HNO_3 etc., show acidic characters in aqueous solutions while solutions of compounds like alcohol and glucose do not show acidic character?

Ans. HCl and HNO_3 get ionised in their aqueous solutions and produce free ions, $H^+(aq)$ and $Cl^-(aq)$ and $H^+(aq)$ and $NO_3^-(aq)$ respectively. Due to the presence of free $H^+(aq)$ ions, HCl and HNO_3 show acidic character. Alcohol and glucose are covalent compounds and do not furnish free $H^+(aq)$ ions in solutions. So, these compounds do not show acidic character.

7. Why does an aqueous solution of an acid conduct electricity?

Ans. Due to the presence of free ions in the solution of an acid in water, the acid solution conducts electricity.

8. Why does dry HCl gas not change colour of the dry litmus paper?

Ans. Dry HCl gas does not undergo ionisation and, therefore, does not contain H^+ ions. Hence, it does not change colour of the dry litmus paper.

9. While diluting an acid, why is it recommended that the acid should be added slowly to water and not water to the acid?

Ans. Dissolution of a concentrated acid, sulphuric acid, is a highly exothermic reaction. When water is added to a concentrated acid, a large amount of heat is released. This may cause spurting of the hot acid solution and harm the person. Excessive local heating may even break the glass container. That is why concentrated acids are diluted by slowly adding concentrated acid into water with constant stirring and not by adding water to the acid.

10. How is the concentration of hydronium ions (H_3O^+) affected when a solution of an acid is diluted?

Ans. When a solution of an acid is diluted, the concentration of H_3O^+ decreases.

11. Which one of the following types of medicines is used for treating indigestion?

(A) Antibiotic (B) Analgesic (C) Antacid (D) Antiseptic

Ans. The correct answer is (C).

Indigestion is caused by excessive acid in the stomach. Antacids are mild bases, that neutralise the excess acid and provide relief.

12. Write word equations and then balanced equations for the reaction taking place when :

(a) Dilute sulphuric acid reacts with zinc granules.



(b) Dilute hydrochloric acid reacts with magnesium ribbon.
(c) Dilute sulphuric acid reacts with aluminium powder.
(d) Dilute hydrochloric acid reacts with iron filings.

Ans. (a) Zinc + Sulphuric acid (*dilute*) ⟶ Zinc sulphate solution + Hydrogen gas

$Zn(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2(g)$.

(b) Magnesium ribbon + Hydrochloric acid (*dilute*) ⟶ Magnesium chloride solution + Hydrogen gas

$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$

(c) Aluminium + Sulphuric acid (*dilute*) ⟶ Aluminium sulphate solution + Hydrogen gas

$2Al + 3H_2SO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + 3H_2(g)$

(d) Iron filings + Hydrochloric acid (*dilute*) ⟶ Iron (II) chloride solution + Hydrogen gas

$Fe(s) + 2HCl(aq) \longrightarrow FeCl_2(aq) + H_2(g)$

13. Compounds such as alcohols and glucose also contain hydrogen but are not categorised as acids. Describe an activity to prove it.

Ans. We will perform the following activity to prove this fact.

Procedure:

- Take a beaker and place two carbon electrodes into it.
- Connect the electrodes to a battery and bulb through a key and a dry cell.
- Pour ethanol into the beaker and press the key. See, if the bulb glows.
- Repeat similar experiment with glucose solution. Record your observations.

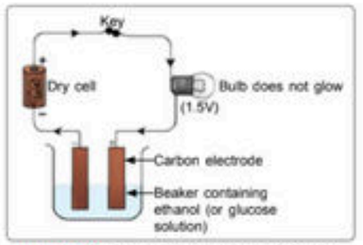


Fig. 2.27: Ethanol and glucose solutions do not conduct electricity

Observations. It is observed that the bulb does not glow with both the solutions.

Conclusion. The solutions of glucose and ethanol are non-conductors.

Explanation. Ethanol and the solution of glucose containing hydrogen in their molecules but do not conduct electricity. Because, these compounds do not produce $H^+(aq)$ ions in solutions. Hence, these are not categorised as acids.

14. Why does distilled water not conduct electricity, whereas rainwater does?

Ans. Distilled water contains very small concentration of free $H^+(aq)$ and $OH^-(aq)$ ions and therefore it does not conduct electricity. The rainwater dissolves carbon dioxide and other gases (present in the air) to form free $H^+(aq)$ or/and $OH^-(aq)$ ions. That is why rainwater conducts electricity.

15. Why do acids not show acidic behaviour in the absence of water?

Ans. In the absence of water, acids do not furnish free hydrogen ions. As a result, they do not show acidic behaviour.

Assess Yourself – 2

1. Do all acids react with metals? Explain your answer.
2. Why does the dry HCl gas not show its characteristic acidic character on a dry litmus paper?
3. What do you know about the electrical conductivity of acids?
4. State some uses of the commonly used acids.
5. When an acid reacts with a base, what is this reaction called and what are the products so formed?
6. An acid reacts with metal hydroxides and oxides in a similar manner. Why is that so?

2.4 BASES



Fig. 2.28: Soap solution contains bases

We have discussed that acids have a sour taste. It is one of the characteristics of acid. Similarly bases have a characteristic bitter taste. Solutions of substances like washing soda, and slaked lime are bitter in taste. Those chemical substances that have a bitter taste and are soapy to touch are known as **bases**.

Arrhenius Theory of Bases: *A base is a substance which on dissolution, dissociates in water to produce hydroxide ions (OH^-).*

Base: *A compound which reacts with an acid to form salt and water is called a* ***base****.*

Examples :

1. Metallic oxides are bases.
   (i) Na_2O (ii) K_2O (iii) MgO (iv) CaO (v) CuO
2. Metallic hydroxides (also ammonium hydroxide) are bases.
   (i) NaOH (ii) KOH (iii) $Mg(OH)_2$ (iv) $Ca(OH)_2$ (v) $Zn(OH)_2$
3. Metal carbonates and metal hydrogen carbonates are bases.

Metal carbonate	Metal hydrogen carbonates
(i) Na_2CO_3	$NaHCO_3$
(ii) K_2CO_3	$KHCO_3$
(iii) $MgCO_3$	$Mg(HCO_3)_2$
(iv) $CaCO_3$	$Ca(HCO_3)_2$

During neutralisation reaction, an acid reacts with a base. They neutralise each other's effect and form a salt. This basically means that bases are the opposite of acids.

Alkali

A base which is soluble in water is called an ***alkali****.*

Modern concept of alkali: *A compound which on dissolving in water furnishes OH^- ions as the only negative ions is called an* ***alkali****.*

Note: All alkalis are bases, but all bases are not alkalis. For example, potassium hydroxide [KOH] is a base. However, as it dissolves in water to furnish OH^- ions, hence it is an alkali.

On the other hand, zinc hydroxide is a base. However, it does not dissolve in water and hence, is not an alkali.



Fig. 2.29: Sodium hydroxide is an alkali

Examples of alkalis:

1. Sodium oxide : $Na_2O(s) + H_2O(l) \rightleftharpoons 2Na^+(aq) + 2OH^-(aq)$
2. Potassium oxide : $K_2O(s) + H_2O(l) \rightleftharpoons 2K^+(aq) + 2OH^-(aq)$
3. Calcium oxide : $CaO(s) + H_2O(l) \rightleftharpoons Ca^{2+}(aq) + 2OH^-(aq)$
4. Sodium hydroxide : $NaOH(s) \xrightarrow{H_2O} Na^+(aq) + OH^-(aq)$
5. Potassium hydroxide : $KOH(s) \xrightarrow{H_2O} K^+(aq) + OH^-(aq)$

6. Calcium hydroxide : $Ca(OH)_2(s) \xrightleftharpoons{H_2O} Ca^{2+}(aq) + 2OH^-(aq)$

7. Ammonium hydroxide : $NH_4OH(aq) \xrightleftharpoons{H_2O} NH_4^+(aq) + 2OH^-(aq)$

Strong and Weak Bases

OX2KWQMDEJ

- Bases that almost completely ionise in water are called **strong bases**. Hence, strong bases are also called alkalis. Sodium hydroxide (NaOH) and potassium hydroxide (KOH) are examples of strong bases. Solutions of strong bases have high electrical conductivity because they contain high concentration of $OH^-(aq)$ ions.
- Bases that partially ionise in their aqueous solutions or in water are called weak bases. The solutions of weak bases contain both ions and molecules of the base. Some examples of weak bases are : ammonium hydroxide (NH_4OH), magnesium hydroxide ($Mg(OH)_2$).
- Conductivity of solutions of weak bases is very poor because they contain very low concentration of OH^- ions.

Properties of Bases

1XNL7ZDGR6

1. **Touch:** They have a soapy touch (slippery).
2. **Taste:** Bases have a characteristic bitter taste.
3. **Corrosive nature:** Just like acids, strong bases also have a corrosive nature and hence, they are also very harmful.
4. **Dissolution:** On dissolving bases (alkalis) in water, they dissociate into ions. The hydroxide $OH^-(aq)$ ions are the common factor for all the bases. Bases give $OH^-(aq)$ ions in their aqueous solution. Strong bases dissociate completely into ions while weak bases dissociate partially.



Fig. 2.30: Strong base are highly corrosive in nature

For Example:

(a) Strong base: $\underset{\text{Sodium hydroxide}}{NaOH(s)} \xrightarrow{H_2O} \underset{\text{Hydroxide ion}}{OH^-(aq)} + \underset{\text{Sodium ion}}{Na^+(aq)}$

(b) Weak base: $\underset{\text{Ammonium hydroxide}}{NH_4OH(s)} \xrightarrow{H_2O} \underset{\text{Hydroxide ion}}{OH^-(aq)} + \underset{\text{Ammonium ion}}{NH_4^+(aq)}$

Dilution results in lowering the concentration of $OH^-(aq)$ ions (hydroxide ions) of a base per unit volume.

For example. If 1 mole of NaOH (40 g) is dissolved in one litre of water its concentration is 1 mole/L. However, if 0.1 mole of NaOH (4 g) is dissolved in one litre of water its concentration is 0.1 mol/L.

Now, amongst NaOH solutions of 1 mol/L and 0.1 mol/L, the solution with a lesser concentration is dilute, that is 0.1 mol/L.

5. **Action on Indicators:** A base has following effects on various indicators.
   (a) A base changes red litmus to blue.
   (b) Methyl orange to yellow.
   (c) Phenolphthalein colourless to pink.
   (d) Turmeric solution to red.

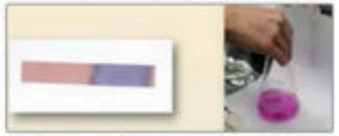


Fig. 2.31: Red litmus paper turns blue in contact with base and phenolphthalein turns pink in a base

6. **Reaction with Metals:** *Bases react with metals to form a metal salt and hydrogen gas is evolved as a result of the reaction.*

Base + Metal ⟶ Metal salt + Hydrogen gas

For Example:

$$\underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \underset{\text{Zinc}}{Zn(s)} \longrightarrow \underset{\text{Sodium zincate}}{Na_2ZnO_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

Although all metals do not undergo this reaction.

7. **Reaction with Acids (Neutralisation Reaction):** We studied this characteristic for acids as well. The reaction involves the reaction of an acid with a base to form a salt and water, as a result of the neutralisation between them.

Base + Acid ⟶ Salt + Water

For Example:

$$\underset{\text{Sodium hydroxide}}{NaOH(aq)} + \underset{\text{Hydrochloric acid}}{HCl(aq)} \longrightarrow \underset{\text{Sodium chloride}}{NaCl(aq)} + \underset{\text{Water}}{H_2O(l)}$$

H^+ ions released by the acid combine with the OH^- ions released by the base resulting in ***neutralisation reaction***.

$$\underset{\text{Hydrogen ion (from acid)}}{H^+(aq)} + \underset{\text{Hydroxide ion (from base)}}{OH^-(aq)} \longrightarrow \underset{\text{Water}}{H_2O(l)}$$

8. **Action of Heat:** This characteristic is not for all the bases. Some bases on heating decompose to lose a water molecule and form the corresponding oxides.

Although strong alkalis do not decompose on heating. They only melt.

Weak base:

$$\underset{\text{Magnesium hydroxide}}{Mg(OH)_2(s)} \xrightarrow{\text{heat}} \underset{\text{Magnesium oxide}}{MgO(s)} + \underset{\text{Water}}{H_2O(g)}$$

Strong base (alkali):

$$\underset{\text{Sodium hydroxide}}{NaOH(s)} \xrightarrow{\text{heat}} \underset{\text{Sodium hydroxide (molten)}}{NaOH(l)}$$

9. **Reaction with Non-metal Oxides (Acidic Oxides):** As non-metal oxides are acidic in nature (will be taught in chapter-3), this reaction is also a kind of neutralisation reaction. Salt and water are formed as products.

$$\underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \underset{\text{Sulphur dioxide}}{SO_2(g)} \longrightarrow \underset{\text{Sodium sulphite}}{Na_2SO_3(aq)} + \underset{\text{Water}}{H_2O(l)}$$

$$\underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \longrightarrow \underset{\text{Sodium carbonate}}{Na_2CO_3(aq)} + \underset{\text{Water}}{H_2O(l)}$$

$$\underset{\text{Calcium hydroxide}}{Ca(OH)_2(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \longrightarrow \underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{Water}}{H_2O(l)}$$

Uses of Bases

1. Sodium hydroxide (caustic soda) is used in the manufacture of soap. It is used in petroleum-refining; in making medicines, paper, pulp, rayon, etc.
2. Calcium hydroxide also known as slaked lime, is used for the following purposes :
   (i) To neutralise acid in water supplies.
   (ii) In the manufacture of bleaching powder.
   (iii) As a dressing material for acid burns.
   (iv) As an antidote for food poisoning; in the preparation of fungicides and in the mixture of whitewash.
   (v) It is mixed with sand and water to make mortar which is used in the construction of buildings.
   (vi) It is also used by farmers in the fields to neutralise the harmful acidic effects of acid rain.

SAMPLE PROBLEMS

1. What is a neutralisation reaction? Give two examples.

Ans. The reaction between an acid and a base is called neutralisation reaction.

Examples:

$$NaOH(aq) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l)$$

$$2NaOH(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2H_2O(l)$$



2. How is the concentration of hydroxide ions (OH^-) affected when excess base is dissolved in a solution of sodium hydroxide?

Ans. The OH^- concentration increases with the concentration of NaOH and reaches a limiting value.

2.5 COMMON FACTOR OF ACIDS AND BASES

20QVPSNILK

Aqueous solutions of both acids and bases conduct electricity. This is because both acids and bases dissociate into ions in their aqueous solutions.

Not all compounds dissociate into ions in water.

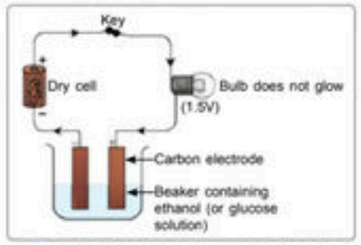


Fig. 2.32: Ethanol and glucose solutions do not conduct electricity

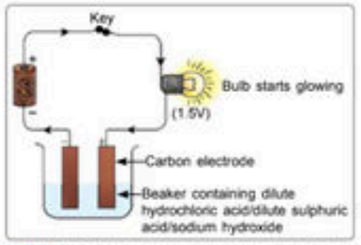


Fig. 2.33: Dil. hydrochloric acid. (or dil. sulphuric acid) and dil. solution of sodium hydroxide conduct electricity

Let us perform the following activity. We will be taking four solutions that is dilute hydrochloric acid solution, dilute sodium hydroxide solution, ethanol and glucose solution.

Procedure:

- Take a beaker and place two carbon electrodes into it.
- Connect the electrodes to a battery and bulb through a key and a dry cell.
- Prepare solutions of hydrochloric acid, sodium hydroxide, ethanol and glucose.
- Pour dilute hydrochloric acid into the beaker and press the key.
- Perform similar experiment with all the given solutions.

Observations:

Solution	Bulb glows	Nature of the substance
Hydrochloric acid	✓	Conducting
Sodium hydroxide	✓	Conducting
Ethanol	✗	Nonconducting
Glucose	✗	Nonconducting

Conclusion: So from the above data, we can conclude that :

The solutions of acids and bases conduct electricity while the solutions of glucose and ethanol are nonconductors of electricity. This happens because acids produce $H^+(aq)$ ions and bases produce $OH^-(aq)$ ions in water.

Ethanol and the solution of glucose do not conduct electricity because they do not produce ions in their aqueous solutions. Hence, the tendency to dissociate into ions in water is a common property of acids and bases.

If we repeat the same experiment using different acids and alkalis (water-soluble bases), we will obtain the same results.

Particularly, all acids dissociate into ions in water, to produce $H^+(aq)$ ions in their solution. Similarly bases dissociate into ions in water to produce $OH^-(aq)$ ions in the solution.

These examples will make the concept more clear for you.

Sodium hydroxide dissolves in water to produce hydroxide ions :

$$\underset{\text{Sodium hydroxide}}{NaOH(s)} \xrightarrow{\text{Water}} \underset{\text{Sodium ion}}{Na^+(aq)} + \underset{\text{Hydroxide ion}}{OH^-(aq)}$$

Sodium hydroxide shows basic behaviour due to the presence of hydroxide ions (OH^- ions) in its solution.

Similarly, potassium hydroxide dissolves in water to give hydroxide ions :

$$\underset{\text{Potassium hydroxide}}{KOH(s)} \xrightarrow{\text{Water}} \underset{\text{Potassium ion}}{K^+(aq)} + \underset{\text{Hydroxide ion}}{OH^-(aq)}$$

The presence of hydroxide ions (OH^- ions) in potassium hydroxide solution imparts alkaline properties.

$$\underset{\text{Calcium hydroxide}}{Ca(OH)_2(s)} \xrightleftharpoons{H_2O} \underset{\text{Calcium ion}}{Ca^{2+}(aq)} + \underset{\text{Hydroxide ion}}{2OH^-(aq)}$$

$$\underset{\text{Magnesium hydroxide}}{Mg(OH)_2(s)} \xrightleftharpoons{H_2O} \underset{\text{Magnesium ion}}{Mg^{2+}(aq)} + \underset{\text{Hydroxide ion}}{2OH^-(aq)}$$

Important Note: It is useful to remember that alkali solutions are **soapy to touch, bitter** in **taste** and **corrosive in nature**. They should never be tasted or handled with bare hands as they can cause severe burns.

Having learnt that all acids generate $H^+(aq)$ and all alkalis generate $OH^-(aq)$, we are in a position to define acids, alkalis and bases.

Definition of an acid: *An acid is a compound, which on dissolving in water gives hydronium ions [H_3O^+] or $H^+(aq)$ ions as the positively charged ions.*

$$HCl(g) + H_2O(l) \rightleftharpoons H_3O^+(aq) + Cl^-(aq)$$

Definition of an alkali: *An alkali is a compound, which on dissolving in water gives hydroxyl [$OH^-(aq)$] ions as the only negatively charged ions.*

$$NaOH(s) \xrightleftharpoons{H_2O} Na^+(aq) + OH^-(aq)$$

Definition of a base: *An oxide or hydroxide of a metal which reacts with $H^+(aq)$ ions of an acid to form a salt and water as the only products is called base.*

$$CuO(s) + 2HNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + H_2O(l)$$

$$Cu(OH)_2(s) + 2HNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + 2H_2O(l)$$

Note: Ammonium hydroxide [NH_4OH] is the only alkali solution that does not contain any metallic ion. Instead NH_4^+ is the positively charged ion.

Exercise-2 (A)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

1. If a few drops of a concentrated acid accidentally spills over the hand of a student, what should be done?
   (A) Wash the hand with saline solution
   (B) Wash the hand immediately with plenty of water and apply a paste of sodium hydrogen carbonate
   (C) After washing with plenty of water, apply solution of sodium hydroxide on the hand
   (D) Neutralise the acid with a strong alkali [HOTS]

2. Sodium hydrogen carbonate when added to acetic acid evolves a gas. Which of the following statements are true about the gas evolved?
   (i) It turns lime water milky.
   (ii) It extinguishes a burning splinter.
   (iii) It dissolves in a solution of sodium hydroxide.
   (iv) It has a pungent odour.



(A) (i) and (ii) (B) (i), (ii) and (iii)
(C) (ii), (iii) and (iv) (D) (i) and (iv) [HOTS]

3. What happens when a solution of an acid is mixed with a solution of a base in a test tube?
(i) The temperature of the solution increases
(ii) The temperature of the solution decreases
(iii) The temperature of the solution remains the same
(iv) Salt formation takes place
(A) (i) only (B) (i) and (iii)
(C) (ii) and (iii) (D) (i) and (iv) [HOTS]

4. An aqueous solution turns red litmus solution blue. Excess addition of which of the following solutions would reverse the change?
(A) Baking powder (B) Lime
(C) Ammonium hydroxide solution (D) Hydrochloric acid [HOTS]

5. One of the followings is a medicine used for indigestion. This is :
(A) sodium hydroxide (B) manganese hydroxide
(C) magnesium hydroxide (D) potassium hydroxide

6. Bee sting contains :
(A) an acidic solution (B) a salt solution
(C) an alkaline solution (D) an alcohol

Ans: 1. (B) 2. (B) 3. (D) 4. (D) 5. (C) 6. (A)

II. VERY SHORT ANSWER TYPE QUESTIONS

1. Name three natural plant materials that can be used as indicators.
2. Why does nitric acid not produce hydrogen, when treated with metals?
3. A student prepared solutions of (i) an acid and (ii) a base in two separate beakers. The student forgot to label the solutions and the litmus paper is not available in the laboratory. Since both the solutions are colourless, how will the student distinguish between the two? [HOTS]
4. What is a neutralisation reaction?
5. Pick out the basic substance from the following :
(i) Lemon juice (ii) Curd
(iii) Raw mangoes (iv) Lime water
6. What is the action of litmus on :
(a) dry ammonia gas (b) solution of ammonia gas in water
7. Name the gas evolved when zinc granules are treated/heated with :
(a) hydrochloric acid solution (b) Solution of ammonia gas in water
8. What are alkalis?
9. What is common in all the water soluble bases?

III. SHORT ANSWER TYPE QUESTIONS

1. Which gas is evolved when aluminium powder or zinc granules are heated with concentrated sodium hydroxide solution? Write word equations and balanced equation for the reaction of these metals with sodium hydroxide.
2. A metal compound X reacts with dilute hydrochloric acid to produce effervescence. The gas evolved turns limewater milky. Write balanced equations for the reaction, if one of the compound formed is calcium chloride?
3. How will you test for a gas, which is liberated, when hydrochloric acid reacts with an active metal?
4. Name the gas evolved, when dilute HCl reacts with sodium hydrogen carbonate. How is it recognised?
5. Name the gas evolved when dilute sulphuric acid reacts with sodium carbonate. Write the balanced chemical equation for the reaction involved.

6. What happens when nitric acid is added to egg shell? [HOTS]
7. What is observed when dilute sulphuric acid is added to solid sodium carbonate. Also write balanced chemical equations.
8. What is meant by strong bases and weak bases? Classify the following into strong bases and weak bases :

NH_4OH, $Ca(OH)_2$, NaOH, KOH, $Mg(OH)_2$

9. What ions are present in the solutions of following substances?

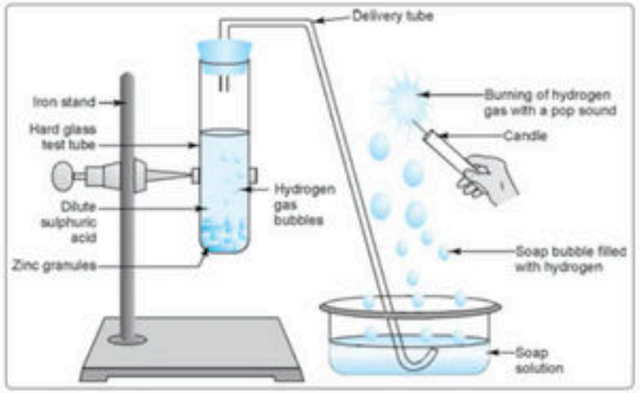
(i) Hydrochloric acid (ii) Nitric acid (iii) Sulphuric acid
(iv) Sodium hydroxide (v) Potassium hydroxide (vi) Calcium hydroxide

10. Metal oxides and metal hydroxides are called bases. Explain and support your answer with two chemical equations. Give an example of (i) a soluble base, (ii) a partially soluble base and (iii) an insoluble base.
11. What is the colour change of methyl orange, phenolphthalein and neutral litmus solution in :
    (a) lemon juice?
    (b) dilute sodium hydroxide solution? Write your answer in tabular form.
12. (a) What do you understand by the terms 'acid' and 'base"?
    (b) Give the names and formulae of two strong bases and two stong acids.
    (c) What type of ions are formed : when an acid is dissolved in water?
    (d) Write an example of the neutralisation reaction between acid and base. Explain in detail.
13. (a) What happens when zinc granules are heated with sodium hydroxide solution?
    (b) What happens when bases react with non-metal oxides? Explain with the help of an example. What does this reaction tell us about the nature of non-metal oxide?
14. Write fully balanced equations for the reaction between :
    (a) Magnesium bicarbonate and dilute sulphuric acid.
    (b) Zinc carbonate and dilute hydrochloric acid.
    (c) Copper oxide and dilute nitric acid.
15. How do we make dilute solutions of concentrated acids? Explain.
16. How do we test for hydrogen gas and carbon dioxide gas? Explain in detail with the help of relevant reactions.
17. Mention the action of bases on common indicators. What are olfactory indicators? Explain with examples.
18. How did Arrhenius define acids and bases? Choose a strong acid and a weak base from the following substances :
    CH_3COOH, NH_4OH, HCl, KOH
19. (i) Differentiate between strong and weak base.
    (ii) Choose strong acid and strong base from the following :
    CH_3COOH, NH_4OH, KOH, HCl
20. Why should water be never added to concentrated sulphuric acid?
21. Blue litmus solution is added to two test tubes containing dilute HCl (A) and NaOH (B) solution. In which test tube a colour change will be observed? State the colour change and give its reason.
22. What is observed when 2 mL of dilute hydrochloric acid is added to 1 g of sodium carbonate taken in a clean and dry test tube? Write chemical equation for the reaction involved.

IV. LONG ANSWER TYPE QUESTIONS

1. Describe your observations :
    (i) When sodium carbonate powder is treated with dilute hydrochloric acid. Write a fully balanced equation in support of your answer.
    (ii) Carbon dioxide evolved in question (i) is passed through limewater for a long time. State your observations and support by two balanced chemical equations.
2. (i) In the following schematic diagram for the preparation of hydrogen gas as shown in the figure what would happen if the following changes are made?

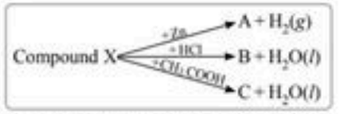




(a) In place of zinc granules, same mass of zinc dust is taken in the test tube.
(b) Instead of dilute sulphuric acid another acid, dilute hydrochloric acid is taken.
(c) In place of zinc, copper turnings are taken.
(d) Sodium hydroxide is taken in place of dilute sulphuric acid and the tube is heated.

(ii) Which of the following is acidic in nature?
(a) lime juice (b) human blood
(c) lime water (d) antacid [HOTS]

3. (i) Identify the compound X on the basis of the reactions given below. Also, write the name and chemical formulae of A, B and C.



(ii) Which of the following substance will not give carbon dioxide on treatment with dilute acid?
(a) marble (b) limestone
(c) baking soda (d) lime [HOTS]

2.6 HOW STRONG ARE ACID OR BASE SOLUTIONS

9EUDY4KR8C

You have learnt in the previous few sections that dilution with water decreases the concentration of $H^+(aq)$ or $OH^-(aq)$ ions in acidic and basic solutions respectively.

Can we find quantitatively, the amount of $H^+(aq)$ ions present in a solution? If we are able to do so, we can judge how strong an acid or a base is?

Acid-base indicators which we have learnt in the previous sections cannot tell about the concentration of $H^+(aq)$ ions. Furthermore, they cannot determine whether a substance is acidic or basic within a certain range. So, for finding the concentration of $H^+(aq)$ ions in a particular solution, we use a universal indicator.

A universal indicator is a mixture of several indicators. It shows different colours for different concentrations of $H^+(aq)$ ions in a particular solution.

2.7 UNIVERSAL INDICATOR

02A4NS3BXK

It is a mixture of dyes (pH indicator) that changes colour gradually over a range of pH and is used (especially as indicator paper) in testing for acids and alkalis. It is made up of a solution of several coloured compounds that exhibit several colour changes over the wide range of pH values to indicate the strength of acidic and basic solutions.



Fig. 2.34: Universal indicator provides us with different colours for different pH values

Common indicators cannot tell us the relative strengths of acids or bases. For example, litmus can only tell us whether a substance is acidic or not, it will not be able to tell us about the strength of the acidic or basic solution. For that we use universal indicator. It gives different colours for different pH values. The colour produced by the universal indicator is matched with the pH value colour chart and that is how pH is determined.

Here are a few pH values and the colours that are produced on the universal indicator accordingly.

pH	Colour	pH	Colour
0	Dark red	8	Greenish blue
1	Red	9	Blue
2	Red	10	Navy blue
3	Orange red	11	Purple
4	Orange	12	Dark purple
5	Orange yellow	13	Violet
6	Greenish yellow	14	Violet
7	Green		

For using a universal indicator paper, a drop of the test solution is put on the paper. The indicator paper will undergo a change in colour. The colour produced can be easily matched with the colour chart and hence the pH can be easily detected. For example, water produces a green colour on the indicator paper.

pH Scale

0G96VWSHB8

We have used pH word in the previous section let us understand its concept now. Sorensen, a Danish chemist in 1909 introduced the concept of measuring the concentration of $H^+(aq)$ ions in a particular solution. This concept is called **pH scale**, where the word **p** stands for "**potenz**" meaning 'power' in the German language. Thus, pH stands for "**power** of $H^+(aq)$ ions" or "concentration of $H^+(aq)$ ions".

Note: Concentration is defined as the amount of a substance dissolved in particular volume.

On pH scale varies [from 0 (very acidic) to 14 (very alkaline)] we measure the concentration of $H^+(aq)$ ions or H_3O^+ ions. The points to remember on pH scale are :

(i) pH of distilled water or any other neutral solution is 7 at room temperature.

(ii) As the value of pH decreases from 7 to 0, the concentration of $H^+(aq)$ ions goes on increasing, and so does the acidic character of the solution.

(iii) As the value of pH increases from 7 to 14, the concentration of $H^+(aq)$ ions decreases and that of $OH^-(aq)$ ions increases. So the solution gradually changes to alkaline character, such that at pH 14, it is highly alkaline.

(iv) pH is generally measured by a pH paper, which is prepared by impregnating filter paper in an universal indicator and then drying.

Change in concentration of $H^+(aq)$ ions is shown by pH paper in Fig. 2.33.

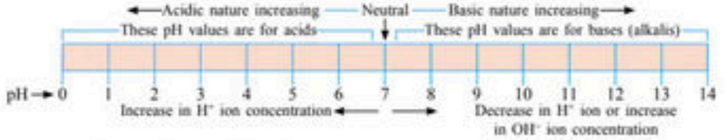


Fig. 2.35: Variation of pH with the change in concentration of $H^+(aq)$ and $OH^-(aq)$ ions

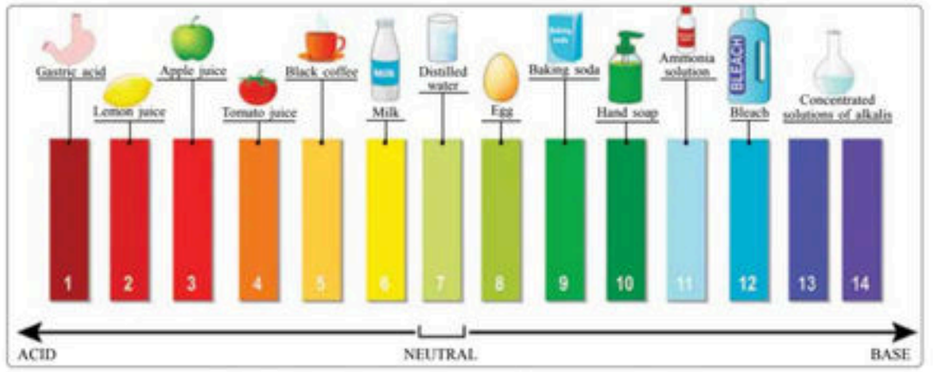


Fig. 2.36: The pH scale indicating the pH of some common substances

Strong and Weak Acids and Alkalis

HVECKDPTF

The strength of an acid or a base depends upon the $H^+(aq)$ ions or $OH^-(aq)$ ions produced for the same concentration.

For example, if we take hydrochloric acid and acetic acid of one molar concentration, then hydrochloric acid produces far more $H^+(aq)$ ions than acetic acid. Thus, we can say that hydrochloric acid is a strong acid and acetic acid is a weak acid.

Similarly, if we try to find $OH^-(aq)$ ions in 0.1 molar NaOH solution and 0.1 molar $Ca(OH)_2$ solution, the concentration of $OH^-(aq)$ ions in NaOH is far more than that in $Ca(OH)_2$. Thus, we can say that NaOH is a strong alkali and calcium hydroxide is a weak alkali.

Definition of a strong acid: *An acid that produces a large number of $H^+(aq)$ ions for an aqueous solution of one molar concentration is called a* **strong acid**.

Examples of strong acids:

(1) Sulphuric acid [H_2SO_4]
(2) Hydrochloric acid [HCl]
(3) Nitric acid [HNO_3]
(4) Phosphoric acid [H_3PO_4]

Definition of a weak acid: *An acid that produces few $H^+(aq)$ ions for an aqueous solution of one molar concentration, is called a* **weak acid**.

Examples of weak acids:

(1) Carbonic acid [H_2CO_3]
(2) Formic acid [HCOOH]
(3) Sulphurous acid [H_2SO_3]
(4) Oxalic acid [$(COOH)_2$]
(5) Hydrogen sulphide [H_2S]
(6) Hydroiodic acid [HI]
(7) Acetic acid [CH_3COOH]
(8) Hydrocyanic acid [HCN]
(9) Nitrous acid [HNO_2]
(10) Hydrobromic acid [HBr]

Definition of a strong alkali: *An alkali that produces a large number of OH^- (aq) ions for an aqueous solution of one molar concentration is called a* **strong alkali**.

Examples of strong alkalis:

(1) Lithium hydroxide [LiOH]
(2) Sodium hydroxide [NaOH]
(3) Potassium hydroxide [KOH]
(4) Rubidium hydroxide [RbOH]

Definition of a weak alkali: *An alkali that produces few OH^- (aq) ions for an aqueous solution of one molar concentration is called a* **weak alkali**.

Examples of weak alkalis:

(1) Calcium hydroxide [$Ca(OH)_2$]
(2) Magnesium hydroxide [$Mg(OH)_2$]
(3) Barium hydroxide [$Ba(OH)_2$]
(4) Ammonium hydroxide [NH_4OH]

Acids in the Living World

The acid produced from minerals, such as sulphur, nitrogen, chlorine, bromine, etc., are corrosive and dangerous. The acids produced by plants and animals do not create much harm. In fact they are beneficial, except a few acids produced by insects and plants. The table below describes some natural acids and their sources. These acids are also called organic acids, as they are derived from the living world.

Table 2.1 : Acids in living world

Natural source	Organic acid
1. Vinegar	Acetic acid
2. Citrus fruits (oranges, lemons)	Citric acid
3. Rancid butter	Butyric acid
4. Sting of bees, brown ants	Formic acid
5. Sour milk, curd, etc.	Lactic acid
6. Apples	Maleic acid
7. Olive oil	Oleic acid
8. Fats	Stearic acid
9. Grapes, tamarind	Tartaric acid
10. Urine	Uric acid
11. Tomatoes	Oxalic acid
12. Proteins	Amino acid
13. Chromosomes	Nucleic acid
14. Nettle sting	Methanoic acid

2.8 IMPORTANCE OF pH IN EVERYDAY LIFE

GWQBKOZ6CY

pH of a substance plays very important role in all kinds of living beings and the products that we use in everyday life. Let us discuss a few examples.

Importance of pH to Aquatic Life

Human body works efficiently within a pH range of 7 and 7.8. Some living organisms can survive only within a narrow range of pH. In industrial areas, the pH of rainwater is less than 5.6, on account of dissolution of acidic gases, such as sulphur dioxide and nitrogen dioxide. Such a rain with pH less than 5.6 is called **acid rain**.

When the acid rainwater flows into rivers, it lowers the pH of river water, this is, river water gets acidic. This in turn kills most of the aquatic life.

Importance of pH in Soil

Some crops, such as citrus fruit plants grow better in alkaline soil. Sugarcane grows better in neutral soil. Acidic soil is generally unfit for growing any crops. The soils get acidic when plant roots and plant residues are not removed from the soil. They rot in the soil to produce acids. Soils also get acidic when excess of artificial fertilisers are used. The acidic soil can be brought back to normal health by spraying slaked lime in the fields. Conversely, the alkaline soils can be cured by spraying gypsum powder.



Fig. 2.37: The pH of soil must be 7 for proper growth of plants

As stated earlier, different plants grow better in soil with specific pH values. Thus, it is very important for the farmers to get the pH value of their soil tested, before growing a particular crop. Otherwise, they would suffer huge financial loss due to crop failure.

You can perform the following activity to check the pH value of soil in your backyard or fields.

- Take a test tube and put about 2 g of the soil to be tested in it.
- Add 5 mL of water in the test tube and shake it well.
- Filter the contents of the test tube and collect the clear filtrate.
- Find the pH of the filtrate with a strip of universal indicator and decide what to grow in soil and what not.

Importance of pH in Our Digestive System

Many people have frequent gastric complaint, commonly called acidity of the stomach. Our stomach produces gastric juice that contains large amounts of hydrochloric acid. The acid so produced does not harm the stomach walls, but kills germs and bacteria that enter our digestive system along with food. Thus, in a way it protects us from diseases and helps in digestion.

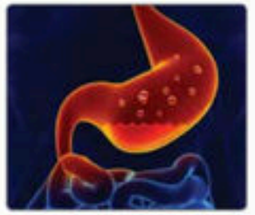


Fig. 2.38: Acidity in our stomach is a condition when the pH of our stomach becomes acidic

However, when we overeat, or eat spicy foods or have worries or tension, then the stomach produces large amount of hydrochloric acid. Sometimes, this excess acid damages the walls of the stomach and causes stomach ulcers.

The acidity of the stomach can be reduced by taking antacid tablets. These tablets generally consist of magnesium hydroxide and aluminium hydroxide, which are mild bases. They react chemically with the hydrochloric acid, and neutralise it.

pH of the Mouth and Tooth Decay

Normally, the pH in the mouth is more than 7 as the saliva produced in the mouth is basic in nature. However, when we take food, some food particles remain stuck to the teeth and other parts of the mouth. These particles rapidly decay due to bacterial action and the pH in the mouth starts falling. This happens due to the consumption of sugary foods.

Teeth in our mouth are coated with an enamel of calcium phosphate that is the hardest substance in our body. It is normally not attacked by organic acids, if the pH is more than 5.5. However, if the pH of mouth falls below 5.5, the acids produced in the mouth attack the enamel, thereby creating tooth cavities.

The best way to avoid tooth cavities is to brush your teeth with some toothpaste. All toothpastes contain some substances that are basic in nature, and hence, neutralise acids.

Importance of pH in Dairy Industry

Milk goes sour by bacterial action if its pH falls below 6.6. Thus, milk is treated in milk plants in such a way, that its pH does not fall below 6.6.

Importance of pH in Other Fields

(i) Biochemical reactions taking place in breweries, fruit processing and meat processing plants take place at some fixed pH. Thus, pH is controlled rigorously in such plants.

(ii) By testing the pH of blood, urine, etc., certain diseases can be diagnosed. Thus, it helps the doctors.

(iii) Special shampoos, soaps, face creams are prepared for consumers having different pH values compatible with their skin secretions.

Self-Defence of Animals and Plants Through Chemical Warfare

Insects use acids to ward off their enemies. The sting of the honeybee contains formic acid. When someone is stung by a honeybee, formic acid is injected in the skin. This acid causes a lot of irritation and pain. The pain can be reduced by applying baking soda paste on the affected region as the acid gets neutralised.



Fig. 2.39: Nettle plant leaves

In the plant kingdom Nettle *(Bichu Booti)* is a herbaceous plant that grows in wild. Its leaves have very fine hairs, that contain methanoic acid. When these leaves are accidently touched, then the acid in them is injected in the skin, which causes a lot of irritation.

A traditional rubbing of the affected area with the leaf of dock plant *(Palak Patti)*, which often grows besides the nettle plants in the wild exists. Can you guess the nature of the dock plant? Obviously, the dock plant has some kind of alkali that neutralises methanoic acid. Alternately you can rub the affected part with baking soda paste or soap.

When a wasp stings, it injects an alkaline solution into the skin. Then rubbing a mila acid like vinegar on the stung area, gives relief.

SAMPLE PROBLEMS

1. A solution turns red litmus blue, its pH is likely to be

(A) 1 (B) 4 (C) 5 (D) 10

Ans. (D) because bases have pH > 7 and bases turn red litmus blue.

2. You have two solutions, A and B. The pH of solution A is 6 and pH of solution B is 8. Which solution has higher hydrogen ion concentration? Which of this is acidic and which one is basic?

Aus. A: pH = 6, B : pH = 8

- A will have higher concentration of $H^+(aq)$
- A is acidic (pH < 7)
- B is basic (pH > 7)

3. What effect does the concentration of $H^+(aq)$ ions have on the acidic nature of the solution?

Ans. With the concentration of $H^+(aq)$ in the solution increases, the acidic strength of the solution also increases, that is the solution will become more acidic.

4. Do basic solutions also have $H^+(aq)$ ions? If yes, then why are these basic?

Ans. Yes, basic solutions also have $H^+(aq)$ ions. This is because in aqueous solutions water is present and it dissociates to produce H^+ and OH^- ions.

In a basic solution, $H^+(aq)$ concentration is much lower than the $OH^-(aq)$ concentration.

5. Under what soil condition do you think a farmer would treat the soil of his fields with quicklime (calcium oxide) or slakedlime (calcium hydroxide) or chalk (calcium carbonate)?

Ans. The farmer will use quicklime, slakedlime or chalk for an acidic soil.

6. Five solutions A, B, C, D and E when tested with universal indicator showed pH as 4, 1, 11, 7 and 9, respectively. Which solution is

(a) neutral? (b) strongly alkaline? (c) strongly acidic? (d) weakly acidic? (e) weakly alkaline?

Arrange the pH in increasing order of hydrogen-ion concentration.

Ans.

Solutions	A	B	C	D	E
pH	4	1	11	7	9

(a) D is neutral (pH = 7) (b) C is highly alkaline (pH = 11) (c) B is strongly acidic (pH = 1)
(d) A is weakly acidic (pH= 4) (e) F is weakly alkaline (pH = 9)

The arrangement of pH in the increasing order of hydrogen ion concentration is 11, 9, 7, 4, 1.

7. Fresh milk has a pH of 6. How do you think the pH will change as it turns into curd? Explain your answer.

Ans. Curd contains lactic acid. So, pH of the curd will be lower than that of the fresh milk.

8. A milkman adds a very small amount of baking soda to fresh milk.
(a) Why does he shift the pH of the fresh milk from 6 to slightly alkaline?
(b) Why does this milk take a long time to set as curd?

Ans. (a) The milkman shifts the pH of the fresh milk to slightly alkaline just to neutralise the acid which might be produced during the storage of milk.
(b) The enzyme which converts milk into curd is active only in acidic conditions. So, the acid produced during curd formation first neutralises the base present in the milkman's milk.

Exercise-2 (B)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

1. During the preparation of hydrogen chloride gas on a humid day, the gas is usually passed through the guard tube containing calcium chloride. The role of calcium chloride taken in the guard tube is to :
(A) absorb the evolved gas (B) moisten the gas
(C) absorb moisture from the gas (D) absorb Cl^- ions from the evolved gas [HOTS]

2. Which of the following statements is correct about an aqueous solution of an acid and of a base?
(i) Higher the pH, stronger the acid (ii) Higher the pH, weaker the acid
(iii) Lower the pH, stronger the base (iv) Lower the pH, weaker the base
(A) (i) and (iii) (B) (ii) and (iii) (C) (i) and (iv) (D) (ii) and (iv) [HOTS]

3. Which of the following phenomena occur, when a small amount of acid is added to water?
(i) Ionisation (ii) Neutralisation (iii) Dilution (iv) Salt formation
(A) (i) and (ii) (B) (i) and (iii) (C) (ii) and (iii) (D) (ii) and (iv) [HOTS]

4. Which of the following gives the correct increasing order of acidic strength?
(A) Water < Acetic acid < Hydrochloric acid (B) Water < Hydrochloric acid < Acetic acid
(C) Acetic acid < Water < Hydrochloric acid (D) Hydrochloric acid < Water < Acetic acid [HOTS]

5. Which of the following statements is not correct?
(A) All metal carbonates react with an acid to give a salt, water and carbon dioxide.
(B) All metal oxides react with water to give salt and acid.
(C) Some metals react with acids to give salt and hydrogen.
(D) Some non-metal oxides react with water to form an acid. [HOTS]

6. A solution turns red litmus blue. The pH of the solution must be :
(A) 2 (B) 3 (C) 7 (D) 10

7. A solution turns phenolphthalein indicator pink. The pH of this solution will be around :
(A) 6 (B) 4 (C) 9 (D) 7

8. Rubbing vinegar on the stung area of the skin of a person gives him relief. This tells us that the person has been stung by :
(A) wasp (B) ant (C) honey bee (D) nettle leaf hair

9. Fresh milk has a pH of 6. When milk changes into curd the pH value will :
(A) become 7 (B) become less than 6 (C) become more than 7 (D) remain unchanged

10. The acid produced naturally in our stomach is :
(A) citric acid (B) nitric acid (C) hydrochloric acid (D) boric acid

Ans: 1. (C) 2. (D) 3. (B) 4. (A) 5. (B) 6. (D) 7. (C) 8. (A) 9. (B) 10. (C)

II. VERY SHORT ANSWER TYPE QUESTIONS

1. Which bases are called alkalis? Give few examples of alkalis.
2. How is the concentration of hydronium ions affected, when concentrated hydrochloric acid is diluted?
3. How is concentration of hydroxyl ions affected, if more of solid sodium hydroxide dissolves in a solution of sodium hydroxide?
4. The pH values of five solutions A, B, C, D and E are given below :

A	1
B	5
C	7
D	11
E	13

Which solution is: (i) weakly alkaline (ii) neutral (iii) strongly acidic (iv) strongly alkaline and (v) weakly a cidic?

5. In which pH range does the huma body function efficiently?
6. What kind of crop is best grown in (i) alkaline soil and (ii) neutral soil?
7. Why is acid rain harmful to aquatic life?
8. What is the importance of low pH of the gastric juice produced in our stomach?
9. How can you make an acid soil fertile?
10. What is the pH value of distilled water?
11. Write the name and the chemical formula of the organic acid present in vinegar.
12. Why is the pH of milk rigorously controlled at 6.6 at milk plants?
13. State the use of pH in cosmetic industry.
14. You are provided with one molar HCl solution and one molar acetic acid solution. Which of the two is likely to have a higher pH and why?
15. Fresh milk has pH 6. When it changes to curd (yogurt), will its pH value increase or decrease? Why?
16. Why does tooth decay start, when pH of mouth is lower than 5.5?
17. What would be the colour of litmus in a solution of sodium carbonate?
18. What effect does an increase in concentration of $H^+(aq)$ in a solution have on the pH of a solution?
19. The pH of a sample of vegetable soup was found to be 6.5. How is this soup likely to taste?
20. Why is hydrogen gas not evolved when a metal reacts with nitric acid?
21. How does the pH of a solution change, when the solution of a base is diluted?
22. Arrange the following in the increasing order of their pH values. (i) NaOH, (ii) blood, and (iii) lemon juice.

III. SHORT ANSWER TYPE QUESTIONS

1. (i) Why does the pH of the mouth fall after taking meal? (ii) What harm is caused by low pH?
2. How do some plants and animals protect themselves with acids present in their sting?
3. Why does distilled water not conduct electricity, but rain water does?
4. A solution has pH 6. To it is added another solution X, when its pH drops to 3. Is the solution X acidic or basic in nature? Is the pH of the solution X less or more than 3?
5. What is meant by the term "pH of a solution"? The pH of gastric juices extracted from the stomach of two persons A and B were found to be 1 and 3 respectively. The stomach juice of which person is more acidic?
6. An aqueous solution has a pH value of 7.0 is this solution acidic, basic or neutral?
7. Given below are the pH value of four different liquids: 7.0, 14.0, 4.0, 2.0

   Which of these could be that of (i) lemon juice, (ii) distilled water, (iii) one molar sodium hydroxide solution and (iv) tomato juice?
8. What is meant by pH of a solution?
9. Which will be more acidic and why?
   (i) A solution with pH value of 6.0 or
   (ii) A solution with pH value of 5.0.



10. Match the acids given in Column (A) with their correct source given in Column (B)

Column (A)	Column (B)
(a) Lactic acid	(i) Tomato
(b) Acetic acid	(ii) Lemon
(c) Citric acid	(iii) Vinegar
(d) Oxalic acid	(iv) Curd

11. How does the flow of acid rainwater into a river, make the survival of aquatic life in the river difficult?
12. At what pH does the tooth decay start?
13. What do you understand by the term hydronium ion? Name a class of compounds that forms hydronium ions with water. Support your answer with two equations.
14. (a) Why do compounds like hydrochloric acid and sulphuric acid, show acidic character in aqueous solution, but compounds like alcohol and glucose do not?
    (a) Why does the colour of dry blue litmus paper not change to red with dry HCl gas?
15. (a) Why is it wrong to treat a bee sting with vinegar?
    (b) Why is it wrong to treat a wasp sting with baking soda solution?
16. (a) Three solutions A, B and C have pH values of 5, 7 and 12 respectively. Which of the solutions is acidic, basic and neutral?
    (b) A farmer has found that the pH of soil in his fields is 4.2. Name any two chemical materials which he can mix with the soil to adjust its pH.
17. Name the acids or alkalis used to make (i) car batteries (ii) explosives (iii) soaps (iv) fertilisers.
18. The pH of a cold drink is 5. What will be its action on blue and red litmus solutions?
19. Under what soil conditions do you think a farmer would treat the soil of his fields with quickline (calcium oxide), or slaked lime (calcium hydroxide) or chalk (calcium carbonate)?
20. Which acid is produced in our stomach? What happens if there is an excess of acid in the stomach? How can its effect be cured?
21. Out of HCl and CH_3COOH, which one is a weak acid and why? Explain with the help of an example.

IV. LONG ANSWER TYPE QUESTIONS

1. (i) Describe an activity to show that acids produce ions only in an aqueous solution.
   (ii) Name the acid present in ant sting. Also, give the common method to get relief from the discomfort caused by ant sting. [HOTS]
2. How is universal indicator more useful to than the other common indicators like litmus and phenolphthalein? Explain.
   Here are some results of solutions tested with universal indicator paper :

Sulphuric acid : Red	Washing solution : Yellow	Milk of magnesia : Light blue
Oven cleaner : Purple	Car battery acid : Pink	

   Arrange the solutions in order of their increasing pH values (starting with the one with the lowest pH)
3. A teacher provided acetic acid, water, lemon juice, aqueous solution of sodium hydrogen carbonate and sodium hydroxide to students in the school laboratory to determine the pH values of these substances using pH papers. One of the students reported the pH values of the given substances as 3, 12, 4, 8 and 14 respectively. Which one of these value is not correct? Write its correct value stating the reason. Give reason.

MQO87J1R22

2.9 SALTS

You have learnt that when metals or metal oxides or metal hydroxides or metal carbonates, etc., are treated with acids, one of the products formed is a salt of the metal. Let us try to understand more about salts. Salts are ionic compounds. They dissociate into ions in water an hence conduct electricity.

Definition of Salt

An ionic compound containing a positive ion other than hydrogen ion and a negative ion other than hydroxyl ion or oxide ion, is called a **salt**.

OR

A compound formed by the partial or complete replacement of $H^+(aq)$ ions of an acid by a metal ion or an electropositive ion, is called a **salt**.

For example, hydrochloric acid is HCl if we replace the hydrogen of this acid by a metal atom, for example, sodium (Na), we obtain a salt, NaCl. This is a salt called sodium chloride. In some salts, the hydrogen is replaced by an ammonium ion (NH^+_4) as in the case of ammonium chloride, NH_4Cl. Sodium chloride (NaCl) is usually known as common salt. Sodium chloride is a member of a huge family of compounds called 'salts'. We have a large number of other salts too.



Fig. 2.40: Common salt

Salts are formed when acids react with bases. Hence, a salt has two parents : an acid and a base the name of a salt consists of two parts; the first part of the name of salt is derived from the name of base, and the second part of the name of the salt is derived from the name of the acid. Majorly all salts are made from the following acids, hence are named as follows.

(i) The salts of 'hydrochloric acid' are chlorides.
(ii) The salts of 'sulphuric acid' are sulphates.
(iii) The salts of 'nitric acid' are nitrates.
(iv) The salts of 'carbonic acid' are carbonates.
(v) The salts of 'acetic acid' are acetates, and so on.

Name of salt	Chemical formula	Base from which salt is obtained	Acid from which salt is obtained
Sodium sulphate	$Na^+_2\ SO^{2-}_4$	NaOH	H_2SO_4
Potassium sulphate	$K^+_2\ SO^{2-}_4$	KOH	H_2SO_4
Calcium sulphate	$Ca^{2+}\ SO^{2-}_4$	$Ca(OH)_2$	H_2SO_4
Magnesium sulphate	$Mg^{2+}\ SO^{2-}_4$	$Mg(OH)_2$	H_2SO_4
Copper sulphate	$Cu^{2+}\ SO^{2-}_4$	$Cu(OH)_2$	H_2SO_4
Copper chloride	$Cu^{2+}\ Cl^-_2$	$Cu(OH)_2$	HCl
Sodium nitrate	$Na^+\ NO^-_3$	NaOH	HNO_3
Sodium carbonate	$Na^+_2\ CO^{2-}_3$	NaOH	H_2CO_3
Ammonium chloride	$NH^+_4\ Cl^-$	NH_4OH	HCl
Ammonium sulphate	$(NH_4)^+_2\ SO^{2-}_4$	NH_4OH	H_2SO_4

Definition of Family of Salts

Salts belonging to the same positive or negative radicals are said to belong to a family.

On the basis of the above definition, a family of salts can be named after

(i) positive radicals, that is, metallic ions
(ii) negative radicals, that is, non-metallic ions.

For example, Na_2SO_4, $NaNO_3$, Na_2CO_3 belong to the family of *sodium salts*.

Similarly, NH_4Cl and $(NH_4)_2SO_4$ belong to the family of *ammonium salts*.

$\Rightarrow$ Na_2SO_4, K_2SO_4, $CaSO_4$, $MgSO_4$ and $CuSO_4$ belong to the family of sulphates.

$\Rightarrow$ $CuCl_2$ and NH_4Cl belong to the family of chlorides

pH of Salts

1. The salts of strong acids and strong bases are neutral, such that their pH is 7. Such salts are called normal salts.
   Note: It has been found that if there is a salt of weak acid and weak base, it also acts as neutral salt. For example, zinc acetate is a neutral salt.
2. The salts of strong acids and weak bases are acidic in nature and the pH of their solutions is less than 7.
3. The salts of weak acids and strong bases are basic in nature and the pH of their solutions is more than 7.

On the basis of above discussion, we can classify salts as follows :

(a) **Normal salts :** *The salts formed by the action of strong acids with strong bases, are called normal salts.*

Examples :

(i)	$NaCl$;	NaF;	$NaNO_3$;	Na_2SO_4
(ii)	KCl;	KF;	KNO_3;	K_2SO_4

(b) **Acid salts :** *The salts formed by the action of strong acids and weak bases are called acid salts.*

Examples :

(i)	$AlCl_3$;	$ZnCl_2$;	$FeCl_2$;	$PbCl_2$;	$CuCl_2$.
(ii)	$Al(NO_3)_3$;	$Zn(NO_3)_2$;	$Fe(NO_3)_2$;	$Pb(NO_3)_2$;	$Cu(NO_3)_2$.
(iii)	$Al_2(SO_4)_3$;	$ZnSO_4$;	$FeSO_4$;	$PbSO_4$;	$CuSO_4$.

(c) **Basic salts :** *The salts formed by the action of weak acids and strong alkalis are called basic salts.*

Examples :

Na_2CO_3;	$NaHCO_3$;	K_2CO_3;	$KHCO_3$.
Na_2SO_3;	K_2SO_3;	CH_3COONa;	CH_3COOK.

Let us perform the following activity to test the pH of salts.

- Make solutions of the following salts in distilled water :
  (i) Sodium chloride ($NaCl$) (ii) Potassium nitrate (KNO_3)
  (iii) Aluminium chloride ($AlCl_3$) (iv) Zinc sulphate ($ZnSO_4$)
  (v) Copper sulphate ($CuSO_4$) (vi) Sodium acetate (CH_3COONa)
  (vii) Sodium carbonate (Na_2CO_3) (viii) Sodium hydrogen carbonate ($NaHCO_3$).
- Check the pH of the above solutions with universal pH paper.
- Find which salts are neutral, acidic or basic. Also identify the acid/base used in the formation of salt in tabular form.

2.10 COMMON SALT—A RAW MATERIAL FOR CHEMICALS

Common salt obtained from sea or mines is a raw material for the manufacture of the following important chemicals.

(1) Chlorine,
(2) Hydrogen,
(3) Sodium hydroxide,
(4) Baking soda,
(5) Washing soda,
(6) Bleaching powder.



Fig. 2.41: Common salt

Common salt is sodium chloride ($NaCl$). It is used for many purposes, including household.

Production of Common Salt

Sea water contains about 4% of common salt dissolved in it. The sea water is collected in the shallow pits near the seashore and allowed to evaporate, when it leaves behind crude common salt. The crude common salt contains some amount of other dissolved salts and sand. It is purified by crystallisation and then put to a number of uses.



Fig. 2.42: Dandi March by Mahatma Gandhi

Deposits of solid common salt are also found in several parts of the world. These deposits are often brown in colour due to the presence of impurities. This solid common salt is often called **"rock salt"**. It is believed that these deposits are formed when the inland seas of the bygone ages dried up. It is mined like coal from the earth's crust.

You must have heard about famous the "**Dandi March**" by Father of our Nation, Mahatma Gandhi to protest against the tax imposed by British Government on common salt. As a matter of fact this Dandi March was an important symbol in our freedom struggle.

Let us see how sodium chloride is used for making different substances.

O4J3PRNCFS

2.11 SODIUM HYDROXIDE—CHLOR-ALKALI PROCESS

A saturated solution of sodium chloride is prepared in water. This solution is commonly called ***brine solution***.

The brine solution is poured in a specially designed rectangular tank in which a U-shaped steel wire gauze container lined with asbestos sheet is fixed. A graphite electrode is suspended in brine and is connected to the positive terminal of the power source or anode.

The steel wire gauze connected to the negative terminal of the power source that acts as a cathode.

When the electric current is switched on the following reactions take place :

$2Cl^-(aq) - 2e^- \longrightarrow 2Cl \longrightarrow Cl_2(g)$ [At anode]

$2Na^+(aq) + 2e^- \longrightarrow 2Na(s)$ [At cathode]

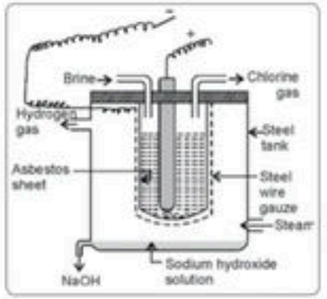


Fig. 2.43: Making sodium hydroxide, hydrogen and chlorine from sodium chloride solution

Chlorine gas so formed in the U-shaped vessel is collected separately. It is then compressed and filled in stainless steel cylinders for marketing.

Sodium metal is formed outside the U-shaped vessel. In the rectangular tank steam is passed, which reacts with sodium metal to form sodium hydroxide and hydrogen gas.

$$2Na(s) + 2H_2O(g) \longrightarrow 2NaOH(aq) + H_2(g)$$

Sodium hydroxide collects at the base of the rectangular tank in the solution form. It is drawn out and then evaporated to obtain solid sodium hydroxide.

The hydrogen gas passes out of the tank. It is collected separately, then compressed and finally filled in steel cylinders for marketing.

The above chemical reactions can be summed in a single equation as follows :

$$\underset{\text{Brine}}{2NaCl(aq)} + \underset{\text{Steam}}{2H_2O(l)} \xrightarrow[\text{current}]{\text{Electric}} \underset{\substack{\text{Sodium}\\\text{hydroxide}}}{2NaOH(aq)} + \underset{\text{Hydrogen}}{H_2(g)} + \underset{\text{Chlorine}}{Cl_2(g)}$$

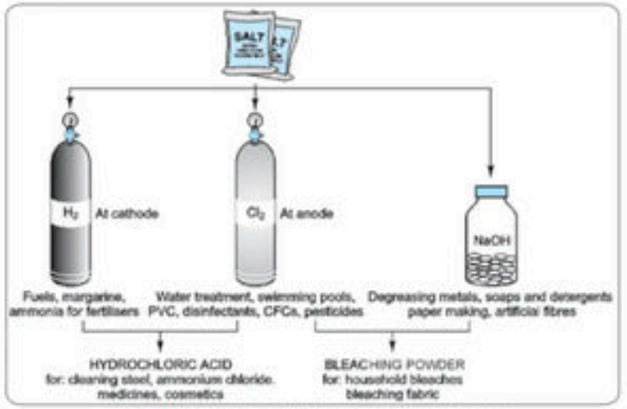


Fig. 2.44: Important products from the chlor-alkali process

You can see that by using common salt, water and electricity, we can obtain the important chemical products, sodium hydroxide, hydrogen and chlorine. Following are the uses of these products.

Uses of Hydrogen

1. It is used in hydrogenating vegetable oil to make *vanaspati ghee* (margarine).
2. It is used in oxy-hydrogen flames for cutting and welding purposes.
3. It is used in the manufacture of ammonia gas that is further used for making important fertilisers, such as ammonium nitrate, calcium ammonium nitrate and urea.
4. When combined with chlorine, it forms hydrogen chloride gas. The hydrogen chloride gas is dissolved in water to form hydrochloric acid, which is further used in cleaning the surface of metals, in the manufacturing drugs and cosmetics. It is used in the manufacture of ammonium chloride that is used extensively in dry cells, cough mixture and tinning industry.
5. Liquid hydrogen is used as a fuel for rocket engines.

Uses of Chlorine

1. It is used as a disinfectant for drinking water and for cleaning swimming pools.
2. It is used in the manufacture of various kinds of pesticides.
3. It is used in bleaching cotton fabrics and paper pulp.
4. It is used in making plastics such as polyvinyl chloride (PVC).
5. It is used in making refrigerant, such as chlorofluorocarbons (CFC).
6. It is used in the manufacture of bleaching powder and hydrochloric acid.

Uses of Sodium Hydroxide

1. It is used in the manufacture of all kinds of soaps and detergents.
2. It is used in making paper pulp in the paper industry.
3. It is used for making artificial fibres such as rayon and nylon.
4. It is used for degreasing the surface of metals.
5. It is used for making bleaching agents such as sodium hypochlorite for household bleaching.

The electrolysis of brine solution to obtain products such as chlorine and sodium hydroxide is called chlor-alkali process, because the products formed are chlorine (chlor) and sodium hydroxide (an alkali).

2.12 BLEACHING POWDER [$CaOCl_2$]

WM2PVZF8TS

Chemically, bleaching powder is calcium oxychloride [$CaOCl_2$]. It is commonly called **chloride of lime**.

It is prepared by passing chlorine gas through freshly prepared slaked lime paste, till the gas stops reacting with it. The following chemical reaction takes place :

$$\underset{\text{Slaked lime}}{Ca(OH)_2(s)} + \underset{\text{Chlorine}}{Cl_2(g)} \longrightarrow \underset{\text{Bleaching powder}}{CaOCl_2(s)} + \underset{\text{Water}}{H_2O(l)}.$$

In the above reaction, slaked lime does not react completely with chlorine. So bleaching powder is always a mixture of calcium oxychloride and calcium hydroxide.

Properties of Bleaching Powder

- Bleaching powder is a yellowish white powder which smells exactly like chlorine.
- Bleaching powder is soluble in water. However, some amount of white residue is always left on account of the presence of unreacted slaked lime.
- Bleaching powder on coming in contact with moist air containing carbon dioxide, liberates chlorine gas.

$$\underset{\text{Bleaching powder}}{CaOCl_2(s)} + \underset{\text{Carbon dioxide}}{CO_2(g)} \xrightarrow{\text{Moisture}} \underset{\text{Calcium carbonate}}{CaCO_3(s)} + \underset{\text{Chlorine}}{Cl_2(g)}$$

Uses of Bleaching Powder

Bleaching powder is a convenient source of chlorine gas. It is put to the following uses:

1. It is used for bleaching white cotton clothes in laundry and cotton fabric in textile mills.
2. It is used for bleaching wood pulp in paper industry.
3. It is used in the sterilisation of drinking water.
4. It is used for disinfecting lavatories, drains and ditches.
5. It is used for making unshrinkable wool.
6. It is used in the manufacture of chloroform.
7. It is used as an oxidising agent in various organic and inorganic reactions.



Fig. 2.45: Bleaching powder

Quality of bleaching powder is measured by the percentage of chlorine it can liberate when treated with dilute hydrochloric acid. A standard bleaching powder contains 35% of chlorine.

2.13 BAKING SODA [$NaHCO_3$]

7PV0HU3JN

Chemically baking soda is sodium hydrogen carbonate [$NaHCO_3$].

It is a fine, white, crystalline solid. It is sometimes called **"mitha soda"**.

The raw materials required for its manufacture are : (i) sodium chloride, (ii) ammonium chloride, (iii) limestone or calcium carbonate.

Following steps are involved in the manufacture of baking soda :

- A saturated solution of common salt (brine) is prepared by dissolving common salt in water.
- Limestone is heated in separate kiln where it decomposes to form calcium oxide and carbon dioxide gas. The carbon dioxide formed is saved for future use and the quicklime is treated with water to form slaked lime.



Fig. 2.46: Baking soda ($NaHCO_3$)

$$\underset{\text{Limestone}}{CaCO_3(s)} \xrightarrow{\text{heat}} \underset{\text{Quicklime}}{CaO(s)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

$$\underset{\text{Quicklime}}{CaO(s)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Slaked lime}}{Ca(OH)_2(s)}$$

- The slaked lime is mixed with ammonium chloride and heated when it liberates ammonia gas.

$$\underset{\text{Ammonium chloride}}{2NH_4Cl(aq)} + \underset{\text{Slaked lime}}{Ca(OH)_2(aq)} \xrightarrow{\text{heat}} \underset{\text{Ammonia}}{2NH_3(g)} + \underset{\text{Calcium chloride}}{CaCl_2(aq)} + \underset{\text{Water}}{2H_2O(l)}$$

- Ammonia gas is passed through brine solution to form ammoniacal brine solution.
- Carbon dioxide is passed through ammoniacal brine solution when a chemical reaction takes place with the formation of sodium hydrogen carbonate as shown by the equation below.

$$\underbrace{\underbrace{NaCl(s) + H_2O(l)}_{\text{Brine solution}} + NH_3(g)}_{\text{Ammoniacal brine solution}} + \underset{\text{Carbon dioxide}}{CO_2(g)} \rightarrow \underset{\text{Sodium hydrogen carbonate}}{NaHCO_3(s)} + \underset{\text{Ammonium chloride}}{NH_4Cl(aq)}$$

- Thus, to put it briefly, we can say that when carbon dioxide gas is passed through ammoniacal brine, it forms sodium hydrogen carbonate and ammonium chloride.

Sodium hydrogen carbonate is sparingly soluble in water. Thus, it is filtered out and dried.

Sodium hydrogen carbonate is a fine white crystalline salt basic in nature. On heating, it decomposes to form sodium carbonate as is shown in the following equation :

$$2NaHCO_3(s) \xrightarrow{\text{heat}} Na_2CO_3(s) + H_2O(l) + CO_2(g)$$

Uses of Baking Soda

1. It is an essential constituent of baking powder. For example, **baking powder is a mixture of baking soda** and some organic acid, such as **citric acid**, **tartaric acid**, etc. When baking powder comes in contact with the water present in dough, a chemical reaction takes place with the formation of sodium tartarate, carbon dioxide gas and water. The gas then raises the dough and, hence, makes it light.

$$\underset{\text{Baking soda}}{NaHCO_3(aq)} + \underset{\text{(from tartaric acid)}}{H^+(aq)} \longrightarrow \underset{\text{(from sodium salt of tartaric acid)}}{Na^+(aq)} + \underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Water}}{H_2O(l)}$$



Fig. 2.47: Baked bread

2. It is an essential constituent of antacids, as it neutralises the gastric acid present in the stomach.
3. It is used in fire extinguishers to produce carbon dioxide gas instantly. Soda-acid fire extinguisher contains a saturated solution of baking soda and a thin glass bottle containing concentrated sulphuric acid. When the knob of the fire extinguisher is pressed from outside, the glass bottle breaks. The acid mixes with baking soda solution to form carbon dioxide gas under pressure. When the nozzle of the fire extinguisher is directed towards a fire, a stream of effervescent liquid containing carbon dioxide envelops the fire. It cuts off the supply of oxygen and the fire dies.



Fig. 2.48: Fire extinguisher

2.14 WASHING SODA [$Na_2CO_3.10H_2O$]

The chemical name of washing soda is sodium carbonate-decahydrate or hydrated sodium carbonate [$Na_2CO_3.10H_2O$]. As its formula shows 10 molecules of water for every molecule of sodium carbonate, it does not mean that is in the form of a solution. It is in the form of white crystals and the water molecules are not free, but are attached to the molecule of sodium carbonate. These molecules of water are commonly called **water of crystallisation**.



Fig. 2.49: Washing soda ($Na_2CO_3.10H_2O$)

Preparation

First of all sodium hydrogen carbonate is prepared from common salt as described in the previous section. The sodium hydrogen carbonate obtained is strongly heated when it forms anhydrous sodium carbonate, commonly called **soda ash.**

$$\underset{\text{Sodium hydrogen carbonate}}{2NaHCO_3(s)} \xrightarrow{\text{heat}} \underset{\text{Sodium carbonate or soda ash}}{Na_2CO_3(s)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

The soda ash is dissolved in a large amount of water. The solution so formed is evaporated, when washing soda crystallises out. It is then filtered and dried.

$$\underset{\text{Anhydrous sodium carbonate}}{Na_2CO_3(s)} + \underset{\text{Water}}{10H_2O(l)} \longrightarrow \underset{\text{Hydrated sodium carbonate}}{Na_2CO_3.10H_2O(s)}$$

Washing soda crystals are white and transparent in nature. When exposed to air they lose their water of crystallisation to form a white powdery mass of sodium carbonate monohydrate.

$$\underset{\text{Sodium carbonate decahydrate}}{Na_2CO_3.10H_2O(s)} \xrightarrow{\text{Exposure to air}} \underset{\text{Sodium carbonate monohydrate}}{Na_2CO_3.H_2O(s)} + 9H_2O(g)$$

Uses of Washing Soda

1. It is used in softening hard water. It prevents wastage of soap, when water used for washing clothes is hard in nature.
2. It is used in the manufacture of glass and dry soap powders (detergents).
3. It is a common household cleansing agent.
4. It is used in the manufacture of caustic soda, borax, sodium phosphate and water glass.
5. It is an important laboratory reagent and is used as a standard base in acid-base titrations.

2.15 PLASTER OF PARIS [$(CaSO_4)_2.H_2O$]

Egyptians are credited with discovering Plaster of Paris (POP) about 5000 years ago. They prepared this powder by heating gypsum in an open air fire. They used this powder for cementing big stone blocks that were used in the construction of monuments.

The term Plaster of Paris (POP) comes from **Montmartre** in Paris, because the gypsum found there was converted into cementing powder by heating. Initially, Plaster of Paris was used in the construction of houses. However, these days it finds number of other uses in addition to the construction industry.

The chemical name of **Plaster of Paris** is **calcium sulphate hemihydrate**. Its chemical formula is $CaSO_4.\frac{1}{2}H_2O$ or $(CaSO_4)_2.H_2O$



Fig. 2.50: Plaster of Paris is used for making sculpture



Fig. 2.51: Plaster of Paris is used to decorate wall ceilings

Preparation

It is prepared from naturally occurring gypsum [$CaSO_4.2H_2O$]. Gypsum is crushed to a fine powder and heated at a **controlled temperature of 100°C (373 K)** for a long time when each molecule of it loses three-fourths of water of crystallisation to form Plaster of Paris.

$$\underset{\text{Gypsum}}{CaSO_4.2H_2O(s)} \xrightarrow[100°C]{\text{Heat}} \underset{\text{Plaster of paris}}{CaSO_4.\frac{1}{2}H_2O(s)} + \underset{\text{Water}}{\frac{3}{2}H_2O(g)}$$

Or

$$\underset{\text{Gypsum}}{2CaSO_4.2H_2O(s)} \xrightarrow[100°C]{\text{Heat}} \underset{\text{Plaster of Paris}}{(CaSO_4)_2.H_2O(s)} + \underset{\text{Water}}{3H_2O(g)}$$

When gypsum is heated above 100°C (373 K), it completely looses its water of crystallisation and forms anhydrous calcium sulphate ($CaSO_4$). It is commonly called **dead burnt plaster**.

Properties of Plaster of Paris

(i) It is a white powder having very fine crystals.

(ii) It gets hydrated, when treated with water and sets into a hard mass in about half an hour.

$$\underset{\text{Plaster of Paris}}{(CaSO_4)_2.H_2O(s)} + 3H_2O(l) \longrightarrow \underset{\text{Gypsum crystals}}{2CaSO_4.2H_2O(s)}$$

The gypsum crystals, so formed, tightly interlock with one another to form a solid mass within half an hour. Furthermore, on solidification, it slightly expands, and hence, is excellent for making casts in moulds.

Note: Plaster of Paris should be stored in a moisture proof containers because the presence of moisture can cause slow setting of Plaster of Paris.

Uses of Plaster of Paris

(i) Plaster of Paris, when mixed with water rapidly sets into a hard mass. It is this property that is utilised to keep the fractured bones in a fixed position by applying Plaster of Paris around the affected bones.

(ii) It is used for casting statues, toys and decorative showpieces.

(iii) It is used in panelling of the roofs in houses.

(iv) It is used for making fireproof materials.

(v) It is used for making blackboard chalk.

JBLQG4RZ5O

2.16 WATER OF CRYSTALLISATION

We have stated above that 10 molecules of water that crystallise out from one molecule of sodium carbonate is called **water of crystallisation**.

Definition of water of crystallisation

The fixed number of water molecules, that are in loose combination with one molecule of a salt, is called ***water of crystallisation****.*

Examples of salts containing water of crystallisation

	Name of Salt	Chemical Formula
1.	Gypsum or calcium sulphate bihydrate	$CaSO_4.2H_2O$
2.	Washing soda or sodium carbonate decahydrate	$Na_2CO_3.10H_2O$
3.	Magnesium sulphate heptahydrate	$MgSO_4.7H_2O$
4.	Zinc sulphate heptahydrate (White vitriol)	$ZnSO_4.7H_2O$
5.	Ferrous sulphate heptahydrate (Green vitriol)	$FeSO_4.7H_2O$
6.	Copper (II) sulphate pentahydrate (Blue vitriol)	$CuSO_4.5H_2O$

Let us perform the following activity to show the presence of water in hydrated copper sulphate.

Method : Fill one-third of the hard glass test tube with copper sulphate crystals. Clamp the test tube in an iron stand. In the mouth of the test tube fit a delivery tube whose other end goes into another test tube placed in cold water.

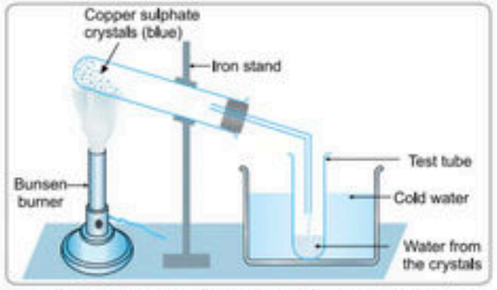


Fig. 2.52: Heating removes water of crystallisation from copper sulphate crystals

Heat the crystals of copper sulphate strongly. You will notice :

(1) The crystals give out steamy fumes. The fumes move to the test tube placed in water and condense to form colourless liquid.

(2) The crystals crumble to form powdery mass.

(3) The crystals lose their blue colour and change to white powder.

$$\underset{\text{Hydrated copper sulphate (Blue)}}{CuSO_4.5H_2O(s)} \xrightarrow{\text{heat}} \underset{\text{Anhydrous copper sulphate (White)}}{CuSO_4(s)} + \underset{\text{Water}}{5H_2O(g)}$$

Allow the apparatus to cool. Remove the test tube containing anhydrous copper sulphate. Add a few drops of water to the anhydrous copper sulphate. You will notice that copper sulphate regains its colour.

$$\underset{\text{Anhydrous copper sulphate (White)}}{CuSO_4(s)} + \underset{\text{Water}}{5H_2O(l)} \longrightarrow \underset{\text{Hydrated copper sulphate (Blue)}}{CuSO_4.5H_2O(s)}$$

Thus, the activity proves that hydrated copper sulphate contains water.

SAMPLE PROBLEMS

1. Give two important uses of washing soda and baking soda.

Ans. (a) Two uses of washing soda are given below :

- Washing soda (or sodium carbonate) is used for washing clothes (laundry purposes).
- Sodium carbonate is used for the manufacture of many important compounds, such as borax ($Na_2B_4O_7$), (sodium thiosulphate) hypo ($Na_2S_2O_3.5H_2O$), etc.

(b) Two uses of sodium hydrogencarbonate (baking soda) are given below :

- Sodium hydrogencarbonate is used for preparing baking powder and effervescent drinks.
- Sodium hydrogencarbonate is used in soda-acid type fire extinguishers.

2. Plaster of Pairs should be stored in a moisture-proof container. Explain why?

Aus. Plaster of Paris absorbs water and sets into a hard mass. This makes the plaster of Paris unusable. That is why it should be stored in a moisture-proof container.

3. What is the common name of the compound $CaOCl_2$?

Aus. $CaOCl_2$ is commonly called bleaching powder.

4. Name the substance which on treatment with chlorine yields bleaching powder.

Aus. Slaked lime [$Ca(OH)_2(s)$] gives bleaching powder when treated with chlorine gas.

5. Name the sodium compound which is used for softening hard water.

Aus. Sodium carbonate (or washing soda) is used for softening hard water.

6. What will happen if a solution of sodium hydrogencarbonate is heated? Give the equation of the reaction involved.

Aus. Sodium hydrogencarbonate on heating decomposes to give sodium carbonate and carbon dioxide.

$$2NaHCO_3(aq) \xrightarrow{\text{heat}} Na_2CO_3(aq) + CO_2(g) + H_2O(l)$$

7. Write an equation to show the reaction between plaster of Paris and water.

Aus. $CaSO_4.\frac{1}{2}H_2O(s) + \frac{3}{2}H_2O(l) \longrightarrow CaSO_4.2H_2O(s)$

Plaster of Pairs — Gypsum (hard mass)

KEY POINTS

- **Acid.** It is a hydrogen-containing compound which gives free hydrogen or hydronium ions (H_3O^+ or H^+) when dissolved in water. Naturally-occurring acids are weak, whereas mineral acids are strong acids.
- Acids turn blue litmus to red and give hyrogen gas when reacted with active metals.
- **Base.** It is a compound which gives free hydroxide ions (OH^-) when dissolved in water.
- The basic solution turn red litmus to blue.
- Acid-base indicators are organic dyes derived from plant materials that show the presence of acids and bases.
- Phenolphthalein and methyl orange are synthetic indicators that show the presence of acids and bases.
- Acidic nature of the substances is due to the formation of $H^+(aq)$ ions in an aqueous solution.
- Basic nature of the substances is due to the formation of $OH^-(aq)$ ions in an aqueous solution.
- Metals displace hydrogen from the acids, forming corresponding metal salt.
- A few metals displace hydrogen from alkalis, forming a metal salt containing oxygen.
- Acids react with metal oxides and metal hydroxides (bases) to form their respective salts and water as the only products.
- Acids react with metal carbonates to form their respective salts, water and carbon dioxide gas.
- Acidic and basic solutions conduct electricity, because they produce $H^+(aq)$ and $OH^-(aq)$ ions respectively.
- **Neutralisation reaction.** It is the reaction between an acid and a base/alkali to form a salt and water.
- In a neutralisation reaction, the $H^+(aq)$ ions of an acid react with $OH^-(aq)$ ions of a base to form water.
- **pH.** It tells us about potential of hydronium ions for any solution. pH scale extends from 0 to 14. A neutral solution has a, pH = 7; an acidic solution has a pH < 7 and, a basic solution has a pH > 7.
- **Salt.** It is the compound formed when an acid reacts with a base.
  - A salt may be normal, acidic or basic salt.
  - Salts containing a common ion are said to belong to a family.
  - Salts of sodium, potassium and some salts of calcium, magnesium, barium, aluminium are highly soluble.
- Salts of pH 7 are called normal or neutral salts. They are formed when a strong acid neutralises a strong alkali.
- Salts of pH less than 7 are called acidic salts. They are formed when a strong acid reacts with a weak alkali.
- Salts of pH more than 7 are called basic salts. They are formed when a strong alkali reacts with a weak acid.
- **Sodium hydroxide (NaOH).** Aqueous solution of sodium hydroxide turns red litmus to blue. It is used in the manufacturing of saops and detergents, and in textile industry. It is also known as caustic soda.
- **Washing soda ($Na_2CO_3.10H_2O$).** is the hydrated form of sodium carbonate which is called soda ash.
  - Aqueous solution of washing soda is basic and it turns red litmus blue.
- **Bleaching powder.** Bleaching powder ($CaOCl_2$) is obtained by the action of chlorine on slakedlime. It is used for bleaching cotton fibre, wood pulp, etc. and for sterlizing drinking water.
- **Baking soda.** Baking soda is sodium hydrogen carbonate ($NaHCO_3$). It is used for making baking powder.
- **Baking powder.** Baking powder is a mixture containing baking soda (sodium hydrogen carbonate, $NaHCO_3$) and an acidic compound, such as tartaric acid, or citric acid. It is used for preparting fluffy cakes, bread, etc.

♦ **Plaster of Paris.** Plaster of Paris ($CaSO_4.\frac{1}{2}H_2O$) is obtained by heating gypsum ($CaSO_4.2H_2O$) at 373 K. It is used for making statues, toys, etc., and for plastering fractured bones.

Exercise–2 (C)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

1. Which one of the following is not a neutral salt?
   (A) NaCl (B) $NaNO_3$ (C) Na_2SO_4 (D) Na_2CO_3

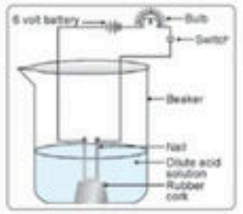
2. Plaster of Paris on mixing with water forms fine crystals of :
   (A) gypsum (B) anhydrous calcium sulphate
   (C) calcium hydrogen sulphate (D) none of the above

3. Match the chemical substances given in Column (A) with their appropriate application given in Column (B)

Column (A)	Column (B)
(a) Bleaching powder	(i) Preparation of glass
(b) Baking soda	(ii) Production of H_2 and Cl_2
(c) Washing soda	(iii) Decolourisation
(d) Sodium chloride	(iv) Antacid

   (A) a—(ii), b—(i), c—(iv), d—(iii) (B) a—(iii), b—(ii), c—(iv), d—(i)
   (C) a—(iii), b—(iv), c—(i), d—(ii) (D) a—(ii), b—(iv), c—(i), d—(iii) [BOTS]

4. In an attempt to demonstrate electrical conductivity through an electrolyte, the following apparatus was set up. Which among the following statements is correct?
   (A) Bulb will not glow because electrolyte is not acidic.
   (B) Bulb will glow because NaOH is a strong base and furnishes ions for conduction.
   (C) Bulb will not glow because circuit is incomplete.
   (D) Bulb will not glow because it depends upon the type of electrolytic solution.



5. Identify the correct representation of reaction occurring during chlor-alkali process.
   (A) $2NaCl(l) + 2H_2O(l) \longrightarrow 2NaOH(l) + Cl_2(g) + H_2(g)$
   (B) $2NaCl(aq) + 2H_2O(aq) \longrightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$
   (C) $2NaCl(aq) + 2H_2O(l) \longrightarrow 2NaOH(aq) + Cl_2(aq) + H_2(aq)$
   (D) $2NaCl\ (aq) + 2H_2O(l) \longrightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$

6. The products of chlor-alkali process are :
   (A) NaCl, Cl_2 and H_2 (B) H_2, Cl_2 and NaOH (C) Cl_2, Na_2CO_3 and H_2O (D) NaOH, Cl_2 and HCl

7. The number of molecules of water of crystallisation present in washing soda crystals is :
   (A) five (B) two (C) ten (D) seven

8. Plaster of Paris is prepared by heating one of the following to a temperature of 100°C. This is :
   (A) $CaSO_3.2H_2O$ (B) $CaCl_2.2H_2O$ (C) $CaCO_3.2H_2O$ (D) $CaSO_4.2H_2O$

9. One of the following salts will give an alkaline solution on dissolving in water. This is :
   (A) Na_2CO_3 (B) Na_2SO_4 (C) NaCl (D) $(NH_4)_2SO_4$

10. The salt which will give a neutral solution on dissolving in water will be :
    (A) CH_3COONa (B) NH_4Cl (C) KCl (D) Na_2CO_3

Ans: 1. (D) 2. (A) 3. (C) 4. (B) 5. (D) 6. (B) 7. (C) 8. (D) 9. (A) 10. (C)

II. ASSERTION (A) AND REASON (R)

For question numbers 1 and 5, two statements are given one labelled *Assertion* (A) and the other labelled *Reason* (R). Select the correct answer to these questions from the codes (i), (ii), (iii) and (iv) as given below:
(i) Both A and R are true and R is the correct explanation of the assertion.
(ii) Both A and R are true but R is not the correct explanation of the assertion.



(iii) A is true but R false.
(iv) A is false but R is true.

1. **Assertion:** An indicator is a chemical substance that indicates the nature of substances by means of sharp change in colour or in odour.
   Reason: Onion has a characteristic pungent smell. In basic solutions the smell of onion cannot be detected. An acidic solution does not destroy the smell of onions.
2. **Assertion:** An acid can be diluted by adding water to it.
   Reason: If water is added to concentrated acid to dilute it, then a large amount of heat is evolved at once.
3. **Assertion:** Nitric acid is a powerful oxidising agent.
   Reason: Nitric acid dilute or concentrated form produces hydrogen gas with metals.
4. **Assertion:** Ethanol (CH_3CH_2OH) and glucose ($C_6H_{12}O_6$) solutions are not acidic in nature while sulphuric acid (H_2SO_4) is acidic in nature.
   Reason: Ethanol and glucose do not produce H_3O^+ in solutions.
5. **Assertion:** Hydrochloric acid is a strong acid whereas, acetic is a weak acid.
   Reason: Hydrochloric acid completely ionises in water, whereas acetic acid partially ionises in water.

III. VERY SHORT ANSWER TYPE QUESTIONS

1. Write the names and chemical formula of the products formed by the action of chlorine on slaked lime.
2. Write a fully balanced equation when carbon dioxide is passed through ammoniacal brine solution.
3. Write the name and chemical formula of the products formed by heating gypsum at 373 K.
4. Why is baking powder kept in air tight containers?
5. Write the name and chemical formula of the main product formed by heating baking soda.
6. What is the chemcial formula of (a) baking soda, and (b) washing soda?
7. Write the chemical formula of (i) soda ash, and (ii) sodium carbonate decahydrate.
8. Which of the following salt has a blue colour and why?
   $CuSO_4.5H_2O$ or $CuSO_4$
9. What would be the colour of litmus in a solution of sodium carbonate?
10. What is the commercial name of calcium sulphate hemihydate?

IV. SHORT ANSWER TYPE QUESTIONS

1. How is Plaster of Paris prepared? Why is Plaster of Paris stored in air-tight container?
2. Write two observations you would make when quicklime is added to water.
3. A calcium compound, which is a yellowish-white powder is used as a disinfectant and also in textile industry. Name the compound. Which gas is released when this compound is left exposed to air?
4. How is Plaster of Paris chemically different from gypsum? How can they be interconverted? Write one use of Plaster of Paris.
5. What is baking powder? How does it make a cake soft and spongy?
6. What is meant by water of crystallisation? How would you show that copper sulphate crystals contain water of crystallisation?
7. Write the name and formula of a compound used for disinfecting drinking water. How is this compound manufactured?
8. Name the three products obtained on the electrolysis of an aqueous solution of sodium chloride. Why is this process called chlor-alkali process.
9. Name the products formed when sodium hydrogen carbonate is heated. Write a chemical equation for the above reaction.
10. How is chloride of lime chemically different from calcium chloride? Why does chloride of lime gradually lose its chlorine when kept exposed to air?
11. What is the chemical name of washing soda? Name the three chief raw materials used for making washing soda by the Solvay process. [HOTS]
12. State the chemical property in each case on which the following uses of baking soda are based:
    (i) as an antacid (ii) as a constituent of baking powder.
13. What is the formula of washing soda crystals? What happens when washing soda crystals are exposed to air? Write a chemical equation in support of your answer.



14. Give three uses of: (i) baking soda, (ii) washing soda.

15. Classify the following as neutral, acidic and basic salts, giving reasons for your answers :
(i) KCl (ii) Na_2SO_4 (iii) $FeSO_4$ (iv) $KHCO_3$ (v) $CuSO_4$ (vi) CH_3COONa

16. Sodium chloride, ammonium chloride and limestone are used as raw materials in the manufacture of baking soda. What is the importance of each raw material?

17. Write the chemical formula for washing soda. How may it be obtained from baking soda? What are the industrial uses of washing soda, other than washing clothes?

18. Write the chemical formula for bleaching powder. How is it prepared? Why is it used in paper factories?

19. Write the chemical formula of washing soda and baking soda. Which one of these two is an ingredient of antacids? How does it provide relief in stomach ache?

20. A compound that is prepared from gypsum has a property of hardening when mixed with proper quantity of water. Identify the compound. Write the chemical equation for its preparation. For what purpose it is used in hospitals?

21. Crystals of copper sulphate are heated in a test tube for some time.
(a) What is the colour of copper sulphate crystals : (i) before heating and (ii) after heating?
(b) What is the source of liquid droplets seen on the inner side of the test tube, during the heating process?

22. What is the chemical formula of "Plaster of Paris"? How is it prepared? State the common and the chemical names of the compound formed, when Plaster of Paris is mixed with water.

23. (a) Name the raw materials used in the manufacture of sodium carbonate by Solvay process.
(b) How is sodium hydrogen carbonate formed during Solvay process separated from a mixture of NH_4Cl and $NaHCO_3$?
(c) How is sodium carbonate obtained from sodium hydrogen carbonate?

24. Write the chemical name and formula of washing soda. What are the raw materials used for its manufacture by Solvay process? What happens when crystals of washing soda are exposed to air?

25. Name the raw materials that are required for the manufacture of washing soda by Solvay process. Describe the chemical reactions involved in the process.

26. (a) Write the formula and chemical name of bleaching powder.
(b) Write chemical equation to represent the action of atmospheric CO_2 gas on bleaching powder when left exposed in open.
(c) State for what purpose is bleaching powder used in water treatment plants.

27. (a) Write the chemical name and formula of bleaching powder.
(b) Why does bleaching powder smell of chlorine when exposed to air?
(c) Write chemical equation to represent the action of dilute hydrochloric acid on bleaching powder.

28. A compound X of sodium forms a white powder. It is a constituent of baking powder and is used in some antacid prescriptions. When heated, X gives out a gas and steam. The gas forms a white precipitate with limewater. Write the chemical formula and name of X and the chemical equation for its decomposition on heating. What is its role in baking powder and in antacids?

29. Identify the compound of calcium that is a yellowish-white powder and is used for disinfecting drinking water. How is it manufactured? Write the chemical equation for the reaction involved. What happens when it is left exposed to air?

30. Identify the compound of calcium that is used for plastering of fractured bones. With the help of a chemical equation, describe how this compound is prepared. What special precaution should be taken during the preparation of this compound?

31. 2 mL of sodium hydroxide solution is added to a few pieces of granulated zinc metal taken in a test tube. When the contents are warmed, a gas evolves which is bubbled through a soap solution before testing. Write the equation of the chemical reaction involved and the test to detect the gas. Name the gas which will be evolved when the same metal reacts with dilute solution of a strong acid.

32. The pH of a salt solution used to make tasty and crispy pakoras is 14. Identify the salt and write a chemical equation for its formation. List its two uses.

IV. LONG ANSWER TYPE QUESTIONS

1. What is the name of compound $CaSO_4 \cdot \frac{1}{2}H_2O$? Is it possible to have half water molecule? Explain how the above formula is correct. What do you understand by the terms : (a) hydrated salt, (b) water of crystallisation? Give one example of each.



2. (i) Salt A commonly used in bakery products on heating gets converted into another salt B which itself is used for the removal of hardness of water and a gas C is evolved. The gas C when passed through limewater, turns it milky. Identify A, B and C.

   (ii) In one of the industrial processes used for the manufacture of sodium hydroxide, a gas X is formed as a byproduct. The gas X reacts with limewater to give a compound Y, which is used as a bleaching agent in the chemical industry. Identify X and Y giving the chemical equation of the reactions involved.

3. (i) A dry pellet of a common base B, when kept in open absorbs moisture and turns sticky. The compound is also a byproduct of the chlor-alkali process. Identify B. What type of reaction occurs when B is treated with an acidic oxide? Write a balanced chemical equation for one such reaction.

   (ii) A sulphate salt of Group 2 element of the Periodic Table is a white, soft substance, which can be moulded into different shapes by making its dough. When this compound is left in the open for some time, it becomes a solid mass and cannot be used for moulding purposes. Identify the sulphate salt and why does it show such a behaviour? Give the reaction involved. [HOTS]

4. (i) For making cake, baking powder is taken. If at home your mother uses baking soda instead of baking powder in cake,

   (a) how will it affect the taste of the cake and why?

   (b) how can baking soda be converted into baking powder?

   (c) what is the role of tartaric acid added to baking soda?

   (ii) A metal carbonate X on reacting with an acid gives a gas which when passed through a solution Y gives the carbonate back. On the other hand, a gas G that is obtained at the anode during electrolysis of brine when passed on dry Y, gives a compound Z, used for disinfecting drinking water. Identify X, Y, G and Z.

5. A white powder is added while baking cakes to make it soft and spongy. Name its main ingredients. Explain the function of each ingredient. Write the chemical reaction taking place when the powder is heated during baking.

6. "Sodium hydrogen carbonate is a basic salt." Justify this statement. How is it converted into washing soda?

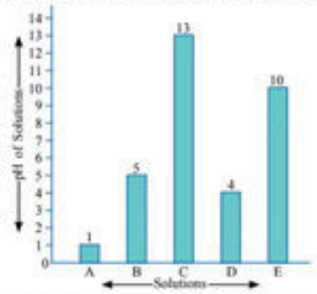
7. Write the chemical formula of washing soda. How can it be obtained from baking soda? List two industries in which washing soda is used for other purposes than washing clothes.

VI. PASSAGE–BASED QUESTIONS

Answer the questions (1–4) on the basis of your understanding of the following paragraphs and the related studied concepts.

We can quantitatively find the amount of H^+ ions present in a solution. We can judge how strong a given acid or base is, by making use of a universal indicator, which is a mixture of several indicators. The universal indicator shows different colours at different concentrations of hydrogen ions in a solution. A scale for measuring hydrogen ion concentration in a solution, called pH scale has been developed. The p in pH stands for 'potenz' in German, meaning power. On the pH scale we can measure pH generally from 0 (very acidic) to 14 (very alkaline). The pH of a neutral solution is 7.

1. What is meant by the term "pH of a solution"?
2. The pH of tomato soup is 4. Is it safe to keep the soup in a copper bowl?
3. If the pH of a sample of soil is 5.5. What will you mix in the soil to make it fertile?
4. On the basis of above information and graph given below, answer these questions.



(i) Which solution is highly acidic in nature?

(ii) Which solution is a mild base?

3 Metals and Non-Metals



INSIDE THE CHAPTER

3.1 Metals
- Physical properties of metals

3.2 Non-metals
- Physical properties of non-metals

3.3 How do metals and non-metals react chemically?

3.4 Formation of ionic compounds
- Properties of ionic compounds

3.5 Formation of covalent bond
- Properties of covalent compounds

3.6 Chemical properties of metals

3.7 Chemical properties of non-metals

3.8 Extraction of metals
- Extraction of metals near the top of metal reactivity series
- Extraction metals in the middle of reactivity series
- Extraction of metals low in reactivity series

3.9 Corrosion of metals

3.10 Alloys

INTRODUCTION

In the previous class, you have learnt about various elements. Elements are the building blocks of matter. 118 elements are discovered so far. On the basis of their physical and chemical properties, we can classify elements into two main classes, that is, metals and non-metals.



Iron bars | Gold bangles | Coal | Sulphur

Fig. 3.1: Metals and non-metals

Metals and non-metals are present all around us. For example, iron, aluminium, silver, gold, etc., are some examples of metals and coal, sulphur, phosphorus, chlorine, etc., are some examples of non-metals. Metals are hard and lustrous, whereas non-metals are brittle and dull in appearance.

3.1 METALS

In Class IX you have learnt that elements like aluminium, zinc, iron and copper, etc., are metals. Let us study their physical properties with the help of the following activity :

Take small samples of the metals aluminium, iron and copper in the form of thin wires and perform the following activities :

(i) Note the appearance of each sample. Now rub their surfaces with sand paper and again note their appearance. You will find that metals in their pure state having a shining surface. This property is called ***metallic lustre***.

(ii) Try to cut each metal with a sharp knife or with a pair of scissors.
You will find that ***metals are hard*** and cannot be cut with a knife.

(iii) Take an iron rod and start heating one of its end. After a minute, touch the other end of the rod. You will notice that the other end has also become hot this means that ***metals are good conductors of heat***.

(iv) Set-up the electric circuit as shown in Fig. 3.2. Insert each of the metal strips in between the clamps A and B and switch on the circuit. You will observe that bulb glows in each case. Thus, we can say that ***metals are good conductors of electricity***.

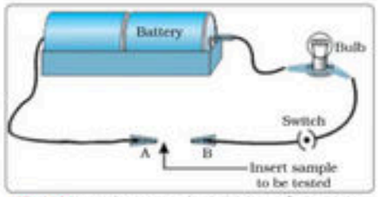


Fig. 3.2: Metals are good conductors of electricity

(v) Strike each of the metal pieces on some hard surface. You will observe that all of them produce a peculiar metallic sound. We can say that ***metals are sonorous***.

(vi) Place a small sample of a metal on an iron block and hammer it with a hammer. Repeat the procedure with other metals.
You will see that the pieces of metal flatten. *The property of metals by which they can be beaten into sheets is called* ***malleability***.

Gold and silver are the most malleable metals. The thin leaves of gold and silver are used in decorating sweets as well as making *ayurvedic* medicines and jewellery.

(vii) *The property of an element by which it can be drawn into wires is called* ***ductility***. Most of the metals are ductile.

A wire of about 2 km in length can be drawn from 1 g of gold.

So according to the above properties, we can say that metals are the elements that conduct heat and electricity, which are also malleable and ductile.

In a chemical reaction metals form positive ions by losing electrons. Thus, metals are also known as ***electropositive elements***. So, we can say that, 'metals are the elements, which form positive ions in a chemical reaction by losing electrons.' For example, sodium (Na) is a metal it forms a positively charged ion (Na^+) by losing an electron.

Let us look at the physical properties of metals in detail.

Physical Properties of Metals

ZWV6NYJOBG

(i) **State:** Metals are generally solid at room temperature. They have very high melting and boiling points. **Mercury is an exception as it is liquid at room temperature**. Iron has a melting point of 1535°C and Copper has a melting point of 1083°C.

(ii) **Hardness:** Metals are generally hard. *However, metals like* ***sodium***, ***potassium*** *are soft and can be cut with a knife*. Similarly, metals like gold and aluminium are not very hard.

(iii) **Lustre:** When metals are freshly cut, they have a brilliant shine over the cut surface. *This metallic shine is called* ***lustre***. Thus, metals can be highly polished.

(iv) **Density:** Metals generally have a high density. Iron has a density of 7.8 g/cm^3. ***Lithium, sodium*** *and* ***potassium*** *metals are exceptions, as their densities are less than 1 g/cm*^{3}, and they can float on water.

(v) **Melting Point and Boiling Point:** Metals generally have high melting and boiling points. ***Mercury, caesium*** *and* ***gallium*** *metals are exceptions as they have low melting as well as boiling points.*

(vi) **Malleability:** *The property of metals, due to which they can be beaten into sheets, is called* ***malleability***.
Metals are generally malleable. *However, metals like* ***zinc***, ***arsenic*** *and* ***antimony*** *are exceptions to the rule.*

(vii) **Ductility:** *The property by which a substance can be drawn into wires is called* ***ductility***. Platinum is the most ductile metal. Gold, silver, copper and aluminium are also highly ductile. Metals are generally ductile. *However, metals like* ***zinc***, ***arsenic*** *and* ***antimony*** *are exceptions.*

(viii) **Tensile Strength:** *The property due to which a substance can bear a lot of strain without breaking, is called* ***tensile strength***. Iron has a very high tensile strength due to which all the bridges, buildings, railway lines, machines, etc., are made up of iron.
Metals generally have high tensile strength. However, zinc, arsenic, sodium, potassium and antimony are exceptions to the rule.


Fig. 3.3: Metals are malleable


Fig. 3.4: Copper is ductile and a good conductor of electricity


Fig. 3.5: Metals are used for the construction of bridges


Fig. 3.6: Metals are sonorous

(ix) **Conductivity:** Metals are generally good conductors of heat and electricity. Silver is the best conductor. Copper and aluminium are also good conductors of heat, hence utensils and electric wires are made from them. *However,* ***bismuth*** *and* ***tungsten*** *are poor conductors.*

(x) **Sonorous:** When metals are struck with some hard material, they produce ringing sound. Thus, metals are said to be ***sonorous***.

3.2 NON-METALS

6NOT3MRA42

Now collect the samples of some solid non-metals, such as charcoal (carbon), sulphur and iodine. Carry out the activities from (i) to (vii) as in case of metals.

You will find that *non-metals do not have lustre, are bad conductors of heat and electricity, are brittle solids, which are neither malleable nor ductile. Furthermore, they are not sonorous.*

In a chemical reaction non-metals form negative ions by accepting or gaining electrons. Thus, non-metals are also known as ***electronegative elements***. So we can say that, 'non-metals are the elements, which form negative ions, in a chemical reaction by gaining electrons.' For example, chlorine is a non-metal, it forms a negatively charged ion (Cl^-) by accepting an electron.

Physical Properties of Metals

(i) **State:** Non-metals are generally brittle solids or liquids or gases. They exist in all the three physical states.

(ii) **Hardness:** Non-metals are generally not hard, they are soft and can be cut with a knife. *However, diamond (an allotrope of carbon) is the hardest, naturally occurring substance.*

(iii) **Lustre:** Non-metals have no lustre that is they do not have a shiny surface. However, ***iodine, diamond*** *and* ***graphite*** *have lustre.*

(iv) **Density:** Non-metals generally have low density, for example, sulphur has a low density of 2 g/cm^3.

(v) **Melting Point and Boiling Point:** Non-metals have low melting and boiling points. For example, the melting point of sulphur is 115°C. *However,* ***carbon***, ***silicon*** *and* ***boron*** *have high melting and boiling points. The melting point of diamond is 3500°C.*

(vi) **Malleability:** Non-metals are non-malleable. If hammered, they form powdery mass. This property of not getting converted into wires and sheets as well as forming a powdered mass on beating is known as ***brittleness***.

(vii) **Ductility:** Non-metals are not ductile. However, **carbon fibre** *(a recently developed allotrope of carbon) is highly ductile.*

(viii) **Tensile Strength:** Non-metals do not have tensile strength that is they connot bear strain as iron can. *However,* ***carbon fibre*** *is as tensile as steel.*

(ix) **Conductivity:** Non-metals are generally bad conductors of electricity. ***Graphite*** *and* ***gas carbon*** *are good conductors of electricity, hence they are exceptions.*

(x) **Sonorous:** Non-metals are non-sonorous, that is when struck with a hammer, they do not produce a sound.

Exceptions

1. Metals have high melting points. However, *metals like gallium and caesium have so low melting points that they can even melt in your hands.* Diamond, even after being a non metal, has a very high melting point.
2. Metals are generally hard, except the metals like sodium and potassium, which can be cut with a knife. Diamond is a non-metal and is the hardest known substance on earth.
3. Iodine is a non-metal that has lustre.
4. Carbon is a non-metal that can exist in different physical forms. Each physical form is called its **allotrope** and the phenomenon is called **allotropy**.

   Amongst the allotropes of carbon, diamond is the hardest naturally occurring substance. Graphite is another allotrope of carbon that has lustre and is a good conductor of electricity.
5. Mercury is a metal that exists as a liquid at room temperature.
6. We studied that metals have high densities, but alkali metals do not have high densities.

DID YOU KNOW?

1. Sodium and potassium metals are lighter than water. They are commonly called ***alkali*** metals.
2. Calcium and magnesium are called alkaline ***earth metals***.
3. Silver is the best conductor of heat and electricity, followed by copper, gold and aluminium.
4. Platinum, silver and gold are called ***noble metals***, as they are not corroded by moist air, acids or alkalis.
5. Uranium, polonium, thorium and radium are called ***radioactive metals***. They emit radiations that are harmful to all kinds of living beings.
6. Metals like titanium, manganese, zirconium and chromium are called ***strategic metals***. The alloys of these metals are used in space science projects, atomic power plants, jet engines and in making high grade steel. As these metals are essential for the defence services of a country, so they are called strategic metals.

Table 3.1 : Comparison of metals and non-metals

Metals	Non-metals
1. Metals are malleable and ductile.	Non-metals are brittle.
2. Metals are good conductors of heat and electricity.	Non-metals are bad conductors of heat and electricity.
3. Metals are lustrous and can be polished.	Non-metals are dull and cannot be polished.
4. Metals are generally solid at room temperature.	Non-metals may be solids, liquids or gases at room temperature.
5. Metals are strong (have high tensile strength).	Non-metals are not strong (have low tensile strength).

Assess Yourself – 1

1. Tick (✓) the Correct Answer.
   (a) A metal whose density is less than 1 g cm^{-3} is :
   (A) aluminium (B) magnesium (C) calcium (D) sodium
   (b) Aluminium is used for making cooking utensils. Which of the following properties of aluminium are responsible for the same?
   (i) Good thermal conductivity (ii) Good electrical conductivity
   (iii) Ductility (iv) High melting point
   (A) (i) and (ii) (B) (i) and (iii) (C) (ii) and (iii) (D) (i) and (iv) [HOTS]
2. Give an example of a non-metal that is the hardest substance.
3. Give two examples of metals which can be cut with a knife.
4. Give two examples of non-metals that have lustre.
5. Why are titanium and chromium classified as strategic metals? [2006]
6. Give an example of a metal which:
   (i) is a liquid at room temperature. (ii) is kept immersed in kerosene for storing.
   (iii) is both malleable and ductile. (iv) is the best conductor of heat.

SAMPLE PROBLEMS

1. Explain the meaning of malleability.

Ans. The tendency of metals to form very **thin sheets** by hammering is called malleability. Metals are malleable because they can be hammered to form thin films. Gold and silver are among the most malleable metals. Both gold and silver can be hammered into foils much thinner than the thinnest paper.

2. What do you understand by ductility?

Ans. The tendency of metals to get drawn into **thin wires** is called ductility. All metals are ductile but not equally, that is, some metals are more ductile others are less ductile. Platinum, gold, silver and copper are among the most ductile metals.

3. Why is sodium kept immersed in kerosene oil?

Ans. Sodium is a reactive metal. It reacts with oxygen at room temperature to form sodium oxide (Na_2O). Sodium also reacts with water present in the air as moisture to form sodium hydroxide. To protect sodium from air and moisture, it is kept under kerosene.

4. You are given a hammer, a battery, a bulb, wires and a switch.
(a) How could you use them to distinguish between samples of metals and non-metals?
(b) Assess the usefulness of these tests in distinguishing between metals and non-metals.

Ans. (a)

	Equipment	Purpose of the use of the equipment	Change observed	Conclusion
1.	Hammer	To find out if the sample is brittle or malleable.	• The substance breaks into pieces – it is brittle. • On hammering, the substance gets shaped into thin sheet–it is malleable.	• The given substance is a non-metal. • The given substance is a metal.
2.	A battery, a bulb, wires and a switch	To find out if the given sample allows electricity to pass through it or not.	• The sample does not allow electricity to pass through it–it is a non-conductor. • The sample allows electricity to pass through it–it is a conductor.	• The given substance is a non-metal. • The given sample is a metal.

(b) These two tests are reasonably conclusive to differentiate between metals and non-metals.



3.3 HOW DO METALS AND NON-METALS REACT CHEMICALLY?

03O7SA1QUV

Elements can be more clearly classified as metals and non-metals on the basis of their chemical properties. However, before we learn about chemical properties of metals and non-metals, let us try to find out why do metals react with non-metals on the basis of the atomic model.

Let us first look at the electronic configuration of noble gases.

(a) Noble gases

Table 3.2 : Electronic configuration of noble gases

Type of element	Element	Atomic number	Number of electrons in shells					
			K	L	M	N	O	P
Noble gases	Helium (He)	2	2					
	Neon (Ne)	10	2	8				
	Argon (Ar)	18	2	8	8			
	Kryton (Kr)	36	2	8	18	8		
	Xenon (Xe)	54	2	8	18	18	8	
	Radon (Rn)	86	2	8	18	32	18	8

If you look at the number of electrons in the valence shell (outermost shell) of these gases, then you will find, that helium has two electrons in its only shell. All other noble gases have 8 electrons in their valence shell or outermost shell. As all noble gases are chemically inactive, following conclusions can be drawn:

(i) Duplet structure of valence K shell makes an element inactive.

(ii) Octet structure of valence shell makes an element inactive.

Atoms of all elements except noble gases have one to seven electrons in their valence shells. Therefore, they are not stable. Thus, to attain a stable electronic structure in their valence shell, the atoms of the elements redistribute their electrons in such a way that each atom has a stable electronic configuration of the nearest noble gas.

Hence the reactivity of elements is their tendency to attain a completely filled outer shell (stable electronic arrangement) and become stable.

(b) Metals

Table 3.3 : Electronic configuration of metals

Type of element	Element	Atomic number	No of electrons in different shells					
			K	L	M	N	O	P
Metals	Sodium (Na)	11	2	8	1			
	Magnesium (Mg)	12	2	8	2			
	Aluminium (Al)	13	2	8	3			
	Potassium (K)	19	2	8	8	1		
	Calcium (Ca)	20	2	8	8	2		

If you look at the number of electrons in the valence shell of metals, you will find that they have 1, 2 or 3 electrons.

From the above deduction, we can conclude :

(i) *If there are 1 to 3 electrons in the valence shell of an element then the element is a metal.*

(ii) *As the valence shell of metals does not have a duplet or octet structure, therefore, metals are chemically active.*



Table 3.4 : Electronic configuration of non-metals

Type of element	Element	Atomic number	No. of electrons in different shells					
			K	L	M	N	O	P
Non-Metals	Carbon (C)	6	2	4				
	Nitrogen (N)	7	2	5				
	Oxygen (O)	8	2	6				
	Fluorine (F)	9	2	7				
	Silicon (Si)	14	2	8	4			
	Phosphorus (P)	15	2	8	5			
	Sulphur (S)	16	2	8	6			
	Chlorine (Cl)	17	2	8	7			

If you look at the number of electrons in the valence shell of non-metals, you will find that they have 4, 5, 6 or 7 electrons.

From the above deduction we can conclude :

(i) *If there are 4 to 7 electrons in the valence shell of an element then the element is a non-metal.*

(ii) *As the valence shell of non-metals does not have an octet structure, therefore, non-metals are chemically active.*

Atoms combine with one another to achieve the inert gas electron arrangement and become stable. So we can say that, atoms form ***chemical bonds to achieve stability by acquiring the inert gas electron arrangement***. Atoms combine to form chemical bonds in such a way that each atom gets 8 electrons in its outermost shell (or 2 electrons in the outermost K-shell). *An atom can achieve the inert gas electronic configuration by :*

(i) losing one or more electrons

(ii) gaining one or more electrons

(iii) sharing one or more electrons

Transfer of electrons takes place between *metals* and *non-metals, this results in the formation of* ***ionic bonds***. On the other hand, sharing of electrons takes place between *non-metals, this results in the formation of covalent bonds.*

Ionic Bond

When a metal reacts, it does so by losing (donating) all electrons from its valence shell so as to attain a stable octet structure of the nearest noble gas. This in turn upsets the electrical balance of the protons and electrons, and hence, there is a net positive charge on the residual atom. ***This electrically charged particle is called an ion***. In case of a metal the charge is positive and hence, we say that a ***metal forms a cation***.

Formation of Cations (Positive Ions)

When an atom of a metal donates an electron or electrons from its valence shell, so as to acquire the electronic configuration of the nearest noble gas, the residual particle is called a ***positive ion*** or ***cation***.

Following examples will illustrate the point :

Sodium atom has electronic configuration 2 (K), 8 (L), 1 (M). Now, when sodium atom loses one electron from the M-shell, L shell with 8 electrons is exposed, which is similar to the valence shell of neon gas. Thus, sodium ion has electronic configuration of the nearest noble gas neon. However, as there are 11 protons in its nucleus, therefore, it has a net unit positive charge.

Sodium atom	$Na^{\bullet}$	$\xrightarrow{-e^-}$	Na^+
Electronic configuration	K L M 2, 8, 1		Sodium ion 2, 8



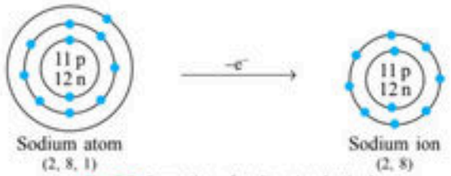


Fig. 3.7: Formation of sodium ion (cation)

The atomic number of magnesium is 12 and the electronic configuration is 2(K), 8(L), 2(M). It has 2 valence electrons. In order to attain a stable electronic configuration, magnesium donates its 2 valence electrons and forms a magnesium ion (Mg^{2+}). The magnesium ion has a stable electronic configuration that is 2, 8 which is similar to that of the noble gas neon. However, as there are 12 protons in the nucleus of magnesium, therefore, it has 2 units of positive charge.





Fig. 3.8: Formation of magnesium ion (cation)

Formation of Anions (Negative Ions)

When a non-metal reacts, it does so to attain a stable octet structure of the nearest noble gas, by gaining (accepting) electrons donated by the metal in its valence shell. This in turn upsets the electrical balance of protons and electrons, and hence, there is a net negative charge on the atom. This electrically charged particle is called an ion. In case of a non-metal the charge is negative, and hence, we say that a ***non-metal forms an anion***.

When an atom of a non-metal accepts an electron or electrons, the new particle formed is a ***negative ion*** or an ***anion***.

Following examples will illustrate the point :

Chlorine atom has the electronic configuration 2(K), 8(L), 7(M). Now, when a chlorine atom gains an electron in the M-shell, the total number of valence electrons become 8. Thus, configuration of the valence shell of chlorine corresponds to the valence shell of the nearest noble gas argon. However, as there are 17 protons in its nucleus, but 18 electrons, therefore, it has a net unit negative charge.



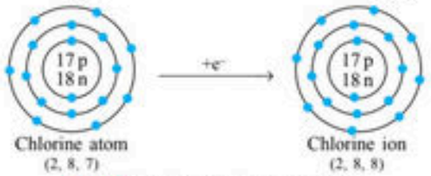


Fig. 3.9: Formation of chlorine ion (anion)

The atomic number of oxygen is 8 and the electronic configuration is 2(K), 6(L). It has 6 valence electrons. In order to attain a stable electronic configuration, oxygen atom gains 2 electrons and forms oxide ion (O^{2-}). The oxide ion has a stable electronic configuration that is 2, 8, which is similar to that of the noble gas neon. However, as there are 8 protons in the nucleus of oxygen, therefore, it has 2 units of negative charge.

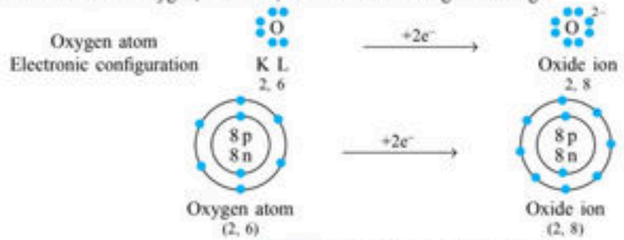


Fig. 3.10: Formation of oxygen ion (anion)

Now, once the positive ions are formed by the metals and negative ions are formed by the non-metals, they mutually attract each other to form an ***ionic bond*** and the ***compound so formed is called*** **an ionic compound**.

3.4 FORMATION OF IONIC COMPOUNDS

ZEF84A9GDK

1. **Formation of Sodium Chloride:** The electronic configuration of sodium atom (Na) is (2, 8, 1). It is an electropositive element, which can attain the electronic configuration of the nearest noble gas neon [Ne = (2, 8)] by donating (losing) one electron from its valence shell to form sodium ion (Na^+).

$$\underset{\substack{(2,8,1)\\ \text{Sodium atom}}}{Na} - e^- \longrightarrow \underset{\substack{(2,8)\\ \text{Sodium ion}}}{Na^+}$$

The electronic configuration of chlorine atom (Cl) is (2, 8, 7). It is an electronegative element, which can attain the electronic configuration of the nearest noble gas argon [Ar = (2, 8, 8)] by accepting (gaining) one electron in its valence shell to form chloride ion (Cl^-).

$$\underset{\substack{(2,8,7)\\ \text{Chlorine atom}}}{Cl} + e^- \longrightarrow \underset{\substack{(2,8,8)\\ \text{Chloride ion}}}{Cl^-}$$

The positively charged sodium ion attracts the negatively charged chloride ion with a strong electrostatic force which binds them together. This results in the formation of an ionic bond between sodium and chlorine. The compound so formed is called an ***ionic compound***. The above combination of sodium cation and chlorine anion to form sodium chloride, can be represented by geometric diagram, dot diagram and ionic equation is shown below.

Geometric diagram:

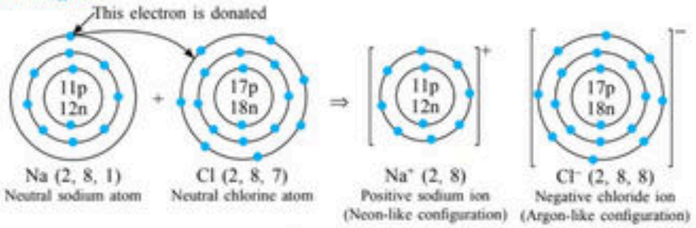


Fig. 3.11: Formation of sodium chloride

Electron dot diagram :



Ionic equation :

$$Na - e^- \longrightarrow Na^+$$
$$Cl + e^- \longrightarrow Cl^-$$
$$Na + Cl \longrightarrow Na^+ Cl^- \text{ or } NaCl$$

Structure of Sodium Chloride Crystal: *Sodium chloride crystals consist of a giant ionic lattice in which sodium ions and chloride ions are held by electrostatic forces of attraction.* Thus, a crystal of sodium chloride has a formula $(Na)_n^+(Cl)_n^-$ or $(Na^+Cl^-)_n$, where *n* denotes the number of sodium ions and chloride ions held in ionic lattice in three dimensions as illustrated in Fig. 3.12.

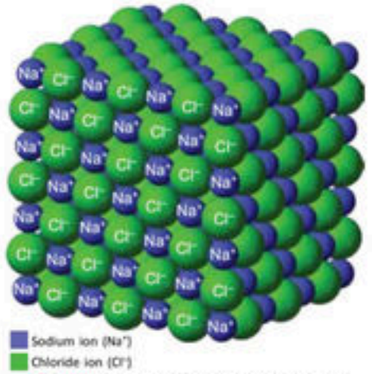


Fig. 3.12: Structure of sodium chloride crystal

2. **Formation of Magnesium Chloride:** The electronic configuration of magnesium atom (Mg) is (2, 8, 2). It is an electropositive element, which can attain the electronic configuration of the nearest noble gas neon [Ne = (2, 8)] by donating (losing) two electrons from its valence shell, so as to form magnesium ion (Mg^{2+}).

$$\underset{\substack{(2,8,2)\\\text{Magnesium atom}}}{Mg} - 2e^- \longrightarrow \underset{\substack{(2,8)\\\text{Magnesium ion}}}{Mg^{2+}}$$

The electronic configuration of chlorine atom (Cl) is (2, 8, 7). It is an electronegative element, which can attain the electronic configuration of the nearest noble gas argon [Ar = (2, 8, 8)] by accepting (gaining) one electron in its valence shell to form chloride ion (Cl^-).

$$\underset{\substack{(2,8,7)\\\text{Chlorine atom}}}{Cl} + e^- \longrightarrow \underset{\substack{(2,8,8)\\\text{Chloride ion}}}{Cl^-}$$

However, single magnesium atom donates two electrons from its valence shell, whereas a single chlorine atom can accept only one electron in its valence shell. Thus, in order to accept another electron donated by magnesium atom, there must be another chlorine atom. In simple words, one magnesium atom will combine with two chlorine atoms. The combination of one magnesium atom with two chlorine atoms to form magnesium chloride can be represented by geometric diagram, dot diagram and an ionic equation as follows.

Geometric diagram:

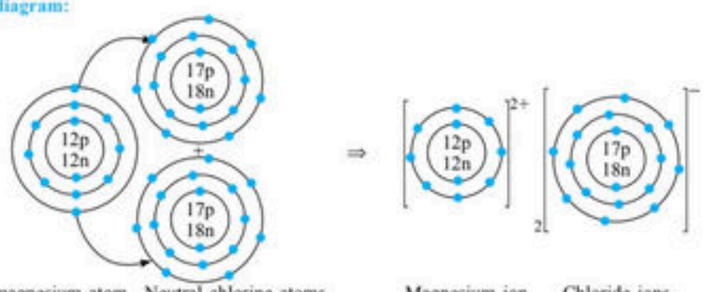
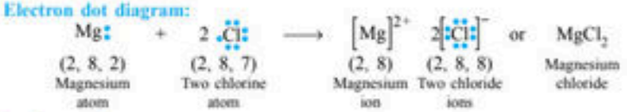


Fig. 3.13: Formation of magnesium chloride

Electron dot diagram:



Ionic equation:

$$Mg - 2e^- \longrightarrow Mg^{2+}$$
$$2Cl + 2e^- \longrightarrow 2Cl^-$$
$$Mg + 2Cl \longrightarrow Mg^{2+}\ 2Cl^- \text{ or } MgCl_2$$

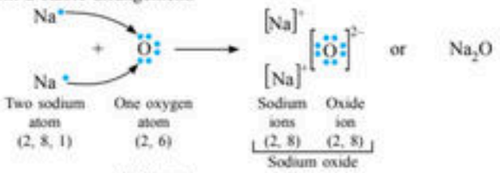
3. **Formation of Sodium Oxide:** We have discussed the formation of sodium cation. Let us write the equation.



The electronic configuration of oxygen atom (O) is (2, 6). It is an electronegative atom which can attain the nearest noble gas configuration by gaining/accepting (two electrons) in its valence shell to form oxide anion (O^{2-}).



As you can see, one sodium atom can donate only one electron. Hence, one oxide anion combines with two sodium cations to form a stable arrangement.



N41R762PHB

Properties of Ionic Compounds

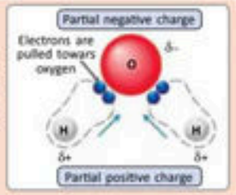
1. **Ionic compounds are generally hard crystalline solids:** The reason for hardness is due to the existence of strong electrostatic forces, which bind the oppositely charged ions very tightly in set patterns. Since these oppositely charged ions cannot be pulled apart easily, therefore, ionic compounds are hard.
2. **Ionic compounds are non-volatile, have very high melting and boiling points:** The reason for the above properties is linked to strong electrostatic forces, which bind the oppositely charged ions. As a lot of energy is required to weaken strong electrostatic force. Therefore, ionic compounds are non-volatile and have very high melting and boiling points. Table 3.5 shows melting and boiling points of some ionic compounds.

Table 3.5 : Melting and boiling points of some ionic compounds

Ionic compound	Melting point (K)	Boiling point (K)
NaCl	1074	1738
LiCl	878	1655
KBr	1007	1708
KI	953	1600
$CaCl_2$	1055	2208
CaO	2886	3123
$MgCl_2$	987	1685

3. **Ionic compounds are usually soluble in water, but insoluble in organic solvents:** Water is a polar covalent compound having positive and negative poles. Thus, the molecules of ionic compounds ionise in water to form water can easily overcome the electrostatic forces holding the cations and anions together. As the cations and anions are not held firmly, therefore, they mix up with the molecules of water to form a solution.

Polar covalent bonding is a type of chemical bond where a pair of electron is unequally shared between two atoms. In water molecule, the electrons are not equally shared because oxygen atom has a stronger pull than the hydrogen atoms and attracts electrons. Thus, oxygen atom carries a partial negative charge and hydrogen atoms carry partial positive charge.



4. **An aqueous solution of an ionic compound is a good conductor of electricity:** Ionic compounds ionise in water to form independent positively and negatively charged ions. These ions can easily migrate towards the cathode and anode, with the result that aqueous solution of the ionic compound conducts electricity.

Ionic compounds in the solid state are bad conductors of electricity. It is because, the cations and anions are held firmly in the crystal lattice of ionic compound by electrostatic force. As the ions cannot migrate to the cathode and anode, therefore, no electric current flows through the ionic compound in the solid state. For example, ionic compounds like sodium chloride, potassium chloride, lead bromide, etc., are bad conductors of electricity in the solid state, but are good conductors of electricity in aqueous solution.

5. **The chemical reaction between ionic compounds in an aqueous solution is very fast:** Aqueous solution of ionic compounds have freely moving oppositely charged ions. When the ions of two different ionic compounds come in contact with each other, they rapidly unite with each other to form new compounds.

SAMPLE PROBLEMS

1. (a) Write the electron-dot structures for sodium, oxygen and magnesium.
(b) Show the formation of Na_2O and MgO by the transfer of electrons.
(c) What are the ions present in these compounds?

Ans. (a) The electron dot structures for sodium, oxygen and magnesium are:

Sodium	Oxygen	Magnesium
$Na^{\bullet}$	$:\ddot{O}:$	$:Mg$

(b) **Formation of Na_2O**

$$2Na \ (2, 8, 1) \longrightarrow 2Na^{+} \ (2, 8) + 2e^{-}$$
Neon configuration

$$O \ (2, 6) + 2e^{-} \longrightarrow O^{2-} \ (2, 8)$$
Oxide ion

$$2Na^{+} + O^{2-} \longrightarrow Na^{+}O^{2-}Na^{+} \longrightarrow Na_2O$$
Sodium ion, Oxide ion, Sodium oxide

Formation of MgO

$$Mg \ (2, 8, 2) \longrightarrow Mg^{2+} \ (2, 8) + 2e^{-}$$
Magnesium atom, Magnesium ion

$$O \ (2, 6) + 2e^{-} \longrightarrow O^{2-} \ (2, 8)$$
Oxide ion, Oxide ion

$$Mg^{2+} + O^{2-} \longrightarrow Mg^{2+}O^{2-} \longrightarrow MgO$$
Magnesium ion, Oxide ion, Magnesium oxide

(c) Ions present in $Na_2O \rightarrow Na^+$ and O^{2-}
Ions present in $MgO \rightarrow Mg^{2+}$ and O^{2-}

2. Why do ionic compounds have high melting points?

Ans. Due to strong electrostatic force of attraction, the ions in the ionic compounds are bound to each other firmly. As a result, these compounds have high melting points.

Assess Yourself – 2

1. Tick (✓) the Correct Answer.
   (a) Reaction between X and Y, forms compound Z. The substance, X loses an electron and Y gains an electron. Which of the following properties is not shown by Z?
   (A) Has high melting point (B) Has low melting point
   (C) Conducts electricity in molten state (D) Occurs as solid
   (b) The metal that is not malleable at room temperature is :
   (A) copper (B) zinc (C) lead (D) tin
2. What happens during an ionic bond formation?
3. The bond formed between magnesium and oxygen is _____.

Q4OGZVB7U

3.5 FORMATION OF COVALENT BOND

The chemical bond formed by the sharing of electrons between two atoms is known as a covalent bond. The resulting molecule has atoms which have stable noble gas electronic configuration. The reactant atoms share the electrons present in their outermost shell only.

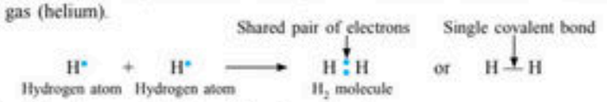
A covalent bond is formed when both the reacting atoms need electrons to achieve the inert gas electronic arrangement. Non-metals have 4, 5, 6 or 7 electrons in the outermost shells of their atoms (only hydrogen has just 1 electron in the outermost shell). Thus whenever a non-metal combines with another non-metal, electrons are shared to attain the stable noble gas electronic configuration and a covalent bond is formed.

Covalent bonds are of three types:
(i) Single covalent bond (ii) Double covalent bond (iii) Triple covalent bond

I. Single Covalent Bond

A single covalent bond is formed by the sharing of 2 electrons or one pair between two atoms (non-metal), each atom contributing one electron for sharing. This pair of electrons is shared between the two atoms and is always drawn in between both the atoms in an electron dot structure. Let us see some examples.

(a) **Hydrogen molecule (H_2):** Hydrogen atom has only one electron and it is very reactive. It cannot exist as an atom, so it forms a molecule to attain stability with the help of sharing of electrons. Two hydrogen atoms share one electron each to fill the duplet and each atom gets two electrons, which is the electronic configuration the nearest noble gas (helium).



This bond formed is strong and holds both the atoms together.

A hydrogen molecule H_2, contains a single covalent bond. It is written as H : H. The two dots drawn between the hydrogen atoms represent a pair of shared electrons. A single covalent bond is denoted by putting a short line (—)

between the two atoms. So, we can write hydrogen molecule as H—H. The short line between the two hydrogen atoms represents a single covalent bond consisting of two shared electrons, one from each hydrogen atom.

We can also show this bond formation with the help of a diagram.

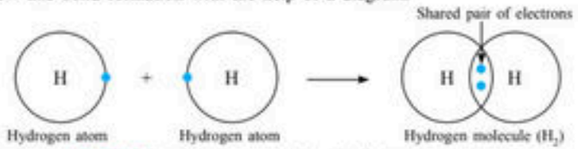


Fig. 3.14: Formation of covalent-bond in hydrogen molecule

(b) Chlorine molecule (Cl_2): A chlorine atom is again very reactive and cannot exist in free state. Hence chlorine gas, consists of Cl_2 molecules. **Each molecule of chlorine contains two chlorine atoms joined by a single covalent bond.**

The atomic number of chlorine is 17, its electronic configuration is 2, 8, 7. Chlorine atom has 7 electrons in its valence shell so it needs 1 more electron to complete its octet and attain a stable electronic arrangement. **So, two chlorine atoms share one electron each to form a chlorine molecule.** Let us see the process with the help of electron dot structures.



The two chlorine atoms share one pair of electrons, the bond between them is called a single covalent bond. In the chlorine molecule, each chlorine atom has 8 outermost electrons **resembling its nearest inert gas argon.** Hence, a chlorine molecule is more stable than two separate chlorine atoms.

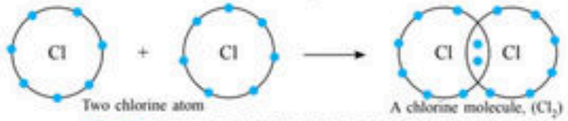


Fig. 3.15: Formation of covalent-bond in chlorine molecule

Here two atoms of chlorine, combine to form a covalent bond. **Whenever two atoms of the same element combine to form a molecule, a covalent bond is formed by the sharing of electrons.**



Fig. 3.16: Chlorine molecule

(c) Hydrogen chloride molecule (HCl): Hydrogen atom has only 1 electron so it needs 1 more electron to attain the helium gas electronic configuration. Chlorine atom has 7 valence electrons, so it needs 1 more electron to complete its octet. As both hydrogen and chlorine atoms need 1 electron each to become stable, so they will share 1 electron with each other.



In the hydrogen chloride molecule (after the sharing of a pair of electrons) the hydrogen atom has 2 electrons in its outermost shell (K) resembling inert gas helium. The chlorine atom in hydrogen chloride molecule

has 8 electrons in its outermost shell and it resembles inert gas argon (2, 8, 8). Hydrogen chloride gas is a covalent compound containing a single covalent bond.

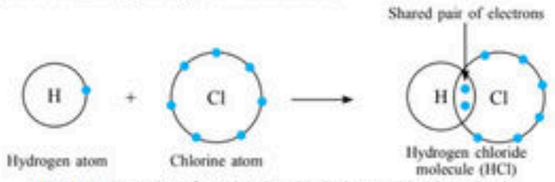


Fig. 3.17: Formation of covalent-bond in hydrogen chloride molecule

V607RD50X1

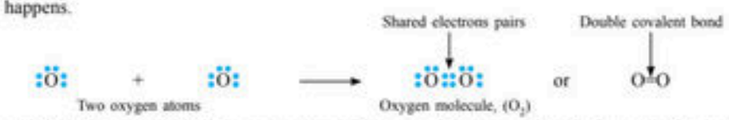
II. Double Covalent Bond

In single bond, we studied that one pair of electrons is shared between two non-metal atoms in order to attain a stable electronic configuration.

In a double covalent bond, two pairs of electrons are shared. This happens when both the atoms need two electrons to attain the nearest noble gas electronic configuration. It is represented by two parallel short lines (=).

Let us see few examples.

(a) **Oxygen (O_2) molecule:** The electronic configuration of oxygen is 2, 6. It requires two electrons to attain the electronic configuration of neon (2, 8). It combines with another 'O' atom to form O_2 molecule. Let us see how this happens.



To complete their octets, both the oxygen atoms share two electrons each and form a double covalent bond.

(b) **Carbon dioxide (CO_2) molecule:** This molcule is made up of one carbon and two oxygen atoms. The electronic configuration of carbon is (2, 4). It needs four more electrons to attain the stable electronic arrangement (complete octet). We know that an oxygen atom needs two electrons to become stable. So, one carbon atom combines with two oxygen atoms by sharing electrons. Carbon shares its all 4 electrons, while each oxygen shares two of their 6 valence electrons each.



Carbon atom shares two electron each with the two oxygen atoms and it is in the centre of the molecule. Here all the atoms have attained the noble gas (neon) electronic configuration.

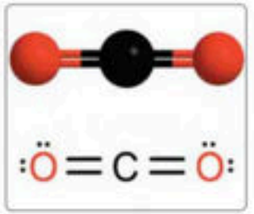
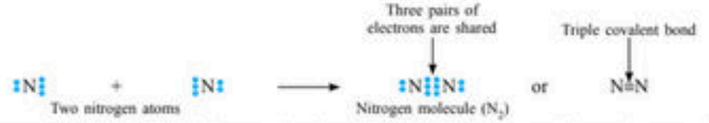


Fig. 3.18: Carbon dioxide molecule

III. Triple Covalent Bond

In case of a triple bond, the two non-metal atoms share three pairs of electrons that is, 6 electrons, where each atom contributes three electrons. It is represented by putting three short and parallel lines (≡) between the two atoms.

Nitrogen (N_2) molecule: The electronic configuration of N is (2, 5). It needs three more electrons to complete its octet. It does not have stable electronic configuration, so it combines with another 'N' atom to attain the nearest noble gas configuration which is of Ne (2, 8). This way both the nitrogen atoms share three electrons each and attain stable configuration.



Here, you can see that three pairs of electrons have been shared between the two 'nitrogen' atoms. So the bond is triple covalent bond. It is the strongest amongst all the three types of covalent bonds.

Covalent compounds are formed by the sharing of electrons between atoms. The covalent compounds are also known as molecular compounds because they are made up of molecules. Here are a few common covalent compounds.

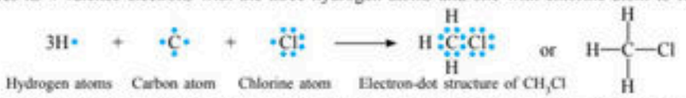
	Name	Formula
1.	Methane	CH_4
2.	Ethane	C_2H_6
3.	Ethene	C_2H_4
4.	Ethyne	C_2H_2
5.	Water	H_2O
6.	Ammonia	NH_3

	Name	Formula
7.	Ethanol	C_2H_5OH
8.	Hydrochloric acid	HCl
9.	Hydrogen sulphide	H_2S
10.	Carbon tetrachloride	CCl_4
11.	Glucose	$C_6H_{12}O_6$
12.	Urea	$CO(NH_2)_2$

SAMPLE PROBLEMS

1. Explain the nature of the covalent bond using the bond formation in CH_3Cl.

Ans. CH_3Cl (chloromethane) is made up of one carbon atom, three hydrogen atoms and one chlorine atom. Carbon atom has 4 (valence electrons), hydrogen atom has 1 outermost electron, and chlorine atom has 7 valence electrons. Carbon atom shares its 4 valence electrons with the three hydrogen atoms and one with chlorine atom to form CH_3Cl:



Here four pair of shared electrons are present between carbon and other atoms. So, CH_3Cl has four single covalent bonds.

2. Draw the electron-dot structures for: (a) H_2S and (b) F_2

Ans. **(a) H_2S is hydrogen sulphide.** It is made up of two hydrogen atoms and one sulphur atom. Each hydrogen atom has 1 valence electron whereas a sulphur atom has 6 valence electrons. The sulphur atom share its two electrons with two hydrogen atoms to form hydrogen sulphide:



(b) F_2 is fluorine molecule. Each fluorine atom has 7 valence electrons. Two fluorine atoms share 1 electron each to form a fluorine molecule:



3. What would be the electron-dot structure of a molecule of sulphur which is made up of eight atoms of sulphur? (**Hint :** The eight atoms of sulphur are joined together in the form of a ring).

Ans. The electronic configuration of a sulphur atom ($^{32}_{16}S$) is 2, 8, 6, which means that it has 6 valence electrons and needs two more electrons to attain the nearest noble gas configuration. So each atom combines with two other sulphur atoms with the help of single covalent bonds and forms a ring made up of sulphur atoms. The formula for this molecule is S_8.

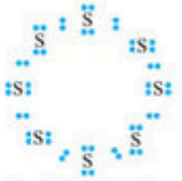


Fig. 3.19: Electron-dot structure of sulphur molecule, S_8

Properties of Covalent Compounds

1. **Covalent compounds are usually liquids or gases. Only a few are solids.** For example, alcohol, carbon disulphide, carbon tetrachloride and bromine are liquids. Methane, ethane, oxygen, hydrogen and chlorine are gases. Glucose, naphthalene and iodine are solid covalent compounds. The covalent compounds have weak forces of attraction between their molecules (as compared to ionic compounds) hence they are usually liquids or gases.
2. **Covalent compounds usually have low melting and boiling points.** For example, carbon tetrachloride has a low boiling point of 77°C. *The forces of attraction between the molecules of a covalent compound are very weak. A small amount of heat energy is required to break these weak molecular forces*, hence covalent compounds have low melting and boiling points.
3. **Covalent compounds are usually insoluble in water and soluble in organic solvents.** Naphthalene is insoluble in water but dissolves in organic solvents like ether. (Glucose and urea, etc., are, however, soluble in water). Polar covalent compounds like hydrogen chloride and ammonia are also soluble in water.
4. **Covalent compounds do not conduct electricity. This is because they do not contain ions.** For example, covalent compounds like glucose, urea, alcohol and carbon tetrachloride, etc., do not conduct electricity. Some polar covalent compounds like hydrogen chloride gas, however, conduct electricity when dissolved in water. This means that usually covalent compounds are non-electrolytes.

Table 3.6 : Difference between ionic and covalent compounds

	Ionic Compounds	Covalent Compounds
1.	Ionic compounds are crystalline solids.	Covalent compounds are usually liquids or gases. Only a few are solids.
2.	Ionic compounds have high melting and boiling points. Ionic compounds are non-volatile.	Covalent compounds usually have low melting and boiling points. Covalent compounds are usually volatile.
3.	Ionic compounds conduct electricity when melted or dissolved in water.	Covalent compounds do not conduct electricity (except few polar covalent compounds).
4.	Ionic compounds are usually soluble in water.	Covalent compounds are insoluble in water.
5.	Ionic compounds are insoluble in organic solvents like alcohol, ether, acetone, etc.	Covalent compounds are soluble in organic solvents.

Exercise-3 (A)

1. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

1. The electronic configurations of three elements X, Y and Z are X – 2, 8; Y – 2, 8, 7 and Z – 2, 8, 2. Which of the following is correct?
   (A) X is a metal (B) Y is a metal
   (C) Z is a non-metal (D) Y is a non-metal and Z is a metal [HOTS]
2. Which of the following substances are not ionic compounds?
   (i) KCl (ii) HCl (iii) CCl_4 (iv) NaCl
   (A) (i) and (ii) (B) (ii) and (iii) (C) (iii) and (iv) (D) (i) and (iii) [HOTS]
3. Which one of the following properties is not generally exhibited by ionic compounds?
   (A) Solubility in water (B) Electrical conductivity in solid state
   (C) High melting and boiling points (D) Electrical conductivity in molten state [HOTS]

Ans: 1. (D) 2. (B) 3. (B)

II. VERY SHORT ANSWER TYPE QUESTIONS

1. Why is the chemical reaction between ionic compounds in aqueous solution very fast?
2. Name a metal which offers higher resistance to the passage of electricity than copper.
3. Name one non-metal and one metal that are found in liquid state at room temperature.
4. Why is tungsten selected for making filaments of incandescent lamp bulbs?
5. A non-metal X exists in two different forms Y and Z. Y is the hardest natural substance, whereas Z is a good conductor of electricity. Identify X, Y and Z. [HOTS]

III. SHORT ANSWER TYPE QUESTIONS

1. Why is a solid ionic compound a bad conductor of electricity, but its aqueous solution a good conductor?
2. Give the formulae of a stable binary compounds that would be formed by the combination of following pairs of elements.
   (a) Mg and N_2 (b) Li and O_2 (c) Al and Cl_2 (d) K and O_2 [HOTS]
3. (a) Show the formation of NaCl from sodium and chlorine atoms by the transfer of electron(s).
   (b) Why has sodium chloride a high melting point?
4. Show the electron transfer in the formation of $MgCl_2$ from its elements.
5. Amongst the metals, non-metals and noble gases to which category do the elements belong, if they form : (i) positively charged ions, (ii) negatively charged ions and (iii) no ions?
6. Write the electron dot structure of Cl_2 molecule.
7. What type of bond is present in the following molecules? Write the electron-dot structures.
   (a) CCl_4 (b) $CaCl_2$ (c) H_2 (d) O_2
8. (a) Show the formation of sodium oxide [Na_2O] by the transfer of electrons between combining atoms.
   (b) Why are ionic compound usually hard?
   (c) How is it that the ionic compounds in the solid state do not conduct electricity and they do so when in the molten state?
9. (a) Show with the help of a diagram the transfer of electrons between the atoms in the formation of MgO.
   (b) Name the solvent in which ionic compounds are generally soluble.
   (c) Why are aqueous solutions of ionic compounds able to conduct electricity?

IV. LONG ANSWER TYPE QUESTIONS

1. (a) Write the electron dot structures for sodium, magnesium, oxygen and chlorine.
   (b) Why are ionic compounds soluble in water?
2. (a) Show the formation of the following by electron transfer : (i) NaCl, (ii) $MgCl_2$, (iii) Na_2O, and (iv) MgO.
   (b) Why do ionic compounds have high melting points while covalent compounds have comparatively low melting points?

0QJ8DNZPBL

3.6 CHEMICAL PROPERTIES OF METALS

1. Reaction of metals with oxygen:

Metals react with oxygen to form basic oxides. We have studied the example of burning of magnesium ribbon in Chapter 1. All metals (except platinum and gold) react with oxygen to form their respective oxides.

Metal + Oxygen (air) ⟶ Metal oxide (Basic)

All metallic oxides are ionic in nature. Metals donate electrons from their valence shell, so as to form positively charged ions. The donated electrons are accepted by oxygen atoms to form negatively charged ions. Thus, the positively charged metallic ions are held by the negatively charged oxygen ions by electrostatic forces, to form metallic oxides. Most of the metal oxides are insoluble in water but some of them dissolve in water to form alkalis.

Let us study the formation of oxides in case of individual metals and the rates of this reaction.

(a) Reaction of magnesium metal with oxygen: Magnesium metal, when heated in a flame, it catches fire and burns with a dazzling white flame producing intense heat. The product so formed is magnesium oxide, which is a white powdery mass.

$$\underset{\text{Magnesium}}{2Mg(s)} + \underset{\text{Oxygen}}{O_2(g)} \xrightarrow{\text{heat}} \underset{\text{Magnesium oxide}}{2MgO(s)} \quad \text{(basic oxide)}$$

This activity can be performed by carrying out the following steps.

(i) Take a magnesium ribbon and burn it by holding it with fire-tongs.

(ii) Collect the white ash formed in a beaker. Dissolve the white ash in distilled water and test it with red litmus.

(iii) You will observe that **red litmus turns blue**, thereby showing that the oxide of magnesium metal is basic in nature.

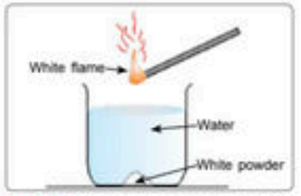


Fig. 3.20: Burning of a magnesium ribbon

$$\underset{\text{Magnesium}}{2\,Mg(s)} + \underset{\text{Oxygen}}{O_2(g)} \xrightarrow{\Delta} \underset{\text{Magnesium oxide}}{2\,MgO(s)}$$

$$\underset{\text{Magnesium oxide}}{MgO(s)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Magnesium hydroxide}}{Mg(OH)_2(aq)}$$

Hence, we can say that metal oxides are basic and they turn red litmus to blue. Magnesium oxide is basic in nature as it reacts with acids to form salt and water as the only products.

$$\underset{\text{Basic oxide}}{MgO(s)} + \underset{\text{Acid}}{H_2SO_4(aq)} \longrightarrow \underset{\text{Salt}}{MgSO_4(aq)} + \underset{\text{Water}}{H_2O(l)}$$

(b) Reaction of potassium metal with oxygen: Potassium is a silvery white metal. It is highly reactive and catches fire causing an explosion. Hence it is kept immersed in kerosene oil. When a freshly cut piece of potassium is placed in air, it rapidly gets oxidised to form potassium oxide. However, if potassium is gently warmed, it catches fire and burns with a ***crimson flame***.

$$\underset{\text{Potassium}}{4K(s)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Potassium oxide}}{2K_2O(s)}$$

Potassium oxide dissolves in water to form an alkali, potassium hydroxide, and hence, is ***basic in nature***.

$$\underset{\text{Potassium oxide}}{K_2O(s)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Potassium hydroxide}}{2KOH(aq)}$$

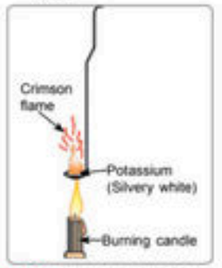


Fig. 3.21: Potassium burning in air

(c) Reaction of sodium metal with oxygen: Sodium is a silvery white metal. It is kept under kerosene oil, as it is also highly reactive. It reacts in the same way as potassium, but burns with **a golden yellow flame**.

$$\underset{\text{Sodium}}{4Na(s)} + \underset{\text{Oxygen}}{O_2(g)} \longrightarrow \underset{\text{Sodium oxide}}{2Na_2O(s)}$$

Sodium oxide reacts with water to form an alkali, sodium hydroxide and hence, is basic in nature.

$$\underset{\text{Sodium oxide}}{Na_2O(s)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\text{Sodium hydroxide}}{2NaOH(aq)}$$

Now we have examples of two metal oxides which show both acidic and basic behaviour.

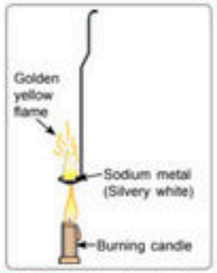


Fig. 3.22: Sodium burning in air

Definition: *The oxides of metals that react with acids as well as alkalis to form salt and water as the only products are called* ***amphoteric oxides***.

It has been noticed that oxides of aluminium and zinc react with acids as well as strong caustic alkali solutions to form salt and water as the only products. Such oxides are called ***amphoteric oxides***.

(d) Reaction of aluminium metal with oxygen: The reaction of aluminium with oxygen takes less readily than the reaction of magnesium with oxygen. Aluminium burns in air to form aluminium oxide.

$$\underset{\text{Aluminium metal}}{4Al(s)} + \underset{\text{Oxygen (air)}}{3O_2(g)} \xrightarrow{\Delta} \underset{\text{Aluminium oxide (amphoteric oxide)}}{2Al_2O_3(s)}$$

Al_2O_3 (aluminium oxide) is amphoteric in nature that is, it reacts with both acids and bases to form salt and water. Let us see the following reactions.

Basic nature of aluminium oxide :

$$\underset{\text{Acid}}{Al_2O_3(s) + 3H_2SO_4(aq)} \longrightarrow \underset{\text{Salt}}{Al_2(SO_4)_3(aq)} + \underset{\text{Water}}{3H_2O(l)}$$

Acidic nature of aluminium oxide :

$$\underset{\text{Base}}{Al_2O_3(s) + 2NaOH(aq)} \longrightarrow \underset{\text{Salt}}{2NaAlO_2(aq)} + \underset{\text{Water}}{H_2O(l)}$$

In the first reaction, Al_2O_3 reacts with sulphuric acid to form salt and water. This means that aluminium oxide is acting as a base. While in the second reaction, aluminum oxide reacts with sodium hydroxide (alkali) to form salt and water. This means that aluminium oxide is acting as an acid. This shows that Al_2O_3 is amphoteric in nature.

DID YOU KNOW?

Anodising is a process by which a thick oxide layer is formed on the surface of aluminium metal by electrolysis.

Aluminium, otherwise, is called a self-protecting metal, because a hard and thin layer of aluminium oxide is formed on its surface due to oxidation by moist air. The hard layer does not allow the atmospheric oxygen to come in contact with the fresh surface of aluminium, and hence, oxidation of the metal stops.

This resistance to corrosion can be improved further by making the oxide layer thick. During the process of anodising, a clean aluminium article is made the anode and electrolysed with dilute sulphuric acid. The oxygen gas evolved at the anode reacts with aluminium to form a thick protective layer of aluminium oxide. This oxide layer can be dyed to give an attractive finish to a given anodised article.

(e) Reaction of zinc with oxygen: Zinc metal burns in air or oxygen to form zinc oxide. However, zinc has to be heated to a higher temperature than magnesium before it catches fire.

$$2Zn(s) + O_2(g) \xrightarrow{\Delta} \underset{\text{Basic oxide}}{2ZnO(s)}$$

Zinc is also an amphoteric oxide. Let us see the following reactions.

$$\underset{\text{Acid}}{ZnO(s) + 2HCl(aq)} \longrightarrow \underset{\text{Salt}}{ZnCl_2(aq)} + \underset{\text{Water}}{H_2O(l)}$$

Zinc oxide reacts with hydrochloric acid to form salt and water, hence it shows basic character in this reaction.

$$\underset{\text{Base}}{ZnO(s) + 2NaOH(aq)} \longrightarrow \underset{\text{Salt}}{Na_2ZnO_2(aq)} + \underset{\text{Water}}{H_2O}$$

Here, zinc reacts with sodium hydroxide (alkali) to form salt and water. Therefore it shows acidic character in this reaction.

(f) Action of iron metal with oxygen: Iron metal when heated to a very high temperature reacts with oxygen to form iron (II, III) oxide, that is, Fe_3O_4. Fe_3O_4 is a mixture of iron (II) oxide [FeO] and iron (III) oxide [Fe_2O_3]. However, iron does not catch fire.

$$\underset{\text{Iron}}{3Fe(s)} + \underset{\text{Oxygen}}{2O_2(g)} \xrightarrow{\text{Strong heating}} \underset{\text{Iron (II, III) oxide}}{Fe_3O_4(s)}$$



Fig. 3.23: Iron reacts with oxygen at a very high temperature to form Fe_3O_4

(g) Action of copper metal with oxygen: Copper does not catch fire in air or oxygen even on strong heating. However, on prolonged strong heating in air or oxygen, it slowly gets oxidised to form black copper (II) oxide.

$$\underset{\text{Copper}}{2Cu(s)} + \underset{\text{Oxygen}}{O_2(g)} \xrightarrow[\text{strong heating}]{\text{Prolonged}} \underset{\text{Copper oxide}}{2CuO(s)}$$

The oxides of metals are commonly called basic oxides.

Metals like magnesium, aluminium and zinc, etc., react with the air and moisture (water vapour) to form their oxides and this oxide layer prevents further oxidation and the metal underneath protect.

SAMPLE PROBLEMS

1. An element reacts with oxygen to give a compound with a high melting point. This compound is also soluble in water. The element is likely to be
(A) calcium (B) carbon (C) silicon (D) iron

Ans. The correct answer is (A).
Calcium forms calcium oxide with oxygen. Calcium oxide has a high melting point. It dissolves in water to give limewater.

2. What are amphoteric oxides? Give two examples of amphoteric oxides.

Ans. The oxides which can react with acids as well as alkalis are called amphoteric oxides. *Examples:* Zinc oxide (ZnO) and aluminium oxide (Al_2O_3).

ENKFUSLTPS

2. Reaction of metals with water: Water or steam reacts with metals to form metal hydroxides or metal oxides and hydrogen gas. The rate of chemical reaction of metals with water, depends upon the chemical reactivity of the metals, that is, more reactive metals react rapidly with water, less reactive metals react with steam and least reactive metals may not react at all with water or steam.

(i) When a metal reacts with water (cold or hot), the products formed are metal hydroxide and hydrogen gas.

Metal + Water ⟶ Metal hydroxide + Hydrogen gas

(ii) When a metal reacts with steam, the products formed are metal oxide and hydrogen gas.

Metal + Steam ⟶ Metal oxide + Hydrogen gas

(a) Reaction of water with potassium: When a small piece of potassium is dropped in cold water, it reacts violently to form potassium hydroxide and hydrogen gas. The hydrogen gas catches fire due to the heat of the reaction, which in turns ignites potassium. Potassium burns with a crimson flame.

$$\underset{\text{Potassium}}{2K(s)} + \underset{\text{Cold water}}{2H_2O(l)} \longrightarrow \underset{\text{Potassium hydroxide}}{2KOH(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

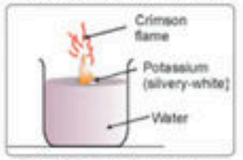


Fig. 3.24: Potassium catches fire in water and burns with a crimson flame

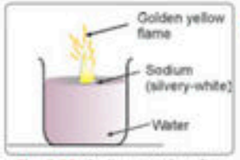


Fig. 3.25: Sodium catches fire in water and burns with a golden yellow flame

(b) Reaction of water with sodium: Cold water reacts explosively with sodium metal. When a small piece of sodium is dropped in a trough of water, it melts to form a silvery ball, which floats over the surface of water. It darts about in all directions producing a hissing sound and gives off tiny bubbles of hydrogen gas. If the piece of sodium is bigger, the hydrogen gas catches fire. This makes the sodium burn with a golden yellow flame.

$$\underset{\text{Sodium}}{2Na(s)} + \underset{\text{Cold water}}{2H_2O(l)} \longrightarrow \underset{\text{Sodium hydroxide}}{2NaOH(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

(c) Reaction of water with calcium: When calcium metal is dropped in a beaker of water, it sinks in water. It reacts rapidly with water to form calcium hydroxide and bubbles of hydrogen gas. It rises up the surface of water as bubbles of hydrogen stick to it. The solution turns somewhat milky, due to the formation of calcium hydroxide, which is sparingly soluble in water.

$$\underset{\text{Calcium}}{Ca(s)} + \underset{\text{Cold water}}{2H_2O(l)} \longrightarrow \underset{\substack{\text{Calcium hydroxide}\\\text{(Sparingly soluble)}}}{Ca(OH)_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

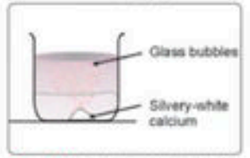


Fig. 3.26: Calcium on coming in contact with water liberates tiny bubbles of hydrogen and forms calcium hydroxide

(d) Reaction of water with magnesium: Magnesium does not react with cold water. However, if powdered magnesium is boiled with water it slowly reacts to form magnesium hydroxide and hydrogen gas.

$$\underset{\text{Magnesium}}{Mg(s)} + \underset{\text{Water}}{2H_2O(l)} \xrightarrow{\text{Boiling}} \underset{\text{Magnesium hydroxide}}{Mg(OH)_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

However, magnesium reacts with steam very rapidly to form magnesium oxide and hydrogen gas.

$$\underset{\text{Magnesium}}{Mg(s)} + \underset{\text{Steam}}{2H_2O(g)} \longrightarrow \underset{\text{Magnesium oxide}}{MgO(s)} + \underset{\text{Hydrogen}}{H_2(g)}$$

(e) Reaction of water wit aluminium: Aluminium does not react with cold water or boiling water. However, when steam is passed over hot aluminium, it slowly reacts to form aluminium oxide and hydrogen gas. Aluminium only reacts with steam when the layer of oxide on its surface is removed.

$$\underset{\text{Aluminium}}{2Al(s)} + \underset{\text{Water}}{3H_2O(g)} \xrightarrow{\text{Heat}} \underset{\text{Aluminium oxide}}{Al_2O_3(s)} + \underset{\text{Hydrogen}}{3H_2(g)}$$

This experiment set-up shows us how the reaction takes place.

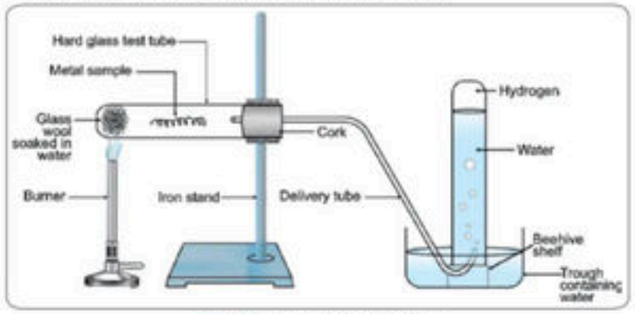


Fig. 3.27: Action of steam on metal

We take a small lump of glass wool soaked in water and place it at the bottom of the boiling tube. The metal sample is placed in the middle of the horizontally placed boiling tube. This boiling tube is then arranged in the apparatus as shown above.

The metal sample is heated with the help of a burner. After the metal gets hot the glass wool is heated, with the help of a separate burner. The water present in the soaked wool turns into steam and that steam passes over the metal sample, leading to the formation of the corresponding metal oxide and hydrogen gas. The hydrogen gas escapes from the boiling tube and it is collected in the gas jar over water as shown in Fig. 3.27. If you bring a candle near the gas, it burns with a pop sound, proving that the gas released is hydrogen gas. The metal oxide remains in the boiling tube.

This experiment is performed with different metal samples, such as aluminium, magnesium, iron and zinc. The reaction with magnesium is the most vigorous while the reaction with iron is very slow.

(f) Action of water with zinc: Zinc does not react with cold or boiling water. However, if steam is passed over heated zinc, it reacts to form zinc oxide and hydrogen gas.

$$\underset{\text{Zinc}}{Zn(s)} + \underset{\text{Steam}}{H_2O(g)} \xrightarrow{\Delta} \underset{\text{Zinc oxide}}{ZnO(s)} + \underset{\text{Hydrogen}}{H_2(g)}$$

(g) Action of water with iron: Iron also does not react with cold water or boiling water or steam. However, if iron is red hot and steam is passed over it, a reversible reaction takes place with the formation of iron (II, III) oxide and hydrogen gas.

$$\underset{\text{Red hot iron}}{3Fe(s)} + \underset{\text{Steam}}{4H_2O(g)} \xrightleftharpoons{\text{heat}} \underset{\text{Iron (II, III) oxide}}{Fe_3O_4(s)} + \underset{\text{Hydrogen}}{4H_2(g)}$$

(b) Action of water with copper, gold, lead and silver: These metals do not react with cold water, boiling water or steam even on strong heating. Therefore, ***they are the least reactive or non-reactive***.

From the above reactions of metals with water, it can be concluded that potassium is the most reactive metal, followed by sodium, calcium, magnesium, aluminium, zinc and iron. Copper is the least reactive metal.

$$\text{(Most reactive)} \xrightarrow[\text{Decreasing chemical reactivity}]{\text{K > Na > Mg > Zn > Fe > Cu}} \text{(Least reactive)}$$

SAMPLE PROBLEMS

1. Write equations for the following reactions :

(a) Iron with steam (b) Potassium and calcium with water

Ans. (a) $\underset{\text{Red hot}}{3Fe(s)} + \underset{\text{Steam}}{4H_2O(g)} \longrightarrow \underset{\text{Iron (II, III) oxide}}{Fe_3O_4(s)} + \underset{\text{Hydrogen}}{4H_2(g)}$

(b) $\underset{\text{Potassium metal}}{2K(s)} + \underset{\text{Water}}{2H_2O(l)} \longrightarrow \underset{\text{Potassium hydroxide}}{2KOH(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$

$\underset{\text{Calcium metal}}{Ca(s)} + \underset{\text{Water}}{2H_2O(l)} \longrightarrow \underset{\text{Calcium hydroxide}}{Ca(OH)_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$

02PITRSJ56

3. Reaction of metals with dilute acids: This is a displacement reaction. The metal atom displaces the hydrogen atom from the acid. Not all metals undergo this reaction.

Metals usually react with ***dilute mineral acids*** to form their respective salts and hydrogen gas. The rate of the reaction depends upon the chemical activity of metal.

Metal + Dilute acid ⟶ Metal salt + Hydrogen gas

(a) Action of sodium with dilute mineral acids: Sodium metal reacts explosively with dilute hydrochloric acid or sulphuric acid to form respective salts and hydrogen gas.

$$\underset{\text{Sodium}}{2Na(s)} + \underset{\text{Hydrochloric acid}}{2HCl(aq)} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

(b) Action of magnesium with dilute mineral acids: Magnesium metal reacts vigorously with dilute sulphuric acid or dilute hydrochloric acid to form their respective salts and hydrogen gas.

$$\underset{\text{Magnesium}}{Mg(s)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq)} \longrightarrow \underset{\text{Magnesium sulphate}}{MgSO_4(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

(c) Action of dilute mineral acid with aluminium: Aluminium reacts slowly with dilute hydrochloric acid. It is because of the presence of a very thin layer of aluminium oxide on its surface. However, as soon as the fresh surface of aluminium metal is exposed, the reaction speeds up.

$$\underset{\text{Aluminium}}{2Al(s)} + \underset{\text{Hydrochloric acid}}{6HCl(aq)} \longrightarrow \underset{\text{Aluminium chloride}}{2AlCl_3(aq)} + \underset{\text{Hydrogen}}{3H_2(g)}$$

(d) Action of zinc with dilute mineral acids: Zinc reacts less vigorously with dilute sulphuric acid or hydrochloric acid to form their respective salts and hydrogen gas.

$$\underset{\text{Zinc}}{Zn(s)} + \underset{\text{Hydrochloric acid}}{2HCl(aq)} \longrightarrow \underset{\text{Zinc chloride}}{ZnCl_2(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

Zinc, dissolves in dilute H_2SO_4 to form tiny bubbles of H_2 gas and $ZnSO_4$, which is soluble in water and hence forms a solution. This reaction has been discussed in detail in Chapter 2, under the topic reaction of acids with metals.

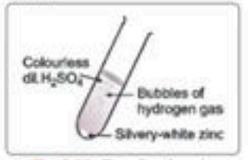


Fig. 3.28: Zinc dissolves in dilute H_2SO_4 to form H_2 gas and $ZnSO_4$ solution

(e) Action of iron with dilute mineral acids: Iron reacts slowly with dilute mineral acids to form their respective salts and hydrogen.

$$\underset{\text{Iron}}{Fe(s)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq)} \longrightarrow \underset{\text{Iron (II) sulphate}}{FeSO_4(aq)} + \underset{\text{Hydrogen}}{H_2(g)}$$

Iron dissolves in dilute H_2SO_4 to form tiny bubbles of H_2 gas and $FeSO_4$ solution, which is light green in colour.

(f) Action of copper with dilute mineral acids: Copper does not react with dilute sulphuric acid or dilute hydrochloric acid.

$$\underset{\text{Copper}}{Cu(s)} + \underset{\text{Sulphuric acid}}{H_2SO_4(aq)} \longrightarrow \text{No action}$$

From the action of oxygen, water and dilute mineral acids with metals, it is clear that some metals are more reactive than the others. On the basis of the rate of reaction of metals with oxygen, water and dilute mineral acids, the metals have been arranged in a ***serial order or a group*** according to their chemical reactivity.

Metal Reactivity Series

5JKWQZEOD

The arrangement of metals in a vertical column in the decreasing order of their chemical reactivities is called ***the metal reactivity series.***

Table 3.7 : Metal reactivity series

React with cold water to liberate hydrogen	Potassium (K)	React explosively with acids to liberate hydrogen	(Most reactive metals)
	Sodium (Na)		
	Calcium (Ca)		
React with boiling water	Magnesium (Mg)	Reacts vigorously with acids to liberate hydrogen	
React, when steam is passed over heated metal	Aluminium (Al)		
	Zinc (Zn)		
	Iron (Fe)	React slowly with acids to liberate hydrogen	
Do not react with water or steam	Tin (Sn)		
	Lead (Pb)		
	Hydrogen (H)	non-metal	
Do not react with boiling water or steam	Copper (Cu)	Do not react with acid to liberate hydrogen	(Least reactive metal)
	Mercury (Hg)		
	Silver (Ag)		
	Gold (Au)		

DECREASING CHEMICAL REACTIVITY

From Table 3.7, it is clear that potassium is the most reactive metal, and gold is the least reactive metal. It is on account of their very less activity, that the metals like gold, silver and copper occur in the free state in nature.

Why do Metals Differ in Their Chemical Reactivities?

All metals undergo a chemical reaction only when they donate their valence electrons. However, it has been observed that some metals can donate valence electrons with relative ease than the other metals, and hence are chemically more reactive. For example, potassium can donate its electrons with maximum ease and, hence, is most reactive. On the other extreme, gold donates valence electrons with great difficulty and, hence, is least reactive.

Metals More Reactive than Hydrogen

The metals, which lose their valence electrons more readily than hydrogen are called **reactive metals**. In the table of metal reactivity series, ***potassium, sodium, calcium, magnesium, aluminium, zinc, iron, tin and lead*** are reactive metals, because they can lose their valence electrons more readily than hydrogen. ***These metals react with water (or steam) and dilute mineral acids to liberate hydrogen gas.***

Metals Less Reactive than Hydrogen

The metals that lose their valence electrons with more difficulty than hydrogen are called ***less reactive metals***. In the table of metal reactivity series, ***copper, mercury, silver and gold*** are less reactive metals. These metals do not react on heating ***with water or steam and do not displace hydrogen from dilute mineral acids.***

Aqua Regia

A freshly prepared mixture of 3 parts of concentrated hydrochloric acid and 1 part of concentrated nitric acid is called ***aqua regia***. Aqua means water and regia means royal. Thus, aqua regia is capable of dissolving royal metals like platinum and gold. It dissolves all the metals. It is highly corrosive and fuming.

SAMPLE PROBLEM

1. A man went door-to-door posing as a goldsmith. He promised to bring back the glitter of old and dull gold ornaments. An unsuspecting lady gave a set of gold bangles to him which he dipped in a particular solution. The bangles sparkled like new but their weight was reduced drastically. The lady was upset but after a futile argument the man beat a hasty retreat. Can you play the detective to find out the nature of the solution he had used.

Ans. The 'so-called' goldsmith might have used **aqua regia**. The aqua regia has dissolved the upper layer of gold. Aqua regia is a freshly prepared mixture of concentrated hydrochloric acid (HCl) and concentrated nitric acid (HNO_3) in the ratio 3 : 1. Aqua regia can dissolve the noble metals like gold and platinum.

OB9NQY68RP

4. Reaction of metals with salt solutions:

You have already learnt in Chapter 1 about displacement reaction, where we stated :

When a more reactive metal displaces a less reactive metal from its aqueous salt solution, then the chemical reaction that takes place, is called a ***displacement reaction.***

$$\underset{\text{More reactive metal}}{A} + \underset{\text{Salt solution of less reactive metal}}{BX} \longrightarrow \underset{\text{Salt solution of more reactive metal}}{AX} + \underset{\text{Less reactive metal}}{B}$$

(a) Reaction of copper metal with silver nitrate solution: When a strip of copper (reddish brown in colour) is placed in clear silver nitrate solution in a beaker, following observations are made :

(i) The clear silver nitrate solution gradually changes to blue solution.

(ii) The strip of copper gets coated with a shining layer of silver.

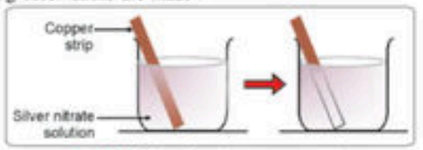


Fig. 3.29: Silver deposits on copper strip

Reason: Copper is higher in metal reactivity series than silver. Thus, when copper is placed in the solution of silver nitrate, it being more reactive than silver, displaces silver from the silver nitrate solution. The copper metal, in turn, dissolves to form copper nitrate which is blue in colour.

$$\underset{\text{(Colourless)}}{2AgNO_3(aq)} + \underset{\text{(Reddish brown)}}{Cu(s)} \longrightarrow \underset{\text{(Blue)}}{Cu(NO_3)_2(aq)} + \underset{\text{(Shining deposit)}}{2Ag(s)}$$

(b) Reaction of iron metal with copper sulphate solution: When a strip of iron metal is placed in copper sulphate solution, following observations are made :

(i) The blue colour of copper sulphate gradually fades.

(ii) The colour of the solution gradually changes to light green.

(iii) Reddish brown precipitate of copper is deposited on the surface of iron.

Reason: Iron metal is more reactive than copper. Thus, iron atoms displace copper atoms from the copper sulphate solution, which appear in the form of reddish brown deposit.

$$\underset{\text{Copper sulphate}}{CuSO_4(aq)} + \underset{\text{Iron}}{Fe(s)} \longrightarrow \underset{\text{Iron (II) sulphate}}{FeSO_4(aq)} + \underset{\text{Copper}}{Cu(s)}$$

(1) Exactly in the same way, zinc metal displaces copper from copper sulphate solution as illustrated below :

$$\underset{\text{Copper sulphate}}{CuSO_4(aq)} + \underset{\text{Zinc}}{Zn(s)} \longrightarrow \underset{\text{Zinc sulphate}}{ZnSO_4(aq)} + \underset{\text{Copper}}{Cu(s)}$$

(2) No action takes place if silver or gold are placed in copper sulphate solution. It is because, these metals are lower in the metal reactivity series as compared to copper and hence, do not displace copper from copper sulphate solution.

5. Reaction of metals with chlorine. Metals react with chlorine to form corresponding metal chlorides. Reactive metals like sodium, potassium, calcium and magnesium combine with chlorine at room temperature. Less reactive metals like zinc, iron, aluminium and copper combine with chlorine on heating.

(a) Reactive metals:

$$\underset{\text{Sodium}}{2Na(s)} + \underset{\text{Chlorine}}{Cl_2(g)} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl(s)}$$

$$\underset{\text{Calcium}}{Ca(s)} + \underset{\text{Chlorine}}{Cl_2(g)} \longrightarrow \underset{\text{Calcium chloride}}{CaCl_2(s)}$$

$$\underset{\text{Magnesium}}{Mg(s)} + \underset{\text{Chlorine}}{Cl_2(g)} \longrightarrow \underset{\text{Magnesium chloride}}{MgCl_2(s)}$$

(b) Less reactive metals:

$$\underset{\text{Zinc}}{Zn(s)} + \underset{\text{Chlorine}}{Cl_2(g)} \longrightarrow \underset{\text{Zinc chloride}}{ZnCl_2(s)}$$

$$\underset{\text{Iron}}{2Fe(s)} + \underset{\text{Chlorine}}{3Cl_2(g)} \longrightarrow \underset{\text{Iron (III) chloride}}{2FeCl_3(s)}$$

$$\underset{\text{Aluminium}}{2Al(s)} + \underset{\text{Chlorine}}{3Cl_2(g)} \longrightarrow \underset{\text{Aluminium chloride}}{2AlCl_3(s)}$$

$$\underset{\text{Copper}}{Cu(s)} + \underset{\text{Chlorine}}{Cl_2(g)} \longrightarrow \underset{\text{Copper (II) chloride}}{CuCl_2(s)}$$

6. Reaction of metals with hydrogen. Metals generally do not react with hydrogen because both are eletropositive. Metals like sodium, potassium, calcium and magnesium combine with hydrogen to form compounds called *metal hydrides*. They are formed by passing hydrogen gas over the heated metal. This happens only with metals which are more reactive than hydrogen.

$$\underset{\text{Sodium}}{2Na(s)} + \underset{\text{Hydrogen}}{H_2(g)} \xrightarrow{\text{Heat}} \underset{\text{Sodium hydride}}{2NaH(s)}$$

$$\underset{\text{Calcium}}{Ca(s)} + \underset{\text{Hydrogen}}{H_2(g)} \xrightarrow{\text{Heat}} \underset{\text{Calcium hydride}}{CaH_2(s)}$$

Note: As metals can lose electrons, therefore they act as reducing agents. The reactions mentioned above showing the reaction of metals with chlorine and hydrogen are the examples of such reactions.

SAMPLE PROBLEMS

1. Samples of four metals A, B, C and D were taken and added to the following solution one by one. The results obtained have been tabulated as follows:

Metal	Iron (II) sulphate	Copper (II) sulphate	Zinc sulphate	Silver nitrate
A	No reaction	Displacement	—	—
B	Displacement	—	No reaction	—
C	No reaction	No reaction	No reaction	Displacement
D	No reaction	No reaction	No reaction	No reaction

Use the above table to answer the following questions about metals A, B, C and D.

(a) Which is the most reactive metal?

(b) What would you observe if B is added to a solution of copper (II) sulphate?

(c) Arrange the metals A, B, C and D in the order of decreasing reactivity.

Ans. According to the activity series of metals, the reactivity of given metals follows the order :

Zinc > Iron > Copper > Silver

From the data given in the above table

(i) A is more reactive than copper but less reactive than iron.

(ii) B is more reactive than iron but less reactive than zinc.

(iii) C is more reactive than silver but less reactive than copper.

(iv) D is equally or less reactive than silver.

(a) From this, it is concluded that metal B is the most reactive metal.

(b) B will displace copper from copper (II) sulphate solution.

(c) The arrangement of metals in the order of decreasing reactivity is, B > A > C > D.

2. Food cans are coated with tin and not with zinc because

(A) zinc is costlier than tin.

(B) zinc has a higher melting point than tin.

(C) zinc is more reactive than tin.

(D) zinc is less reactive than tin.

Ans. The correct answer is (C).

Zinc is more reactive than tin. Moreover, tin is a non-toxic metal.

3. Amongst the following, which will displace hydrogen from dilute sulphuric acid? (i) Carbon, (ii) Copper, (iii) Sulphur, and (iv) Zinc.

Ans. Only those metals, whose position is higher than hydrogen in the metal reactivity series, will displace hydrogen gas from dilute sulphuric acid.

Zinc is the only metal that has a position higher than hydrogen in the metal reactivity series. Hence, **zinc will displace hydrogen gas**.

Copper will not displace hydrogen, as its position is lower than hydrogen in the metal reactivity series.

Carbon and sulphur are **non-metals** and, hence, will not displace hydrogen from dilute sulphuric acid.

4. Copper sulphate solution was placed in a discarded aluminium can. After a few days holes appeared in the aluminium can. Explain this observation in the light of reactivity of metals.



Ans. Aluminium metal is high up in the metal reactivity series as compared to copper. Thus, aluminium displaces copper from copper sulphate solution. As aluminium metal is gradually dissolved from the walls of the aluminium can, therefore, after a few days holes appear in the can.

$$2Al(s) + 3CuSO_4(aq) \longrightarrow Al_2(SO_4)_3(aq) + 3Cu(s)$$

5. A metal P is placed in the aqueous sulphate solution of metal Q. In a few hours metal Q was deposited on the metal P. Which metal amongst P and Q is more reactive and why?

Ans. Metal P is more reactive. It is because, a more reactive metal always displaces a less reactive metal from its salt solution. Since metal P dissolves and metal Q is deposited. Therefore, P is more reactive than Q.

6. Which of the following pairs will give displacement reactions?

(A) NaCl solution and copper metal

(B) $MgCl_2$ solution and aluminium metal

(C) $FeSO_4$ solution and silver metal

(D) $AgNO_3$ solution and copper metal

Ans. The correct answer is (D).

Copper is more reactive than silver. So, it displaces silver from $AgNO_3$ solution.

$$\underset{\text{Silver nitrate}}{2AgNO_3(aq)} + \underset{\text{Copper}}{Cu(s)} \longrightarrow \underset{\text{Silver}}{2Ag(s)} + \underset{\text{Copper (II) nitrate}}{Cu(NO_3)_2(aq)}$$

7. What would you observe when zinc is added to a solution of iron (II) sulphate? Write the chemical reaction that takes place.

Ans. Solution of iron (II) sulphate is green. When zinc is added to a solution of Fe (II) sulphate, it gets decolourised and iron gets precipitated.

$$\underset{\text{Light green}}{FeSO_4(aq)} + Zn(s) \longrightarrow \underset{\text{Colourless}}{ZnSO_4(aq)} + Fe(s)$$

Assess Yourself – 3

1. Metals behave as reducing agents. Why?
2. Name the metal which is stored under kerosene.
3. What types of oxides are formed by metals? Give one example of each.
4. An element reacts with oxygen to form an oxide. The oxide formed turns a solution of red litmus blue. Is the element a metal or a non-metal?
5. Name one metal each of the following types :
   (i) Which reacts with water at room temperature?
   (ii) Which react only with boiling water?
6. What happens when an iron nail is placed in a copper sulphate solution?
7. Which of the following are amphoteric oxides?
   MgO, Al_2O_3, ZnO, Na_2O, Fe_2O_3
8. Name two metals, which cannot displace hydrogen from dilute acids?
9. An element X forms an oxide X_2O. The aqueous solution of X_2O turns red litmus to blue.
   (i) What is the nature of the oxide X_2O?
   (ii) Is X a metal or non-metal?
10. Which of the following reactions do not occur?
    (i) $Na_2SO_4(aq) + Fe(s) \longrightarrow FeSO_4(aq) + 2Na(s)$
    (ii) $CuSO_4(aq) + Fe(s) \longrightarrow FeSO_4(aq) + Cu(s)$
    (iii) $MgSO_4(aq) + 2Ag(s) \longrightarrow Ag_2SO_4(aq) + Mg(s)$



3.7 CHEMICAL PROPERTIES OF NON-METALS

Non-metals have 4 to 7 electrons in their valence shell. So they gain electrons to attain the nearest noble gas electronic configuration. Hence non-metals readily form negatively charged ions by the gain of electrons. *We can say that non-metals are* **electronegative elements**. For example,

$$\underset{\substack{\text{Chlorine atom}\\(2,\,8,\,7)}}{Cl} + e^- \longrightarrow \underset{\substack{\text{Chloride ion}\\(2,\,8,\,8)}}{Cl^-}$$

$$\underset{\substack{\text{Oxygen atom}\\(2,\,6)}}{O} + 2e^- \longrightarrow \underset{\substack{\text{Oxide ion}\\(2,\,8)}}{O^{2-}}$$

Some characteristic reactions of non-metals are as follows.

1. Reaction of non-metals with oxygen: On heating, non-metals react with oxygen to form oxides. *These oxides are either acidic or neutral*. They never form basic oxides.

The *non-metallic oxides* are **covalent compounds** because they are formed by sharing of electrons between the non-metal and the oxygen atom.

(a) Acidic oxides. *The oxides which dissolve in water to form acids are called* **acidic oxides**. *These oxides turn blue litmus to red.*

(i) When carbon burns in excess of air, it forms carbon dioxide.

$$\underset{\substack{\text{Carbon}\\(\textit{Non-metal})}}{C(s)} + \underset{\substack{\text{Oxygen}\\(\textit{From air})}}{O_2(g)} \longrightarrow \underset{\substack{\text{Carbon dioxide}\\(\textit{Acidic oxide})}}{CO_2(g)}$$

CO_2 dissolves in water to form carbonic acid, which turns blue litmus paper to red.

$$\underset{\substack{\text{Carbon dioxide}\\(\textit{Acidic oxide})}}{CO_2(g)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\substack{\text{Carbonic acid}\\(\textit{acid})}}{H_2CO_3(aq)}$$

Hence, CO_2 is an acidic oxide.

(ii) When sulphur is burnt in air, it reacts with oxygen to form sulphur dioxide.

$$\underset{\substack{\text{Sulphur}\\(\textit{Non-metal})}}{S(s)} + \underset{\substack{\text{Oxygen}\\(\textit{From air})}}{O_2(g)} \longrightarrow \underset{\substack{\text{Sulphur dioxide}\\(\textit{Acidic oxide})}}{SO_2(g)}$$

SO_2 dissolves in water to form sulphurous acid, which turns blue litmus paper to red.

$$\underset{\substack{\text{Sulphur dioxide}\\(\textit{Acidic oxide})}}{SO_2(g)} + \underset{\text{Water}}{H_2O(l)} \longrightarrow \underset{\substack{\text{Sulphurous acid}\\(\textit{Acid})}}{H_2SO_3(aq)}$$

(iii) Similarly, phosphorus reacts with excess of oxygen to form phosphorus pentoxide. This oxide dissolves in water to form orthophosphoric acid which turns blue litmus paper to red.

$$\underset{\substack{\text{Phosphorus}\\(\textit{Non-metal})}}{P_4(s)} + \underset{\substack{\text{Oxygen}\\(\textit{From air})}}{5O_2(g)} \longrightarrow \underset{\substack{\text{Phosphorus pentoxide}\\(\textit{Acidic oxide})}}{P_4O_{10}(s)}$$

$$\underset{\substack{\text{Phosphorus pentoxide}\\(\textit{Acidic oxide})}}{P_4O_{10}(s)} + \underset{\text{Water}}{6H_2O(l)} \longrightarrow \underset{\substack{\text{Ortho-phosphoric acid}\\(\textit{An acid})}}{4H_3PO_4(aq)}$$

(b) Neutral oxides. *Oxides which neither react with acids nor with bases are called* **neutral oxides**. They have no action on litmus. Carbon monoxide (CO), water (H_2O), nitric oxide (NO) and nitrous oxide (N_2O) are examples of neutral non-metallic oxides. Carbon monoxide is produced when carbon burns in a limited supply of oxygen or air.

$$\underset{\text{Carbon}\ (\textit{Non-metal})}{2C(s)} + \underset{\text{Oxygen}\ (\textit{From air})}{O_2(g)} \longrightarrow \underset{\text{Carbon monoxide}\ (\textit{Neutral oxide})}{2CO(g)}$$

$$\underset{\text{Hydrogen}\ (\textit{Non-metal})}{2H_2(g)} + \underset{\text{Oxygen}\ (\textit{From air})}{O_2(g)} \xrightarrow{\text{Electric spark}} \underset{\text{Water}\ (\textit{Neutral oxide})}{2H_2O(l)}$$

Water is produced when an electric spark is passed through a mixture of hydrogen gas and oxygen gas.

When nitrogen and oxygen combine at high temperature (3000°C), nitric oxide is formed.

$$\underset{\text{Nitrogen}\ (\textit{Non-metal})}{N_2(g)} + \underset{\text{Oxygen}\ (\textit{From air})}{O_2(g)} \xrightarrow{2700\text{–}3000°C} \underset{\text{Nitric oxide}\ (\textit{Neutral oxide})}{2NO(g)}$$

SAMPLE PROBLEM

1. Surbhi took sulphur powder on a spatula and heated it. She collected the gas evolved by inverting a test tube over it, as shown in Fig. 3.30 given alongside.

(a) What will be the action of gas on :

(i) dry litums paper? (ii) moist litmus paper?

(b) Write a balanced chemical equation for the reaction taking place.

Ans. (a) When sulphur is heated in air, sulphur dioxide gas is formed.

(i) This gas has no effect on dry litmus paper.

(ii) The gas turns the moist blue litmus to red. On prolonged contact with the gas, the litmus paper gets decolourised.

(b) $S(s) + O_2(g) \xrightarrow{\Delta} SO_2(g)$

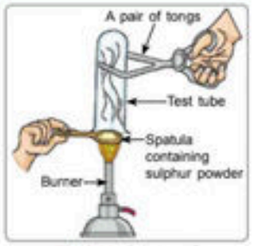


Fig. 3.30: Burning of sulphur powder

2. Reaction of non-metals with water: Non-metals generally do not react with water. This is because non-metals cannot displace hydrogen from water.

3. Reaction of non-metals with dilute acids: Non-metals do not react with acids to produce hydrogen gas as they cannot displace hydrogen gas from acids.

4. Reaction of non-metals with chlorine. Non-metals react with chlorine to form chlorides by sharing of electrons. Hence, these are covalent compounds.

Hydrogen combines with chlorine in the presence of diffused sunlight to form hydrogen chloride gas.

$$\underset{\text{Hydrogen}\ (\textit{Non-metal})}{H_2(g)} + \underset{\text{Chlorine}\ (\textit{Non-metal})}{Cl_2(g)} \xrightarrow{\text{Diffused sunlight}} \underset{\text{Hydrogen chloride}\ (\textit{A covalent chloride})}{2HCl(g)}$$

5. Reaction of non-metals with hydrogen. Non-metals combine with hydrogen to form covalent hydride compounds.

(i) Hydrogen combines with liquid sulphur at 440°C to form hydrogen sulphide.

$$\underset{\text{Hydrogen}\ (\textit{Non-metal})}{H_2(g)} + \underset{\text{Sulphur}}{S(l)} \xrightarrow{440°C} \underset{\text{Hydrogen sulphide}\ (\textit{Covalent hydride})}{H_2S(g)}$$

(ii) At 450–500°C, nitrogen combines with hydrogen in the presence of iron as catalyst to form ammonia.

$$\underset{\text{Nitrogen}\ (\textit{Non-metal})}{N_2(g)} + \underset{\text{Hydrogen}}{3H_2(g)} \xrightleftharpoons{450\text{–}500°C,\ Fe\ catalyst} \underset{\text{Ammonia}}{2NH_3(g)}$$

6. **Reaction of non-metals with salt solutions.** This is a displacement reaction where a more reactive non-metal displaces a less reactive non-metal from the solution of its salt. For example, when chlorine is passed through the solution of sodium bromide, sodium chloride and bromine gas are formed as products. Similarly, iodine is produced when chlorine is passed through the solution of potassium iodide.

$$\underset{\text{Sodium bromide}}{2NaBr(aq)} + \underset{\text{Chlorine}}{Cl_2(g)} \longrightarrow \underset{\text{Sodium chloride}}{2NaCl(aq)} + \underset{\text{Bromine}}{Br_2(l)}$$

$$\underset{\text{Potassium iodide}}{2KI(aq)} + \underset{\text{Chlorine}}{Cl_2(g)} \longrightarrow \underset{\text{Potassium chloride}}{2KCl(aq)} + \underset{\text{Iodine}}{I_2(s)}$$

Note: Non-metals have a strong tendency to accept electrons to form negative ions. Therefore, *non-metals behave as oxidising agents.* You will be studying about this in the higher classes.

Table 3.8 : Comparison of metals and Non-metals (Based on chemical properties)

	Metals	Non-metals
1.	Metals form basic oxides.	Non-metals form acidic oxides.
2.	Metals react with acids and water.	Non-metals do not react with water and acids.
3.	Metals form ionic chlorides.	Non-metals form covalent chlorides.
4.	Some metals react with hydrogen to form ionic metal hydrides.	Non-metals react with hydrogen to form stable covalent hydrides.

Uses of Metals and Non-metal

2ZRWYI0941

Uses of Metals

1. Copper and aluminium metals are used to make wires. This is because they are very good conductors of electricity.
2. Iron, copper and aluminium metals are used to make household utensils and factory equipments because they are good conductors of heat.
3. Chromium and nickel metals are used for electroplating to protect metals like iron from rusting.
4. Zinc is used for galvanising iron articles to protect them from rusting.
5. The aluminium metal is used in packaging of medicines and food materials.
6. Silver, gold and platinum metals are used to make jewellery because these are lustrous noble metals.
7. Mercury metal is used in making thermometers.
8. Lead metal is used in making car batteries.

Uses of Non-metals

1. Hydrogen is used for the hydrogenation of vegetable oils to make *vanaspati ghee*.
2. Hydrogen and nitrogen are used in the formation of ammonia, which is used in the manufacture of fertilisers. Nitrogen is also used in the manufacture of nitric acid.
3. Compounds of nitrogen like tri-nitro toluene (TNT) and nitroglycerine are used as explosives.
4. Carbon (graphite) is used for making the electrodes of electrolytic cells and dry cells.
5. Sulphur is used as a fungicide and in making gun powder.
6. Nitrogen gas is used to preserve packaged food materials.
7. Liquid hydrogen is used as rocket fuel.
8. Sulphur is used for manufacturing sulphuric acid.

Exercise-3 (B)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

1. A small piece of sodium is dropped into a beaker containing water. Which of the following observations are incorrect?
   (A) It floats on the surface of water to form a silvery ball.
   (B) It darts over the surface of water and decreases in size.
   (C) It catches fire and burns with a golden-yellow flame.
   (D) The water on testing turns blue litmus to red.
2. Which of the following reactions is not possible?
   (A) $2AgNO_3(aq) + Cu(s) \longrightarrow Cu(NO_3)_2(aq) + 2Ag(s)$ (B) $2AgNO_3(aq) + Fe(s) \longrightarrow Fe(NO_3)_2(aq) + 2Ag(s)$
   (C) $2AgNO_3(aq) + Mg(s) \longrightarrow Mg(NO_3)_2(aq) + 2Ag(s)$ (D) $Cu(NO_3)_2(aq) + 2Ag(s) \longrightarrow 2AgNO_3(aq) + Cu(s)$
3. Although metals form basic oxides, which of the following metals form an amphoteric oxide?
   (A) Na (B) Ca (C) Al (D) Cu [HOTS]
4. 2 mL each of concentrated HCl, HNO_3 and a mixture of concentrated HCl and concentrated HNO_3 in the ratio of 3 : 1 were taken in test tubes labelled as A, B and C. A small piece of metal was put in each test tube. No change occurred in test tubes A and B but the metal got dissolved in test tube C respectively. The metal could be [HOTS]
   (A) Al (B) Au (C) Cu (D) Fe

Ans: 1. (D) 2. (D) 3. (C) 4. (B)

II. VERY SHORT ANSWER TYPE QUESTIONS

1. Which one of the metals in the following group are : (A) most reactive (B) least reactive – Au, Na, Cu, Ca?
2. When an iron knife is kept dipped in blue copper sulphate solution, the solution changes to light green. Why?
3. Choose neutral oxides out of the following:
   Carbon monoxide, carbon dioxide, nitrous oxide and sulphur dioxide.
4. Write the chemical equation for the reaction of hot aluminium with steam.
5. Write the chemical equation to represent the reaction taking place between sodium metal and cold water.
6. Write the chemical equation to represent the reaction taking place when copper oxide is heated in a stream of hydrogen (give chemical reaction).
7. How does the metal magnesium differ from the metal calcium in their reaction with water?
8. Name any two neutral oxides.
9. Which one of the following metals does not react with oxygen even at high temperatures?
   (i) Calcium (ii) Gold (iii) Sodium
10. Name any one metal that reacts neither with cold water nor with hot water but reacts with heated steam to produce hydrogen gas.
11. Write the chemical equation for the reaction taking place when a piece of zinc is placed in copper (II) sulphate solution.
12. An element forms an oxide A_2O_3 that is acidic in nature. Identify A as a metal or a non-metal. [HOTS]
13. Generally, when metals are treated with mineral acids, hydrogen gas is liberated but when metals (except Mn and Mg), are treated with HNO_3, hydrogen is not liberated, why? [HOTS]
14. For making hydrogen by reaction with hydrochloric acid, granulated zinc is preferred to a block of zinc. Why?
15. Write balanced chemical equation for the reaction taking place when steam is passed over red hot iron.

III. SHORT ANSWER TYPE QUESTIONS

1. Choose a metal out of the following that reacts with hot water but not with cold water : sodium, magnesium and iron. Mention the products formed during the reaction.
2. Which of the following elements would yield : (i) an acidic oxide, (ii) a basic oxide, and (iii) a neutral oxide?
   Na, S, C, K, H



3. What is the nature of the oxide SO_2? What happens when it is dissolved in water? Write the chemical equation of the reaction involved.
4. What type of oxides are formed when metals combine with oxygen? Explain with the help of an example.
5. (a) How do metals react with hydrogen? Explain with an example.
   (b) How do non-metals react with hydrogen? explain with an example.
6. Complete and balance the following equations :
   (a) $Na(s) + O_2(g) \longrightarrow$
   (b) $Na_2O(s) + H_2O(l) \longrightarrow$
   (c) $Fe(s) + H_2O(g) \xrightarrow{\text{Red heat}}$
   (d) $Cu(NO_3)_2(aq) + Zn(s) \longrightarrow$
7. Choose the metal from the list given below that can displace zinc from zinc sulphate solution – lead, copper, magnesium, silver. Write the equation for the chemical reaction involved.
8. What is the activity series of metals? Rearrange the following metals in an increasing order of reactivity: aluminium, zinc, mercury.
9. Write chemical equations for the reactions taking place when :
   (a) Zinc sulphide is heated in air.
   (b) Carbon dioxide gas is passed into limewater.
10. A copper plate was dipped into a solution of $AgNO_3$. After sometime, a black layer was deposited on the copper plate. State the reason for it. Write the chemical equation of the reaction involved.
11. From amongst the metals sodium, calcium, aluminium, copper and magnesium, name the metal :
   (a) that reacts with water only on boiling.
   (b) another that does not react with steam.
12. When the powder of a metal is heated in an open china dish its colour turns black. However, when hydrogen is passed over the hot black substance so formed, it regains its original colour. Based on the above information answer the following questions :
   (i) What type of chemical reaction takes place in each of the two given steps?
   (ii) Name the metal initially taken in the powder form. Write balanced chemical equations for both reactions.
13. An alkali metal A gives a compound B (molecular mass = 40) on reacting with water. The compound B gives a soluble compound C on treatment with aluminium oxide. Identify A, B and C. Give the reaction involved. [HOTS]
14. A solution of $CuSO_4$ was kept in an iron pot. After few days the iron pot was found to have a number of holes in it. Explain the reason in terms of reactivity. Write the equation of the reaction involved. [HOTS]
15. A metal M does not liberate hydrogen from acids but reacts with oxygen to give a black coloured product. Identify M and the black coloured product and also explain the reaction of M with oxygen. [HOTS]
16. Explain, why zinc metal can displace copper from copper sulphate solution but copper cannot displace zinc from zinc sulphate solution?
17. State the reason for the following behaviour of zinc metal :
   On placing a piece of zinc metal in a solution of mercuric chloride it acquires a shining silvery surface but when it is placed in a solution of magnesium sulphate no change is observed.
18. Give reasons for the following :
   (i) Zinc oxide is considered an amphoteric oxide.
   (ii) Non-metals, in general, do not displace hydrogen from dilute acids.
   (iii) Na, K and Ca metals form hydrides by combination with hydrogen gas, but most of the other metals do not.
   (iv) Metals are regarded as electropositive elements.
   (v) When a piece of copper metal is added to a solution of zinc sulphate, no change takes place, but the blue colour of copper sulphate fades away when a piece of zinc is placed in its solution.
19. (a) Name a metal in each of the following case :
      (i) It does not react with cold or hot water, but reacts with steam.
      (ii) It does not react with any physical state of water.
   (b) When calcium metal is added to water, the gas evolved does not catch fire, but the same gas evolved on adding sodium metal to water catches fire. Why is it so?



20. Iqbal treated a lustrous, divalent element M with sodium hydroxide. He observed the formation of bubbles in the reaction mixture. He made the same observations when this element was treated with hydrochloric acid. Suggest how can he identify the gas produced. Write chemical equations for both the reactions. [HOTS]

21. When a metal X is treated with cold water, it gives a basic salt Y with molecular formula XOH (molecular mass = 40) and liberates a gas Z, which easily catches fire. Identify X, Y and Z. Also write the reaction involved. [HOTS]

22. Explain the following :
    (a) Reactivity of Al decreases if it is dipped in HNO_3.
    (b) Carbon cannot reduce the oxides of Na or Mg.
    (c) NaCl is not a conductor of electricity in the solid state whereas it conducts electricity in the aqueous solution as well as in molten state. [HOTS]

23. An element A reacts with water to form a compound B that is used in white washing. The compound B on heating forms an oxide C that on treatment with water gives back B. Identify A, B and C. Give the reactions involved. [HOTS]

IV. LONG ANSWER TYPE QUESTIONS

1. Name two metals that react violently with cold water. Write any three observations you would make, when such a metal is dropped in water. How would you identify the gas evolved, if any, during the reaction.

2. (a) What is an "activity series" of metals? Arrange the metals Zn, Mg, Al, Cu and Fe in a decreasing order of reactivity.
    (b) What would you observe when you put :
        (i) some zinc pieces into blue copper sulphate solution?
        (ii) some copper pieces into green ferrous sulphate solution?
    (c) Name a metal that combines with hydrogen gas. Name the compound formed.

3. Sample pieces of five metals A, B, C, D and E were added to the tabulated solutions separately. The results observed were as shown in the table below.

Metal	Solution				
	$FeSO_4$	$CuSO_4$	$ZnSO_4$	$AgNO_3$	$Al_2(SO_4)_3$
A	No change	No change	No change	A coating on the metal	No change
B	A grey deposit on the metal	Brown coating on the metal	No change	A coating on the metal	No change
C	No change	No change	No change	No change	No change
D	No change	—	No change	A coating on the metal	No change
E	—	Brown coating	New coating	New coating	No change

Based on the observations recorded in the table answer following questions :
(i) Which is the most reactive metal?
(ii) Which is the least reactive metal?
(iii) What would be obseved if metal D were added to the solution of copper (II) sulphate?
(iv) What would be observed if metal E were added to a solution of iron (II) sulphate?
(v) Arrange the metals A, B, C, D and E in the order of their decreasing reactivity.

4. An element A burns with a golden flame in air. It reacts with another element B, atomic number 17 to give a product C. An aqueous solution of the product C on electrolysis gives a compound D and liberates hydrogen. Identify A, B, C and D. Also, write down the equations for the reactions involved.

5. What happens when an iron strip is put into separate beakers containing aqueous solution of copper sulphate and zinc sulphate? Where is iron placed in the activity series with respect to copper? Support your answer with balanced chemical equation for the chemical reactions involved in the process.

3.8 EXTRACTION OF METALS

6DT593CLVY

Metals occur in the earth's crust either in the free state (native state), in the form of elements or in the combined state, in the form of compounds.

Gold, silver, platinum and copper occur in the free state. Copper and silver occur in the form of its compounds, such as oxides and sulphides.

The reason for the occurrence of the above metals in the free state is that their position in the chemical reactivity series is very low. Hence, they are not affected by air, water, carbon dioxide gas, etc.

All other metals occur in the form of their compounds, that is, in the combined state. It is because, their position is above hydrogen in the chemical reactivity series and hence, readily react with air, water, carbon dioxide, etc. They are found in the form of their sulphides, carbonates or oxides. As a matter of fact most of the metals in their combined state are in the form of oxides. It is because oxygen is very reactive and one of the most abundant elements on the surface of the earth.

Minerals and Ores

The natural materials containing metals in the free or combined state are called minerals.

All minerals contain unwanted impurities such as sand, clay, etc. The percentage of a metal in a mineral can be high or low depending upon the percentage of sand and clay. In addition to it, some minerals contain objectionable impurities, which may cause pollution when the metal is extracted from them.

A mineral, from which a metal can be extracted conveniently and profitably, is called an ore.

It must be kept in mind that an ore contains a fairly high percentage of a given metal. Furthermore, ***all ores are mineral, but all minerals are not ores.***

Some of the common ores are given alongside.

Table 3.9 : Some important ores

Metals	Name of ore	Formula of ore
Sodium	Rock salt (Sodium chloride)	NaCl
Aluminium	– Bauxite – Cryolite	$Al_2O_3.2H_2O$ Na_3AlF_6
Manganese	Pyrolusite (Manganese dioxide)	MnO_2
Zinc	– Calamine (Zinc carbonate) – Zinc blende (Zinc sulphide)	$ZnCO_3$ ZnS
Iron	Haematite (Iron oxide)	Fe_2O_3
Copper	– Cuprite (Cupric oxide) – Copper glance (Cupric sulphide) – Copper pyrites	Cu_2O Cu_2S $CuFeS_2$
Calcium	– Limestone (Calcium carbonate) – Gypsum	$CaCO_3$ $CaSO_4.2H_2O$
Lead	Galena (Lead sulphide)	PbS
Mercury	Cinnabar	HgS

Metallurgy

The various processes involved in the extraction of a metal from its ore and then refining of metal, including study of its properties and uses are collectively known as metallurgy.

The three major steps involved in the extraction of metals are :

1. Concentration/enrichment of ore.
2. Conversion of concentrated ore into metals, and
3. Refining/purification of the impure metal.

1. Concentration/Enrichment of Ore

The ore, which is generally in the form of large stony pieces is crushed in ***jaw crushers*** to small pieces. It is then hammered in ***hammer mills*** to very small pieces. These small pieces are then fed in ***ball mills*** or ***stamp mills*** and ground to form a fine powder.

Gangue or Matrix: The unwanted impurities, such as sand, stones, mud, limestone, mica, etc., associated with naturally occurring ore is called gangue or matrix.

***The processes that help in the removal of gangue from the dressed ore, thereby increasing the percentage of metal in the ore, are collectively called* concentration of ore.**

The methods used in the concentration of ore depend upon :

(1) Nature of ore, (2) Impurities present in the ore.

(i) Electromagnetic separation: The pulverised ore is allowed to fall on a moving rubber belt, such that one of the pulleys on which the belt moves, has a strong electromagnet.

The non-magnetic part of the ore falls down directly to form a separate heap. The magnetic part of the ore clings to the belt and falls at a certain distance away from the electromagnetic wheel, to form a separate heap.

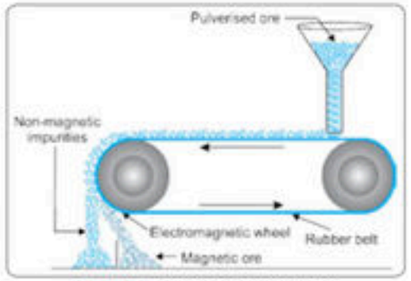


Fig. 3.31: Electromagnetic separation

This method of concentration is used, when :

(i) Ore is magnetic in nature, such as iron ore.

(ii) Ore is non-magnetic but the gangue is magnetic in nature. For example, iron (III) oxide is gangue in the ore of aluminium.

(ii) Gravity process or hydraulic washing: This method of separation of gangue from the ore is followed for most of the ores, **except sulphide ores**.

The pulverised ore is poured over a very wide rocking table, fitted with corrugated boards, such that it has a sloping top. A strong jet of water is directed against the pulverised ore. The lighter particles of gangue are washed away, leaving behind heavier ore particles, which get stuck in the depressions of the corrugated boards.

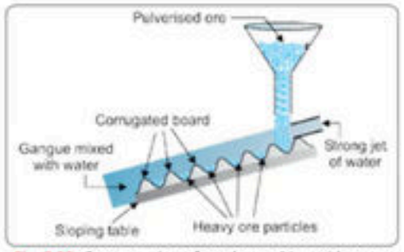


Fig. 3.32: Concentration of ore by washing with water

(iii) Froth floatation process: This method is employed for the concentration of ***sulphide ores only***, such as zinc blende [ZnS], copper pyrites, etc.

The separation of sulphide ore from gangue is based on the principle that when the ore is immersed in a mixture of water and pine oil, the ***sulphide particles are wetted by oil***, whereas the ***gangue particles are wetted by water***.

The sulphide ore is placed in a large tank containing a mixture of water and pine oil. A strong current of air is used to agitate the mixture of the ore, water and pine oil. Due to agitation with air, the pine oil forms a foam. The particles of the ore stick to the oil and are carried up by the foam. The gangue particles settle at the base of the tank.

The foam is allowed to fall in another tank and allowed to settle. The air escapes from the foam, leaving behind concentrated ore. The pine oil floats over the concentrated ore.

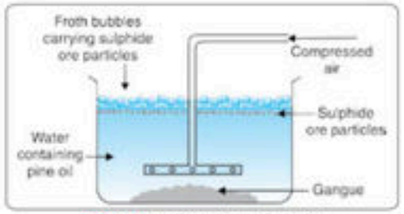


Fig. 3.33: Concentration of ore by froth floatation process

2. Conversion of Concentrated Ore into Metal

As stated earlier some metals are found in the free state in the earth's crust and some are found in the form of their compounds. If you look at the reactivity series of the metals, the metals gold, silver, platinum and copper are at the bottom of it, and hence, are least reactive. They are often found in the free state.

The metals at the top of metal activity series, that is, potassium, sodium, calcium, magnesium and aluminium are highly reactive. These metals are never found in the free state.

The metals in the middle of the metal activity series, that is, zinc, iron, lead and tin are moderately reactive. They are found in the earth's crust as oxides, carbonates and sulphides.

Thus, on the basis of reactivity, the metals can be grouped into the following three categories :

(i) Metals of high reactivity [K, Na, Ca, Mg, Al]

(ii) Metals of moderate reactivity [Zn, Fe, Pb, Sn]

(iii) Metals of low reactivity [Cu, Ag, Pt, Au]

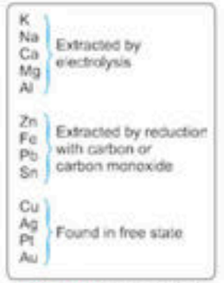


Fig. 3.34: Activity series and metallurgy

Extraction of metals near the top of metal reactivity series

SD1F92G7CQ

These metals are obtained by electrolytic reduction of their molten chlorides or oxides. The oxides of highly reactive metals are very stable and cannot be reduced by 'carbon'. This is because these metals have far more affinity for oxygen or chlorine than carbon.

I. Extraction of sodium from molten (fused) sodium chloride

When an electric current is passed through fused sodium chloride, in a specially designed electrolytic cell, provided with a graphite anode and steel cathode, sodium ions migrate towards the cathode and chloride ions migrate towards the anode.

Reactions at the cathode : At the cathode, sodium ions accept electrons and are reduced to sodium metal.

$$\underset{\text{Sodium ion}}{Na^+} + \underset{\text{Electron}}{e^-} \longrightarrow \underset{\text{Sodium atom}}{Na} \quad \text{[At cathode]}$$

Reactions at the anode : At the anode, chloride ions donate electrons and are oxidised to chlorine atoms, which unite to form chlorine gas.

$$\underset{\text{Chlorine ion}}{Cl^-} - \underset{\text{Electron}}{e^-} \longrightarrow \underset{\text{Chlorine atom}}{Cl} \quad \text{[At anode]}$$

$$\underset{\text{Chlorine atom}}{Cl} + \underset{\text{Chlorine atom}}{Cl} \longrightarrow \underset{\text{Chlorine molecule}}{Cl_2}$$

Sodium or potassium metals cannot be extracted by the electrolysis of their aqueous solutions. It is because, these solutions contain K^+, Na^+ and H^+ ions. On the passage of electric current, the H^+ ions get discharged in preference to Na^+ or K^+ ions. Thus, the product formed at the cathode is hydrogen gas and not sodium metal or potassium metal.

II. Extraction of aluminium from molten (fused) aluminium oxide

When an electric current is passed through fused aluminium oxide containing cryolite [Na_3AlF_6] in a specially designed electrolytic cell, provided with a graphite anode and graphite cathode, aluminium ions migrate towards the cathode and oxide ions migrate towards the anode.

Alumina does not conduct electricity in solid state. It melts at a very high temperature. Therefore, alumina is dissolved in molten cryolite (Na_3AlF_6) containing a small amount of flourspar (CaF_2). This molten mixture is then introduced in the electrolytic cell.

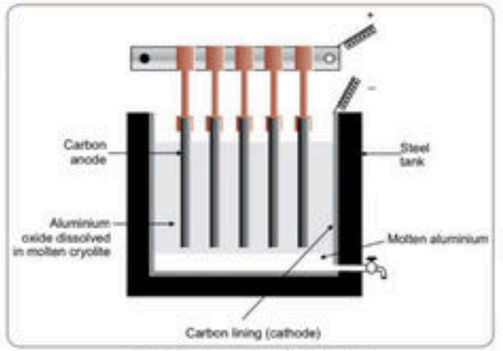


Fig. 3.35: Extraction of Aluminium

Reactions at the cathode: At the cathode, aluminium ions accept electrons and are reduced to aluminium metal. The metal so formed melts and sinks to the bottom of the electrolytic tank, from where it can be drawn from time to time.

$$\underset{\text{Aluminium ion}}{Al^{3+}} + \underset{\text{Electron}}{3e^-} \longrightarrow \underset{\text{Aluminium atom}}{Al} \quad \text{[At cathode]}$$

Reactions at the anode: At the anode, oxide ions donate electrons and are oxidised to oxygen atoms. The oxygen atoms react with graphite anode to form carbon dioxide gas.

$$\underset{\text{Oxide ion}}{O^{2-}} - \underset{\text{Electron}}{2e^-} \longrightarrow \underset{\text{Oxygen atom}}{O} \quad \text{[At anode]}$$

$$\underset{\text{Carbon}}{C} + \underset{\text{Oxygen}}{2O} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2}$$

Pure aluminia (Al_2O_3) melts at a very high temperature and offers a fairly large resistance to the passage of electric current. However, if three parts of Al_2O_3 are mixed with one part of cryolite [Na_3AlF_6], the mixture melts at a fairly low temperature and offers less resistance to the passage of electric current.

Extraction of metals in the middle of reactivity series

WJZFVXQH7L

The concentrated ores of these metals are usually in the form of oxides, carbonates or sulphides. Before the extraction of metals from these ores, they are subjected to the process of calcination or roasting so that the ore gets converted to oxide which can be reduced to obtain the metal.

(a) **Calcination:** ***The process of heating of an ore strongly in the absence of air, such that it decomposes to form a metallic oxide is called calcination***. Calcination is generally employed in case of carbonate ores.

Objectives achieved during calcination

(i) It removes moisture from the wet ore.

(ii) It makes the ore porous.

(iii) It expels the volatile impurities from the ore.

(iv) It decomposes a carbonate ore to its oxide.

$$\underset{\text{Zinc carbonate}}{ZnCO_3(s)} \xrightarrow{\text{heat}} \underset{\text{Zinc oxide}}{ZnO(s)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

(v) It removes water of crystallisation from the hydrated ore.

During calcination, metallic carbonate ores (except Na_2CO_3 and K_2CO_3) decompose to form the respective metallic oxides and carbon dioxide gas.

(b) **Roasting:** ***The process of heating a concentrated ore (only sulphide ores) in the presence of excess of air, such that it changes to a metallic oxide is called*** **roasting.**

Objectives achieved during roasting

(i) It removes moisture present in the wet ore.

(ii) It makes the ore porous.

(iii) It expels the volatile impurities.

(iv) It oxidises sulphide ore to its respective oxide.

$$\underset{\substack{\text{Zinc sulphide}\\\text{(Zinc blende ore)}}}{2ZnS(s)} + \underset{\substack{\text{Oxygen}\\\text{(From air)}}}{3O_2(g)} \xrightarrow{\text{heat}} \underset{\text{Zinc oxide}}{2ZnO(s)} + \underset{\text{Sulphur dioxide}}{2SO_2(g)}$$

$$\underset{\text{Lead sulphide}}{2PbS(s)} + \underset{\text{Oxygen}}{3O_2(g)} \xrightarrow{\text{heat}} \underset{\text{Lead oxide}}{2PbO(s)} + \underset{\text{Sulphur dioxide}}{2SO_2(g)}$$

$$\underset{\text{(Iron pyrites)}}{4FeS_2(s)} + \underset{\text{Oxygen}}{11O_2(g)} \xrightarrow{\text{heat}} \underset{\text{Iron (III) oxide}}{2Fe_2O_3(s)} + \underset{\text{Sulphur dioxide}}{8SO_2(g)}$$

During roasting, the oxygen present in the air reacts with metallic sulphide ores to form the respective metallic oxides and sulphur dioxide gas.

Table 3.10 : Differences between calcination and roasting

	Calcination	Roasting
1.	During calcination, the ore is heated in the absence of air.	During roasting, the ore is heated in the presence of air.
2.	Calcination is carried out for the ores other than sulphide ores.	Roasting is carried out for sulphide ores only.
3.	During calcination, the carbonates decompose to form their respective oxides and carbon dioxide gas.	During roasting, the sulphide ores are oxidised to their respective oxides and sulphur dioxide gas.

If the metallic ore is a halide of a metal, such as KCl or $ZnCl_2$, etc., the roasting or calcination does not change it into an oxide ore. Furthermore, halide or oxide ores remain unaffected by calcination, except that moisture and volatile impurities are removed.

(c) Reduction of metal oxide ore into metal

(i) Reduction by highly reactive metals: Sometimes highly reactive metals, such as sodium, potassium, magnesium, calcium and aluminium are used as reducing agents, because they can easily displace metals of lower reactivity from their compounds.

Examples :

1. Manganese is obtained from manganese dioxide by heating with aluminium powder. The reaction is exothermic in nature and the metal obtained is in the liquid state.

$$\underset{\text{Manganese dioxide}}{3MnO_2(s)} + \underset{\text{Aluminium}}{4Al(s)} \xrightarrow{\Delta} \underset{\text{Manganese}}{3Mn(l)} + \underset{\text{Aluminium oxide}}{2Al_2O_3(s)} + \text{Heat}$$

Similarly, chromium metal is obtained from chromium oxide, by heating it with aluminium powder.

$$\underset{\text{Chromium oxide}}{Cr_2O_3(s)} + \underset{\text{Aluminium}}{2Al(s)} \xrightarrow{\Delta} \underset{\text{Chromium}}{2Cr(l)} + \underset{\text{Aluminium oxide}}{Al_2O_3(s)} + \text{Heat}$$

2. **Thermite reaction:** In this reaction iron metal in the liquid state is produced on the spot. It is used for welding railway lines and broken parts of heavy machinery.

In this reaction, a mixture of iron (III) oxide and aluminium powder is placed in a small earthen pot having a hole at its base. The hole is plugged with wet clay. A cavity is made in the middle of the mixture in which placed a powder of magnesium and barium peroxide.

When the powder of magnesium and barium peroxide is ignited, the heat produced by it starts the chemical reaction between iron (III) oxide and aluminium powder.

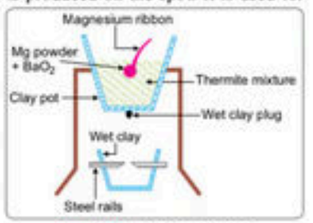


Fig. 3.36: Thermite welding

$$\underset{\text{Iron (III) oxide}}{Fe_2O_3(s)} + \underset{\text{Aluminium}}{2Al(s)} \xrightarrow{\Delta} \underset{\text{Iron}}{2Fe(l)} + \underset{\text{Aluminium oxide}}{Al_2O_3(s)} + \text{Heat}$$

The iron so formed is in the liquid state, and hence, sinks at the bottom of the earthen pot. The earthen pot is then positioned on the cracked iron part and wet clay plug is broken. The molten iron flows into the crack and joins the broken parts.

(ii) Reduction by coke or carbon monoxide: The oxide ore is mixed with coke and heated strongly or the oxide ore is heated strongly and carbon monoxide gas is passed through it.

In either case, carbon or carbon monoxide acts as a reducing agent and the ore as an oxidising agent. The ore is reduced to the metal, whereas carbon is oxidised to carbon monoxide and carbon monoxide is oxidised to carbon dioxide. Various chemical reactions are illustrated below.

$$PbO(s) + C(s) \longrightarrow Pb(l) + CO(g)$$
Lead (II) oxide — Carbon — Lead — Carbon monoxide

$$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(s) + 3CO_2(g)$$
Iron (II) oxide — Carbon monoxide — Iron — Carbon dioxide

$$ZnO(s) + CO(g) \longrightarrow Zn(l) + CO_2(g)$$
Zinc oxide — Carbon monoxide — Zinc — Carbon dioxide

Extraction of metals low in reactivity series 9VXWKE3TDR

As these metals are very unreactive, the ores of these metals in the form of sulphides can be converted into metals by heating them strongly in air (roasting).

I. Extraction of mercury

Cinnabar [HgS] is the ore of mercury. When the concentrated ore of mercury is heated strongly in air, the following reactions take place with the formation of metal mercury.

$$2HgS(s) + 3O_2(g) \xrightarrow{\text{heat}} 2HgO(s) + 2SO_2(g)$$
Mercury (II) sulphide — Oxygen — (roasting) — Mercury (II) oxide — Sulphur dioxide

$$2HgO(s) \xrightarrow{\text{heat}} 2Hg(l) + O_2(g)$$
Mercury (II) oxide — (reduction) — Mercury — Oxygen

II. Extraction of copper

Copper (I) sulphide [Cu_2S] is the ore of copper. When concentrated ore of copper (I) sulphide is heated strongly in air, it forms copper (I) oxide [Cu_2O]. The copper (I) oxide then reacts with copper (I) sulphide to form copper metal.

$$2Cu_2S(s) + 3O_2(g) \xrightarrow{\text{roasting}} 2Cu_2O(s) + 2SO_2(g)$$
Copper (I) sulphide — Oxygen — Copper (I) oxide — Sulphur dioxide

$$2Cu_2O(s) + Cu_2S(s) \xrightarrow{\text{heat}} 6Cu(s) + SO_2(g)$$
Copper (I) oxide — Copper (I) sulphide — Copper — Sulphur dioxide

As now we have understood the extraction of different metals, let us write all this information in the form of a flow chart.

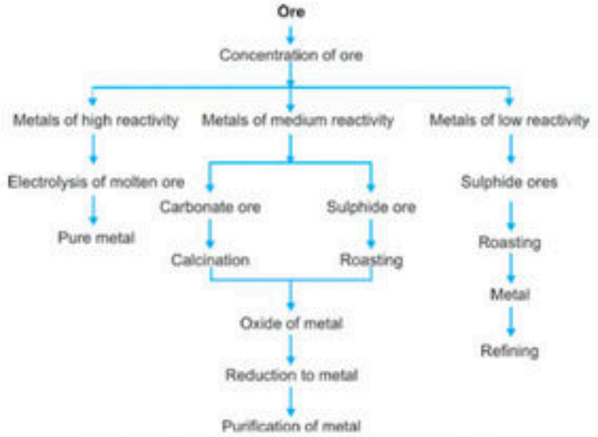


Fig. 3.37: Steps involved in the extraction of metals from ores

3. Refining/Purification of the Impure Metal

DJI8ER23FC

Metals produced by self-reduction of the ores or reduction of the ores with carbon or carbon monoxide are not very pure. They always contain impurities that must be removed to obtain pure metals. The process of removing impurities from the metal extracted from the ore is called **refining**.

The most widely used method for refining impure metals is electrolytic refining.

Electro-refining of the Metals: ***The process by which impurities are removed from an impure metal, by using electrolytic process is called*** **electro-refining.**

Metals like copper, zinc, aluminium are refined by the electrolytic process. Following steps are involved in electro-refining of metals :

1. Electrolyte is made from a soluble ionic salt of the metal, which is to be refined. To the electrolyte, an appropriate acid is added so as to make it a better conductor.
2. The anode consists of impure metal, which needs to be refined.
3. The cathode consists of a strip or rod of pure metal.

On the passage of electric current, the impure metal dissolves in the electrolyte in the form of its ions and the pure metal deposits on the cathode. The impurities in the metal, either dissolve in the electrolyte, or get collected at the base of the anode, and is commonly called **anode mud**.

Electrorefining of Impure Copper

Electrolyte: It consists of an aqueous saturated solution of copper sulphate. This solution is acidulated with sulphuric acid to make it a better conductor and prevent hydrolysis of copper sulphate.

Electrodes:

(i) Cathode: It consists of a strip or a rod of pure copper metal. It is connected to the negative terminal of the battery.

(ii) Anode: It consists of impure cylindrical block of copper. It is connected to the positive terminal of the battery.

Electrolytic dissociation: Before the passage of current, following ions are present in the electrolyte :

(a) From copper sulphate: $CuSO_4(aq) \rightleftharpoons Cu^{2+}(aq) + SO_4^{2-}(aq)$

(b) From sulphuric acid: $H_2SO_4(aq) \rightleftharpoons 2H^+(aq) + SO_4^{2-}(aq)$

(c) From water: $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$

Reactions on the Passage of Current

(a) Reactions at the cathode: Cu^{2+} and H^+ being positively charged, migrate towards the cathode. However, only Cu^{2+} ions discharge in preference to H^+ ions, because the position of Cu^{2+} ions is lower in the metal activity series.

$$Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$$

The copper atoms so formed deposit themselves on the strip of pure copper.

(b) Reactions at the anode : SO_4^{2-} and OH^- ions migrate to anode, but do not discharge. It is because, the copper atoms in the impure copper anode have lower reduction potential than SO_4^{2-} and OH^- ions. Thus, copper atoms discharge to form copper ions and enter in the electrolyte.

$$Cu(s) - 2e^- \longrightarrow Cu^{2+}(aq)$$

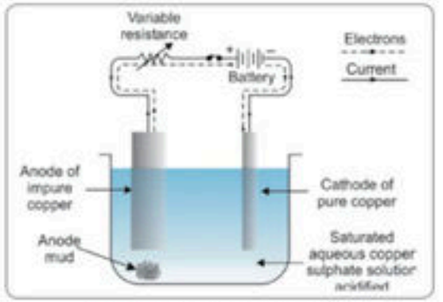


Fig. 3.38: Electro-refining of copper

(c) The impurities present in the anode (impure copper) can be of two kinds:

(i) Impurities of metals, *whose position is lower than copper in the metal activity series, such as silver and gold.*

(ii) Impurities of metals, *whose position is higher than copper in the metal activity series, such as zinc, lead, iron,* etc.

The impurities mentioned in (i) just drop down under the anode. It is commonly called ***anode mud***. **Anode mud is not a waste product, as it is refined to obtain silver and gold.**

The impurities mentioned in (ii) ionise and enter in the electrolyte. However, they do not discharge at the cathode as long as copper ions are present in the electrolyte.

Conclusions :

1. The atoms of pure copper continuously deposit at the cathode, due to discharge of Cu^{2+} ions. Thus, the mass of the cathode containing pure copper goes on increasing.
2. The copper atoms at the anode continuously ionise to form Cu^{2+} ions at the anode. Thus, the mass of the anode goes on decreasing.
3. The impurities present in copper are either deposited in the form of anode mud or dissolve in the electrolyte. However, the impurities do not discharge at the cathode.

Advantages of Electrolytic Refining

(1) It produces metals of very high purity.

(2) It helps in the recovery of valuable metals such as gold and silver.

SAMPLE PROBLEMS

1. What chemical process is used for obtaining a metal from its oxide?

Ans. Metals are obtained from their metal oxides by reduction process:

(a) Carbon reduction process:

$$MO + C \longrightarrow M + CO$$

(b) Metal reduction process:

$$Fe_2O_3(s) + 2Al(s) \longrightarrow 2Fe(l) + Al_2O_3(s)$$

2. In the electrolytic refining of a metal M, what would you take as the anode, the cathode and the electrolyte?

Ans. Anode: A thick slab of crude metal M

Cathode: A thin sheet of pure metal M

Electrolyte: A solution of a stable salt of metal M

3. Name two metals which are found in nature in the free state.

Ans. Gold and silver are metals which are found in nature in the free state.

Assess Yourself – 4

1. What is the name of the ore of mercury? What method do you suggest for the extraction of mercury from its ore?
2. Name an ore each of aluminium and iron.
3. Name the metal that can be extracted from haematite.
4. Name the reducing agent in the following chemical reaction :

   $3MnO_2 + 4Al \longrightarrow 3Mn + 2Al_2O_3$
5. What is the objective of calcination?
6. How does electrolytic refining differ from carbon reduction?



3.9 CORROSION OF METALS

MTSXUQ730H

This topic is already discussed in detail in Chapter 1 in Section "Corrosion of Metals".

Anodising of Aluminium Articles: Anodising is a method of forming a protective layer of aluminium oxide on the surface of an aluminium article. It protects against corrosion, enhances aesthetic qualities and resists scratching.

To prepare aluminium for anodising, the surface of the aluminium article is first thoroughly cleaned and rinsed. In the process of anodising, the aluminium metal article is made the anode and is electrolysed with a dilute acid like dilute sulphuric acid. When the electrical current is passed through, oxygen forms on the surface of the aluminium article (at the anode) reacts with aluminium to create an aluminium oxide layer on the aluminium article. A thicker aluminium oxide layer is made. The thicker is the oxide layer; the greater is the resistance to corrosion.

3.10 ALLOYS

ZH1UQPBDIL

A homogeneous mixture of two or more metals (or a non-metal) obtained by melting them together, is called an ***alloy***.

Why are alloys made?

Pure metals generally do not have all the properties of a good metal, such as malleability, ductility, tensile strength, hardness, resistance to corrosion and conduction of heat and electricity, etc. However, one or more of these properties can be improved by melting two or more metals (or a non-metal) in some fixed proportion and then allowing the molten product to cool at room temperature. Such a product is called an alloy. Duralumin and magnalium are the alloys of aluminium; steel and stainless steel are the alloys of iron; brass and broze are the alloys of copper; solder is an alloy of lead and tin; whereas amalgams are alloys of mercury.

Properties of Alloys

The physical properties of the alloys are, generally, different from the physical properties of the constituent metals. Following examples will illustrate the point :

(1) Change in hardness: Some alloys can be made harder than the constituent metals.

(a) When an alloy of aluminium and magnesium is made, it is harder than both the metals.

(b) When 0·5 to 1·5% of carbon is added to iron, it forms steel, which is harder than iron.

(c) Gold is a soft metal. It is hardened by the addition of copper so as to make jewellery.

(2) Resistance to corrosion:

(a) Iron metal corrodes to form rust in moist air. However, if it is alloyed with chromium and nickel, it forms stainless steel, which is resistant to corrosion.

(b) Monel metal is an alloy of copper, nickel and iron that does not corrode in moist air.

(3) Change in melting points: Some alloys have lower melting points than the constituent metals. For example, solder, an alloy of tin and lead, has a lower melting point than both the constituent metals.

(4) Change in electric conductivity: Generally, metals are good conductors of electricity. However, nichrome, an alloy of nickel, chromium and iron, is a poor conductor of electricity. It is used in making heating elements of electrical devices such as heaters, ovens, toasters, geysers, etc.

Alloying of Gold

Pure gold is seldom used for making ornaments, as it is a soft metal with a high melting point. Thus, it is alloyed with other metals such as copper, silver, brass, cadmium, etc. This makes the gold workable at a lower temperature. Furthermore, it increases the hardness and hence, the ornaments formed from alloyed gold, do not get deformed easily.

However, alloying gold reduces the purity of gold. Thus, in order to know the purity of gold in the article of the alloyed sample, it is expressed in carat/karat, where 1 carat/karat = 4.1666 g per 100 g of alloy.



For example, 22 carat/karat ornament of alloyed gold contains $4.1666 \times 22 = 91.666\%$ pure gold. Much the same way, 24 carat/karat gold contains $4.1666 \times 24 = 99.998$ or 100% of gold.



Fig. 3.39: Gold Jewellery

Common Alloys and Their Uses :

1. **Stainless Steel**
   - It is an alloy of iron.
   - Its composition is iron (3%), carbon (1%), chromium (15%) and nickel (1%).
   - It resists corrosion in moist air.
   - It is used for making cutlery, surgical instruments and ornamental pieces.
2. **Brass**
   - It is an alloy of copper.
   - Its composition is copper (60 to 80%) and zinc (40 to 20%).
   - It is yellow in colour, more malleable and ductile than copper. It resists corrosion better than other metals.
   - It is used for making shells of ammunition rounds, utensils, electric switches and statues.
3. **Bronze**
   - It is an alloy of copper.
   - Its composition is copper (80%), zinc (10%) and tin (10%).
   - It is hard but brittle in nature. It is resistant to corrosion and takes very high polish.
   - It is used for making statues, coins and utensils.
4. **Solder**
   - It is an alloy of lead.
   - Its composition is 60% lead and 40% tin.
   - It melts around 200°C and can be drawn into fine wires. It offers good electrical resistance.
   - It is used for soldering electric wires in electric devices, such as radio, television, etc. It is also used for making electric fuse wires.
5. **Amalgam**
   - It is an alloy of mercury, with one or more other metals.
   - An amalgam made up of mercury, silver, tin and zinc is used by dentists for fillings in the teeth.

DID YOU KNOW?

The iron pillar near Qutub Minar was made around 400 BC. It is a marvel of Indian metallurgy achieved by the Indian metal workers. It is 8 m tall and weighs 6 tonnes. This pillar has not rusted in the last 24 centuries. It is likely because of the formation of thin film of magnetic oxide of iron [Fe_3O_4] on its surface, as a result of the finishing treatment given to the pillar, by painting it with a mixture of different salts, then heating and quenching in water.



Fig. 3.40: Iron Pillar

SAMPLE PROBLEMS

1. Which metals do not corrode easily?

Ans. The metals of low reactivity do not get corroded easily, for example, gold, platinum, chromium do not get corroded.

2. What are alloys?

Ans. A homogeneous mixture of a metal with other metals or with a nonmetal is called an alloy.

(a) Brass is an alloy of two metals–copper and zinc.

(b) Steel is an alloy mainly of one metal and one non-metal–Iron (metal) and carbon (non-metal).

3. You must have seen tarnished copper vessels being cleaned with lemon or tamarind juice. Explain why these sour substances are effective in cleaning the vessels.

Ans. Copper when exposed to moist air gets tarnished due to the formation of basic copper carbonate [$CuCO_3.Cu(OH)_2$]. Lemon or tamarind juice contains organic acids. These acids react with the basic copper carbonate and clean the surface.

4. State two ways to prevent the rusting of iron.

Ans. (a) By galvanisation of iron

(b) By surface coating with oil, grease, paint and varnish

5. Give reasons why copper is used to make hot water tanks and not steel (an alloy of iron).

Ans. This is because copper is the best conductor of heat (next only to silver).

KEY POINTS

- Elements can be classified as metals and non-metals.
- Metals are generally hard, have high melting and boiling points, are malleable, ductile and have high tensile strength, have lustre, are good conductors of heat and electricity and are sonorous.
- Non-metals are not hard, have no lustre, have low melting and boiling points, are not malleable, ductile or tensile and are poor conductors of heat and electricity.
- Metals generally have 1 to 3 electrons in their valence shell. They lose (donate) these electrons to form positively charged ions. The formation of ion from a metal due to loss of electron is basically an oxidation process, and hence, metals are reducing agents.
- Metals combine with oxygen to form their oxides that are basic in nature. However, the oxides of zinc and aluminium are acidic as well as basic in nature. They are called amphoteric oxides.
- Different metals have different reactivities with water and dilute acids.
- A list of metals arranged in the order of their decreasing chemical reactivity is known as the activity series of metals.
- Metals above hydrogen are called reactive metals. They displace hydrogen from dilute acids.
- Metals occur in nature as free elements or in the form of their compounds.
- Unwanted earthly material present in an ore is called gangue.
- A substance which during smelting combines with the earthly impurities present in the ore to form a fusible slag is called a flux.
- Ores are concentrated by using any of the following methods: Hydraulic washing, Magnetic separation, Froth flotation process, Leaching process. Sulphide ores are concentrated by froth flotation process.
- Heating of an ore strongly in limited air below its melting point is called calcination.
- The process of heating an ore strongly below its melting point but in the presence of excess air is called roasting.
- The metal oxide present in a calcined/roasted ore is reduced to metal by using a suitable reducing agent. The choice of the reducing agent depends upon the reactivity of the metal.
- The oxides of moderately reactive metals, such as Fe, Zn, Cu, Ni and Sn which appear in the middle of the reactivity series are reduced by heating with carbon.
- The oxides of metals which react with carbon are reduced by using aluminium powder. Aluminium is used for reducing manganese dioxide (MnO_2) to manganese, iron oxide (Fe_2O_3) to iron and chromium oxide (Cr_2O_3) to chromium.
- Oxides and halides of highly reactive metals, such as sodium, potassium, magnesium and aluminium, etc., are reduced to their respective metals by electrolytic reduction method.
- The process of removing impurities from the metals extracted from their ores is called refining of metals.
- Metals having low melting points, such as tin, lead, bismuth, etc., are refined by liquation method.
- Most metals are refined by electrolytic method.
- Zone refining method is used to obtain metals in high purity state. High purity silicon and germanium are obtained by zone refining method.
- Van Arkel method is used for obtaining metals such as titanium (Ti) in very high purity silicon state.
- A homogeneous mixture of a metal with other metals or with a non-metal is called alloy.
- Brass, bronze, stainless steel, magnalium are some typical alloys.
- Slow destruction of metals due to their interaction with the environment is called corrosion.



- Corrosion takes place in the presence of moist air and reactive gases, such as oxides of sulphur and nitrogen, industrial fumes, etc.
- Iron objects/surfaces when exposed to moist air get rusted.
- Rusting can be prevented by covering the surface with oil, paint, varnish, with a thin layer of zinc, tin, chromium and by alloying.
- Underground pipelines, etc., can be protected from rusting by connecting these to a more electropositive metal, such as magnesium.

Exercise-3 (C)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

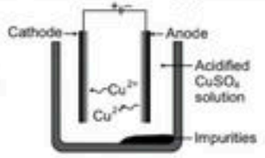
1. The electromagnetic concentration of ore is followed when :
   (A) ore is magnetic in nature
   (B) ore is non-magnetic, but gangue is magnetic in nature
   (C) both ore and gangue are magnetic in nature
   (D) both (A) and (B)

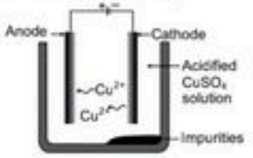
2. Silver articles become black on prolonged exposure to air. This is due to the formation of :
   (A) Ag_3N (B) Ag_2O (C) Ag_2S (D) Ag_2S and Ag_3N [HOTS]

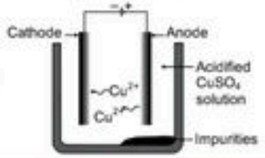
3. Metals are refined by using different methods. Which of the following metals are refined by electrolytic refining?
   (i) Au (ii) Cu (iii) Na (iv) K
   (A) (i) and (ii) (B) (i) and (iii) (C) (ii) and (iii) (D) (iii) and (iv) [HOTS]

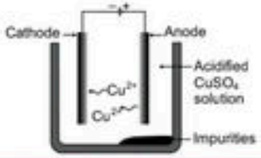
4. Alloys are homogeneous mixtures of a metal with a metal or non-metal. Which among the following alloys contain a non-metal as one of its constituents?
   (A) Brass (B) Bronze (C) Amalgam (D) Steel [HOTS]

5. Which one of the following figures correctly describes the process of electrolytic refining?

(A)


(B)


(C)


(D)


[HOTS]

Ans: 1. (D) 2. (C) 3. (C) 4. (D) 5. (C)

II. ASSERTION (A) AND REASON (R)

For question numbers 1 and 5, two statements are given one labelled *Assertion* (A) and the other labelled *Reason* (R). Select the correct answer to these questions from the codes (i), (ii), (iii) and (iv) as given below.

(i) Both A and R are true and R is the correct explanation of the assertion.
(ii) Both A and R are true but R is not the correct explanation of the assertion.
(iii) A is true but R false.
(iv) A is false but R is true.

1. **Assertion:** Metals are electropositive elements.
   Reason: Metals form positive ions by losing electrons.

2. **Assertion:** Diamond is a non-metal.
   Reason: Diamond has a very high melting point.

3. **Assertion:** All ores are mineral, but all minerals are not ores.
Reason: The natural material containing metals in the free or combined state are called minerals.
4. **Assertion:** Roasting is the process of heating a concentrated ore in the presence of excess of air.
Reason: Roasting is generally employed in case of carbonate ores.
5. **Assertion:** A heterogeneous mixture of two or more metals (or a non-metal) is called an alloy.
Reason: Amalgams are alloys of mercury.

III. VERY SHORT ANSWER TYPE QUESTIONS

1. What would happen to the iron railings on the roadside if they are not painted? Why does it happen so?
2. Write the chemical equation for reaction taking place when zinc carbonate is calcined.
3. Write one constituent each of brass and bronze that is common to both.
4. Name the main constituents of common brass.
5. A green layer is gradually formed on a copper plate left exposed to air for a week in a bathroom. What could this green substance be?
6. Name an ore of zinc other than zinc oxide. By what process can this ore be converted to zinc oxide.
7. Name the anode and cathode used in the electrolytic refining of copper.
8. Why should metal sulphides and carbonates be converted to metal oxides in the process of extraction of metals from them? [HOTS]

IV. SHORT ANSWER TYPE QUESTIONS

1. Write chemical equations for reactions taking place when :
(i) cinnabar is heated in air. (ii) calcium metal reacts with water.
2. Write chemical equations for reactions taking place when :
(i) manganese dioxide is heated with aluminium powder. (ii) steam is passed over hot iron.
3. Write chemical equations for reactions taking place when
(i) a piece of zinc is placed in a solution of copper (II) sulphate.
(ii) sulphur dioxide gas is dissolved in an excess of NaOH solution.
4. Name any two non-metals that are used in industry. How is each one of them important to us?
5. Define the term "alloy". Write two advantages of making alloys.
6. Why do we make alloys? State any two reasons.
7. What are the constituents of bronze? Write its two main uses. Name the common constituent of brass and bronze.
8. Write chemical equations to show what happens when :
(i) manganese dioxide is heated with aluminium. (ii) cinnabar is roasted in a furnace.
9. The oxide X_2O_3 is unaffected by water. Outline a method by which a sample of metal X can be obtained from its ore. Give one reason as to why have you chosen this method.
10. In nature, aluminium is found in the form of its compounds while gold is found in the free state. Give reasons.
11. Explain how the following metals are obtained from their compounds by the reduction process.
(i) Metal M, which is in the middle of the reactivity series.
(ii) Metal N, which is high up in the reactivity series.
12. The following reaction takes place when aluminium powder is heated with MnO_2
$3MnO_2(s) + 4Al(s) \longrightarrow 3Mn(l) + 2Al_2O_3(l) + Heat$
(a) Is aluminium getting reduced? (b) Is MnO_2 getting oxidised? [HOTS]
13. What are the constituents of solder alloy? Which property of solder makes it suitable for welding electrical wires?
14. A metal A, which is used in the thermite process, when heated with oxygen gives an oxide B, which is amphoteric in nature. Identify A and B. Write down the reactions of oxide B with HCl and NaOH. [HOTS]
15. Give the reaction involved during the extraction of zinc from its ore by
(a) roasting of zinc ore. (b) calcination of zinc ore. [HOTS]



16. What happens when
(a) $ZnCO_3$ is heated in the absence of oxygen? (b) a mixture of Cu_2O and Cu_2S is heated? [HOTS]

17. Write chemical equations to show the reactions taking place when :
(i) zinc carbonate is calcined.
(ii) carbon dioxide gas is bubbled into lime water for a long time.

18. What is meant by refining of metals? Describe the electric refining of copper with a neat labelled diagram.

19. Explain how the following metals are obtained from their compounds by the reduction process :
(a) Metal "X", which is low in the reactivity series.
(b) Metal "Y", which is in the middle of the series.
(c) Metal "Z", which is high up in the reactivity series.

20. What is an alloy? Name the constituents of (i) brass and (ii) bronze. Give one use of bronze specifying the property on which this is based.

21. Name with examples three common compounds in which metals occur in nature. Write chemical equations for the metals reacting with a dilute acid to produce hydrogen gas.

22. (i) Explain what corrosion of iron means.
(ii) Why is it that aluminium, which is more reactive than iron does not corrode like iron?
(iii) How is the corrosion of iron prevented by coating it with a layer of oil?

23. State reasons for the following :
(i) Metals are good conductors of heat.
(ii) Addition of some silver to pure gold for making ornaments.
(iii) Inability of a non-metal in displacing hydrogen from dilute sulphuric acid.

24. What is an alloy? Name the constituents of 22-carat gold. Why is 24-carat gold converted to 22-carat gold?

25. Explain the following terms by giving one example of each :
(i) Mineral, (ii) Ore, (iii) Gangue

26. (i) Explain the term, 'roasting' as used in metallurgical processes. Give one suitable example for it.
(ii) What changes take place when cinnabar (HgS) is heated in air for a long time?

27. (a) Name an important ore of iron. Write its formula.
(b) How is this ore concentrated?

28. (a) Name the chief ore of iron. Write its formula.
(b) How is iron ore concentrated? Describe it briefly.

29. Why is it necessary to concentrate an ore before processing? Draw a labelled diagram of 'Froth Floatation Process' for concentrating an ore. State the principle of this process.

30. Describe with labelled diagram, the Froth Floatation Process used to separate the gangue from a sulphide ore.

31. Name the process of obtaining a pure metal from an impure metal through electrolysis. Suppose you have to refine copper using this process, then explain with the help of a labelled diagram the process of purification, mentioning in brief the materials used as (i) anode, (ii) cathode and (iii) electrolyte.

32. During extraction of metals, electrolytic refining is used to obtain pure metals.
(a) Which material will be used as the anode and cathode for refining of silver metal by this process?
(b) Suggest a suitable electrolyte also.
(c) In this electrolytic cell, where do we get pure silver after passing electric current? [HOTS]

33. A metal that exists as a liquid at room temperature is obtained by heating its sulphide in the presence of air. Identify the metal and its ore and give the reactions involved. [HOTS]

34. Compound X and aluminium are used to join railway tracks.
(a) Identify the compound X. (b) Name the reaction. (c) Write down the reaction. [HOTS]

V. LONG ANSWER QUESTIONS

1. (a) Distinguish between roasting and calcination. Which of these two is used for a sulphide ore and why?
(b) Write the chemical equation to illustrate the use of aluminium for joining cracks in railway lines.

(c) Name the anode, the cathode and the electrolyte used in the electrolytic refining of impure copper metal.

2. An ore on heating in air produces sulphur dioxide. What process would you suggest for its concentration. Describe briefly any two steps involved in the conversion of this concentrated ore into the related metal.

3. Give reason for the following:
   (a) Metals conduct electricity.
   (b) Metals generally do not form compounds with hydrogen.
   (c) A piece of zinc placed in blue copper sulphate solution decolourises it.
   (d) Alumina is dissolved in molten cryolite for electrolysis to obtain aluminium metal.
   (e) Nitrogen gas is used to preserve food.

4. (a) Define the terms, mineral, ore and gangue as used in metallurgical operations.
   (b) Describe with a labelled diagram, the method of concentration of a sulphide ore.
   (c) Differentiate between roasting and calcination.

5. (a) What method for concentration of ore is preferred in each of the following cases and why?
      (i) The ore has higher density particles interspersed with a large bulk of low density impurities.
      (ii) The ore consists of copper sulphide intermixed with clay particles.
   (b) Give an example of amalgam.

6. (i) Define the terms "alloy" and "amalgam". Name the alloy used for welding electric wires together. What are its constituents?
   (ii) Name the constituents of the following alloys:
      (a) Brass, (b) Stainless steel and (c) Bronze
      State one property in each of these alloys that is different from its main constituents.

7. Differentiate between an 'alloy' and an 'amalgam'. How are alloys made? State with examples any two properties in which an alloy may be different from those of its constituents. Write the constituents and special advantages of : (i) stainless steel and (ii) magnalium.

8. Describe with examples the following steps associated with the extraction of metals from their ores : (i) Froth floatation process, (ii) Roasting of an ore and (iii) Calcination of an ore.

9. What is meant by the term 'enrichment of ore'? Name four methods generally used for enrichment of ores. With the help of a labelled diagram, describe the method for the enrichment of sulphide ores.

10. (a) What is corrosion of metals? Name one metal that does not corrode and one that corrodes on being kept in the atmosphere.
    (b) How will you show that rusting of iron needs oxygen and moisture at the same time?

11. (i) Given below are the steps for extraction of copper from its ore. Write the reaction involved.
      (a) Roasting of copper (I) sulphide.
      (b) Reduction of copper (I) oxide with copper (I) sulphide.
      (c) Electrolytic refining.
    (ii) Draw a neat and well-labelled diagram for electrolytic refining of copper. [HOTS]

12. Give the steps involved in the extraction of metals of low and medium reactivity from their respective sulphide ores. [HOTS]

VI. PASSAGE–BASED QUESTIONS

Answer the questions (1–4) on the basis of your understanding of the following paragraphs and the related studied concepts.

Anodising is a process of forming a thick oxide layer of aluminium. Aluminium develops a thin oxide layer when exposed to air. This aluminium oxide coat makes it resistant to further corrosion. The resistance can be improved further by making the oxide layer thicker. During anodising, a clean aluminium article is made the anode and is electrolysed with dilute sulphuric acid. The oxygen gas evolved at the anode reacts with aluminium to make a thicker protective oxide layer. This oxide layer can be dyed easily to give aluminium articles an attractive finish.

1. Aluminium is a highly reactive metal, but aluminium articles do not corrode easily. Why?
2. If a scratch is made on the surface of anodised aluminium article. Does the article corrode at the scratched area? Why?
3. Why is aluminium called as self-protecting corrosion-resistant metal?
4. Which other metal is known as self-protecting corrosion-resistant metal?



4 Carbon and Its Compounds

INSIDE THE CHAPTER

4.1 Occurrence of carbon
4.2 Covalent bonding in carbon compounds
4.3 Versatile nature of carbon
4.4 Allotropes of carbon
4.5 Organic compounds
4.6 Kinds of formulae of organic compounds
4.7 Hydrocarbons
- Saturated hydrocarbons
- Unsaturated hydrocarbons
- Cyclic hydrocarbons

4.8 Nomenclature of organic compounds
4.9 Isomers
4.10 Homologous series
4.11 Functional groups
- Haloalkanes • Alcohol • Aldelydes • Ketones
- Carboxylic acids

4.12 Chemical properties of carbon compounds
- Combustion of carbon and its compounds
- Oxidation of carbon compounds
- Substitution reactions of organic compounds
- Addition reactions of organic compounds

4.13 Important carbon compounds
- Ethanol • Ethanoic acid

4.14 Soaps and detergents

0LUEOXIB81

INTRODUCTION

Carbon is considered the third most important element, after oxygen and hydrogen, for the existence of life on earth. As a matter of fact, elements hydrogen, oxygen, carbon and nitrogen are called ***organogens***, which means, these elements are found in organic compounds.

Organic compounds are carbon compounds in which one or more atoms of carbon are covalently linked to atoms of other elements, most commonly hydrogen, oxygen or nitrogen.

Although carbon constitutes only 0.02% of the earth's crust, it is very special and important because it can form innumerable compounds. The importance of carbon can be determined from the fact that carbon is essential for life on earth, as it is the main constituent of organic compounds. Organic compounds make up the cells and other structures of organisms and carry out life processes.

Fuel, clothes, food, paper, plastics, drugs and dyes which we use in our daily life are made of carbon compounds.



Fig. 4.1: Element carbon (coal)



Fig. 4.2: Organic compounds are the basis of life on earth



Fig. 4.3: Most of the food materials are made up of organic compounds

4.1 OCCURRENCE OF CARBON

Carbon occurs in free as well as in combined states in nature.

Free States of Carbon

Diamond, graphite and coal are the free states of carbon. Diamond is the purest form of carbon, whereas graphite is somewhat less pure. Coal is an impure form of carbon in which percentage of carbon varies from 60 to 90%.

Combined States of Carbon

In the combined state, carbon occurs in the form of its compounds in solid, liquid and gaseous states.

Solid states of combined carbon: In nature, all animal and plant products in solid state are compounds of carbon, such as cellulose, carbohydrates, fats, proteins, etc. It also occurs as mineral salts in the form of carbonates.

Liquid states of combined carbon: Petroleum is a mixture of carbon compounds found in the liquid state. It consists of petrol, kerosene, diesel, furnace oil, grease and wax. In addition, vegetable oils are the liquid states of combined carbon.

Gaseous states of combined carbon: Air contains 0.03% by volume of carbon dioxide, which is a gaseous state of combined carbon. In addition, natural gas, marsh gas, petroleum gas and coal gas contain carbon in the form of its compounds.

NBJPHUWK1R

4.2 COVALENT BONDING IN CARBON COMPOUNDS

Element	:	Carbon
Atomic number	:	6
Electronic configuration	:	K L 2 4

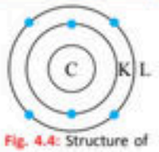


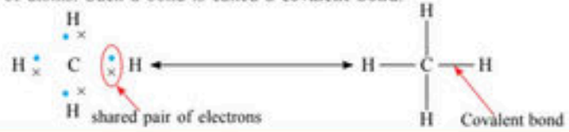
Fig. 4.4: Structure of carbon atom

A neutral atom of carbon contains 6 electrons, such that 2 electrons are in its K-shell and 4 electrons in its L-shell. From the electronic configuration of carbon it is clear that its valence shell has 4 electrons. Carbon atom has 4 valence electrons. In order to attain a stable electronic configuration of the nearest noble gas, it should either lose 4 electrons or gain 4 electrons.

1. The atomic size of carbon atom is very small, hence the valence electrons of carbon atoms are strongly held by its nucleus. It will require a large amount of energy to take out four electrons from the attractive pull of its nucleus.
2. As the size of carbon atom is very small and its nucleus has only 6 protons, it will also require a large amount of energy to gain four extra electrons.

So, both the options are impracticable. However, carbon atom overcomes this problem by sharing its valence electrons with either other carbon atoms or the atoms of other non-metals.

During the sharing of electrons, **each atom of an element contributes one electron, thereby forming an electron pair, mutually shared by both the atoms**. Due to this mutual sharing of electrons, a new kind of bond develops between the given pair of atoms. Such a bond is called a **covalent bond**.



The covalent bond between a pair of atoms is represented by a small line [—] and is called a **single covalent bond**.



However, if two given atoms share two electrons each, that is, ***each atom contributes two electrons so as to form two electron pairs***, then the bond, so formed, is called a ***double covalent bond*** and is represented by two small parallel lines [=].



Similarly, if three electrons each are contributed by two atoms, so as to form ***three shared electron pairs***, then the bond, so formed, is called a ***triple covalent bond*** and is represented by three small parallel lines [≡].



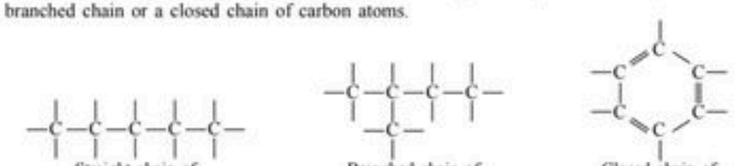
3R57EJ4V0H

4.3 VERSATILE NATURE OF CARBON

Organic compounds are made up of carbon, hydrogen, oxygen and a few other elements. More than 90 elements are involved in the formation of inorganic compounds. However, the number of organic compounds is much bigger than inorganic compounds. The existence of such a large number of organic compounds is because of the versatile nature of carbon.

The characteristic features seen in carbon, namely, ***tetravalency*** and ***catenation***, together give rise to a large number of compounds.

1. **Tetravalency :** Carbon has 4 electrons in its valence shell. Energy considerations do not allow it to gain or lose 4 electrons. Therefore, it forms covalent bonds with other elements to complete its octet. This accounts for its ***tetravalency*** and explains its ability to form a variety of compounds.
2. **Catenation:** When a carbon atom shares electrons with the neighbouring carbon atoms, it forms a straight chain or a branched chain or a closed chain of carbon atoms.



The property of self-linking with other carbon atoms to form long straight chains, branched chains and rings is called ***catenation***.

4.4 ALLOTROPES OF CARBON

YK58FUWR5N

Some chemical elements exist in two or more different forms in the same physical state are known as **allotropes** of the elements.

The element carbon occurs in free state in different crystalline forms in nature, such as diamond, graphite and fullerenes. The difference in their physical properties is due to the difference in the arrangement of carbon atoms in their crystal.

Diamond

It is a solid form of element carbon. In diamond, the carbon atoms are arranged in a crystal structure called diamond cubic.

Most natural diamonds have ages between 1 and 3.5 billion years. Most diamonds were formed at depths between 150 and 250 kilometres in the earth's mantle.

Diamond is the hardest and the least compressible substance. It has a high density, ranging from 3150 to 3530 kilograms per cubic metre. Diamonds have been adapted for many uses because of the material's exceptional physical characteristics. Diamond is also chemically inert towards most corrosive substances.

Structure of diamond

The crystal structure of diamond is called diamond cubic. In a regular diamond crystal, each carbon atom is held firmly in place by four bonds of the neighbouring carbon atoms. Such a configuration form highly strong bonds and hence makes it the hardest naturally occurring substance.

Uses of diamond

1. Diamonds are used in making jewellery, such as rings and necklaces, because of their durability and luster.
2. Diamonds are mostly used industrially. Because of their hardness. Diamonds are extremely useful when used to cut, grind or drill other materials. Therefore, many cutting blades or drills have small diamonds included on tips and edges.



Fig. 4.5: Diamond

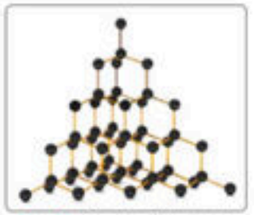


Fig. 4.6: Structure of diamond

3. Sharp-edged diamonds are used by eye surgeons to remove cataract from eyes.

Graphite

Graphite occurs naturally in metamorphic and igneous rocks. It is usually formed when carbon is subjected to a high temperature and pressure in the earth's crust. Graphite is found all over the world in its natural form. It is usually classified into three forms namely flake, crystalline and amorphous depending on the source of the mineral.

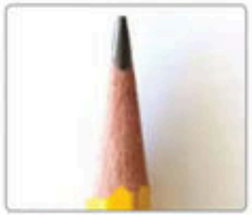


Fig. 4.7: Graphite in pencil

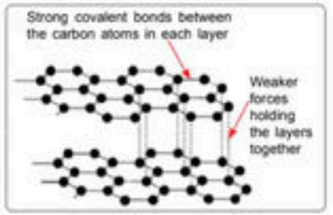


Fig. 4.8: Structure of graphite

Graphite is soft in nature and it splits easily even with light pressure. It is black or greyish in colour. It is an excellent conductor of electricity and heat. Graphite can also withstand extreme temperatures.

1. 'Graphite' means 'to write.' It was named by Abraham Gottlob Werner in 1789. The word 'graphite' comes from Ancient greek language. The most common use of graphite is in making pencil lead.
2. Graphite is one of the main ingredients in lubricants. This mineral reacts with atmospheric vapour and creates a thin film or layer over the surface it is applied and thus reduces friction.

3. Graphite is used in the manufacture of carbon electrodes, brushes and plates needed in dry cell batteries and the electrical industry.

Fullerenes

Crystalline forms of carbon having 30 to 960 atoms in their molecules are called Fullerenes. One of the members of fullerenes family is **Buckminsterfullerene**. It is a spherical crystalline form of carbon having 60 atoms in its molecule. It is obtained by condensing vapourised graphite in helium. **Buckminsterfullerene** also occurs naturally in dust between stars and in some carbon rich rocks.

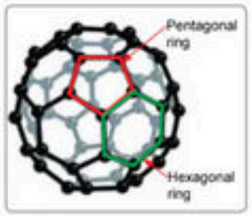


Fig. 4.9: The structure of Buckminsterfullerene


Fig. 4.10: Fullerenes have been named after Buckminster Fuller's geodesic dome

In **Buckminsterfullerene**, each molecule has 60 carbon atoms arranged in 20 hexagons and 12 pentagons. Buckminsterfullerene is a bad conductor of electricity, but some members of fullerene family are superconductors, that is, they do not offer any resistance to electric current.

1. Fullerenes were discovered by **H.W. Kroto, R. F. Curl and R.E. Smalley** in 1985, for which these scientist were awarded Nobel Prize in 1996.
2. The actual chemical name of fullerenes is spheroidal carbon cage molecule.
3. C_{60} molecule has been named as Buckminsterfullerene after the name of an American architect Robert Buckminster Fuller, who designed steel structures similar to those of fullerene molecules.

Fullerenes have been found in nature :
- in ancient rocks in Russia and New Zealand.
- in a crater created by a meteorite in Germany.

Assess Yourself – 1

1. Explain, by giving a reason, why is it very difficult to form (i) cation C^{4+}, (ii) anion C^{4-}.
2. (a) Why does carbon form compounds mainly by covalent bonding?
   (b) List any two reasons for carbon forming a very large number of compounds.
3. Define allotropy. Give one example of allotropy.
4. What is catenation? Explain with examples.
5. How is tetravalency an important factor for the formation of a large number of compounds by carbon?

8TWPJGQUBE

4.5 ORGANIC COMPOUNDS

Generally, all organic compounds consist of carbon and hydrogen atoms. However, many organic compounds contain oxygen, nitrogen, sulphur, phosphorus and halogens.

The compounds of carbon, other than oxides of carbon (carbon monoxide and carbon dioxide), carbonates, hydrogen-carbonates and carbides are called ***organic compounds.***

Examples : Methane, ethane, ethyl alcohol, acetic acid, acetone, formic acid, formaldehyde, etc.

All living things like plants and animals contain four major categories of organic compounds, for example, carbohydrates, lipids, proteins and nucleic acids. Till 1828, it was thought that organic compounds could be derived from plants and animals, that is, from the living beings only.

Chemists found it impossible to synthesise organic compounds in the laboratory. They thought some **vital force** is necessary to synthesise organic compounds, which is present only in living animals and plants. This basically meant that they are syntheised only within the living species (plants and animals). This in turn gave rise to the **vital force theory**. According to this theory. *"organic compounds cannot be prepared in the laboratory from the elements."*

In 1828 German chemist **Friedrich Wohler** succeeded in synthesising **urea**, an **organic compound,** from its elements. This achievement of Wohler, gave a death blow to the vital force theory.

Now-a-days chemists are preparing more synthetic organic compounds in their laboratories than the known organic compounds in nature.

The branch of chemistry dealing with organic compounds is called ***organic chemistry***.

Characteristics of Organic Compounds

1. **Composition:** An organic compound generally consists of carbon and hydrogen atoms. However, some compounds contain, oxygen, nitrogen, sulphur, phosphorus and halogens.
2. **Nature:** All organic compounds are non-ionic in nature. The various atoms of other elements are joined to carbon atoms with covalent bonds.
3. **Solubility:** Most of the organic compounds are insoluble in water but soluble in organic solvents like, alcohol, ether, benzene, etc.
4. **Melting point and boiling point:** All organic compounds have relatively low melting and boiling points.
5. **Combustibility:** All organic compounds burn easily to form carbon dioxide and water vapour as the main products.

4.6 KINDS OF FORMULAE OF ORGANIC COMPOUNDS

5FIHWRMD3O

1. **Molecular formula:** The formula of an organic compound which represents the kind of atoms and the number of each kind of atoms present in one molecule is called **molecular formula**.

   The molecular formula of an organic compound represents :

   (i) kind of atoms present in one molecule of the compound;

   (ii) the number of each kind of atoms present in one molecule.

   Example: Molecular formula of butane is C_4H_{10}. It represents :

   (i) one molecule of butane consists of carbon and hydrogen atoms.

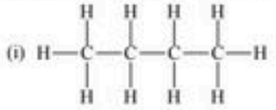
   (ii) one molecule of butane consists of 4 carbon atoms and 10 hydrogen atoms.

2. **Structural formula:** The formula of an organic compound which represents the arrangement of various atoms in one molecule in space is called **structural formula**.

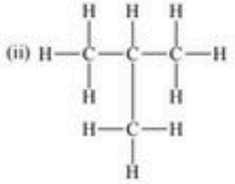
   Organic compounds can have the same molecular formula, but different structural formulae as shown below.

   Molecular formula of butane is C_4H_{10}.

   Structural formulae of butane are as under :

(i) 

n-butane

(ii) 

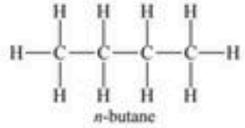
iso-butane

3. **Condensed formula:** A kind of structural formula, which indicates the group of atoms joined together to each of the carbon atom in straight or branched carbon chains is called ***condensed formula***.

Example: Molecular formula of butane is C_4H_{10}

Structural and condensed formulae of butane are as shown under :

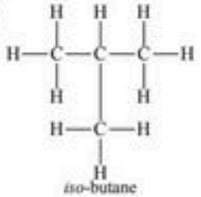
(i)



n-butane

∴ Condensed formula of *n*-butane is $CH_3—CH_2—CH_2—CH_3$

(ii)



iso-butane

∴ Condensed formula of *iso*-butane is $CH_3—\underset{\displaystyle CH_3}{\overset{\displaystyle |}{CH}}—CH_3$

PTAD96WL75

4.7 HYDROCARBONS

The compounds made up of only carbon and hydrogen are called ***hydrocarbons***.

Carbon + Hydrogen → Hydrocarbon

Examples : Methane (CH_4), ethane (C_2H_6), ethene (C_2H_4), ethyne (C_2H_2). All these compounds are made up of only two elements, carbon and hydrogen.

Most hydrocarbons found on the earth occur naturally in petroleum (crude oil). It consists of naturally occurring hydrocarbons of various molecular weights, which are separated using a technique called fractional distillation.

Classification of Hydrocarbons

Hydrocarbons

Open chain hydrocarbon
They are characterised by the presence of straight or branched chain of carbon atoms in their molecules.

Close chain hydrocarbon
They are characterised by the presence of ring of carbon atoms in their molecules. For example, benzene.

Saturated hydrocarbon (Alkanes)
All carbon atoms in one molecule are joined together by a single covalent bond.

Unsaturated hydrocarbons

Alkenes
Straight or branched chain hydrocarbons such that there is a double covalent bond between two carbon atoms.

Alkynes
Straight or branched chain hydrocarbons such that there is a triple covalent bond between two carbon atoms.

Saturated Hydrocarbons (Alkanes)

HU569QZFR0

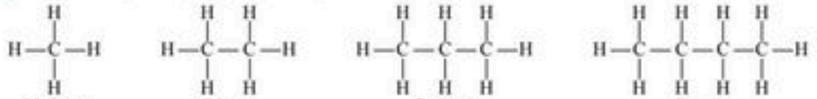
General formula : C_nH_{2n+2}

In saturated hydrocarbons, all four valencies of carbon atoms are fully satisfied by single bonds. These are also called alkanes. So we can define alkanes as, *"Alkanes are the hydrocarbons, in which, all carbon atoms are bonded by carbon-carbon single covalent bonds."* These single bonded compounds are the simplest hydrocarbons. They are also known as paraffins.

Definition of saturated carbon compounds

The compounds of carbon in which each valency of carbon is satisfied by a single covalent bond are called ***saturated carbon compounds***.

Examples: Methane, ethane, propane, butane, etc.



Methane Ethane Propane Butane

General formula of alkanes : $C_nH_{(2n+2)}$, where n = number of carbon atoms.

(i) If $n = 1$
The molecular formula = $C_1H_{(2\times1+2)}$ = CH_4 (Methane)

(ii) If $n = 2$
The molecular formula = $C_2H_{(2\times2+2)}$ = C_2H_6 (Ethane)

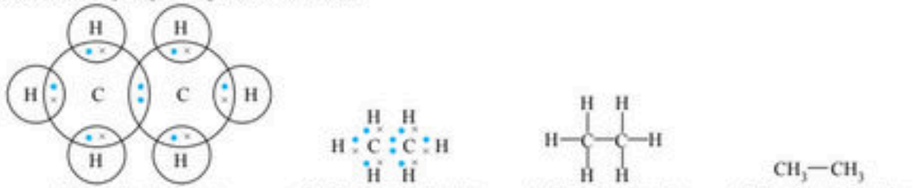
(iii) If $n = 3$
The molecular formula = $C_3H_{(2\times3+2)}$ = C_3H_8 (Propane)

(iv) If $n = 4$
The molecular formula = $C_4H_{(2\times4+2)}$ = C_4H_{10} (Butane)

(v) If $n = 5$
The molecular formula = $C_5H_{(2\times5+2)}$ = C_5H_{12} (Pentane)

The ethane molecule (C_2H_6) is made up of two carbon atoms and six hydrogen atoms. In ethane molecule, the two carbon atoms share one pair of electrons to form a carbon-carbon single covalent bond. This means that each carbon atom shares its one electron with the other carbon atom and the remaining three electrons are shared with three hydrogen atoms, thus forming three carbon-hydrogen single covalent bonds.

As ethane molecule has 2 carbon atoms and 6 hydrogen atoms, thus it has one carbon-carbon single covalent bond and six carbon-hydrogen single covalent bonds.



(a) Structure of ethane molecule (b) Electron-dot structure of ethane molecule (c) Structural formula of ethane molecule (d) Condensed formula of ethane molecule

The three-dimensional (3D)-structures of some alkanes are shown below.

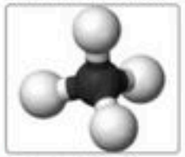


Fig. 4.11: Methane 3D structure

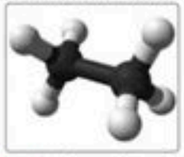


Fig. 4.12: Ethane 3D structure

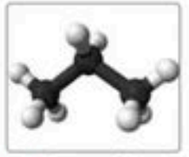


Fig. 4.13: Propane 3D structure

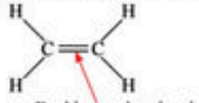
Characteristics of Saturated Carbon Compounds

1. All the valencies of carbon in the molecule of the saturated carbon compounds are fully satisfied by single covalent bonds.
2. These compounds are normally not very reactive in nature.

Unsaturated Hydrocarbons

Z9Y26GS8NX

Unsaturated hydrocarbons are the compounds which consist at least one **double** or **triple covalent bond between two adjacent carbon atoms** in the molecule.



Ethene



Ethyne

The unsaturated compounds which contain a carbon-carbon double covalent bond are called **alkenes**, and the hydrocarbons which contain a carbon-carbon triple covalent bond are called **alkynes**.

Definition of Unsaturated Carbon Compounds

The compounds of carbon in which the valency between two carbon atoms in a carbon chain is satisfied by ***a double covalent bond*** *or* ***a triple covalent bond*** *are called unsaturated carbon compounds.*

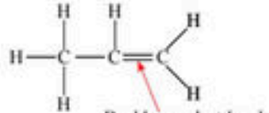
Characteristics of Unsaturated Carbon Compounds

(a) There is a double covalent bond (=) or a triple covalent bond (≡) between two adjacent carbon atoms in the carbon chain of their molecules.

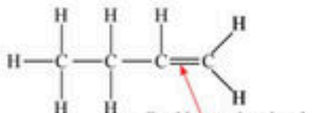
(b) These compounds are chemically far more reactive than saturated compounds of carbon.

1. **Alkenes:** The unsaturated hydrocarbons which contain a double covalent bond between two adjacent carbon atoms are called **alkenes** that is an alkene contains the  group.

Examples : ethene, propene, butene, pentene, etc.



Propene



Butene

General formula of alkenes : C_nH_{2n}, where n stands for number of carbon atoms in one molecule.

Alkene with one carbon atom is not possible as there must be a double bond between two adjacent carbon atoms ($n \neq 1$, $n = 2, 3$).

(i) If $n = 2$
The molecular formula = $C_2H_{(2 \times 2)} = C_2H_4$
(Ethene)

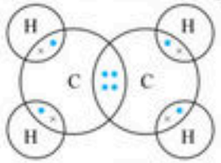
(ii) If $n = 3$
The molecular formula = $C_3H_{(2 \times 3)} = C_3H_6$
(Propene)

(iii) If $n = 4$
The molecular formula = $C_4H_{(2 \times 4)} = C_4H_8$
(Butene)

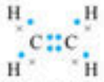
(iv) If $n = 5$
The molecular formula = $C_5H_{(2 \times 5)} = C_5H_{10}$
(Pentene)

In ethene molecule, the two carbon atoms share two pairs of electrons to form a carbon-carbon double covalent bond. This means that each carbon atom shares its two electrons with the other carbon atom and remaining two electrons are shared with two hydrogen atoms (one electron with each hydrogen atom) to form two carbon-hydrogen single covalent bonds.

As ethene molecule has two carbon atoms and four hydrogen atoms, thus, it has one carbon-carbon double covalent bond and four carbon-hydrogen single covalent bonds.



(a) Structure of ethene molecule

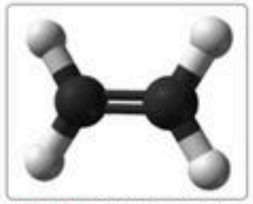


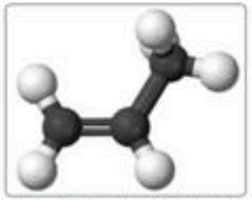
(b) Electron-dot structure of ethene molecule



(c) Structural formula of ethene molecule

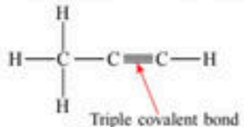
The 3D structures of ethene and propene are shown below.


Fig. 4.14: Ethene 3D structure

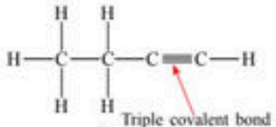

Fig. 4.15: Propene 3D structure

2. **Alkynes :** The unsaturated hydrocarbons which contain a triple covalent bond between two adjacent carbon atoms are called alkynes, that is an alkyne contains —C≡C— group.

Examples : ethyne, propyne, butyne, pentyne, etc.



Propyne



Butyne

General formula of alkynes : C_nH_{2n-2}, where n stands for number of carbon atoms in one molecule.

Alkyne with one carbon atom is not possible as there must be a triple covalent bond between two adjacent carbon atoms (—C≡C—) ($n \neq 1$).

(i) If $n = 2$
The molecular formula = $C_2H_{(2 \times 2 - 2)} = C_2H_2$ (Ethyne)

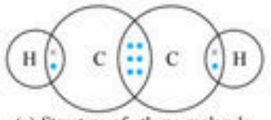
(ii) If $n = 3$
The molecular formula = $C_3H_{(2 \times 3 - 2)} = C_3H_4$ (Propyne)

(iii) If $n = 4$
The molecular formula = $C_4H_{(2 \times 4 - 2)} = C_4H_6$ (Butyne)

(iv) If $n = 5$
The molecular formula = $C_5H_{(2 \times 5 - 2)} = C_5H_8$ (Pentyne)

In ethyne molecule, the two carbon atoms share three pairs of electrons to form a carbon-carbon triple covalent bond and the remaining one electron is shared with a hydrogen atom. Thus, forms a carbon-hydrogen single covalent bond.

As ethyne molecule has two carbon atoms and two hydrogen atoms, so it has one carbon-carbon triple covalent bond and two carbon-hydrogen single covalent bonds.



(a) Structure of ethyne molecule



(b) Electron-dot structure of ethyne molecule



(c) Structural formula of ethyne molecule

The 3D structures of ethyne and propyne are shown below :

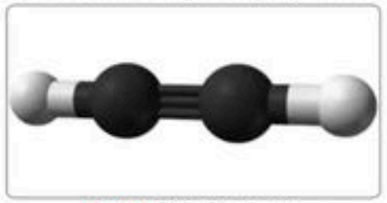


Fig. 4.16: Ethyne 3D structure

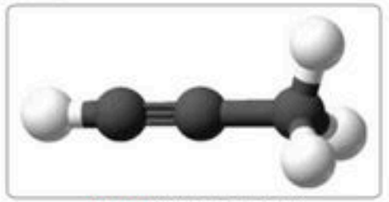


Fig. 4.17: Propyne 3D structure

Assess Yourself – 2

1. Name three major classes of open-chain hydrocarbons.
2. How do saturated hydrocarbons differ from unsaturated hydrocarbons?
3. With reference to butane, explain what do you understand by the following terms :
   (a) Molecular formula
   (b) Condensed formula
   (c) Structural formula
4. What are the general formulas of alkanes, alkenes and alkynes?
5. If $n = 2$, write the molecular formula of alkane, alkene and alkyne.
6. What are closed-chain hydrocarbons? Give example.
7. Why was vital force theory discarded?
8. What do you understand by the following terms :
   (a) Organic compounds
   (b) Organic chemistry
9. Name the scientist who disproved the 'Vital Force Theory'?

DH7YMTW0B2

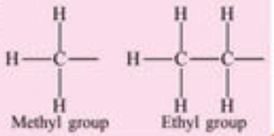
Alkyl group/alkyl radical

An alkyl group is formed by removing one hydrogen atom from an alkane molecule. For example, methyl (—CH_3), ethyl (—C_2H_5), etc.

Methyl group is formed by the removal of one hydrogen atom from methane molecule. Similarly, ethyl group is formed by the removal of one hydrogen atom from ethane molecule.

General formula of alkyl groups is C_nH_{2n+1}.

$$\underset{\text{Alkane}}{C_nH_{2n+2}} \xrightarrow{-H} \underset{\text{Alkyl group}}{-C_nH_{2n+1}}$$



Methyl group

Ethyl group

Characteristics of an alkyl radical

1. The general formula of an alkyl radical is C_nH_{2n+1}, where n denotes the number of carbon atoms in one molecule of the alkyl radical.
2. The alkyl group (or radical) has one **unpaired electron**, which is indicated by a line (——) in case of the structural formula and by a dot (•) in case of electronic formula.
3. An alkyl radical generally keeps its identity during chemical reactions.
4. An alkyl radical forms a single covalent bond with the atoms of other elements or a group of elements (radicals).
5. An alkyl group is denoted by the letter '—R'.

How to find out whether a given hydrocarbon is an alkane, alkene or alkyne from the molecular formula

48FOAIZ1UH

The following steps help us to find whether the hydrocarbon is alkane, alkene or alkyne.

1. Note the number of carbon atoms in the molecular formula of the given hydrocarbon and multiply it with 2.
2. (a) If double the number of carbon atoms is ***two less than the hydrogen atoms in the molecular formula***, then the hydrocarbon is ***alkane***.

   (b) If double the number of carbon atoms is ***equal to the hydrogen atoms in the molecular formula***, then the hydrocarbon is ***alkene***.

   It must be kept in mind that an alkene is characterised by the presence of a double bond between two carbon atoms ($>C=C<$) and is an unsaturated hydrocarbon.

   (c) If double the number of carbon atoms is ***two more than the hydrogen atoms in the molecular formula***, then the hydrocarbon is ***alkyne***.

   It must be kept in mind that an alkyne is characterised by the presence of a triple bond ($-C\equiv C-$) between two carbon atoms and is an unsaturated hydrocarbon.

   Following sample problem will make the above rules clear.

SAMPLE PROBLEMS

1. C_4H_6, C_3H_6, and C_2H_6, are hydrocarbons. Identify the (i) alkane, (ii) alkene and (iii) alkyne and state clearly which of them are saturated or unsaturated.

Ans. (a) For C_4H_6

Number of carbon atoms in the molecular formula = 4

$\therefore$ Double the number of carbon atoms = $4 \times 2 = 8$.

As double the number of carbon atoms are two more than the total number of hydrogen atoms in the molecule of C_4H_6 it corresponds to the general formula C_nH_{2n-2}.

$\therefore$ C_4H_6 is an **alkyne**. It is an **unsaturated hydrocarbon**.

(b) For C_3H_6

Number of carbon atoms in the molecular formula = 3

Double the number of carbon atoms = $3 \times 2 = 6$.

As double the number of carbon atoms are equal to the total number of hydrogen atoms in the molecule of C_3H_6, it corresponds to the general formula C_nH_{2n}.

C_3H_6 is an ***alkene***. It is an ***unsaturated hydrocarbon***.

(c) For C_2H_6

Number of carbon atoms in molecular formula = 2

$\therefore$ Double the number of carbon atoms = $2 \times 2 = 4$.

As double the number of carbon atoms are two less than the total number of hydrogen atoms in the molecule of C_2H_6, it corresponds to the general formula C_nH_{2n+2}.

C_2H_6 is an ***alkane***. It is a ***saturated hydrocarbon***.

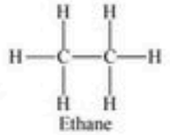
2. Ethane with the molecular formula C_2H_6 has : [NCERT]

(A) 6 covalent bonds (B) 7 covalent bonds

(C) 8 covalent bonds (D) 9 covalent bonds

Ans. (B) 7 covalent bonds

Explanation : Ethane molecule has one carbon-carbon single covalent bond and six carbon-hydrogen single covalent bonds.


Ethane

3. Which of the following hydrocarbons is saturated?

C_2H_4, C_5H_{10}, C_3H_8, C_4H_8

Ans. We know that alkanes are saturated hydrocarbons. Out of the above compounds, C_3H_8 is an alkane.

General formula of alkanes = C_nH_{2n+2}

Here, $n = 3$, then molecular formula = $C_3H_{2\times3+2} = C_3H_8$

4. If $n = 3$, write the molecular formula of alkane, alkene, and alkyne.

Ans. If $n = 3$

Molecular formula for alkane = $C_3H_{(2\times3+2)} = C_3H_8$

Molecular formula for alkene = $C_3H_{(2\times3)} = C_3H_6$

Molecular formula for alkyne = $C_3H_{(2\times3-2)} = C_3H_4$

5. Which of the following compounds have a triple covalent bond?

C_2H_4, C_3H_8, C_3H_6, C_4H_6

Ans. Alkynes have a triple covalent bond between two adjacent carbon atoms.

General formula of alkynes = C_nH_{2n-2}

Here C_4H_6 has a triple covalent bond.

6. Which of the following compounds have a double and triple covalent bonds?

C_2H_4, C_2H_6, C_3H_4

Ans. Alkenes have a double covalent bond between two adjacent carbon atoms.

General formula of alkenes = C_nH_{2n}

Here, C_2H_4 has a double covalent bond.

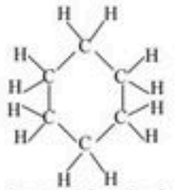
Note: Please solve the remaining part of the problem by yourself.

Cyclic Hydrocarbons

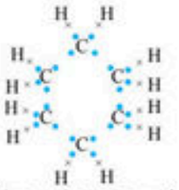
The cyclic hydrocarbons are hydrocarbons having a ring structure. Cyclic hydrocarbons are also of two types, namely saturated and unsaturated.

1. **Saturated Cyclic Hydrocarbons:** In this kind of hydrocarbons, the carbon atoms are arranged in the form of a ring and are bonded by single covalent bonds.

   An example of this kind of hydrocarbons is cyclohexane of molecular formula C_6H_{12}. The right side figures show the structural and electron dot diagram of the molecule of cyclohexane.



Structural formula of cyclohexane



Electron-dot structure of cyclohexane

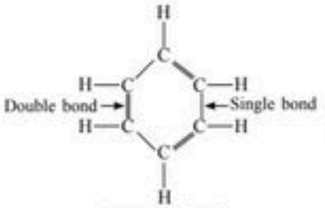
   As we saw the molecular formula of cyclohexane, contains 6 carbon atoms and 12 hydrogen atoms. Each carbon atom is bonded with two other carbon atoms by carbon-carbon single covalent bonds and two hydrogen atoms with carbon-hydrogen covalent bonds.

   The saturated cyclic hydrocarbons are also called as cycloalkanes. The general formula of cycloalkanes is C_nH_{2n}. Other examples of cycloalkanes are : Cyclopropane (C_3H_6), Cyclobutane (C_4H_8), Cyclopentane (C_5H_{10}), etc.

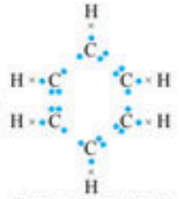
2. **Unsaturated Cyclic Hydrocarbons:** In this kind of hydrocarbons, the carbon atoms are arranged in the form of a ring and are bonded by one or more double covalent bonds.

   Benzene [C_6H_6] is an example of this kind of hydrocarbons. Figures alongside show the structural and electron-dot structure of benzene.

   A benzene molecule contains 6 carbon atoms arranged in a hexagonal ring with alternate carbon-carbon double bonds.



Structural formula of benzene



Electron-dot structure of benzene

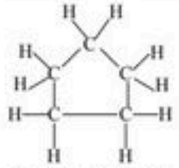
   We can see from the structure of benzene, that a benzene molecule contains 3 carbon-carbon double covalent bonds and 3 carbon-carbon single covalent bonds. Each carbon atom in the benzene molecule is also bonded with one hydrogen atom. Benzene is also called as **aromatic compound**. We will study the cycloalkanes and aromatic hydrocarbons in details in higher classes.

SAMPLE PROBLEMS

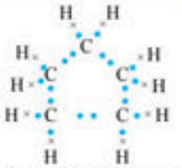
1. What will be the formula structure and electron-dot structure of cyclopentane? [NCERT]

Ans. Molecular formula of cyclopentane = C_5H_{10}

As this is a cyclic compound, all 5 carbon atoms are arranged in a pentagonal ring. It is an alkane, hence all carbon atoms are bonded with single covalent bond.



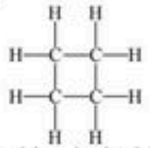
Structural formula of cyclopentane



Electron-dot structure of cyclopentane

2. What will be the molecular formula and structural formula of cyclobutane?

Ans. Molecular formula of cyclobutane = C_4H_8



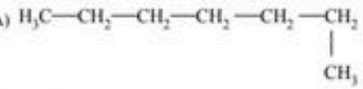
Structural formula of cyclobutane

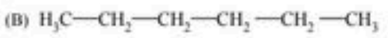
Exercise-4 (A)

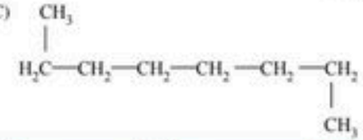
I. MULTIPLE CHOICE QUESTIONS

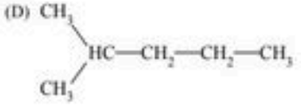
Tick (✓) the Correct Answer.

1. Which amongst the following is not a free state of carbon?
   (A) Diamond (B) Graphite (C) Petrol (D) Coke
2. A chemical bond formed between two non-metallic elements by the mutual sharing of one or more pairs of electrons is called :
   (A) an ionic bond (B) molecular bond (C) covalent bond (D) both (B) and (C)
3. Buckministerfullerene has _____ atoms in its molecule.
   (A) 30 (B) 200 (C) 160 (D) 60
4. Which of the following statements are usually correct for carbon compounds? These :
   (i) are good conductors of electricity.
   (ii) are poor conductors of electricity.
   (iii) have strong forces of attraction between their molecules.
   (iv) do not have strong forces of attraction between their molecules.
   (A) (i) and (iii) (B) (ii) and (iii) (C) (i) and (iv) (D) (ii) and (iv) [HOTS]
5. Which of the following is not a straight chain hydrocarbon?

   (A) 

   (B) 

   (C) 

   (D)  [HOTS]

Ans: 1. (C) 2. (D) 3. (D) 4. (D) 5. (D)

II. VERY SHORT ANSWER TYPE QUESTIONS

1. Name the gas formed by the decomposition of plant and animal matter in marshy areas.
2. Carbon (Group 14) element in the periodic table, is known to form compounds with many elements. Write an example of a compound formed with :
   (a) chlorine (Group 17 of periodic table)
   (b) oxygen (Group 16 of periodic table)
3. Why are covalent compounds generally poor conductors of electricity?
4. What is the reason for the versatile nature of carbon?

5. Write the molecular formula and electron-dot structure of cyclopropane.
6. What is the general formula of alkyl groups?

III. SHORT ANSWER TYPE QUESTIONS

1. Name a molecule of an element that has :
   (i) single covalent bond (ii) double covalent bonds (iii) triple covalent bonds.
2. (i) Why do covalent compounds occur in the form of gases or liquids?
   (ii) Why do covalent compounds have low melting and boiling points?
   (iii) Why are covalent compounds either poor conductors or non-conductors of electricity?
3. Write the number of covalent bonds in the molecule of butane, C_4H_{10}. [2015]
4. Why are most carbon compounds poor conductors of electricity?
5. Write the name and structure of a saturated compound in which the carbon atoms are arranged in a ring. Give the number of single bonds present in this compound.
6. Carbon forms a large number of compounds. Why? Explain.
7. What will be the molecular formula and electron-dot structure of benzene?

IV. LONG ANSWER TYPE QUESTIONS

1. (a) Define covalency.
   (b) What do you understand by the term 'catenation'? Explain with examples.
2. Choose from the list given below, the substance or substances that have :
   (i) single covalent bond only (ii) double covalent bond only (iii) single and double covalent bonds
   (iv) triple covalent bond only (v) single and triple covalent bonds.
   List : H_2O, Cl_2, N_2, O_2, C_2H_4, C_2H_6, C_2H_2

X01U2WCT0S

4.8 NOMENCLATURE OF ORGANIC COMPOUNDS

In early stages, all the organic compounds were known by their ***common names*** or ***trivial names***.

For Example: (i) **Methane** was known as **marsh gas**, as it was found in marshy places.
(ii) **Acetic acid** was obtained from **vinegar** (Latin: acetum = vinegar).

However, with the discovery of a large number of organic compounds, a proper scheme was evolved by the **International Union of Pure and Applied Chemistry (IUPAC)**. In short, the scheme is referred to as **IUPAC Nomenclature**.

The IUPAC name of an organic compound may consist of three parts:

(i) Word root (ii) Suffix (iii) Prefix

(i) Word root: It denotes the number of carbon atoms in the longest possible chain.

Table 4.1 : Word roots

Number of Carbon Atoms		Word root
One carbon atom	C_1	Meth
Two carbon atoms	C_2	Eth
Three carbon atoms	C_3	Prop
Four carbon atoms	C_4	But
Five carbon atoms	C_5	Pent
Six carbon atoms	C_6	Hex
Seven carbon atoms	C_7	Hept
Eight carbon atoms	C_8	Oct
Nine carbon atoms	C_9	Non
Ten carbon atoms	C_{10}	Dec

(ii) **Suffix:** The word root is followed by an appropriate suffix. It denotes the nature of carbon to carbon bond in the organic compounds.

Table 4.2 : Suffixes

Bond type	Suffix
C — C	ane
C = C	ene
C ≡ C	yne

(iii) **Prefix:** It represents the substituent group if present in the organic compound.

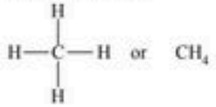
Table 4.3 : Substituents and their prefixes

Substituent group	Prefix
—F	Fluoro
—Cl	Chloro
—Br	Bromo
—I	Iodo
$-CH_3$	Methyl
$-C_2H_5$	Ethyl
$-C_3H_7$	Propyl

A. **Naming of Straight Chain Saturated Hydrocarbons:** Saturated straight chain hydrocarbon are named by using: **Word root + ane**.

Examples:

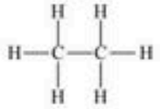
(i) **Naming of CH_4:** The compound contains one carbon atom, for one carbon atom word root 'meth' is used. The compound has all single covalent bond, hence it is a saturated hydrocarbon. For saturated hydrocarbon suffix 'ane' is used.



or CH_4

Word root : Meth
Suffix : ane
IUPAC name : Meth + ane = Methane

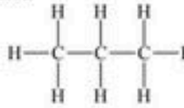
(ii) **Naming of C_2H_6:** The compound contains two carbon atoms. For two carbon atoms, word root 'eth' is used. The compound has all single bonds between carbon atoms, hence it is a saturated hydrocarbon. For saturated hydrocarbon suffix 'ane' is used.



or $CH_3—CH_3$

Word root : Eth
Suffix : ane
IUPAC name : Eth + ane = Ethane

(iii) **Naming of C_3H_8:** The compound contains three carbon atoms. For three carbon atoms, word root 'prop' is used. The compound has all single bonds between carbon atoms, hence it is a saturated compound, thus suffix 'ane' is used.



or $CH_3—CH_2—CH_3$

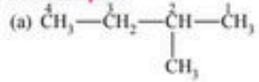
Word root : Prop
Suffix : ane
IUPAC name : Prop + ane = Propane

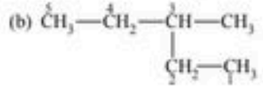
B. Naming of Branched Chain Saturated Hydrocarbons:

Branched chain saturated hydrocarbons are named as the derivatives of straight chain saturated hydrocarbons. Here, we have some rules which are followed while naming branched chain saturated hydrocarbon.

1. Select the longest continuous chain of carbon atoms known as parent chain which may or may not be straight.

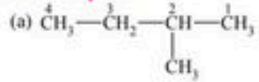
For examples:

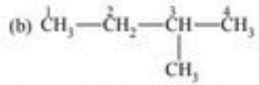
(a)  Word root : But

(b)  Word root : Pent

2. The carbon atoms of the parent chain are numbered starting from one end in such a way that the substituents get the smallest possible number.

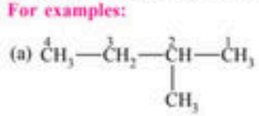
For examples:

(a)  Right

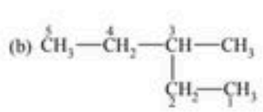
(b)  Wrong

3. While naming, the position of the substituent is indicated by the number of carbon atoms to which they are attached.

For examples:

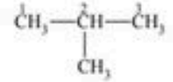
(a) 

Prefix	: 2-methyl
Word root	: but
Suffix	: ane
IUPAC name	: 2-methyl + but + ane = 2-methyl butane

(b) 

Prefix	: 3-methyl
Word root	: pent
Suffix	: ane
IUPAC name	: 3-methyl + pent + ane =3-methyl pentane

Examples:

(i) 

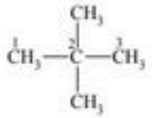
Prefix	: 2-methyl
Word root	: prop
Suffix	: ane
IUPAC name	: 2-methyl + prop + ane = 2-methylpropane
Common name	: iso-butane

In the compound, there are 3 carbon atoms in the longest or parent chain, hence it is a propane derivative.

It has an extra methyl group. Now number the carbon chain in such a way that the carbon atom having methyl group gets the lowest possible number. As the chain contains only three carbon atoms, the carbon

atom having the substituents gets the number 2, whether we number the carbon chain from left to right or from right to left.

(ii)



Prefix	: 2, 2-dimethyl
Word root	: prop
Suffix	: ane
IUPAC name	: 2, 2-dimethyl + prop + ane = 2, 2-dimethylpropane
Common name	: neo-pentane

In the compound, there are 3 carbon atoms in the longest or parent chain, hence it is a propane derivative.

It has two extra methyl groups. As the chain contains only three carbon atoms, the carbon atom having the substitents gets the number 2, whether we number the carbon chain from left to right or from right to left.

Multiple substituent groups are indicated by prefix - *'di'* for two. *'tri'* for three, *'tetra'* for four, and so on.

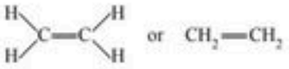
QAIEVJ085K

C. Naming of Unsaturated Hydrocarbons Containing a Double Covalent Bond :

While naming unsaturated hydrocarbons containing a double bond, the presence of the double bond is indicated by the suffix **'ene'**.

Examples:

(i) Naming of C_2H_4: The compound contains two carbon atoms, so word root for the compound is 'eth'. The compound also contains a carbon-carbon double bond. To indicate the presence of the double bond the suffix 'ene' is used.

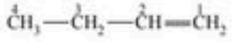


or $CH_2=CH_2$

Word root	: Eth
Suffix	: ene
IUPAC name	: Eth + ene = Ethene
Common name	: Ethylene

(ii) Naming of C_4H_8: The compound contains four carbon atoms, the word root for the compound is 'but'. The compound also contains a carbon-carbon double bond. To show the presence of the double bond the suffix 'ene' is used.

For showing the position of the double bond, the carbon atoms of the parent chain are numbered starting from one end in such a way that the carbon atoms involved in the multiple bond get the least possible numbers.



Word root	: But
Suffix	: 1-ene
IUPAC name	: But + 1-ene = But-1-ene

KDLXMIA6CP

D. Naming of Unsaturated Hydrocarbons Containing a Triple Covalent Bond :

While naming unsaturated hydrocarbons containing a triple bond, the presence of the triple bond is indicated by the suffix 'yne'.

Examples:

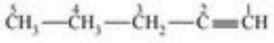
(i) **Naming of C_2H_2:** The compound contains two carbon atoms, so word root for the compound is 'eth'. The compound also contains a carbon-carbon triple bond. To indicate the presence of the triple bond the suffix 'yne' is used.



Word root	: Eth
Suffix	: yne
IUPAC name	: Eth + yne = Ethyne
Common name	: Acetylene

(ii) **Naming of C_5H_8:** The compound contains five carbon atoms, the word root for the compound is 'pent'. The compound contains a carbon triple bond so 'yne' suffix is used to indicate the presence of the triple bond.

For showing the position of the triple bond, the carbon atoms of the parent chain are numbered starting from one end in such a way that the carbon atoms involved in the multiple bond get the least possible numbers.



Word root	: Pent
Suffix	: 1-yne
IUPAC name	: Pent + 1-yne = Pent-1-yne

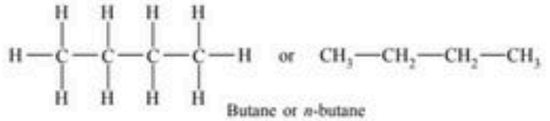
4.9 ISOMERS

XN28TDEKI0

Organic compounds having the same molecular formula but different structural formulae, and hence, different physical and chemical properties are called ***isomers****.*

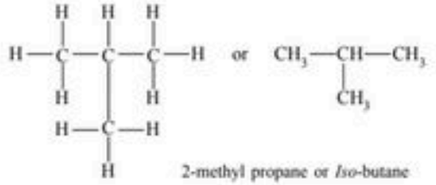
Let us take an example of a compound C_4H_{10}, called butane. There are four carbon atoms in this compound. These four carbon atoms can be joined in two different ways to get two different structures.

(a) If all the carbon atoms are joined in a straight chain, the compound butane is obtained. The common name of butane is *n*-butane. Here, *'n'* stands for *'normal'*.



Butane or *n*-butane

(b) If one carbon atom is present as a side chain, the following structure will be obtained.



2-methyl propane or *Iso*-butane

So we can see that the molecular formula C_4H_8 can have two structures that are : butane and 2-methylpropane. Butane commonly known as *n*-butane has a straight chain structure, whereas 2-methyl propane commonly known as *iso*-butane has a branched chain structure.

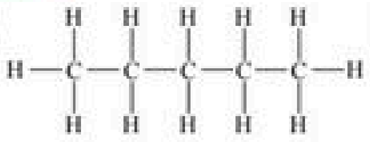
The organic compounds having same molecular formula, but different structural formulae are called ***isomers*** *and the phenomenon is called* ***isomerism***.

As we have seen that the hydrocarbon with molecular formula C_4H_{10} has two isomers. The hydrocarbon with molecular formula C_5H_{12} has three isomers.

Molecular formula — C_5H_{12}

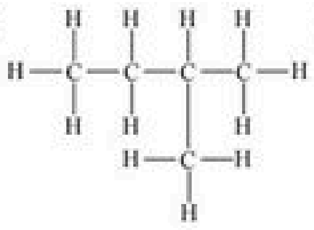
Isomers :

(i)



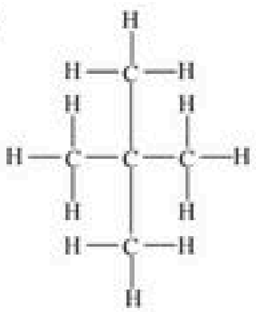
IUPAC Name : Pentane
Common Name : *n*-pentane

(ii)



IUPAC Name : 2-methylbutane
Common Name : *Iso*-pentane

(iii)



IUPAC Name : 2, 2-dimethyl propane
Common Name : *Neo*-pentane

Similarly, the hydrocarbon with molecular formula C_6H_{14} has five isomers. So, we can say that as the number of carbon atoms in an organic compound increases the number of possible isomers increases rapidly.

SAMPLE PROBLEMS

1. How many structural isomers can you draw for pentane? [NCERT]

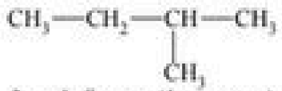
Ans. Molecular formula of pentane : C_5H_{12}

Possible isomers = 3

Isomers:

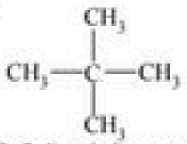
(i) $CH_3—CH_2—CH_2—CH_2—CH_3$
Pentane (*n*-pentane)

(ii)



2-methylbutane (*Iso*-pentane)

(iii)



2, 2-dimethylpropane (*Neo*-pentane)

2. Draw the condensed formulae of all the possible isomers of hexane.

Ans. Molecular formula of hexane = C_6H_{14}

Possible isomers = 5

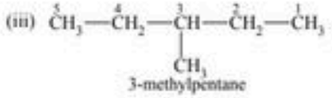
Condensed structures:

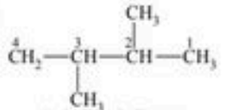
(i) $CH_3—CH_2—CH_2—CH_2—CH_2—CH_3$
Hexane

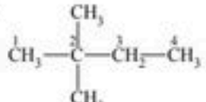
(ii)



2-methylpentane

(iii) 
3-methylpentane

(iv) 
2, 3-dimethylbutane

(v) 
2, 2-dimethylbutane

4.10 HOMOLOGOUS SERIES

The members of the same class of organic compounds, when arranged in the order of ascending molecular mass such that two consecutive compounds differ from each other by a —CH_2 group, are collectively called **homologues**. Such a class of one particular kind of organic compounds is called a **homologous** series and the phenomenon is called **homology**.

Let us try to find the difference between carbon and hydrogen atoms in the first four members of alkanes.

1. Difference between ethane and methane = [C_2H_6–CH_4] = CH_2.
2. Difference between propane and ethane = [C_3H_8–C_2H_6] = CH_2.
3. Difference between butane and propane = [C_4H_{10}–C_3H_8] = CH_2.

Notice the difference of carbon and hydrogen atoms between the two consecutive members of the alkanes is —CH_2. This —CH_2 unit is called **methylene group**.

By removing one or more —CH_2 groups from a given saturated hydrocarbon, we can obtain another saturated hydrocarbon with lesser number of carbon atoms.

Similarly, by adding one or more —CH_2 groups in a given saturated hydrocarbon, we can obtain another hydrocarbon with more number of carbon atoms.

Characteristics of Homologous Series

1. All members of a homologous series can be represented by the same general formula.
   Example: General formula for the alkanes is $\mathbf{C_nH_{2n+2}}$, where 'n' stands for the number of carbon atoms in one molecule of the alkane.
2. Each member of the homologous series differs from the next member by —CH_2 group.
3. Each member of the homologous series differs from the next member by 14 g mol^{-1} molar mass.
4. Due to the change in the molecular mass, the physical properties of the homologue differ appreciably from other homologues.
   Example:
   (i) First four members of the alkane series (from CH_4 to C_4H_{10}) are gaseous in nature.
   (ii) The homologues between C_5H_{12} to $C_{16}H_{34}$ are liquids such that the density of the liquid rises with the increase in the number of carbon atoms.
   (iii) The homologues beyond $C_{17}H_{36}$ are soft solids such that their melting point, boiling point and density increase with the increase in the number of carbon atoms.

5. All homologues can be prepared by the same general method.
6. All homologues have similar, but graded chemical properties.

The homologous series of alkanes, alkenes and alkynes are given in the following tables :

Table 4.4 : Homologous series of alkanes

Alkane	
General formula: C_nH_{2n+2}	
Name	**Molecular formula**
Methane	CH_4
Ethane	C_2H_6
Propane	C_3H_8
Butane	C_4H_{10}
Pentane	C_5H_{12}

Table 4.5 : Homologous series of alkenes

Alkenes	
General formula: C_nH_{2n}	
Name	**Molecular formula**
Ethene	C_2H_4
Propene	C_3H_6
Butene	C_4H_8
Pentene	C_5H_{10}
Hexene	C_6H_{12}

Table 4.6 : Homologous series of alkynes

Alkynes	
General formula: C_nH_{2n-2}	
Name	**Molecular formula**
Ethyne	C_2H_2
Propyne	C_3H_4
Butyne	C_4H_6
Pentyne	C_5H_8
Hexyne	C_6H_{10}

SAMPLE PROBLEMS

1. What is the molecular formulae of the second and fourth members of homologous series of hydrocarbons represented by the general formula C_nH_{2n}?

Ans. C_nH_{2n} is the general formula of alkene series. We already have discussed that the first member of alkene series is C_2H_4 that is ethene. Therefore,

(a) The second member of C_nH_{2n} series is C_3H_6.

(b) The fourth member of the C_nH_{2n} series is C_5H_{10}.

2. Identify the compounds which belong to the same homologous series?

C_2H_6, C_2H_4, C_3H_4, C_4H_{10}

Ans. General formula for $C_2H_6 = C_nH_{2n+2}$ (Alkane)

General formula for $C_2H_4 = C_nH_{2n}$ (Alkene)

General formula for $C_3H_4 = C_nH_{2n-2}$ (Alkyne)

General formula for $C_4H_{10} = C_nH_{2n+2}$ (Alkane)

Therefore, C_2H_6 and C_4H_{10} belong to the same that is, alkane homologous series.

Assess Yourself – 3

1. Write the IUPAC name of the following compounds:

(i) $CH_3—CH_2—\underset{\displaystyle CH_3}{\underset{|}{CH}}—CH_3$

(ii) $CH_3—\underset{\displaystyle CH_3}{\underset{|}{CH}}—CH_3$

(iii) $CH_3—CH{=}CH_2$

(iv) $CH_3—C{\equiv}C—CH_3$

(v) $CH_3—CH_2—CH_2—CH_3$

(vi) $CH_3—CH_2—\underset{\displaystyle CH_2—CH_3}{\underset{|}{CH}}—CH_3$

2. What do you understand by isomerism?
3. Draw chain isomers of the following compounds :
   (i) C_5H_{12} (ii) C_6H_{14}
4. A special name is assigned to compound having the same molecular formula, but different structural arrangement of atoms. What is that name? Write two different structural formulae of C_4H_{10}.
5. Write the structural formula of any two isomers of *n*-heptane (C_7H_{16}).
6. Write the structural formula of one isomer of *n*-hexane (C_6H_{14}).
7. What are isomers? Write two isomers of butane with their structural formulae.
8. Give the IUPAC name, molecular formula, condensed formula, general formula and structural formula of the following hydrocarbons :
   (i) Propane (ii) *n*-Butene (iii) Ethene
9. What prefix is used to show the presence of $—C_2H_5$ group?
10. What suffixes are used to show the presence of the following groups :
    (i) Alkane (ii) Alkene (iii) Alkyne
11. Identify the compounds that belong to the same homologous series : C_2H_4, C_3H_8, C_3H_6, C_7H_{14}, C_2H_6.
12. Write the names of two alkanes, one having three carbon atoms and the other having four carbon atoms.
13. Write the names of alkenes having two and three carbon atoms respectively.

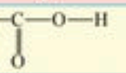
L2SPG5EAUQ

4.11 FUNCTIONAL GROUPS

An atom or a group of atoms, attached to a hydrocarbon in a specific manner, which gives the chemical properties of the organic compound and is the center for chemical reactivity is known as ***functional group***.

Example, the alcohol group (—OH), present in ethanol (C_2H_5OH) is an example of functional group.

Table 4.7 : Some functional groups in carbon compounds

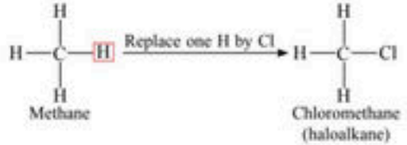
Name of functional group	Formula of functional group	Structure of functional group
Halo group (Fluoro/ Chloro/Bromo/Iodo)	—X (—F/—Cl/ —Br/—I)	—F, —Cl, —Br, —I
Alcohol	—OH	—OH
Aldehyde	—CHO	
Ketone	—CO—	
Carboxylic acid	—COOH	

19FOH7JPRL

Haloalkanes

Haloalkanes are the alkane derivatives. When one hydrogen atom from an alkane is substituted by a halogen atom, we get the haloalkane accordingly.

For example, if we replace one hydrogen atom from a methane molecule with a chlorine atom, we get chloromethane.



The general formula of haloalkanes is $C_nH_{2n+1}X$. Here X represents halogens like–Chlorine (Cl), Bromine (Br), Iodine (I). Here we have a homologous series of chloroalkanes. You can also write the corresponding bromoalkane or iodoalkane.

Table 4.8 : Homologous series of haloalkanes

IUPAC name	Common name	Formula
Chloromethane	Methyl chloride	CH_3Cl
Chloroethane	Ethyl chloride	CH_3CH_2Cl
Chloropropane	Propyl chloride	$CH_3CH_2CH_2Cl$
Chlorobutane	*n*-butylchloride	$CH_3CH_2CH_2CH_2Cl$
Chloropentane	*n*-pentylchloride	$CH_3CH_2CH_2CH_2CH_2Cl$

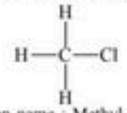
Naming of Haloalkanes

All organic compounds are named after the parent alkane in IUPAC system. According to IUPAC nomenclature, haloalkanes are named after the parent alkane by using a suitable prefix to show the presence of the halogen group.

For example, *'Fluoro'* for —F group, *'Chloro'* for —Cl group, *'Bromo'* for —Br group and *'Iodo'* for —I group are used as prefixes.

Let us take some examples to understand the naming of haloalkanes.

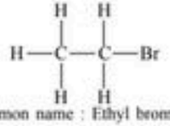
1. **Naming of CH_3Cl:** This compound is a derivative of methane, as it contains only one carbon atom. This compound also contains a chloro group (—Cl). The presence of —Cl group is indicated by a prefix 'chloro'. Thus, the IUPAC name of the compound is:



Common name : Methyl chloride

Halo (prefix) + alkane = Haloalkane
= Chloro + methane = Chloromethane

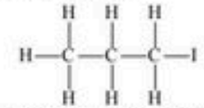
2. **Naming of C_2H_5Br:** This compound contains two carbon atoms, hence it is a derivative of ethane. This compound also contains a bromo group (—Br). The presence of —Br group is indicated by a prefix 'bromo'. Thus, the IUPAC name of the compound is:



Common name : Ethyl bromide

Halo (prefix) + alkane = Haloalkane
Bromo + ethane = Bromoethane

3. **Naming of C_3H_7I:** This compound is a derivative of propane, as it contains three carbon atoms. This compound also contains an iodo group (—I). The presence of —I group is indicated by a prefix 'iodo'. Thus, the IUPAC name of the compound is:

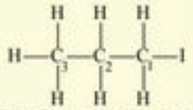


Common name: Propyl iodide

Halo (prefix) + alkane = Haloalkane
Iodo + propane = Iodopropane

Note: We can also indicate the position of the substituent. To indicate the position of the substituent the carbon atoms of the parent chain are numbered starting from one end in such a way that the substituent gets the smallest possible number. The position of the substituent is indicated by the number of carbon atoms to which they are attached.

Example,



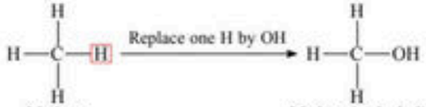
IUPAC name: 1-Iodopropane

Alcohols

Z1975PHGVO

Alcohols are the carbon compounds containing —OH group (hydroxyl group) attached to a carbon atom. When a hydrogen atom attached to any carbon atom of an alkane is replaced by the functional group (—OH), then the organic compound so formed belongs to an **alcoholic group**.

For example, if we replace one hydrogen atom from a methane molecule with '—OH' group (hydroxyl group), then we get methanol.



Methane — Methanol (alcohol)

The general formula of alcohols is '$C_nH_{2n+1}OH$ or '$C_nH_{2n+2}O$'. Here we have a homologous series of alcohols.

Table 4.9 : Homologous series of alcohols

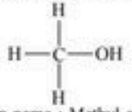
IUPAC name	Common name	Molecular formula	Condensed formula
Methanol	Methyl alcohol	CH_3OH	$CH_3—OH$
Ethanol	Ethyl alcohol	C_2H_5OH	$CH_3—CH_2—OH$
Propanol	*n*-Propyl alcohol	C_3H_7OH	$CH_3—CH_2—CH_2—OH$
Butanol	*n*-Butyl alcohol	C_4H_9OH	$CH_3—CH_2—CH_2—CH_2—OH$
Pentanol	*n*-Pentyl alcohol	$C_5H_{11}OH$	$CH_3—CH_2—CH_2—CH_2—CH_2—OH$

Naming of Alcohols: In IUPAC nomenclature, alcohols are named after the parent alkane by using a suffix to show the presence of the hydroxyl group (—OH).

While naming, the terminal 'e' of the parent alkane is replaced by a suffix 'ol' to show the presence of hydroxyl group (—OH).

Let us take some examples to understand the naming of alcohols.

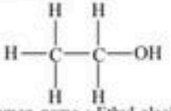
1. **Naming of CH_3OH:** This compound is a methane derivative, because it contains only one carbon atom. This compound also contains a hydroxyl group (—OH). The presence of the hydroxyl group is indicated by a suffix 'ol'. Thus, the name of the compound is :



Common name : Methyl alcohol

Alkane – e + ol ⟶ Alkanol
Methane – e + ol ⟶ Methanol

2. **Naming of C_2H_5OH:** This compound contains two carbon atoms, so it is an ethane derivative. This compound also contains hydroxyl group (—OH). The presence of the hydroxyl group is indicated by a suffix 'ol'. Thus, the name of the compound is :



Common name : Ethyl alcohol

Ethane – e + ol ⟶ Ethanol

Aldehydes

GON8RJIX8EI

When the hydrogen atom of an alkane is replaced by the functional group (—**CHO**), then the organic compound so formed belongs to the **aldehydic group**.

Aldehydes are the compounds containing the '—CHO' group attached to the carbon atom of alkyl chain.

The general formula of aldehydes is $C_nH_{2n+1}CHO$.

Note : The simplest aldehyde is HCHO.

Table 4.10 : Homologous series of aldehydes

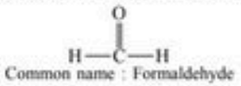
IUPAC Name	Common Name	Formula
Methanol	Formaldehyde	H—CHO
Ethanal	Acetaldehyde	CH_3—CHO
Propanal	Propionaldehyde	CH_3—CH_2—CHO
Butanal	Butyraldehyde	CH_3—CH_2—CH_2—CHO
Pentanal	Valeraldehyde	CH_3—CH_2—CH_2—CH_2—CHO

Naming of Aldehydes

In IUPAC nomenclature, aldehydes are named after the parent alkane by using a suffix to show the presence of the aldehyde group (—CHO).

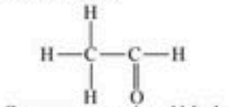
While naming aldelydes according to IUPAC system, the terminal 'e' of the parent alkane is replaced by a suffix 'al' to show the presence of aldehyde group (—CHO). Let us take some examples to understand the naming of aldehydes.

1. **Naming of HCHO:** This compound is a methane derivative because it contains only one carbon atom. This compound also contains an aldehyde group (—CHO). The presence of the aldehyde group is indicated by a suffix 'al'. Thus the name of the compound is:


Common name : Formaldehyde

Alkane – e + al ⟶ Alkanal
Methane – e + al ⟶ Methanal

2. **Naming of CH_3CHO:** This compound is an ethane derivative, as it contains two carbon atoms. This compound also contains an aldehyde group (—CHO). The presence of the aldehyde group is indicated by suffix 'al'. Thus the name of the compound is:

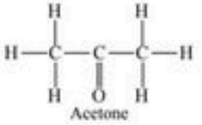

Common name : Acetaldehyde

Ethane – e + al = Ethanal

AUK8ZB401X

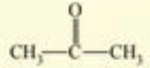
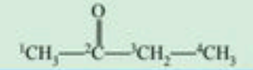
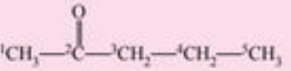
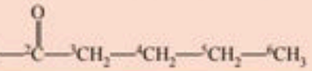
Ketones

Ketones are the compounds containing the $>C=O$ *group.* Ketone group always occurs in the middle of a carbon chain, hence a ketone must contain at least three carbon atoms in its molecule. Therefore, the simplest ketone is acetone (CH_3COCH_3).


Acetone

The general molecular formula for ketones is $C_nH_{2n}O$. Here, we have a homologous series of ketones.

Table 4.11 : Homologous series of ketones

IUPAC Name	Common Name	Formula
Propanone	Acetone or dimethyl ketone	
Butan-2-one	Methyl ethyl ketone	
Pentan-2-one	Methyl peopyl ketone	
Hexan-2-one	Methyl butyl ketone	

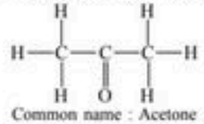
Naming of Ketones

In IUPAC nomenclature, ketones are named after the parent alkane by using a suffix to show the presence of the ketone group ($>C=O$).

While naming ketones according to IUPAC system, the terminal 'e' of the parent alkane is replaced by a suffix 'one' to show the presence of ketone group ($>C=O$).

Let us take some examples to understand the naming of ketones.

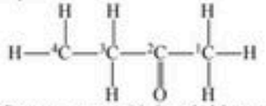
1. **Naming of CH_3COCH_3:** This compound is a propane derivative, because it contains three carbon atoms. This compound also contains a ketone group ($>C=O$). The presence of the ketonic group is indicated by a suffix 'one'. Thus, the name of the compound is:



Common name : Acetone
or dimethyl ketone

Alkane – e + one ⟶ Alkanone
Propane – e + one ⟶ Propanone

2. **Naming of $C_2H_5COCH_3$:** This compound is a butane derivative as it contains four carbon atoms. This compound also contains a ketone group ($>C=O$). The presence of the ketone group is indicated by a suffix 'one'. To indicate the position of the ketone group. the carbon atoms of the parent chain are numbered starting from one end in such a way that the carbon atom having ketone group gets the smallest possible number. The position of the ketone group is indicated by the number of carbon atom, which has the ketone group. Thus the name of the compound is :



Common name : Methy ethyl ketone

Butane – e + 2 – one ⟶ Butan – 2 – one

Carboxylic Acids

Carboxylic acids are the compounds containing the '—COOH' group attached to the carbon atom of an alkyl chain.

When the hydrogen atom of an alkane is replaced by the functional group $\left(-\overset{\overset{O}{\|}}{C}-OH\right)$, then the organic compound so formed belongs to the **carboxylic group**.

The general formula of carboxylic acid group is $\left(R-\overset{\overset{O}{\|}}{C}-OH\right)$, where R stands for alkyl radical having the gerenal formula C_nH_{2n+1}.

In case, there is one carbon atom in the carboxylic acid, then **R** stands for 'H' atom.

The names and formula of the first four members of carboxylic acids are given in the table given below.

Table 4.12 : Homologous series of carboxylic acids

IUPAC Name	Common Name	Formula
Methanoic acid	Formic acid	$HCOOH\ \left[H-\overset{\overset{O}{\|}}{C}-OH\right]$
Ethanoic acid	Acetic acid	$CH_3COOH\ \left[CH_3-\overset{\overset{O}{\|}}{C}-OH\right]$
Propanoic acid	Propionic acid	$C_2H_5COOH\ \left[CH_3-CH_2-\overset{\overset{O}{\|}}{C}-OH\right]$
Butanoic acid	Butyric acid	$C_3H_7COOH\ \left[CH_3-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-OH\right]$

Naming of Carboxylic acids

In IUPAC system, the carboxylic acid homologous series is called **alkanoic acid homologous series**. The name of a given member of alkanoic series can be obtained by replacing **—e** of a given alkane by **—oic** and then writing the word **acid**.

Examples:

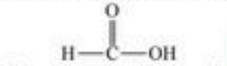
Alkane – e + oic acid ⟶ Alkanoic acid

Methane – e + oic acid ⟶ Methanoic acid

Ethane – e + oic acid ⟶ Ethanoic acid

Let us take some examples to understand the naming of carboxylic acids.

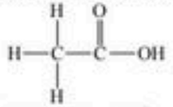
1. **Naming of HCOOH:** This compound is a methane derivative, because it contains only one carbon atom. This compound also contains a carboxylic group (COOH). The presence of the carboxylic group is indicated by a suffix **'oic acid'**. Thus, the name of the compound is :



Common name : Formic acid

Methane – e + oic acid ⟶ Methanoic acid

2. **Naming of CH_3COOH:** This compound contains two carbon atoms, so it is an ethane derivative. This compound also contains carboxylic group (—COOH). The presence of the carboxylic group is indicated by a suffix **'oic acid'**. Thus, the name of the compound is :



Common name : Acetic acid

Ethane – e + oic acid ⟶ Ethanoic acid

COAL AND PETROLEUM

A fuel is a substance which releases energy on burning. Coal and petroleum both are fuels as their combustion releases energy. The fuels such as coal and petroleum have some nitrogen and sulphur in them. When they are burnt, they lead to the formation of oxides of nitrogen and sulphur, which are major pollutants of the air.

Coal: Coal was formed in pre-historic times (200–250 million years ago), when huge forest areas got buried under the surface of the earth. Under *humid and hot conditions, they were attacked by anaerobic bacteria that progressively removed hydrogen and oxygen*, leaving behind carbon. Due to the very high temperature and pressure of the earth, the carbon got compressed to form a stony residue, called coal. Some amount of methane was also formed due to the action of anaerobic bacteria, which was trapped in coal. *The slow conversion of wood into coal by a biochemical process extending over millions of years is called* ***carbonisation***.

Petroleum: **Crude oil or petroleum** ***is a complex mixture of solid, liquid and gaseous hydrocarbons, mixed with salt water and earthly particles.***

It is believed that petroleum was formed as a result of the anaerobic decomposition of extremely small sea animals and plants, which got buried millions of years ago. Let us explain how this happened.

Millions of years ago, very large number of microscopic plants and animals lived in the sea. They died because of some calamity and their bodies sank to the bottom of the sea. These dead bodies then got covered by mud and sand. These bodies of dead plants and animals decayed in the absence of air under very high temperatures and pressure of the earth. The products of this decay were petroleum and natural gas. This product got trapped between the two layers of impervious rocks forming an ***oil trap***. Natural gas always collects above the petroleum under high pressure in the dome shaped impervious rock, commonly, called **rock cap**.

From the above discussion you can make out why coal and petroleum are called fossil fuels. It is because, they are decomposed remains of pre-historic dead plants and animals.

Exercise-4 (B)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

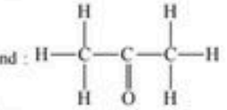
1. Organic compounds having the same molecular formula, but different structural formula are called :
   (A) allotropes (B) isomers (C) isobars (D) none of the above
2. The members of same class of organic compounds when arranged in the order of ascending molecular mass, such that they differ from each other by — CH_2 group are called :
   (A) allotropes (B) homologues
   (C) both (A) and (B) (D) none of the above
3. Amongst C_4H_{10}, C_3H_8, C_5H_{12} and C_5H_{10} the homologues are :
   (A) C_4H_{10} and C_5H_{12} only (B) C_3H_8 and C_4H_{10} only
   (C) C_5H_{10} and C_5H_{12} only (D) C_4H_{10}, C_3H_8 and C_5H_{12}
4. A homologous series of unsaturated hydrocarbons, characterised by the presence of triple covalent bond in straight chain carbon compound is called :
   (A) alkyne series (B) alkene series
   (C) alkane series (D) none of the above
5. Carbon forms four covalent bonds by sharing its four valence electrons with four univalent atoms, for example, hydrogen. After the formation of four bonds, carbon attains the electronic configuration of :
   (A) helium (B) neon (C) argon (D) krypton

Ans: 1. (B) 2. (B) 3. (D) 4. (A) 5. (B)

II. VERY SHORT ANSWER TYPE QUESTIONS

1. What is meant by the term functional group?
2. Write the names of functional groups present in (a) ethanol (b) ethanoic acid.
3. Write IUPAC names of the following:
   (i) CH_3OH, (ii) CH_3COOH
4. What is the common name of CH_3COOH?
5. Which of the following compounds could belong to the same homologous series:
   $C_2H_6O_2$, C_2H_6O, C_2H_6, CH_4O
6. Name the classes of organic compounds represented by the following formulae:
   (i) C_2H_5COOH (ii) $H_3C-\overset{\overset{O}{\|}}{C}-CH_3$
7. Write the formula of the functional groups of alcohol and carboxylic acid.
8. Write the (i) name and (ii) formula of the functional group present in the compound, CH_3COOH.
9. The molecular formula of the consecutive members of a homologous series are C_6H_{14} and C_7H_{16}. Write the molecular formulae of the members having 9 and 11 carbon atoms of this homologous series.
10. Write the molecular formula of (i) ethanol and (ii) propanoic acid.
11. Name the classes of organic compound associated with the following functional groups:
    (i) —CHO (ii) —OH
12. Name the following functional groups of organic compounds: (i) $-\overset{|}{C}=O$, (ii) $-\overset{\overset{O}{\|}}{C}-H$
13. Give the names of the following functional groups :
    (i) —CHO (ii) $-\overset{|}{C}=O$
14. Give the names of the following functional groups :
    (i) —OH (ii) —COOH



15. How are the molecules of aldehydes and ketones structurally different?
16. Name the elements other than carbon that constitute carbohydrates.
17. Name the functional group present in propanone (acetone).
18. Name the following compound : 
19. Write names of any two alkenes.
20. What is the difference in the molecular formula of any two consecutive members of a homologous series of organic compounds?

III. SHORT ANSWER TYPE QUESTIONS

1. What category of compounds will be formed when one hydrogen of alkane molecule is replaced by a hydroxyl group? Name the functional groups present in the following compounds:



2. What is a homologous series? Which two of the following organic compounds belong to the same homologous series?
   C_2H_6, C_2H_6O, $C_2H_6O_2$, CH_4O
3. Draw the structures of the following compounds
   (i) ethanoic acid (ii) butanone.
4. (a) What is "homologous series" of a substance?
   (b) In an organic compound, which part largely determines its physical and chemical properties.
5. Name the functional groups present in the following compounds
   (a) $CH_3—CO—CH_2—CH_2—CH_2—CH_3$ (b) $CH_3—CH_2—CH_2—COOH$
   (c) $CH_3—CH_2—CH_2—CH_2—CHO$ (d) $CH_3—CH_2—OH$ [HOTS]
6. What is a homologous series of a compound? List any two characteristics of a homologous series.
7. Write the formula of the given compounds and name the functional groups present in each of them:
   (i) ethanoic acid (ii) propanone
8. The molecular formula of two members of the homologous series are C_3H_4 and C_6H_{10}. Write down the molecular formula of the member with four carbon atoms in its molecule.
9. Write the (i) structural and (ii) electronic formula of any one isomer of *n*-pentane (C_5H_{12}).
10. Acetone is the first member of ketones. Answer the following questions:
    (a) What is its molecular formula?
    (b) What is its IUPAC name?
    (c) Give its structural formula.
11. Write the molecular formula of the 2nd and the 3rd member of the homologous series whose first member is methane.

IV. LONG ANSWER TYPE QUESTIONS

1. (a) What are hydrocarbons? Give examples.
   (b) Give the structural differences between saturated and unsaturated hydrocarbons with two examples each.
   (c) What is a functional group? Give examples of four different functional groups. [HOTS]
2. (a) Give the general name of the class of compounds having the general formula C_nH_{2n-2}. Write the name of the first member of this homologous series.
   (b) Write the structural formula of propane.
   (c) What are isomers? Write two isomers of butane with their structural formulae.



4.12 CHEMICAL PROPERTIES OF CARBON COMPOUNDS

NTW30C74KS

In this section we shall study some important properties of carbon compounds. Carbon and most of its compounds are used as fuels, therefore, first of all we shall study the combustion of carbon and its compounds.

I. Combustion of Carbon and Its Compounds

Let us perform an activity, before arriving at some conclusions regarding combustion of compounds of carbon.

Light a bunsen burner and close its air holes. Hold a strip of clear glass above the flame. Make observations, regarding the colour of flame and the strip of clear glass.

You will observe that when air holes are closed the flame is yellowish in colour and a black sooty deposit is formed on the strip of the clear glass plate.

The formation of soot on the clear glass plate implies that combustion of the Liquefied Petroleum Gas (LPG) gas is not complete. It partly decomposes to form carbon particles, which settle on the clear glass plate.

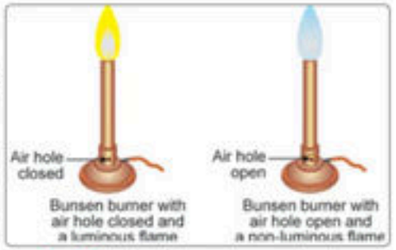


Fig. 4.18: Affect of air supply on combustion

The yellowish colour of the flame is due to the heating up of the carbon particles above 1500°C. At this temperature they emit yellow light.

Now open the air holes of the lighted bunsen burner. Hold another clear glass strip above the flame. Make observations regarding the colour of the flame and the strip of clear glass.

You will observe that when air holes are open, the flame is of pale blue colour. Such a flame is commonly called non-lumious flame, and no sooty deposit is formed on the clear glass strip.

From the above observations we can conclude :

1. When there is an excess supply of air (as air holes are open), complete combustion of LPG gas takes place.
2. The flame becomes non-luminous when carbon particles are completely oxidised.

Now we are in a position to say about the combustion of carbon and its compounds.

1. All allotropic forms of carbon burn in oxygen or in air on heating to form carbon dioxide gas with the release of large amount of heat and some amount of light energy.

$$\underset{\text{Carbon}}{C(s)} + \underset{\text{Oxygen}}{O_2(g)} \xrightarrow{\Delta} \underset{\text{Carbon dioxide}}{CO_2(g)} + \text{Heat and light energy}$$

2. The compounds of carbon such as alkanes, alkenes, alkynes, alcohol, etc., burn in oxygen or in air to form carbon dioxide, water (in the form of steam) and large amount of heat and some amount of light energy.

(i) $\underset{\text{Methane}}{CH_4(g)} + \underset{\text{Oxygen}}{2O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{CO_2(g)} + \underset{\text{Steam}}{2H_2O(g)} + \underset{\text{energy}}{\text{Heat and light}}$

(ii) $\underset{\text{Ethane}}{2C_2H_6(g)} + \underset{\text{Oxygen}}{7O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{4CO_2(g)} + \underset{\text{Steam}}{6H_2O(g)} + \underset{\text{energy}}{\text{Heat and light}}$

(iii) $\underset{\text{Ethanol}}{2C_2H_5OH(l)} + \underset{\text{Oxygen}}{7O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{4CO_2(g)} + \underset{\text{Steam}}{6H_2O(g)} + \underset{\text{energy}}{\text{Heat and light}}$

(iv) $\underset{\text{Propane}}{C_3H_8(g)} + \underset{\text{Oxygen}}{5O_2(g)} \longrightarrow \underset{\text{Carbon dioxide}}{3CO_2(g)} + \underset{\text{Steam}}{4H_2O(g)} + \underset{\text{energy}}{\text{Heat and light}}$

(v) $C_2H_4(g)$ (Ethene) + $3O_2(g)$ (Oxygen) $\longrightarrow$ $2CO_2(g)$ (Carbon dioxide) + $2H_2O(g)$ (Steam) + Heat and light energy

(vi) $2C_2H_2(g)$ (Ethyne) + $5O_2(g)$ (Oxygen) $\longrightarrow$ $4CO_2(g)$ (Carbon dioxide) + $2H_2O(g)$ (Steam) + Heat and light energy

Important Points

1. Saturated hydrocarbons generally give clean and a non-luminous flame because of the complete combustion of carbon atoms in them.
2. Unsaturated hydrocarbons generally give yellow sooty flame. It is because, some carbon atoms escape combustion, thereby imparting yellow and sooty flame.
3. The gas/kerosene oil stove used at home has large number of inlets for air so that sufficient amount of oxygen can burn the gas/kerosene oil, and hence, a blue flame is formed. If these air holes get choked due to some reason, the flame turns yellow and sooty. Such a flame can blacken the bottom of vessels used for cooking.
4. Fuels like coal and petroleum products always have very small amount of compounds containing sulphur and nitrogen, which on combustion form sulphur dioxide gas and nitrogen dioxide respectively. These gases are the major pollutants of the environment.

Why do Substances Burn with or without Flame?

Flame is defined as a region of burning gases. Now when coke or charcoal are used as fuel, they glow with a reddish colour, but do not produce any flame. It is because, they consist of mostly carbon and do not produce any combustible gases, which could give rise to a flame.

However, when wood is ignited by heating, it produces a flame. It is because wood contains large number of organic compounds. When it is heated to start fire, the organic compounds in it change into the gaseous form. This gaseous form of organic compounds mixes with air and catches fire to produce flame.

In the same way, when we light a candle with a burning matchstick, the heat of the matchstick not only melts the wax, but changes it into wax vapours. These wax vapours on mixing with air get ignited to form a candle flame.



Fig. 4.19: Candle flame

II. Oxidation of Carbon Compounds

We have studied about the combustion of organic compounds. In fact combustion of organic compounds is a very fast oxidation process.

Organic compounds can be oxidised slowly so as to form new organic compounds, by using oxidising agents, such as acidified potassium dichromate ($K_2Cr_2O_7$) or alkaline potassium permanganate ($KMnO_4$). The above oxidising agents are called strong oxidising agents.

There are mild oxidising agents, such as copper (II) oxide [CuO] and chromium oxide (in acetic acid).

Let us study the following examples.

Example 1:

- Take 5 mL of ethanol [C_2H_5OH] in a test tube and warm it gently in a water bath.
- With the help of a dropper, add 5% alkaline potassium permanganate in the test tube drop by drop, and continuously stirring the reaction mixture.
- You will observe that the pink colour of potassium permanganate fades at once. Continue adding drops of potassium permanganate, till the colour stops fading. At this stage the ethanol is completely oxidised to ethanoic acid.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} + \underset{\text{Nascent oxygen}}{2[O]} \xrightarrow[KMnO_4]{\text{Alkaline}} \underset{\text{Ethanoic acid}}{CH_3COOH} + \underset{\text{Water}}{H_2O}$$

Example 2:

When ethanol [C_2H_5OH] is treated with 5% solution of chromium oxide (with ethanoic acid), it is oxidised to acetaldehyde [ethanal]. Chromium oxide acts as mild oxidising agent.

$$\underset{\text{Ethanol}}{CH_3.CH_2.OH} + \underset{\text{Nascent oxygen}}{[O]} \xrightarrow[CH_3COOH]{CrO_3 \text{ in}} \underset{\text{Ethanal}}{CH_3CHO} + \underset{\text{Water}}{H_2O}$$

Example 3:

When vapours of ethanol are passed over heated copper (II) oxide [CuO], (which acts as a mild oxidising agent), ethanol is oxidised to acetaldehyde [ethanal].

$$\underset{\text{Ethanol}}{CH_3.CH_2.OH} + \underset{\text{Copper (II) oxide}}{CuO} \xrightarrow{300°C} \underset{\text{Ethanal}}{CH_3CHO} + \underset{\text{Water}}{H_2O} + \underset{\text{Copper}}{Cu}$$

III. Substitution Reactions of Organic Compounds

Saturated hydrocarbons are fairly unreactive for most of the chemical reagents. However, they react rapidly with chlorine in which their hydrogen atoms are replaced by chlorine one by one.

Substitution Reaction : *A type of reaction in which one type of atoms in a saturated hydrocarbon are replaced by another type of atoms is called* ***substitution reaction***.

Example:

(i) 

Methane — Chlorine — Monochloro methane

(ii) 

Monochloro methane — Chlorine — Dichloro methane

(iii) 

Dichloro methane — Chlorine — Trichloro methane

(iv) 

Trichloro methane — Chlorine — Tetrachloro methane

IV. Addition Reactions of Organic Compounds

(a) Unsaturated hydrocarbons such as ethene [C_2H_4] and ethyne [C_2H_2] are added to hydrogen in the presence of heated nickel or palladium so as to form saturated hydrocarbons. *The addition reaction proceeds with the breaking of the double/triple covalent bond and formation of new single covalent bonds.*





In the above reactions, nickel or palladium acts as catalytic agents. *The substances that do not undergo any chemical change, but help in changing the rate of reaction are called* ***catalysts***.

Hydrogenation of vegetable oils: Most of the vegetable oils are unsaturated fatty acids having double bond in a long carbon chain. They do not solidify like butter or animal fat on cooling.

When vegetable oils are heated to 300°C in the presence of finely divided nickel and hydrogen gas is passed through it, *the double bond between the carbon atoms break to form single bonds and two hydrogen atoms are added at the reaction site.*

Thus, the unsaturated vegetable oil changes to saturated vegetable oil. It is commonly called *hydrogenated oil or vanaspati ghee.*

(b) Unsaturated hydrocarbons such as ethene and ethyne is added to halogens in the presence of sunlight to form saturated halogen compounds of alkanes. The addition reaction proceeds with the breaking of double/triple covalent bonds and the formation of single bonds at the site of the reaction.





J26CN5Q4MD

4.13 IMPORTANT CARBON COMPOUNDS

Ethanol

(A) Physical properties of ethanol [C_2H_5OH]

1. Ethanol is a colourless and inflammable liquid.
2. Ethanol has a strong spirituous smell and a burning taste.
3. Its boiling point is 78.2°C and freezing point –118°C.
4. It is miscible in water in all proportions.
5. It is a very good solvent for fats and resins.



Fig. 4.20: Ethanol

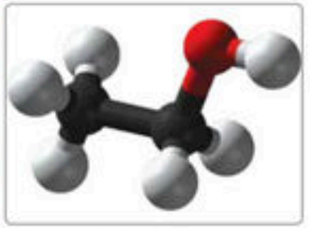


Fig. 4.21: A molecule of ethanol

6. It is a covalent compound and hence does not ionise. Thus, it is a bad conductor of electricity.
7. Ethanol, containing less than 5% of water is called rectified spirit.

(B) Chemical properties of ethanol

(i) Reaction with sodium: When sodium metal is treated with 100% ethanol, it reacts to form sodium ethoxide and hydrogen gas. Alcohols can be tested by the action of sodium metal.

$$\underset{\text{Ethanol}}{2CH_3.CH_2.OH(l)} + \underset{\text{Sodium}}{2Na(s)} \longrightarrow \underset{\text{Sodium ethoxide}}{2CH_3CH_2ONa(l)} + \underset{\text{Hydrogen}}{H_2(g)}$$

(ii) Dehydration of ethanol: When ethanol is mixed with excess of concentrated sulphuric acid and heated to 443 K (170°C), the sulphuric acid removes a molecule of water from its molecule to form unsaturated ethene gas.

$$\underset{\text{Ethanol}}{CH_3{-}CH_2{-}OH} + \underset{\text{Sulphuric acid}}{H_2SO_4\ (\text{conc.})} \xrightarrow{443K} \underset{\text{Ethene}}{CH_2 = CH_2} + \underset{\text{Hydrated sulphuric acid}}{H_2SO_4.H_2O}$$

In the above reaction, concentrated sulphuric acid acts as a dehydrating agent.

(iii) We have already studied the oxidation reactions of ethanol.

(C) Uses of ethanol

1. Ethanol is used as an important beverage in the form of whisky, wine, beer, etc. Whisky contains about 35% ethanol, wine 10 to 20% and beer 6 to 10%.
2. A mixture of 20% petrol and 80% alcohol is used as a **substitute for petrol**. It is commonly called **power alcohol**.
3. It is used as a fuel in spirit lamps and stoves.
4. It is used in the preservation of biological specimens.
5. It is used for making scientific instruments, such as alcohol thermometers and spirit levels.
6. It is extensively used in the manufacture of paints, varnishes, lacquers, dyes, soaps and detergents.
7. It is used for making organic compounds, such as ether, chloroform, iodoform, etc.
8. The freezing point of ethanol is very low, that is, −118°C. Thus, when a mixture of water and ethanol is cooled to a temperature of −50°C, it does not freeze. This mixture of water and alcohol is called **anti-freeze** and is used in the radiators of motor cars in cold countries. It prevents water from freezing in the radiators.
9. It is used for sterilising wounds and, hence, is used as an antiseptic.

(D) Harmful effects of drinking alcohol: Medically ethyl alcohol (commonly referred to as alcohol) is an intoxicant. If a person takes alcohol regularly, even in small doses, he/she become dependent on it, as it is addictive in nature.

However, when a person consumes alcohol in excess, he loses all sense of discrimination under its influence. His body functions are uncontrollable and ultimately he loses consciousness.

Prolonged consumption of alcohol, damages the liver and kidneys and many a time results in death. Thus, the use of alcohol on any pretext should be discouraged, as its harmful effects are too serious to be ignored.

(E) Methylated spirit or denatured spirit (alcohol): Ethyl alcohol (ethanol) in pure form or the beverages prepared from it, such as whisky, wine and beer, etc., are subjected to very heavy excise duty, so as to prevent people from drinking it excessively, as drinking is highly injurious to health. However, alcohol is needed in bulk for various industrial purposes for which it should be taxed nominally.

To achieve the above objective ***methanol [CH_3OH]*** is added to ethanol in small quantities.

Methanol, even if consumed in very small quantities can cause death. It is oxidised in the liver to form methanal [HCHO]. The methanal so produced reacts with the components of the living cells. It causes the protoplasm to get coagulated, in the same way as an egg is coagulated by cooking. It also affects the optic nerve and causes blindness.

Ethanol mixed with methanol is called methylated spirit and is used only for industrial purposes.

In addition to methanol, ethanol is sometimes mixed with ***pyridine*** or ***copper sulphate***. These chemicals render the ethanol unfit for human consumption. It is commonly called ***denatured spirit***.

Ethanoic Acid UOFG0M7ISP

(A) Physical properties of ethanoic acid [CH_3COOH]

1. At room temperature pure acetic acid is a corrosive and colourless liquid.
2. It has a pungent smell of its own, like that of vinegar and has a sour taste.
3. It freezes below 16·5°C to form an icy mass, which gives its name glacial acetic acid. 5–8% solution of glacial acetic acid is called vinegar.
4. It boils at 118°C (391 K).
5. Its density is 1·08 g cm^{-3} at 0°C.
6. It is soluble in water in all proportions.
7. It is a good solvent for iodine, sulphur, phosphorus and a number of organic compounds.



Fig. 4.22: Acetic acid

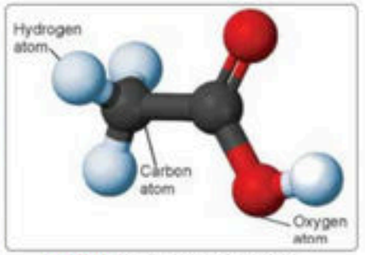


Fig. 4.23: A molecule of acetic acid

Note : Ethanoic acid is weaker than mineral acids (HCl, H_2SO_4, HNO_3) as its pH is around 3 as compared to the mineral acids whose pH is between 0 and 1.

(B) Chemical properties of ethanoic acid [CH_3COOH]

(i) Acidic properties: Ethanoic acid is a weak acid and ionises to the extent of 0.4% to produce $H^+(aq)$ ions.

$$CH_3COOH(l) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+$$

If you compare the action of ethanoic acid with HCl (that almost completely ionises), with litmus paper, you will find that both of them turn blue litmus red.

However, if we find the pH of HCl and CH_3COOH then pH of HCl is around 1 whereas that of CH_3COOH is around 3.

(ii) Esterification: A chemical reaction in which an alcohol reacts with alkanoic acid to form a sweet smelling compound (ester) is called esterification.

Ethanol (100%) reacts with glacial acetic acid in the presence of concentrated sulphuric acid on warming to form ethyl ethanoate (ester) and water.

$$\underset{\text{Ethanoic acid}}{CH_3COOH(l)} + \underset{\text{Ethanol}}{C_2H_5OH(l)} \xrightarrow[\text{Warming}]{\text{Conc. } H_2SO_4} \underset{\text{Ethyl ethanoate (ester)}}{CH_3COOC_2H_5(l)} + \underset{\text{Water}}{H_2O(l)}$$

In the esterification reaction, concentrated H_2SO_4 acts both as a dehydrating agent and as a catalyst.

Esters are sweet smelling compounds which are used for making perfumes and flavouring agents.

Let us perform an activity.

- Pour 1 mL of ethanol (absolute alcohol in a test tube).
- Pour 1 mL of glacial acetic acid in the same test tube and then add a few drops of concentrated sulphuric acid.
- Warm the contents of the test tube in a hot water bath for 10 minutes.
- Pour the contents of the test tube in another beaker containing 20 mL of water.

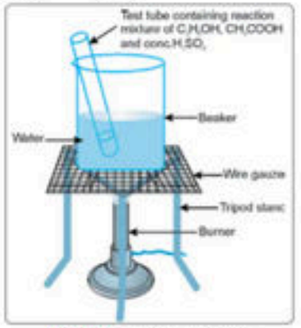


Fig. 4.24: Formation of ester

- Smell the contents of the beaker. You find a sweet fruity smell. This smell is due to the formation of ester ethyl ethanoate.

Note : This reaction is used to test both alcohols and carboxylic acids.

Saponification: **The process by which an ester gets hydrolysed in the presence of sodium hydroxide into the constituent alcohol and sodium salt of the alkanoic acid is known as saponification**. This name is given to the reaction because it is used in the formation of soap.

When the ester (ethyl ethanoate) is warmed with sodium hydroxide, it forms ethyl alcohol (ethanol) and sodium acetate.

$$\underset{\text{Ethyl ethanoate}}{CH_3COOC_2H_5(l)} + \underset{\text{Sodium hydroxide}}{NaOH(aq)} \longrightarrow \underset{\text{Sodium acetate}}{CH_3COONa(aq)} + \underset{\text{Ethanol}}{C_2H_5OH(l)}$$

The acetic acid can be recovered from sodium acetate by treating it with dilute HCl.

$$\underset{\text{Ethyl acetate}}{CH_3COONa(aq)} + HCl(aq) \longrightarrow \underset{\text{Acetic acid}}{CH_3COOH(aq)} + NaCl(aq)$$

(iii) **Action with alkalis:** Dilute ethanoic acid reacts with alkalis to form their respective sodium ethanoates and water, much the same way as the mineral acids.

$$\underset{\text{Ethanoic acid}}{CH_3COOH(aq)} + \underset{\text{Sodium hydroxide}}{NaOH(aq)} \longrightarrow \underset{\text{Sodium ethanoate}}{CH_3COONa(aq)} + \underset{\text{Water}}{H_2O(l)}$$

(iv) **Action with carbonates/bicarbonates:** Dilute ethanoic acid reacts with sodium carbonate/sodium bicarbonate with lot of effervesence and gives off carbon dioxide gas, much the same way as the mineral acids.

$$\underset{\text{Ethanoic acid}}{2CH_3COOH(l)} + \underset{\text{Sodium carbonate}}{Na_2CO_3(s)} \longrightarrow \underset{\text{Sodium ethanoate}}{2CH_3COONa(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

$$\underset{\text{Ethanoic acid}}{CH_3COOH(l)} + \underset{\text{Sodium hydrogen carbonate}}{NaHCO_3(s)} \longrightarrow \underset{\text{Sodium ethanoate}}{CH_3COONa(aq)} + \underset{\text{Water}}{H_2O(l)} + \underset{\text{Carbon dioxide}}{CO_2(g)}$$

This reaction is used to test carboxylic acids.

Uses of Ethanoic Acid (Acetic Acid)

1. Salts of ethanoic acid are used in paints and also in certain medicines.
2. Ethanoic acid is used in the manufacture of various dyes, perfumes and rayon.
3. Synthetic vinegar is used in pickles, etc.
4. Ethanoates of aluminum and chromium are used as mordants.

VWT0UGOSN1

4.14 SOAPS AND DETERGENTS

Introduction to Soaps and Detergents

We use soaps or washing powders of various kinds to remove unwanted materials, such as oils, greases, dirt, etc., sticking to our bodies or the surfaces of clothes or utensils.

Any material that has a cleansing action in water and does not harm the substance that is being cleaned is called a detergent.

The word '*deterge*' means to clear and the substance used for such cleansing action is called **detergent**, whereas the process of removing unwanted materials from various substances is called **detergency**. The detergents are sometimes called **surfactants** as they reduce the surface tension of the liquids to which they are added.

Soaps

A sodium salt of a long chain of carboxylic acid (fatty acid) that has a cleansing action in water is called ***soap***. The general formula for soap is **RCOO—Na$^+$**, where **R** stands for the ***large non-ionic hydrocarbon group*** that may be saturated or unsaturated in nature.

The formula of soap prepared from stearic acid (oil) and alkali is $C_{17}H_{35}COONa$

$C_{17}H_{35}COO^-$: Na^+

Hydrophobic end : hydrophilic end

(long chain hydrocarbon) : (sodium ion)



Fig. 4.25: Soaps

Soaps are prepared from vegetable oils or animal fats by treating them with 10% sodium hydroxide solution, when the reaction takes place with the formation of sodium salt of fatty acids (soap) and glycol.

The process of making soap by the hydrolysis of vegetable oils or animal fats with alkalis is called saponification.

Cleansing Action of Soaps and Detergents

OJUIYRA49N

Our body secretes oils and greasy materials. These materials stick to the clothes we wear. The dirt sticks to these secretions and hence clothes get soiled. The soiled clothes can be cleaned only, if the oil or grease holding dirt particles is broken down into very small molecules.

The process of breaking down of bigger droplets of oil or grease into smaller droplets is called emulsification and the substance used to do so is called emulsifier.

Soaps and detergents are good emulsifiers. During washing with soap or detergent, each small droplet of oil is surrounded by a soap film or a detergent film, which is washed away with water along with dirt it is holding.

Formation of Micelle: The formulae of a soap or detergent molecule consists of a long hydrocarbon chain, with a negative charge and a short ionic part, consisting of positively charged ion. In order to avoid writing a long formula for the soap or detergent molecules, ***its long hydrocarbon chain is represented by a zig-zag line and sodium ion by a dark dot head***.

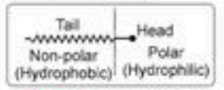


Fig. 4.26: Representation of soaps

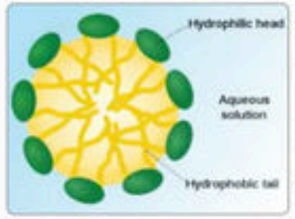


Fig. 4.27: Micelle

It has been found that the long hydrocarbon chain of soap or detergent is hydrophobic. **Hydrophobic** means, it is ***repelled by water molecules***. Further, it is found that this long chain is attracted by the ***molecules of oils or grease***.

Sodium ions, forming the short ionic part are ***hydrophilic*** in nature. It means, that sodium ions are ***attracted by the water molecules, but repelled by the organic oils and greases***.

When soap dissolves in water, it forms a colloidal suspension of soap molecules. The soap molecules then cluster together, to form **soap micelles** as illustrated in Fig. 4.28(a). The micelles remain suspended in water, such that the molecules of soap are arranged radially, with hydrocarbon ends (negatively charged) directed towards the centre and the ionic ends (positively charged) directed outwards.

When a soiled fabric is immersed in a soap solution or a detergent, the hydrocarbon part sinks in the bigger droplets of oil, for the fear of water molecules. This, in turn, breaks bigger oil drops to smaller droplets of oil. Thus, oil gets free from the fabric. When the fabric is hand rubbed or agitated in a washing machine, the tiny droplets of oil along with dirt pass into the soap solution. Thus, oil along with dirt is removed from the fabric.

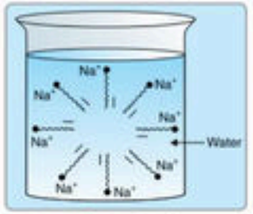


Fig. 4.28(a): Soap or detergent micelle

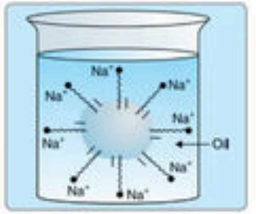


Fig. 4.28(b): Soap or detergent micelle entraps oil particles

Limitations of Soap

Soap is an excellent cleansing agent only, as long as, water is soft. It becomes ineffective under the following situations :

(a) If the **water is hard**, that is, it contains dissolved Ca^{2+} and Mg^{2+} ions, then soap reacts with them to form their respective insoluble salts, commonly, called **scum**.

The scum, so formed, not only wastes soap, but also sticks to clothes, which are being cleaned. Thus, cleaning of clothes becomes a problem.

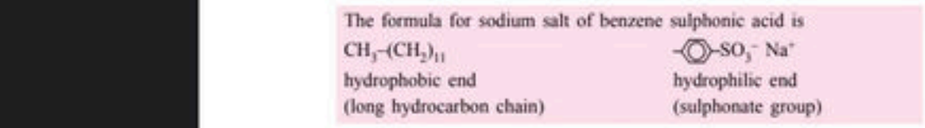
(b) Soap cannot be used as a cleansing agent in acidic waters. It is because, acid precipitates free fatty acids and, hence, soap loses its utility.

Detergents

YAP60OTV93

Detergents are also called ***soapless soaps***. They are either ***sodium salt*** of ***long chain benzene sulphonic acid*** or ***sodium salt*** of long chain ***alkyl hydrogen sulphate***, which show cleansing properties in water.

The formula for sodium salt of benzene sulphonic acid is



All soaps or detergents have one non-polar group of long chain carbon atoms and one polar group of sodium ions in their molecules.

Advantages of Detergents

1. Detergents can be used for cleansing, even when the water is hard. It is because the calcium or magnesium salts of detergents are soluble in water and do not form any scum.
2. Detergents can be used, if water is acidic in nature. It is because, they do not form any scum.
3. Detergents are prepared from petroleum products, which are comparatively cheaper than natural oils and fats. Thus, they are cost effective. Furthermore, vegetable oils and fats are safe for human consumption.

KEY POINTS

- Carbon is a versatile element that forms the basis of all living things.
- Carbon can form a vast variety of compounds because of its tetravalency and the property of catenation.
- Covalent bonds are formed between two similar or different atoms by sharing electrons in their valence shell, such that both of them can achieve the structure of the nearest noble gas.
- Carbon forms covalent bonds with itself as well as atoms of hydrogen, oxygen, nitrogen, sulphur and halogens.
- Carbon can form compounds having a straight chain between carbon atoms with a single bond, or double bond or triple bond. It can also form compounds with branched chains and closed chains.
- Homologous series of carbon compounds is a group of carbon compounds having the same functional group with the same general formula.
- The functional groups such as alcohols, aldehydes, ketones, carboxylic acids and halogens impart characteristic properties to the carbon compounds.
- Carbon and its compounds are major sources of fuels.
- Ethanol and ethanoic acid are the most important compounds of carbon in our daily life.
- Soaps and detergents have cleansing action, because of the presence of hydrophobic and hydrophilic groups in their molecules, which help in emulsifying oil, and hence, in the removal of dirt.

Exercise–4 (C)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

1. Unsaturated hydrocarbons on burning produce :
   (A) light blue non sooty flame (B) yellow sooty flame (C) yellow non-sooty flame (D) none of the above
2. Ethanoic acid dissolves in water to furnish :
   (A) CH_3^+ and $COOH^-$ ions (B) CH_3COO^- and H^+ ions (C) CH_3CO^+ and OH^- ions (D) none of the above
3. Hydrolysis of an ester by sodium hydroxide solution is known as :
   (A) neutralisation (B) saponification (C) both (A) and (B) (D) none of the above
4. In the soap micelles,
   (A) the ionic end of soap is on the surface of the cluster while the carbon chain is in the interior of the cluster
   (B) the ionic end of soap is in the interior of the cluster and the carbon chain is out of the cluster.
   (C) both ionic end and carbon chain are in the interior of the cluster.
   (D) both ionic end and carbon chain are on the exterior of the cluster. [HOTS]

Ans: 1. (B) 2. (B) 3. (B) 4. (A)

II. ASSERTION (A) AND REASON (R)

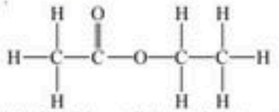
For question numbers 1 and 5, two statements are given–one labeled *Assertion* (A) and the other labelled *Reason* (R). Select the correct answer to these questions from the codes (i), (ii), (iii) and (iv) as given below.

(i) Both A and R are true and R is the correct explanation of the assertion.
(ii) Both A and R are true but R is not the correct explanation of the assertion.
(iii) A is true but R false.
(iv) A is false but R is true.

1. **Assertion:** Hydrocarbons have low melting and boiling points.
   Reason: Hydrocarbons are covalent compounds.
2. **Assertion:** Alkenes are unsaturated hydrocarbons.
   Reason: The general formula of alkenes is C_nH_{2n}.
3. **Assertion:** All homologues have similar, but graded chemical properties.
   Reason: The first member of alkyne homologous series is methyne.
4. **Assertion:** Saturated hydrocarbons are highly reactive.
   Reason: Saturated hydrocarbons react rapidly with chlorine.
5. **Assertion:** In a micelle the hydrocarbon ends directed towards the centre.
   Reason: The long hydrocarbon chain of soap or detergent is hydrophobic.

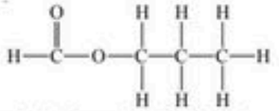
III. VERY SHORT ANSWER TYPE QUESTIONS

1. The structural formula of an ester is :



   Write the molecular formula of the alcohol and the acid from which it would have been formed.

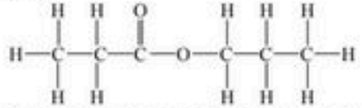
2. The structural formula of an ester is :



   Write the formula of the acid and the alcohol from which it is formed.

3. Name the main products formed when :
   (i) Ethanol is oxidised by an alkaline solution of $KMnO_4$.
   (ii) Sodium ethanoate is heated with soda lime.

4. Name the product formed beside soap that is obtained during the saponification process.
5. What happens when soap solution in a test tube is shaken with (i) soft water and (ii) hard water?
6. What is denatured alcohol?
7. Mention the name of the byproduct of the soap industry.
8. What is observed when bromine water is added to ethene?
9. Complete the following chemical equation: $CH_3CH_2OH + Na$
10. The structural formula of an ester is :



Write the molecular formula of the alcohol and the acid from which it would have been formed.

11. Which gas will be evolved if sodium bicarbonate is added to a solution of tartaric acid?

IV. SHORT ANSWER TYPE QUESTIONS

1. Give reasons for the following :
   (i) Oxidation of ethanol with Cr_2O_3 produces ethanal while ethanol when oxidised with alkaline $KMnO_4$ produces ethanoic acid.
   (ii) Alcohol supplied for industrial purposes is mixed with copper sulphate.
2. Complete the following equations and write the names of the products formed :
   (i) $CH_3COONa + NaOH \xrightarrow{heat}$ (ii) $CH_3OH + O_2 \xrightarrow[Ag\ catalyst]{heat}$
3. Explain giving reasons : Detergents, made up of molecules, in which branching is minimum, are preferred these days.
4. Name the products obtained and the chemical equations for oxidation of ethanol to different stages.
5. Explain the cleansing action of soaps.
   An organic compound "A" is a constituent of anti-freeze. The compound on heating with oxygen forms another compound "B" that has a molecular formula $C_2H_4O_2$. Identify the compound "A" and "B". Write the chemical equation of the reaction that takes place to form the compound "B".
6. How do acetic acid and ethyl alcohol react when warmed together in the presence of a small quantity of concentrated sulphuric acid? Write the chemical equation for the reaction taking place.
7. Compound "X" is a symmetrical gaseous hydrocarbon. Its empirical formula is CH_2. "X" decolourises bromine water.
   It forms monochloro addition product "Y" with gaseous HCl. Molecular mass of "Y" is 64.5. Idenify the compounds "X" and "Y". Write the chemical reaction of "X" with bromine water and HCl gas.
8. An organic compound "X" that is sometimes used as anti-freeze has the molecular formula C_2H_6O. "X" on oxidation gives a compound "Y", which gives effervescence with baking soda solution. What can "X" and "Y" be? Write their structural formulae.
9. Acetic acid reacts with ethyl alcohol in the presence of conc. H_2SO_4 producing a sweet smelling compound. For the reaction : (i) Name the main product and (ii) Write the chemical equation.
10. Explain the following :
    (i) Air holes of a gas burner have to be adjusted, when a heated vessel gets blackened by the flame.
    (ii) Use of synthetic detergents causes pollution of water.
11. Name the gas evolved when ethanoic acid is added to sodium carbonate. How would you prove the presence of this gas?
12. Match the reactions given in Column A with names given in Column B.

Column A	**Column B**
(a) $CH_3OH + CH_3COOH \xrightarrow{H^+} CH_3COOCH_3 + H_2O$	(i) Addition reaction
(b) $CH_2 = CH_2 + H_2 \xrightarrow{Ni} CH_3 - CH_3$	(ii) Substitution reaction
(c) $CH_4 + Cl_2 \xrightarrow{Sunlight} CH_3Cl + HCl$	(iii) Neutralisation reaction
(d) $CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$	(iv) Esterification reaction

13. A gas is evolved when ethanol reacts with sodium. Name the gas evolved and also write the balanced chemical equation of the reaction involved. [HOTS]

14. Unsaturated hydrocarbons contain multiple bonds between the two C-atoms and show addition reactions. Give the test to distinguish ethane from ethene. [HOTS]

15. What is saponification? Write the reaction involved in this process. [HOTS]

16. Intake of small quantity of methanol can be lethal. Comment. [HOTS]

17. Write the name and molecular formula of an organic compound having its name suffixed with "ol" and having two carbon atoms in the molecule. With the help of a balanced chemical equation indicate what happens when it is heated with excess of conc. H_2SO_4.

18. What happens when wood is burnt in a limited supply of oxygen? Name the residue left behind after the reaction and state two advantages of using this residue as a fuel over wood.

19. Write the names and molecular formula of two organic compounds having functional group suffixed as '–oic acid'. With the help of a balanced chemical equation explain what happens when any one of them reacts with sodium hydroxide.

20. Complete the following reaction equations :

(i) $CH_3CH_2OH \xrightarrow[CH_3COOH]{CrO_3 \text{ in}}$ (ii) $CH_3COOH + C_2H_5OH \xrightarrow{H_2SO_4}$

21. Name the product(s) formed when :

(i) Chromic anhydride dissolved in glacial ethanoic acid is added dropwise to ethanol.

(ii) Ethanol burns in air.

22. (i) Name the organic acid present in vinegar. Write its chemical formula also.

(ii) Name the products formed when

(a) Ethanol burns in air. (b) Ethanol is heated with excess of conc. H_2SO_4.

23. What are detergents chemically? Why are they more effective than soaps for cleansing action? How can detergent molecules be altered to make them biodegradable?

24. Write one example each to illustrate the following : (i) Saponification and (ii) Esterification.

25. (a) Write the chemical equation representing the preparation reaction of ethanol from ethene.

(b) Give an example of an esterification reaction.

26. What happens when ethanoic acid reacts with : (i) magnesium, (ii) sodium carbonate, and (iii) sodium hydroxide? Write the necessary chemical equation in each case.

27. What happens when ethanol reacts with (i) sodium (ii) chromic anhydride and (iii) alkaline potassium permanganate solution? Write the necessary chemical equations for the reactions involved in the above cases.

28. An organic compound "A" is an essential constituent of wine and beer. Oxidation of "A" yields an organic acid 'B' which is present in vinegar. Name the compounds "A" and "B" and write their structural formula. What happens when "A" and "B" react in the presence of an acid catalyst? Write the chemical equation for the reaction.

29. An ester has the molecular formula $C_4H_8O_2$. Write its structural formula. What happens when this ester is heated in the presence of sodium hydroxide solution? Write the balanced chemical equation for the reaction and name the products. What is a saponification reaction?

30. An organic compound "X" is an essential constituent of wine and beer. "X" is responsible for the intoxication caused by these drinks. Oxidation of "X" yields an oganic acid "Y" which is present in vinegar. Name the compounds "X" and "Y" and write their structural formula.

31. Describe along with chemical equations, what happens when : (i) Ethene reacts with bromine water, (ii) Ethanol burns in air and (iii) Ethanoic acid reacts with ethanol in the presence of sulphuric acid.

32. What are esters? How are they formed? Where do they occur in nature? Give one example.

33. An organic compound "A" of molecular formula C_2H_6O on oxidation gives an acid "B" with the same number of carbon atoms in the molecule as "A". Compound "A" is often used for sterilization of skin by doctors. Name the compounds "A" and "B". Write the chemical equation involved in the formation of "B" from "A".

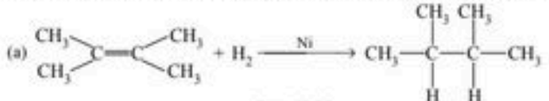
34. Two compounds "A" and "B" have the same molecular formula $C_4H_8O_2$. Compound "A" is an acid and compound "B" has a fruity smell. Suggest (i) chemical formulae and (ii) structural formulae of compounds "A" and "B". Name the functional group of compound "B". What name would you give to the relationship between the compounds "A" and "B"?



35. Why are detergents better cleansing agents than soaps? Explain. [HOTS]

36. How would you bring about the following conversions? Name the process and write the reaction involved.
   (a) Ethanol to ethene.
   (b) Propanol to propanoic acid.

37. What is the role of metal or reagents written on arrows in the given chemical reactions?



(b) $CH_3COOH + CH_3CH_2OH \xrightarrow{\text{Conc. } H_2SO_4} CH_3COOC_2H_5 + H_2O$

(c) $CH_3CH_2OH \xrightarrow[\text{Heat}]{\text{Conc. } H_2SO_4} CH_2 = CH_2 + H_2O$ [HOTS]

38. Write the name and general formula of a chain of hydrocarbons in which an addition reaction with hydrogen is possible. State the essential condition for an addition reaction. Stating this condition, write a chemical equation giving the name of the reactant and the product of the reaction. [2015]

V. LONG ANSWER TYPE QUESTIONS

1. (a) Distinguish between esterification and saponification reactions of organic compounds.
   (b) With a labelled diagram describe and activity to show the formation of an ester.
   (c) What is vinegar? Describe with chemical equation its reaction with sodium hydrogen carbonate.

2. (a) An organic acid "X" is a liquid that often freezes in winter in cold countries, has a molecular formula $C_2H_4O_2$. On warming with ethanol in the presence of a few drops of concentrated sulphuric acid, a compound "Y" with a sweet smell is formed. (i) Identify "X" and "Y" and (ii) Write chemical equations for the reaction involved.
   (b) (i) What would be observed by adding 5% solution of alkaline potassium permanganate solution drop by drop to some warm ethanol taken in a test-tube.
   (ii) Write the name of the compound formed during the chemical reaction.
   (c) How would you distinguish experimentally between an alcohol and carboxyclic acid on the basis of a chemical property.

3. (a) State the principle on which the cleansing action of soap is based?
   (b) Why is conversion of ethanol to ethanoic acid considered oxidation reaction?
   (c) What are esters? How are they formed? Write two uses of esters.

4. Explain the given reactions with examples :
   (a) Hydrogenation reaction (b) Oxidation reaction (c) Substitution reaction
   (d) Saponification reaction (e) Combustion reaction [HOTS]

5. How is ethene prepared from ethanol? Give the reaction involved in it. [HOTS]

6. Esters are sweet smelling substances and are used in making perfumes. Suggest some activity and the reaction involved for the preparation of an ester with a well labelled diagram. [HOTS]

7. A compound C (molecular formula, $C_2H_4O_2$), reacts with Na–metal to form a compound R and evolves a gas that burns with a pop sound. Compound C, on treatment with an alcohol A in the presence of an acid forms a sweet smelling compound S (molecular formula, $C_3H_6O_2$). On addition of NaOH to C, it also gives R and water. S on treatment with NaOH solution gives back R and A. Identify C, R, A, S and write down the reactions involved. [HOTS]

8. A salt X is formed and a gas is evolved when ethanoic acid reacts with sodium hydrogen carbonate. Name the salt X and the gas evolved. Describe an activity and draw the diagram of the apparatus to prove that the evolved gas is the one that you have named. Also, write chemical equation of the reaction involved. [HOTS]

9. Name the reaction that is commonly used in the conversion of vegetable oils to fats. Explain the reaction involved in detail. [HOTS]

10. List two tests for experimentally distingusihing between an alcohol and a carboxylic acid and describe how these tests are performed. [2015]

11. Write the name and structure of an aldehyde with four carbon atoms in its molecule. [2016]

12. Write three different chemical reactions showing the conversion of ethanoic acid to sodium ethanoate. Write a balanced chemical equation in each case. Write names of the reactants and the products other than ethanoic acid and sodium ethanoate in each case. [2016]

13. For preparing soap in the laboratory, we require an oil and a base. Which of the following combinations of an oil and a base would be best suited for the preparation of soap? [2016]

(i) Castor oil and calcium hydroxide (ii) Turpentine oil and sodium hydroxide
(iii) Castor oil and sodium hydroxide (iv) Mustard oil and calcium hydroxide

14. A student puts a drop of reaction mixture of a saponification reaction first on a blue litmus paper and then on a red litmus paper. He may observe that : [2016]

(i) there is no change in the blue litmus paper and the red litmus paper turns white.
(ii) there is no change in the red litmus paper and the blue litmus paper turns red.
(iii) there is no change in the blue litmus paper and the red litmus paper turns blue.
(iv) no change in colour is observed on both the litmus paper.

15. A student adds a spoon full of powdered sodium hydrogen carbonate to a flask containing ethanoic acid. List two main observations that he/she must note in his/her notebook about the reaction that takes place. Also, write chemical equation for the reaction. [2016]

16. Write the structural formula of ethanol. What happens when it is heated with excess of conc. H_2SO_4 at 443 K? Write the chemical equation for the reaction stating the role of conc. H_2SO_4 in this reaction. [2017]

17. Why are certain compounds called hydrocarbons? Write the general formula for homologous series of alkanes, alkenes and alkynes and also draw the structure of first member of each series. Write the name of the reaction that converts alkenes mto alkanes and also write a chemical equation to show the necessary conditions for the reaction to occur. [2017]

18. When you add a few drops of acetic acid to a test tube containing sodium bicarbonate powder, which one of the following is your observation? [2017]

(i) No reaction takes place.
(ii) A colourless gas with pungent smell is released with brisk effervescence.
(iii) A brown coloured gas is released with brisk effervescence.
(iv) Formation of bubbles of a colourless and odourless gas.

19. While studying the saponification reaction, what do you observe when you mix an equal amount of colourless vegetable oil and 20% aqueous solution of NaOH in a breaker? [2017]

(i) The colour of the mixture has become dark brown. (ii) A brisk effervescence is taking place in the beaker.
(iii) The outer surface of the beaker has become hot. (iv) The outer surface of the beaker has become cold.

20. A compound 'X' on heating with excess concentrated sulphuric acid at 443 K gives an unsaturated compound 'Y' . 'X' also reacts with sodium metal to evolve a colourless gas 'Z'. Identify 'X', 'Y' and 'Z' . Write the equation of the chemical reaction of formation of 'Y' and also write the role of sulphuric acid in the reaction. [2018]

21. What happens when 5% alkaline potassium permanganate solution is added drop by drop to warm propyl alcohol (propanol) taken in a test tube? Explain with the help of a chemical equation. [2018]

22. What is the difference between soaps and detergents ? State in brief the cleansing action of soaps in removing an oily spot from a fabric. Why are soaps not very effective when a fabric is washed in hard water? How is this problem resolved? [2018]

VI. PASSAGE–BASED QUESTIONS

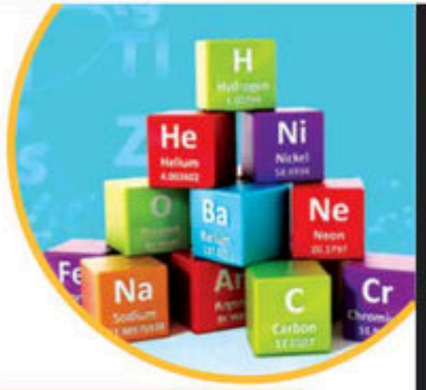
Answer the questions (1–4) on the basis of your understanding of the following paragraphs and the related studied concepts.

Most carbon compounds are poor conductors of electricity. They have low melting and boiling points as compared to ionic compounds. We can conclude that the forces of attraction between the molecules are not very strong. Since these compounds are largely non-conductors of electricity, we can conclude that the bonding in these compounds does not give rise to any ions. We know that the reactivity of elements is explained as their tendency to attain a completely filled outer shell, that is, attain noble gas configuration. Elements forming ionic compounds achieve this by either gaining or losing electrons from the outermost shell.

1. What is the nature of bond formed by carbon?
2. Is it possible for carbon to lose or gain four electrons?
3. Compounds of carbon are either bad conductors of electricity or insulators. Why is that so?
4. Why do covalent compounds occur in the form of gases or liquids?



5 Periodic Classification of Elements



INSIDE THE CHAPTER

5.1 Early attempts at classification of elements
- Dobereiner's triads
- Newlands' law of octaves
- Mendeleev's periodic table

5.2 Modern periodic table – long form of the periodic table
5.3 Position of hydrogen in the periodic table
5.4 Periodicity in the periodic table
5.5 Trends in properties
- Atomic size
- Metallic character
- Non-metallic character
- Chemical reactivity

5.6 Merits of the long form of the periodic table

S3CYMI18R2

INTRODUCTION

At present, 118 elements are known and it is very difficult to study the properties of all these elements individually. So the need arose to group the elements of similar properties together. Following are the reasons for the classification of elements :

(a) It helps us to study elements better.
(b) It correlates the properties of elements with some fundamental properties, characteristic to all elements.
(c) It reveals the relationship between one element and another element.

Various attempts were made to classify the elements from time to time. Let us discuss some of the early attempts to classify the elements.

5.1 EARLY ATTEMPTS AT CLASSIFICATION OF ELEMENTS

Dobereiner's Triads

Dobereiner's triads and Newland's law of octaves were early attempt at classifying elements into groups based on their properties.

J.W. Dobereiner's, in 1817, tried to classify elements on the basis of their physical and chemical properties. He noticed a pattern with certain elements that had similar physical and chemical properties; he classified these elements in groups of three elements. He called these group of three elements as 'triads'. In a triad the elements are arranged in increasing order of their atomic masses, in such a way that the atomic mass of the middle element is the average of the atomic masses of the first and third elements.

Dobereiner's Triad: *"A group of three chemically similar elements arranged in the order of their atomic masses, constitute a* ***triad.****"*

Dobereiner's Law of Triads

It states that, *when we put elements of similar physical and chemical properties, in increasing order of their atomic masses, the average of the atomic masses of the first and third elements in the triad is almost equal to the atomic mass of the second element.*

Let us look at some examples :

1. **Triad of Alkali Metals:** This triad consists of Lithium (Li), Sodium (Na) and Potassium (K). The appearance and chemical reactions of these three elements are similar to each other. For example :

   (i) In this triad, all the three elements are metal.

   (ii) All the three elements react with water and form alkalis and hydrogen gas.

   Because these elements have similar physical and chemical properties, therefore, these three elements were put in one triad. This triad is also called alkali metal group or alkali metal family.

   In this triad the first element is lithium with atomic mass 7, second element is sodium with atomic mass 23 and the third element is potassium with atomic mass 39.

   Table 5.1 : Triad of alkali metals

Elements of the Triad	Symbol	Atomic masses
Lithium	Li	7
Sodium	Na	23
Potassium	K	39

   According to the Dobereiner's law of triads, *"the atomic mass of the second element of a triad is approximately equal to the average of the atomic masses of the first and third elements."*

   Let us calculate the atomic mass of sodium, from the atomic masses of lithium and potassium.

   Atomic mass of lithium = 7

   Atomic mass of potassium = 39

   Atomic mass of sodium (middle element) = $\frac{7 + 39}{2} = \frac{46}{2} = 23$.

   Atomic mass of sodium = 23.

   Here we have seen that, the average of the atomic masses of lithium and potassium is 23, this is equal to the atomic mass of sodium.

2. **Triad of Alkaline Earth Metals:** This triad consists of Calcium (Ca), Strontium (Sr) and Barium (Ba). The appearance and chemical reactions of these elements are similar to each other. For example :

   (i) All the three elements are metals.

   (ii) All the three elements form basic oxides.

   Because these elements have similar physical and chemical properties, therefore, all these three elements were put in one triad. This triad is also called alkaline earth metal group or alkaline earth metal family. Please note that *the alkaline earth metal family was the first triad which Dobereiner identified.*

   Table 5.2 : Triad of alkaline earth metals

Elements of the Triad	Symbol	Atomic masses
Calcium	Ca	40
Strontium	Sr	88
Barium	Ba	137

   In this triad the first element is calcium with atomic mass 40, second element is strontium with atomic mass 88 and the third element is barium with atomic mass 137.

   According to the Dobereiner's law of triads, *"the atomic mass of the second element of a triad is approximately equal to the average of the atomic masses of the first and third elements."*

   Let us calculate the atomic mass of strontium, from the atomic masses of calcium and barium.

   Atomic mass of calcium = 40

   Atomic mass of barium = 137

   Atomic mass of strontium = $\frac{40 + 137}{2} = \frac{177}{2} = 88.5$.

   The calculated atomic mass of strontium is 88.5, which is approximately equal to the actual atomic mass of strontium that is 88.



3. **Triad of Halogens:** This triad consists of Chlorine (Cl), Bromine (Br) and Iodine (I). At room temperature and pressure, chlorine is gas, bromine is liquid and iodine is solid. But still they have similar physical and chemical properties. For example :

(i) All the three elements are non-metals.

(ii) All these elements react with metals to form salts.

Because of their similar properties, these elements were put in one triad. This triad is also called halogen group or halogen family.

Table 5.3 : Triad of halogens

Elements of the Triad	Symbol	Atomic masses
Chlorine	Cl	35.5
Bromine	Br	80
Iodine	I	127

In this triad the first element is chlorine with atomic mass 35.5, second element is bromine with atomic mass 80 and third element is iodine with atomic mass 127.

Let us calculate the atomic mass of bromine, from the atomic masses of chlorine and iodine.

Atomic mass of chlorine = 35.5

Atomic mass of iodine = 127

Atomic mass of bromine = $\frac{35.5 + 127}{2}$ = 81.25

The calculated atomic mass of bromine is 81.25, which is approximately equal to the actual atomic mass of bromine, that is 80.

Note: Dobereiner discovered that the atomic mass of the middle element in each triad was almost equal to the average of the atomic masses of the other two elements. This gave other scientists a clue that the atomic masses were important when arranging the elements.

Limitation of Dobereiner's Classification

Dobereiner could identify only three such triads of elements having similar properties. Further, this type of classification of elements into triads could not be applied to all the known elements of that time.

Newlands' Law of Octaves

HM062YFNQ5

In 1864, an English scientist John Newlands attempted the then known elements. He arranged the elements in an increasing order of their atomic masses and observed that every eighth element had similar properties. Newlands compared the similarity between the elements to the octaves of music, where every eighth notes is comparable to the first. On the basis of this observation, Newlands' law of octaves was formulated.

Law of Octaves

When the elements are arranged in the order of increasing atomic masses, the properties of the eighth element (starting from a given element) are the repetition of the properties of the first element.

Table 5.4 : Newlands' Octaves

Notes of Music	Sa (do)	re (re	ga (mi)	ma (fa)	pa (so)	da (la)	ni (li)
	H	Li	Be	B	C	N	O
	F	Na	Mg	Al	Si	P	S
	Cl	K	Ca	Cr	Ti	Mn	Fe
	Co and Ni	Cu	Zn	Y	In	As	Fe
	Br	Rb	Sr	Ce and La	Zr	–	–

* Dobereiner first expressed his idea as early as 1817, but the first published explanation of his system of triads appeared in 1829.

Table 5.4 shows the 17 elements arranged by Newland on the basis of his law.

If we start from lithium (Li) then the eighth element is sodium (Na) and the next eighth element is potassium (K). They are known to have similar physical and chemical properties. Similarly, **Be, Mg** and **Ca, B** and **Al, C** and **Si**, etc., have similar chemical and physical properties.

Limitations of Newlands' Law of Octaves

1. This law of classification was applicable only up to calcium. After calcium, every eighth elements did not possess similar physical or chemical properties. So, this law worked with only lighter elements.
2. Newlands assumed that only 56 elements exist in nature. However, several new elements were discovered whose properties did not fit into law of octaves.
3. Several elements were fit into same slots, to fit the elements in his table. For example, cobalt (Co) and nickel (Ni) were placed in the same slot. Also cerium (Ce) and lanthanum (La) were placed in the same slot.
4. Elements with dissimilar properties were grouped together. For example, the halogens were grouped with some metals such as cobalt, nickel and platinum.

Assess Yourself – 1

1. Why there was necessity for classification of elements? Give at least two reasons.
2. From the list of elements given below, make three triads and name the family of each triad.
   Cl, Li, Ca Br, Na, Sr, I, K and Ba.
3. What is the achievement of Dobereiner's law of triads?
4. Complete the statement given below :
   On the basis of Newland's law of classification of elements, the properties of sodium and potassium are similar, because potassium is the _____ element, starting from sodium.
5. State two achievements of the law of octaves.
6. State two reasons for rejecting the law of octaves.
7. The elements A and B obey law of octaves. How many elements are there in between A and B?

Mendeleev's Periodic Table

KJ4L1U0IZR

By the year 1869, **Dmitri Invanovich Mendeleev,** a Russian scientist studied the chemical properties of all the 63 elements known at that time. He tried to arrange these elements in the form of a table on the following basis :

(a) increasing order of ***atomic mass*** of elements.

(b) similarities in the ***chemical properties*** of elements.

In such an arrangement, he noticed that the elements with similar physical and chemical properties repeat after regular intervals. Because of the repetition of similar chemical properties after fixed interval (period), Mendeleev called this repetition **Periodic Law**.

Mendeleev's Periodic Law

The physical and chemical properties of all elements are the periodic function of their atomic masses.



Mendeleev's Periodic Table

A tabular chart, representing a systematic arrangement of elements in groups and periods in the order of their increasing atomic masses is called ***Mendeleev's periodic table.***

The original Mendeleev's periodic table was published in 1869 in his scientific paper titled ***"Relation of properties to atomic masses of elements"***. The periodic table is shown below.

In this periodic table, Mendeleev arranged **all the 63 elements known at that time** in the increasing order of atomic masses in the horizontal rows in such a way, that elements having similar chemical properties, came directly under one another in the same vertical column or group.

Table 5.5 : Mendeleev's periodic table

	GROUP I	GROUP II	GROUP III	GROUP IV	GROUP V	GROUP VI	GROUP VII	GROUP VIII
Oxides → Hydrides →	R_2O RH	RO RH_2	R_2O_3 RH_3	RO_2 RH_4	R_2O_5 RH_3	RO_3 RH_2	R_2O_7 RH	RO_4 —
PERIODS ↓ 1	H 1.0							
2	Li 7.0	Be 9.1	B 11.0	C 12.0	N 14.0	O 16.0	F 19.0	
3	Na 23.0	Mg 24.3	Al 27.0	Si 28.4	P 31.0	S 32.0	Cl 35.5	
1st series: 4 2nd series:	K 39.1 Cu 63.5	Ca 40.1 Zn 65.4	... 44 ... 68	Ti 48.1 ... 72	V 51.4 As 75	Cr 52.1 Se 79	Mn 55.0 Br 79.9	Fe Co Ni 55.8 58.9 58.7
1st series: 5 2nd series:	Rb 85.4 Ag 107.9	Sr 87.6 Cd 112.4	Y 89.0 In 114.0	Zr 90.6 Sn 119.0	Nb 94.0 Sb 120.0	Mo 96.0 Te 127.6	Tc 99 I 126.9	Ru Rh Pd 101.0 102.9 106.4
1st series: 6 2nd series:	Cs 132.9 Au 197.2	Ba 137.3 Hg 200.0						

Mendeleev used **English Numerals** to identify periods and **Roman Numerals** to identify group.

Mendeleev's table did not include noble gases for the simple reason that they were not discovered when he framed the periodic table.

In the formula for oxides and hydrides at the top of the columns, the letter 'R' is used to represent any of the elements in the group.

Characteristics of Mendeleev's Periodic Table

1. There are eight vertical columns called **groups.** Groups *I to VIII* are further divided into two sub-groups, that is, **subgroup 'A'** and **subgroup 'B'.**
2. The horizontal rows in the periodic table are called **periods.** There are seven periods numbered from 1 to 7. Among chemical properties, Mendeleev gave importance on the compounds formed by the elements with hydrogen and oxygen, because they are highly reactive.



3. In a period, the properties of elements gradually change from **metallic to non-metallic** character.
4. There are few gaps in the periodic table. Mendeleev left these gaps knowingly as these elements were not known at that time.
5. Some of the spaces left for the unknown elements are listed below :
   (i) **Eka - aluminium,** which is **gallium**.
   (ii) **Eka - silicon,** which is **germanium**.
   (iii) **Eka - boron,** which is **scandium**.

Merits of Mendeleev's Classification of Elements over Previous Classifications

1. It is based on the fundamental property of atomic mass of an element, also the grouping of elements was done in such a manner that elements with similar properties are placed together in the same vertical group. For example, cobalt (atomic mass = 58.93) was placed before nickel (atomic mass = 58.71) because the properties of cobalt (Co) were similar to those of rhodium (Rh) and iridium (Ir) whereas properties of nickel (Ni) were similar to those of palladium (Pd) and platinum (Pt).
2. Mendeleev left some gaps knowingly for those elements which were not known at that time. By leaving gaps, he made the bold prediction that these elements will be discovered later. He also predicted their properties by placing them in the same group. For example, Mendeleev named elements by prefixing sanskrit word ***eka*** (for one) to the name of preceding element in same group, that is, ***eka***-boron for scandium, ***eka***-aluminium for gallium and ***eka***-silicon for germanium. Later, these elements were discovered and Mendeleev's prediction were found correct.
3. One more merit of Mendeleev's Periodic Table is that, when noble gases were discovered, they could be placed in a new group without disturbing the existing order.

Limitations of Mendeleev's Periodic Table

Anomalous Pairs: In the Mendeleev's periodic table, the elements were arranged on the basis of their atomic masses. However, there were three such pairs in which atomic mass of the preceding element is higher than that of the following elements :

Preceding element	Following element
Cobalt (58·9)	Nickel (58·6)
Tellurium (127·6)	Iodine (126·9)

The above pairs are against Mendeleev's periodic law. However, with the modern correction on the basis of atomic numbers, this anomaly is removed.

Position of Hydrogen: Hydrogen is not given a definite position. It was placed in Group I with alkali metals, because hydrogen also combines with halogens, oxygen and sulphur like alkali metals. Hydrogen also resembles halogens. For example, hydrogen also exists in diatomic form like halogens. Also, it combines with metals to form ionic compounds and with non-metals it forms covalent compounds. All these properties show that hydrogen could also be placed with halogens in Group VII. Thus, Mendeleev was unable to assign a correct position to hydrogen.

Position of Isotopes: Mendeleev's periodic table is silent about isotopes because isotopes discovered long after Mendeleev's periodic table. Isotopes are atoms of same element having similar properties but different atomic masses. So, isotopes of elements posed a challenge to the Mendeleev's Periodic Law.

Mendeleev's periodic law was unable to locate hydrogen in the periodic table, the atomic mass was not regular and placement of isotopes in the periodic table could not explained. Thus, it was thought that there must be a more fundamental property of elements which could give an explanation for the periodicity in the properties of elements.



Exercise-5 (A)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

1. Classification of elements helps us to :
   (A) study elements better in a systematic way.
   (B) correlate the properties of elements with some fundamental properties of matter.
   (C) to reveal relationship of various elements with each other.
   (D) all the above
2. If atomic mass of calcium is 40 and that of barium is 137, then the atomic mass of strontium, which constitutes the triad of Ca, Sr and Ba is :
   (A) 90 (B) 88.5 (C) 100 (D) 54
3. Law of octaves for the classification of elements was stated by :
   (A) Mendeleev (B) Newland (C) Dobereiner (D) none of these
4. Two elements A and B obey Newland's law of octaves. The number of elements between A and B are :
   (A) 8 (B) 7 (C) 6 (D) none of the above
5. The reasons for rejecting the law of octaves is :
   (A) it does not extend beyond calcium.
   (B) position of hydrogen was not justified with fluorine and chlorine.
   (C) it did not recognise transition elements.
   (D) all the above
6. According to Mendeleev's periodic table, gaps were left for the elements to be discovered later. Which of the following elements found a place in the periodic table :
   (A) Germanium (B) Chlorine (C) Oxygen (D) Silicon
7. According to Mendeleev's periodic law, properties of all elements are a periodic function of
   (A) atomic masses (B) atomic numbers
   (C) symbols (D) valencies
8. What was the name given by Mendeleev to the missing element gallium?
   (A) Eka-silicon (B) Eka-boron
   (C) Eka-aluminium (D) Scandium

Ans: 1. (D) 2. (B) 3. (B) 4. (C) 5. (D) 6. (A) 7. (A) 8. (C)

II. VERY SHORT ANSWER TYPE QUESTIONS

1. Why was the system of classification of elements into triads not found suitable?
2. Calcium, strontium and barium form a Dobereiner's triad. The atomic masses of calcium and barium are 40 and 137 respectively. Predict the atomic mass of strontium.
3. Chlorine, bromine and iodine form a Dobereiner's triad. The atomic masses of chlorine and iodine are 35.5 and 126.9 respectively. Predict the atomic mass of bromine.
4. Lithium, sodium and potassium form a Dobereiner's triad. The atomic masses of lithium and potassium are 7 and 39 respectively. Predict the atomic mass of sodium.
5. Name three elements for which Mendeleev left gaps in the periodic table?
6. In Mendeleev's Periodic Table, why was there no mention of Noble gases like Helium, Neon and Argon?
7. State two limitations of the Mendeleev's periodic table.
8. In Mendeleev's periodic table the elements were arranged in the increasing order of their atomic masses. However, cobalt with atomic mass of 58.93 was placed before nickel having an atomic mass of 58.71. Give reasons for the same.

III. SHORT ANSWER TYPE QUESTIONS

1. Why is there a necessity for the classification of elements? Give at least two reasons.



2. (i) What do you understand by triad of elements. Give an example.
   (ii) State Dobereiner's law of triads.
3. Cl, Li, Ca, Br, Na, Sr, I, K and Ba
   From the list of elements given above make three triads and name the family of each triad.
4. Can the following groups of elements be classified as Dobereiner's triad?
   (a) Na, Si, Cl (b) Be, Mg, Ca
   Atomic mass of Be 9; Na 23; Mg 24; Si 28; Cl 35; Ca 40. [HOTS]
   Explain by giving reason.
5. The three elements A, B and C with similar properties have atomic masses X, Y and Z respectively. The mass of Y is appeoximately equal to the average mass of X and Z. What is such an arrangement of elements called? Give one example of such a set of elements. [HOTS]
6. Which group of elements could be placed in Mendeleev's periodic table without disturbing the original order? Give reason. [HOTS]
7. Give an account of the process adopted by Mendeleev for the classification of elements. How did he arrive at the "Periodic Law"?
8. Mendeleev "predicted the existence of certain elements not known at that time and named two of them as Eka-silicon and Eka-aluminium". Name the elements that have taken the place of these elements.

IV. LONG ANSWER TYPE QUESTIONS

1. (i) What is the achievement of Dobernier's law of triads?
   (ii) What were the reasons for rejecting this classification?
2. (i) State the law of octaves.
   (ii) Name the scientist who framed the above law.
   (iii) Two elements A and B obey the law of octaves. How many elements are there in between A and B?
3. What physical and chemical properties of elements were used by Mendeleev in creating his periodic table? List two observations that posed challenge to Mendeleev's periodic law.
4. (a) Why do we classify elements?
   (b) What were the two criteria used by Mendeleev in creating his period table?
   (c) Why did Mendeleev left some gaps in his periodic table?
   (d) In the Mendeleev's periodic table, why were there no mention of noble gases like helium, neon and argon?
   (e) Would you place the two isotopes of chlorine Cl-35 and Cl-37 in different slots, because of the difference in their atomic masses or in the same slot because their chemical properties are same. Justify your answer.
5. (a) State two criteria Mendeleev used to classify the elements in his periodic table.
   (b) State Mendeleev's periodic law.
   (c) Why could no fixed position be given to hydrogen in Mendeleev's periodic table?
   (d) Why did Mendeleev left gaps in his periodic table?
   (e) State three limitations of Mendeleev's classification of elements.
6. (i) State two achievements of the law of octaves.
   (ii) What were the reasons for rejecting the law of octaves?

V43OW8BNPQ

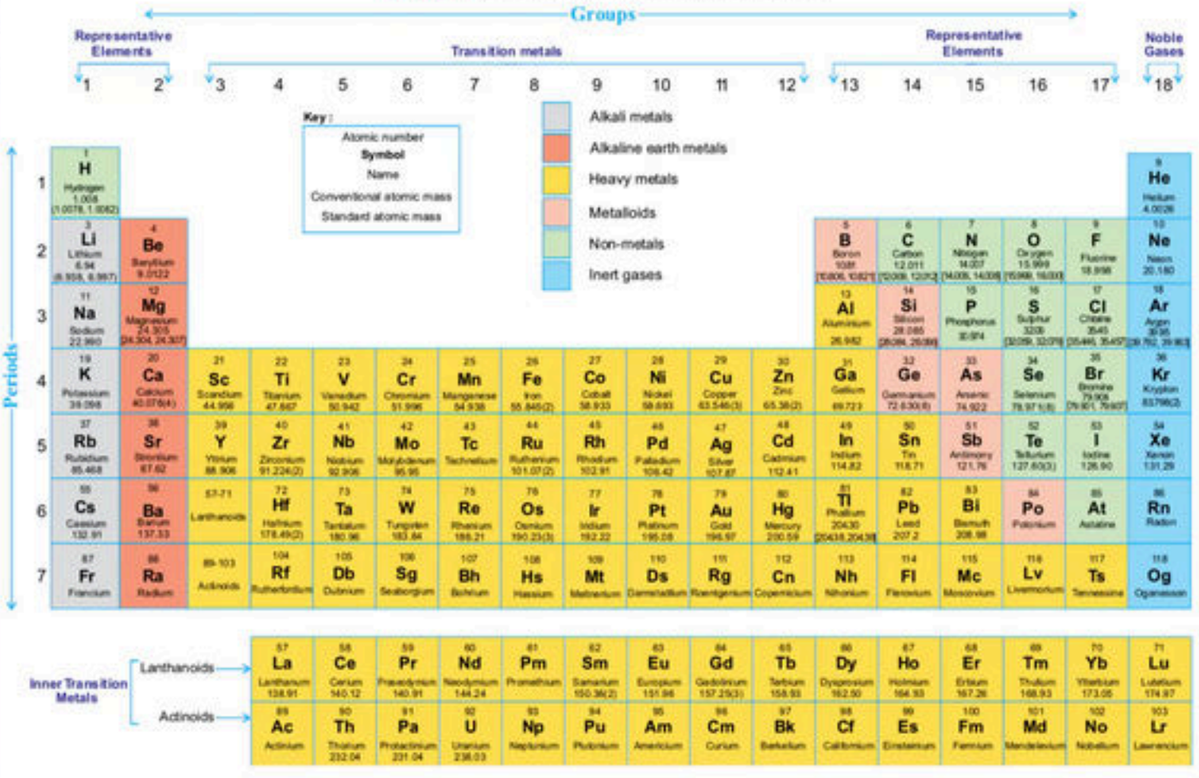
5.2 MODERN PERIODIC TABLE — LONG FORM OF THE PERIODIC TABLE

In 1913, ***H.G.J. Moseley*** showed by X-ray analysis that ***atomic number is a more fundamental property of an element than its atomic mass***. Therefore, he slightly modified Mendeleev's periodic law and replaced the ***word atomic mass by atomic number (proton number)***.

Modern Periodic Law

It states that the physical and chemical properties of all elements are the periodic function of their **atomic numbers**.

Table 5.6 : The Long form of Periodic Table of Elements



In the long form of the periodic table, the elements are arranged in order of ***increasing atomic numbers in horizontal rows*** called ***periods,*** such that all elements having ***same number of valence electrons*** come under the same ***vertical column*** called ***group***. This not only ensures ***periodicity in electronic configuration,*** but ***periodicity in chemical properties***.

Characteristics of the Long Form of the Periodic Table

FIV3EMPK6D

Groups

1. There are 18 vertical columns called ***groups*** in the modern periodic table.
2. Group 1 includes hydrogen and the ***alkali metals***, which have one electron in their outermost shell.
3. Group 2 elements are also called the ***alkaline earth metals***. These elements have two electrons in their outermost shell.
4. Groups 3 to 12 are called ***transition elements*** which are placed in the middle of the periodic table.
5. Group 13 is the ***boron group***. All the elements in this group are metals except boron, which is a metalloid.
6. Group 14 is the ***carbon group***. It contains a combination of non-metals, metalloids and metals.
7. Group 15 is called the ***pnictogens*** or ***nitrogen group***. It contains a combination of non-metals, metalloids and metals.
8. Group 16 is called the ***chalcogens***, or ***oxygen family***. It contains a combination of non-metals, metalloids and metals.
9. Group 17 is called the ***halogens***. This is a group of highly reactive non-metals. This is the only group that contains elements in all three states of matter at room temperature and pressure. Fluorine and chlorine are gases, bromine is a liquid and iodine is a solid.
10. The group 18 elements are commonly known as the ***noble gases***. They are typically unreactive. The noble gases each have a full outer electron shell.

Group 1, 2 and 13 to 17 elements are called normal elements or representative elements which occupy the left and the right side of the table.

Periods

The ***horizontal rows*** in the periodic table are called ***periods***. There are ***seven periods*** in all, such that each period has consecutive (or continuous) atomic number.

The period of an element can be determined by the number of shells present in an atom.

For example, every element in the first period has one shell for its electrons. All elements in the second period have two shells for their electrons and so on.

The lanthanides are often called the rare earth elements. They actually placed in the sixth period. They are usually shown as a separate row below the rest of the periodic table to make it easier to display the entire table.

The actinides sit in the seventh period. They are usually shown as a separate row below the rest of the periodic table to make it easier to display the entire table. The actinides include plutonium, which is the heaviest naturally occurring element.

We can determine the period and group number of an element with the help of its electronic configuration.

The number of shells represents the period. The electrons present in the valence or outermost shell represent the group number.

For example, the atomic number of lithium is 3 and its electronic configuration is 2, 1. It has two shells and has one electron in the outermost shell. Hence, it is placed in second period and group 1 in the periodic table.

Example 1: ***An element E has atomic number 14. To which period does this element belong?***

Table 5.7 : Types of periods

Period number	Number of shells	Elements in the period	Nature of the period
1	1	2	Very short period
2	2	8	Short period
3	3	8	Short period
4	4	18	Long period
5	5	18	Long period
6	6	32	Very long period
7	7	32	Very long period

Solution: Electronic configuration of E is 2(K), 8(L), 4(M). As, there are three electron shells, therefore, E belongs to the third period.

As, there are four electrons in the outermost shell, therefore, E belongs to group 14.

Example 2: ***Element X and Y have atomic numbers 9 and 12 respectively. Write the electronic configuration of X and Y and find out the periods and the groups to which they belong in the periodic table.***

Solution: Electronic configuration of X = 2, 7

Electronic configuration of Y = 2, 8, 2

For X

As there are two electron shells, therefore, X belongs to the second period.

As, there are seven electrons in the outermost shell, therefore, X belongs to group 17.

For Y

As there are three electron shells, therefore, Y belongs to the third period.

As, there are two electrons in the outermost shell, therefore, Y belongs to group 2.

N5YT3FP2ZE

5.3 POSITION OF HYDROGEN IN THE PERIODIC TABLE

Hydrogen is the first element of the periodic table as its atomic number is one, which means it has only one electron in its atom. Thus only one electron is present in its outermost shell. The placement of elements in the periodic table is based on their electronic configuration. This structure is similar to that of alkali metals, which have one electron in their outermost shell. It can attain the noble gas configuration of helium, by accepting one electron. This character is very much similar to that of halogens, which are also short of one electron to complete the octet of electrons in their valence shells. It exists as a diatomic molecule like that of halogens (for example, chlorine Cl_2).

Though hydrogen shows a lot of resemblance to halogens and alkali metals, it is very different from both. So a great thought has to be given for the position of hydrogen in the periodic table. Hydrogen is treated as a very special element because of its unique behaviour, thus it is placed separately at the head of the periodic table.

The Modern Periodic Table could remove various anomalies of Mendeleev's Periodic Table :

(a) In the Modern Periodic Table, elements are arranged in the increasing order of their atomic numbers, removing the anomaly regarding certain pairs of elements in Mendeleev's Periodic Table. For example, atomic number of cobalt is 27 and nickel is 28. Hence cobalt will come before nickel even though its atomic mass is greater.

(b) All isotopes of the same elements have different atomic masses, but same atomic number. Therefore, they are placed in the same position in the modern periodic table.

Assess Yourself – 2

1. (a) Who prepared the modern periodic table?
   (b) Define : (i) Modern Periodic Law and (ii) Modern Periodic Table.
2. With reference to the long form of the periodic table, fill in the blank spaces with appropriate words :
   (a) The chemical properties of elements are the periodic function of their _____.
   (b) The serial number of an element in the periodic table is also its _____.
   (c) The number of electrons in the valence shell of an atom represents its _____ in the periodic table.
   (d) The number of electron shells around the nucleus of an atom represents its _____ in the periodic table.

(e) _____ metals and alkaline _____ metals are placed in the Groups 1 and _____ respectively on the left hand side of the periodic table.

(f) _____ elements are placed on the right hand side of the periodic table.

(g) The elements occupying left and right wing vertical columns are called _____ elements.

(h) Noble _____ are placed in _____ group in the last _____ of the periodic table.

(i) The _____ elements are accommodated in the middle of the periodic table in _____ series.

(j) The first period has _____ elements and is called _____ period.

(k) The second and third periods have _____ elements and are called _____ periods.

(l) The fourth and fifth periods have _____ elements and are called _____ periods.

3. Give the name and symbol of the elements which occupy the following positions in the periodic table.
   (a) period 2, group 13
   (b) period 3, group 17
4. Name two alkali metals. To which group do they belong?
5. Name two alkaline earth metals. To which group do they belong?
6. Name two elements of 17 group. State the common name of this group of elements.
7. Silicon (atomic number 14) and phosphorus (atomic number 15) belong to the same period of the periodic table. Write down the electronic configuration of silicon and phosphorus. Name the period in which these elements occur.

V15CSW4UI0

5.4 PERIODICITY IN THE PERIODIC TABLE

When elements are arranged in increasing order of their atomic numbers, there arises a periodicity in the properties of elements.

Periodicity in the properties of elements means that characteristics properties of elements occur at definite intervals in the modern periodic table.

It has been observed that the properties of elements are repeated after 2 or 8 or 18 or 32 elements, in the modern periodic table.

Now the question arises, what are the periodic properties? periodic properties are the properties which appear at regular intervals in the modern periodic table. The ***periodic properties*** are atomic radii, non-metallic, metallic character, density, melting and boiling points.

Reasons for Periodicity of Properties of Elements in Periods and Groups: Periodicity in properties of elements at regular intervals is due to the occurrence of similar valence shell electronic configuration. The properties of elements depend upon number and arrangement of electrons in the shells including valence shell. That is why in the same period or group, a particular property increases or decreases due to gradual change in electronic configuration of elements.

(a) Valence Electrons

(i) Across a period (*from left to right*)

1. The elements in the same period have ***same number of electron shells***.
2. Electrons in the valence shell (outermost shell) **increase** progressively by **one**, across the period, that is, ***first element*** in a given period will have ***one electron*** in its valence shell and the **last element** in the same period will have ***8 electrons***.

Exception : In the first period, the first element (hydrogen) has one electron and the last element (helium) has two electrons in their valence shells.

The table given below shows the electronic configuration of the elements of the 1st, 2nd and 3rd periods :

Table 5.8 : Electronic configurations of elements of periods 1, 2 and 3

Groups →	1	2	13	14	15	16	17	18
1st period elements	Hydrogen H	—	—	—	—	—	—	Helium He
Atomic number	1	—	—	—	—	—	—	2
Electronic configuration	K 1	— —	— —	— —	— —	— —	— —	K 2
Valence electrons	1	—	—	—	—	—	—	2
2nd period element	Lithium Li	Beryllium Be	Boron B	Carbon C	Nitrogen N	Oxygen O	Fluorine F	Neon Ne
Atomic number	3	4	5	6	7	8	9	10
Electronic configuration	K, L 2, 1	K, L 2, 2	K, L 2, 3	K, L 2, 4	K, L 2, 5	K, L 2, 6	K, L 2, 7	K, L 2, 8
Valence electrons	1	2	3	4	5	6	7	8
3rd period elements	Sodium Na	Magnesium Mg	Aluminium Al	Silicon Si	Phosphorus P	Sulphur S	Chlorine Cl	Argon Ar
Atomic number	11	12	13	14	15	16	17	18
Electronic configuration	K, L, M 2, 8, 1	K, L, M 2, 8, 2	K, L, M 2, 8, 3	K, L, M 2, 8, 4	K, L, M 2, 8, 5	K, L, M 2, 8, 6	K, L, M 2, 8, 7	K, L, M 2, 8, 8
Valence electrons	1	2	3	4	5	6	7	8

(ii) Down a group (*from top to bottom*)

The number of valence electrons remains same as one moves down a group. The number of shells keeps on increasing progressively by 1 as one move down a group.

Table 5.9 : Valence electrons of elements of groups 1 and 17

Elements of Group 1			
Element	Atomic number	Electronic configuration	Valence electrons
Lithium, Li	3	2, 1	1
Sodium, Na	11	2, 8, 1	1
Potassium, K	19	2, 8, 8, 1	1
Rubidium, Rb	37	2, 8, 18, 8, 1	1
Caesium, Cs	55	2, 8, 18, 18, 8, 1	1

Elements of Group 17			
Element	Atomic number	Electronic configuration	Valence electrons
Fluorine, F	9	2, 7	7
Chlorine, Cl	17	2, 8, 7	7
Bromine, Br	35	2, 8, 18, 7	7
Iodine, I	53	2, 8, 18, 18, 7	7
Astatine, At	85	2, 8, 18, 32, 18, 7	7



(b) Valency of the Elements

(i) Across a period (*from left to right*)

As one moves from left to right in a period, the valency of elements first increases from 1 to 4 and then decreases to 1.

Table 5.10 : Trends in valency of elements of periods 2 and 3

Elements of 2nd period	Li	Be	B	C	N	O	F
Atomic number and electronic configuration	3 (2, 1)	4 (2, 2)	5 (2, 3)	6 (2, 4)	7 (2, 5)	8 (2, 6)	9 (2, 7)
Valency	1	2	3	4	3	2	1

Elements of 3rd period	Na	Mg	Al	Si	P	S	Cl
Atomic number and electronic configuration	11 (2, 8, 1)	12 (2, 8, 2)	13 (2, 8, 3)	14 (2, 8, 4)	15 (2, 8, 5)	16 (2, 8, 6)	17 (2, 8, 7)
Valency	1	2	3	4	3	2	1

(ii) Down a group (*from top to bottom*)

The valency of metallic elements is the same as the group number of the element, because they have same number of valence electrons.

For example: The valency of Group 1 elements is 1.

The valency of non-metallic elements is given by the formula = 8 – valence electrons.

For example: The valency of Group 17 elements = 8 – 7 (valence electrons) = 1.

The valency of Group 16 elements = 8 – 6 = 2.

"All the elements in a group have the same valency".

SAMPLE PROBLEMS

1. The atomic numbers of nitrogen and phosphorus are 7 and 15 respectively. Write the electronic configuration of each of them and state to which group and the period do they belong.

Ans. **(i) For nitrogen (Atomic number 7)**

Electronic configuration of nitrogen is 2(K), 5(L).

Group: As there are 5 electrons in its valence shell, therefore, nitrogen belongs to Group 15.

Period: As there are only 2 electron shells, therefore, nitrogen belongs to the second period.

(ii) For phosphorus (Atomic number 15)

Electronic configuration of phosphorus is 2(K), 8(L), 5(M).

Group: There are 5 electrons in its valence shell, therefore, phosphorus belongs to Group 15.

Period: There are 3 electron shells. Therefore, phosphorus belongs to the third period.

2. An element P belongs to Group 2 and element Q belongs to Group 17 of the long form of the periodic table.

(i) How many valence electrons are there in P?

(ii) What is the valency of P?

(iii) How many valence electrons are there in Q?

(iv) What is the valency of Q?

(v) Write the chemical formula of the compound of P and Q.



Ans. (i) Valence electrons are always equal to the group number. Thus, **P has 2 valence electrons.**
(ii) As all elements in Groups 1, 2 and 13 are metals, therefore, P is a metal and hence, its valency is **+2.**
(iii) Valence electrons are always equal to the ones digit of group number. Thus, **Q has 7 valence electrons.**
(iv) Elements in 14 to 17 group numbers are non-metals. As Q has group number 17, therefore, it is a non-metal. The valency of a non-metal is given by the formula "8 – valence electrons."
The valency of Q is 8 – 7 = **1.**
(v) As the valency of P is 2 and that of Q is 1, therefore, the formula of the compound of P and Q is $\mathbf{PQ_2}$.

3. Table below represents three elements P, Q and R along with their atomic numbers. Which elements belong to (i) same group and (ii) same period?

Elements	P	Q	R
Atomic number	2	11	18

Ans. Let us write the electronic configuration of the above elements.

Elements	P	Q	R
Atomic number	2	11	18
Electronic configuration	2(K)	2(K), 8(L), 1(M)	2(K), 8(L), 8(M)

(i) Element P has only two electrons in its only shell. This element is helium and, hence, is a noble gas. Thus, it belongs to group 18.
Element R has 8 electrons in its valence shell and hence, it belongs to group 18.
Thus, P and R belong to the same group, that is, group 18.
(ii) Elements Q and R have three electron shells. Thus, **elements Q and R belong to the third period.**

4. By giving reasons, state which amongst the elements given below does not belong to the same period :
$^{12}_{6}P$, $^{14}_{7}Q$, $^{16}_{8}R$ and $^{23}_{11}S$.

Ans. Let us write electronic configuration of the elements.

Element	Atomic number	Electronic configuration
		K L M
P	6	2, 4
Q	7	2, 5
R	8	2, 6
S	11	2, 8, 1

Elements P, Q and R have only two electron shells and hence, they belong to the same period, that is, second period.
Element S has three electron shells and hence, it belongs to the third period.
Thus, the element S does not belong to the same period as P, Q and R.

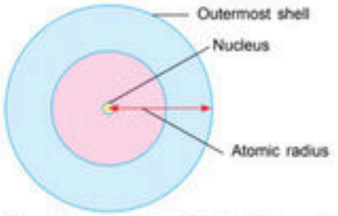
SR74CIVJDM

5.5 TRENDS IN PROPERTIES

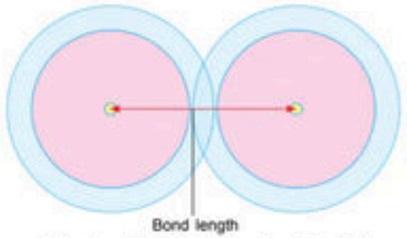
The periodic table arranges the elements by periodic properties, which are recurring trends in physical and chemical characteristics. These trends can be predicted merely by examining the periodic table and can be explained and understood by analysing the electronic configurations of the elements. We shall discuss the following periodic properties and their variations in groups and periods: atomic size, metallic character and non-metallic character

Atomic Size (Atomic Radius)

The size of the atom is indicated in terms of radius of the atom, that is, distance between the centre of nucleus to the outermost shell of the atom.



The radius is measured in angstrom units.
1 Å = 10^{-10}m.



(Atomic radius determines bond length.)

The size of an atom depends on the following factors:

1. **Nuclear charge:** It is the positive charge of an atom present in the nucleus. It is equal to the number of protons present in the nucleus.

   As the nuclear charge increases the atomic size decreases.

   This is because the electrons in the outermost shell are attracted with greater force, which brings the outermost shell closer to the nucleus.

2. **Number of shells:** As the number of shells increases the distance of the outermost shell from the nucleus also increases.

Trends in Atomic Size

Across a Period : *The atomic radii gradually decreases as one moves from left to right in a given period.*

As one moves horizontally from left to right, there is consecutive *addition of one proton in the nucleus and one electron in the valence shell of the element.* However, the electron is always added in the *same valence shell* in a given period. The addition of proton in the nucleus *increases the positive charge,* which consequently pulls the *extra-nuclear electrons* in the outermost shell *inward.* Thus, the atomic radius decreases with the increase in number of protons as one moves from left to right in a period.

Table 5.11 : Trends in atomic size across second period.

Groups	Group 1	Group 2	Group 13	Group 14	Group 15	Group 16	Group 17
Elements	Lithium	Beryllium	Boron	Carbon	Nitrogen	Oxygen	Fluorine
Atomic number	3	4	5	6	7	8	9
Atomic radius Å	1.30	0.99	0.84	0.75	0.70	0.64	0.60
Electronic configuration	K L 2 1	K L 2 2	K L 2 3	K L 2 4	K L 2 5	K L 2 6	K L 2 7
Atomic structure							

Atomic Radii of Noble Gases: The *atomic radii of the noble gases (neon and argon) suddenly increase as compared to its predecessor.*

Reason: When an octet is formed in the valence shell of a noble gas, the arrangement of electrons in the outermost shell become *structurally stable.* Thus, the *nucleus can no longer pull the extra-nuclear electrons with the same force* and hence, atomic radius increases.

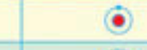


Down the group

The size of the atoms increases progressively as one moves down from top to bottom in a group.

Reason : With the change in period, the new element in the group *adds an extra shell of electrons*. This in turn results in the increase in the size of atoms while moving down in a group. Table 5.12 given below shows Group 1 elements in which the first member **hydrogen** has the smallest atomic radius and last member **caesium** has the largest atomic radius.

Table 5.12 : Atomic radii of group 1 elements

Elements	Atomic No.	Atomic radius (Å)	Electronic configuration K L M N O P	Atomic structure
Hydrogen	1	0.32	1	
Lithium	3	1.30	2, 1	
Sodium	11	1.60	2, 8, 1	
Potassium	19	2.00	2, 8, 8, 1	
Rubidium	37	2.15	2, 8, 18, 8, 1	
Caesium	55	2.38	2, 8, 18, 18, 8, 1	

Assess Yourself – 3

1. Fill in the blank spaces :
   (i) As one moves from left to right in the long form of the periodic table, the atomic size of elements _____.
   (ii) The atomic size of lithium is _____ than fluorine.
2. How is the atomic size of sodium related to (i) magnesium and (ii) potassium?
3. Arrange the following sets of elements in the increasing order of their atomic sizes.
   (a) K, Li, Na (b) O, C, N
4. Pick out the element having the smallest size from the list given below. Give a reason for your answer:
   Na, Cl, Si, Ar

Metallic Character



Metals have a tendency to lose their valence electrons and form positive ions and hence are called electropositive elements.

$$Na\ (2,8,1) - e^- \longrightarrow Na^+\ (2,8) \qquad Mg\ (2,8,2) - 2e^- \longrightarrow Mg^{2+}\ (2,8)$$

Factors which affect the metallic character :

Atomic Size: The increase in atomic radius decreases attraction between the nucleus and electron(s), causing the electron(s) to be held more loosely. As a result, electron(s) from valence shell can be removed more easily, thus making the elements more metallic.

Nuclear Charge: As the nuclear charge increases, the size of the atom decreases because the outer electrons are held more tightly. Because the outer electrons are held more tightly, it is more difficult to remove the electron(s) from the outermost shell. Thus metallic character decreases.

Trends in Metallic Character

Across a period: On moving from left to right in a given period, the *metallic character of elements gradually decreases.*

Table 5.13 below shows metallic nature of the elements of the third period.

In the third period, sodium is the most metallic element.

Table 5.13 : Trends in metallic character across third period

Groups	Group 1	Group 2	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
Elements	Na	Mg	Al	Si	P	S	Cl	Ar
Atomic Number	11	12	13	14	15	16	17	18
Electronic Configuration	2, 8, 1	2, 8, 2	2, 8, 3	2, 8, 4	2, 8, 5	2, 8, 6	2, 8, 7	2, 8, 8
Metallic Property	Metal	Metal	Metal	Metalloid	Non-metal	Non-metal	Non-metal	Noble gas
Metallic character decreases →								

Reason: As one move across a period from left to right, the nuclear charge increases, thus the atomic size decreases. Hence, the element cannot lose electrons easily.

Down a group

While going down in a ***group the metallic character of elements gradually increases.*** In Table 5.14 given alongside for Group 1 elements. *Lithium is the least metallic and least electropositive, whereas the francium is the most metallic* and *most electropositive.*

Table 5.14 : Trends in metallic character in Group 1

Element	Symbol	Character
Lithium	Li (3)	Least Metallic
Sodium	Na (11)	↓ Metallic character increases
Potassium	K (19)	
Rubidium	Rb (37)	
Caesium	Cs (55)	
Francium	Fr (87)	Most Metallic

Reason: As one moves down a group, an extra electron shell is added after every change of the period. Thus, the hold of the nucleus on the valence electrons gradually decreases. In other words, more the electron shells around the nucleus, more loosely the electrons are held by the nucleus and hence, the element can easily donate them to form electropositive ions. It is for the same reason that lithium is least metallic and least electropositive, whereas francium is most metallic and most electropositive.



Non-metallic Character

Non-metals have a tendency to gain electrons in order to attain octet in their outermost shell. These elements gain electron(s) to form anions and hence are called electronegative elements.

For example: Chlorine atom gains one electron to form chloride ion.

$Cl + e^- \rightarrow Cl^-$

Oxygen atom gains two electrons to form oxide ion.

$O + 2e^- \rightarrow O^{2-}$

Non-metallic character also depends on the following factors:

(i) **Atomic size:** A decrease in atomic radius increases the attraction between the nucleus and electron(s) and tendency to gain electrons. This makes the element more non-metallic.

(ii) **Nuclear charge:** Greater the nuclear charge, the greater is the tendency to gain electron(s) and hence more non-metallic is the element.

Trends in Non-metallic Character

Across a Period: On moving from left to right in a period, the non-metallic character increases.

Reason: The tendency to gain electrons increases on moving across a period due to an increase in the nuclear charge and decrease in the atomic size. Hence, the non-metallic character increases across a period.

For example: In the second period the non-metallic character increases from lithium to fluorine. Thus, fluorine is the most non-metallic element in the second period.

Table 5.15 : Trends in non-metallic character across second period

Groups	Group 1	Group 2	Group 13	Group 14	Group 15	Group 16	Group 17
Elements	Li	Be	B	C	N	O	F
Atomic Number	3	4	5	6	7	8	9
Electronic Configuration	K L 2 1	K L 2 2	K L 2 3	K L 2 4	K L 2 5	K L 2 6	K L 2 7
Metallic Property	Metal	Metal	Metalloid	Non-metal	Non-metal	Non-metal	Non-metal
Non-metallic character increases →							

Down a Group

As we move down the group, the non-metallic character decreases.

Reason: As one moves down a group, an electron shell is added after every change of a period. Thus, the nuclear charge decreases so the tendency to gain electron also decreases.

For example, in case of group 17 elements, ***fluorine atom has only two electron shells, whereas astatine has 6 electron shells.***

Table 5.16 : Trends in non-metallic character of group 17 elements

Element	Symbol	Character
Fluorine	F (9)	Most Non-metallic
Chlorine	Cl (17)	↓ Non-metallic character
Bromine	Br (35)	
Iodine	I (53)	
Astatine	At (85)	Least Non-metallic

Thus, the nucleus of fluorine has a ***greater tendency to attract an extra electron*** than astatine. Thus, fluorine can easily form F^- ions and hence is ***more electronegative*** (non-metallic) in character than astatine.

Note: Amongst all the elements in the periodic table, **francium is the most electropositive element** and **fluorine is the most electronegative element.**

Assess Yourself – 4

1. Metallic properties change to non-metallic properties as one moves from left to right in a period. Explain.
2. (a) Bigger the atomic size, more metallic is an element. Explain.
   (b) Name: (i) the most metallic element and (ii) the most non-metallic element.
3. Explain why elements lying on the extreme right of the periodic table are non-metals, but those lying on the extreme left are metals.
4. Explain, why metallic character of an element increases while moving down a group.
5. Explain, why non-metallic character of the elements increases while moving from left to right in a periodic table.

Chemical Reactivity

CR3WEUBQNT

Reactivity is the tendency of an element to lose or gain electrons to complete their outermost shell.

(i) In case of metals, greater the tendency to lose electron(s), greater is the reactivity.

(ii) In case of non-metals, greater the tendency to gain electron(s), greater is the reactivity.

Trends in Chemical Reactivity

Across a Period: As one moves from left to right in a period, the chemical reactivity of elements first decreases and then increases.

For example: In the third period, first reactivity decreases from sodium to silicon, then it increases from phosphorus to chlorine.

Table 5.17 : Trends in chemical reactivity across third period

Elements of third period	Na (11)	Mg (12)	Al (13)	Si (14)	P (15)	S (16)	Cl (17)	Ar (18)
Chemical Reactivity	Very reactive			Least reactive			Very reactive	Inert
	REACTIVITY DECREASES →						REACTIVITY INCREASES →	

Down a Group

For Metals: ***While going down in Groups 1, 2 and 13 the chemical activity of elements increases.*** In the table of Group 1 elements, the order of reactivity of elements is Fr > Cs > Rb > K > Na > Li.

Reason: As the number of electron shells increases while going down the group, so does the tendency to lose electrons from the valence shell and hence, elements tend to be more reactive.

Table 5.18 : Chemical reactivity of group 1 elements

Element	Symbol	Character
Lithium	Li (3)	Least Reactive
Sodium	Na (11)	↓ Chemical activity increases
Potassium	K (19)	
Rubidium	Rb (37)	
Caesium	Cs (55)	
Francium	Fr (87)	Most Reactive

For Non-metals: ***While moving down a group of non-metals the chemical activity of elements decreases.*** In the table of group 17 elements, the order of reactivity of elements is F > Cl > Br > I > At.

Reason: As the number of electron shells increases while going down the group, so does the tendency to gain electrons in the valence shell decreases and hence, elements tend to be less reactive.

All the metals are good reducing agents as they help in reduction by providing electrons. Non-metals are good oxidising agents as they help in oxidation by accepting the electrons.

Table 5.19 : Chemical reactivity of group 17 Elements

Element	Symbol	Character
Fluorine	F (9)	Most Reactive
Chlorine	Cl (17)	↓ Chemical activity decreases
Bromine	Br (35)	
Iodine	I (53)	
Astatine	At (85)	Least Reactive

Gradation of Physical Properties of the Elements

(i) While going down ***a group of metals, the physical properties such as melting and boiling points decrease gradually.*** While going down a group, density of both metals and non-metal increases gradually.

Table 5.20 below shows Group 1 metals in which melting and boiling points of Li, Na and K decrease gradually as one moves down the group.

Table 5.20 : Melting and boiling points of elements of group

Element	Symbol	Melting point	Boiling point	Comments
Lithium	Li (3)	180°C	1347°C	Melting points and boiling points decrease
Sodium	Na (11)	97°C	883°C	
Potassium	K (19)	63°C	774°C	

(ii) While going down ***a group of non-metals, the physical properties such as melting and boiling points increase gradually.***

In the table 5.21 shown below the first two members of Group 17 elements, that is, fluorine and chlorine are gases, bromine is a liquid, whereas iodine is a solid. The melting points and boiling points of the elements increase gradually.

Table 5.21 : Melting and boiling points of elements of group 17

Element	Symbol	State	Melting point	Boiling point	Comments
Fluorine	F (9)	Gas	–220°C	–188°C	Melting points and boiling points increase
Chlorine	Cl (17)	Gas	–101°C	–35°C	
Bromine	Br (35)	Liquid	–7.2°C	59°C	
Iodine	I (53)	Solid	114°C	184°C	

On moving across a period from left to right, melting point and boiling point generally increase upto Group 14 and then decreases.

SAMPLE PROBLEM

1. Elements A, B, C, D, E and F belong to the same period of the periodic table and have atomic radii 0.64 Å, 1.52 Å, 0.66 Å, 1.06 Å, 0.70 Å and 0.88 Å respectively. (Assume none of the elements is a noble gas).
   (i) Arrange the elements in the order of increasing atomic numbers.
   (ii) From the data, state how the atomic size of the elements varies from left to right in a period.
   (iii) Name two elements which are metals.
   (iv) Name two elements which are non-metals.

(v) Which element is expected to be the least reactive?

(vi) Which two elements are expected to be the most reactive?

Ans. (i)

	⟹ INCREASING ATOMIC NUMBERS ⟹					
Elements	B	D	F	E	C	A
Atomic Radius	1.52 Å	1.06 Å	0.88 Å	0.70 Å	0.66 Å	0.64 Å

(ii) Atomic radius decreases as one moves from left to right in a period.

(iii) B and D are metals.

(iv) C and A are non-metals.

(v) Element E is expected to be the least reactive.

(vi) Elements B and A are expected to be the most reactive

5.6 MERITS OF THE LONG FORM OF THE PERIODIC TABLE

KBGYQA3C0XC

1. It is easier to remember, learn and reproduce, because it is organised in a systematic manner.
2. The classification of elements is based on the fundamental property of elements, that is, ***atomic number.***
3. It explains variations and similarities in the properties of elements in terms of electronic configuration. Thus, it clearly brings out trends in chemical properties across the long periods.
4. It relates the position of an element to its ***electronic configuration***. Each group of elements have similar electronic configuration that is, the number of electrons in the valence shell are same and hence, have similar properties.
5. It provides clear demarcation of different kinds of elements, such as :
   (i) Active metals (ii) Transition metals (iii) Non-metals (iv) Metalloids
   (v) Lanthanides (vi) Actinides (vii) Inert gases.
6. The group 1 and 2 elements of active metals and alkaline earth metals are located on extreme left of the periodic table and the most active of non metals (halogens) on the extreme right of the periodic table, just before group 18. The transition elements are located in the middle of the periodic table.
7. Inert gases, in which valence shells are completely filled, have been placed at the end of each period. Such a location of inert gases shows a logical completion of each period.

SAMPLE PROBLEMS

1. Table shows three elements A, B and C along with their electronic configuration.

Elements	A	B	C
Electronic configuration	2, 7	2, 8, 7	2, 8

(i) Which elements belong to same period?

(ii) Which element belongs to Group 18?

(iii) Which elements belong to the same group?

(iv) Which element amongst A and B, is less reactive?

Ans. (i) Elements A and C have same number of electron shells, that is, 2 electron shells. Thus, A and C belong to the same period, number 2.



(ii) Element C belongs to Group 18, because it has 8 electrons in its valence shell, and GROUP No. = Valence Electron +10

(iii) Elements A and B have same number of valence electrons. Thus, they belong to the same group.

(iv) The reactivity of non-metals decreases, as one moves down in the same group. Thus, element B is less reactive than element A.

2. Amongst the elements P (Atomic number 4), Q (Atomic number 11) and R (Atomic number 20), which two elements have similar chemical properties and why?

Ans. Let us write electronic configurations of P, Q and R.

Element	Atomic number	Electronic configuration K	L	M	N
P	4	2	2		
Q	11	2	8	1	
R	20	2	8	8	2

The elements P and R will have similar chemical properties. It is because both have two electrons in their valence shells and belong to same Group, group 2.

3. The table shows a part of the long form of the periodic table. Answer the following questions regarding the element strontium (Sr) :

Group 1	Group 2
H (1)	
Li (3)	Be (4)
Na (11)	Mg (12)
K (19)	Ca (20)
Rb (37)	Sr (38)
Cs (55)	Ba (56)

(i) Is it a metal or a non-metal?

(ii) Is it more reactive or less reactive than magnesium?

(iii) What is its valency ?

(iv) What is the formula of its :

(a) chloride and (b) sulphate?

(v) How does its atomic size compare with :

(a) rubidium and (b) barium?

Ans. (i) Strontium is a metal. It is because all elements in Groups 1, 2 and 13 are metals.

(ii) It is more reactive than magnesium. It is because, the chemical reactivity increases as one moves down a group.

(iii) The valency of strontium is 2+. It is because, the electronic configuration of strontium is (2, 8, 18, 8, 2). As it has two valence electrons, therefore, its valency is 2+.

(iv) (a) Formula of strontium chloride is $SrCl_2$.

(b) Formula of strontium sulphate is $SrSO_4$.

(v) (a) Atomic size of strontium is less than rubidium, as atomic size decreases from left to right in a period.

(b) Atomic size of strontium is less than barium. As one moves from top to bottom in a group, atomic size increases.

4. An element P belongs to the fourth period and group 17, of the long form of the periodic table. Answer the following questions :

(i) How many valence electrons are in element P?

(ii) What is the valency of P?

(iii) Is the element P a metal or a non-metal?



(iv) Name the element.

(v) Name the family to which the element belongs.

(vi) Write the formula of its compound, when it reacts with element Q having valency 3+.

Ans. (i) As the element P belongs to Group 17, therefore, it has seven electrons in its valence shell.

(ii) The valency of P = (8 – number of electrons in valence shell) = 8 – 7 = 1.

(iii) The element P is a non-metal, as all elements which have valence electrons between 4 and 7 are non-metals.

(iv) The element is bromine.

(v) The family of the element is halogen family.

(vi) Formula of element P with Q is $Q^{3+}P^{-1} \Rightarrow QP_3$.

KEY POINTS

- Elements are classified on the basis of similarities in their physical and chemical properties.
- Dobereiner grouped elements into triads.
- Newland grouped elements on the basis of law of octaves.
- Mendeleev grouped elements in the increasing order of their atomic masses and the similarity in chemical properties.
- Mendeleev was able to predict the existence of some elements on the basis of gaps in the periodic table.
- Elements in the long form of the Modern Periodic Table are arranged in 18 vertical columns called groups and 7 horizontal rows called periods.
- The elements arranged in the long form of the periodic table show periodicity in properties like, atomic size, valency, metallic and non-metallic character.

Exercise–5 (B)

I. MULTIPLE CHOICE QUESTIONS

Tick (✓) the Correct Answer.

1. Which of the following statements is not correct about the trends when going from left to right across the long form of the periodic table?

(A) Elements become less metallic in nature.

(B) Number of valence electrons increases.

(C) Elements lose their electrons more easily.

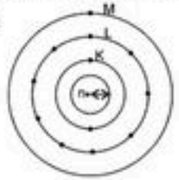
(D) The oxides become more acidic.

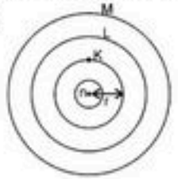
2. The element with atomic number 14 is hard and forms an acidic oxide and a covalent halide. To which of the following categories does the element belong?

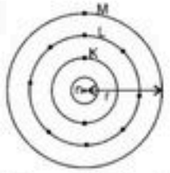
(A) Metal (B) Metalloid

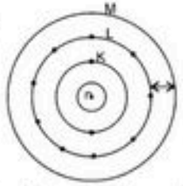
(C) Non-metal (D) Left-hand side element [HOTS]

3. Which one of the following depict the correct representation of atomic radius of an atom? [HOTS]

(A) 

(B) 

(C) 

(D) 

4. Which one of the following does not increase while moving down the group of the periodic table? [HOTS]
   (A) Atomic radius
   (B) Metallic character
   (C) Valency
   (D) Number of shells in an element

5. Which of the following are the characteristics of isotopes of an element? [HOTS]
   (i) Isotopes of an element have same atomic masses
   (ii) Isotopes of an element have same atomic number
   (iii) Isotopes of an element show similar physical properties
   (iv) Isotopes of an element show similar chemical properties
   (A) (i), (iii) and (iv) (B) (ii), (iii) and (iv)
   (C) (ii) and (iii) (D) (ii) and (iv)

Ans: 1. (C) 2. (B) 3. (C) 4. (C) 5. (D)

II. ASSERTION (A) AND REASON (R)

For question numbers 1 and 5, two statements are given one labeled *Assertion* (A) and the other labelled *Reason* (R). Select the correct answer to these questions from the codes (i), (ii), (iii) and (iv) as given below.

(i) Both A and R are true and R is the correct explanation of the assertion.
(ii) Both A and R are true but R is not the correct explanation of the assertion.
(iii) A is true but R false.
(iv) A is false but R is true.

1. **Assertion:** Mendeleev's periodic table did not include noble gases.
   Reason: Noble gases are inert in nature.
2. **Assertion:** Mendeleev placed cobalt (atomic mass = 58.93) before nickel (atomic mass = 58.71).
   Reason: The properties of cobalt were similar to those of rhodium and iridium, whereas properties of nickel were similar to those of palladium and platinum.
3. **Assertion:** Group 2 elements are called alkali metals.
   Reason: Group 2 elements have two valence electrons.
4. **Assertion:** Isotopes are placed in the same position in the modern periodic table.
   Reason: All isotopes of same elements have same atomic masses.
5. **Assertion:** While going down in group the metallic character of elements gradually increases.
   Reason: Lithium is the least metallic whereas the francium is the most metallic.

III. VERY SHORT ANSWER TYPE QUESTIONS

1. Write the formulae of chlorides of *Eka*-silicon and *Eka*-aluminium, the elements predicted by Mendeleev. [HOTS]
2. Arrange the following elements in the increasing order of their atomic radii. [HOTS]
   (a) Li, Be, F, N (b) Cl, F, Br, I
3. Arrange the following elements in the increasing order of their metallic character : [HOTS]
   Mg, Ca, K, Ge, Ga
4. If an element X is placed in Group 14, what will be the formula and the nature of bonding of its chloride? [HOTS]
5. How many valence electrons are present in *Eka*-silicon and *Eka*-aluminium? [HOTS]

IV. SHORT ANSWER TYPE QUESTIONS

1. The elements of the third period of the periodic table are given below:

Group →	I	II	III	IV	V	VI	VII
Period 3 ↓	Na	Mg	Al	Si	P	S	Cl

(a) Which atom is bigger, Na or Mg? Why?

(b) Identify the most (i) metallic and (ii) non-metallic element in period 3.

2. Two elements M and N belong to groups I and II respectively and are in the same period of the periodic table. How do the following properties of M and N vary in the period?

(i) Size of their atoms

(ii) Their metallic characters

(iii) Their valencies in forming oxides

(iv) Molecular formulae of their chlorides

3. The elements of the second period of the periodic table are given below :

Li Be B C N O F

(a) Give reason to explain why atomic radii decreases from Li to F.

(b) Identify the most (i) metallic and (ii) non-metallic element.

4. Compare the radii of two elements X and Y. Give reasons for your answer.

(a) X has 12 protons and 12 electrons

(b) Y has 12 protons and 10 electrons [HOTS]

5. Elements have been arranged in the following sequence on the basis of their increasing atomic masses.

F, Na, Mg, Al, Si, P, S, Cl, Ar, K

(a) Pick two sets of elements that have similar properties.

(b) The given sequence represents which law of classification of elements? [HOTS]

6. Three elements A, B and C have 3, 4 and 2 electrons respectively in their outermost shell. Give the group number to which they belong in the modern periodic table. Also, give their valencies. [HOTS]

7. (a) If an element X is placed in group 14, what will be the nature of bond in its chloride? Write the chemical formula of the compound?

(b) An element X has mass number = 35 and number of neutrons = 18. What is the atomic number of X? Write electonic configuration of X and determine its valency?

8. The electronic configuration of an element is 2, 8, 4. State its :

(a) group and period in the Modern Periodic Table.

(b) name and write its one physical property.

9. (a) Name three elements that have a single electron in their outermost shell.

(b) Name three elements with completely filled outermost shell.

10. How can it be proved that the basic structure of the Modern Periodic Table is based on the electronic configuration of atoms of different elements?

11.

H								He
Li	Be		B	C	N	O	F	Ne
Na	Mg		Al	Si	P	S	Cl	Ar

Using the above table explain why :

(i) Li and Na are considered active metals.

(ii) Atomic size of magnesium is less than sodium.

(iii) Fluorine is more reactive than chlorine.

12. (a) What is meant by periodicity in properties of elements with reference to the periodic table.

(b) Why do all elements in a same group have similar properties.

(c) How will the tendency to gain electrons changes as we go from left to right across a period and why?



13. The position of three elements A, B and C in the periodic table are shown alongside.

Group VI	Group VII
–	–
–	A
–	–
B	C

Give reasons for the following :
(a) Element A is a non-metal.
(b) Element B has a larger atomic size than element C.
(c) Element C has a valency of 1.

14. Identify the elements with the following property and arrange them in the increasing order of their reactivity.
(a) An element that is a soft and reactive metal.
(b) The metal that is an important constituent of limestone.
(c) The metal that exists in the liquid state at room temperature. [HOTS]

15. Write the formula of the product formed when element A (atomic number 19) combines with element B (atomic number 17). Draw its electronic dot structure. What is the nature of the bond formed? [HOTS]

16. How does metallic character of elements in Modern Periodic Table vary on moving from :
(i) left to right in a period?
(ii) top to bottom in a group?
Explain with the help of an example in each case?

17. An element 'X' belongs to third period and group 16 of the Modern Periodic Table.
(a) Determine the number of valence electrons and the valency of 'X'.
(b) Give molecular formula of the compound when 'X' reacts with hydrogen and write its electron dot structure.
(c) Name the element 'X' and state whether it is metallic or non-metallic.

18. An element P (atomic number 20) reacts with an element Q (atomic number 17) to form a compound. Write the position of P and Q in the Modern Periodic Table and molecular formula of the compound formed when P reacts with Q.

19. Write the names given to the vertical columns and horizontal rows in Modern Periodic Table. How does the metallic character of elements vary on moving down a vertical column? How does the size of atomic radius vary on moving left to right in a horizontal row? Give reason in support of your answer in the above two cases.

20. Taking the example of an element of atomic number 16, explain how the electronic configuration of the atom of an element relates to its position in the modern periodic table. How valency of an element is calculated on the basis of its atomic number?

21. From the following elements.
$_4$Be; $_9$F; $_{19}$K; $_{20}$Ca
(i) Select the element having one electron in the outermost shell.
(ii) Two elements of the same group.
Write the formula of the compound and mention the nature of the compound formed by the union of $_{19}$K and element X (2, 8, 7).

22. How many groups and periods are there in the modern periodic table? How do the atomic size and metallic character of elements vary as we move :
(a) down a group and
(b) from left to right in a period.

23. An element 'M' with electronic configuration (2, 8, 2) combines separately with NO_3^-, SO_4^{2-} and PO_4^{3-} radicals. Write the formula of the three compounds so formed. To which group and period of the Modern Periodic Table does the elements "M' belong? Will 'M' form covalent or ionic compounds? Give reason to justify your answer.

24. An element 'X' has mass number 35 and number of neutrons 18. Write the atomic number and electonic configuration of 'X' Also, write group number, period number and valency of 'X'.

25. Calcium is an element with atomic number 20. Stating reason answer the following questions :
(i) Is calcium a metal or non-metal?
(ii) Will its atomic radius be larger or smaller than that of potassium with atomic number 19?
(iii) Write the formula of its oxide.



V. LONG ANSWER TYPE QUESTIONS

1. On the basis of Mendeleev's periodic table given below, answer the questions that follow the table :

(a) Name the elements that is in

(i) Ist group and 3rd period

(ii) VIIth group and 2nd period

(b) Suggest the formula for the following:

(i) oxide of nitrogen

(ii) hydride of oxygen

(c) In group VIII of the periodic table, why does cobalt with atomic mass 58.93 appear before nickel having atomic mass 58.71?

(d) Besides gallium, which other two elements have been discovered for which Mendeleev had left gaps in his periodic table?

Groups →	I	II	III	IV	V	VI	VII	VIII
Oxide : **Hydride :**	R_2O RH	RO RH_2	R_2O_3 RH_3	RO_2 RH_4	R_2O_5 RH_3	RO_3 RH_2	R_2O_7 RH	RO_4
Periods ↓	A B	A B	A B	A B	A B	A B	A B	Transition series
1.	H 1.008							
2.	Li 6.9.9	Be 9.012	B 10.81	C 12.011	N 14.007	O 15.999	F 18.998	
3.	Na 22.99	Mg 24.31	Al 29.98	Si 28.09	P 30.974	S 32.06	Cl 35.453	
4. First series: **Second series:**	K 39.102 Cu 63.54	Ca 40.08 Zn 65.37	Sc 44.96 Ga 69.72	Ti 47.90 Ge 72.59	V 50.90 As 94.92	Cr 50.20 Se 78.96	Mn 54.94 Br 79.909	Fe Co Ni 55.85 58.93 58.71
5. First series: **Second series:**	Rb 85.47 Ag 107.87	Sr 87.62 Cd 112.40	Y 88.91 In 112.82	Zr 91.22 Sn 118.69	Nb 92.91 Sb 121.95	Mo 95.94 Te 127.60	Tc 99 I 126.90	Ru Rh Pd 101.07 102.91 106.4
6. First series: **Second series:**	Cs 132.90 Au 196.97	Ba 137.34 Hg 200.59	La 138.91 Tl 204.37	Hf 178.49 Pb 207.19	Ta 180.95 Bi 208.98	W 183.85		Os Ir Pt 190.2 192.2 195.09

(e) Using atomic masses of Li, Na and K, find the average atomic mass of Li and K and compare it with the atomic mass of Na. State the conclusion drawn from this activity.

2. Properties of the elements are given below. Where would you locate the following elements in the periodic table?

(a) A soft metal stored under kerosene

(b) An element with variable (>1) valency stored under water.

(c) An element that is tetravalent and forms the basis of organic chemistry.

(d) An element that is an inert gas with atomic number 2.

(e) An element whose thin oxide layer is used to make other elements corrosion resistant by the process of "anodising". [HOTS]



3. An element is placed in second group and third period of the periodic table, burns in the presence of oxygen to form a basic oxide.
   (a) Identify the element.
   (b) Write the electronic configuration.
   (c) Write the balanced equation when it burns in the presence of air.
   (d) Write a balanced equation when this oxide is dissolved in water.
   (e) Draw the electron dot structure for the formation of this oxide. [HOTS]

4. An element X (atomic number 17) reacts with an element Y (atomic number 20) to form a divalent halide.
   (a) Where in the periodic table are elements X and Y placed?
   (b) Classify X and Y as metal (s), non-metal (s) or metalloid (s).
   (c) What will be the nature of the oxide of element Y? Identify the nature of bonding in the compound formed.
   (d) Draw the electron dot structure of the divalent halide.

5. Atomic number of a few elements are 10, 20, 7, 14. [HOTS]
   (a) Identify the elements.
   (b) Identify the group number of these elements in the periodic table.
   (c) Identify the periods of these elements in the periodic table.
   (d) What would be the electronic configuration for each of these elements?
   (e) Determine the valency of these elements.

6. (i) Electropositive nature of the element(s) increases down the group and decreases across the period.
   (ii) Electronegativity of the element decreases down the group and increases across the period.
   (iii) Atomic size increases down the group and decreases across a period (left to right).
   (iv) Metallic character increases down the group and decreases across a period.

   On the basis of the above trends of the periodic table, answer the following about the elements with atomic numbers 3 to 9.
   (a) Name the most electropositive element among them.
   (b) Name the most electronegative element.
   (c) Name the element with the smallest atomic size.
   (d) Name the element which is a metalloid.
   (e) Name the element which shows maximum valency.

7. Atoms of seven elements A, B, C, D, E, F and G have a different number of electronic shells but have the same number of electrons in their outermost shells. The elements A and C combine with chlorine to form an acid and common salt respectively. The oxide of element A is liquid at room temperature and is a neutral substance, while the oxides of the remaining six elements are basic in nature. Based on the above information answer the following questions :
   (i) Identify element A.
   (ii) Will elements A to G belong to the same period or same group of the periodic table?
   (iii) Write the formula of the compound formed by the reaction of the element A with oxygen.
   (iv) Show the formation of the compound by a combination of element C with chlorine with the help of an electronic structure.
   (v) What would be the ratio of the number of combining atoms in a compound formed by the combination of element A with carbon?
   (vi) Which one of the given elements is likely to have the smallest atomic radius?

8. An element X of group 15 exists as diatomic molecule and combines with hydrogen at 773 K in presence of a catalyst to form a compound, ammonia which has a characteristic pungent smell.
   (a) Identify the element X. How many valence electrons does it have?
   (b) Draw the electron dot structure of the diatomic molecule of X. What type of bond is formed in it?
   (c) Draw the electron dot structure for ammonia and what type of bond is formed in it? [HOTS]

9. Answer the following questions based on the elements with atomic number 3 to 9 :
   (a) Name the element with smallest atomic radius.
   (b) Name the element which shows maximum valency.
   (c) Name the element which is metalloid.



(d) Name the element which is most electropositive.

(e) Write the chemical formula of the compound formed when the elements of atomic number 6 and 8 react together.

10. (a) The modern periodic table has been evolved through the early attempts of Dobereiner, Newland and Mendeleev. List one advantage and one limitation of all the three attempts.

(b) Name the scientist who first of all showed that atomic number of an element is a more fundamental property than its atomic mass.

(c) State Modern periodic law.

11. Two elements 'P' and 'Q' belong to the same period of the modern periodic table and are in Group–1 and Group–2 respectively. Compare their following characteristics in tabular form.

(a) The number of electrons in their atoms

(b) The sizes of their atoms

(c) Their metallic characters

(d) Their tendencies to lose electrons

(e) The formula of their oxides

(f) The formula of their chlorides.

12. (a) List any three observations which posed a challenge to Mendeleev's Periodic Law.

(b) How does the metallic character of elements vary on moving from

(i) left to right in a period,

(ii) from top to bottom in a group of the Modern Periodic Table?

Give reason for your answer.

VI. PASSAGE–BASED QUESTIONS

Answer the questions (1–4) on the basis of your understanding of the following paragraphs and the related studied concepts.

When Mendeléev started his work, 63 elements were known. He examined the relationship between the atomic masses of the elements and their physical and chemical properties. Among chemical properties, Mendeléev concentrated on the compounds formed by elements with oxygen and hydrogen. He selected hydrogen and oxygen as they are very reactive and formed compounds with most elements. The formulae of the hydrides and oxides formed by an element were treated as one of the basic properties of an element for its classification. He then took 63 cards and on each card he wrote down the properties of one element. He sorted out the elements with similar properties and pinned the cards together on a wall. He observed that most of the elements got a place in a Periodic Table and were arranged in the order of their increasing atomic masses. It was also observed that there occurs a periodic recurrence of elements with similar physical and chemical properties. On this basis, Mendeléev formulated a Periodic Law, which states that 'the properties of elements are the periodic function of their atomic masses'.

1. Why did Mendeleev place cobalt (atomic mass = 58.93) before nickel (atomic mass = 58.71)?
2. Why did Mendeleev left some gaps in his periodic table?
3. What is the Mendeleev's periodic law?
4. Would you place the two isotopes of an element C-12 and C-13 in different slots or in the same slot?



CBSE SAMPLE QUESTION PAPER 2019-20

TIME: 3 Hrs. M.M.: 80

General Instructions:

1. *The question paper comprises three sections – A, B and C. Attempt all the sections.*
2. *All questions are compulsory.*
3. *Internal choice is given in each section.*
4. *All questions in Section A are one-mark questions comprising MCQ, VSA type and assertion-reason type questions. They are to be answered in one word or in one sentence.*
5. *All questions in Section B are three-mark, short-answer type questions. These are to be answered in about 50 - 60 words each.*
6. *All questions in Section C are five-mark, long-answer type questions. These are to be answered in about 80–90 words each.*
7. *This question paper consists of a total of 30 questions.*

SECTION A

1. Define catenation. 1
2. How does valency of an element vary across a period? 1
3. **Answer question numbers 3(a) – 3(d) on the basis of your understanding of the following paragraph and the related studied concepts.**

   Renewable energy sources such as wind energy are vital for the Indian economy, not only from the point of view of supply, but also from the perspective of environmental and social benefits. India is the world's fifth largest wind-power producer and the largest windmill facilities in India are installed in Tamil Nadu. Muppandal is a small village of Tamil Nadu and one of the most important sites of wind-farm in the state. It uses wind from the Arabian Sea to produce renewable energy. The suitability of Muppandal as a site for wind farms stems from its geographical location as it has access to the seasonal monsoon winds.



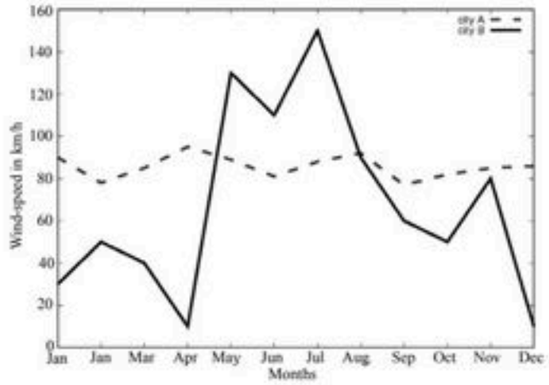
The electrical generators used on wind turbines in sites like Muppandal, produce an output AC of 240 V and a frequency of 50 Hz even when the wind speed is fluctuating. A transformer may be required to increase or decrease the voltage so it is compatible with the end usage, distribution or transmission voltage, depending on the type of interconnection.

3. (a) State the principle behind electric generator. 1

3. (b) The output frequency of wind turbine is 50 Hz. What is meant by this statement? 1

3. (c) Why do you think Muppandal is at an advantageous position for this project? 1

3. (d) Based on the data represented in the graph below, which of the two cities A or B would be an ideal location for establishing a wind-farm and why? 1



4. **Question numbers 4(a) - 4(d) are based on the two tables given below. Study these tables related to blood sugar levels and answer the questions that follow.**

Table A (Blood glucose chart)

	Mean Blood Glucose Level (mg/dL)
Doctor's advice needed	380
	350
	315
	280
	250
	215
Good	180
	150
Excellent	115
	80
	50

Table B (Blood Report of Patient X and Y)

Time of check	**Blood Glucose ranges** (mg/dL)	
	Patient X	Patient Y
Before breakfast (Fasting)	< 100	70 – 130
Before lunch, supper and snack	< 110	70 – 130
Two hours after meals	< 140	< 180
Bedtime	< 120	90–15

4. (a) Refer to Table B showing the blood report of the levels of glucose of patients X and Y. Infer the disease which can be diagnosed from the given data. 1

4. (b) Identify the hormone whose level in the blood is responsible for the above disease. 1

4. (c) Which one of the following diets would you recommended to the affected patient? 1

i) High sugar and low fat diet. ii) Low sugar and high protein diet.

iii) High Fat and low fiber diet. iv) Low sugar and high fiber diet.

4. (d) Refer to the Table A and suggest the value of the mean blood glucose level beyond which doctor's advice is necessary: 1

i) 180 mg/dL ii) 115 mg/dL

iii) 50 mg/dL iv) 80 mg/dL

5. When we enter a dark room coming from outside, immediately the things inside the room do not appear clear to our eyes. This is because 1

i) pupils do not open at all in the dark. ii) pupils take time to adjust.

iii) light travels slower in a dark room. iv) pupils open very quickly in the dark.

OR

The phenomena of light responsible for the working of the human eye is

i) reflection ii) refraction

iii) power of accommodation iv) persistence of vision

6. When a 4V battery is connected across an unknown resistor there is a current of 100 mA in the circuit. The value of the resistance of the resister is: 1

i) 4 Ω ii) 40 Ω

iii) 400 Ω iv) 0.4 Ω

7. Unit of electric power may also be expressed as: 1

i) volt-ampere ii) kilowatt-hour

iii) watt-second iv) joule-second

8. It was found that water from a river was contaminated with Coliform bacteria. Which one of the following pollutant might have got mixed with the water? 1

i) Fertilizer run off ii) Industrial waste

iii) Pesticides iv) Human faecal matter

OR

Which one of the following stakeholders of forests causes the maximum damage to forest?

i) People who live in or around the forest
ii) The forest department of the government
iii) The wildlife and native enthusiasts
iv) The industrialists

9. Which one of the following green house gases is a contributor due to incomplete combustion of coal and petroleum? 1

i) Oxides of nitrogen
ii) Methane
iii) Carbon monoxide
iv) Carbon dioxide

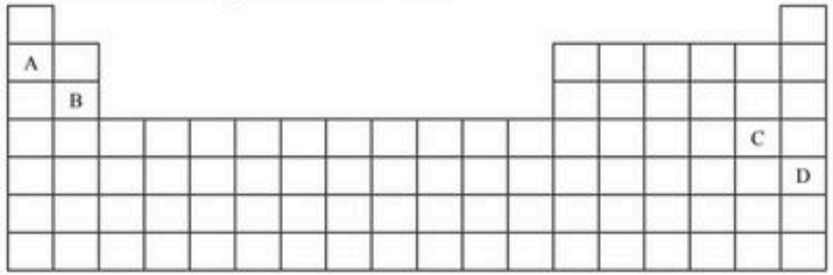
10. Which of the following reactions is an endothermic reaction? 1

i) Burning of coal.
ii) Decomposition of vegetable matter into compost.
iii) Process of respiration.
iv) Decomposition of calcium carbonate to form quick lime and carbon dioxide.

11. Identify the basic salt from the following salts: 1

i) Na_2CO_3
ii) NH_4Cl
iii) $NaNO_3$
iv) KCl

12. The positions of four elements A, B, C and D in the modern periodic table are shown below.
Which element is most likely to form an acidic oxide? 1



i) A
ii) B
iii) C
iv) D

OR

Elements P, Q, R and S have atomic numbers 11, 15, 17 and 18 respectively. Which of them are reactive non-metals?

i) P and Q
ii) P and R
iii) Q and R
iv) R and S

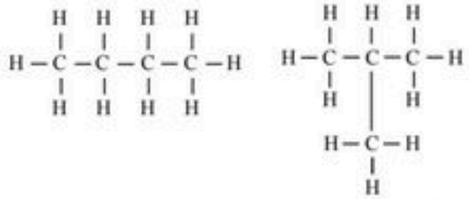
For question numbers 13 and 14, two statements are given- one labeled *Assertion* (A) and the other labeled *Reason* (R). Select the correct answer to these questions from the codes (i), (ii), (iii) and (iv) as given below

i) Both A and R are true and R is correct explanation of the assertion.
ii) Both A and R are true but R is not the correct explanation of the assertion.

iii) A is true but R is false.

iv) A is false but R is true.

13. **Assertion:** Following are the structural isomers of butane. 1



Reason: Structural isomers have the same molecular formula but they differ in their structures.

14. **Assertion:** A fuse wire is always connected in parallel with the mainline. 1

Reason: If a current larger than the specified value flows through the circuit, fuse wire melts.

SECTION B

15. (i) Write two observations when lead nitrate is heated in a test tube. 3

(ii) Name the type of reaction.

(iii) Write a balanced chemical equation to represent the above reaction.

16. A compound 'X' of sodium is used as an antacid and it decomposes on strong heating. 3

(i) Name the compound 'X' and give its chemical formula.

(ii) Write a balanced chemical equation to represent the decomposition of 'X'.

(iii) Give one use of compound 'X' besides an antacid.

OR

You are provided with 90 mL of distilled water and 10 mL of concentrated sulphuric acid to prepare dilute sulphuric acid.

(i) What is the correct way of preparing dilute sulphuric acid? Give reason.

(ii) How will the concentration of H_3O_+ ions change on dilution?

17. Two elements X and Y have atomic numbers 12 and 16 respectively. To which period of the modern periodic table do these two elements belong? What type of bond will be formed between them and why? Also give the chemical formula of the compound formed. 3

18. (i) Create a terrestrial food chain depicting four trophic levels.

(ii) Why do we not find food chains of more than four trophic levels in nature? 3

OR

How will you create an artificial aquatic ecosystem, which is self-sustainable?

19. Explain the processes of aerobic respiration in mitochondria of a cell and anaerobic respiration in yeast and muscle with the help of word equations. 3

20. In a pea plant, the trait of flowers bearing purple colour (PP) is dominant over white colour (pp). Explain the inheritance pattern of F1 and F2 generations with the help of a cross following the rules of inheritance of traits. State the visible characters of F1and F2 progenies. 3

21. Explain giving reasons the bending of the shoot tip of a plant towards light source coming from one side of the plant. 3

22. It is desired to obtain an erect image of an object, using concave mirror of focal length of 12 cm. 3

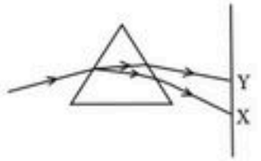
    (i) What should be the range of the object distance in the above case?

    (ii) Will the image be smaller or larger than the object? Draw a ray diagram to show the formation of image in this case.

    (iii) Where will the image of this object be, if it is placed 24 cm in front of the mirror?

23. Suppose your parents have constructed a two room house and you want that in the living room there should be a provision of one electric bulb, one electric fan, a refrigerator and a plug point for appliances of power up to 2 kilowatt. Draw a circuit diagram showing electric fuse and earthing as safety devices. 3

24. In the figure given below, a narrow beam of white light is shown to pass through a triangular glass prism. After passing through the prism, it produces a spectrum XY on the screen. 3



    (i) Name the phenomenon.

    (ii) State the colours seen at X and Y.

    (iii) Why do different colours of white light bend at different angles through a prism?

OR

    (i) What is visible spectrum?

    (ii) Why is red used as the stopping light at traffic signals?

    (iii) Two triangular glass prisms are kept together connected through their rectangular side. A light beam is passed through one side of the combination. Will there be any dispersion? Justify your answer.

SECTION C

25. Metal X is found in nature as its sulphide XS. It is used in the galvanisation of iron articles. Identify the metal X. How will you convert this sulphide ore into the metal? Explain with equations. 5

OR

State the reason for the following:

(i) Aluminium oxide is called an amphoteric oxide.

(ii) An iron strip dipped in a blue copper sulphate solution turns the blue solution pale green.

(iii) Hydrogen gas is not evolved when most metals react with nitric acid.

(iv) Calcium does not occur in free state in nature.

(v) Sodium or potassium metals are kept immersed under kerosene.

26. The formulae of four organic compounds are given below: 5

A	B	C	D
C_2H_4	CH_3COOH	C_2H_5OH	C_2H_6

(i) Which one of these compounds A, B, C or D is a saturated hydrocarbon?

(ii) Identify the organic acid and give its structural formula.

(iii) Which of the above compounds when heated at 443K in the presence of concentrated H_2SO_4 forms ethene as the major product? What is the role played by concentrated H_2SO_4 in this reaction? Also write the chemical equation involved.

(iv) Give a chemical equation when B and C react with each other in presence of concentrated H_2SO_4. Name the major product formed and mention one of its important use.

27. (i) Identify any two parts from the above diagram which carry oxygenated and deoxygenated blood. 5

(ii) Explain the process of double circulation with the help of a flow chart.



28. (i) Describe the various steps involved in the process of binary fission with the help of a diagram. 5

(ii) Why do multicellular organisms use complex way of reproduction?

OR

(i) Describe the role of prostate gland, seminal vesicle and testes in the human male reproductive system.

(ii) How is the surgical removal of unwanted pregnancies misused?

(iii) Explain the role of oral contraceptive pills in preventing conception.

29. (i) Consider a conductor of resistance 'R', length 'L', thickness'd' and resistivity 'ρ'. 5

Now this conductor is cut into four equal parts. What will be the new resistivity of each of these parts? Why?

(ii) Find the resistance if all of these parts are connected in:

(a) Parallel

(b) Series

(iii) Out of the combinations of resistors mentioned above in the previous part, for a given voltage which combination will consume more power and why?

30. (i) A lens produces a magnification of -0.5. Is this a converging or diverging lens? If the focal length of the lens is 6 cm, draw a ray diagram showing the image formation in this case.

(ii) A girl was playing with a thin beam of light from a laser torch by directing it from different directions on a convex lens held vertically. She was surprised to see that in a particular direction, the beam of light continues to move along the same direction after passing through the lens. State the reason for her observation. Draw a ray diagram to support your answer. 5

OR

(i) On entering in a medium from air, the speed of light becomes half of its value in air. Find the refractive index of that medium with respect to air?

(ii) A glass slab made of a material of refractive index n_1 is kept in a medium of refractive index n_2.

A light ray is incident on the slab. Draw the path of the rays of light emerging from the glass slab, if (i) $n_1 > n_2$ (ii) $n_1 = n_2$ (iii) $n_1 < n_2$



unacademy

Unacademy Store

Opens on March 13

Delhi Address

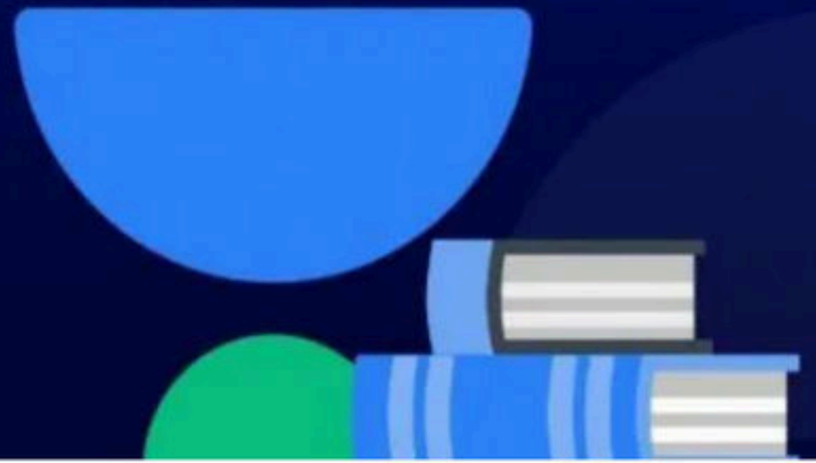
30, Pusa Road, Old Rajinder Nagar.
Near Metro Pillar 121

Registration is mandatory to visit the Unacademy Store on

March 12 - 13

Register Now

*Source: The Indian Edtech Story : Q1 2021 Round - Up by Markelytics.



unacademy

CBSE Class 10

33% off

on 3 months subscription for
CBSE Class 10

~~₹ 7500~~ ₹ 4,999

Use Code:

Valid till 10th March



unacademy | EMERGE

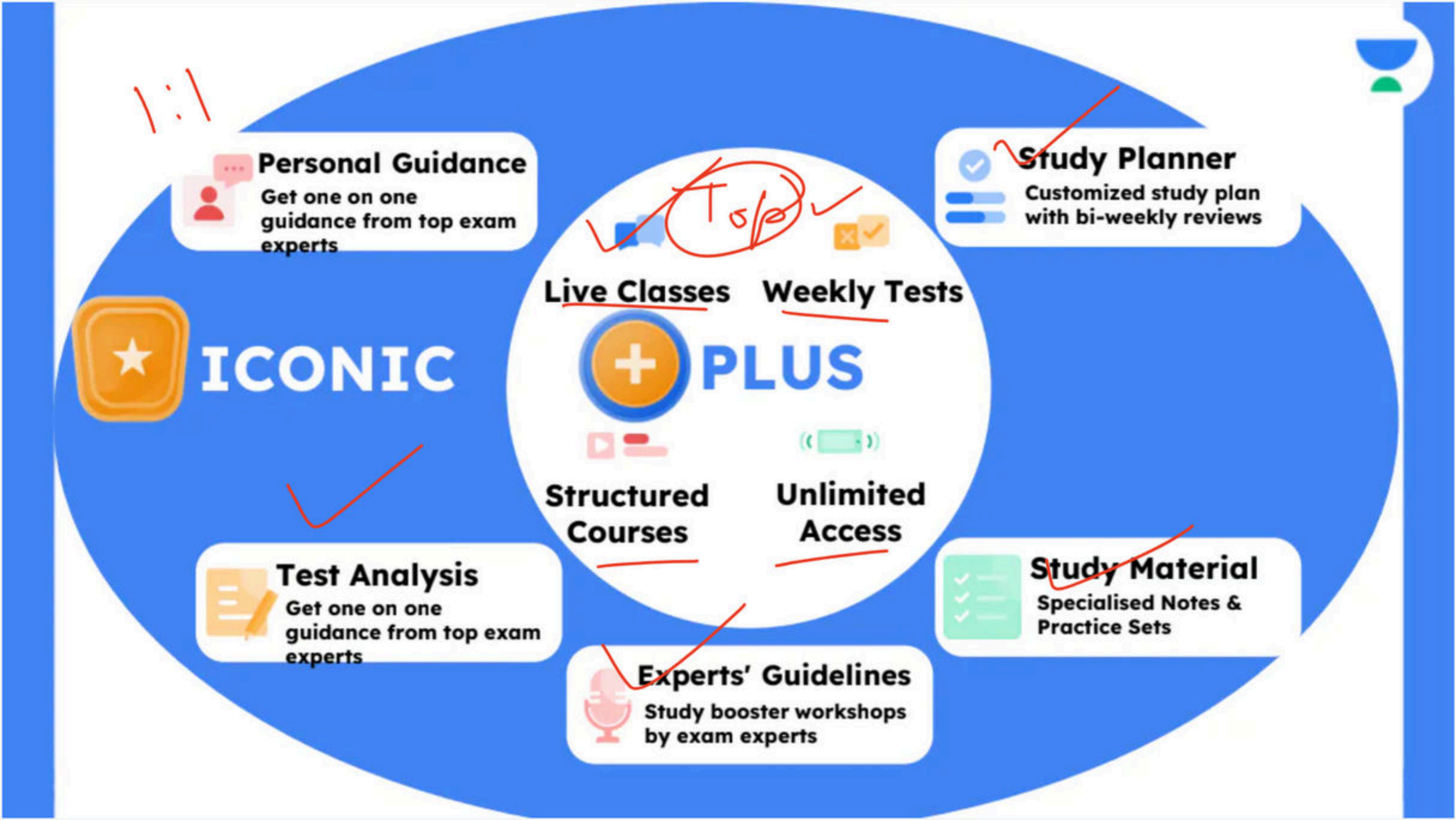
Make it to the Finish Line
with Flying Colors
with Unacademy Emerge

For CBSE Class 10 and 12 learners

Every Saturday - Tuesday
5 PM onwards

Enroll Now




Personal Guidance
Get one on one guidance from top exam experts
Study Planner
Customized study plan with bi-weekly reviews
ICONIC
Live Classes
Weekly Tests
PLUS
Structured Courses
Unlimited Access
Test Analysis
Get one on one guidance from top exam experts
Study Material
Specialised Notes & Practice Sets
Experts' Guidelines
Study booster workshops by exam experts

Upcoming Batches - CBSE Class 9

unacademy

Target Term 1 - Maths Science SST

Class 9 | Start date : March 9 | End Date: June 30

Mode of Delivery: Hindi



Rashmi Singh

SST

Mon, Wed, Fri

6:15 PM - 7:15 PM



Himaal Sharma

Science

Mon, Wed, Fri

7:30 PM - 8:30 PM



Ankit Dhingra

Maths

Tue, Thu, Sat

8:30 PM - 9:30 PM

Term 1 Syllabus - New Session

unacademy

Darwin's Batch on Science - Term 1

Class 9 | Start date : March 9 | End Date: June 30

Mode of Delivery: Hinglish



Akshay Kumar

Physics

Tue, Thu, Sat

9:00 PM - 10:00 PM



Himaal Sharma

Chemistry

Mon, Wed, Fri

6:15 PM - 7:15 PM



Shalini Kumari

Biology

Tue, Thu, Sat

4:00 PM - 5:00 PM



Harsh Sharma

Science

Mon, Wed, Fri

7:30 PM - 8:30 PM

Term 1 Syllabus - New Session

Upcoming Batches - CBSE Class 10

unacademy

Aryabhatta's batch on Maths - Term 1

Class 10 | Batch start date : March 9

Mode of Delivery: Hinglish



Vinay Bajaj

Maths

Tue, Thu, Sat

3:45 PM - 4:45 PM



Shreya Bhansal

Maths

Mon, Wed, Fri

6:00 PM - 7:00 PM



Imran

Maths

Tue, Thu, Sat

7:30 PM - 8:30 PM

Term 1 Syllabus - New Session

unacademy

Newton's Batch on Science - Term 2

Class 10 | Batch start date : March 9

Mode of Delivery: Hindi



Ankit Dhingra

Science

Tue, Thu, Sat

5:00 PM - 6:00 PM



Harpreet Singh

Science

Mon, Wed, Fri

8:30 PM - 9:30 PM



Ajinkya Solunke

Science

Tue, Thu, Sat

3:45 PM - 4:45PM



Arpit Bankhede

Biology

Tue, Thu, Sat

9:00 PM - 10:00 PM

Delivery in Hinglish

Term 1 Syllabus - New Session

Upcoming Batches - CBSE Class 10

unacademy

Last Mile - Maths and SST Practice with Ajinkya Sir

Class 10 | Batch start date : March 10 | Mode of Delivery: Hinglish

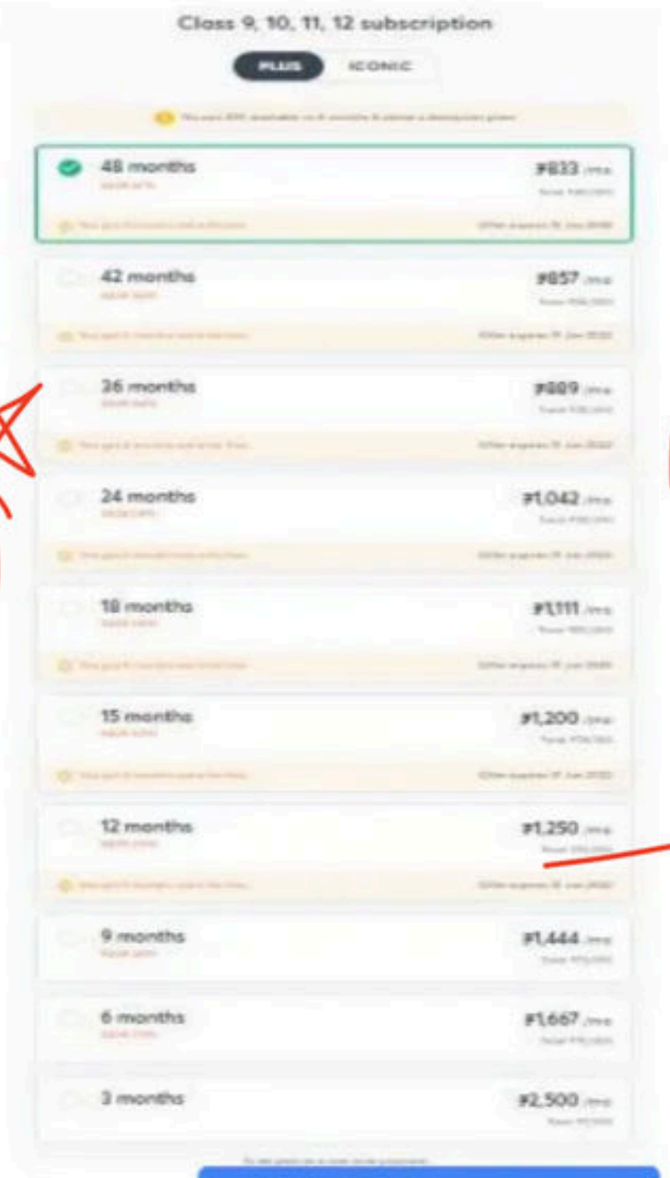


Ajinkya

Maths	SST
Tue, Thurs, Sat	Tue, Thurs, Sat
5:00 PM - 6:00 PM	6:15 PM - 7:15 PM

Unacademy Plus Subscription

Pricing



SUSHI10

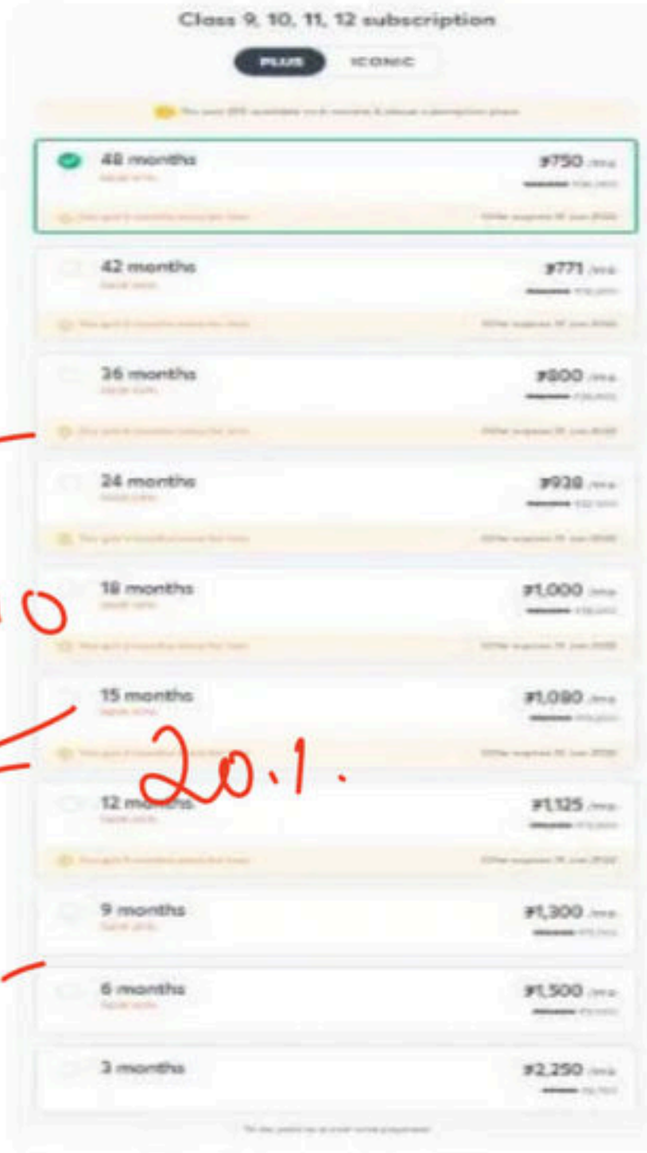
1250/-

SUSHI10

1125/-

20.1.

1000/-



15%

12 500/-

Educator Code

unacademy

CBSE Class 10

33% off

on 3 months subscription for
CBSE Class 10

~~₹ 7500~~ ₹ 4,999

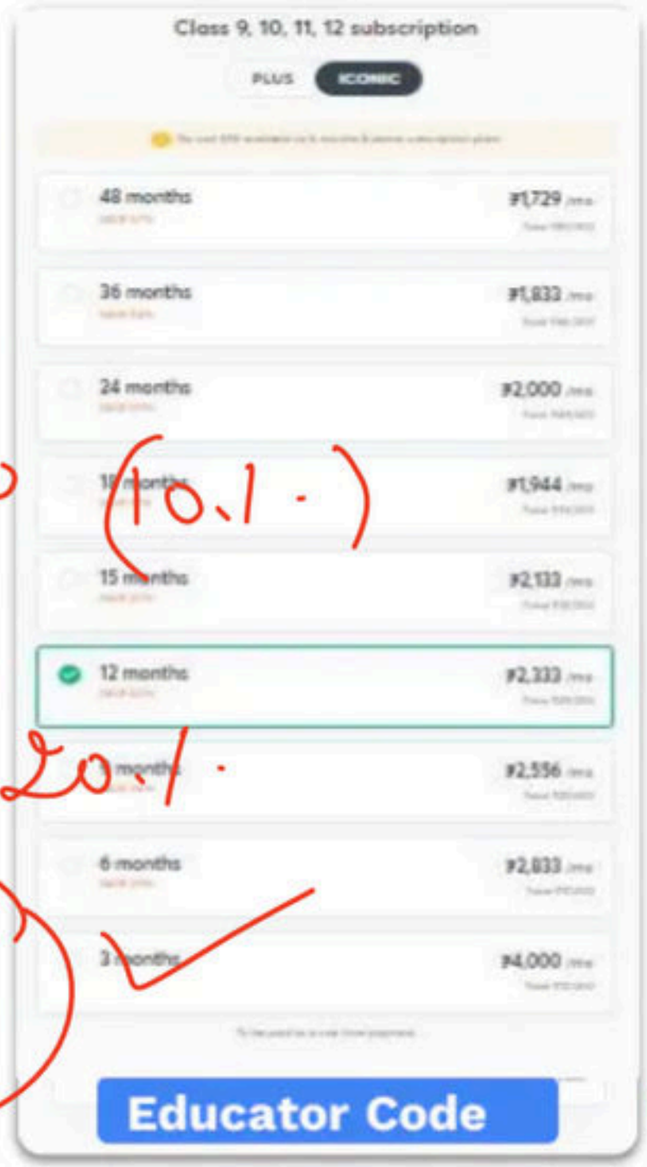
Use Code:

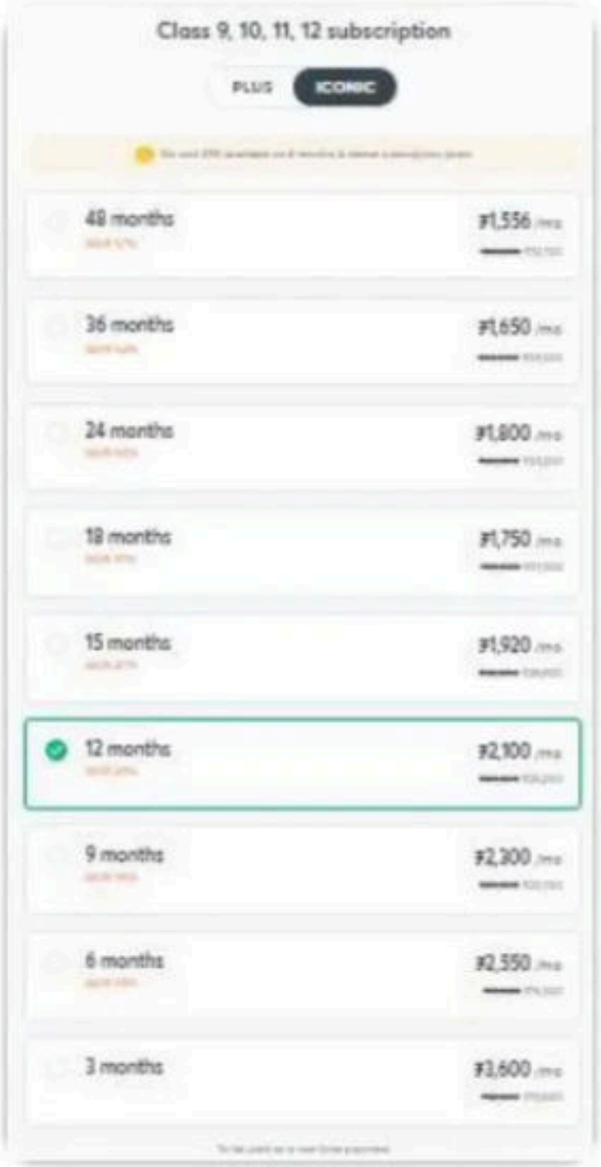
Valid till 10th March



Unacademy Iconic Subscription

Pricing





unacademy

ACE YOUR EXAM

10th or 12th CBSE Board

Buy 3 Months Plus

Get 1 Month FREE





*Valid for the first 500 subscription

unacademy

Accelerate

No more breaks in your prep

Free 6-month extension on subscriptions of 1-year and above

Limited period offer*

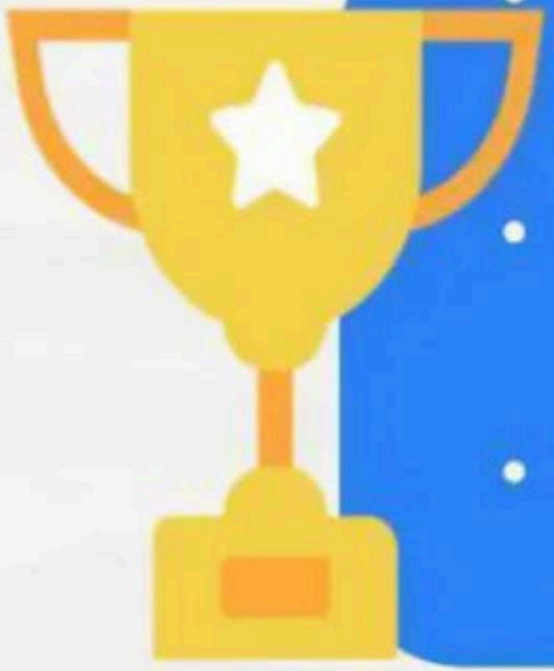
Subscribe now

Use code _____ for 10% off

*T&C Apply. Offer valid on first-come first-serve basis



BUGS BOUNTY



- Opportunity for all Learners to report any inappropriate content in the video
- Be the first one to report a particular issue to claim your prize
- Report any inappropriate content using the form in the description



Thank You!

+ SUBSCRIBE





PDF Download Now !