9. Solutions

Result of health drink

Health drink

Anu has got back home from playfield after winning a match. She is received by her mother cheerfully with a glass of health drink.

Anu: Mother! What is this?

Mother: This is your health drink – a solution of fruit juice and sugar for your revitalisation.

Solutions are of great importance in **everyday** life. The process of food assimilation by man is in the form of solution. Blood and lymph are in the form of solution to decide the physiological activity of human beings.

A solution is a homogeneous mixture of two (or) more substances.

All solutions exist in homogeneous form. **Homogeneous** refers to the state in which two (or) more substances, that are uniformly present in a given mixture. If a solution contains two components, then it is called as a **Binary Solution**.

Salt solution containing common salt in water is a suitable example for binary solution.

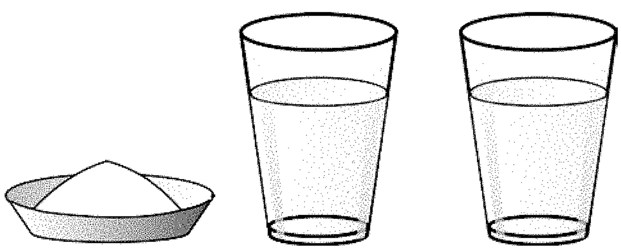


Fig. 9.1 A solution is a homogenous mixture of solute and solvent

CHEMISTRY

9.1. SOLUTE AND SOLVENT

In a solution, the component present in lesser amount by weight is called solute and the component present in a larger amount by weight is called solvent. Generally a solvent is a dissolving medium. It surrounds the particles of solute to form solution.

In short, a solution can be represented, as follows

(Solute + Solvent → Solution)

9.2. TYPES OF SOLUTIONS

9.2.1. Based on the particle size

Based on the particle size of the substance, the solutions are divided into three types.

1. True solutions: It is a homogeneous mixture that contains small solute particles that are dissolved throughout the solvent eg. Sugar in water.

2. Colloidal solutions: It is a heterogeneous mixture made up of two phases namely, dispersed phase and dispersion medium. The substance distributed as particles is called dispersed phase. The continuous phase in which the colloidal particles are dispersed is called dispersion medium.

(Dispersed phase + Dispersion medium → Colloidal solution)

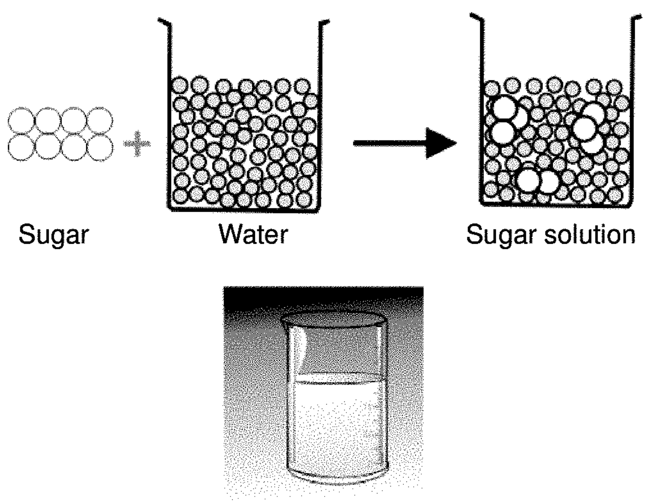


Fig. 9.2 Mixture of sugar and water forming true solution

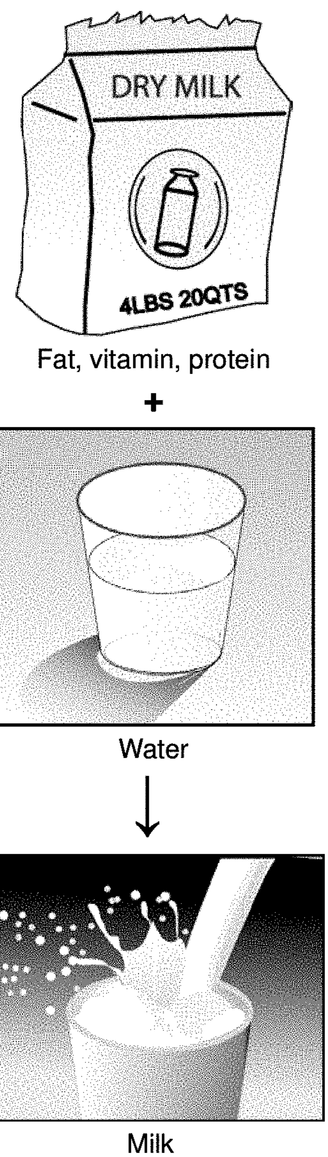
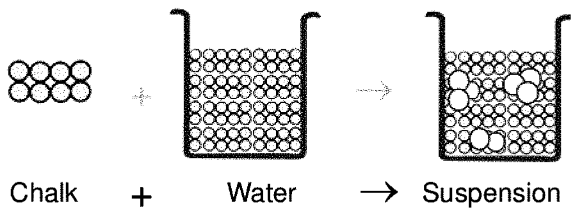


Fig. 9.3 A mixture of milk powder and water forming colloid

3. **Suspensions:** It is a heterogeneous mixture of small insoluble particles in a solvent. In a suspension, the particles of solid stay in clusters that are large enough to be seen (e.g. Chalk powder in water).



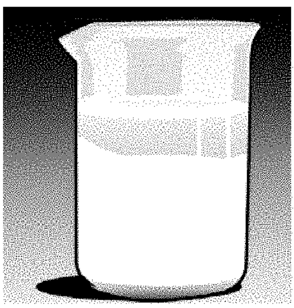


Fig. 9.4 A mixture of chalk and water forming suspension

MORE TO KNOW

Tyndall effect, The phenomenon by which colloidal particles scatter light is called **Tyndall effect**. If a beam of light is allowed to pass through a true solution, some of the light will be absorbed and some will be transmitted. The particles in true solution are not large enough to scatter the light. However if light is passed through a colloid, the light is scattered by the larger colloidal particles and the beam becomes visible. This effect is called TYNDALL EFFECT

ACTIVITY 9.1

Students may be asked to observe the scattering of light (Tyndall effect) when sunlight passes through the window of the class rooms. The dust particles scatter the light making the path of the light visible.

Fig. 9.5 Tyndall effect in nature

MORE TO KNOW

Brownian movement: The phenomenon by which the colloidal particles are in continuous random motion is called **Brownian movement.**

Brownian motion is named in honour of ROBERT BROWN a biologist.He observed the motion of the particles in suspension of pollen grains in water.

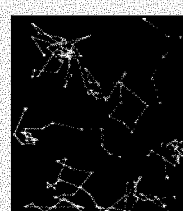
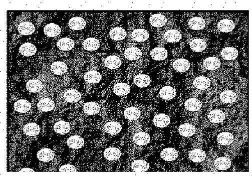
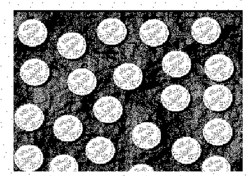
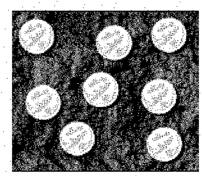


Fig. 9.6 Brownian movement

Comparing the properties of true solution,colloidal solution and suspension

Property	True Solution	Colloidal Solution	Suspension
Particle size in A° (1A° = 10^{-10}m)	 1A° to 10 A°	 10A° to 2000 A°	 More than 2000 A°
Appearance	Transparent	Translucent	Opaque
Visibility of particles	Not visible even under ultra microscope	Visible under ultra microscope	Visible to the naked eye
Nature	Homogeneous	Heterogeneous	Heterogeneous
Diffusion of particles	diffuses rapidly	diffuses slowly	diffusion does not occur
Scattering effect	Does not scatter light	It scatters light	It does not scatter light

9.2.2. Based on the type of solvent

Based on the type of solvent solutions are classified into two types

1. **Aqueous solution:** The solution in which water acts as a solvent, is called **aqueous solution**. For e.g., sugar solution.
2. **Non-aqueous solution:** The solution in which any liquid other than water acts as a solvent is called **non-aqueous solution**. Solution of sulphur in carbon disulphide is a suitable example for non-aqueous solution. (Benzene, ether, CS_2, are some of the examples for non aqueous solvents.)

9.2.3. Based on the amount of solute in the given solution

Based on the amount of solute in the given amount of solvent, solutions are classified into the following types.

1. Unsaturated solution
2. Saturated solution
3. Super saturated solution

1. **Unsaturated solution:** A solution in which the solute is in lesser amount in comparison with the solvent is called unsaturated solution. In this, addition of solute is possible till the solution reaches the point of saturation.

   e.g., 5g or 10g or 20g of NaCl in 100g water

2. **Saturated solution:** A solution in which no more solute can be dissolved in a definite amount of solvent at a given temperature is called a saturated solution e.g.,

i) A saturated solution of CO_2 in H_2O

ii) 36g of NaCl in 100g of water at room temperature forms saturated solution

3. **Super saturated solution:** A solution which has more of solute at a given temperature than that of saturated solution is called **super saturated solution**.

MORE TO KNOW

Nitrogen in earth soil is an example for saturated solution in nature. (Earth soil cannot store more N_2 than it can hold)

ACTIVITY 9.2

Test whether a solution is saturated, unsaturated or super-saturated with respect to the addition of salt at a particular temperature to the solution.

Take a glass containing 100ml of water, three packets of salts each weighing 20g, 16g, and 1g and a table spoon (see fig 9.7).

Record your observations after the addition of each packet in the given order followed by stirring at each stage.

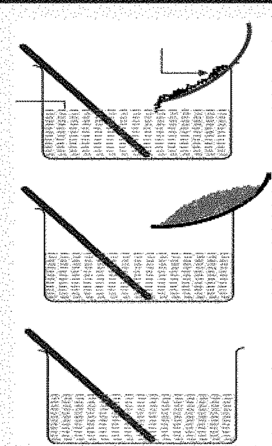


Fig. 9.7 To test Unsaturation, Saturation and Super Saturation in a given solution

9.2.4 Based on the physical state of the solute and the solvent the solutions are of 9 types

Solute	Solvent	Examples
Solid	Solid	Alloys
Solid	Liquid	Sugar solution
Solid	Gas	smoke
Liquid	Solid	cheese
Liquid	Liquid	Milk
Liquid	Gas	Cloud
Gas	Solid	Cork
Gas	Liquid	Soda water
Gas	Gas	Helium-oxygen mixture (for deep sea diving)

9.3. SOLUBILITY

Solubility of a solute in a given solvent at a particular temperature is defined as the number of grams of solute necessary to saturate 100g of the solvent at that temperature. For example

Solubility of $CuSO_4$ in H_2O is 20.7g at 20°C

MORE TO KNOW

Dilute and concentrated solutions: Concentration of a solution is the amount of solute dissolved in a given amount of solvent. A solution containing less amount of solute is known as dilute solution whereas a solution containing large amount of solute is known as concentrated solution. It may be noted that dilute and concentrated are the relative terms and they have only quantitative meaning.

ACTIVITY 9.3

Determine the solubility of a solid (say KCl) in water at room temperature.

- Prepare saturated solution of KCl in about 30 ml of water at room temperature. Add more of KCl ensuring that solution is saturated and some KCl is left undissolved.
- Filter the solution to remove solid KCl.
- Find temperature of the solution by dipping a thermometer in it.
- Evaporate the solution to dryness by using a low flame to avoid bumping.
- Allow the dish and solid to cool to room temperature. Place the dish and solid in a dessicator containing anhydrous calcium chloride (calcium chloride is dehydrating agent, it absorbs moisture).

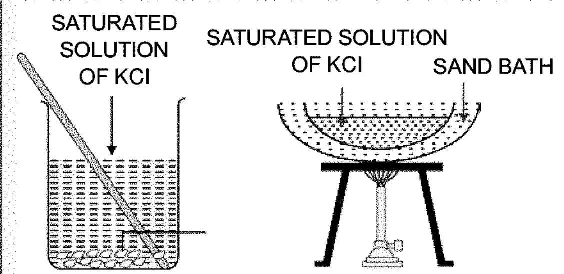


Fig. 9.8 Determination of solubility

- Take out the evaporating dish and again weigh it.
- The observation and calculation are given as follows.

Observation

Weight of the dish = Wg

Weight of dish + saturated solution of KCl = W_1g

Weight of dish + dry KCl = W_2g

Calculation

Weight of saturated solution = $(W_1 - W)$g

Weight of KCl = $(W_2 - W)$g

Weight of water present in saturated solution

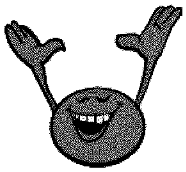
$$= [(W_1 - W) - (W_2 - W)]\text{g}$$

$$= [(W_1 - W_2)]\text{g}$$

$$\textbf{Solubility of KCl} = \frac{\textbf{Weight of KCl}}{\textbf{Weight of solvent}} \times 100$$

$$= \frac{(W_2 - W)}{(W_1 - W_2)} \times 100$$

CHAPTER 9



Tit Bit

100ml of water can dissolve 36g of NaCl at 25^0C to attain saturation.

Solubility of some ionic compounds at 25°c

Substance	Solubility (g per 100g water)
NaCl	36 g
NaBr	95 g
NaI	184 g
$NaNO_3$	92 g

9.4. FACTORS AFFECTING SOLUBILITY

1. Temperature
2. Nature of solute (or) solvent
3. Pressure

1. Effect of Temperature

In endothermic process, solubility increases with increase in temperature.

e.g., Solubility of KNO_3 increases with the increase in temperature.

In exothermic process, solubility decreases with increase in temperature.

e.g., Solubility of CaO decreases with increase in temperature.

2. Nature of solute and solvent

Solubility of a solute in a solvent depends on the nature of both solute and solvent. A polar compound dissolves in a polar solvent.

e.g., Common salt dissolves in water. A polar compound is less soluble (or) insoluble in a non polar solvent.

3. Effect of pressure

Effect of pressure is observed only in the case of gases. An increase in pressure increases the solubility of a gas in a liquid. For eg. CO_2 gas is filled in soft drinks using the effect of pressure.

Fig. 9.9 CO_2 filled in soft drinks

MORE TO KNOW

Increase in pressure increases the solubility of gases. At a given temperature, the mass of gas dissolved in a fixed volume of liquid is directly proportional to the pressure of the gas on the surface of the liquid. This is called **Henry's Law.**

PROBLEM 1

Take 10g of common salt and dissolve it in 40g of water. Find the concentration of solution in terms of weight percent.

Weight percent

$$= \frac{\text{Weight of the solute}}{\text{Weight of solute + Weight of solvent}} \times 100$$

$$= \frac{10}{10+40} \times 100 = 20\%$$

PROBLEM 2

2g of potassium sulphate was dissolved in 12.5 ml of water. On cooling, the first crystals appeared at 60°C. What is the solubility of potassium sulphate in water at 60°C?

SOLUTION

12.5 ml of water weighs 12.5g.

In 12.5g of water, amount of potassium sulphate dissolved, is 2g

In 1g of water, amount of potassium sulphate dissolved, is 2/12.5 g

Hence in 100g of water, amount of potassium sulphate dissolved, is (2 x 100)/12.5=16g.

The solubility of potassium sulphate in water at 60ºC is 16g.

PROBLEM 3

50g of saturated solution of NaCl at 30°C is evaporated to dryness when 13.2g of dry NaCl was obtained. Find the solubility of NaCl at 30°C in water.

Mass of water in solution = 50-13.2 = 36.8g

Solubility of NaCl =

$$\frac{\text{Mass of NaCl}}{\text{Mass of water}} \times 100 = \frac{13.2}{36.8} \times 100 = 36g$$

Solubility of NaCl = 36g (appx.)

PROBLEM 4

An empty evaporating dish weighs 20.0g On the addition of saturated solution of $NaNO_3$, the dish weighs 66.0g. When evaporated to dryness, the dish with crystals weighs 41.5g. Find the solubility of $NaNO_3$ at 20°C.

SOLUTION

Weight of saturated solution of $NaNO_3$ = (66.0 – 20.0) g = 46.0g

Weight of crystals of $NaNO_3$ = (41.5-20.0) g = 21.5g

Weight of water in saturated solution = (46.0-21.5) g = 24.5g

Solubility of $NaNO_3$ =

$$\frac{\text{Weight of } NaNO_3 \text{ Crystals}}{\text{Weight of water}} \times 100$$

$$= \frac{21.5}{24.5} \times 100 = 87.7g$$

Solubility of $NaNO_3$ at 20°C is = 87.7g in 100g H_2O

EVALUATION

PART - A

1. A true solution is a homogeneous mixture of solute and solvent. Chalk powder in water is a heterogenous mixture. Is it a true solution?
2. Solution that contains water as the solvent is called aqueous solution. If carbon disulphide is a solvent in a given solution, then the solution is called ______.
3. Solubility of common salt in 100g water is 36g. If 20g of salt is dissolved in it how much more is required to attain saturation.
4. If two liquids are mutually soluble, they are called ________ liquids. (miscible, immiscible)
5. When sunlight passes through window of the classrooms its path is visible. This is due to ________of light. (reflection, scattering)
6. The particles in various forms are visible only under ultramicroscope. A solution containing such particles is called ___________. (True solution, colloidal solution)
7. The mixture of gases used by deep sea divers is ________(Helium-oxygen, oxygen-nitrogen)
8. Earth soil cannot store more nitrogen than it can hold. Hence earth soil is referred to be in a state of __________. (saturation, unsaturation)
9. In an endothermic process, solubility increases with __________ in temperature. (increase, decrease)

PART - B

10. From the table given below, furnish your points of inferences.

Substance	Solubility at 25°C
NaCl	36g
NaBr	95g
NaI	184g

11. Distinguish between the saturated and unsaturated solution using the data given below at a temperature of 25°C
    A. 16g NaCl in 100g water
    B. 36g NaCl in 100g water

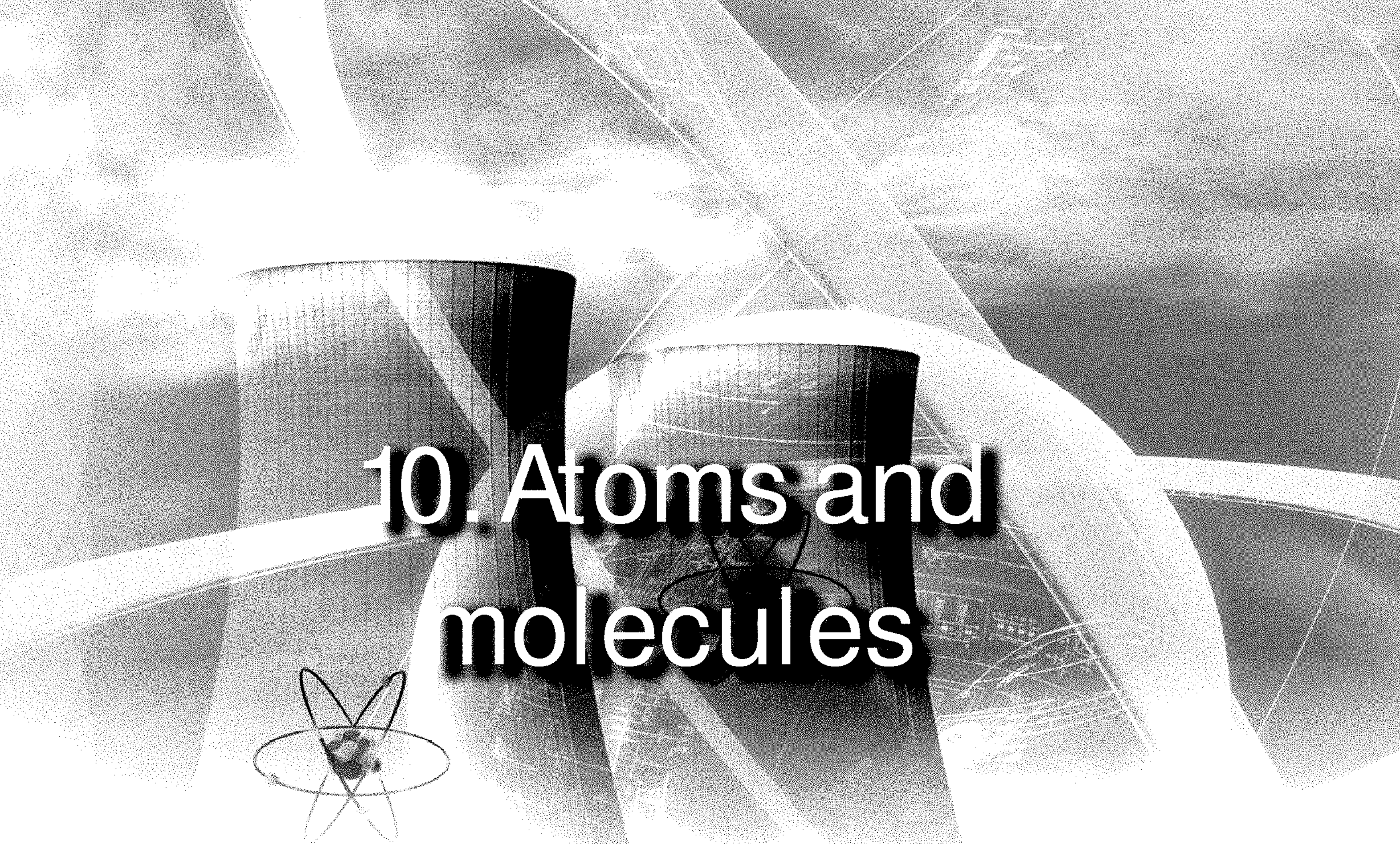
Note : Solubility of NaCl is 36g

12. You have prepared a saturated solution of sugar at room temperature. Is it possible to dissolve some more grams of sugar to this solution? Justify your stand.
13. Find the concentration of solution in terms of weight percent if 20 gram of common salt is dissolved in 50 gram of water.

FURTHER REFERENCE :

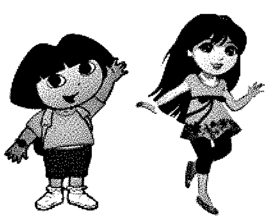
Books : 1. Physical Chemistry by : **Puri & Sharma** - Vishal Publication
2. Advanced Chemistry by: **Bahl & Arun Bahl** - S.Chand publishers

Website : www.chemistry explained.com www.sparknotes.com



10. Atoms and molecules

ATOMS AND MOLECULES



Rani shows a piece of chalk to Vani & asks her to break it into minute particles. The breaking spree, goes on and on endlessly and finally they come to conclude that the minute particle is a group of invisible atoms. They get set to probe further.

EXPLORING THE ATOM

The word atom is derived from the Greek word **"Atomos"** which means indivisible. John Dalton modelled atoms as hard indivisible spheres.

His theory remained undisputed for about a century without any changes. However towards the end of 19th and in the beginning of 20th centuries, the introduction of matter wave concept by de Broglie, the principle of uncertainty by Heisenberg etc., paved the way for **modern atomic theory or modified atomic theory.**

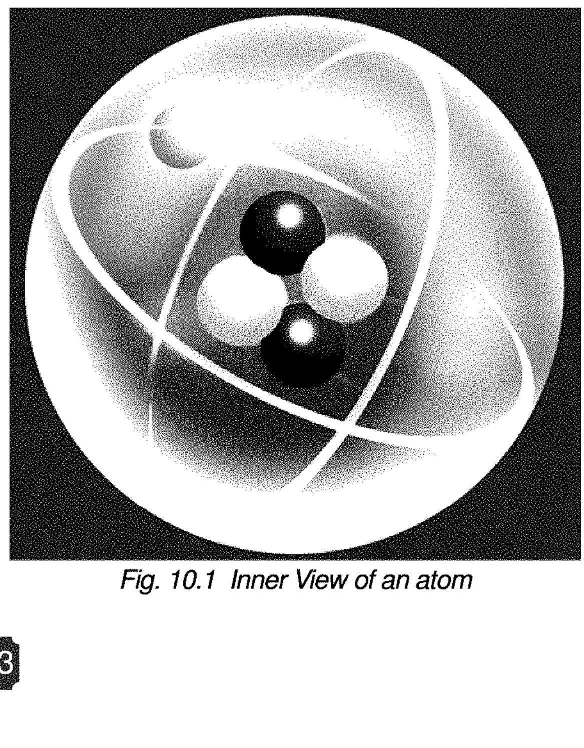


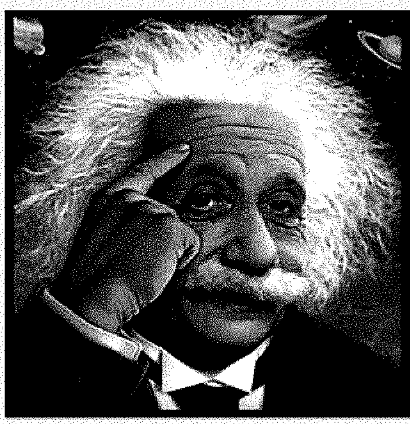
Fig. 10.1 Inner View of an atom

10.1. MODERN ATOMIC THEORY

The findings of **modern atomic theory** are given as follows.

- Atom is considered to be a divisible particle.
- Atoms of the same element may not be similar in all respects.
  eg: Isotopes ($_{17}Cl^{35}, _{17}Cl^{37}$)
- Atoms of different elements may be similar in some respects
  eg. Isobars ($_{18}Ar^{40}, _{20}Ca^{40}$)
- Atom is the smallest particle which takes part in chemical reactions.
- The ratio of atoms in a molecule may be fixed and integral but may not be simple
  e.g., $C_{12}H_{22}O_{11}$ is not a simple ratio (Sucrose)

ALBERT EINSTEIN



When a nuclear reaction occurs the mass of the product is found to be less than the mass of the reactants. The difference in mass is converted into energy in accordance with the equation $E = mc^2$, where E = energy liberated, m = disappeared mass and c = speed of light. This famous equation of Einstein, made revolution in nuclear science.

- Atoms of one element can be changed into atoms of other element by transmutation.
- The mass of an atom can be converted into energy. This is in accordance with Einstein's equation $E = mc^2$

10.2. AVOGADRO'S HYPOTHESIS

Amedeo Avogadro put forward hypothesis and is based on the relation between number of molecules and volume of gases.

Avogadro's Law: Equal volumes of all gases under the same conditions of temperature and pressure. contain the equal number of molecules.

10.2.1. Atomicity

The number of atoms present in one molecule of an element is called the atomicity of an element.

Depending upon the number of atoms in one molecule of an element, molecules are classified into monoatomic, diatomic, triatomic, and poly atomic molecules.

For any homo atomic molecule atomicity can be deduced using the formula

$$\text{Atomicity} = \frac{\text{Molecular Mass}}{\text{Atomic mass}}$$

Avogadro's Law enables us to change over directly from a statement about volume of gases to a statement about molecules of gases and vice-versa.

MORE TO KNOW

Isotopes ⇒ These are the atoms of same element with same atomic number (Z) but different mass number (A). example $({}_{17}Cl^{35}, {}_{17}Cl^{37})$

Isobars ⇒ These are the Atoms of the different element with same mass number but different atomic number. example $({}_{18}Ar^{40}, {}_{20}Ca^{40})$

Isotones ⇒ These are the atoms of different elements with same number of neutrons Example : $({}_{6}C^{13}, {}_{7}N^{14})$

Atomicity	No. of atoms per molecule	Eg
Monoatomic	1	Helium (He) Neon (Ne) Metals
Diatomic	2	Hydrogen H_2 Chlorine Cl_2
Triatomic	3	Ozone (O_3)
Polyatomic	>3	phosphorous P_4 Sulphur S_8

e.g.,

N_2 + O_2 → 2 NO

Nitrogen Oxygen Nitric oxide

(1 Vol) (1 Vol) (2 Vols)

After applying Avogadro's Law, the equation,becomes

N_2 + O_2 → 2 NO

1 Molecule 1 Molecule 2 Molecules

MORE TO KNOW

Avogadro an Italian Scientist (1766 – 1856) He was the One to propose that volume of a gas at a given temperature and pressure is proportional to the number of particles.

TEST YOUR UNDERSTANDING SKILL

1. Find the atomicity of chlorine if its atomic mass is 35.5 and its molecular mass is 71
2. Find the atomicity of ozone if its atomic mass is 16 and its molecular mass is 48

It is found that two molecules of nitric oxide contains 2 atoms of nitrogen and 2 atoms of oxygen.

These two atoms of nitrogen and the two atoms of oxygen should have come from 1 molecule of nitrogen and 1 molecule of oxygen, respectively.

Hence, nitrogen and oxygen are called **diatomic molecules** and are written as N_2 and O_2.

This proves that, atomicity of Nitrogen is 2 and the atomicity of oxygen is 2

Thus Avogadro's hypothesis is used in the deduction of atomicity of elementary gases.

To establish the relationship between vapour density and relative molecular mass of a gas

i. **Relative Molecular Mass:** It is defined as the ratio of the mass of 1 molecule of the gas or vapour to the mass of 1 atom of hydrogen.

$$\text{Relative molecular mass of a gas} = \frac{\text{Mass of 1 molecule of the gas or vapour}}{\text{Mass of 1 atom of hydrogen}}$$

ii. **Vapour Density (V.D):** It is defined as the ratio of the mass of a certain volume of the gas or vapour to the mass of the same volume of hydrogen at the same temperature and pressure.

$$V.D = \frac{\text{Mass of 1 volume of gas or vapour}}{\text{Mass of 1 volume of hydrogen}}$$

Applying Avogadro's Law,

$$V.D = \frac{\text{Mass of 1 molecule of gas or vapour}}{\text{Mass of 1 molecule of hydrogen}}$$

Since hydrogen is diatomic,

$$V.D = \frac{\text{Mass of 1 molecule of gas or vapour}}{2 \times \text{Mass of 1 atom of hydrogen}}$$

Multiplying both sides by 2, we get

$$2 \times V.D = \frac{\text{Mass of 1 molecule of gas or vapour}}{\text{Mass of 1 atom of hydrogen}}$$

2 x V.D = relative molecular mass of a gas or vapour

2xVapour density = Relative molecular mass

How to arrive at the value of *GRAM MOLAR VOLUME (GMV)*

$$GMV = \frac{\text{GRAM MOLAR MASS}}{\text{DENSITY OF GAS AT STP}}$$

To find the value of

$$\text{GMV OF OXYGEN} = \frac{\text{GMM of } O_2}{\text{DENSITY OF } O_2}$$

$$= 32/1.429$$

$$= 22.4 \text{ lit}$$

Therefore GMV = 22.4 litre at STP

MORE TO KNOW

Gay-Lussac's law of Combining volumes of gases

Whenever gases react, they do so in volumes which bear a simple ratio to one another, and to the volumes of the gaseous products, provided all the volumes are measured under the same conditions of temperature and pressure.

Applications of Avogadro's law

1. It is used to determine the atomicity of gases.

2. It is helpful in determining the molecular formula of gaseous compound.
3. It establishes the relationship between the vapour density and molecular mass of a gas.
4. It gives the value of molar volume of gases at STP. Molar Volume of a gas at STP=22.4 lit (or) 22400 cm^3.
5. It explains Gay Lussac's law effectively.

10.3. ATOMS AND MOLECULES

Atoms and molecules are the building blocks of the matter.

10.3.1. Atom: It is the ultimate particle of an element which may or may not have independent existence. The atoms of certain elements such as hydrogen, oxygen, nitrogen, etc.do not have independent existence whereas atoms of helium,neon,argon,etc. do have independent existence. All elements are composed of atoms.

10.3.2. Molecule: A molecule is the simplest structural unit of an element (or) a compound which contains one (or) more

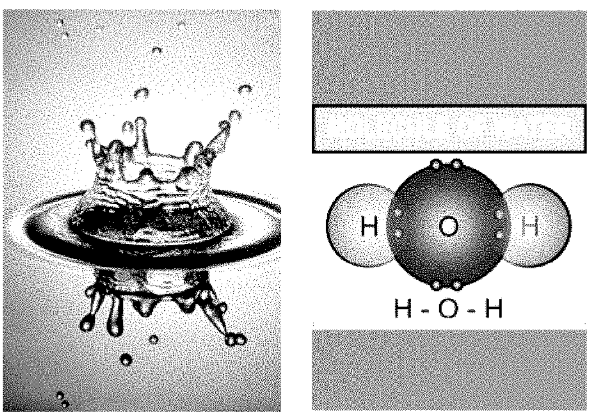


Fig 10.2 Molecule of water

POINT TO EXPLORE

Name the elements and find their number of atoms in one molecule of a) Nitrogen b) Water c) Ammonia d) Sulphuric acid.

atoms. It retains the characteristics of an element.

A molecule can exist freely and it is a combined form of bonded units whereas an atom is a singular smallest form of non bonded unit.

10.3.3. Differences between atom and molecule:

Atom	Molecule
The smallest particle of an element that can take part in a chemical reaction.	The smallest particle of an element or a compound that can exist freely.
An atom is a non bonded entity	A molecule is a bonded entity
An atom may or may not exist freely	A molecule can exist freely

Molecules are of two types, namely homo atomic molecules and hetero atomic molecules.

1. Homo atomic molecules

These are the molecules which are made up of atoms of the same element.

Most of the elementary gases consist of homo atomic molecules. For example hydrogen gas consists of two atoms of hydrogen (H_2).Similarly oxygen gas consists of two atoms of oxygen (O_2). In accordance with the number of atoms present in these molecules they are classified as monoatomic, diatomic, triatomic or poly atomic molecules showing that they contain one, two, three, or more than three atoms respectively.

2. HETRO ATOMIC MOLECULES

The hetro atomic molecules are made up of atoms of different elements. They are also classified as diatomic, triatomic, or polyatomic molecules depending upon the number of atoms present. H_2O, NH_3, CH_4, etc., are the examples for hetero atomic molecules.

10.4. RELATIVE ATOMIC MASS (RAM)

$$\text{RAM} = \frac{\text{Mass of 1 atom of an element}}{\text{Mass of 1 atom of hydrogen}}$$

10.4.1. Definition (based on hydrogen scale)

The relative atomic mass of an element is the ratio of mass of one atom of the element to the mass of one atom of hydrogen taken as standard.

10.4.2. Definition (based on carbon scale)

$$\text{RAM} = \frac{\text{Mass of 1 atom of an element}}{\frac{1}{12}\text{ th part of the mass of one atom of carbon}}$$

Relative atomic mass of an element is the ratio of mass of one atom of element to the **1/12th** part of mass of one atom of carbon.

Relative atomic mass is a pure ratio and has no unit. If the atomic mass of an element is expressed in grams, it is known as **gram atomic mass.**

e.g.,

Gram atomic mass of hydrogen = 1g

Gram atomic mass of carbon = 12g

Gram atomic mass of nitrogen = 14g

Gram atomic mass of oxygen = 16g

Gram atomic mass of sodium = 23g

Atomic mass is expressed in atomic mass unit (**amu**). **One atomic mass unit is defined as 1/12th part of the mass of one atom of carbon.**

10.5. RELATIVE MOLECULAR MASS(RMM)

Definition (based on hydrogen scale)

$$\text{RMM} = \frac{\text{Mass of 1 molecule of an element / compound}}{\text{Mass of 1 atom of hydrogen}}$$

The relative molecular mass of an element or a compound is the ratio of mass of one molecule of the element or a compound to the mass of one atom of hydrogen.

Definition (based on carbon scale)

$$\text{RMM} = \frac{\text{Mass of 1 molecule of an element / compound}}{\frac{1}{12}\text{ th part of the mass of one atom of carbon}}$$

The relative molecular mass of an element or a compound is the ratio of mass of one molecule of the element or a compound to the mass of 1/12 th part of mass of one atom of carbon.

Relative Molecular mass is a pure ratio and has no unit. If the molecular mass of a given substance is expressed in gram, it is known as **gram molecular mass** of that substance.

Molecular mass is the sum of the masses of all the atoms present in one molecule of the compound or an element.

Gram molecular mass calculations to test your numerical skill

1. Find the gram molecular mass of water (H_2O)

calculation

$2(H) = 2 \times 1 = 2$

$1(O) = 1 \times 16 = 16$

18

$\therefore$ **Gram molecular mass of H_2O = 18g**

2. Find the gram molecular mass of carbon dioxide (CO_2)

$1(C) = 1 \times 12 = 12$

$2(O) = 2 \times 16 = 32$

44

Gram molecular mass of CO_2 = 44 g

10.6. MOLE CONCEPT

While performing a reaction, to know the number. of atoms (or) molecules involved, the **concept of mole** was introduced. The quantity of a substance is expressed in terms of mole.

Shown here in Fig.10.3 are one mole quantities of each of the following materials: (clockwise from top left) 180g of acetylsalicylic acid (aspirin), 18.0g of water, 342g of sucrose (table sugar), 201g

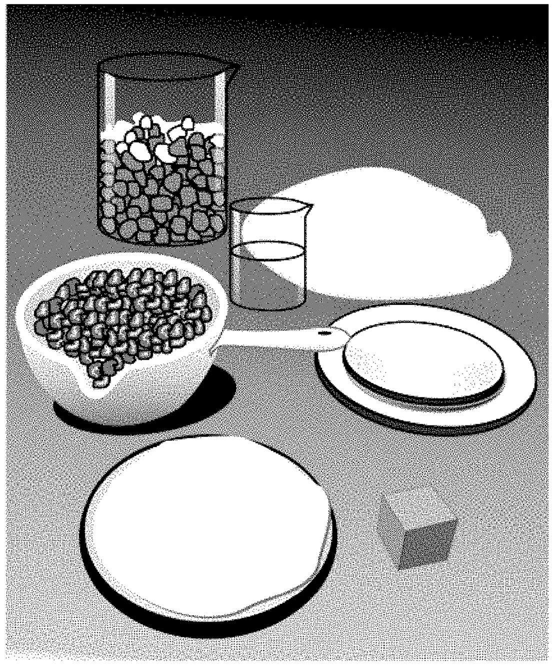


Fig. 10.3 Mole in various forms

of mercury, 55.9g of iron, 58.5g of sodium chloride (table salt), and 254g of iodine.

10.6.1. Definition of mole

Mole is defined as the amount of substance that contains as many specified elementary particles as the number of atoms in 12g of carbon-12 isotope.

One mole is also defined as the amount of substance which contains Avogadro number (6.023×10^{23}) of particles.

Avogadro number: Number of atoms or molecules or ions present in one mole of a substance is called Avogadro number. Its value is 6.023×10^{23}.

Therefore, one mole of any substance contains Avogadro number of particles. The particles may be atoms, molecules, ions etc.,

For eg. one mole of oxygen atoms represents 6.023×10^{23} atoms of oxygen and 5 moles of oxygen atoms contain $5 \times 6.023 \times 10^{23}$ atoms of oxygen.

To find the number of moles, the following formulae are useful

$$\text{Number of moles} = \frac{\text{Mass}}{\text{atomic mass}}$$

$$\text{Number of moles} = \frac{\text{Mass}}{\text{molecular mass}}$$

$$\text{Number of moles} = \frac{\text{No. of atoms}}{6.023 \times 10^{23}}$$

$$\text{Number of moles} = \frac{\text{No. of molecules}}{6.023 \times 10^{23}}$$

WATCH OUT !

It may be noted that while using the term mole it is essential to specify the kind of particles involved.

10.6.2. Problems (based on mole concept)

1. When the mass of the substance is given:

$$\text{Number of moles} = \frac{\text{given mass}}{\text{atomic mass}}$$

a. Calculate the number of moles in

i) 81g of aluminium ii) 4.6g sodium iii) 5.1g of Ammonia iv) 90g of water v) 2g of NaOH

$$\text{Number of moles} = \frac{\text{given mass}}{\text{atomic mass}} = \frac{81}{27}$$

= 3 moles of aluminium

FOLLOW UP: Find the number of moles for remaining problems given above.

b. Calculate the mass of 0.5 mole of iron

Solution: mass = atomic mass x number of moles

$= 55.9 \times 0.5 = 27.95$ g

FOLLOW UP: Find the mass of 2.5 mole of oxygen atoms

Mass = molecular mass x number of moles

2. Calculation of number of particles when the mass of the substance is given:

$$\text{Number of particles} = \frac{\text{Avogadro number x given mass}}{\text{gram molecular mass}}$$

a. Calculate the number. of molecules in 11g of CO_2

Solution: gram molecular mass of CO_2 = 44g

$$\text{Number. of molecules} = \frac{6.023 \times 10^{23} \times 11}{44}$$

$= \mathbf{1.51 \times 10^{23}}$ **molecules**

FOLLOW UP: Calculate the number of molecules in 360g of glucose.

3. Calculation of mass when number of particles of a substance is given:

Mass of a substance

$$= \frac{\text{gram molecular mass x number of particles}}{6.023 \times 10^{23}}$$

a. Calculate the mass of 18.069×10^{23} molecules of SO_2

Sol: Gram molecular mass SO_2 = 64g

Mass of SO_2

$$= \frac{64 \times 18.069 \times 10^{23}}{6.023 \times 10^{23}} = 192 \text{ g}$$

b. Calculate the mass of glucose in 2×10^{24} molecules

Gram molecular mass of glucose = 180g

Mass of glucose

$$= \frac{180 \times 2 \times 10^{24}}{6.023 \times 10^{23}} = 597.7\text{g}$$

FOLLOW UP: Calculate the mass of 12.046×10^{23} molecules in CaO.

4. Calculation of number of moles when you are given number of molecules:

a. Calculate the number moles for a substance containing 3.0115×10^{23} molecules in it.

$$\text{Number of moles} = \frac{\text{Number of molecules}}{\text{Avogadro Number}}$$

$$= \frac{3.0115 \times 10^{23}}{6.023 \times 10^{23}} = 0.5 \text{ moles}$$

b. Calculate number of moles in 12.046×10^{22} atoms of copper

Number of moles of atoms

$$= \frac{\text{Number of atoms}}{\text{Avogadro Number}}$$

$$= \frac{12.046 \times 10^{22}}{6.023 \times 10^{23}} = 0.2 \text{ moles}$$

FOLLOW UP: Calculate the number of moles in 24.092×10^{22} molecules of water.

MORE TO KNOW

Molar volume: Volume occupied by one mole of any gas at STP is called molar volume. Its value is 22.4 litres

22.4 litres of any gas contains 6.023×10^{23} molecules.

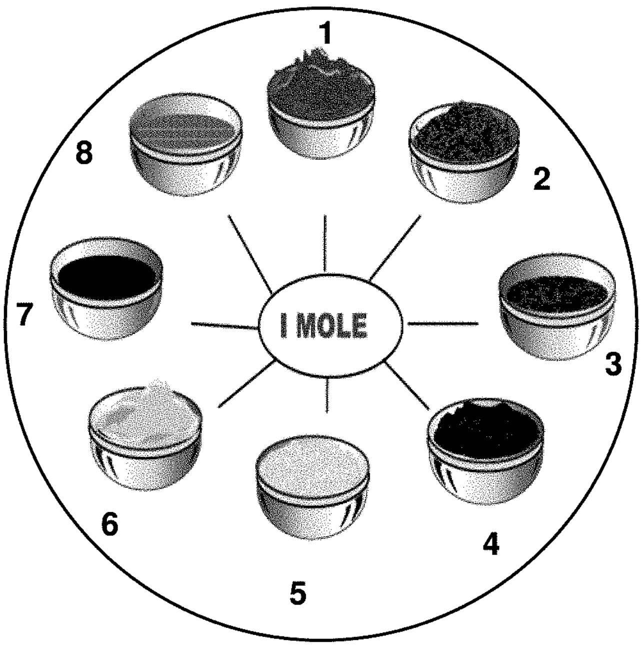


Fig. 10.4 More illustrations for mole in various forms

Answers :

1. 162.4 g of $FeCl_3$

2. 159.6g of $CuSO_4$

3. 27g of Al

4. 56g of Fe

5. 58.5 g of NaCl

6. 32g of S

7. 12g of C

8. 200.6g of Hg

EVALUATION

PART - A

1. From the given examples, form the pair of isotopes and the pair of isobars

   $_{18}Ar^{40}$, $_{17}Cl^{35}$, $_{20}Ca^{40}$, $_{17}Cl^{37}$
2. Molecular mass of nitrogen is 28. Its atomic mass is 14. Find the atomicity of nitrogen.
3. Gram molecular mass of oxygen is 32g. Density of oxygen is 1.429g/cc. Find the gram molecular volume of oxygen.
4. 'Cl' represents chlorine atom, 'Cl_2' represents chlorine molecule.

   List out any two differences between atoms and molecules.
5. Calculate the gram molecular mass of water from the values of gram atomic mass of hydrogen and of oxygen.

   Gram atomic mass of hydrogen = 1g

   Gram atomic mass of oxygen = 16g
6. One mole of any substance contains 6.023×10^{23} particles.

   If 3.0115×10^{23} particles are present in CO_2. Find the number of moles.

PART - B

1. Modern atomic theory takes up the wave concept, principle of uncertainty and other latest discoveries to give a clear cut picture about an atom. State the findings of modern atomic theory.
2. You are given the values of mass of one volume of oxygen gas and the mass of one volume of hydrogen. By applying Avagadro's law how will you establish the relation between vapour density and molecular mass of a gas?
3. Calculate the number of moles in
   a. 12.046×10^{23} atoms of copper
   b. 27.95g of iron
   c. 1.51×10^{23} molecules of CO_2

FURTHER REFERENCE :

Books: 1. Physical Chemistry : Puri and sharma - **Vishal publications**

2. Inorganic Chemistry : P.L. Soni - **S.Chand publication**

Website : www.ehow.com/atomsandmolecules

www.chem4kids.com/tag/atomsandmolecules

11. Chemical Reactions

All living beings born in this beautiful world have their own life styles. Have you observed and analyzed your daily life from the view point of a chemist? Chemical reactions happen around us all the time and even in our body.

Any change can be classified as physical change and chemical change. Physical changes can be easily reversed but, it is not easy to reverse a chemical change. What is the reason? In chemical changes, new substances are formed and it is difficult to regenerate the original substances. Chemical changes are more permanent than physical changes. All chemical changes are accompanied by chemical reactions.

How do we come to know that a chemical reaction has taken place? Let us perform some activities to find out the answer to this question.

ACTIVITY 11.1

- Look at the new silver anklet of your mother or sister
- Note the colour of the anklet
- Observe the colour of an old anklet
- What change do you observe?

The lustrous white colour of the silver anklet slowly changes into slightly black colour. That is, silver anklet has got tarnished. Can you guess the reason behind it?

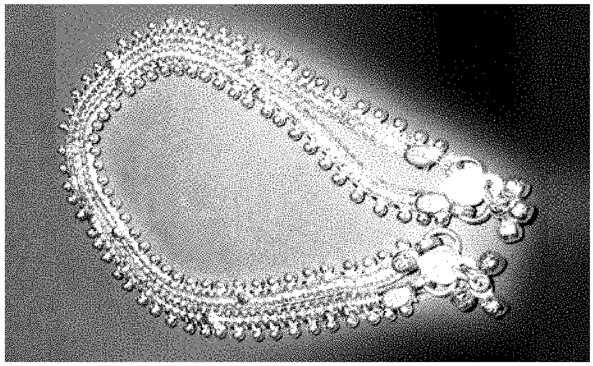


Fig. 11.1 Silver Anklet

It is due to the formation of silver sulphide (Ag_2S), as a result of the reaction between silver and hydrogen sulphide in the air.

ACTIVITY 11.2

- Take lead nitrate solution in a beaker
- Take potassium iodide solution in a test tube.(Both solutions are colourless)
- Add potassium iodide solution slowly to the lead nitrate solution
- What do you observe?

You observe a deep yellow precipitate, don't you?

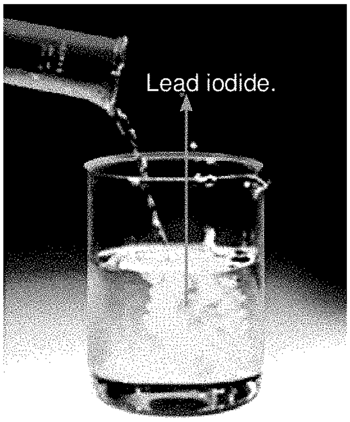


Fig. 11.2 Yellow precipitate of lead iodide.

It is lead iodide (pbI_2).

ACTIVITY 11.3

- Take 5g of calcium oxide (quick lime) in a beaker
- Add water to it slowly
- Touch the beaker
- What do you feel?

Do you feel hot? Let us see what happens

Calcium oxide reacts with water to produce slaked lime (calcium hydroxide). This reaction is exothermic and will be accompanied by hissing sound and bubbles leading to the release of considerable amount of heat.

ACTIVITY 11.4

- Take a pinch of calcium carbonate powder in a test tube
- Add dilute hydrochloric acid
- Note the changes in the test tube carefully

Do you observe any brisk effervescence? It is due to the evolution of carbon dioxide gas.

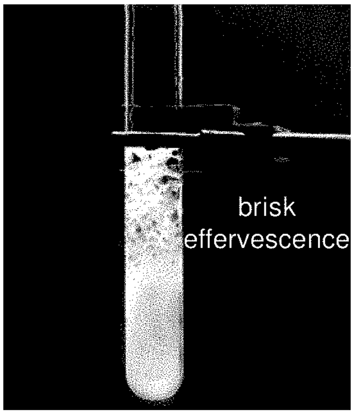


Fig. 11.3 Reaction of calcium carbonate with dil.HCl

These are some of the common observations in a chemical reaction. From the activities that we have discussed, it is clear that chemical reactions will bring about a permanent change resulting in the formation of new product(s).

The substances taking part in the reaction are known as reactants and those formed as a result of the reaction are called products.

MORE TO KNOW

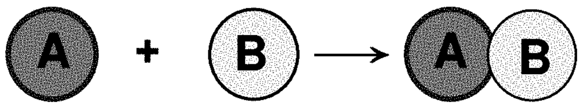
A solution of slaked lime produced in the Activity 11.3 is used for white washing. Calcium hydroxide reacts slowly with carbon dioxide in air to form a thin layer of calcium carbonate on the walls. Calcium carbonate is formed after two to three days of white washing and gives a shiny finish to the walls. It is interesting to note that the chemical formula for marble is also $CaCO_3$.

11.1.TYPES OF CHEMICAL REACTIONS

Since there are numerous chemical reactions, the study of these reactions can be made easier by classifying them. All the chemical reactions are classified into six broad categories depending on the way the product formed.

Let us see the different types of classifications of chemical reactions.

1. COMBINATION REACTION



A combines with **B** to form a new product **AB**. It is the simple representation of combination reaction.

ACTIVITY 11.5

- Take a clean piece of magnesium ribbon
- Hold the ribbon with a pair of tongs
- Burn it in air using a burner (keeping Mg ribbon as far as possible from your eyes)
- Collect the ash

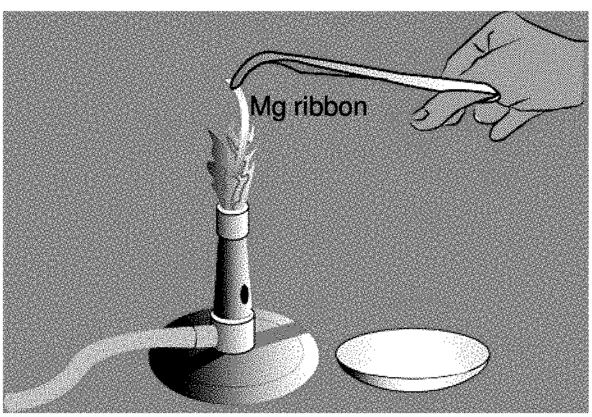


Fig. 11.4 Burning of Mg ribbon

In the above activity, magnesium combines with oxygen to form a single product, magnesium oxide. **Such a reaction in which a single product formed from two or more reactants is known as combination reaction.**

$$2Mg + O_2 \rightarrow 2MgO$$

Repeat "**Activity 11.3**". This reaction is also an example for COMBINATION REACTION. Attempt to write the equation yourself.

Let us discuss some more examples of combination reactions.

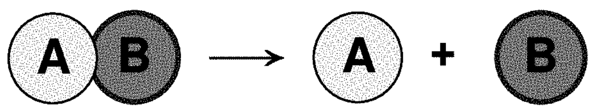
- Combustion of coal

  $C + O_2 \rightarrow CO_2\uparrow$

- Combustion of hydrogen

  $2H_2 + O_2 \rightarrow 2H_2O$

2 DECOMPOSITION REACTION



AB splits into **A** and **B.** It is the representation of decomposition reaction.

ACTIVITY 11.6

- Take about 2 g of copper carbonate powder in a dry test tube
- Note the colour of copper carbonate
- Heat the test tube over the flame
- Observe the change after heating

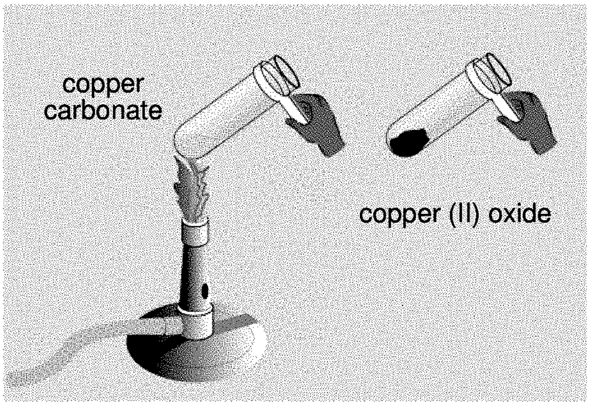


Fig. 11.5 Heating the test tube containing copper carbonate

Change of colour from green to black is observed. This is due to the decomposition of copper carbonate to copper (II) oxide.

$$CuCO_3 \xrightarrow{\Delta} CuO + CO_2\uparrow$$

ACTIVITY 11.7

- Take lead nitrate in a test tube
- Heat it over the flame
- Observe the changes

Liberation of a reddish brown gas (NO_2) is observed. This is because of the decomposition of lead nitrate into lead oxide, nitrogen dioxide and oxygen.

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

From the above two activities (11.6 and 11.7), It can be noted that a **single compound breaks down to produce two or more substances. Such type of reaction is called decomposition reaction.**

Some other examples for decomposition reaction:

1. Decomposition of lime stone

$$CaCO_3 \xrightarrow{\Delta} CaO + CO_2\uparrow$$

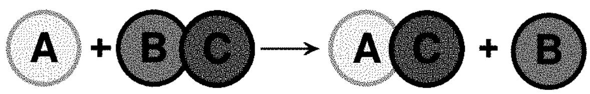
2. Decomposition of ammonium dichromate

$$(NH_4)_2Cr_2O_7 \xrightarrow{\Delta} Cr_2O_3\uparrow + N_2\uparrow + 4H_2O\uparrow$$

MORE TO KNOW

At very high temperature,ammonium dichromate decomposes immediately to green vapours which gets released along with the steam. It seems as if a volcano erupts and is termed as chemical volcano.

3. DISPLACEMENT REACTION



In the reaction between **A** and **BC, A** displaces **B** from **BC** to form **AC**. This shows that A is more reactive than **B**.

ACTIVITY 11.8

- Take 20 ml of copper sulphate solution in a beaker
- Drop an iron nail into the beaker
- Leave it for few days
- Observe the colour of the copper sulphate solution and the iron nail

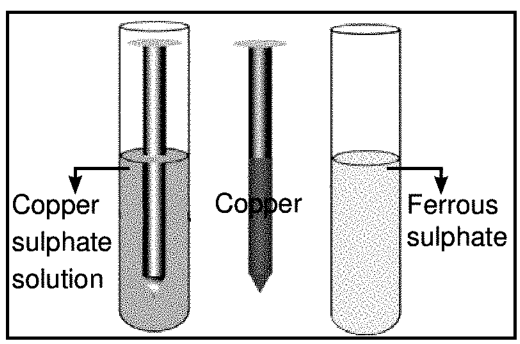


Fig. 11.6 Iron displaces copper from copper sulphate solution

Blue colour of the copper sulphate solution changes into green colour and the iron nail acquires a brownish look. It is a noticeable change. Is it not? This change confirms that iron is more reactive than copper. The following chemical reaction takes place in this activity.

$$Fe + CuSO_4 \rightarrow FeSO_4 + Cu$$

In this reaction, iron displaces copper from $CuSO_4$ solution.

Repeat "**Activity 11.8**" but use zinc rod instead of an iron nail. What colour changes do you observe on the rod and in the solution? Write the chemical equation.

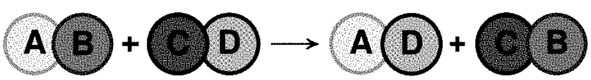
Other example:

$$Pb + CuCl_2 \rightarrow PbCl_2 + Cu$$

Lead can displace copper from its salt solutions. Can copper displace zinc or lead from their salt solutions? No, because copper is less reactive than zinc and lead.

The reaction in which, a more reactive element displaces a less reactive element from its compound is called displacement reaction.

4. DOUBLE DECOMPOSITION REACTION (DOUBLE DISPLACEMENT REACTION)



In the reaction between **AB** and **CD**, both the reactants decompose to form **AD** and **CB** through the rearrangement of ions.

ACTIVITY 11.9

- Take 5ml of sodium sulphate solution in a test tube
- In another test tube, take 5ml of barium chloride
- Mix both the solutions
- What do you observe?

barium sulphate

Fig. 11.7 Formation of barium sulphate

You will observe formation of a white substance, which is insoluble in water. The insoluble substance formed is known as *precipitate*. Any reaction that produces a precipitate is called a **precipitation reaction.** The formed white precipitate of barium sulphate, is due to the reaction of SO_4^{2-} and Ba^{2+} ions. The other product formed is sodium chloride.

$$Na_2SO_4 + BaCl_2 \rightarrow BaSO_4\downarrow + 2NaCl$$

Repeat **"Activity 11.2"** for double decomposition reaction. Attempt to write the equation by yourself.

Double decomposition reaction is any reaction in which exchange of ions between two reactants occur, leading to the formation of two different products.

Other example :

$$CuSO_4 + H_2S \rightarrow CuS\downarrow + H_2SO_4$$

5. OXIDATION AND REDUCTION

We are all aware of the fact that oxygen is the most essential element for sustaining life. One can live without food or even water for a number of days, but not without oxygen. In our daily life we come across phenomena like fading of the colours of the clothes, burning of combustible substances like cooking gas, wood and coal, and also rusting of iron articles. All such processes fall in the category of a specific type of chemical reaction called oxidation – reduction reaction (redox reaction). A large number of industrial processes like electroplating, extraction of metals like aluminium, are based upon the redox reaction.

Oxidation:

A chemical reaction which involves addition of oxygen or removal of hydrogen or loss of electron(s) is called as oxidation.

$2Mg + O_2 \rightarrow 2MgO$ (addition of oxygen)

$H_2S + Br_2 \rightarrow 2HBr + S$ (removal of hydrogen)

$Fe^{2+} \rightarrow Fe^{3+} + e^-$ (loss of electron)

Reduction:

A chemical reaction which involves addition of hydrogen or removal of oxygen or gain of electron(s) is called as reduction.

$2Na + H_2 \rightarrow 2NaH$ (addition of hydrogen)

$CuO + H_2 \rightarrow Cu + H_2O$ (removal of oxygen)

$Fe^{3+} + e^- \rightarrow Fe^{2+}$ (gain of electron)

Redox reaction:

A chemical reaction in which oxidation and reduction take place simultaneously is called redox reaction.

$$Zn + CuSO_4 \rightarrow Cu + ZnSO_4$$

Attempt to write any other redox reaction

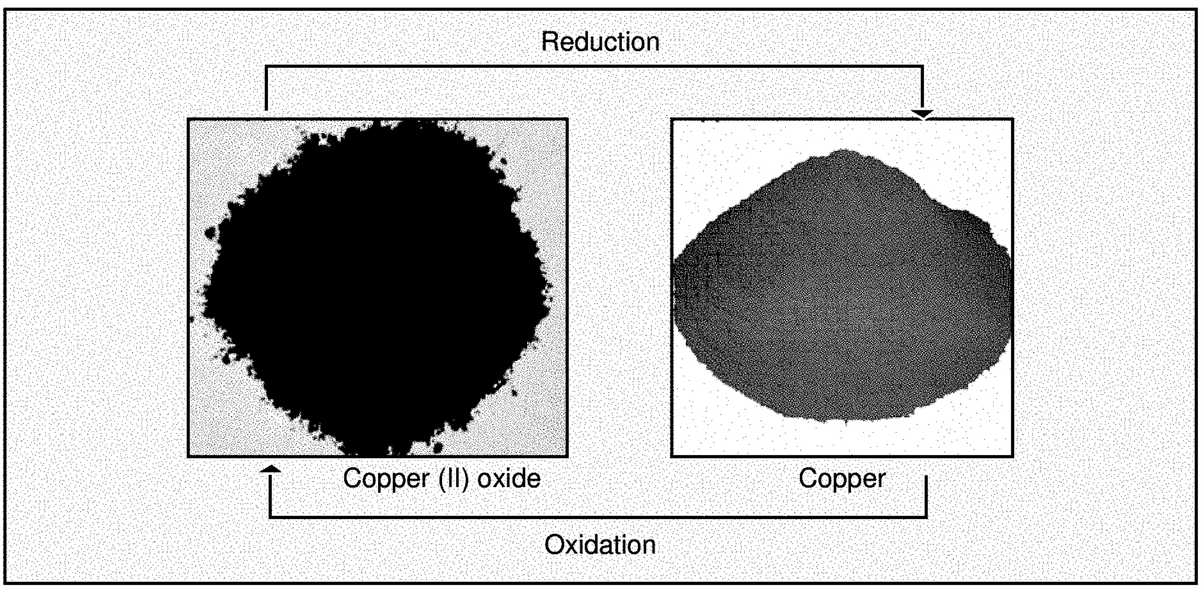


Fig. 11.8 Redox reaction

During the conversion of copper(II) oxide to copper, the copper(II) oxide is losing oxygen and is being reduced. The hydrogen is gaining oxygen and is being oxidised. In other words, one reactant gets oxidised while the other gets reduced during the reaction. Such reactions are called oxidation – reduction reactions or redox reactions.

Oxidation is	**Reduction is**
Gain of oxygen Loss of hydrogen Loss of electron(s)	Loss of oxygen Gain of hydrogen Gain of electron(s)
Oxidation and reduction always takes place together, so the reaction is called redox reaction.	

DON'T FORGET

Loss of electron is oxidation.

Gain of electron is reduction.

The term LEO, GER will help you to remember.

MORE TO KNOW

Oxidation also has damaging effects on food and eatables. When food containing fat and oil is left as such for a long time, it becomes stale. The stale food develops bad taste and smell. This is very common in curd or chees particularly in summer. Oils and fats are slowly oxidised to certain bad smelling compounds.

6. EXOTHERMIC AND ENDOTHERMIC REACTIONS

During chemical reactions one of the most common change is a change in temperature. When detergent is dissolved in water to wash clothes, heat is given out. When glucose is kept on our tongue, a chilling effect is felt. During these processes, heat is either given out or absorbed from the surroundings. In the same way, in most of the chemical reactions, energy is either taken up or given out.

a. Exothermic reactions

The chemical reactions which proceed with the evolution of heat energy are called exothermic reactions.

$$N_2 + 3H_2 \rightarrow 2NH_3 + Heat$$

All combustion reactions are exothermic. Heat energy is liberated as the reaction proceeds.

b. Endothermic reactions

The chemical reactions which proceed with the absorption of heat energy are called endothermic reactions.

$$2NH_3 + Heat \rightarrow N_2 + 3H_2$$

11.2 RATE OF THE CHEMICAL REACTION

Rate of the chemical reaction is defined as change in concentration of any one of the reactants or product per unit time.

Consider the reaction

$$A \rightarrow B$$

Rate of the reaction is given by

$$\text{Rate} = -\frac{d[A]}{dt} = +\frac{d[B]}{dt}$$

[A] - concentration of reactant A

[B] - concentration of product B

- ve sign indicates decrease in con centration of A with time.

+ ve sign indicates increase in concentration of B with time.

11.2.1 FACTORS INFLUENCING THE RATE OF THE CHEMICAL REACTION

1. NATURE OF THE REACTANTS

ACTIVITY 11.10

- Take magnesium ribbon in two test tubes A and B
- Add hydrochloric acid to test tube A
- Add acetic acid to test tube B
- Observe the changes in two test tubes

Magnesium ribbon reacts with both hydrochloric acid and acetic acid but reaction is faster in hydrochloric acid than in acetic acid. Do you know why? Hydrochloric acid is more reactive than acetic acid. It shows that **nature of the reactant influences the rate of the reaction**.

2. CONCENTRATION OF THE REACTANTS

ACTIVITY 11.11

- Take 3g of granulated zinc in the test tube A and B
- Add 5 ml of 1 M hydrochloric acid in test tube A
- Add 5 ml of 2 M hydrochloric acid in test tube B
- Observe the changes

Granulated zinc reacts with both 1M hydrochloric acid and 2M hydrochloric acid, the rate of evolution of hydrogen gas is more from the test tube B than from the test tube A. This is because, 2M hydrochloric acid is more concentrated than 1M hydrochloric acid. That is, **greater the concentration of the reactant, greater will be the rate of the reaction.**

3. SURFACE AREA OF THE REACTANTS

ACTIVITY 11.12

- Take powdered calcium carbonate in beaker A
- Take marble chips (calcium carbonate) in beaker B
- Add hydrochloric acid in both beakers A and B
- Observe the changes

Powdered calcium carbonate reacts more quickly with hydrochloric acid than marble chips. What is the reason?.

Powdered calcium carbonate offers large surface area for the reaction to occur at a faster rate. **This shows that greater the surface area, greater is the rate of the reaction.**

4. TEMPERATURE

ACTIVITY 11.13

- Take 3g of marble chips in a beaker
- Add 5 ml of 1M hydrochloric acid
- Observe the changes
- Heat the beaker
- Observe the changes

Calcium carbonate present in marble chips react slowly with hydrochloric acid at room temperature and evolves carbon dioxide at slower rate, whereas on heating, the evolution of carbon dioxide is made faster. **This shows that increase in temperature increases the rate of the reaction.**

5. CATALYST

ACTIVITY 11.14

- Take potassium chlorate in a test tube
- Heat the test tube
- Observe what happens
- Add manganese dioxide as a catalyst
- Observe the changes

When potassium chlorate is heated, oxygen is evolved very slowly whereas after the addition of manganese dioxide to the reactant, oxygen is liberated at a faster rate. **This shows that manganese dioxide acts as a catalyst and influences the rate of the reaction.**

GROUP ACTIVITY

- From dawn to dusk observe any 10 chemical changes taking place around you and classify them
- Prepare volcano using ammonium dichromate (vigorous)
- Prepare volcano using baking soda (silent).

MORE TO KNOW

A substance which alters the rate of the reaction without undergoing any change in mass and composition is known as catalyst.

ACIDS, BASES AND SALTS

Nivi : Hai Vini, you look tired. Take this fresh lime juice.

Vini : No, it has sour taste.

Nivi : Do you know why is it sour?

Vini : Sorry, I have no idea at all.

Nivi : It is due to the presence of acid. Ok let's get set to learn about this.

Acids, bases and salts are used in everyday life. Let it be a fruit juice or a detergent or a medicine. They play a key role in our day-to-day activities. Our body metabolism is carried out by means of hydrochloric acid secreted in our stomach.

11.3. ACIDS

Acid is a substance which furnishes H^+ ions or H_3O^+ ions when dissolved in water. Acids have one or more replaceable hydrogen atoms. The word acid is derived from the Latin name 'acidus' which means sour taste. Substances with 'sour taste' are acids. Lemon juice, vinegar and grape juice have sour taste, so they are acidic. They change blue litmus to red. They are

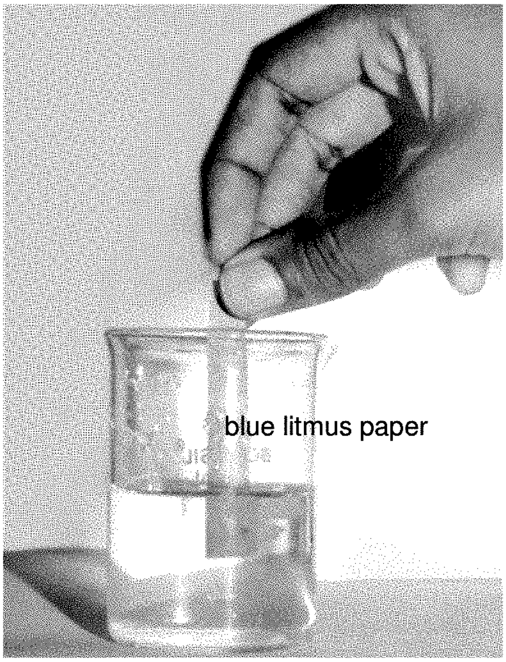


Fig. 11.9 Acid solution turns blue litmus paper red

colourless with phenolphthalein and pink with methyl orange. Many organic acids are naturally present in food items.

11.3.1 CLASSIFICATION OF ACIDS

1. Based on their sources : Acids are classified into two types namely organic acids and inorganic acids.

   Organic acids:- Acids present in plants and animals (living beings) are **organic acids** eg. HCOOH, CH_3COOH (Weak acids).

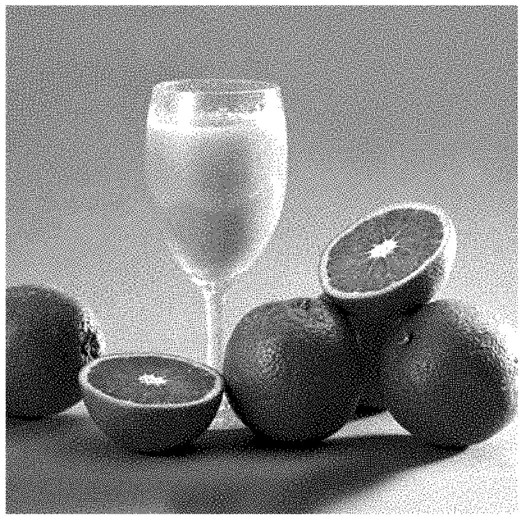
   Inorganic acids:- Acids from rocks and minerals are **inorganic acids** or mineral acids eg. HCl, HNO_3, H_2SO_4 (Strong acids).

2. Based on their basicity

   Monobasic acid: - It is an acid which gives one hydrogen ion per molecule of the acid in solution eg. HCl, HNO_3.

   Dibasic acid:- It is an acid which gives

Source	**Acid present**
Apple	Malic acid
Lemon	Citric acid
Grape	Tartaric acid
Tomato	Oxalic acid
Vinegar (food preservative)	Acetic acid
Curd	Lactic acid



What is the acid present in it?

two hydrogen ions per molecule of the acid in solution eg. H_2SO_4, H_2CO_3.

Tribasic acid:- It is an acid which gives three hydrogen ions per molecule of the acid in solution. eg. H_3PO_4

MORE TO KNOW

For acids, we use the term basicity which means the number of replaceable hydrogen atoms present in one molecule of an acid. For example acetic acid has four hydrogen atoms but only one can be replaced. Hence it is monobasic.

3. Based on ionisation

Acids are classified into two types based on ionisation.

Strong acids:- These are acids which ionise completely in water eg.HCl

Weak acids:-These are acids which ionise partially in water eg. CH_3COOH

4. **Based on concentration:-** Depending on the percentage or amount of acid dissolved in water acids are classified into concentrated acid and dilute acid.

Concentrated acid:- It is an acid having a relatively high percentage of acid in its aqueous solution.

Dilute acid:- It is an acid having a relatively low percentage of acid in aqueous solution.

MORE TO KNOW

Care must be taken while mixing any concentrated mineral acid with water. The acid must always be added slowly to water with constant stirring. If water is added to a concentrated acid the large amount of heat is generated which may cause burns. The mixture splashes out of the container.

11.3.2 CHEMICAL PROPERTIES OF ACIDS

1. REACTION OF METALS WITH ACID

Note that zinc reacts with dilute hydrochloric acid to form zinc chloride

ACTIVITY 11.15

- Take 5 g of zinc granules in a test tube
- Add 10 ml of dilute hydrochloric acid through thistle funnel
- During the course of addition, what do you observe?

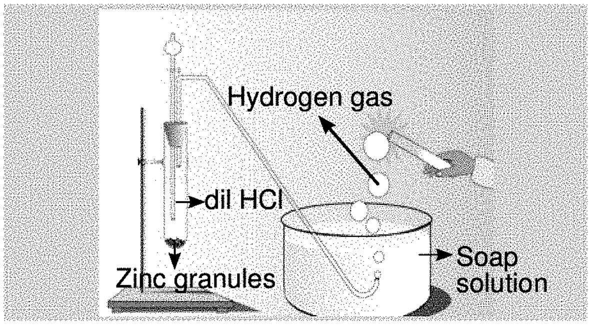


Fig. 11.10 Reaction of Zn granules with dilute HCl

and hydrogen gas.

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2\uparrow$$

When a burning candle is brought near the bubble containing hydrogen gas, the flame goes off with a '**pop**'ing sound. This confirms that metal displaces hydrogen from the dilute acid. (Hydrogen gas burns with a '**pop**'ing s und)

Metal + Acid → Salt + Hydrogen

Another example

$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2\uparrow$$

MORE TO KNOW

- All metals do not liberate hydrogen gas on reaction with acids. eg., Ag,Cu.
- Lime stone, chalk and marble are different physical forms of calcium carbonate. They react with acids giving corresponding salt, carbon dioxide and water.

2. REACTION OF METAL CARBONATE AND METAL BICARBONATE WITH ACIDS

ACTIVITY 11.16

- Take two test tubes, label them as I and II
- Take small amount of washing soda (Na_2CO_3) in test tube I and small amount of baking soda ($NaHCO_3$) in test tube II
- Add dilute hydrochloric acid to both the test tubes
- What do you observe?
- Pass the gas produced in each case, through lime water [$Ca(OH)_2$] solution and record your observations

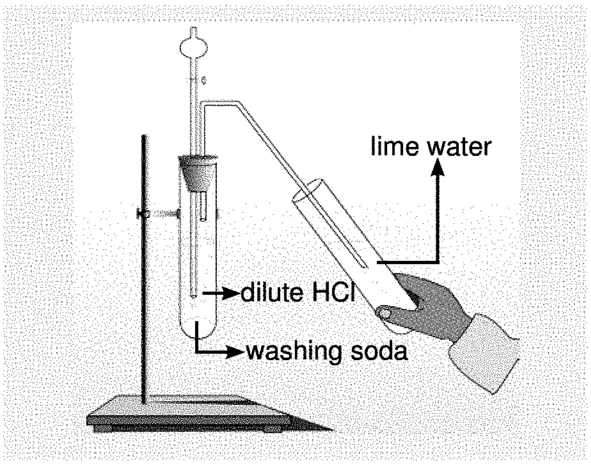


Fig. 11.11 Testing of carbon dioxide

Test tube I

$Na_2CO_3 + 2\ HCl \rightarrow 2\ NaCl + H_2O + CO_2\uparrow$

Test tube II

$NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2\uparrow$

When carbon dioxide is passed through lime water, it turns milky.

$$Ca(OH)_2 + CO_2 \rightarrow \underset{\text{(milky)}}{CaCO_3} + H_2O$$

From the above activity the reaction can be summarized as

Metal carbonate or Metal bicarbonate + Acid ⟶ Salt + Water + Carbon dioxide

Other examples

$MgCO_3 + 2\ HCl \rightarrow MgCl_2 + H_2O + CO_2\uparrow$

$Mg(HCO_3)_2 + 2\ HCl \rightarrow MgCl_2 + 2H_2O + 2CO_2\uparrow$

MORE TO KNOW

Since metal carbonates and metal bicarbonates are basic they react with acids to give salt and water with the liberation of carbon dioxide.

3. REACTION OF METALLIC OXIDES WITH ACIDS

ACTIVITY 11.17

- Take about 2g copper (II) oxide in a watch glass and add dilute hydrochloric acid slowly
- Note the colour of the salt
- What has happened to the copper (II) oxide?

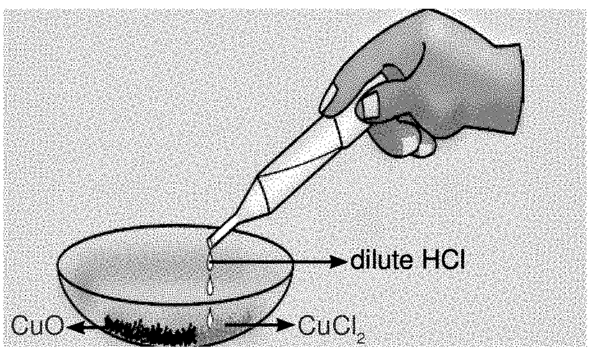


Fig. 11.12 Reaction of copper(II) oxide with dilute hydrochloric acid

The colour changes from **black to green.** This is due to the formation of copper (II) chloride in the reaction. Since metal oxides are basic, they react with acid to form salt and water.

$$CuO + 2HCl \rightarrow CuCl_2 + H_2O$$

From the above activity we conclude that

Metallic oxide + Acid → Salt + Water

Another example

$$CaO + 2HCl \rightarrow CaCl_2 + H_2O$$

4 . ACTION OF ACIDS WITH WATER.

An acid produces hydrogen ions in water.

$$HCl + H_2O \rightarrow H_3O^+ + Cl^-$$

Hydrogen ions cannot exist alone, but they exist in the form of hydronium (H_3O^+) ions. When water is absent, the separation of hydrogen ions from an acid does not occur.

11.3.3. USES OF ACIDS

1. Sulphuric acid (King of chemicals) is used in car battery and in the preparation of many other compounds.
2. Nitric acid is used in the production of ammonium nitrate which is used as fertilizer in agriculture.
3. Hydrochloric acid is used as cleansing agent in toilet.
4. Tartaric acid is a constituent of baking powder.
5. Salt of benzoic acid (sodium benzoate) is used in food preservation.
6. Carbonic acid is used in aerated drinks.

MORE TO KNOW

The atmosphere of Venus is made up of thick white and yellowish clouds of sulphuric acid. Do you think life can exist on this planet?

11.4. BASES

Base is a substance which releases hydroxide ions when dissolved in water. It is a substance which is bitter in taste and soapy to touch (e.g. Washing soda, caustic soda and caustic potash). They change red litmus to blue. They are pink with phenolphthalein and yellow with methyl orange.

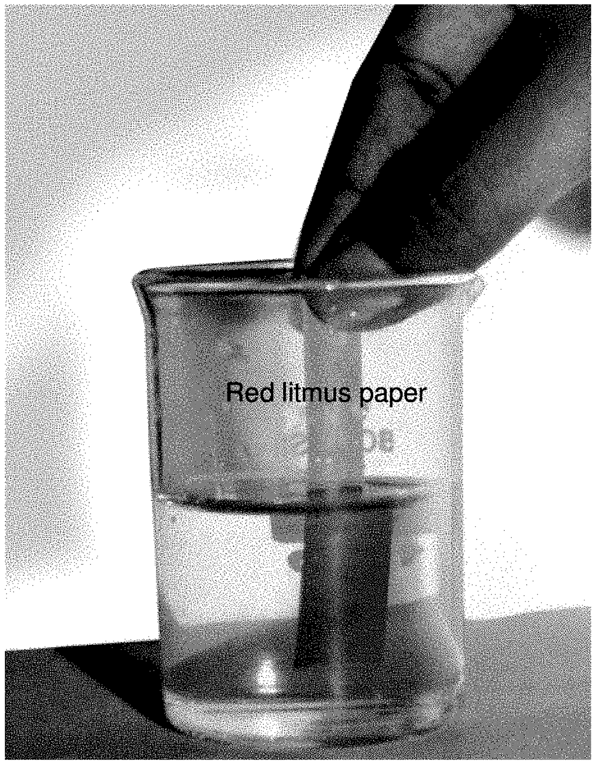


Fig. 11.13 Bases turns red litmus paper blue

11.4.1. Classification of bases

1. Based on ionisation

   Strong bases:- These are bases which ionise completely in aqueous solution eg.NaOH, KOH.

   Weak bases:- These are bases which ionise partially in aqueous solution eg. NH_4OH, $Ca(OH)_2$.

2. Based on their acidity

   Monoacidic base:- It is a base which ionises in water to give

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one hydroxide ion per molecule eg.NaOH, KOH.

Diacidic base:- It is a base which ionises in water to give two hydroxide ions per molecule eg. $Ca(OH)_2$, $Mg(OH)_2$.

Triacidic base:- It is a base which ionises in water to give three hydroxide ions per molecule eg. $Al(OH)_3$, $Fe(OH)_3$.

MORE TO KNOW

The term acidity is used for base which means the number replaceable hydroxyl groups present in one molecule of a base.

3. Based on the concentration:

Depending on the percentage or amount of base dissolved in water, bases are classified as concentrated alkali and dilute alkali.

Concentrated alkali:- It is an alkali having a relatively high percentage of alkali in its aqueous solution.

Dilute alkali:- It is an alkali having a relatively low percentage of alkali in its aqueous solution.

MORE TO KNOW

Bases which dissolve in water are called alkalies. All alkalies are bases, but not all bases are alkalis. NaOH and KOH are alkalies whereas $Al(OH)_3$ and $Zn(OH)_2$ are bases.

11.4.2. Chemical Properties Of Bases

1. REACTION OF BASE WITH METALS

Zinc reacts with sodium hydroxide to form sodium zincate with the liberation of hydrogen gas.

$$Zn + 2\,NaOH \rightarrow Na_2ZnO_2 + H_2\uparrow$$

Metal + Base → Salt + Hydrogen

Another example

$$2\,Al + 2\,NaOH + 2\,H_2O \rightarrow 2\,NaAlO_2 + 3\,H_2\uparrow$$

MORE TO KNOW

All metals do not react with sodium hydroxide eg. Cu, Ag, Cr

2. REACTION OF NON METALLIC OXIDES WITH BASES

Sodium hydroxide reacts with carbon dioxide gives sodium carbonate and water.

$$2NaOH + CO_2 \rightarrow Na_2CO_3 + H_2O$$

The above reaction confirms that

Non metallic oxide + Base → Salt + Water

Another example

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

3. ACTION OF BASES WITH WATER

Bases generate hydroxide (OH^-) ions when dissolved in water.

$$NaOH \rightarrow Na^+ + OH^-$$

CHAPTER 11

4. REACTION OF ACIDS WITH BASES

ACTIVITY 11.18

- Indira takes 20 ml of 0.1N sodium hydroxide solution in a conical flask and adds few drops of phenolphthalein.
- What colour does she observe?
- She is adding 20 ml of 0.1N hydrochloric acid solution to the above conical flask drop by drop.
- Does she observe any colour change in the reaction mixture?

In the above activity, Indira observed that the effect of a base is nullified by an acid.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

The above reaction between an acid and a base is known as neutralisation reaction.

Acid + Base → Salt + Water

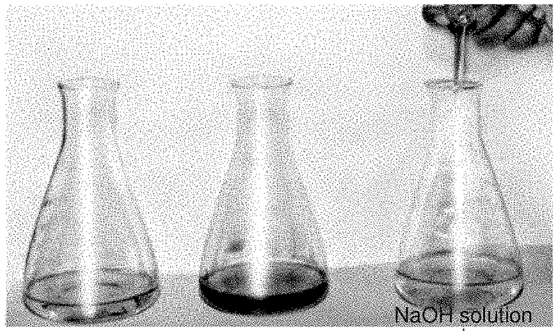


Fig. 11.14 Reaction of sodium hydroxide with hydrochloric acid

11.4.3 USES OF BASES

1. Sodium hydroxide is used in the manufacture of soap.
2. Calcium hydroxide is used in white washing the buildings.
3. Magnesium hydroxide is used as a medicine for stomach troubles.
4. Ammonium hydroxide is used to remove grease stains from clothes.

11.5 IDENTIFICATION OF ACIDS AND BASES

ACTIVITY 11.19

- Collect lemon juice, washing soda solution, soap solution and soft drinks.
- Take 2 ml of each solution in a test tube and test with a litmus paper or indicator.
- What change in colour do you observe with red litmus, blue litmus, phenolphthalein and methyl orange?
- Tabulate your observations.

Sample solution	Red litmus	Blue litmus	Phenolphthalein	Methyl orange
Lemon Juice				
Washing soda Solution				
Soap solution				
Soft drinks				

Same activity can be repeated for dilute hydrochloric acid, dilute sulphuric acid, sodium hydroxide solution and potassium hydroxide solution with the help of your teacher.

INDICATOR	COLOUR IN ACID	COLOUR IN BASE
Litmus	Red	
Phenolphthalein		
Methyl orange	Red	Yellow

11.6 p^H SCALE

p^H stands for the power of hydrogen ion concentration in a solution. p^H values decide whether a solution is acidic or basic or neutral. p^H scale was introduced by S.P.L. Sorenson. It is mathematically expressed as

$$p^H = -\log_{10}[H^+]$$

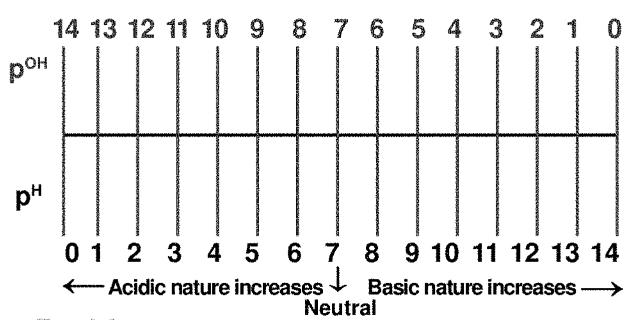
For neutral solution $[H^+] = 10^{-7}M$; $p^H = 7$

For acidic solution $[H^+] > 10^{-7}M$; $p^H < 7$

For basic solution $[H^+] < 10^{-7}M$; $p^H > 7$

When OH^- ions are taken into account the p^H expression is replaced by p^{OH}

$$p^{OH} = -\log_{10}[OH^-]$$



Problems

1. The hydrogen ion concentration of a solution is 0.001M. What is the p^H of the solution?

Solution

$p^H = -\log_{10}[H^+]$

$p^H = -\log_{10}(0.001)$

$p^H = -\log_{10}(10^{-3})$

$= -(-3)\log_{10}10 \quad [\log 10 = 1]$

$p^H = 3$

2. The hydrogen ion concentration of a solution is 1.0×10^{-9} M. What is the p^H of the solution? Predict whether the given solution is acidic, basic or neutral.

Solution

$p^H = -\log_{10}[H^+]$

$p^H = -\log_{10}(1.0 \times 10^{-9})$

$p^H = -(\log_{10}1.0 + \log_{10}10^{-9}) \; [\log_{10} 1 = 0]$

$= -(0-9\log_{10}10)$

$p^H = -(0-9) = 9$

$p^H = 9$ ie $p^H > 7$

Therefore the given solution is basic.

3. The hydroxyl ion concentration of a solution is 0.001M. What is the p^H of the solution?

Solution

$p^{OH} = -\log_{10}[OH^-]$

$p^{OH} = -\log_{10}(10^{-3})$

$p^{OH} = 3$

$p^H = 14 - p^{OH}$

$p^H = 14 - 3 = 11$

$p^H + p^{OH} = 14$

$p^H = 14 - p^{OH}$

4. The hydroxyl ion concentration of a solution is 1.0×10^{-9} M. What is the p^H of the solution?

Solution

$p^{OH} = -\log_{10}[OH^-]$

$p^{OH} = -\log_{10}(1.0 \times 10^{-9})$

$p^{OH} = 9$

$p^{H} = 14 - p^{OH}$

$p^{H} = 14 - 9 = 5$

11. 6.1 p^H paper

A more common method of measuring p^H in a school laboratory is by using p^H paper. p^H paper contains a mixture of indicators, which gives different colours across the entire p^H range. p^H value of the various solutions are given in the table.

$$p^H = -\log_{10}[H^+]$$

$$p^H = -\log_{10}\left[\frac{1}{H^+}\right]$$

$$[H^+] = 10^{-\,pH}$$

$$[H^+] = 1 \times 10^{-7} ;\ p^H = 7$$

$$[H^+] = 1 \times 10^{-2} ;\ p^H = 2$$

$$[H^+] = 1 \times 10^{-14} ;\ p^H = 14$$

Solution	Approximate p^H
Lemon juice	2.2 – 2.4
Tomato juice	4.1
Coffee	4.4 - 5.5
Human saliva	6.5 - 7.5
House hold ammonia	12.0

Fig. 11.15 p^H paper

ACTIVITY 11.20

- Take lemon juice, orange juice, 1M NaOH, 1M HCl, pure water and vinegar
- Dip p^H paper into these solutions
- Observe the changes

Sl. No.	Sample	Colour of p^H paper	Approximate p^H	Nature of substance
1.	Lemon juice			
2.	Orange juice			
3.	1M NaOH			
4.	1M HCl			
5.	Pure H_2O			
6.	Vinegar			

11.6.2 Importance of p^H in everyday life

1. p^H in human body

(i) Using p^H factor the healthiness of our body is predicted. At p^H level 6.9, the body becomes prone to viral infections like colds, cough and flu. Cancer cells thrive inside the body at a p^H of 5.5.

(ii) The p^H of a normal, healthy human skin is 4.5 to 6. Proper skin p^H is essential for a healthy complexion.

(iii) p^H of stomach fluid is approximately 2.0. This fluid is essential for the digestion of food.

(iv) Human blood p^H range is 7.35 to 7.45. Any increase or decrease in this value, leads to diseases. The ideal pH for blood is 7.4.

(v) p^H of normal saliva ranges between 6.5 to 7.5.

(vi) White enamel coating in our teeth is calcium phosphate, hardest substance in our body. It does not dissolve in water. If p^H of mouth falls below 5.5, the enamel gets corroded. Toothpastes are generally basic, and is used for cleaning the teeth, can neutralize the excess acid and prevent tooth decay.

2. p^H in soil

In agriculture, the p^H of soil is very important. Citrus fruits require slightly alkaline soil, while rice requires acidic soil and sugar cane requires neutral soil.

3. p^H in rain water

p^H of rain water is approximately 7 showing high level of its purity and neutrality. If rain water is polluted by SO_2 and NO_2, acid rain occurs, bringing the p^H value less than 7.

11.7 SALT

When you say salt, you may think of white stuff put on chips. But that is just one salt called common salt. There are many other salts used in other fields. Salts are the products of the reaction between acids and bases (see reaction of acids and bases), which produce positive ions and negative ions when dissolved in water.

11.7.1 Classification of salts

1. Normal salts

A normal salt is obtained by complete neutralization of an acid by a base

$$NaOH + HCl \rightarrow NaCl + H_2O$$

2. Acid salts

Acid salts are derived by the partial replacement of hydrogen ions of an acid by a metal. When a calculated amount of a base is added to a polybasic acid, acid salt is obtained, as follows.

$$NaOH + H_2SO_4 \rightarrow NaHSO_4 + H_2O$$

3. Basic salts

Basic salts are formed by the partial replacement of hydroxide ions of a diacidic or triacidic base by an acid radical.

A basic salt may further reacts with an acid to give a normal salt.

$$\underset{\text{(Diacidic base)}}{Pb(OH)_2} + HCl \rightarrow \underset{\text{Basic salt}}{Pb(OH)Cl} + H_2O$$

CHAPTER 11

4. Double salts

Double salts are formed by the combination of saturated solution of two simple salts in equimolar ratio followed by crystallization.

e.g. potash alum

11.7.2 USES OF SALTS

Common salt (NaCl)

It is used in our daily food and as preservative.

Washing soda (Na_2CO_3)

1. It is used in softening hard water.
2. It is used as a cleaning agent for domestic purposes.

Baking soda ($NaHCO_3$)

1. It is used in making baking powder, which is the mixture of baking soda and tartaric acid. Baking powder is used to make cake and bread soft and spongy .
2. It is an ingredient in antacid. Being alkaline, it neutralises excess of acid in the stomach.

Bleaching powder ($CaOCl_2$)

1. It is used for disinfecting drinking water to make it free from microorganisms.
2. It is used for bleaching cotton and linen in the textile industry

Plaster of paris($CaSO_4 . \frac{1}{2}H_2O$)

It is used for plastering fractured bones and in making casts for statues

GROUP ACTIVITY

Prepare the following salt in the laboratory

1. Sodium chloride
2. Potash alum

EVALUATION

PART - A

1. $Zn + 2HCl \rightarrow ZnCl_2 + H_2 \uparrow$

The above reaction is an example of

a. Combinationreaction
b. Double displacement reaction
c. Displacement reaction
d. Decomposition reaction.

2. A reddish brown coloured element 'X' on heating in air becomes black coloured compound 'Y'. X and Y are______ and ________(Cu, CuO / Pb, PbO).

3. A student tested the p^H of pure water using a p^H paper. It showed green colour. If a p^H paper is used after adding lemon juice into water, what color will he observe? (Green / Red / Yellow)

4. Chemical volcano is an example of (combination reaction / decomposition reaction)

5. When crystals of lead nitrate on heating strongly produces a ____ gas and the colour of the gas is _________.

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6. When aqueous solution of silver nitrate and sodium chloride are mixed _______ precipitate is immediately formed (white / yellow / red).

7. aluminium can displace Zinc metal from aqueous solution of Zinc sulphate (zinc is more reactive than aluminium / aluminium is more reactive than zinc).

8. To protect tooth decay, we are advised to brush our teeth regularly. The nature of the tooth paste commonly used is _______ in nature.

9. Vinegar is present in acetic acid. Curd contains ______ acid (Lactic acid / Tartaric acid).

10. $p^H = -\log_{10} [H^+]$. The p^H of a solution containing hydrogen ion concentration of 0.001M solution is _____(3 / 11 / 14)

PART - B

11. What type of chemical reaction takes place when i) limestone is heated ii) a magnesium ribbon is burnt in air

12. The p^H values of certain familiar substances are given below

Substance	pH value
Blood	7.4
Baking soda	8.2
Vinegar	2.5
Household ammonia	12

analyse the data in the table and answer the following questions

a. Which substance is acidic in nature?

b. Which substances are basic in nature?

13. Why does the colour of copper sulphate change when an iron nail is kept in it? Justify your answer.

14. The hydroxyl ion concentration of a solution is 1.0×10^{-8}M. What is the p^H of the solution?

15. Equal lengths of magnesium ribbons are taken in test tubes A and B. Hydrochloric acid is added to test tube A, while acetic acid is added to test tube B. Amount and concentration taken for both the acids are same in which test tube reaction occurs more vigourously and why?

FURTHER REFERENCE

Books:

1. Text book of Inorganic Chemistry–**P.L. Soni - S.Chand & sons** publishers
2. Principles of Physical Chemistry –B.R. Puri, L.R. Sharma Vishal publishers

Website:

www. ask.com

www.chem4kids.com

CHAPTER 11

12. Periodic classification of elements

Have you ever visited a library? There are thousands of books in a large library. If you ask for a book in general it is very difficult to trace. Whereas if you ask for a particular book, the library staff can locate it very easily. How is it possible? In library the books are classified into various categories and sub categories. They are arranged on shelves accordingly. Therefore locating books become very easy.

As on date one hundred and eighteen elements are known. It is difficult to identify each and every element individually and to know its property and uses. Therefore they have been classified on the basis of their similarities in properties. One of the important instincts of mankind is to be systematic. Scientists felt the necessity to group elements of similar characteristics together so that if the properties of one of them are known, those of the others could be guessed and related.

Henry Gwyn-Jeffreys Moseley, an English physicist (1887–1915), used X-rays to determine the atomic numbers of the elements.

When a large number of elements were discovered, several attempts were being made to arrange them on the basis of their properties, nature, character, valency, etc., (Real credit for preparing the periodic table goes to Mendeleev).

12.1. MODERN PERIODIC LAW

A large number of scientists made attempts to eliminate the drawbacks of Mendeleev's periodic table. In 1912, Moseley, an English physicist measured the frequencies of X-rays emitted by a metal, when the metal was bombarded with high speed electrons. He plotted square roots of the frequencies against atomic numbers. The plot obtained was a straight line. He found that the square root of the frequency of the prominent X-rays emitted by a metal was proportional to the atomic number and not to the atomic weight of the atom of that metal.

MORE TO KNOW

Atomic number is number of protons in the nucleus or number of electrons revolving around the nucleus in an atom.

Moseley suggested that atomic number (Z) should be the basis of the classification of the element. Thus, he gave modern periodic law as follows:

Modern periodic law states that **"the physical and chemical properties of elements are the periodic function of their atomic numbers."**

Thus, according to the modern periodic law, if elements are arranged in the increasing order of their atomic numbers, the elements with similar properties are repeated after certain regular intervals.

12.2. MODERN PERIODIC TABLE

Based on the modern periodic law, a number of forms of periodic table have been proposed from time to time but general plan of the table remained the same as proposed by Mendeleev. The table which is most commonly used and which is based upon the **electronic configuration of elements** is called the **long form of the periodic table**. This is called the **modern periodic table.**

12.2.1. Description of modern or long form of the periodic table

Long form of the periodic table is a chart of elements in which the elements have been arranged in the increasing order of their atomic numbers. This table consists of **horizontal rows called periods and vertical columns called groups**.

12.2.3. Study of periods

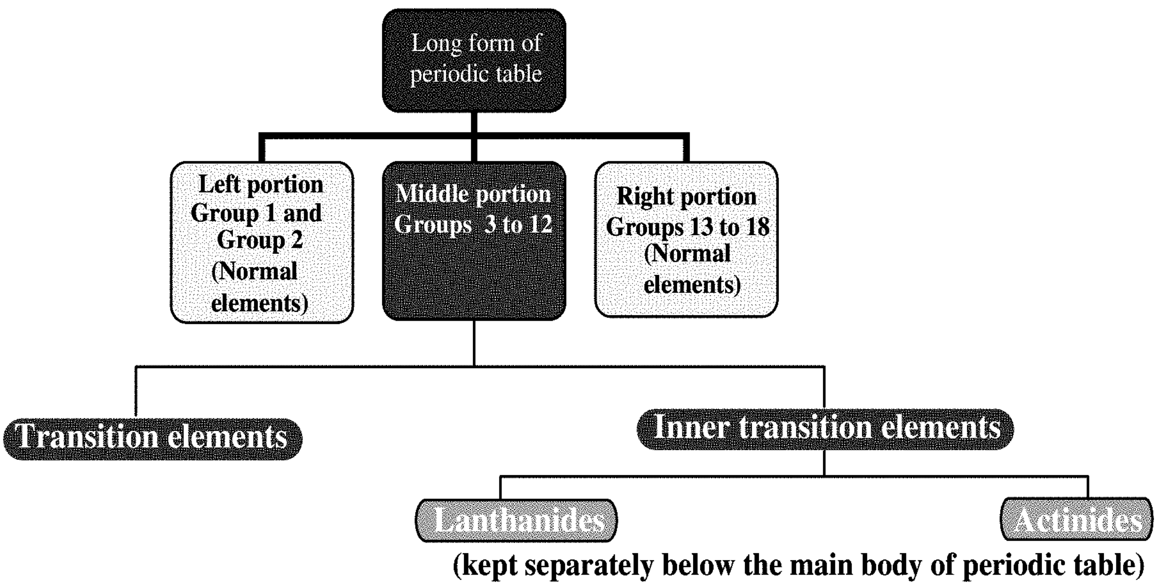
The **horizontal rows are called periods**. There are **seven** horizontal rows in the periodic table.

> **MORE TO KNOW**
>
> The modern periodic table has also been divided into four blocks known as s,p,d and f blocks.

- First period (Atomic number 1 and 2): This is the shortest period. It contains only two elements (Hydrogen and Helium).
- Second period (Atomic number 3 to 10): This is a short period. It contains eight elements (Lithium to Neon).

Third period (Atomic number 11 to 18): This is also a short period. It contains eight elements (Sodium to Argon).

12.2.2. Different portions of long form of periodic table



- **Fourth period** (Atomic number 19 to 36):

  This is a long period. It contains eighteen elements (Potassium to Krypton). This includes 8 normal elements and 10 transition elements.

- **Fifth period** (Atomic number 37 to 54): This is also a long period. It contains 18 elements (Rubidium to Xenon). This includes 8 normal elements and 10 transition elements.

- **Sixth period** (Atomic number 55 to 86): This is the longest period. It contains 32 elements (Ceasium to Radon). This includes 8 normal elements, 10 transition elements and 14 inner transition elements (Lanthanides).

- **Seventh period** (Atomic number 87 to 118): As like the sixth period, this period also can accomodate 32 elements. Till now only 26 elements have been authenticated by IUPAC

12.2.4. Study of groups

- Vertical columns in the periodic table starting from top to bottom are called groups. There are 18 groups in the periodic table.
- First group elements are called alkali metals.
- Second group elements are called alkaline earth metals.
- Groups three to twelve are called transition elements .
- Group 1, 2 and 13 - 18 are called normal elements or main group elements or representative elements .
- Group 13 is Boron family.
- Group 14 is Carbon family.
- Group 15 is Nitrogen family.
- Group 16 elements are called chalcogen family (except polonium).
- Group 17 elements are called halogen family.
- Group 18 elements are called noble gases or inert gases.
- The Lanthanides and actinides which form part of the group 3 are called inner transition elements.

12.3. CHARACTERISTICS OF MODERN PERIODIC TABLE

12.3.1. Characteristics Of Periods

- In a period, the electrons are filled in the same valence shell of all elements.
- As the electronic configuration changes along the period, the chemical properties of the elements also change.
- Atomic size of the elements in a period decrease from left to the right.
- In a period, the metallic character of the element decreases while their non-metallic character increases.

12.3.2. Characteristics of Groups

- The elements present in 2 and 18 groups differ in atomic number by 8,8,18,18,32.
- The elements present in 13 – 17 groups differ in atomic number by 8,18,18,32.
- The elements present in 4 - 12 groups differ in atomic number by 18,32,32.

MODERN PERIODIC TABLE

Group Numbers

PERIODS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1	1 H Hydrogen 1.00794 (1)	Atomic Number, Symbol, Name, Atomic Mass																2 He Helium 4.002602 (2)	K
2	3 Li Lithium 6.941 (2, 1)	4 Be Beryllium 9.012182 (2, 2)											5 B Boron 10.811 (2, 3)	6 C Carbon 12.0107 (2, 4)	7 N Nitrogen 14.0067 (2, 5)	8 O Oxygen 15.9994 (2, 6)	9 F Fluorine 18.9984032 (2, 7)	10 Ne Neon 20.1797 (2, 8)	K L
3	11 Na Sodium 22.98976928 (2, 8, 1)	12 Mg Magnesium 24.3050 (2, 8, 2)											13 Al Aluminium 26.9815386 (2, 8, 3)	14 Si Silicon 28.0855 (2, 8, 4)	15 P Phosphorus 30.973762 (2, 8, 5)	16 S Sulfur 32.065 (2, 8, 6)	17 Cl Chlorine 35.453 (2, 8, 7)	18 Ar Argon 39.948 (2, 8, 8)	K L M
4	19 K Potassium 39.0983 (2, 8, 8, 1)	20 Ca Calcium 40.078 (2, 8, 8, 2)	21 Sc Scandium 44.955912 (2, 8, 9, 2)	22 Ti Titanium 47.867 (2, 8, 10, 2)	23 V Vanadium 50.9415 (2, 8, 11, 2)	24 Cr Chromium 51.9961 (2, 8, 13, 1)	25 Mn Manganese 54.938045 (2, 8, 13, 2)	26 Fe Iron 55.845 (2, 8, 14, 2)	27 Co Cobalt 58.933195 (2, 8, 15, 2)	28 Ni Nickel 58.6934 (2, 8, 16, 2)	29 Cu Copper 63.546 (2, 8, 18, 1)	30 Zn Zinc 65.409 (2, 8, 18, 2)	31 Ga Gallium 69.723 (2, 8, 18, 3)	32 Ge Germanium 72.64 (2, 8, 18, 4)	33 As Arsenic 74.92160 (2, 8, 18, 5)	34 Se Selenium 78.96 (2, 8, 18, 6)	35 Br Bromine 79.904 (2, 8, 18, 7)	36 Kr Krypton 83.798 (2, 8, 18, 8)	K L M N
5	37 Rb Rubidium 85.4678 (2, 8, 18, 8, 1)	38 Sr Strontium 87.62 (2, 8, 18, 8, 2)	39 Y Yttrium 88.90585 (2, 8, 18, 9, 2)	40 Zr Zirconium 91.224 (2, 8, 18, 10, 2)	41 Nb Niobium 92.90638 (2, 8, 18, 12, 1)	42 Mo Molybdenum 95.94 (2, 8, 18, 13, 1)	43 Tc Technetium (98) (2, 8, 18, 14, 1)	44 Ru Ruthenium 101.07 (2, 8, 18, 15, 1)	45 Rh Rhodium 102.90550 (2, 8, 18, 16, 1)	46 Pd Palladium 106.42 (2, 8, 18, 18, 0)	47 Ag Silver 107.8682 (2, 8, 18, 18, 1)	48 Cd Cadmium 112.411 (2, 8, 18, 18, 2)	49 In Indium 114.818 (2, 8, 18, 18, 3)	50 Sn Tin 118.710 (2, 8, 18, 18, 4)	51 Sb Antimony 121.760 (2, 8, 18, 18, 5)	52 Te Tellurium 127.60 (2, 8, 18, 18, 6)	53 I Iodine 126.90447 (2, 8, 18, 18, 7)	54 Xe Xenon 131.293 (2, 8, 18, 18, 8)	K L M N O
6	55 Cs Caesium 132.9054519 (2, 8, 18, 18, 8, 1)	56 Ba Barium 137.327 (2, 8, 18, 18, 8, 2)	57-71	72 Hf Hafnium 178.49 (2, 8, 18, 32, 10, 2)	73 Ta Tantalum 180.94788 (2, 8, 18, 32, 11, 2)	74 W Tungsten 183.84 (2, 8, 18, 32, 12, 2)	75 Re Rhenium 186.207 (2, 8, 18, 32, 13, 2)	76 Os Osmium 190.23 (2, 8, 18, 32, 14, 2)	77 Ir Iridium 192.217 (2, 8, 18, 32, 15, 2)	78 Pt Platinum 195.084 (2, 8, 18, 32, 17, 1)	79 Au Gold 196.966569 (2, 8, 18, 32, 18, 1)	80 Hg Mercury 200.59 (2, 8, 18, 32, 18, 2)	81 Tl Thallium 204.3833 (2, 8, 18, 32, 18, 3)	82 Pb Lead 207.2 (2, 8, 18, 32, 18, 4)	83 Bi Bismuth 208.98040 (2, 8, 18, 32, 18, 5)	84 Po Polonium (209) (2, 8, 18, 32, 18, 6)	85 At Astatine (210) (2, 8, 18, 32, 18, 7)	86 Rn Radon (222) (2, 8, 18, 32, 18, 8)	K L M N O P
7	87 Fr Francium (223) (2, 8, 18, 32, 18, 8, 1)	88 Ra Radium (226) (2, 8, 18, 32, 18, 8, 2)	89-103	104 Rf Rutherfordium 178.49 (2, 8, 18, 32, 32, 10, 2)	105 Db Dubnium (262) (2, 8, 18, 32, 32, 11, 2)	106 Sg Seaborgium (266) (2, 8, 18, 32, 32, 12, 2)	107 Bh Bohrium (264) (2, 8, 18, 32, 32, 13, 2)	108 Hs Hassium (277) (2, 8, 18, 32, 32, 14, 2)	109 Mt Meitnerium (268) (2, 8, 18, 32, 32, 15, 2)	110 Ds Darmstadtium (281) (2, 8, 18, 32, 32, 17, 1)	111 Rg Roentgenium (272) (2, 8, 18, 32, 32, 18, 1)	112 Cn Copernicium (285) (2, 8, 18, 32, 32, 18, 2)	113 Uut Ununtrium (284) (2, 8, 18, 32, 32, 18, 3)	114 Uuq Ununquadium (289) (2, 8, 18, 32, 32, 18, 4)	115 Uup Ununpentium (288) (2, 8, 18, 32, 32, 18, 5)	116 Uuh Ununhexium (292) (2, 8, 18, 32, 32, 18, 6)	117 Uus Ununseptium (2, 8, 18, 32, 32, 18, 7)	118 Uuo Ununoctium (294) (2, 8, 18, 32, 32, 18, 8)	K L M N O P Q

57 La Lanthanum 138.90547 (2, 8, 18, 18, 9, 2)	58 Ce Cerium 140.116 (2, 8, 18, 19, 9, 2)	59 Pr Praseodymium 140.90765 (2, 8, 18, 21, 8, 2)	60 Nd Neodymium 144.242 (2, 8, 18, 22, 8, 2)	61 Pm Promethium (145) (2, 8, 18, 23, 8, 2)	62 Sm Samarium 150.36 (2, 8, 18, 24, 8, 2)	63 Eu Europium 151.964 (2, 8, 18, 25, 8, 2)	64 Gd Gadolinium 157.25 (2, 8, 18, 25, 9, 2)	65 Tb Terbium 158.92535 (2, 8, 18, 27, 8, 2)	66 Dy Dysprosium 162.500 (2, 8, 18, 28, 8, 2)	67 Ho Holmium 164.93032 (2, 8, 18, 29, 8, 2)	68 Er Erbium 167.259 (2, 8, 18, 30, 8, 2)	69 Tm Thulium 168.93421 (2, 8, 18, 31, 8, 2)	70 Yb Ytterbium 173.04 (2, 8, 18, 32, 8, 2)	71 Lu Lutetium 174.967 (2, 8, 18, 32, 9, 2)
89 Ac Actinium (227) (2, 8, 18, 32, 18, 9, 2)	90 Th Thorium 232.03806 (2, 8, 18, 32, 18, 10, 2)	91 Pa Protactinium 231.03588 (2, 8, 18, 32, 20, 9, 2)	92 U Uranium 238.02891 (2, 8, 18, 32, 21, 9, 2)	93 Np Neptunium (237) (2, 8, 18, 23, 8, 2)	94 Pu Plutonium (244) (2, 8, 18, 32, 24, 8, 2)	95 Am Americium (243) (2, 8, 18, 32, 25, 8, 2)	96 Cm Curium (247) (2, 8, 18, 32, 25, 9, 2)	97 Bk Berkelium (247) (2, 8, 18, 32, 27, 8, 2)	98 Cf Californium (251) (2, 8, 18, 32, 28, 8, 2)	99 Es Einsteinium (252) (2, 8, 18, 32, 29, 8, 2)	100 Fm Fermium (257) (2, 8, 18, 32, 30, 8, 2)	101 Md Mendelevium (258) (2, 8, 18, 32, 31, 8, 2)	102 No Nobelium (259) (2, 8, 18, 32, 32, 8, 2)	103 Lr Lawrencium (262) (2, 8, 18, 32, 32, 9, 2)

C Solid
Hg Liquid
H Gas
Rf Unknown

Metals: Alkali Metals, Alkaline earth metals, Lanthanoids, Actinoids, Transition metals, Poor metals

Nonmetals: Other nonmetals, Noble gases

- The elements present in a group have the same number of electrons in the valence shell of their atoms.
- The elements present in a group have the same valency.
- The elements present in a group have identical chemical properties.
- The physical properties of the elements in group such as melting point, boiling point, density vary gradually.
- Atomic radii of the elements present in a group increases downwards.

12.3.3. Advantages of the Modern Periodic Table

- The table is based on a more fundamental property ie., atomic number.
- It correlates the position of the element with its electronic configuration more clearly.
- The completion of each period is more logical. In a period as the atomic number increases, the energy shells are gradually filled up until an inert gas configuration is reached.
- It is easy to remember and reproduce.
- Each group is an independent group and the idea of sub-groups has been discarded.
- One position for all isotopes of an element is justified, since the isotopes have the same atomic number.
- The position of eighth group (in Mendeleev's table) is also justified in this table. All transition elements have been brought in the middle as the properties of transition elements are intermediate between left portion and right portion elements of the periodic table.
- The table completely separates metals from non-metals. The non-metals are present in upper right corners of the periodic table.
- The positions of certain elements which were earlier misfit (inter-changed) in the Mendeleev's periodic table are now justified because it is based on atomic number of the elements.
- Justification has been offered for placing lanthanides and actinides at the bottom of the periodic table.

12.3.4. Defects in the Modern Periodic Table

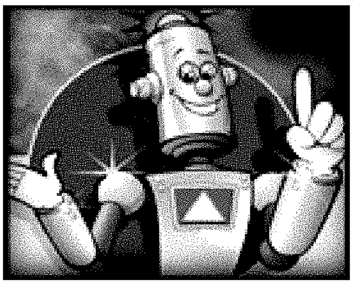
- Position of hydrogen is not fixed till now.
- Position of lanthanides and actinides has not been given inside the main body of periodic table.
- It does not reflect the exact distribution of electrons of some of transition and inner transition elements.

MORE TO KNOW

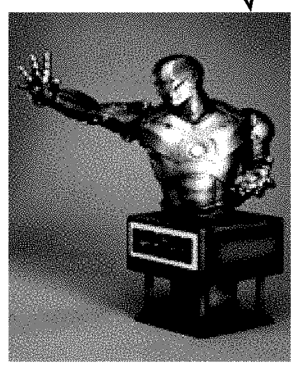
The last element authenticated by IUPAC is Cn112 [Copernicium]. However, the number of elements discovered so far is 118.

12.4. METALLURGY

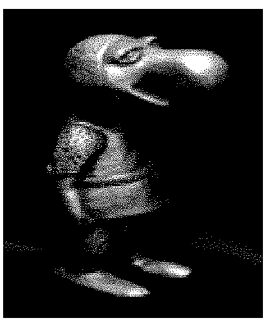
I (Al) am a light silvery white metal to build aircraft. So, I am great.



I (Fe) am a lustrous steel metal to make machineries and bridges.So, I am great.



I (Cu) am a reddish brown metal to make coins. So, I am great.



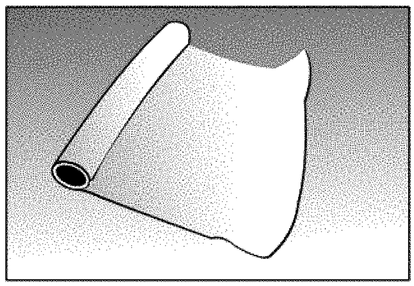
Individually you are great in your aspect.You will become the GREATEST IF YOU ARE ALLOYED TOGETHER. ***Unity is strength.***

INTRODUCTION

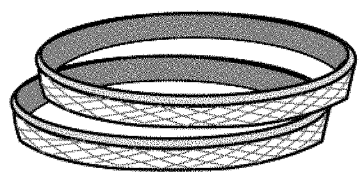
Metallurgy is as old as our civilization. Copper was the first metal to be used for making utensils, weapons and for other works. Metals play a significant role in our life. They constitute the mineral wealth of a country which is the measure of prosperity.

Metals like titanium, chromium, manganese, zirconium etc. find their applications in the manufacture of defence equipments. These are called **strategic metals**. The metal uranium plays, a vital role in nuclear reactions releasing enormous energy called nuclear energy. Copper, silver and gold are called **coinage metals** as they are used in making coins, jewellery etc.

Vietnameses Craft Work in silver



Aluminium foil



Bangles

MORE TO KNOW

Purity of gold is expressed in carat.

24 carat gold = pure gold.

For making ornaments 22 carat gold is used which contains 22 parts of gold by weight and 2 parts of copper by weight. The percentage of purity is $\frac{22}{24} \times 100 = 91.6\%$ (**916 Make gold**)

From one gram of gold, nearly 2km of wire can be drawn. Its an amazing fact indeed!

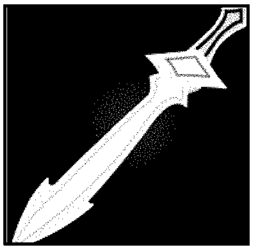
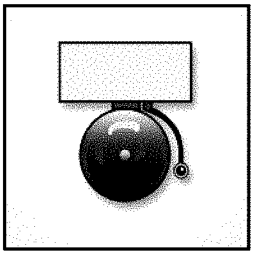
MORE TO KNOW

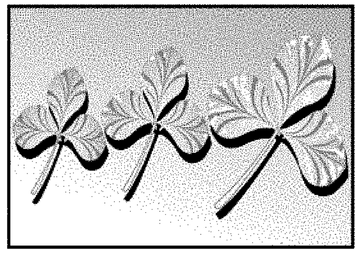
THE VITALITY OF METALS FOR THE TOTALITY OF LIFE

Metals in minute amounts are essential for various biological purposes. **Fe** – a constituent of blood pigment (haemoglobin).

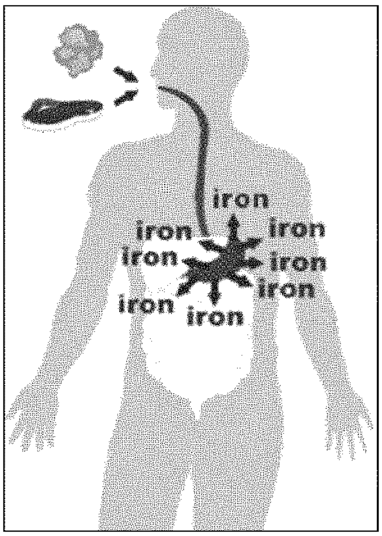
Ca - a constituent of bone and teeth. **Co** - a constituent of vitamin B-12

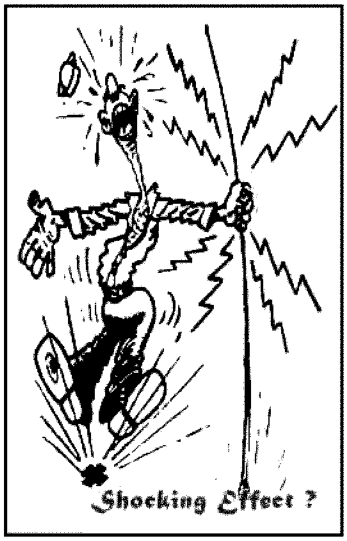
Mg - constituent of chlorophyll.

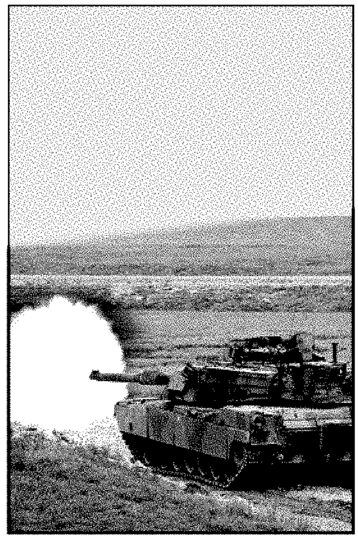





METALS AROUND US





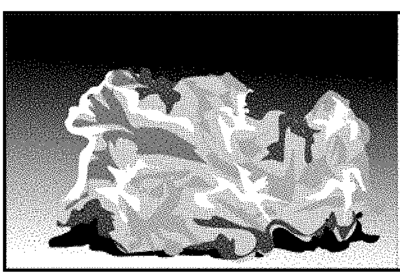


12.4.1. TERMINOLOGIES IN METALLURGY

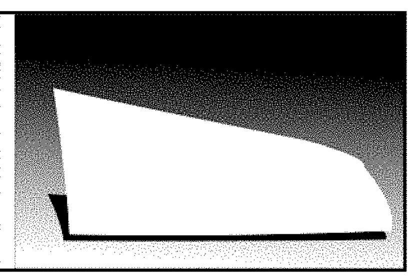
Minerals: A mineral may be a single compound or complex mixture of various compounds of metals which are found in earth.

Ores: The mineral from which a metal can be readily and economically extracted on a large scale is said to be a ore.

For example, clay ($Al_2O_3.2SiO_2.2H_2O$) and bauxite ($Al_2O_3.2H_2O$) are the two minerals of aluminium. But aluminium can be profitably extracted only from bauxite. Hence **bauxite is an ore of aluminium and clay is its mineral**.


Gold


Silver


Aluminium

12.4.2. Differences between minerals and ores

- Minerals contain a low percentage of metal while ores contain a large percentage of metal.
- Metals cannot be extracted easily from mineral. On the other hand,ores can be used for the extraction of metals.
- All minerals cannot be called as ores,but all ores are minerals.

Mining: The process of extracting the ores from the earth crust is called mining.

Metallurgy: Various steps involved in the extraction of metals from their ores as well as refining of crude metal are collectively known as metallurgy.

Gangue or Matrix: The rocky impurity, associated with the ore is called gangue or matrix.

Flux: It is the substance added to the ore to reduce the fusion temperature

Slag: It is the fusible product formed when flux reacts with gangue during the extraction of metals.

$$\text{Flux} + \text{Gangue} \rightarrow \text{Slag}$$

Smelting: Smelting is the process of reducing the roasted oxide to metals in the molten condition.

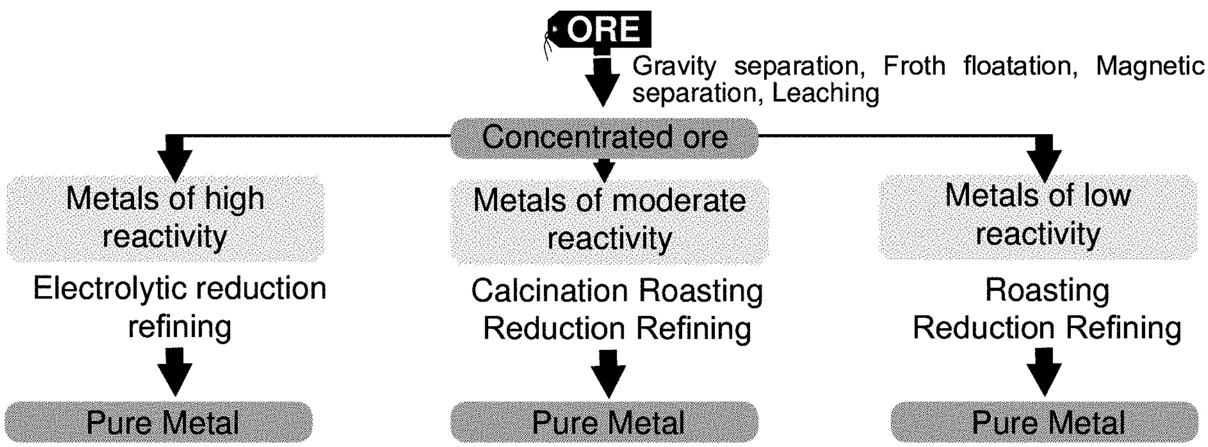
12.5. OCCURRENCE OF METALS

Nearly 80 metallic elements are obtained from mineral deposits on or beneath the surface of the earth.Metals which have low chemical reactivity are found in **free state, or in native state.**

Gold, silver and platinum are examples of metals that are partly found in a free state. Most of the other metals are found in a combined state in the form of their oxide ores, carbonate ores, halide ores, sulphide ores, sulphate ores and so on.

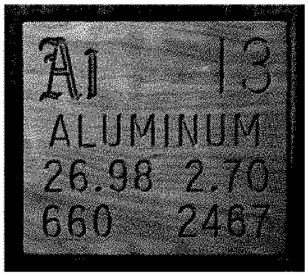
Oxide Ores	Carbonate Ores	Halide Ores	Sulphide Ores
Bauxite ($Al_2O_3.2H_2O$)	**Marble ($CaCO_3$)**	**Cryolite (Na_3AlF_6)**	**Galena (PbS)**
Cuprite (Cu_2O)	**Magnesite ($MgCO_3$)**	**Fluorspar (CaF_2)**	**Iron pyrite (FeS_2)**
Haematite (Fe_2O_3)	**Siderite ($FeCO_3$)**	**Rock salt ($NaCl$)**	**Zinc blende (ZnS)**

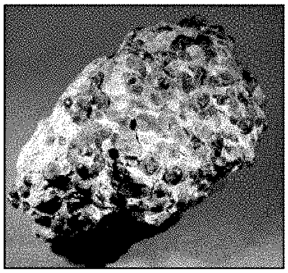
Flow Chart (Extraction of Metal from its ore)



12.6. METALLURGY OF ALUMINIUM, COPPER AND IRON

12.6.1. Metallurgy of aluminium





Symbol : Al
Colour : Silvery white
Atomic number : 13
Electronic configuration:2, 8, 3
Valency : 3
Atomic mass : 27

Position in the periodic table: period=3, group=13 (III A)

Aluminium is the most abundant metal in the earth's crust. Since it is a reactive metal it occurs in the combined state. The important ores of aluminium are as follows:

Name of the ore	Formula
Bauxite	$Al_2O_3.2H_2O$
Cryolite	Na_3AlF_6
Corundum	Al_2O_3

The chief ore of aluminium is bauxite ($Al_2O_3.2H_2O$).

Extraction of aluminium from bauxite involves two stages:

I. Conversion of Bauxite into Alumina by Baeyer's Process

The conversion of Bauxite into Alumina involves the following steps:

i.Bauxite ore is finely grounded and heated under pressure with concentrated caustic soda solution at 150°C to obtain sodium meta aluminate.

$$\underset{\text{Bauxite}}{Al_2O_3.2H_2O} + 2NaOH \xrightarrow{150°C} \underset{\text{Sodium Meta aluminate}}{2NaAlO_2} + 3H_2O$$

ii.On diluting sodium meta aluminate with water, aluminium hydroxide precipitate is obtained.

$$NaAlO_2 + 2H_2O \rightarrow NaOH + Al(OH)_3$$

iii.The precipitate is filtered, washed, dried and ignited at 1000°C to get alumina.

$$2Al(OH)_3 \xrightarrow{1000°C} Al_2O_3 + 3H_2O$$

2.Electrolytic reduction of Alumina by Hall's process

Aluminium is produced by the electrolytic reduction of fused alumina (Al_2O_3) in the electrolytic cell.

Cathode : Iron tank lined with graphite

Anode : A bunch of graphite rods suspended in molten electrolyte

Electrolyte : Pure alumina + molten cryolite + fluorspar (fluorspar lowers the fusion temperature of electrolyte)

Temperature : 900-950°C

Voltage used : 5-6V

The overall equation for aluminium extraction is

$$2Al_2O_3 \rightarrow 4Al + 3O_2$$

Aluminium deposits at cathode and oxygen gas is liberated at anode

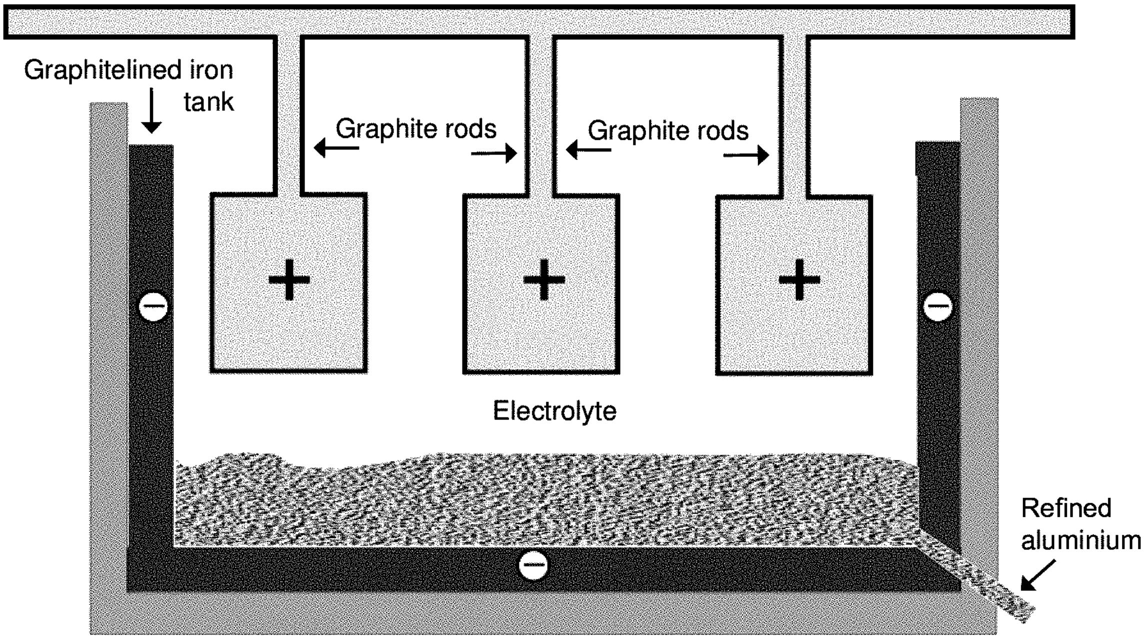


Fig 12.1 Electrolytic refining of aluminium

Properties of Aluminium

Physical properties:

i. It is a silvery white metal.
ii. It has low density and it is light
iii. It is malleable and ductile.
iv. It is a good conductor of heat and electricity.

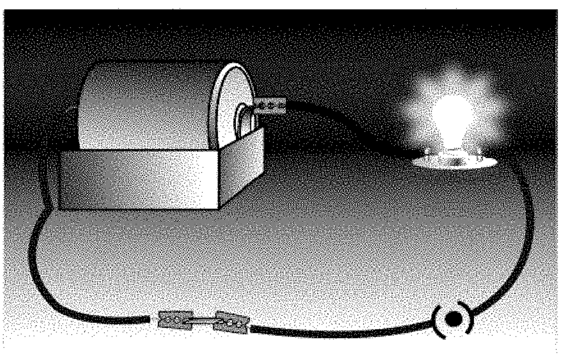


Fig. 12.2 Electric conductivity of metal

v. Melting point: 660°C
vi. It can be well polished to produce attractive shiny appearance.

Chemical properties:

1. Reaction with air: It is not affected by dry air. On heating at 800°C, aluminium burns very brightly forming its oxide and nitride.

$4Al + 3O_2 \rightarrow 2Al_2O_3$ (Aluminium Oxide)
$2Al + N_2 \rightarrow 2AlN$ (Aluminium Nitride)

2. Reaction with water: Water has no reaction on aluminium due to the layer of oxide on it. When steam is passed over red hot aluminium, hydrogen is produced.

$$2Al + \underset{\text{Steam}}{3H_2O} \rightarrow \underset{\text{Aluminium Oxide}}{Al_2O_3} + 3H_2\uparrow$$

3. Reaction with alkalis: It reacts with strong caustic alkalis forming aluminates.

$$2Al + 2NaOH + 2H_2O \rightarrow \underset{\text{Sodium meta aluminate}}{2NaAlO_2} + 3H_2\uparrow$$

4. Reaction with acids: With dilute and con. HCl it liberates H_2 gas.

$$2Al + 6HCl \rightarrow \underset{\text{Aluminium Chloride}}{2AlCl_3} + 3H_2\uparrow$$

Aluminium liberates hydrogen on reaction with dilute sulphuric acid. Sulphur dioxide is liberated with hot concentrated sulphuric acid.

$$2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2\uparrow$$

Dilute

$$2Al + 6H_2SO_4 \rightarrow Al_2(SO_4)_3 + 6H_2O + 3SO_2\uparrow$$

hot & conc. Sulphuric acid — Aluminium Sulphate

MORE TO KNOW

Dilute or concentrated nitric acid does not attack aluminium. But it renders aluminium passive due to the formation of an oxide film on its surface.

5. Reducing action : Aluminium is a powerful reducing agent. When a mixture of aluminium powder and iron oxide is ignited, the latter is reduced to metal. This process is known as aluminothermic process.

$$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$$

Uses of Aluminium

USES	FORM	REASON
1. Household utensils	Aluminium metal	It is light, cheap, corrosion resistant, and good conductor of heat.
2. Electrical cable industry	Aluminium wires	It is a good conductor of electricity.
3. Aeroplanes and other industrial parts	Duralumin Al,Cu,Mg,Mn Magnalium Al,Mg	Its alloys are light, have high tensile strength and are corrosion resistant.
4. Thermite welding	Al powder and Fe_2O_3	Its powder is a strong reducing agent and reduces Fe_2O_3 to iron.

AirCraft - An alloy of aluminium

INDUSTRIAL VISIT

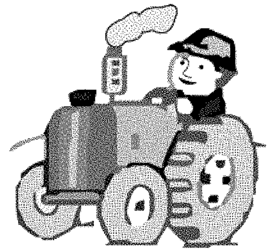
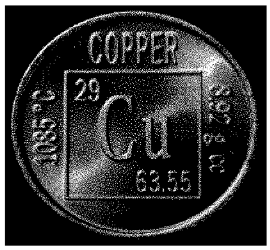
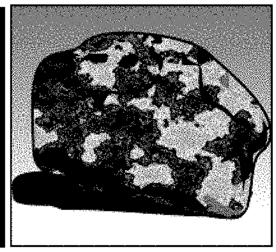


Fig 12.3

Make an industrial visit to the place where **Thermite welding** is actually done and record your observations on joining the gap between the broken pieces of rails.

12.6.2 Metallurgy of Copper





Symbol : Cu
Atomic mass : 63.55
Atomic number : 29
Electronic configuration : 2, 8, 18, 1
Valency : 1 and 2

Occurrence: It was named as cuprum by the Romans because they used to get it from the island of Cyprus. Copper is found in the **native state** as well as in the combined state.

Ores of copper	Formula
i. Copper pyrite	$CuFeS_2$
ii. Cuprite or ruby copper	Cu_2O
iii. Copper glance	Cu_2S

The chief ore of copper is copper pyrite. It yields nearly 76% of the world production of copper.

Extraction from copper pyrites:

Extraction of copper from copper pyrites involves the following steps.

1.Crushing and concentration: The ore is crushed and then concentrated by froth-floatation process.

2.Roasting: The concentrated ore is roasted in excess of air. During roasting,

i.moisture and volatile impurities are removed.
ii.copper pyrite is partly converted into sulphides of copper and iron.

$2CuFeS_2 + O_2 \rightarrow Cu_2S + 2FeS + SO_2$

3.Smelting: The roasted ore is mixed with powdered coke and sand and is heated in a blast furnace to obtain matte and slag. ***(Matte = Cu_2S + FeS)*** The slag is removed as a waste.

4.Bessemerisation: The molten matte is transferred to Bessemer converter in order to obtain ***blister copper.*** Ferrous sulphide from matte is oxidised to ferrous oxide which is removed as slag using silica.

$2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$
$2Cu_2O + Cu_2S \rightarrow 6Cu + SO_2$
$FeO + SiO_2 \rightarrow FeSiO_3$ (Iron silicate, slag)

5.Refining: Blister copper contains 98% pure copper and 2% impurities and are purified by electrolytic refining.

Electrolytic refining.

This method is used to get metal of high degree of purity. For electrolytic refining of copper, we use

Cathode: A thin plate of pure copper metal.

Anode: A block of impure copper metal.

Electrolyte: Copper sulphate solution acidified with sulphuric acid. When electric current is passed through the electrolytic solution pure copper gets deposited at the cathode, impurities settled at the bottom of the anode in the form of sludge called anode mud.

Properties

Physical properties: Copper is a reddish brown metal, with high lustre, high density and high melting point (1356^0C).

Chemical properties:

i.Action of air and moisture: Copper gets covered with a green layer of basic copper carbonate in the presence of CO_2 and moisture.

$2Cu + O_2 + CO_2 + H_2O \rightarrow CuCO_3.Cu(OH)_2$

ii. Action of Heat: On heating at different temperatures in the presence of oxygen it forms two types of oxides CuO, Cu_2O.

$2Cu + O_2 \xrightarrow{\text{below 1370K}} 2CuO$ (copper II oxide –black)

$4Cu + O_2 \xrightarrow{\text{above 1370K}} 2Cu_2O$ (copper I oxide-red)

iii. Action of Acids:

a) with dil.HCl and dil.H_2SO_4

Dilute acids such as HCl and H_2SO_4 have no action on these metals in the absence of air. Copper dissolves in these acids in the presence of air.

$2Cu + 4HCl + O_2 \text{ (air)} \rightarrow 2CuCl_2 + 2H_2O$
$2Cu + 2H_2SO_4 + O_2 \text{ (air)} \rightarrow 2CuSO_4 + 2H_2O$

b) with dil.HNO_3 Copper reacts with dil. HNO_3 with the liberation of Nitric Oxide gas.

$3Cu + 8HNO_3(dil) \rightarrow 3Cu(NO_3)_2 + 2NO\uparrow + 4H_2O$

c) with con.HNO_3 and con.H_2SO_4

Copper reacts with con. HNO_3 and con. H_2SO_4 with the liberation of nitrogen dioxide and sulphur dioxide respectively.

$Cu + \underset{\text{(conc.)}}{4HNO_3} \rightarrow Cu(NO_3)_2 + 2NO_2\uparrow + 2H_2O$

$Cu + 2H_2SO_4 \rightarrow CuSO_4 + SO_2\uparrow + 2H_2O$
(conc.)

iv. Action of chlorine: Chlorine reacts with copper, resulting in the formation of copper (II) chloride.

$Cu + Cl_2 \rightarrow CuCl_2$

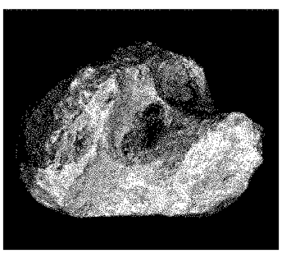
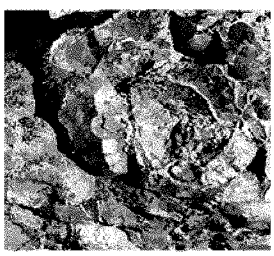
v. Action of alkalis: Copper is not attacked by alkalis.

Uses

- It is extensively used for making electric cables and other electric appliances.
- It is used for making utensils, containers, calorimeters, coins.
- It is used in electroplating.
- It is alloyed with gold and silver for making coins and jewels.

PROJECT
Students may be asked to submit a project report on the important applications of copper in everyday life along with the samples.

12.6.3 METALLURGY OF IRON

Symbol : Fe
Colour : Greyish white
Atomic mass : 55.9
Atomic number: 26
Valency : 2 & 3
Electronic configuration : 2, 8, 14, 2

Occurrence:

Iron is the second most abundant metal after aluminium. It occurs in nature as oxides, sulphides and carbonates. The ores of iron are given in the following table:

Ores of iron	Formula
I.Red haematite	Fe_2O_3
ii.Magnetite	Fe_3O_4
iii.Iron pyrites	FeS_2

Extraction of Iron from haematite ore (Fe_2O_3)

1.Concentration by gravity separation

The powdered ore is washed with stream of water. As a result, the lighter sand particles and other impurities are washed away and heavier ore particles settle down.

2.Roasting and calcination

The concentrated ore is strongly heated in a limited supply of air in a reverberatory furnace. As a result, moisture is driven out and sulphur, arsenic, phosphorus impurities are oxidised off.

3.Smelting (in Blast furnace)

The **charge** consisting of roasted ore, coke and limestone in the ratio **8 : 4 : 1** is smelted in a blast furnace by introducing it through the **cup and cone** arrangement at the top. There are three important regions in the furnance.

i.The lower region(combustion zone)- temperature is at 1500°C.

In this region, coke burns with oxygen to form CO_2 when the charge comes in contact with the hot blast of air.

$$C + O_2 \xrightarrow{1500°C} CO_2 + \text{heat}$$

It is an exothermic reaction since heat is liberated.

ii.The middle region (fusion zone)-The temperature prevails at 1000^{0}C.In this region CO_2 is reduced to CO.

$$CO_2 + C \xrightarrow{1000°C} 2CO$$

Limestone decomposes to calcium oxide and CO_2.

$$CaCO_3 \xrightarrow{\blacktriangle} CaO + CO_2$$

These two reactions are endothermic due to the absorption of heat. Calcium oxide combines with silica to form calcium silicate slag.

$$CaO + SiO_2 \rightarrow CaSiO_3$$

iii.The upper region (reduction zone)-temperature prevails at 400^{0}C. In this region carbon monoxide reduces ferric oxide to form a fairly pure spongy iron.

$$Fe_2O_3 + 3CO \xrightarrow{400°C} 2Fe + 3CO_2$$

The molten iron is collected at the bottom of the furnace after removing the slag.

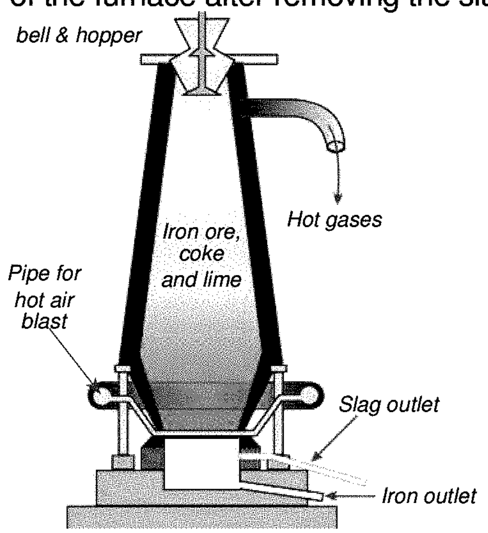


Fig. 12.4 Blast furnace

The iron thus formed is called **pig iron**. It is remelted and cast into different moulds. This iron is called **cast iron.**

MORE TO KNOW

CALCINATION AND ROASTING

CALCINATION: It is a process in which ore is heated in the absence of air. As a result of calcinations the carbonate ore is converted into its oxide.

ROASTING: It is a process in which ore is heated in the **presence of excess of air**. As a result of roasting the sulphide ore is converted into its oxide.

MORE TO KNOW

Depending upon the carbon content iron is classified into 3 types.

Pig iron with carbon content of 2- 4.5%

Wrought iron with carbon content <0.25%

Steel with carbon content of 0.25-2%.

Physical properties

- It is a heavy metal of specific gravity 7.9 g/cc
- It is a lustrous metal and greyish white in colour.
- It has high tensility, malleability and ductility.
- It is a good conductor of heat and electricity.
- It can be magnetised.

Chemical properties

1.Reaction with air or oxygen: Only on heating in air, iron forms magnetic oxide

$3Fe + 2O_2 \rightarrow Fe_3O_4$ (black)

2.Reaction with moist air: When iron is exposed to moist air, it forms a layer of brown hydrated ferric oxide on its surface. This compound is known as rust and the phenomenon of forming this rust is known as rusting.

$4Fe + 3O_2 + \underset{\text{(Moisture)}}{3H_2O} \rightarrow 2Fe_2O_3.3H_2O$(Rust)

3.Reaction with steam: When steam is passed over red hot iron,magnetic oxide of iron is formed.

$3Fe + 4H_2O(\text{steam}) \rightarrow Fe_3O_4 + 4H_2\uparrow$

4.Reaction with chlorine: Iron combines with chlorine to form ferric chloride.

$2Fe + 3Cl_2 \rightarrow 2FeCl_3$(ferric chloride)

5.Reaction with acids: With dilute HCl and dilute H_2SO_4 it evolves H_2 gas

$Fe + 2HCl \rightarrow FeCl_2 + H_2\uparrow$

$Fe + H_2SO_4 \rightarrow FeSO_4 + H_2\uparrow$

With conc. H_2SO_4 it forms ferric sulphate

$2Fe + 6H_2SO_4 \rightarrow Fe_2(SO_4)_3 + 3SO_2 + 6H_2O$

With dilute HNO_3 in cold condition it gives ferrous nitrate

$4Fe + 10HNO_3 \rightarrow 4Fe(NO_3)_2 + NH_4NO_3 + 3H_2O$

When iron is dipped in conc. HNO_3 it becomes chemically **inert or passive** due to the formation of a layer of iron oxide (Fe_3O_4) on its surface.

Uses of iron

i.**Pig iron** is used in making pipes, stoves, radiators, railings, man hole covers and drain pipes.

ii. **Steel** is used in the construction of buildings, machinery, transmission and T.V towers and in making alloys.

iii.**Wrought iron** is used in making springs, anchors and electromagnets.

12.7 ALLOYS

An alloy is a homogeneous mixture of of a metal with other metals or with non-metals that are fused together.

Alloys are solid solutions. Alloys can be considered as solid solutions in which the metal with high concentration is **solvent** and the metal with low concentration is **solute**. For example, brass is an alloy of zinc(solute) in copper(solvent).

12.7.1 Methods of making alloys:

1.By fusing the metals together.

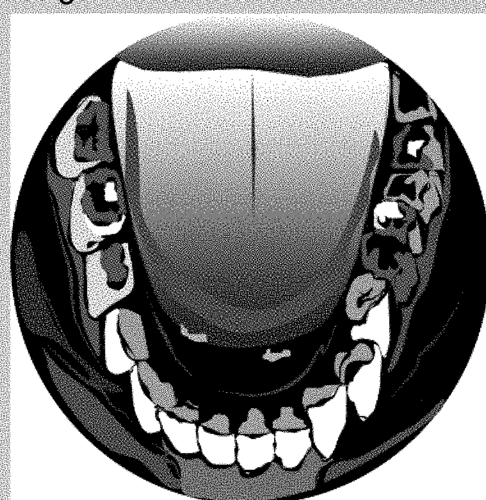
2.By compressing finely divided metals one over the other.

Amalgam: An amalgam is an alloy of mercury with metals such as sodium, gold, silver, etc.,

MORE TO KNOW

DENTAL AMALGAMS

It is an alloy of mercury with silver and tin metals. It is used in dental filling.



Dental amalgam

12.7.2 Copper Alloys

Name of the alloy	Reason for alloying	Uses
i.Brass(Cu,Zn)	Lusturous,easily cast,malleable, ductile,harder than Cu.	Electrical fittings, medals, hard ware, decorative items.
ii.Bronze(Cu,Sn,Zn)	Hard,brittle,takes up polish.	Statues, coins, bells, gongs.

12.7.3 Aluminium Alloys

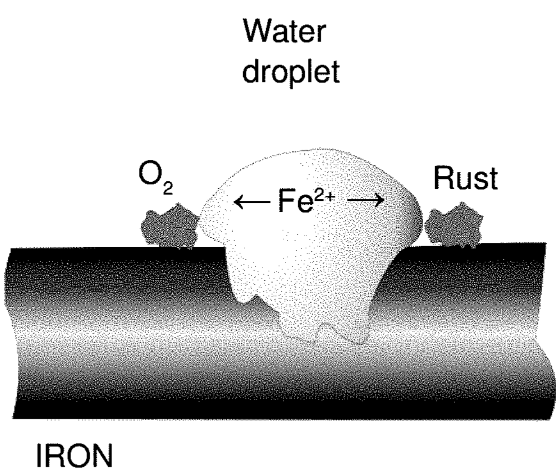
Name of the alloy	Reason for alloying	Uses
i.Duralumin(Al,Mg,Mn,Cu)	Light,strong,resistant to corrosion stronger than aluminium.	Aircraft,tools,pressure cookers
ii.Magnalium(Al,Mg)	Light,hard,tough,corrosion resistant.	Aircraft,scientific instrument

12.7.4 Iron Alloys

Name of the alloy	Reason for alloying	Uses
i.Stainless steel (Fe,C,Ni,Cr)	Lusturous,corrosion resistant,high tensile strength.	Utensils,cutlery,automobile parts.
ii.Nickel steel (Fe,C,Ni)	Hard, corrosion resistant,elastic.	Cables,aircraft parts,propeller.

12.8 CORROSION

Corrosion is defined as the slow and steady destruction of a metal by the environment. It results in the deterioration of the metal to form metal compounds by means of chemical reactions with the environment.



Rusting of iron

MORE TO KNOW

MECHANISM OF CORROSION

Corrosion is a simple electro chemical reaction.

When the surface of iron is in contact with a piece of carbon and water, iron acts as the anode and the carbon acts as a cathode.CO_2 from air dissolves in water to form carbonic acid(H_2CO_3).This acid acts as an electrolyte.

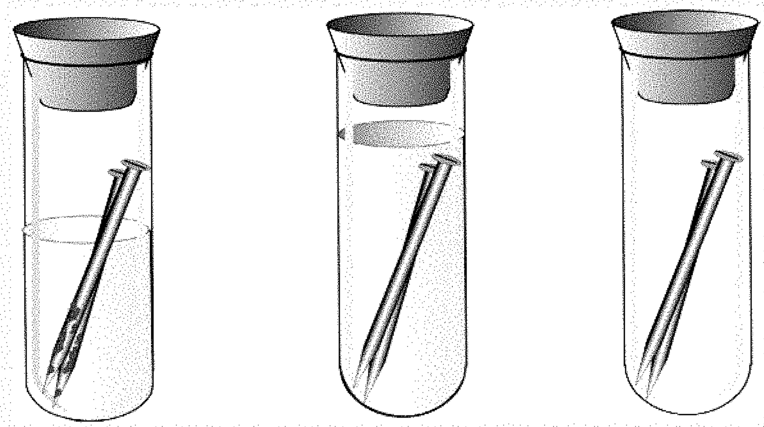
The electrochemical reactions are as follows:

$Fe \rightarrow Fe^{2+} + 2e^-$

$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$

The Fe^{2+} ions are oxidised to Fe^{3+} ions. The Fe^{3+} ions combine with OH^- ions to form $Fe(OH)_3$.This becomes **rust ($Fe_2O_3.xH_2O$) which is hydrated ferric oxide.**

ACTIVITY 12.1



The conditions for rusting

Take three test tubes provided with rubber corks and label them as A, B and C. Place few iron nails of same size in these tubes. Pour some water in test tube A, some boiled water along with turpentine oil in test tube B and anhydrous $CaCl_2$ in test tube C.Keep them under observation for few days. Notice the changes.

The nails in A are rusted while the nails in B and C are unaffected.

The rusting of nails in A is due to air and water. In B, the oily layer above water does not allow air to come in contact with nails. In C, the substance anhydrous $CaCl_2$ has absorbed moisture completely. This activity shows that rusting of iron requires air and water.

Methods of preventing corrosion:

Corrosion of metals is prevented by not allowing them to come in contact with moisture,CO_2 and O_2.This is achieved by the following methods:

- By coating with paints: Paint coated metal surfaces keep out air and moisture.
- By coating with oil and grease: Application of oil and grease on the surface of iron tools prevents them from moisture and air.
- By alloying with other metals: Alloyed metal is more resistant to corrosion.
- Example: stainless steel.
- By the process of galvanization: This is a process of coating zinc on iron sheets by using electric current. In this zinc forms a protective layer of zinc carbonate on the surface of iron. This prevents corrosion.
- Electroplating: It is a method of coating one metal with another by passing electric current. Example: silver plating, nickel plating. This method not only lends protection but also enhances the metallic appearance.
- Sacrificial protection: Magnesium is more reactive than iron. When it is coated on the articles made of steel it sacrifices itself to protect the steel.

EVALUATION

PART - A

1. In the modern periodic table periods and groups are given. Periods and groups indicate_________
   a) Rows and Columns b) Columns and rows
2. Third period contains 8 elements, out of these elements how many elements are non-metals?.
3. An element which is an essential constituent of all organic compounds belongs to _________ group. (14^{th} group / 15^{th} group)
4. Ore is used for the extraction of metals profitably. Bauxite is used to extract aluminium, it can be termed as ________. (ore / mineral)
5. Gold does not occur in the combined form. It does not react with air (or) water. It is in ______. (native state / combined state)

PART - B

6. Assertion: Greenish layer appears on copper vessels if left uncleaned.

   Reason: It is due to the formation of layer of basic copper carbonate

   Give your correct option

   a) assertion and reason are correct and relevant to each other

   b) assertion is true but reason is not relevant to the assertion
7. A process employed for the concentration of sulphide ore is __________. (froth floation / gravity separation)
8. Coating the surface of iron with other metal prevents it from rusting. If it is coated with thin layer of zinc it is called _________ (galvanization / painting / cathodic protection)
9. Any metal mixed with mercury is called amalgam. The amalgam used for dental filling Is _________. (Ag – Sn amalgam / Cu – Sn amalgam)
10. Assertion: In thermite welding, aluminium powder and Fe_2O_3 are used. Reason: Aluminium powder is a strong reducing agent. Does the reason satisfy the assertion?

PART - C

11. Can rusting of iron nail occur in distilled water. Justify your answer.
12. Why cannot aluminium metal be obtained by the reduction of aluminium oxide with coke?
13. Iron reacts with con. HCl and con. H_2SO_4. But it does not react with con. HNO_3. Suggest your answer with proper reason.
14. To design the body of the aircraft aluminium alloys are used. Give your reason.
15. X is a silvery white metal. X reacts with oxygen to form Y. The same compound is obtained from the metal on reaction with steam with the liberation of hydrogen gas. Identify X and Y.

FURTHER REFERENCE:

Books: Text Book of Inorganic chemistry – P.L. Soni S.Chand Publishers

Website: www.tutorvista.com. www.sciencebyjones.com

13. Carbon and its compounds

Symbol	:	C
Atomic Number	:	6
Atomic Mass	:	12
Valency	:	4

The electronic configuration of carbon is K=2, L=4. It has four electrons in the valence shell and belongs to group IV A (group 14) of the periodic table.

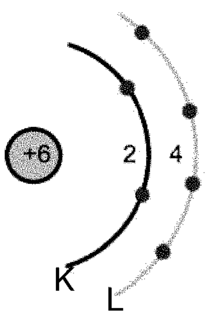


Fig. 13. 1 electronic configuration of carbon

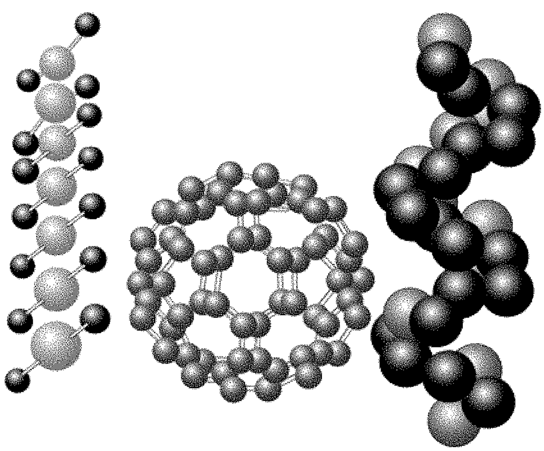


Fig. 13.2 An arrangement depicting carbon and its compounds.

INTRODUCTION

Without carbon, no living thing could survive. Human beings are made up of carbon compounds. Carbon is a non metal. In nature, it occurs in its pure form as **diamond and graphite.** When fuels burn, the carbon in them reacts with oxygen to form carbon dioxide.

Carbon compounds hold the key to plant and animal life on earth. Hence, carbon chemistry is called **Living Chemistry.** Carbon circulates through air, plants, animals and soil by means of complex reactions. This is called **carbon cycle**.

13.1. COMPOUNDS OF CARBON

In the beginning of 19th century scientists classified the compoundsof carbon into two types, based on their source of occurence:

i) Inorganic compounds (obtained from non living matter)
ii) Organic compounds (obtained from living matter, such as plant and animal sources) however the basis of classification was subjected to alteration after wohler synthesis.

LIVING CHEMISTRY

All living organisms are made of carbon atoms. This means that, carbon atoms form the building blocks for living organisms. These carbon atoms, in combination with other atoms decide life on earth. Hence **carbon chemistry** is also called as **living chemistry**.

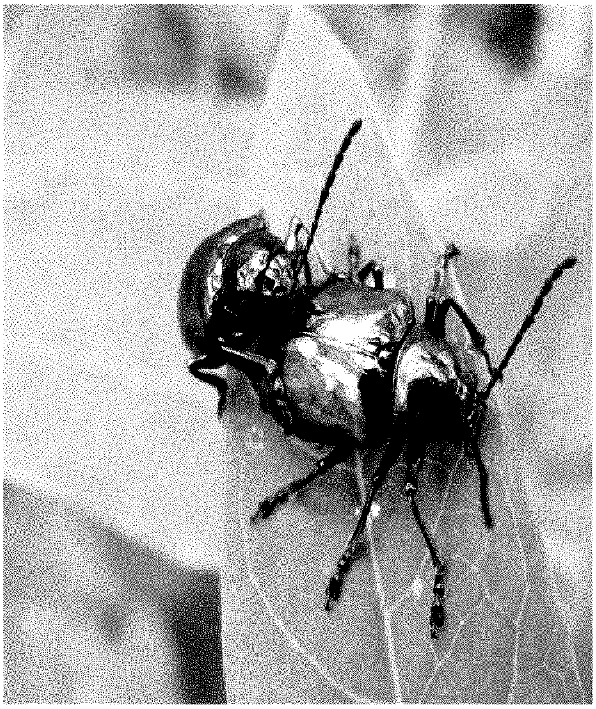


Fig. 13.3

Fig. 13.4

FRIEDRICH WOHLER

A creator of revolution in **ORGANIC CHEMISTRY**

MORE TO KNOW

ORGANIC CHEMISTRY:

The word organic signifies life. The term organic chemistry was used by the Swedish chemist Berzelius. This refers to the chemistry of living things. However, the German chemist Wohler succeeded in creating an organic compound (urea) from an inorganic compound (ammonium cyanate) in his laboratory. This has dealt a severe blow to the Vital force theory (a theory of life process).

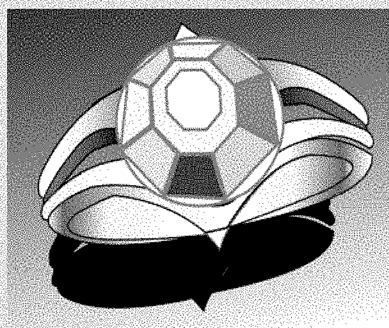
FRIEDRICH WOHLER
A German Chemist

CHEMISTRY

13.2. MODERN DEFINITION OF ORGANIC CHEMISTRY

Organic chemistry is defined as the branch of chemistry that deals with organic compounds which are made up of the hydrocarbons and their derivatives. It gives a thorough insight into the nature of bonding, synthesis, characteristics and their usefulness in various fields.

MORE TO KNOW



A polished diamond

The most precious diamond is a crystalline allotrope of carbon. KOHINOOR DIAMOND is a 105 carat diamond (21.68g) It was seized by the EAST INDIA COMPANY and became the part of British Crown Jewels. May it be an ordinary coal or the most precious Kohinoor diamond,it is an allotropic modification of carbon indeed!

13.3. BONDING IN CARBON AND ITS COMPOUNDS

The atomic number of carbon is 6 and its ground state electronic configuration is $1s^2\ 2s^2\ 2p^2$. Since it has four electrons in its outermost shell, its valency is four. To achieve noble gas configuration, carbon atom has to lose or gain four electrons to form C^{4+} and C^{4-} ions.

1. It could gain four electrons forming C^{4-} anion, but it would be difficult for the nucleus with six protons to hold on to ten electrons i.e.four extra electrons.
2. It could lose four electrons to form C^{4+} cations, but it would require a large amount of energy to remove four electrons leaving behind the carbon cations with six protons in its nucleus holding on to just two electrons.

Carbon overcomes this problem by sharing its valence electrons with other atoms of carbon or with atoms of other elements. *This characteristic of carbon atom by virtue of which it forms four covalent bonds is generally referred as* **tetra valency of carbon.**

A molecule of methane (CH_4) is formed when four electrons of carbon are shared with four hydrogen atoms.

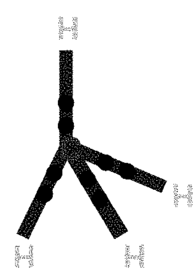


Fig. 13.5 Structure of methane

•• Represents shared pair of electrons

13.4 ALLOTROPY

Allotropy is defined as the property by which an element can exist in more than one form that are physically different but chemically similar.

Allotropes of carbon

- Carbon exists in three allotropic forms. They are crystalline form (diamond and graphite), amorphous form (coke,charcoal) and fullerene.
- In diamond each carbon atom is bonded to four other carbon atoms forming a rigid three dimensional structure, accounting for it's hardness and rigidity.

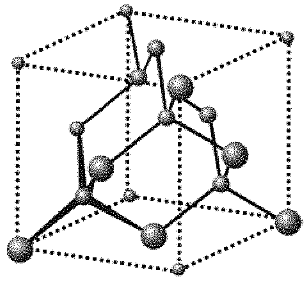


Fig. 13.6 Structure of diamond

- In graphite each carbon atom is bonded to three other carbon atoms in the same plane giving hexagonal layers held together by weak **vander Waals forces** accounting for softness.
- Graphite is a good conductor of electricity unlike other non-metals since it has free electrons in it.

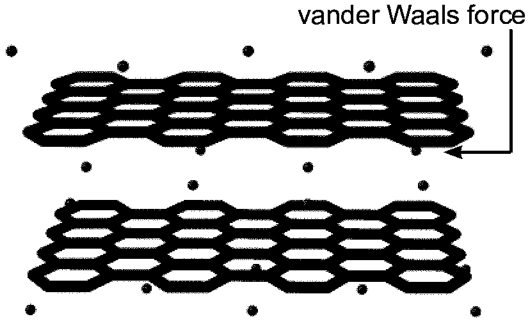


Fig. 13.7 Structure of graphite

- Fullerenes form another type of carbon allotropes. The first one was identified to contain 60 carbon atoms in the shape of a football. (C-60). Since this looks like the geodesic dome designed by the US architect Buck Minster Fuller, it is named as Buck Minster Fullerene.

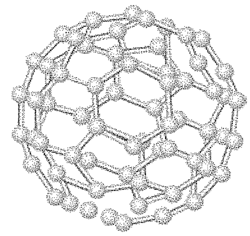


Fig. 13.8 Fullerene

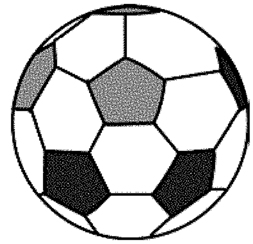


Fig. 13.9 Foot ball

13.5 Physical nature of carbonand its compounds :

- Carbon has the ability to form covalent bonds with other atoms of carbon giving rise to large number of molecules through self linking property This property is called ***catenation***. Since the valency of carbon is four, it is capable of bonding with four other atoms.
- Carbon combines with oxygen, hydrogen, nitrogen, sulphur, chlorine and many other elements to form various stable compounds.
- The stability of carbon compounds is due to the small size of carbon which enables the nucleus to hold on to the shared pair of electrons strongly.
- Carbon compounds show ***isomerism***, the phenomenon by which two or more compounds to have same molecular formula but different structural formula with difference in properties. i.e the formula C_2H_6O represents two different compounds namely ethyl alcohol (C_2H_5OH) and dimethyl ether (CH_3OCH_3).
- Carbon compounds have low melting and boiling points because of their covalent nature.

- The reactions shown by carbon compounds involve breaking of old bonds in the reacting molecules and the formation of new bonds in the product molecules.
- Carbon compounds are easily combustible.

13.6 CHEMICAL PROPERTIES

- Carbon and its compounds burn in oxygen to give carbon dioxide along with heat and light.

e.g.,

$C + O_2 \rightarrow CO_2$ + heat + light

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + heat + light

$C_2H_5OH + 2O_2 \rightarrow 2CO_2 + 3H_2O$ + heat + light

- Carbon compounds can be easily oxidized using suitable oxidizing agent Alkaline potassium permanganate to form carboxylic acids.
- Unsaturated carbon compounds undergo addition reactions with hydrogen in the presence of palladium or nickel catalyst.

e.g.,

$$\underset{\text{Ethene}}{CH_2 = CH_2} \xrightarrow[\text{Ni-catalyst}]{\text{Addition of hydrogen}} \underset{\text{Ethane}}{CH_3 - CH_3}$$

- Carbon compounds undergo substitution reactions in the presence of either sunlight or any other reagents. e.g., methane undergoes substitution reaction to form different types of products.
- Carbon compounds such as alcohols react with sodium to liberate hydrogen gas.

e.g., $2CH_3CH_2OH + 2Na \rightarrow 2CH_3CH_2ONa + H_2$

13.7 HOMOLOGOUS SERIES

A homologous series is a group or a class of organic compounds having similar structure and similar chemical properties in which the successive compounds differ by a CH_2 group.

13.7.1 Characteristics of homologous series

- Each member of the series differs from the preceeding or succeeding member by a common difference of CH_2 and by a molecular mass of 14 amu (amu = atomic mass unit).
- All members of homologous series contain same elements and the same functional groups.
- All members of homologous series have same general molecular formula.

e.g **Alkane = C_nH_{2n+2}**

Alkene = C_nH_{2n}

Alkyne = C_nH_{2n-2}

- The members in homologous series show a regular gradation in their physical properties with respect to increase in molecular mass.
- The chemical properties of the members of the homologous series are similar.
- All members of homologous series can be prepared by using same general method.

13.8 IMPORTANCE OF HOMOLOGOUS SERIES

1. It helps to predict the properties of the members of the series that are yet to be prepared.
2. Knowledge of homologous series gives a systematic study of the members.
3. The nature of any member of the family can be ascertained if the properties of the first member are known.

13.9 HYDROCARBONS

The simplest organic compounds containing only carbon and hydrogen are called ***Hydrocarbons***. These are regarded as the **parent organic compounds** and all other compounds are considered to be derived from them by the replacement of one or more hydrogen atoms by other atoms or groups of atoms.

Hydro carbons are classified into two types: *saturated and unsaturated hydrocarbons*.

13.9.1 Saturated hydrocarbons – Alkanes

General formula = C_nH_{2n+2} Suffix : ane

These are the organic compounds which contain carbon – carbon single bond. These were earlier named as **paraffins** (Latin : meaning little affinity) due to their least chemical reactivity. According to IUPAC system, these are named as ***alkanes*** (ane is suffix with root word).

Formula	Common name	IUPAC name
CH_4	Methane	Methane
CH_3CH_3	Ethane	Ethane
$CH_3CH_2CH_3$	Propane	Propane
$CH_3CH_2CH_2CH_3$	n-Butane	Butane

13.9.2 Unsaturated hydrocarbons

These are hydrocarbons which contain carbon to carbon double bonds $\left(-\overset{|}{C}=\overset{|}{C}-\right)$ or carbon to carbon triple bonds **$-C\equiv C-$** in their molecules. These are further classified into two types: *alkenes and alkynes.*

i) ***Alkenes*: *General formula:* C_nH_{2n} *Suffix:* ene**

The hydrocarbons containing atleast one carbon to carbon double bond are called ***alkenes.*** They have the general formula C_nH_{2n} . These were previously called ***olefins*** (Greek : olefiant – oil forming) because the lower gaseous members of the family form oily products when treated with chlorine.

In IUPAC system, the name of alkene is derived by replacing suffix **ane** of the correspding alkane by **ene**. For example,

CH_3-CH_3	$H_2C=CH_2$
ethane	ethene

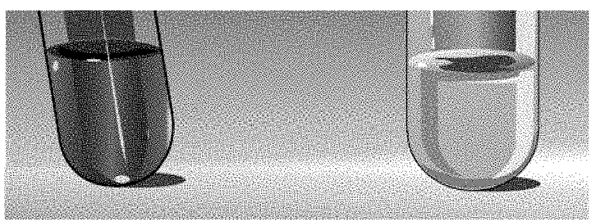


Fig. 14.0 Bromine Test

(Left) No change in colour - saturated, (Right) Decolouration occurs - unsaturated

In higher alkenes, the position of the double bond, can be indicated by assigning numbers 1, 2, 3, 4, ……to the carbon atoms present in the molecule.

Alkene	Common name	IUPAC name
$CH_2 = CH_2$	Ethylene	Ethene
$CH_3CH = CH_2$	Propylene	Propene
$CH_3CH_2–CH=CH_2$	α-Butylene	But–1–ene
$CH_3CH = CHCH_3$	β-Butylene	But–2–ene

ii) ***Alkynes***: ***General formula:*** C_nH_{2n-2} ***Suffix :*** **yne**

The hydrocarbons containing carbon to carbon triple bond are called *alkynes*. Alkynes are named in the same way as alkenes i.e., by replacing suffix **ane** of alkane by **yne.** In higher members, the position of triple bond is indicated by giving numbers 1, 2, 3, 4, ….to the carbon atom in the molecule.

Alkyne	Common name	IUPAC name
$HC \equiv CH$	Acetylene	Ethyne
$H_3C – C \equiv CH$	Methyl acetylene	Propyne
$H_3C – C \equiv C – CH_3$	Dimethyl acetylene	But–2-yne
$H_3C - CH_2 –C \equiv CH$	Ethyl acetylene	But–1–yne

13.10. FUNCTIONAL GROUP

Functional group may be defined as an atom or group of atoms or reactive part which is responsible for the characteristic properties of the compounds. The chemical properties of organic compounds are determined by the functional groups while their physical properties are determined by the remaining part of the molecule.

Example: -OH => Alcohol | >C=O => Ketone

-CHO => Aldehyde | -COOH => Carboxylic acid

13.10.1. Classification of organic compounds based on functional group

1. Alcohols

Alcohols are carbon compounds containing **–OH** group attached to alkyl group. The general formula of alcohol is **R-OH** where '**R**' is an **alkyl group** and **–OH** is the **functional group**. The IUPAC name of alcohol is derived by replacing –**e**, in the word **alkane,** by the suffix –**ol**. Hence we get the name **alkanol**.

Molecular formula	Common name	IUPAC name
CH_3OH	Methyl alcohol	Methanol
CH_3-CH_2-OH	Ethyl alcohol	Ethanol
CH_3- CH_2-CH_2-OH	n-Propyl alcohol	1-Propanol
CH_3-CH-CH_3 I OH	Isopropyl alcohol or secondary propyl alcohol	2-Propanol
CH_3- CH_2-CH_2-CH_2-OH	n-Butyl alcohol	1-Butanol
CH_3-CH-CH_2-OH I CH_3	Isobutyl alcohol	2-Methyl-1-propanol

2. Aldehydes

Aldehydes are carbon compounds containing -**CHO** group attached to alkyl group or hydrogen atom. The general formula of aldehydes is **R – CHO** where **'R'** is an **alkyl group** or **hydrogen atom** and – **CHO** is the **functional group**. The IUPAC name of aldehyde is derived by replacing –**e**, in the word alkane, by the suffix –**al**. Hence we get the name **"alkanal"**.

Molecular formula	Common name	IUPAC name
HCHO	Formaldehyde	Methanal
CH_3- CHO	Acetaldehyde	Ethanal
CH_3- CH_2- CHO	Propionaldehyde	Propanal
CH_3- CH_2-CH_2- CHO	Butyraldehyde	Butanal

3. Ketones

Ketones are carbon compounds containing carbonyl – **CO** – group attached to two alkyl groups. The general formula of ketone is **R-CO-R'** where **R** and **R'** are **alkyl groups** and – **CO** – is the **functional group**. The IUPAC name of ketone is derived by replacing –**e**, in the word alkane, by the suffix -**one**. Hence we get the name **"alkanone"**.

Molecular formula	Common name	IUPAC name
CH_3COCH_3	Dimethyl ketone (Acetone)	Propanone
$CH_3COCH_2CH_3$	Ethyl methyl ketone	2-Butanone
$CH_3CH_2COCH_2CH_3$	Diethyl ketone	3-Pentanone

4. Carboxylic Acids

Carboxylic acids are carbon compounds containing **–COOH** group attached to a hydrogen atom or alkyl group. The general formula of acid is **R-COOH** where **'R'** is a **hydrogen atom** or **alkyl group** and **–COOH** is the **functional group**. The IUPAC name of acid is derived by replacing – e, in the word alkane, by the suffix –oic acid. Hence we get the name **"alkanoic acid"**.

Molecular formula	Common name	IUPAC name
HCOOH	Formic acid	Methanoic acid
CH_3-COOH	Acetic acid	Ethanoic acid
CH_3- CH_2-COOH	Propionic acid	Propanoic acid
CH_3- CH_2-CH_2-COOH	n-Butyric acid	Butanoic acid

SOME IMPORTANT ORGANIC COMPOUNDS

Almost all the compounds are useful to us in a number of ways. Most of the fuels, medicines, paints, explosives, synthetic polymers, perfumes and detergents are basically organic compounds. In fact, organic chemistry has made our life colourful and also comfortable. Two commercially important compounds, ethanol and ethanoic acid are briefly discussed here.

13.11 ETHANOL (C_2H_5OH)

Ethanol or ethyl alcohol or simply alcohol is one of the most important members of the family of alcohols.

(1) Manufacture of ethanol from molasses

Molasses is a dark coloured syrupy liquid left after the crystallization of sugar from the concentrated sugar cane juice. Molasses still contain about 30% of sucrose which cannot be separated by crystallization. It is converted into ethanol by the following steps:

(i) Dilution

Molasses is first diluted with water to bring down the concentration of sugar to about 8 to 10 percent.

(ii) Addition of ammonium salts

Molasses usually contains enough nitrogenous matter to act as food for yeast during fermentation. If the nitrogen content of the molasses is poor, it may be fortified by the addition of ammonium sulphate or ammonium phosphate.

(iii) Addition of yeast

The solution from step (ii) is collected in large 'fermentation tanks' and yeast is added to it. The mixture is kept at about 303K for a few days.During this period, the enzymes invertase and zymase present in yeast, bring about the conversion of sucrose into ethanol.

$$\underset{\text{Sucrose}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{\text{invertase}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{zymase}} \underset{\text{Ethanol}}{2C_2H_5OH} + 2CO_2\uparrow$$

The fermented liquid is technically called wash.

(iv) Distillation of wash

The fermented liquid containing 15 to 18 percent alcohol and the rest of the water, is now subjected to fractional distillation. The main fraction drawn, is an aqueous solution of ethanol which contains 95.5% of ethanol and 4.5% of water. This is called rectified spirit. This mixture is then heated under reflux over quicklime for about 5 to 6 hours and then allowed to stand for 12 hours. On distillation of this mixture, pure alcohol (100%) is obtained. This is called absolute alcohol.

MORE TO KNOW

FERMENTATION :

The slow chemical change taking place in an organic compound by the action of enzymes leading to the formation of smaller molecules is called fermentation.

2. Physical properties

(i) Ethanol is a clear liquid with burning taste.

(ii) Its boiling point is 351.5 K which is higher than corresponding alkane.

(iii) It is completely miscible with water in all proportions.

3. Chemical properties

(i) Dehydration

(a) Intra molecular dehydration : Ethanol, when heated with excess conc. H_2SO_4 at 443 K undergoes intra molecular dehydration (i.e. removal of water within a molecule of ethanol).

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[443K]{Conc.H_2SO_4} \underset{\text{Ethene}}{CH_2{=}CH_2 + H_2O}$$

(b) Intermolecular dehydration : When excess of alcohol is heated with conc. H_2SO_4 at 413K two molecules condense by losing a molecule of water to form ether (i.e. removal of water from two molecules of ethanol).

$$C_2H_5\text{-}OH + HO\text{-}C_2H_5 \xrightarrow[413K]{Conc.H_2SO_4} \underset{\text{Diethyl ether}}{C_2H_5\text{-}O\text{-}C_2H_5} + H_2O$$

(ii) Reaction with sodium : Ethanol reacts with sodium metal to form sodium ethoxide and hydrogen gas.

$$2C_2H_5OH + 2Na \longrightarrow \underset{\text{sodium ethoxide}}{2C_2H_5ONa} + H_2\uparrow$$

(iii) Oxidation : Ethanol is oxidized to ethanoic acid with alkaline $KMnO_4$ or acidified $K_2Cr_2O_7$

$$CH_3CH_2OH \xrightarrow{Oxidation} \underset{\text{Ethanoic acid}}{CH_3COOH} + H_2O$$

During this reaction, orange colour of $K_2Cr_2O_7$ changes to green. Therefore, this reaction can be used for the **identification of alcohols**.

(iv) Esterificaiton : Ethanol reacts with ethanoic acid in the presence of conc.H_2SO_4 (catalyst) to form ethyl ethanoate and water. The compound formed by the reaction of an alcohol with carboxylic acid is known as ester (fruity smelling compound) and the reaction is called esterification.

$$\underset{\text{Ethanol}}{C_2H_5OH} + \underset{\text{Ethanoic acid}}{CH_3COOH} \xrightarrow{\text{conc.}H_2SO_4} \underset{\text{Ethyl ethanoate}}{CH_3COOC_2H_5} + H_2O$$

(v). Dehydrogenation : When the vapour of ethanol is passed over reduced copper catalyst at 573 K, it is dehydrogenated to acetaldehyde.

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow[573\ K]{Cu} \underset{\text{Acetadehyde}}{CH_3CHO} + H_2$$

4. Uses

Ethanol is used

1. as an anti-freeze in automobile radiators.
2. as a preservative for biological specimen.
3. as an antiseptic to sterilize wounds in hospitals.
4. as a solvent for drugs, oils, fats, perfumes, dyes, etc.
5. in the preparation of methylated spirit (mixture of 95% of ethanol and 5% of methanol), rectified spirit (mixture of 95.5% of ethanol and 4.5% of water), power alcohol (mixture of petrol and ethanol) and denatured spirit (ethanol mixed with pyridine).
6. in cough and digestive syrups.

Evil effects of consuming alcohol

- If ethanol is consumed, it tends to slow down metabolism of our body and depresses the central nervous system.
- It causes mental depression and emotional disorder.
- It affects our health by causing ulcer, high blood pressure, cancer,
- brain and liver damage.
- Nearly 40% accidents are due to drunken drive.

- Unlike ethanol, intake of methanol in very small quantities can cause death.
- Methanol is oxidized to methanal (formaldehyde) in the liver and methanal reacts rapidly with the components of cells.
- Methanal causes the protoplasm to get coagulated, in the same way an egg is coagulated by cooking. Methanol also affects the optic nerve, causing blindness.

13.12. ETHANOIC ACID (CH_3COOH)

Ethanoic acid is most commonly known as acetic acid and belongs to a group of acids called carboxylic acids. Acetic acid is present in many fruits and sour taste of fruits is because of this acid.

1. Preparation of Ethanoic acid

Ethanol on oxidation in the presence of alkaline potassium permanganate or acidified potassium dichromate gives ethanoic acid.

2. Physical properties

$$\underset{\text{Ethanol}}{CH_3CH_2OH} \xrightarrow{\text{Oxidation}} \underset{\text{Ethanoic acid}}{CH_3COOH} + H_2O$$

(i) Ethanoic acid is a colourless liquid and has a sour taste.

(ii) It is miscible with water in all proportions.

(iii) Boiling point (391 K) is higher than corresponding alcohols, aldehydes and ketones.

(iv) On cooling, pure ethanoic acid is frozen to form ice like flakes. They look like glaciers, so it is called glacial acetic acid.

3. Chemical properties

(i) Ethanoic acid is a weak acid but it turns blue litmus to red.

(ii) Reaction with metal

Ethanoic acid reacts with metals like Na, K, Zn, etc to form metal ethanoate and hydrogen gas.

$$2CH_3COOH + Zn \longrightarrow (CH_3COO)_2Zn + H_2\uparrow$$

$$2CH_3COOH + 2Na \longrightarrow 2CH_3COONa + H_2\uparrow$$

(iii) Reaction with carbonates and bicarbonates.

Ethanoic acid reacts with carbonates and bicarbonates and produces brisk effervescence due to the evolution of carbon dioxide.

$$2CH_3COOH + Na_2CO_3 \longrightarrow 2CH_3COONa + CO_2\uparrow + H_2O$$

$$CH_3COOH + NaHCO_3 \longrightarrow CH_3COONa + CO_2\uparrow + H_2O$$

(iv) Reaction with base

Ethanoic acid reacts with sodium hydroxide to form sodium ethanoate and water.

$$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$$

(v) Decarboxylation (Removal of CO_2)

When sodium salt of ethanoic acid is heated with soda lime (Solid mixure of 3 parts of NaOH and 1 part of CaO) methane gas is formed.

$$CH_3COONa \xrightarrow{NaOH\ /\ CaO} CH_4\uparrow + Na_2CO_3$$

4. USES

Ethanoic acid is used

1. for making vinegar which is used as a preservative in food and fruit juices.
2. as a laboratory reagent.
3. for coagulating rubber from latex.
4. in the preparation of dyes, perfumes and medicine.

EVALUATION

PART - A

1. Assertion: Chemical bonds in organic compounds are covalent in nature. Reason: Covalent bond is formed by the sharing of electrons in the bonding atoms. Does the reason satisfy the given assertion.

2. Assertion: Diamond is the hardest crystalline form of carbon Reason: Carbon atoms in diamond are tetrahedral in nature (Verify the suitability of reason to the given Assertion mentioned above)

3. Assertion: Due to catenation a large number of carbon compounds are formed.
Reason: Carbon compounds show the property of allotropy.
(Is the reason holding good for the given Assertion)

4. Buckminster fullerene is the allotropic form of (Nitrogen / Carbon / Sulphur)

5. Eventhough it is a non metal, graphite conducts electricity. It is due to the presence of ____________(free electrons / bonded electrons)

6. Formula of methane is CH_4 and its succeeding member ethane is expressed in C_2H_6. The common difference of succession between them is (CH_2 / C_2H_2)

7. IUPAC name of first member of alkyne is ____________ (ethene / ethyne)

8. Out of ketonic and aldehydic group which is the terminal functional group?

9. Acetic acid is heated with a solid 'X' kept in a test tube. A colourless and odourless gas (Y) is evolved. The gas turns lime water milky when passed through it. Identify X and Y.

10. Assertion: Denaturation of ethyl alcohol makes it unfit for drinking purposes.
Reason: Denaturation of ethyl alcohol is carried out by methyl alcohol.
Check whether the reason is correct for assertion.

PART - B

11. Write down the possible isomers and give their IUPAC names using the formula C_4H_{10}.

12. Diamond is the hardest allotrope of Carbon. Give reason for its hardness.

13. An organic compound (A) is widely used as a preservatives in pickles and has a molecular formula $C_2H_4O_2$. This compound reacts with ethanol to form a sweet smelling compound (B).

    (i) Identify the compound A and B.

    (ii) Name the process and write corresponding chemical equation.

14. An organic compound (A) of molecular formula C_2H_6O on oxidation with alkaline $KMnO_4$ solution gives an acid (B) with the same number of carbon atoms. Compound A is used as an antiseptic to sterilize wounds in hospitals. Identify A and B. Write the chemical equation involved in the formation of B from A.

PART - C

15. Fill in the blanks using suitable formula in the given table

No.	Alkane	Alkene	Alkyne
1.	C_2H_6 ethane	______ethene	C_2H_2 ethyne
2.	______Propane	C_3H_6 Propene	______propyne
3.	C_4H_{10} Butane	______Butene	______Butyne

16. Homologous series predict the properties of the members of hydrocarbon. Justify this statement through its characteristics.

17. Write the common name and IUPAC name of the following.

a) CH_3CH_2CHO

b) CH_3COCH_3

c) $CH_3 - \underset{\displaystyle OH}{\underset{|}{CH}} - CH_3$

d) CH_3COOH

e) HCHO

FURTHER REFERENCE

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2.Organic chemistry - **R.T. Morrision & R.N. Boyd** - Practice Hall Publishers.

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