CHAPTER-1
PERIODIC PROPERTIES AND VARIATIONS OF PROPERTIES

Topic-1

Periodic properties and their Variations

Concepts covered: • *Features of Modern Periodic Table,* • *Trends of the periodic properties in periodic table.*

Revision Notes

- **General Introduction of Periodic Table:**
  - According to modern periodic table, "The physical and chemical properties of elements are the periodic function of their atomic number."
  - Niels Bohr gave the extended form of the table known as long form of the modern periodic table.
  - A tabular arrangement of elements in groups (vertical columns) and periods (horizontal rows) highlighting the regular trends in properties of elements is known as periodic table.
- **Salient Features of the modern periodic table:**

Groups:

There are 1 to 18 vertical columns arranged from left to right in the modern periodic table known as groups. It is assigned depending upon the number of the valence electrons.

- Group 1 elements are called alkali metals. They form strong alkalis with water.
- Group 2 elements are called alkaline earth metals. They form weaker alkalis as compared to group 1.
- Group 13 elements are known as boron family.
- Group 14 elements are known as carbon family.
- Group 15 elements are known as nitrogen family (Pnictogen).
- Group 16 elements are known as oxygen family or chalcogen family.
- Group 17 elements are called halogen family. They form salts with metallic elements.
- Group 18 (zero group) elements are called noble gases or inert gases. Due to stable electronic configuration, they hardly react with other elements.

The elements of groups 1, 2, 13, 14, 15 , 16 and 17 are known as the main group elements or representative elements. The outermost shell of all the elements of these groups are incomplete. The elements of group 3, 4, 5, 6, 7, 8, 9, 10, 11 and 12 are known as transition elements. They have their two outermost shells incomplete.

Periods:

There are seven horizontal rows in the modern periodic table, called periods.

“The number of shells present in an atom determines its period.”

- First period is the shortest period containing only two elements, i.e., hydrogen and helium.
- Second period is a short period containing eight elements (Li, Be, B, C, N, O, F and Ne).
- Third period is also a short period containing eight elements (Na, Mg, Al, Si, P, S, Cl and Ar).
- Fourth and fifth periods are long periods, each containing eighteen elements (atomic numbers 19 to 36 in the fourth period and atomic numbers 37 to 54 in the fifth period).
- Sixth and seventh periods are longest periods, each containing 32 elements (atomic numbers 55 to 86 in the sixth period and atomic numbers 87 to 118 in the seventh period).

Periods	Number of elements
1	2
2	8
3	8
4	18
5	18
6	32
7	32

- In group 3 and sixth period, the elements from atomic numbers 57 to 71 are present which are called as Lanthanides (rare earth metals).
- In group 3 and seventh period, the elements from atomic numbers 89 to 103 are present which are called Actinides (radioactive elements).

- The recurrence of elements with similar properties after certain regular intervals when these are arranged in the increasing order of their atomic number is called periodicity.
- The recurrence of similar electronic configuration, i.e., having same number of electron in the outermost orbit is the cause of periodicity.
- The chemical properties of elements depend upon the number of electrons in their outermost shell, so, elements of the same group have similar properties.

  Example: Characteristics of Halogens:
  - They are coloured nonmetals.
  - They form anions, e.g., Cl^-.
  - They are very reactive and so, found in combined state.
  - Their melting and boiling points increase on moving down the group.
  - They are good oxidising agents.

- **Atomic Size (Atomic Radius):**

  Atomic size is the most probable distance from the centre of the nucleus to the outermost shell of electrons.

  Atomic size depends upon the number of shells and nuclear charge.

  (i) Number of shells: An increase in the number of shells increases the size of an atom, because the distance between the outermost shell electrons and the nucleus increases.

  (ii) Number charge: The positive charge present on the nucleus of an atom is called nuclear charge. An increase in nuclear charge decreases the size of the atom because nucleus attracts the electrons more closer towards itself leading to the decrease in atomic size.

  Trends in Atomic Size:

  (i) Down a group: Atomic size increases on moving down a group, i.e., from top to bottom due to increase in the number of shells which over-weighs the increased nuclear charge.

  (ii) Across a period: Atomic size decreases from left to right across a period due to increase in the effective nuclear charge (atomic number).

- **Metallic Character:**

  It refers to the tendency of a metal to lose their valence electrons to form a cation (positive ion). Thus, larger the tendency of a metal to lose their valence electrons, greater is their metallic character.

  Trends in Metallic Character:

  (i) Down a group: Metallic character increases down a group due to increase in atomic size nd nuclear charge.

  (ii) Across a period: Metallic character decreases across a period i.e., on moving from left to right.

- **Non-Metallic Character:**

  Non-metallic character refers to the tendency of a non-metal to gain electrons to form an anion (negative ion).

- **Trends in Non-metallic Character:**

  (i) Down a group: Non-metallic character decreases down a group due to increase in atomic size and nuclear charge.

  (ii) Across a period: Non-metallic character increases across a period (left to right) due to decrease in atomic size.

Mnemonics

Mnemonics for first 20 elements : (1 to 20)
First 10 elements.
Mnemonics:
Hi, **H**ello **L**isten **BBC** **N**ews on **F**riday **N**ight
Interpretation:
Hi – Hydrogen
Hello – Helium
Listen – Lithium
B – Beryllium
B – Boron

C – carbon
News – Nitrogen
On – Oxygen
Friday - Fluorine
Night - Neon

Second 10 elements.
Mnemonics:
Na **M**ango **A**man Se **P**epsi **S**oda **C**ola **A**ur **K**eemti **C**ar
Interpretation:
Na - sodium
Mango – Magnesium
Aman – Aluminium
Se – Silicon
Pepsi – Phosphorus

Soda – Sulphur
Cola – Chlorine
Aur – Argon
Keemti – Potassium
Car – Calcium

Key Terms

- **Periodic Table:** It is n arrangement of various elements in such a way that the similar property bearing elements are grouped together and dissimilar property bearing elements are separated from each other.
- **Modern Periodic Law:** The physical and chemical properties of the elements are the periodic functions of their atomic numbers.
- **Periodic Properties:** These are the properties related to the electronic configuration of elements that change periodically down a group and across a period.
- **Periodicity:** The recurrence of elements with similar properties after certain regular intervals when these are arranged in the increasing order of their atomic number is called periodicity.
- **Cause of Periodicity:** The cause of periodicity is the recurrence of similar electronic configuration, i.e., same number of electrons in the outermost orbit. In a particular group, electrons in the outermost orbit remain the same, i.e, electronic configuration is similar.
- **Valency:** It is the combining capacity of an atom of the element. For normal elements, valency is equal to the number of valence electrons in an atom of the element (Ex: group 1, 2 and 3) or eight minus number of electrons in the valence shell of an atom (Ex: Group 15,16 and 17).

Key Terms

- In the modern periodic table,
  - Elements are arranged in order of increasing atomic number.
  - The vertical columns of elements with similar properties are called groups.
  - The horizontal rows are called periods.
- Valency depends on the number of electrons in the outer most shell.
  - If number of electrons in the outer most shell = 1, 2, 3 or 4
    then their valency = 1, 2, 3 or 4 respectively
  - If the number of electrons present in the outermost shell = 5, 6 or 7
    then their valency = 8 – 5 = 3, 8 – 6 = 2 and 8 – 7 = 1
- Valency is the combining capacity, so it is always positive.

Topic-2

Periodicity and related Properties

Concepts covered:
- *Periodicity on the basis of: 1. Atomic number, 2. Nuclear charge,*
- *Study of different groups in periodic table*

Revision Notes

- The **atomic number(Z)** of an element is equal to the number of protons in the nucleus.
  However, it a unique property of an element because no two elements have the same atomic number.
  Atomic Number(Z) = Number of protons (p)
  Number of electrons (e)
  - **(i)** It gives the electronic configuration of an element, e.g., an element with atomic number 13 will have electronic configuration 2, 8, 3.
  - **(ii)** It helps in finding the position of element in periodic table. For example, the element with atomic number 17 will have electronic configuration 2, 8, 7. This element will be placed in the 3rd period of group 17, i.e., VIIA, because it has: (i) three energy shell and (ii) seven electrons in its outermost shell.
- The **mass number(A)** of an element is the sum of number of protons and neutrons in the nucleus of an atom of that element.
  Mass Number (A) = Number of protons (p) + Number of neutrons (n)
  However, if we look at the electronic configurations of lighter elements it reveals that those elements which have even number of protons, for example, atomic numbers like $^{4}_{2}\text{He}$, $^{12}_{6}\text{C}$, etc., have their mass numbers twice the atomic numbers except $^{9}_{4}\text{Be}$ and $^{40}_{18}\text{Ar}$.
  Elements which have odd number of protons like $^{7}_{3}\text{Li}$, $^{11}_{5}\text{B}$, $^{19}_{9}\text{F}$, $^{23}_{11}\text{Na}$, etc., have their mass numbers twice the atomic numbers +1 (A = 2Z+1) except $^{14}_{7}\text{N}$ and $^{1}_{1}\text{H}$.

(i) Elements with n/p (neutron/proton) ratio around 1 are stable, e.g., light metals like sodium, potassium, calcium, etc.

(ii) Elements with n/p ratio 1.5 and above are radioactive, i.e., they emit radiations. They are unstable elements, e.g., heavy metals like uranium.

- **Ionization Energy or Ionization Potential:**

  (First) Ionization enthalpy is the amount of energy required to remove one valency electron from an isolated neutral gaseous atom.

  Trends in Ionization Energy:

  (i) Down a group: Ionisation energy decreases due to an increase in atomic number and atomic size as one moves down a group.

  (ii) Across a period: Ionisation energy tends to increase across a period. This is because as one moves from left to right, the atomic size decreases due to increase in the nuclear charge. Thus, more energy is required to remove the electron(s).

- **Electron Affinity (EA) or Electron Gain Enthalpy:**

  The amount of energy released when one electron is added to a neutral gaseous atom to form a monovalent negative ion.

  $$X(g) + e^- \longrightarrow X^-(g) + EA$$

  X is any element taken in its gaseous state.

  Trends in Electron Affinity:

  (i) Down a group: As we move from top to bottom in a group, the atomic size increases more than the nuclear charge, so there is a net decrease in electron affinity.

  (ii) Across a period: As we move from left to right, the atomic size decreases and nuclear charge increases and the electron affinity increases.

- **Electronegativity:**

  Electronegativity is the relative tendency of an atom in a molecule to attract the shared pair of electrons towards itself. Noble gases have complete octet, so they do not have tendency to attract electrons.

  Trends in Electronegativity

  (i) Down a group: Electronegativity decreases down a group.

  (ii) Across a period: Electronegativity increases from left to right in a period. This is due to an increase in atomic number and nuclear charge.

Key Words

- **Metals:** The elements, which posses a tendency to lose their valence electrons and form a positive ion, are considered as metals.
- **Non-metals:** The elements, which posses a tendency to gain electrons, in order to attain octet in their outermost orbit, are considered as non-metals.
- **Atomic Number:** The number of protons in the nucleus.
- **Mass Number:** It is the sum of the number of protons and neutrons in the nucleus of the atom of that element.

Key Terms

- 1Å = 10^{-10} m
- 1 pm = 10^{-12} m
- In group 17, the size of fluorine is smallest.

F	<	Cl	<	Br	<	I	<	At
64 pm		99 pm		114 pm		133 pm		140 pm

- In the third period, sodium atom is largest in size and chlorine atom is smallest.

Na	>	Mg	>	Al	>	Si	>	P	>	S	>	Cl
186 pm		160 pm		143 pm		117 pm		110 pm		104 pm		99 pm

- Exceptionally, the atomic size of inert gases are bigger. It is due to the fact that the outer shell of inert gas is complete. They have the maximum number of electrons in the outermost orbit so the electronic repulsions are maximum. (Noble gases have fully filled outer shell due to which their radius is expressed as Vander Waal's radius which represents the overall size of the atom which includes its valence shell in a non-bonded situation.) Thus, the size of the atom of an inert gas is bigger.

- Cation is always smaller than the parent atom, because, cation is formed by the loss of electrons, so, protons are more than electrons in a cation. Therefore, electrons are strongly attracted by the nucleus, hence the size decreases.
- Anion is larger then the parent atom, because, anion is formed by the gain of electrons, so the number of electron are more than protons. The effective positive charge in the nucleus is less so less inward pull takes place. Hence, the size of anion increases.
- The ions having the same number of electrons are called isoelectronic ions. Greater is the nuclear charge, smaller is the size.

  e.g., Mg^{2+} (10 electrons)
  Na^{+} (10 electrons)
  F^{-} (10 electrons)
  O^{2-} (10 electrons)
- Elements which lose electrons to complete their octet are called reducing agents. Metals are good reducing agents. Greater the tendency to lose electrons (s), stronger is the reducing agent.
- The oxides of elements in a particular period show decreasing basic nature and finally become acidic.

  e.g.,

Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	SO_3	Cl_2O_7
Strongly basic	Basic	Amphoteric	Feebly acidic	Acidic	More acidic	Most acidic

- The basic nature of oxides of metals increases down the group.
- Helium will have the highest ionization energy (I.E. 2372 kJ mol^{-1}) whereas caesium will have the lowest ionization energy (375 kJ mol^{-1}).
- Metals usually have low I.E. while non-metals have high I.E.
- The elements of the second period exhibit resemblance in properties with the elements of the next group of the third period, due to very less electronegativity difference. This leads to a diagonal relationship. e.g., Li and Mg, Be and Al, B and Si. These elements are known as **bridge elements**.

Group →	1		2		13		14
Period 2	Li		Be		B		C
		⤡		⤡		⤡	
Period 3	Na		Mg		Al		Si

- Atomic number (Z) = Number of protons (p) = Number of electrons (e)
- Mass number (A) = Number of proton (p) + Number of neutrons (n)

❑❑

CHAPTER-2
CHEMICAL BONDING

Topic-1

Electrovalent and Covalent Bonding

Concepts covered: • *Electron dot structures,* • *Electrovalent bonding and its properties,* • *Covalent bonding and its properties.*

Revision Notes

- Stability of an atom means possessing the electron arrangement of an inert gas, i.e., octet in its outermost shell.
- To attain stability, atoms tends to combine chemically by the redistribution of electrons in the outermost shell or valence electrons in the outermost shell so that they attain a **stable electronic configuration** (duplet or octet).
- Chemical combination occurs due to tendency of elements to acquire the nearest noble gas configuration in their outermost orbit.
- An atom is electrically neutral. The number of positively charged particles (i.e., proton) is equal to the number of negatively charged particles (i.e., electrons). Every atom tries to attain the stable configuration of nearest inert gas, i.e., eight electrons in the valence shell. Atoms attain the stable electronic configuration by either losing, gaining or sharing electrons.
- The force of attraction that holds two atoms together to maintain the stability of a molecule is called **chemical bond.** Atoms form chemical bonds in order to attain stable electronic configuration of the nearest noble gas with the release of energy.

A stable electronic configuration is achieved by:

(i) transfer of valence electrons from one atom to another (ionic bond or electrovalent bond).

(ii) sharing the pairs of electrons between two atoms (covalent bond).

(iii) donation of a pair of electrons from one atom to another (coordinate bond).

- **Electrovalent Bond**

A chemical bond formed by the transfer of valence electrons from one atom (metal) to another atom (non-metal) is called an **electrovalent** or an **ionic bond.**

- **Electrovalency**

The number of electrons lost or gained by an atom to form an electrovalent bond is called **electrovalency.**

Conditions for the formation of an electrovalent bond are:

(i) Low ionisation potential (ii) High electron affinity

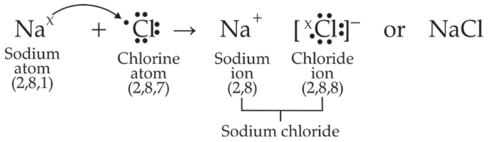
(iii) Large electronegativity difference

- **Electron Dot Structure**

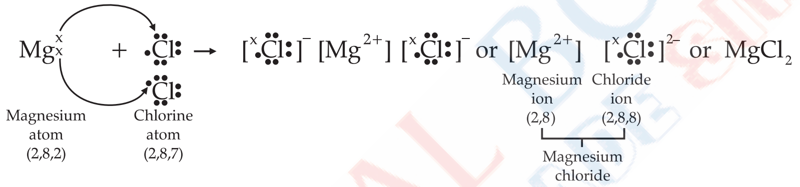
The symbolic representation of an element indicating their valence shell electrons is called **electron dot structure** or **Lewis structure.** *For example,* Electron dot structure for hydrogen is H• and for oxygen is $:\ddot{O}:$

- **Electron Dot Structure of Some Electrovalent Compounds:**

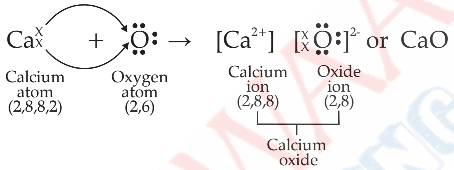
(i) NaCl



(ii) $MgCl_2$



(iii) CaO



- **Properties of Electrovalent Compounds:**

(i) Electrovalent or Ionic compounds are hard solids. As their constituent particles are ions that are held by strong electrostatic forces of attraction, hence they cannot be separated easily.

(ii) Ionic compounds have high melting point and boiling point. They are non-volatile solids. As in these compounds ions are held by strong electrostatic forces of attraction so there exists a large amount of attraction between the ions.

(iii) Ionic compounds do not conduct electricity in their solid state as the ions are not free. They are held by strong electrostatic forces of attraction. However they can conduct electricity in their fused, molten and in their aqueous solution. However, in their molten state the strong forces of attraction gets weakened and thus, the ions become free to conduct electricity. In aqueous solution, the high dielectric constant overcomes strong electrostatic forces of attraction thus, the ions become free to carry the electric current so they also act as strong electrodes.

(iv) Ionic compounds are soluble in water but they are insoluble in organic solvents. As water has maximum dielectric constant, the force of attraction decreases between the ions and thus it forms free ions and hence they dissolve.

(v) On passing electric current through molten, fused and aqueous solution of ionic compounds, the ions dissociate and migrate towards electrodes.

(vi) Ionic compounds undergo fast reactions in their aqueous solutions.

- **Covalent Bond**

The bond formed as a result of neutral sharing of electrons is called **covalent bond.** The covalent bond formation takes place between two non-metallic elements.

- **Conditions for the Formation of a Covalent Bond**

The combining atoms should have:

(i) Four or more electrons in outermost shell (ii) High electronegativity

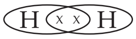
(iii) High electron affinity (iv) High ionisation energy

(v) Electronegativity difference should be zero or negligible.

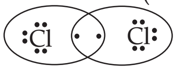
➢ **Types of covalent bonds**

(i) A **single covalent bond** is formed by the sharing of one pair of electrons between the atoms, each atom is contributing only one electron. A single covalent bond is denoted by putting a single short line (—) between the two atoms.

(a) Formation of **hydrogen molecule** (H = 1)

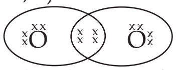

Or H — H $\longrightarrow$ H_2

(b) Formation of **chlorine molecule** (Cl = 2, 8, 7)


or Cl — Cl $\longrightarrow$ Cl_2

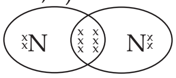
(ii) A **double covalent bond** is formed by the sharing of two pairs of electrons between the two atoms to acquire stable electronic configuration. A double covalent bond is denoted by putting a double line (=) between the two atoms.

Formation of oxygen molecule (O = 2, 6)


or O = O $\longrightarrow$ O_2

(iii) A **triple covalent bond** is formed by the sharing of three pairs of electrons between the two atoms. A triple covalent bond is denoted by putting three short lines (≡) between the two atoms.

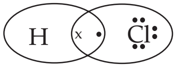
Formation of nitrogen molecule (N = 2, 5)

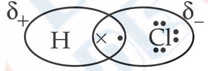

or N ≡ N $\longrightarrow$ N_2

(iv) Polar covalent bonds: The covalent compounds in which the combining elements have large difference in their electronegativity are called polar covalent compounds.

Example: Hydrogen chloride gas (HCl), Water (H_2O) and Ammonia (NH_3).

(v) In case of hydrogen chloride gas, chlorine is more electronegative than hydrogen, therefore chlorine attracts the shared pair of electrons towards its side. Hence, chlorine acquires a partial negative charge and hydrogen acquires a partial positive charge. Thus, the bonds become polar.


Mutual sharing


Chlorine is more electronegative than hydrogen

(vi) The compounds formed by the mutual sharing of electrons are called as covalent compounds.

➢ **Properties of covalent compounds:**

(i) Covalent compounds are liquids or gases. Their constituent particles are held together by weak van der Waals forces.

(ii) Covalent compounds are volatile compounds with low melting point and boiling point. As in these compounds, the molecules are held by weak van der Waals forces, so less amount of energy is required to overcome these forces of attraction.

(iii) Covalent compounds do not conduct electricity as they do not contain ions. They only contain molecules.

(iv) On passing electric current through the covalent compounds, they do not ionise as they contain only molecules and not ions. However, polar covalent compounds on dissolving in water produce ions and thus act as electrolytes.

(v) Covalent compounds are insoluble in water but soluble in organic solvents.

(vi) Covalent compounds only contain molecules and their dissociation to ions does not take place.

(vii) Covalent compounds undergo slow speed of reactions.

Mnemonics

1. Concept: Bonding **Mnemonics:** **S**hare **C**oconuts **T**ogether **I**ndia **Interpretation:** **S**- Shared pair of electrons **C**- Covalent bond **T** – Transfer of electrons **I** – Ionic bonding	**Interpretation:** **D** – double bond **O** – Oxygen **N** – Nitrogen **T** – Triple bond **S** – Single bond **H** – Hydrogen **C** – Covalent **B** – Bond Oxygen has double Covalent bond Nitrogen has triple Covalent bond Hydrogen has single Covalent Bond
2. Concept: Covalent bond examples **Mnemonics:** **D**O **N**OT **SH**UT **C**ARE **B**OX	

Key Words

- **Ion:** Charged species of particles which exist freely in the solution.
- **Cation:** When an atom loses electron, it gets converted to positively charged particle called cation.
- **Anion:** When an atom gains electron, it gets converted to negatively charged particle called anion.
- **Octet rule:** It is the tendency of the atoms of the element to have eight electrons in its valence shell.
- **Noble Gases:** Gases which are chemically unreactive and have eight electrons in their valence shells. (except helium which has only two electrons in the first orbit).
- **Electropositive elements:** The elements which easily loose electrons and acquire positive charge are called electropositive elements. Metals are electropositive elements.

  Example: Na^+, K^+, Ca^{2+}, Mg^{2+}, Al^{3+}, etc.
- **Electronegative elements:** The elements which easily gain electrons and acquire negative charge are called electronegative elements. Non-metals are electronegative elements.

  Example: Cl^-, Br^-, I^-, F^-, O^{2-}, S^{2-}, N^{3-}, etc.
- **Electrovalency:** It is the number of electrons lost or gained by an atom of the element during the formation of ionic bond.
- **Crystal Lattice:** It is the definite, three dimensional geometrical arrangement of constituent atoms or ions in space.
- **Covalency:** It is the number of electrons contributed by an atom of the element for mutual sharing during the formation of a covalent bond.

Key Terms

- Sharing of one, two or three pairs of electrons between two atoms to form a covalent or molecular bond.
- The cation and anion being oppositely charged attract each other and form a chemical bond. Since, this chemical bond formation is due to the electrostatic force of attraction between a cation and an anion, it is known as electrovalent or ionic bond.
- Caesium fluoride (CsF) is the most ionic compound.
- Bonds formed between metals and non-metals are ionic or electrovalent.
- The electropositive atom undergoes oxidation while the electronegative atom undergoes reduction. This is known as redox process.
- The process by which covalent compounds are converted into ions is known as **ionisation.**
- The molecule that possesses both partial positive charge (δ^+) and partial negative charge (δ^-) is called a **dipole molecule.**
- Hydrogen can combine with all non-metals of Group IV A to VII A with the help of covalent bonds.

Topic-2

Coordinate Bonding

Concepts covered: • *Introduction of coordinate bond,* • *Characteristic properties of coordinate bond,* • *Formation of ammonium ion, hydronium ion and hydroxyl ion*

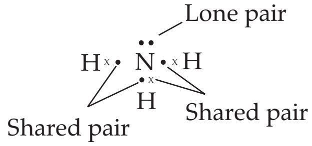
Revision Notes

Coordinate Bond:

- The bond formed between two atoms by sharing a pair of electrons both of which are contributed by only one of the bonding atoms but shared by both the atoms is called **coordinate bond.**
- The atom which provides the electron pair for the formation of a coordinate bond is known as **donor.** The atom or ion sharing the donated electron pair is known as **acceptor.**
- Coordinated bond has properties of both covalent and ionic bonds, thus, it is also known as **co-ionic bond.**
- A pair of electrons is not shared with any other atom for the formation of coordinate bond.
- The coordinate bond is shown by an arrow with its head pointing away from the donor to the acceptor atom $(\longrightarrow)$.
- **Conditions for the Formation of Coordinate Bond**

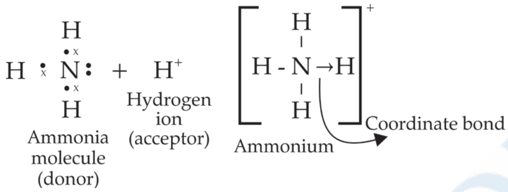
  One of the two atoms must have at least one lone pair of electrons. While another atom should be deficient of at least one lone pair of electrons.

- **Formation of Ammonium Ion (NH_4^+)**
  Ammonium ion (NH_4^+) is formed from ammonia molecule and hydrogen ion.

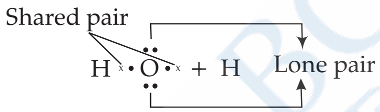


Formation of Ammonia

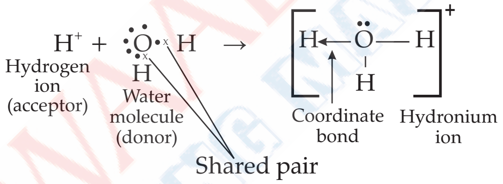
In ammonia (NH_3), N-atom have one lone pair of electrons, which is use for donation to H^+ ion for the formation of NH_4^+ ion.



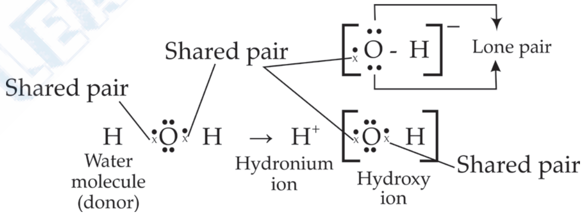
- **Formation of H_3O^+ Ion**
  Hydronium ion is formed from water molecule and hydrogen ion. The oxygen atom of a water molecule possesses two lone pair of electrons.



Out of these two lone pairs of electrons, one lone pair is used to donate to hydrogen ion.



- **Formation of Hydroxyl ion (OH^-)**
  The hydroxyl ion or hydroxide ion is formed when one hydrogen ion (H^+) is removed from water molecule. After removing one hydrogen ion from water, the shared pair of electron remains with oxygen, as oxygen is more electronegative and thus hydroxyl ion has negative charge.



- **Self-ionization of water**

$$H_2O + H_2O \rightleftharpoons \underset{\text{Hydronium ion}}{H_3O^+} + \underset{\text{Hydroxide ion}}{OH^-}$$

Mnemonics

Concept: Examples of coordinate bond

Mnemonics: **A**ishwarya **M**ust **H**ave **N**ew **H**eels **X**tra **L**arge

nterpretation:

A M – ammonium
H N – Hydronium
HXL – hydroxyl ion

Key Words

- **Bond pair:** Bond pair of electrons is the pair of electrons shared between two atoms.
- **Lone pair:** Lone pair of electrons is present on one atom which does not take part in sharing.
- **Coordinate bond:** It is a special case of coordinate bond formed between two atoms in which both the electrons are contributed by one of the atoms whereas the other atom simply takes part in sharing.
- **Oxidation:** It is a chemical process in which an atom or an ion loses one or more electrons.
- **Reduction:** It is a chemical process in which an atom or ion loses one or more electrons.

Key Terms

- Addition of released H^+ ion to a lone pair of electrons of the oxygen atom of the polar water molecule leads to the formation of a hydronium ion.
- Hydronium ion is a hydrated proton.

$$\underset{\text{Proton}}{H^+} + \underset{\text{Water}}{H_2O} \longrightarrow \underset{\text{Hydronium ion}}{H_3O^+}$$

- When ammonium chloride (NH_4Cl) is formed, the cation NH_4^+ (possessing three covalent bonds and one coordinate bond) and anion Cl^- are attracted towards each other due to electrical charge between them, then ionic bond or electrovalent bond is formed. Hence, NH_4Cl is a good example of compound having all three types of bonds, i.e., covalent, coordinate and ionic bond.

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CHAPTER-3
ACIDS, BASES AND SALTS

Topic-1

Acids and Bases

Concepts covered: • *Acids - Physical and chemical properties,* • *Bases - Physical and chemical properties,* • *pH and its application.*

Revision Notes

- **Acids:** The 'acid' comes from the Latin word 'acidus' meaning 'sour'.
- Acids are defined as compounds which contain one or more hydrogen atoms and when dissolved in water, produces hydronium ions (H_3O^+), the only positively charged ions, for example, hydrochloric acid (HCl), sulphuric acid (H_2SO_4), nitric acid (HNO_3).
- **Ions present in acids:** Mineral acids (inorganic acids) like HCl, H_2SO_4 and HNO_3 ionises completely in the solution. So, they contain high concentration of hydronium ion (H_3O^+). Hydronium ion is hydrated hydrogen ion. Organic acids like acetic acid (CH_3COOH), oxalic acid $(COOH)_2$ do not ionise completely in solution. So, they contain ions as well as molecules.
- **Classification of Acids:**

  1. **Depending on their sources -** (i) Organic acids (ii) Inorganic acids
     - **(i) Organic acids:** Acids which are obtained usually from plants are called **organic acids.** They contain carbon atom also along with hydrogen atom.
       Example: CH_3COOH (Acetic acid).
     - **(ii) Inorganic acids:** Acids which are obtained usually from minerals are known as **inorganic acids.** They do not contain carbon (except carbonic acid H_2CO_3).
       Example: H_2SO_4 (Sulphuric acid), HCl (Hydrochloric acid)
  2. **Depending on their strength –** (i) Strong acid (ii) Weak acid
     - **(i) Strong acid:** A strong acid vigorously ionises in aqueous solution, there by producing a high concentration of hydronium ion $[H_3O]^+$.
       Example: HCl, H_2SO_4
     - **(ii) Weak acid:** Weak acid ionises only partially in aqueous solution, and thus they produce ions as well as molecules.
       Example: CH_3COOH (Acetic acid).

3. **Depending on their concentration :**
   - **(i)** Concentrated acid (Contains less water)
   - **(ii)** Dilute acid (Contains more water)
4. **Depending on molecular composition:** (i) Oxy-acids (ii) Hydro-acids
   - **(i) Oxy-Acids :** Oxy-acids are those acids, which contain oxygen along with hydrogen and some other element.
     Example: Nitric acid, Sulphuric acid
   - **(ii) Hydro-acids :** Hydro-acids are those acids which contain hydrogen and a non-metallic element, and no oxygen.
     Example: Hydrochloric acid.
5. **Depending on their basicity -** The **basicity** of an acid is defined as the number of hydronium ions $(H_3O)^+$ that can be produced by ionisation of one molecule of that acid in aqueous solution.

Acid	Basicity
$HCl \longrightarrow H^+ + Cl^-$	Monobasic acid
$H_2SO_4 \longrightarrow 2H^+ + SO_4^{2-}$	Dibasic acid
$H_3PO_4 \longrightarrow 3H^+ + PO_4^{3-}$	Tribasic acid

- **Physical properties of acids :**
  - **(a)** Acids have a sour taste in their aqueous solutions.
  - **(b)** Acids turn blue litmus paper or solution red, orange or yellow colour of methyl orange solution pink and deep red colour of phenolphthalein colourless.
  - **(c)** The aqueous solution of all mineral acids contains hydrogen ions.
  - **(d)** Mineral acids such as HCI, HNO_3, H_2SO_4, etc., are highly corrosive and cause painful burns on the skin. Conc. H_2SO_4 stains the skin black while conc. HCl stains the skin amber-coloured.
- **Chemical properties of acids :**
  - **(a)** Metals which are more electropositive than hydrogen, react with dil. HCl and dil. H_2SO_4 to liberate hydrogen gas.

$$Zn(s) + 2HCl(aq) \longrightarrow ZnCl_2(aq) + H_2(g)$$

Nitric acid (HNO_3) does not liberate hydrogen gas on reaction with metals. However, Mg and Mn react with very dilute nitric acid to produce hydrogen gas.

  - **(b)** Acids react with metal oxides to form the corresponding salt and water.

$$CaO(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + H_2O(l)$$

When MnO_2 is heated with conc. HCl, a greenish-yellow, chlorine gas, is produced.

$$MnO_2(s) + 4HCl(aq) \longrightarrow MnCl_2(aq) + 2H_2O(l) + Cl_2(g)$$

  - **(c)** Bicarbonates and carbonates are decomposed by dilute acids with the liberation of carbon dioxide (CO_2) gas.

$$NaHCO_3(s) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l) + CO_2(g)$$

$$CaCO_3(s) + 2HNO_3(aq) \longrightarrow Ca(NO_3)_2(aq) + H_2O(l) + CO_2(g)$$

  - **(d)** Bisulphites and sulphites are decomposed by dilute acids to liberate sulphur dioxide (SO_2) gas.

$$NaHSO_3(s) + HCl(aq) \longrightarrow NaCl(aq) + H_2O(l) + SO_2(g)$$

$$Na_2SO_3(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + H_2O(l) + SO_2(g)$$

  - **(e)** Dilute acids react with metal sulphides and liberate hydrogen sulphide gas.

$$FeS(s) + H_2SO_4(aq) \longrightarrow FeSO_4(aq) + H_2S(g)$$

  - **(f)** Hydrogen chloride gas is produced when concentrated sulphuric acid is added to common salt.

$$2\,NaCl(s) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + 2HCl(g)$$

  - **(g)** When sodium or potassium nitrate is heated with concentrated sulphuric acid, vapours of nitric acid are evolved.

$$KNO_3(s) + H_2SO_4(aq) \longrightarrow KHSO_4(aq) + HNO_3(g)$$

General Uses of Some Acids:

(a) Boric acid	-	Antiseptic for Eye-wash
(b) Oxalic acid	-	Ink stain remover
(c) Tartaric acid	-	Baking powder
(d) Citric acid	-	Food preservative
(e) Carbonic acid	-	Flavoured drink
(f) Phosphoric acid	-	Fertilizers.

- **Bases :** A base is either a metallic oxide or a metallic hydroxide which reacts with hydronium ions of an acid to form salt and water only.
- **Alkali :** An alkali is a basic hydroxide which when dissolved in water produces hydroxyl (OH^-) ions as the only negatively charged ions.

$$NaOH\,(aq) \longrightarrow Na^+ + OH^-$$

- **Classification of Bases :**

1. **On the basis of strength**
   - **(i) A Strong base :** It undergoes almost complete ionisation in aqueous solution to produce a high concentration of OH^-.
     Example: Sodium hydroxide (NaOH), potassium hydroxide (KOH).
   - **(ii) A Weak base :** A weak base is a substance which ionises only to a small extent when dissolved in water
     Example: NH_4OH, $Ca(OH)_2$, etc.
2. **On the basis of acidity :** The number of hydroxyl ions $[OH]^-$ which can be produced per molecule of the base in aqueous solution or the number of hydrogen ions (of an acid) with which a molecule of that base will react to produce salt and water is known as **acidity of the base**.

Base	Acidity
$NaOH \longrightarrow Na^+ + OH^-$	Monoacidic base
$Ca(OH)_2 \longrightarrow Ca^{2+} + 2OH^-$	Diacidic base
$Al(OH)_3 \longrightarrow Al^{3+} + 3OH^-$	Triacidic base

3. Concentration of a base depends on the amount of water present in it. A concentrated base has more quantity of base and a little or no water while a dilute base has more water and less base.

Preparation of Bases : The common methods of preparing bases are as follows:

(i) From Metals : Metals when react with oxygen give bases.

$$4Na + O_2 \longrightarrow 2Na_2O$$
$$2Mg + O_2 \longrightarrow 2MgO$$

(ii) By the action of water on metals; like sodium, potassium and calcium :

$$2Na + 2H_2O \longrightarrow 2\,NaOH + H_2 \uparrow$$
$$2K + 2H_2O \longrightarrow 2\,KOH + H_2 \uparrow$$
$$Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2 \uparrow$$

(iii) By the action of water on soluble metallic oxides :

$$Na_2O + H_2O \longrightarrow 2\,NaOH$$
$$K_2O + H_2O \longrightarrow 2\,KOH$$

(iv) By Double Decomposition: Aqueous solution of salts with a base (alkali) precipitate the respective metallic hydroxide.

$$FeCl_3 + 3NaOH \longrightarrow Fe(OH)_3 \downarrow + 3\,NaCl$$
$$CuSO_4 + 2\,NaOH \longrightarrow Cu(OH)_2 \downarrow Na_2SO_4$$

(v) By the action of oxygen on metal sulphides :

$$2\,ZnS + 3O_2 \longrightarrow 2\,ZnO + 2SO_2$$
$$2\,PbS + 3O_2 \longrightarrow 2\,PbO + 2SO_2$$

(vi) By Decomposition of salts :

$$CaCO_3 \longrightarrow CaO + CO_2 \uparrow$$
$$CuCO_3 \longrightarrow CuO + CO_2 \uparrow$$
$$2Ca\,(NO_3)_2 \longrightarrow 2CaO + 4\,NO_2 + O_2 \uparrow$$
$$2Zn(NO_3)_2 \longrightarrow 2ZnO + 4NO_2 + O_2$$

- **Physical Properties of Bases**
  - **(a)** Alkalis have a bitter taste and are soapy to touch.
  - **(b)** Alkalis turn red litmus paper or solution blue, colourless phenolphthalein pink, pink colour of methyl orange to yellow colour and turmeric powder to brown colour.

- **Chemical Properties of Bases**

(a) Alkalis react with acids to from salt and water.

$$2\,NaOH\,(aq) + H_2SO_4\,(aq) \longrightarrow Na_2SO_4\,(aq) + 2H_2O$$

$$CuO\,(s) + H_2SO_4\,(aq) \longrightarrow CuSO_4\,(aq) + H_2O\,(l)$$

(b) Alkalis react with ammonium salts to liberate ammonia gas with a pungent smell.

$$2\,NaOH\,(aq) + (NH_4)_2SO_4\,(aq) \longrightarrow Na_2SO_4\,(aq) + 2\,H_2O\,(l) + 2NH_3\,(g)$$

(c) Alkalis react with solutions of salts of heavy metals (copper, iron, zinc, lead, etc.) to form insoluble precipitates of metal hydroxides.

$$CuCl_2\,(aq) + 2\,NaOH\,(aq) \longrightarrow Cu(OH)_2\downarrow + 2\,NaCl\,(aq)$$

$$FeCl_3\,(aq) + 3\,NaOH\,(aq) \longrightarrow Fe(OH)_3\downarrow + 3\,NaCl\,(aq)$$

$$ZnCl_2(aq) + 2\,NaOH\,(aq) \longrightarrow Zn(OH)_2\downarrow + 2\,NaCl\,(aq)$$

(d) Hydroxides of zinc, lead and aluminium behave like acids in the presence of strong alkalis, while they behave like bases in the presence of strong acids, so as to from salt and water.

$$Zn(OH)_2\,(aq) + 2\,NaOH\,(aq) \longrightarrow Na_2ZnO_2\,(aq) + 2H_2O\,(l)$$

$$Zn(OH)_2\,(aq) + H_2SO_4\,(aq) \longrightarrow ZnSO_4\,(aq) + 2H_2O\,(l)$$

$$Al(OH)_3\,(aq) + NaOH\,(aq) \longrightarrow NaAlO_2\,(aq) + 2H_2O\,(l)$$

$$Al(OH)_3\,(aq) + 3\,HCl\,(aq) \longrightarrow AlCl_3\,(aq) + 3H_2O\,(l)$$

(e) All bases except NaOH and KOH decompose on heating to from their respective oxides.

$$Ca(OH)_2\,(aq) \xrightarrow{\text{Heat}} CaO\,(aq) + H_2O\,(l)$$

$$2Al(OH)_3\,(aq) \xrightarrow{\text{Heat}} Al_2O_3\,(aq) + 3\,H_2O\,(l)$$

(f) Caustic alkalis (NaOH and KOH) are corrosive to the skin as they combine with the oils and fats in the skin.

- **Uses of Bases**

(1) Aluminium hydroxide is used as a foaming agent in fire extinguishers.

(2) Sodium hydroxide is used in the manufacture of soaps.

(3) Ammonium hydroxide is used for removing grease and stains from woollen clothes.

(4) Potassium hydroxide is used in the manufacturing of soft soaps and alkaline batteries.

(5) Calcium hydroxide is used in the manufacture of bleaching powder, softening of hard water, neutralising acidity of soil, as a general germicide and in making mortar.

- **Neutralisation Reaction:** The reaction between an acid and a base to form salt and water is known as a **neutralisation** reaction.

$$HCl\,(aq) + NaOH\,(aq) \longrightarrow NaCl\,(aq) + H_2O\,(l)$$

$$H^+ + Cl^- + Na^+ + OH^- \xrightarrow{\text{Water}} Na^+ + Cl^- + H_2O\,(l)$$

$$H^+ + OH^- \longrightarrow H_2O\,(l)$$

Or,

When ammonia is dissolved in water, it acts as a base and water as an acid. The following are the applications of neutralisation reaction:

(a) Farmers reduce acidity of the soil by adding slaked lime (calcium hydroxide) to it.

(b) Antacid tablets containing magnesium hydroxide are given to person suffering from acidity to neutralise excess acid produced in the stomach.

(c) Cold milk which is alkaline also helps a person in neutralising the hydrochloric acid present in the stomach.

(d) The sting of ants and bees contains formic acid. This can be neutralised by rubbing soap which contains free sodium hydroxide, on the affected area of the skin.

(e) The sting of yellow wasps contains an alkali. This is neutralised by rubbing acetic acid (vinegar) on the affected area of the skin.

- The acidity or alkalinity of a liquid is expressed in terms of pH. It is a measure of hydrogen ion concentration of the solution.

pH of a solution is the number by which negative power of 10 has to be raised in order to express the hydrogen ion concentration of the solution.

$$\left[H^+\right] = 10^{-x}\,; \quad \therefore\ pH = x$$

It is also defined as the negative logarithm to the base 10 of the hydrogen ion concentration, i.e.,

$$pH = -\log\,[H^+]$$

A pH of 7 indicates a neutral solution, i.e., pure water. Numbers less than 7, i.e., pH 6, 5, 4, ..., 1, indicate **acidic solutions.** The acidity increases as the pH number decreases. Numbers greater than 7, i.e., pH 8, 9, 10, ..., 14, indicate **alkaline solutions.** The alkalinity increases as the pH number increases.

A reasonably accurate value of the pH of the solution can be determined by putting two or three drops of the solution on a wide range pH paper. A colour will appear and by matching this colour with the chart provide by the supplier, the pH can be determined.

Mnemonics

1. **Concept :** Uses of acid

Mnemonics:

BEW
FPCA
ISRO
FDCA
BPT

Interpretation:

Boric acid -eye wash (BEW)
Food preservative -citric acid (FPCA)
Ink Stain Remover -Oxalic acid (ISRO)
Flavouring Drinks -carbonic acid(FDCA)
Baking Powder –Tartaric acid (BPT)

2. **Concept :**

Properties of acid

Mnemonics:

A student **t**old **t**eacher **B**us **R**ider called “**HI**”

Interpretation:

A—Acid
S—Sour
T—taste
T—turns
B—blue
R—red
C—contains
HI—hydrogen ion

Key Words

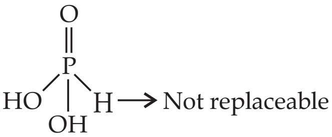
- The bases having an acidity of 1, 2 and 3 are called monoacidic, diacidic, triacidic bases respectively.
- **Concentration of Acid :** It means the amount of acid present in a definite amount of its aqueous solution.
- **Monobasic Acid :** It is an acid which on ionisation in water produces hydronium ion per molecule of the acid.
- **Dibasic Acid:** It is an acid which on ionisation in water produces two hydronium ions (H_3O^+) per molecule of the acid.
- **Tribasic Acid:** It is an acid which on ionisation in water produces three hydronium ions per molecule of the acid.
- **Indicator:** It is a complex substance that indicates separate colour in acidic and basic medium.
- **Monoacidic Base:** It is a base that dissociates in molten (fused) state or in aqueous solution to produces one OH^- ion per molecule of that base.
- **Diacidic Base:** It is a base that dissociates in molten (fused) state or in aqueous solution to produce two OH^- ions per molecule of that base.
- **Triacidic Base:** It is a base that dissociates in molten (fused) state or in aqueous solution to produce three OH^- ions per molecule of that base.
- **pH:** The pH of solution is the negative logarithm to the base 10 of the hydrogen ion concentration expressed in moles per litre.

Key Terms

- The hydrated hydrogen ion that exists in the solutions of acids is known as hydronium ion (H_3O^+).

$$H^+ + H_2O \longrightarrow H_3O^+$$

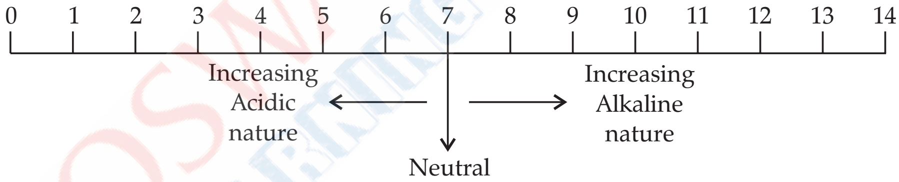
- Carbonic acid (H_2CO_3) is a weak mineral acid. It contains ions as well as molecules. It turns blue litmus pink. It is non-corrosive and so used in soft drinks.
- Basicity of an acid depends not on the number of hydrogen atoms in one molecule of that acid, but on the number of ionizable hydrogen atoms that it has per molecule.
- H_3PO_3 is a dibasic acid because in oxyacid of phosphorus, hydrogen atoms which are attached to oxygen atoms are replaceable. Hydrogen atoms directly bonded to phosphorus atoms are not replaceable.



- In order to dilute an acid, pour acid into water in small amounts and stir constantly.
  It is noted that water is not added to acid as it is an exothermic process.
- Strength of an acid is the measure of concentration of hydronium ion, it produces in its aqueous solution.
- Dilute HCl is stronger acid than highly concentrated acetic acid.
- The strength of an acid depends on the degree of ionisation (α) and concentration of H_3O^+ ions produced by that acid in aqueous solution.
- Degree of ionisation (α) = $\frac{\text{Number of acid molecules ionised}}{\text{Total number of acid molecules present in aqueous solution}} \times 100$
- If the value of α for an acid or base is greater than 30%, it is strong and if it is less then 30%, it is weak.
- All mineral acids have corrosive action on the skin and cause painful burns.
  For example, Conc. H_2SO_4 — stains the skin black
  Conc. HNO_3 — stains the skin yellow
  Conc. HCl — stains the skin amber
- Those substances whose smell changes in acidic or basic solutions are known as **olfactory indicators**. For example, onion, vanilla and clove oil.
-

Indicator	Colour change in acidic medium	Colour change in basic medium
Litmus	Blue to red	Red to blue
Methyl orange	Orange to pink	Orange to yellow
Phenolphthalein	Remains colourless	Colourless to pink

- Nitric acid is a very strong oxidising agent so it is not used in the preparation of hydrogen. It oxidises hydrogen and form water. Only magnesium and manganese can produce hydrogen with very dil. HNO_3 (1%).
  $$\underset{}{Mn} + \underset{(1\%)}{2HNO_3} \longrightarrow Mn(NO_3)_2 + H_2\uparrow$$
- An alkali is a base soluble in water.
- All alkalis form OH^- ions in aqueous solution as the only negative ions. They turn red litmus blue.
- All alkalis are bases but all bases are not alkalis.
  For example, $Fe(OH)_3$ and $Cu(OH)_2$ are bases, but not alkalis because they are insoluble in water.
- **pH Scale :**



- The **universal indicator** is a mixture of indicator dyes that gives a spectrum of colours depending on how acidic or alkaline a solution is.
- Universal indicators give different colours at different concentration of hydrogen ions in a solution.
  For example, a universal indicator produces green colour in a neutral solution, i.e., when pH = 7. It changes in a basic solution progressively from 7 to 14.
- If the pH is less then 5.6 of rain water, it is said to be **acid rain**.
- To get rid of acidity in stomach, antacids like milk of magnesia [$Mg(OH)_2$] is generally used to adjust the pH.
- When the pH of mouth falls to 5.5, tooth decay starts.
- Bee sting leaves acid in the body. If baking soda ($NaHCO_3$), a base, is applied on the stung area, it gives relief.

Topic-2

Salts

Concepts covered: • *Classification of salts,* • *Preparation and properties of different types of salts.*

Revision Notes

- **Salts:** The chemical compounds which on dissolving in water produce positively charged particles other than hydrogen ions and negatively charged particles other than hydroxyl ions are called salts.

$$NaCl \rightleftharpoons Na^+ + Cl^-$$
$$KCl \rightleftharpoons K^+ + Cl^-$$

- **Classification of Salt :** There are six kinds of salts.

(a) Normal salt : The salt formed by complete replacement of replaceable hydrogen ions of an acid by a basic radical or metallic ion. Some examples of normal salts are sodium chloride (NaCl), potassium nitrate (KNO_3), copper sulphate ($CuSO_4$) and sodium acetate (CH_3COONa).

$$\text{Acid} + \text{Base} \longrightarrow \text{Salt} + \text{Water}$$

$$HCl + NaOH \longrightarrow NaCl + H_2O$$

$$HNO_3 + KOH \longrightarrow KNO_3 + H_2O$$

$$H_2SO_4 + Cu(OH)_2 \longrightarrow CuSO_4 + 2H_2O$$

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

These salts on dissolving in water dissociate into their constituent ions. Normal salts have no ionizable hydrogen atoms.

(b) Acid Salt: A salt formed by incomplete or partial replacement of replaceable hydrogen ions of an acid by a basic radical or metallic ion. Some examples of acid salt are sodium hydrogen sulphate ($NaHSO_4$), potassium bisulphate ($KHSO_4$), sodium hydrogen sulphite ($NaHSO_3$).

$$\text{Acid} + \text{Alkali} \longrightarrow \text{Salt} + \text{Water}$$

$$H_2SO_4 + NaOH \longrightarrow NaHSO_4 + H_2O$$

$$H_3PO_4 + NaOH \longrightarrow NaH_2PO_4 + H_2O$$

$$H_2SO_3 + NaOH \longrightarrow NaHSO_3 + 2H_2O$$

Acid salts are formed when the basicity of the acid taken is more than the acidity of a base. In aqueous solution, acid salts furnish hydrogen ion or hydronium ion (H_3O^+).

(c) Basic Salt: The salt formed by the partial or incomplete replacement of replaceable hydroxyl ions of diacidic or triacidic base by an acid radical. Some example of basic salts are basic lead chloride [Pb(OH)Cl], basic copper chloride [Cu(OH)Cl], basic magnesium chloride [Mg(OH)Cl].

$$\text{Base} + \text{Acid} \longrightarrow \text{Salt} + \text{Water}$$

$$Pb(OH)_2 + HCl \longrightarrow Pb(OH)Cl + H_2O$$

$$Cu(OH)_2 + HCl \longrightarrow Cu(OH)Cl + H_2O$$

$$Mg(OH)_2 + HCl \longrightarrow Mg(OH)Cl + H_2O$$

The basic salts are only formed when the acidity of the the base taken is more than the basicity of an acid. The basic salts contain a metallic cation, a hydroxyl ion from base and an anion obtained from the acid.

(d) Double salt: The salts that contain more than one cation or anion are known as double salt. They are obtained by the combination of two different salts but differ in their crystalline structure. For example, potash alum, (K_2SO_4. $Al_2(SO_4)_3$. $24H_2O$), (Mohr's salt).

(e) Mixed salts: The salt that consists of a fixed proportion of two salts, often sharing either a common cation or common anion is known as **mixed salt.**

e.g., bleaching powder ($CaOCl_2$), sodium potassium carbonate ($NaKCO_3$).

(f) Complex salts : The salts which contain different types of metal atoms which on hydrolysis produces complex ions along with simple ions are called complex salts. For example, silver amino chloride $[Ag(NH_3)_2]\,Cl$, tetraammine copper (II) sulphate $[Cu(NH_3)_4]\,SO_4$, sodium argentocyanide $\{Na[Ag(CN)_2]\}$.

- **Preparation of Soluble Salts :**

(a) By synthesis: Several soluble salts are prepared by heating the constituent elements together.

$$2Fe + 3Cl \longrightarrow 2FeCl_3$$

$$2Na + Cl_2 \longrightarrow 2NaCl$$

(b) Simple displacement: Soluble salts of active metals like Mg, Zn, Fe etc. can be prepared by the simple displacement reactions involving an active metal and dilute acid.

$$Mg + \text{dil. } 2HCl \rightarrow \underset{\text{(magnesium chloride)}}{MgCl_2} + H_2\uparrow$$

$$Zn + \text{dil.}H_2SO_4 \rightarrow \underset{\text{Zinc sulphate}}{ZnSO_4} + H_2\uparrow$$

(c) Double decomposition: Insoluble or soluble bases react with acids to form salt and water. By this reaction only soluble salts are prepared. (Neutralisation reaction)

$$NH_4OH + dil.HCl \rightarrow \underset{\text{(Ammonium chloride)}}{NH_4Cl} + H_2O$$

$$2KOH + dil.H_2SO_4 \rightarrow \underset{\text{Potassium sulphate}}{K_2SO_4} + 2H_2O$$

(d) By the reaction of metallic carbonates, bicarbonates, sulphites, bisulphites, sulphides and bisulphides with dilute acids**:**

$$CaCO_3 + dil.2HCl \rightarrow \underset{\text{Calcium chloride}}{CaCl_2} + H_2O + CO_2\uparrow$$

$$ZnSO_3 + dil.H_2SO_4 \rightarrow \underset{\text{Zinc sulphate}}{ZnSO_4} + H_2O + SO_2\uparrow$$

(e) By the reaction of metals with alkali:

$$Zn + 2NaOH \xrightarrow{\text{Boiling}} \underset{\substack{\text{Sodium}\\ \text{Zincate}}}{Na_2ZnO_2} + H_2\uparrow$$

$$Pb + 2KOH \xrightarrow{\text{Boiling}} \underset{\substack{\text{Potassium}\\ \text{metaplumbate}}}{K_2PbO_2} + H_2\uparrow$$

$$2Al + 2NaOH + 2H_2O \xrightarrow{\text{Boiling}} \underset{\substack{\text{Sodium}\\ \text{aluminate}}}{2NaAlO_2} + 3H_2\uparrow$$

- **Preparation of Insoluble Salts :**

(i) By direct combination

$$Pb + S \longrightarrow PbS$$

(ii) Combination of an acidic oxide with a basic oxide

$$CO_2 + CaO \longrightarrow CaCO_3$$

(iii) By the precipitation reaction (double decomposition)

$$BaCl_2 + H_2SO_4 \longrightarrow BaSO_4\downarrow + 2HCl$$

- **Laboratory Preparation of Some Salts :**

(Normal and Acid Salts)

- **Preparation of an Acid Salt (Sodium bicarbonate)**

Method of preparation: Sodium bicarbonate is obtained by passing carbon dioxide gas into a cold solution of sodium carbonate (Na_2CO_3).

$$\mathbf{Na_2CO_3 + CO_2 + H_2O \longrightarrow 2NaHCO_3}$$

Procedure: Dissolve anhydrous sodium carbonate (5g) in distilled water (nearly 25 cm^3) in a flask. Cool the solution by keeping the flask in a freezing mixture, then pass CO_2 gas in the solution. After sometime crystals of sodium bicarbonate will precipitate out, filter the crystals and dry it.

- **Preparation of Sodium sulphate crystals ($Na_2SO_4 . 10H_2O$)**

Method of preparation: By neutralisation of caustic soda with dilute sulphuric acid.

$$2NaOH + H_2SO_4 \longrightarrow Na_2SO_4\downarrow + 2H_2O$$

Titration is conducted to determine the completion of the neutralisation reaction because the reactants as well as the products are soluble.

- **General Properties of Salts:**

(i) Salts are electrovalent compounds, which conduct electricity in molten state as well as in their aqueous solution.

(ii) Non-volatile solids that form crystals.

(iii) Most of the salts are soluble in water. Degree of solubility in water varies with temperature.

(iv) Hydrolysis of salts

Salt formed by a strong acid and weak base or by a weak acid and a strong base, reacts with water to give acidic or basic solution, is known as **hydrolysis of salts.**

(a) Salts of strong acids and weak bases on hydrolysis give acidic solution. (pH<7), e.g., iron (III) chloride ($FeCl_3$), copper sulphate ($CuSO_4$).

(b) Salts of weak acids (H_2CO_3, CH_3COOH) and strong bases (KOH, NaOH) on hydrolysis give alkaline solution (pH > 7).

(c) Salts of strong acids and weak bases on hydrolysis give neutral solution.

(d) Salts of weak acids and weak bases on hydrolysis may give acidic, alkaline or neutral solution depending upon the dissociated ions and undissociated molecules. For example ammonium acetate [CH_3COONH_4] and ammonium carbonate [$(NH_4)_2CO_3$].

- **Water of Crystallisation:**

  It is that definite amount of water with which the substance is associated when crystallising out from an aqueous solution, e.g., copper (II) sulphate crystallises out as a pentahydrate, $CuSO_4 . 5H_2O$. Thus, one mole of copper (II) sulphate is associated with five moles of water.

- **Hydrated Salts - Water of Crystallisation:**
  - The compounds which crystallise out of their saturated solutions with fixed number of molecules of water of crystallisation are called **hydrated salts.**
  - These molecules of water of crystallisation are in loose chemical combination with the salt.
  - The hydrated salts owe their crystalline nature to the molecules of water of crystallisation.

Salts containing water of crystallisation

Common Name	Chemical Name	Formula
White vitriol	Zinc sulphate heptahydrate	$ZnSO_4.7H_2O$
Glauber's salt	Sodium sulphate decahydrate	$Na_2SO_4.10H_2O$
Washing soda	Sodium carbonate decahydrate	$Na_2CO_3.10H_2O$
Potash alum	Potassium aluminium sulphate	$KAl(SO_4)_2.12H_2O$
Epsom salt	Magnesium sulphate heptahydrate	$MgSO_4.7H_2O$
Green vitriol	Iron(II) sulphate heptahydrate	$FeSO_4.7H_2O$
Blue vitriol	Copper(II) sulphate pentahydrate	$CuSO_4.5H_2O$
Lime saltpetre	Calcium nitrate	$Ca(NO_3)_2.4H_2O$

- **Efflorescence:**

  It is the property of some hydrated salts to lose wholly or partly their water of crystallisation, when exposed to atmosphere. These substances crumble into powder and are called **efflorescent salts.**

  For example :

$$\underset{\text{Washing Soda crystals}}{Na_2CO_3 . 10H_2O} \xrightarrow{\text{Dry air}} \underset{\text{Washing Powder}}{Na_2CO_3 . H_2O} + 9H_2O$$

Higher the temperature of the air, higher the efflorescence because that air absorbs more water with rising temperature and decreasing moisture.

Deliquescence: Certain water soluble substances, when exposed to the atmosphere at ordinary temperature, absorb moisture from the atmospheric air becomes moist, lose their crystalline form and ultimately dissolve in the absorbed water forming a saturated solutions. Such substances are called **deliquescent substances** and this property is called **deliquescence.**

Examples:

- Anhydrous calcium chloride, $CaCl_2$
- Caustic soda NaOH
- Caustic potash KOH
- Ferric chloride $FeCl_3$

Hygroscopic Substances: Certain substances when exposed to the atmosphere at ordinary temperature, absorb moisture from the atmosphere without dissolving in it. These are called **hygroscopic substances** and this property is called **hygroscopy.** These substances are generally used for drying of gases in laboratory, e.g., conc. sulphuric acid (H_2SO_4), quick lime (CaO), silica gel, phosphorus pentaoxide (P_2O_5).

Drying or desiccating agents: Certain substances remove moisture from other substances and are therefore called **desiccating agents** or **drying agents** or **desiccants.** Almost all hygroscopic substances are desiccating agents.

For example, Conc. sulphuric acid, phosphorus pentaoxide, quick lime.

Dehydrating agents: The substances that can remove water molecules even from compounds are called dehydrating agents. For example, concentrated sulphuric acid can remove water molecules from blue vitriol ($CuSO_4.5H_2O$), so it is a dehydrating agent.

$$\underset{\text{Hydrated Salt}}{CuSO_4 .5H_2O} + \underset{\text{Conc.}}{H_2SO_4} \rightarrow \underset{\text{Anhydrous Salt}}{CuSO_4} + 5H_2O$$

Key Words

- **Displacement:** It is a chemical change in which a more active element displaces a less active element from its salt solution.
- **Decomposition:** It is a chemical change in which a compound breaks up into its elements or simpler compounds.

- **Hydrolysis:** The phenomenon due to which salt formed by a weak acid and a strong base, or by a strong acid and a weak base, reacts with water to give an acidic or alkaline solution is called hydrolysis.

Key Terms

- Acid salts ionise in water solution to give hydronium ions and hence, they exhibit all the properties of an acid.
- Soluble slats are obtained by the evaporation of water, followed by crystallisation.
- Some soluble salts, like zincates and aluminates, are found only in solution. These salts can not be obtained in their pure forms by crystallisation.
- An insoluble salt can be obtained from another insoluble salt, by double decomposition.
- If at least 1 g of a substance can be dissolved in 100 mL of water at 298 K, it is called **a soluble salt.**
- If 0.1 g to 1 g of a substance can be dissolved in 100 mL of water at 298 K, it is called a **partially soluble salt.**
- If less than 0.1 g of a substance can be dissolved in 100 mL of water at 298 K, it is called an **insoluble salt.**
- All metallic oxides and hydroxides are insoluble except of sodium, potassium and ammonium. Calcium hydroxide is slightly soluble. $NaHCO_3$ is sparingly soluble, but $KHCO_3$ is fairly soluble in water.
- Efflorescent substances lose their weight while hygroscopic and deliquescent substances gain weight when exposed to atmosphere.
- Table salt (NaCl) turns moist and ultimately forms a solution, on exposure to air, especially during the rainy season. Though, pure sodium chloride is not deliquescent, the commercial version of the salt contains impurities like $MgCl_2$ and $CaCl_2$, which are deliquescent substances.

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CHAPTER-4
ANALYTICAL CHEMISTRY

Revision Notes

- Qualitative analysis is carried out with the help of reagents. A reagent is a substance that reacts with another substance. Alkalis such as NaOH, KOH, NH_4OH are important laboratory reagents. These alkalis give characteristic tests with various metal ions from which these metal ions can be identified.
- **Colour of the Salts and Their Solutions:**

  The salts of normal elements, i.e., the elements of group 1, 2 and 13 to 17 are generally colourless. Salts of transition elements, i.e., the elements of group 3 to 12 are generally coloured.

Colourless Ions		
Cation	**Symbol**	**Colour**
Ammonium ion	NH_4^+	
Sodium ion	Na^+	
Potassium ion	K^+	
Calcium ion	Ca^{2+}	
Magnesium ion	Mg^{2+}	
Aluminium ion	Al^{3+}	
Lead ion	Pb^{2+}	
Zinc ion	Zn^{2+}	
Cupric ion	Cu^{2+}	Blue
Ferrous ion	Fe^{2+}	Light green
Ferric ion	Fe^{3+}	Yellow/brown
Nickel ion	Ni^{2+}	Green
Chromium ion	Cr^{3+}	Green
Manganese ion	Mn^{2+}	Pink

Colourless ions	Symbol	Coloured ions	Symbol	Colour
Chloride ion	Cl^-	Permanganate ion	MnO_4^-	Pink or Purple
Sulphate ion	SO_4^{2-}			
Carbonate ion	CO_3^{2-}	Dichromate ion	$Cr_2O_7^{2-}$	Orange
Nitrate ion	NO_3^-			
Hydride ion	H^-	Chromate ion	CrO_4^{2-}	Yellow
Bicarbonate ion	HCO_3^-			
Sulphide ion	S^{2-}			
Bromide ion	Br^-			
Acetate ion	CH_3COO^-			

- **Action of Sodium hydroxide (NaOH) with solution of salts of metals:**

Ion	Salt (Colour)	Reaction	Precipitate formed	Colour of the precipitate	Solubility of the precipitate in an excess of NH_4OH
Mg^{2+}	$MgSO_4$ (Magnesium sulphate) (White)	$MgSO_4 + 2NaOH \rightarrow Mg(OH)_2\downarrow + Na_2SO_4$	$Mg(OH)_2$ (Magnesium hydroxide)	White	Insoluble
Fe^{2+}	$FeSO_4$ (Ferrous sulphate) (Green)	$FeSO_4 + 2NaOH \rightarrow Fe(OH)_2\downarrow + Na_2SO_4$	$Fe(OH)_2$ (Ferrous hydroxide or Iron (II) hydroxide)	Dirty green	Insoluble
Fe^{3+}	$FeCl_3$ (Ferric chloride) (Brown)	$FeCl_3 + 3NaOH \rightarrow Fe(OH)_3\downarrow + 3NaCl$	$Fe(OH)_3$ (Ferric hydroxide or Iron (III) hydroxide)	Reddish brown	Insoluble
Cu^{2+}	$CuSO_4$ (Copper sulphate) (Blue)	$CuSO_4 + 2NaOH \rightarrow Cu(OH)_2\downarrow + Na_2SO_4$	$Zn(OH)_2$ (Zinc hydroxide)	Pale blue	Soluble
Zn^{2+}	$ZnSO_4$ (Zinc sulphate) (Colourless)	$ZnSO_4 + 2NaOH \rightarrow Zn(OH)_2\downarrow + Na_2SO_4$ $\underset{\text{(Excess)}}{Zn(OH)_2 + 2NaOH} \rightarrow Na_2ZnO_2 + 2H_2O$ Sodium zincate (Soluble)	$Zn(OH)_2$ (Zinc hydroxide)	White gelatinous	Soluble
Pb^{2+}	$Pb(NO_3)_2$ (Lead nitrate) (Colourless)	$Pb(NO_3)_2 + 2NaOH \rightarrow Pb(OH)_2\downarrow + 2NaNO_3$ $\underset{\text{(Excess)}}{Pb(OH)_2 + 2NaOH} \rightarrow Na_2PbO_2\downarrow + 2H_2O$ Sodium plumbite (Soluble)	$Pb(OH)_2$ (Lead (II) hydroxide)	Chalky White	Soluble

Ca^{2+}	$Ca(NO_3)_2$ (Calcium nitrate) (Colourless)	$Ca(NO_3)_2 + 2NaOH \rightarrow Ca(OH)_2\downarrow + 2NaNO_3$	$Ca(OH)_2$ (Calcium hydroxide)	White	Sparingly Soluble

- **Action of Ammonium hydroxide (NH_4OH) with solution of salts:**

Ion	Salt (Colour)	Reaction	Precipitate formed	Colour of the precipitate	Solubility of the precipitate in an excess of NH_4OH
Mg^{2+}	$MgCl_2$ (Magnesium chloride) (White)	$MgCl_2 + 2NH_4OH \rightarrow Mg(OH)_2\downarrow + 2NH_4Cl$	$Mg(OH)_2$ (Magnesium hydroxide)	White	Insoluble
Fe^{2+}	$FeSO_4$ (Iron (II) sulphate) (Green)	$FeSO_4 + 2NH_4OH \rightarrow Fe(OH)_2\downarrow + (NH_4)_2SO_4$	$Fe(OH)_2$ (Iron (II) hydroxide)	Dirty green	Insoluble
Fe^{3+}	$FeCl_3$ (Iron (III) chloride) (Brown)	$FeCl_3 + 3NH_4OH \rightarrow Fe(OH)_3\downarrow + 3NH_4Cl$	$Fe(OH)_3$ Iron (III) hydroxide)	Reddish brown	Insoluble
Cu^{2+}	$CuSO_4$ (Copper sulphate) (Blue)	$CuSO_4 + 2NH_4OH \rightarrow Cu(OH)_2\downarrow + (NH_4)_2SO_4$ $Cu(OH)_2 + (NH_4)_2SO_4 + 2NH_4OH \rightarrow [Cu(NH_3)_4]SO_4 + 4H_2O$ (Excess)	$Cu(OH)_2$ (Copper (II) hydroxide) Tetraammine copper (II) sulphate	Pale blue Deep blue solution	Soluble
Zn^{2+}	$ZnSO_4$ (Zinc sulphate) (Colourless)	$ZnSO_4 + 2NH_4OH \rightarrow Zn(OH)_2\downarrow + (NH_4)_2SO_4$ $Zn(OH)_2 + (NH_4)_2SO_4 + 2NH_4OH \rightarrow [Zn(NH_3)_4]SO_4 + 4H_2O$ (Excess)	$Zn(OH)_2$ (Zinc(II) hydroxide) Tetraammine zinc(II) sulphate	White gelatinous colourless solution	Soluble (Soluble)
Pb^{2+}	$Pb(NO_3)_2$ (Lead (II) nitrate) (white)	$Pb(NO_3)_2 + 2NH_4OH \rightarrow Pb(OH)_2\downarrow + 2NH_4NO_3$	$Pb(OH)_2$ (Lead(II) hydroxide)	Chalky White	Soluble

- **Action of Sodium hydroxide (NaOH) with zinc, aluminium and lead (action of alkalis on metals):**

$$Zn + \underset{\text{(conc.)}}{2NaOH} \xrightarrow{\Delta} \underset{\substack{\text{Sodium zincate}\\ \text{(colourless)}}}{Na_2ZnO_2} + H_2$$

$$2Al + \underset{\text{Conc.}}{2NaOH} + 2H_2O \xrightarrow{\Delta} \underset{\substack{\text{Sodium}\\ \text{meta-aluminate}\\ \text{(colourless)}}}{2NaAlO_2} + 3H_2$$

$$Pb + \underset{\text{Conc.}}{2NaOH} \xrightarrow{\Delta} \underset{\substack{\text{Sodium}\\ \text{Plumbite}\\ \text{(colourless)}}}{Na_2PbO_2} + H_2$$

Similarly, we can write reactions with potassium hydroxide (KOH).

- **Action of alkalis on amphoteric metal oxides / metal hydroxides (Action with sodium hydroxide (NaOH):**

$$\underset{\text{(white)}}{ZnO} + \underset{\text{Conc.}}{2NaOH} \xrightarrow{\Delta} \underset{\substack{\text{Sodium}\\ \text{Zincate}\\ \text{(colourless, soluble)}}}{Na_2ZnO_2} + H_2O$$

$$\underset{\text{(white)}}{Zn(OH)_2} + \underset{\text{Conc.}}{2NaOH} \xrightarrow{\Delta} \underset{\substack{\text{Sodium}\\ \text{Zincate}\\ \text{(colourless, soluble)}}}{Na_2ZnO_2} + 2H_2O$$

$$\underset{\text{(Yellow)}}{PbO} + \underset{\text{Conc.}}{2NaOH} \xrightarrow{\Delta} \underset{\substack{\text{Sodium}\\ \text{plumbite}\\ \text{(colourless, soluble)}}}{Na_2PbO_2} + H_2O$$

$$\underset{\text{(Yellow)}}{Pb(OH)_2} + \underset{\text{Conc.}}{2NaOH} \xrightarrow{\Delta} \underset{\substack{\text{Sodium}\\ \text{plumbite}\\ \text{(colourless, soluble)}}}{Na_2PbO_2} + 2H_2O$$

$$\underset{\text{(White)}}{Al_2O_3} + \underset{\text{Conc.}}{2NaOH} \xrightarrow{\Delta} \underset{\substack{\text{Sodium}\\ \text{meta-aluminate}\\ \text{(colourless, soluble)}}}{2NaAlO_2} + H_2O$$

$$\underset{\text{(White)}}{Al(OH)_3} + \underset{\text{Conc.}}{NaOH} \xrightarrow{\Delta} \underset{\substack{\text{Sodium}\\ \text{meta-aluminate}\\ \text{(colourless, soluble)}}}{NaAlO_2} + 2H_2O$$

Similarly, we can write reactions with KOH.

Key Words

- **Analysis:** Involves the determination of chemical components present in a given sample in case of chemistry.
- **Analytical chemistry:** A branch of chemistry which deals with the experimental study of sample by qualitative as well as quantitative means.
- **Qualitative analysis:** Deals with the identification of unknown substances in a given sample by chemical tests.
- **Quantitative analysis:** Deals with the determination of composition of a mixture.
- **Precipitation:** It is the process of formation of an insoluble solid substance in water by mixing which is called precipitate.
- **Reagent:** It is a substance which reacts with another substance.

Key Terms

- When the sodium hydroxide solution is added drop by drop to the solution of metallic salts, the metal hydroxide formed gets precipitated.
- Colour of the precipitate identifies the specific metal ion.
- When ammonium hydroxide solution is added drop-wise to the solutions of metallic salts, precipitates of their hydroxides are formed, which are identified by their distinct colours.
- Some precipitated metallic hydroxides are soluble in excess of NH_4OH due to the formation of soluble amino compounds on further reaction with excess of NH_4OH.
- Certain metals like Zn, Al and Pb react with hot concentrated caustic alkalis (NaOH or KOH) to form the corresponding soluble salt and liberate hydrogen.
- Amphoteric oxides and hydroxides are those compounds which react with both acids and alkalis to form salt and water.

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CHAPTER-5
MOLE CONCEPT AND STOICHIOMETRY

Topic-1

Gay Lussac's Law

Concepts covered: • *Gay Lussac's law of combining volumes*

Revision Notes

- **Gay Lussac's law of combining volumes :**
  - It states that whenever gases react, they always do so in volumes which bear a simple whole number ratio to one another and to the volumes of gaseous products. All volumes being measured under similar conditions of

temperature and pressure. In simple words, it states that, "for a given mass and constant volume of an ideal gas, the pressure exerted on the sides of its container is directly proportional to its absolute temperature."

- Gay Lussac's Law is valid only for gases and the volumes of solids and liquids are considered to be zero. It expresses the relationship between pressure and temperature.

➢ **Example of Gay Lussac's Law :**

Hydrogen chloride : One volume of hydrogen mixed with one volume of chlorine gives two volumes of hydrogen chloride gas.

$$\begin{array}{cccc} H_2 & + \; Cl_2 & \rightarrow & 2HCl \\ 1 \text{ Vol.} & 1 \text{ Vol.} & & 2 \text{ Vol.} \end{array}$$

(At same temperature and pressure)

Simple ratio is 1: 1: 2

➢ **Avogadro's law explains Gay-Lussac's Law**

Avogadro's law states that, under the same conditions of temperature and pressure, equal volume of different gases have the same number of molecules. As substance reacts in simple ratio by the number of molecules, volumes of gaseous reactants and products will also bear a simple ratio. This is the statement of Gay-Lussac's law.

$$\begin{array}{ccccc} H_2 & & Cl_2 & & 2HCl \\ 1 \text{ vol} & + & 1 \text{ vol} & \rightarrow & 2 \text{ vol} \end{array}$$

[by Gay-Lussac's law] [by Avogadro's law]

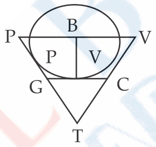
Mnemonics

1. **Concept :** Gas Laws

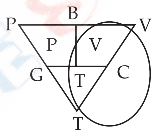
Mnemonics :

Can These **G**uys **P**ossibly **B**e **V**ictorious?
C—Charles
T—Temperature
G—Gay Lussac's Law
P—Pressure
B—Boyles
V—Volume

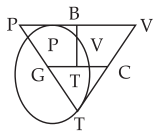
Interpretation :



Boyle's Law
$= P_1V_1 = P_2V_2$



Charles Law:
$= \frac{V_1}{T_1} = \frac{V_2}{T_2}$



Gay Lussacs Law
$= \frac{P_1}{T_1} = \frac{P_2}{T_2}$

Key Words

➢ **Absolute Scale or Kelvin Scale :** A temperature scale with absolute zero (Zero Kelvin) as the starting point is called the absolute scale or Kelvin scale.

➢ **Limiting reagent or reactant :** The reactant which is completely used up in a reaction is called limiting reagent or limiting reactant.

➢ **Stoichiometry :** It measures quantitative relationship which is used to determine the amount of products or reactants that are produced or required in a given reaction.

➢ **Atom :** It is the smallest particle of an element that can take part in a chemical reaction. It may or may not exist independently.

➢ **Molecule :** It is the smallest particle of an element or a compound that can exist by itself. It never breaks up except for taking part in a chemical reaction.

Key Terms

➢ Since the volume of a gas changes remarkably with change of temperature and pressure, it becomes necessary to choose standard values of temperature and pressure to which gas volumes can be referred.

➢ **Standard values :**

- 0°C or 273 K for temperature
- 1 atmospheric pressure or 760 mm or 76 cm of Hg for pressure.

➢ Absolute zero = 0K = – 273°C

➢ Gay-Lussac's Law is valid only for gases. The volume of solids and liquids are considered to be zero.

➢ The relative atomic mass of any element is the weighted average of the relative atomic masses of its natural isotopes. For example, chlorine consists of a mixture of two isotopes of masses 35 and 37 in the ratio of 3 : 1.

➢ Atomicity $= \dfrac{\text{Molecular Mass}}{\text{Atomic Mass}}$

Topic-2

Relative Molecular Mass and Mole Concept

Concepts covered: • *Relative molecular mass,* • *Vapour density,* • *Mole concept*

Revision Notes

- The relative molecular mass of an element or a compound is the mass of one molecule of an element or compound compared with the mass of an atom of carbon - 12, which is arbitrarily assigned a value of 12.00.
- Relative molecular mass is a number dealing with a molecule.
- Gram molecular mass is the mass of one mole of a substance.

  For example,

  (i) Gram molecular mass of oxygen gas = 32 g

  (ii) Gram molecular mass of nitric acid = 63 g.
- The relative molecular mass of a gas or vapour is twice its vapour density (V.D.).
- Relative molecular mass of a gas = 2×VD.
- The molar mass of any gas is its relative molecular mass expressed in g (grams).
- The molar volume of any gas at STP is equal to 22.4 dm^3.
- The volume of a gas, which contains 6.023×10^{23} molecules is always 22.4 dm^3 at STP.
- The number of molecules contained in one mole of any substance is equal to 6.023×10^{23}.
- Mole is the mass of a substance containing 6.023×10^{23} particles. The particles may be atoms, molecules, ions, electrons, etc.

  Thus, the mole of substance is related to

  (a) the mass of a substance,

  (b) particles contained in a substance.

  $$\text{Number of moles of a substance} = \frac{\text{Mass of the substance}}{\text{Gram molecular mass of the substance}}$$

  $$= \frac{\text{Number of particles in the substance}}{6.023\times10^{23}}$$
- **Mole Concept :** Mole is simply like a dozen or a gross. A dozen is a collection of 12 objects, a gross is a collection of 144 objects, similarly a mole is a collection of 6.023×10^{23} (Avogadro's number) elementary particles (atoms or ions or molecules).
- **Mole :** A mole is defined as the amount of a substance containing elementary particles like atoms, molecules or ions in 12 g of carbon (C-12).
- **Mole of Atoms (Relating Mole and Atomic Mass) :** One mole of atoms contain 6.023×10^{23} atoms having mass equal to its gram atomic mass. One mole of oxygen atoms contains 6.023×10^{23} atoms of oxygen and weights 16 g.
- **Mole of Molecules (Relating Mole and Molecular Mass) :** One mole contains 6.023×10^{23} molecules and is equivalent to the given molecular mass of any given substance. For example, 1 mole of O_2 contain, 6.023×10^{23} molecules and weights 32 g.
- **Mole and Molar volume :** One mole of any gaseous molecule occupy 22.4 (dm^3) litre or 22400 cm^3 (mL) at STP. This volume is known as **molar volume**. The molar volume of a gas can be defined as the volume occupied by one mole of a gas at STP.

  $$\text{Gram molecular volume (Molar volume)} = \frac{\text{Gram molecular weight}}{\text{Weight per litre of gas at STP}}$$

  For example :

  1 mole of H_2SO_4 = $(2 \times 1) + 32 + (4 \times 16) = 98g = 6.022 \times 10^{23}$ molecules of H_2SO_4
  1 mole of NH_3 = $14+(3\times1) = 17g = 6.022 \times 10^{23}$ molecules of NH_3
  1 mole of Na = $23g = 6.023 \times 10^{23}$ atoms of Na.
  Volume occupied by 1 mole of NH_3 = 22.4 litres at STP
  Volume occupied by 1 mode of O_2 = 22.4 litres at STP
- **Relative Vapour Density :** The relative vapour density of a gas is the ratio between the masses of equal volumes of gas (or vapour) and hydrogen under the same conditions of temperature and pressure.

  $$\text{Relative VD} = \frac{\text{Mass of volume V of the gas under similar condition}}{\text{Mass of volume V of hydrogen gas under similar condition}}$$

  - According to Avogadro's law, volume at the same temperature and pressure may be substituted by molecules.

- 2 × Relative vapour density (VD) = Relative molecular mass of a gas. The relative molecular mass of gas or vapour is twice its vapour density.

Mnemonics

Concept : Relation in molecular mass and vapour density

Mnemonics :

My **M**om is equal to **2 v**estern **D**ancer

Interpretation :
M—molecular
M—mass
2—2
V—vapour
D—density
Molecular mass = 2 x Vapour density

Key Words

- **Relative Atomic mass :** The relative atomic mass or atomic weight of an element is the number of times one atom of the element is heavier than 1/12 time of the mass of an atom of C-12.
- **Atomic mass unit :** It is defined as 1/12 the mass of carbon atom C-12.
- **Relative molecular mass :** The relative molecular mass or molecular weight of an element or a compound is the number that represents how many times one molecule of the substance is heavier than 1/12 of the mass of an atom of carbon-12.
- **Gram Atomic Mass :** It is defined as the atomic mass of an element expressed in grams.
- **One Gram Atom :** The quantity of the element which weighs equal to its gram atomic mass is known as one gram atom of that element.
- **Gram Molecular mass :** It is defined as the molecular mass of a substance expressed in grams.
- **Avogadro's Number :** It is defined as the number of atoms present in 12 g (gram atomic mass) of C-12 isotope i.e., 6.023×10^{23} atoms.

Key Terms

- One mole of oxygen atoms contain 6.023×10^{23} atoms of oxygen and weighs 16 g.
- 1 G.M.M. of the substance = 1 mole of that substance = 6.02×10^{23} molecules of that substance = 22.4 L at S.T.P.
- The relative vapour density of a gas (or a vapour) is the ratio between the masses of equal volumes of gas (or vapour) and hydrogen under the same conditions of temperature and pressure.
- The relative molecular mass of a gas or vapour is twice its vapour density.
- Mass of one atom = $\dfrac{\text{Atomic mass}}{6.023 \times 10^{23}}$
- Mass of one molecule = $\dfrac{\text{Molecular mass}}{6.023 \times 10^{23}}$
- Number of molecules = moles × 6.023×10^{23}
- Number of atoms = moles × 6.023×10^{23}

Topic-3

Percentage Composition, Empirical and Molecular Formula

Concepts covered: • *Molecular formula,* • *Empirical formula,* • *To calculate percentage of element in a compound,* • *Relationship between molecular formula and empirical formula*

Revision Notes

- **Molecular Formula :** It is the symbolic representation of a molecule of a substance which indicates the actual number of atoms of various elements present in one molecule of it.

  For example, Molecular formula of benzene = C_6H_6.

- **To Calculate Percentage of an Element in a Compound :**

  $$\text{Percentage of an element in a compound} = \frac{\text{Total mass of the element}}{\text{Molecular mass of the compound}} \times 100$$

- **To Calculate Percentage Composition of a compound :**
  - In order to calculate the percentage composition of a compound we have to calculate the percentage of each element in the compound.
- **Empirical Formula :** Empirical formula of a compound gives us the simplest whole number ratio between the atoms of various elements present in one molecule of it.
  - Empirical formula of benzene = C_1H_1
  - Empirical formula of glucose = $C_1H_2O_1$
- **Relationship between Empirical and Molecular formula :**
  - Molecular formula of a compound is a simple whole number multiple of its empirical formula.

    Molecular formula = n × empirical formula

    Where n is a simple whole number

    $$\text{or } n = \frac{\text{Molecular formula}}{\text{Empirical formula}} \quad \text{or} \quad n = \frac{\text{Molecular Mass}}{\text{Empirical Formula Mass}}$$

    $$= \frac{2 \times \text{Vapour density of a gas or vapour}}{\text{Empirical formula mass}}$$

(Note : Molecular and unit less)

Mnemonics

Concept : Relation between molecular formula and empirical formula

Mnemonics:

MF Tyres **N**ot **E**asy To **F**ail

M—Molecular

F—Formula

N—n

E—empirical

F—Formula

Interpretation : Molecular Formula = $n \times E\,F$

Key Terms

- Molecular formula of Blue vitriol is $CuSO_4 \cdot 5H_2O$.
- The empirical formula of glucose ($C_6H_{12}O_6$) is CH_2O. It indicates that the ratio of C, H and O atoms in a molecule of glucose is 1 : 2 : 1.

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CHAPTER-6

ELECTROLYSIS

Topic-1

Electrolytes and Non-electrolytes

Concepts covered: • *Electrochemical changes,* • *Conductors of electric current,* • *Electrolytes and non-electrolytes*

Revision Notes

- **Electrochemical Changes:** The chemical changes which are accompanied by the flow of electricity are called **electrochemical changes**.
- **Electrochemical changes are of two types:**

  (i) The electrochemical changes in which electricity from outside source is used to carry out a reaction called **electrolysis**.

  (ii) Those electrochemical changes in which electricity is produced as a result of indirect redox reactions.

- **Conductors are of two types:**
  - **(i) Metallic Conductors**: These are the substances which conduct electric current in the solid state and at the same time these are not chemically decomposed. Example: Copper, silver, gold, graphite, etc.
  - **(ii) Electrolytes**: These are the substances which conduct electric current in the solution or molten state and at the same time these are chemically decomposed. For example: Sodium chloride (NaCl), hydrogen chloride (HCl), sodium hydroxide (NaOH), etc.
- **Non-electrolytes:** The substances which do not conduct electric current in the molten or dissolved state are called non-electrolytes. For example — Urea, Sucrose, Glucose, Fructose, etc.
- **Differences between metallic conductors and electrolytes:**

Metallic conductors	Electrolytes
(i) Flow of electricity is due to the movement of electrons.	Flow of electricity is due to movement of ions.
(ii) The electrical conductivity decreases with the increase in temperature.	The electrical conductivity increases with the increase in temperature.
(iii) Flow of electricity takes place in the solid state.	Flow of electricity takes place in the molten or dissolved state.
(iv) There is no flow of matter.	There is flow of matter.
(v) There is no chemical decomposition. It involves a physical change.	There is chemical decomposition of the substance. It involves a chemical change.

Theory of Electrolytic Dissociation:

Svante Arrhenius, in 1887, gave the theory of electrolytic dissociation. According to him:

(i) An electrolyte on dissolving in water dissociates into free mobile ions, i.e., cations and anions and allow to flow of an electric current through it.

(ii) All ions carry an electric charge and are responsible for the flow of current through the solution.

(iii) The conductivity of the electrolyte depends upon the concentration of ions in the solution.

(iv) The number of positive charges equals the number of negative charges in the solution and thus the solution is in electrolyte equilibrium.

The equilibrium is also established between the unionised molecules and the ions produced.

(v) In non-electrolytes, such as sugar solution, there is no ionisation and therefore, only molecules are present in solution.

(vi) The degree of dissociation is to that extent that an electrolyte dissociates or breaks up into ions.

- **Electrolysis** is the process by which ionic substances are decomposed into simpler substances when an electric current is passed through them.
- **Characteristics of Electrolysis:**
  - The passage of electricity through an electrolyte causes the metallic ion (cation) to migrate towards the cathode and the non-metallic ion (anions) to migrate towards the anode. The number of electrons gained by the anode is equal to the number of electrons donated by the cathode.
  - Only hydrogen gas and metals are liberated at the cathode and hence are called **electropositive elements**. Only non –metals are liberated at the anode and are called **electronegative elements**. The process of electrolysis is a **redox reaction.**
  - The reaction at the cathode involves reduction of cations as they gain electrons to become neutral atoms while that at anode involves oxidation of anions as they lose electrons to become neutral.

    For example: $NaCl \rightarrow Na^+ + Cl^-$

    At Cathode: $Na^+ + e^- \rightarrow Na$ (Reduction)

    At Anode: $Cl^- \rightarrow Cl + e^-$ (Oxidation)

    $Cl + Cl \rightarrow Cl_2$

    Overall reaction: $2NaCl \rightarrow 2Na + Cl_2$
  - The alternating current (AC) does not cause any chemical change and therefore does not help electrolysis to occur. Electrolysis is caused by direct current (DC).
- **Electrochemical Series:**

The metals are arranged in a series known as the **electrochemical series**. The arrangement is so done that the elements that ionise most readily (discharged with great difficulty) are placed at the top of the series and the other elements in the descending order.

Metal	Cation		At Cathode	At Anode		Anion
K	K^+	Increasing ease of reduction	Discharged with most difficulty. Positive ions (cations) discharged at cathode by gain of electrons. The tendency of the cations to get reduced at the cathode increases on descending the electrochemical series. Discharged most easily.	Discharged with most difficulty. Negative ions (anions) discharged at anode by loss of electrons. The tendency of the anions to get oxidised at the anode increases on descending the electrochemical series. Discharged most easily.	Increasing ease of Oxidation	SO_4^{2-}
Ca	Ca^{2+}					
Na	Na^+					NO_3^-
Mg	Mg^{2+}					
Al	Al^{3+}					Cl^-
Zn	Zn^{2+}					
Fe	Fe^{2+}					Br^-
Pb	Pb^{2-}					
H	H^+					I^-
Cu	Cu^{2+}					
Hg	Hg^{2+}					OH^-
Ag	Ag^+					

- **Preferential or Selective Discharge of Ions at Cathode:**

The preferential discharge of ions present in an electrolyte at the perspective electrodes is also known as **selective discharge of ions.** If a solution contains more than two cations and anions the selective discharge of ions depends upon following three functions.

(i) The relative position of the cations or anion in electrochemical series.

(ii) Concentration of the ions in the electrolyte.

(iii) The nature of the electrode.

- **Concentration of Ions in the Electrolyte:**

Higher the concentration of the ion greater the probability of it being discharged at the respective electrode. For example:

Electrolysis of concentrated NaCl solution. $\mathrm{NaCl} \rightleftharpoons Na^+ + Cl^-$

$$H_2O \rightleftharpoons H^+ + OH^-$$

Cathode: Na^+ ions discharged.

Anode: OH^- ions discharged.

Concentration of Na^+ and Cl^- ion are much higher than H^+ and OH^- ions.

Electrolysis of dilute NaCl solution.

$$\mathrm{NaCl} \rightleftharpoons Na^+ + Cl^-$$

$$H_2O \rightleftharpoons H^+ + OH^-$$

Cathode - Na^+ ions discharged.

Anode - OH^- ions discharged.

H^+ and OH^- ions are lower in electrochemical series than Na^+ and Cl^-.

- **Nature of the Electrode:**

Electrodes used in the process of electrolysis are either inert or active. If an active electrode (i.e., Cu, Ni, Ag) is used, it will take part in a chemical reaction. Then, the anions (e.g., SO_4^{2-} and OH^- ions) migrate to the anode but are not discharged. The active electrode (Cu, Ag) itself loses electrons and forms ions, e.g., Cu^{2+}, Ag^+ at the anode. If inert, electrode like iron, graphite, platinum are used, they will not take part in electrolyte reaction.

I. Electrolysis of Molten Lead Bromide

Electrolyte: Molten Lead Bromide ($PbBr_2$)

Temperature: Above 380°C

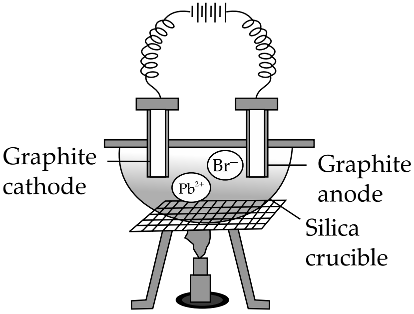
Electrolytic cell: Crucible made of silica.

Electrodes: The cathode and anode are both made of graphite plates which are inert.

Ions present: Pb^{2+} and Br^- i.e., lead ions and bromide ions.

Electrode Reactions:

At the cathode: $Pb^{2+} + 2e^- \rightarrow Pb$



Electrolysis of molten lead bromide

At the anode: $Br^- - e^- \rightarrow Br$

$Br + Br \rightarrow Br_2$

Overall reactions: $PbBr_2(1) \rightarrow Pb(s) + Br_2$

Observation: (a) Dark reddish-brown fumes of bromine evolved at the anode.

(b) Greyish white metal lead is formed on the cathode.

II. Electrolysis of Acidified Water Using Platinum Electrodes

Electrolyte: Acidified water

(Water + Dilute H_2SO_4)

Electrodes: Platinum foils, connected by corner wires to the two terminals of a battery.

Ions present: H^+, OH^-, SO_4^{2-}

Electrode reactions:

At the cathode: $H^+ + e^- \rightarrow H$

$H + H \rightarrow H_2$

At the anode:

$OH^- \rightarrow OH + e^-$

$OH + OH \rightarrow H_2O + O$

$O + O \rightarrow O_2$

Overall reaction: $2H_2O \xrightarrow[\text{Electric currect}]{H_2SO_4} 2H_2(g) + O_2(g)$

The ratio of hydrogen and oxygen liberated at the cathode and anode is in the ratio 2: 1 by volume.

III. Electrolysis of Copper Sulphate Solution Using Platinum Anode and Copper or Platinum cathode

- **Electrolyte:** Saturated solution of copper (II) sulphate proposed in distilled water with a small amount of conc. H_2SO_4.
- **Dissociation of aqueous copper sulphate:**

$$CuSO_4 \rightleftharpoons Cu^{2+} + SO_4^{2-}$$
$$H_2O \rightleftharpoons H^- + OH^-$$

Particles present: Cu^{2+}, H^+, SO_4^{2-}, OH^- and H_2O molecules

Ions present: Cu^{2+}, H^+, SO_4^{2-}, and OH^-

Reactions at cathode: $Cu^{2+} + 2e^- \rightarrow Cu$

Reactions at anode: $4OH^- - 4e^- \rightarrow 4OH$

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

Product at anode: Oxygen

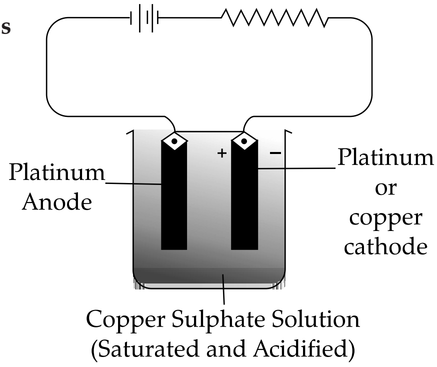
Product at cathode: Pink or reddish brown copper is deposited.

IV. Electrolysis of Aqueous Copper Sulphate Using Copper Electrodes

Electrolytic cell ⟶ Iron crucible/glass voltmeter

Electrolyte ⟶ Aqueous copper sulphate

Electrode ⟶ Cathode: Copper, Anode: Copper



Electrolysis of copper sulphate solution

- Dissociation $\underset{\text{Copper sulphate}}{CuSO_4} \rightleftharpoons Cu^{2+} + SO_4^{2-}$

  [ions present Cu^{2+}, H^+, SO_4^{2-}, OH^- of copper

  Sulphate (aq.) $H_2O \rightleftharpoons H^+ + OH^-$
- At cathode $\underset{\text{reduction reaction}}{Cu^{2+}} + 2e^- \rightarrow Cu$
- At anode $\underset{\text{oxidation reaction}}{Cu} \rightarrow Cu^{2+} + 2e^-$
- **Product at cathode:** Brownish pink metal Cu is deposited at the cathode during electrolysis of $CuSO_4$ solution.
- **Product at anode:** Nil [copper ions formed]

- At cathode, Cu^{2+} ions and H^+ ions migrate to the cathode Cu^{2+} ions are discharged in preference to H^+. (Cu^{2+} is lower in the series).

Mnemonics

1. **Concept:** Electro chemical Series
   Mnemonics:
   KINGS **C**AN **N**OT **M**AKE **A** **Z**EBRA. **I** **L**IKE **H**IS
   CAR'S
   HUGE SILVERY GATE.
   Interpretation:
   K ings- POTASSIUM
   C an- CALCIUM
   N ot- (Na)SODIUM
   M ake- MAGNESIUM
   A - ALUMINIUM
   Z ebra- ZINC
   I – Fe - IRON
   L ike- LEAD
   H is- HYDROGEN
2. **Concept:** Electrode reactions
   Mnemonics:
   AN **O**IL **R**IG **C**AT:
   Interpretation:
   At the **A**node, **O**xidation **I**nvolves **L**oss of electrons.
   Reduction **I**nvolves **G**aining electrons at the **C**athode

Key Words

- **Electrochemistry:** It is the branch of chemistry which deals with the study of relationship between electrical and chemical energy.
- **Conductors:** The substances which conduct electric current when present in one form or the others are called conductors. Examples- Copper, silver, gold, graphite, etc.
- **Insulators:** The substances which don't conduct electric current are called non-conductors or insulators.
  Examples: Rubber, wood, plastic, glass, sulphur, etc.
- **Ionisation:** The process by which a polar covalent compound (molecule) is converted into ions in aqueous solutions is called ionisation.

  For example: $HCl \xrightleftharpoons{\text{water}} H^+ + Cl^-$

  $$H-Cl + H_2O \rightleftharpoons H_3O^+ + Cl^-$$
- **Dissociation:** It is the process of separation of ions of the ionic solid in the aqueous solutions.
  For example: $NaCl(s) \xrightarrow{\text{water}} Na^+(aq) + Cl^-(aq)$
- **Degree of ionisation or dissociation:** It is the fraction of the total number of moles of the electrolytes which undergo ionisation or dissociation in solution at equilibrium.
- **Electrolytic cell**: It is the vessel in which electrolysis is carried out. It is also called voltmeter. The vessel is made up of glass or any other insulating material.
- **Electrodes:** It is a pair of rods or plates of metals (or graphite) dipped in the molten or dissolved electrolyte through which the electric current enters or leaves the electrolytes.
- **Anode:** The electrode connected to the positive terminal of the battery is called anode. During electrolysis, anode acquires a positive charge and hence ions in a solution which are negatively charged (i.e., anions) migrate to the anode. The anions donate excess electrons to the anode and are oxidized to neutral atoms. It is an oxidizing electrode. Oxidation takes place at anode.
- **Cathode:** The electrode connected to the negative terminal of the battery is called cathode. During electrolysis, cathode acquires a negative charge and hence ions in a solution which are positively charged (i.e., cations) migrate to the cathode. The cations gain excess electrons from the cathode and are reduced to neutral atoms. It is a reducing electrode. Reduction takes place at cathode.
- **Ions:** Atoms or groups of atoms which carry a positive or a negative charge are known as ions. The charge on an ion, positive or negative is equal to the valency of the atom or the ion. The ion that carries a positive charge is called cation and which carries a negative charge is called anion.
- **Anions:** Anions migrate to the anode during electrolysis. Anions donate or lose electrons to the anode (oxidation process) and get oxidized to neutral atoms.

  e.g., At anode $\underset{\text{Anion}}{Cl^-} \rightarrow \underset{\text{Atom}}{Cl} + e^-$
- **Cations:** Cations migrate to the cathode during electrolysis. Cations accept or gain electrons from the cathode (reduction process) and get reduced to neutral atoms.

e.g., At Cathode $\underset{\text{cation}}{Na^+} + e^- \rightarrow \underset{\text{Atom}}{Na}$

- **Metal:** It is a solid material which conducts heat and electricity, hard, shiny, malleable, fusible and ductile.
- **Non-metal:** It is an element that doesn't have the characteristics of metal including ability to conduct heat or electricity, lustre or flexibility.
- **Metalloid:** Any chemical element which has properties in between those of metals and non-metals.
- **Alkali metals:** Elements found in Group IA of the periodic table.
- **Alkaline earth metals:** Elements found in Group IIA of the periodic table.

Key Terms

- The term electrolysis is made up of two words:
  'electro' — means flow of electrons of electricity
  'lysis' — means separating
- Electrolysis establishes a relationship between electrical energy and chemical change.
- Metals and alloys are conductors and non-metals are non-conductors.
- Non-electrolytes do not have ions even in solution. They contain only molecules.
- All salts are strong electrolytes. They form acidic or basic or neutral solution after complete dissociation.
- Electrolytic cell (voltameter) converts electrical energy into chemical energy.
- Electrochemical cell converts chemical energy into electrical energy.
- Oxidation is defined as a process which involves:
  - loss of electrons (s)
  - addition of oxygen
  - removal of hydrogen
- Reduction is defined as a process which involves:
  - gain of electron (s)
  - removal of oxygen
  - addition of hydrogen
- For making acidified water, dil. H_2SO_4 is preferred because it is non-volatile while dil. HNO_3 or HCl are volatile acids.

Topic-2

Applications of Electrolysis

Concepts covered: • *Applications of electrolysis,* • *Electroplating with silver and nickel,* • *Electro-refining of copper*

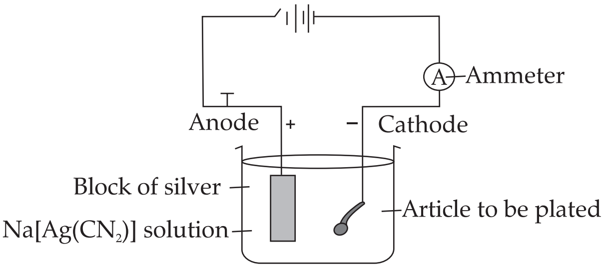
Revision Notes

- **Electrolysis has several technical and commercial applications. These are as follows:**
  1. Electroplating with metals
  2. Electro-refining of metals
  3. Extraction of metals (Electro-metallurgy)
- **I. Electroplating of an Article with Silver:**
  Electrolyte: Sodium argentocyanide, $Na[Ag(CN)_2]$
  Cathode: Article to be plated.
  Anode: Pure plate of silver metals
  Dissociation of $Na[Ag(CN)_2]$

$$Na[Ag(CN)_2] \rightleftharpoons Na^+ + Ag^+ + 2CN^-$$

Dissociation of H_2O

$$H_2O \rightleftharpoons H^+ + OH^-$$



Electroplating an article with silver

Reaction at the cathode: $Ag^+(aq) + e^- \rightarrow Ag(s)$

Reaction at the anode: $Ag(s) \rightarrow Ag^+(aq) + e^-$

- **II. Electrolyte: Nickel Sulphate, $NiSO_4$**

  Cathode: Pure plate of nickel metal

  Anode: Pure plate of nickel metal

  Dissociation of $NiSO_4$

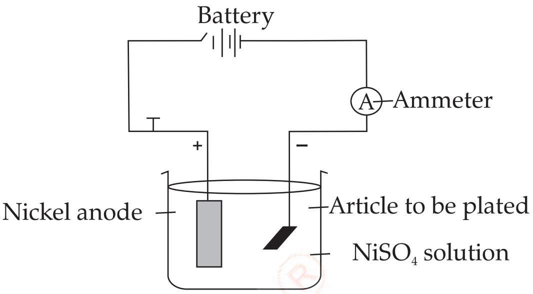
  $$NiSO_4 \rightarrow Ni^{2+} + SO_4^{2-}$$

  Dissociation of H_2O

  $$H_2O \rightleftharpoons H^+ + OH^-$$

  Reaction at the cathode $Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$

  Reaction at the anode $Ni(s) \rightarrow Ni^{2+}(aq) + 2e^-$



Electroplating an article with nickel

- **Reasons for Electroplating**

  It prevents corrosion or rusting, e.g., iron plated with nickel or chromium decoration purpose makes the article attractive and gives it an expensive appearance. e.g., brass metal plated with silver or gold.

  Conditions to be maintained during electroplating:

  (i.) The article to be deposited is always made the cathode in electrolysis, since the metal is deposited at the cathode.

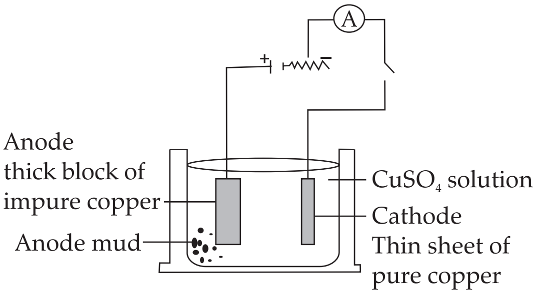
  (ii.) The metal to be plated on the article is always made the anode, since metal continuously dissolves into the solutions; it has to be replaced periodically.

  (iii.) The electrolyte solution must contain the metal ions like Ag, Au, Ni, since these ions travel towards cathode and get deposited on the metal placed at cathode.

  (iv.) Less amount of current is supplied for longer time.

  (v.) Only direct current is to be used because alternating current causes discharge or ionisation on alternate electrode. No effective coating takes place on cathode.

- **Electro-refining**
  - In electro-refining, the impure metal is made the anode in an electrolytic tank containing some suitable electrolyte of the metal. A thin sheet of pure metal is made the cathode. On passing electric current, metallic cations from the electrolyte move to the cathode, lose their charge and get deposited in the form of pure metal. At the same time, the anions travel to the anode and dissolve an equivalent amount of metal from it. The impurities present in the crude metal either pass into solutions or settle down as anode mud.
  - **Reaction at cathode:** $Cu^{2+} + 2e^- \rightarrow Cu$ [deposited]
  - Cu^{2+} ions are discharged at the cathode. Thus, pure copper deposited on the thin sheet of pure copper placed at the cathode. [Cu-active electrode].
  - **Reaction at anode:** $Cu - 2e^- \rightarrow Cu^{2+}$ [cation]
  - SO_4^{2-} and OH^- migrate to the anode but neither are discharged. Instead, the copper anode itself loses electrons to give Cu^{2+} ions in solution. Hence, anode diminishes in mass.
  - The process of extraction of metals from their fused or molten ores by the use of electrolysis or electric current is called **electro-metallurgy.**



Electrorefining of copper

Mnemonics

- **Concept:** Reaction at cathode
- **Mnemonics:** Red cat attack an ox:
- **Interpretation:** Reduction at cathode and anode for oxidation

Key Words

- **Electroplating:** A process in which a thin film of a metal like gold, silver, nickel chromium, etc., gets deposited on another metallic article with the help of electricity.

- **Electro-refining:** A process by which metals such as Al, Pb, Cu, Ni and Zn extracted from their ores by chemical method, are freed from impurities electrolytically to obtain a metals in their pure state.
- **Electro-metallurgy:** It is the process of extraction of metals which are higher in the electrochemical series such as Na, K, Al, Mg etc., from their ores by electrolysis.

Key Terms

- Brass objects are frequently plated with silver to give them shining appearance and beauty of a silver article.
- Iron tools are often electroplated with Ni or Cr or Zn to protect against rusting.
- The article to be electroplated is always placed at the cathode.
- During electrolytic reaction, the metal is always deposited at the cathode by gain of electrons.
- The thickness of the coating will depend on the duration of the current passed.
- Metals like Zn, Pb, Hg, Ag and Cu are refined by electrolysis.
- Reactive metals are not extracted from their aqueous salt solutions by electrolysis. This is because the aqueous solution will contain H^+ ion along with metal ion. On the passage of electric current, the H^+ ion gets discharged in preference to metal. So, the product formed at cathode is hydrogen gas and not the metal.

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CHAPTER-7

METALLURGY

Revision Notes

The **elements** are the basic building blocks of matter. There are about 120 elements known till now. To study the characteristics and the properties of all these elements in simpler way, they are divided into two categories i.e., metals and non-metals.

- **Minerals:** Minerals are naturally occurring compounds of metals which are generally mixed with other substances such as silica, limestone, etc. These earthy impurities are called gangue or matrix.
- **Ores:** Ores are those minerals from which metals are extracted commercially at a comparatively lower cost and with minimum effort.
- **Occurrence of metals:** Most of the metals are reactive so they occur in combined state in the form of their oxides, carbonates, halides, sulphides, sulphates, etc., mixed with mud, clay, sand and stone.

Metals	Main ores
K	Carnallite ($KCl.MgCl_2.6H_2O$)
Na	Rock salt (NaCl) (in sea water)
Ca	Limestone, Marble ($CaCO_3$), Calcium sulphate dihydrate or Gypsum ($CaSO_4.2H_2O$),
Mg	Carnallite ($KCl.MgCl_2.6H_2O$), Magnesite ($MgCO_3$)
Pb	Galena (PbS)
Cu	Copper pyrites ($CuFeS_2$)
Hg	Cinnabar (HgS)
Ag	Argentite (Ag_2S) Horn silver (AgCl)

- **Extraction of Metals:**

  Extraction of a metal from its ore consists of the following processes:

  1. **Crushing and grinding:** Ores are crushed into a fine powder in big jaw crushers and ball mills. This process is called **pulverisation**.
  2. **Concentration (Dressing) of ores:** The process of removing gangue, the rocky impurities like SiO_2 present in an ore is called **concentration of an ore** or **ore dressing** and the purified ore is called **concentrated ore.**

➢ **Chemical Separation Bayer's Process**

This method makes use of difference between the chemical properties of the ore and the gangue. Bauxite ore is impure aluminium oxide ($Al_2O_3.2H_2O$) containing iron (III) oxide (Fe_2O_3) and silica (SiO_2) as the main impurities. Bayer's process is used to obtain pure aluminium oxide from bauxite ore. In this method of chemical purification, the finely powdered ore is treated with hot sodium hydroxide solution.

$$\underset{\text{[Impure bauxite]}}{Al_2O_3.2H_2O} + \underset{\text{[Conc.solution]}}{2NaOH} \xrightarrow{150-200^\circ C} \underset{\text{[Sodium aluminate]}}{2NaAlO_2 + 3H_2O}$$

$$\underset{\substack{\text{[sodium}\\\text{aluminate]}}}{NaAlO_2} + 2H_2O \xrightarrow{50-60^\circ C} \underset{\substack{\text{[Sodium}\\\text{hydroxide]}}}{NaOH} + \underset{\substack{\text{[Aluminium}\\\text{hydroxide]}}}{Al(OH)_3} \downarrow$$

$$\underset{\substack{\text{[Aluminium}\\\text{hydroxide]}}}{2Al(OH)_3} \xrightarrow{1100^\circ C} \underset{\text{[Pure alumina]}}{Al_2O_3} + 3H_2O$$

Reduction by aluminium: The oxides of metals of chromium or manganese cannot be reduced by conventional reducing agents. These metal oxides can be reduced by aluminium powder. This method of reduction is also known as **Thermite process.**

$$3MnO_2 + 4Al \xrightarrow{\text{Heat}} 2Al_2O_3 + 3Mn + \text{Heat energy}$$

$$Cr_2O_3 + 2Al \xrightarrow{\text{Heat}} Al_2O_3 + 2Cr + \text{Heat energy}$$

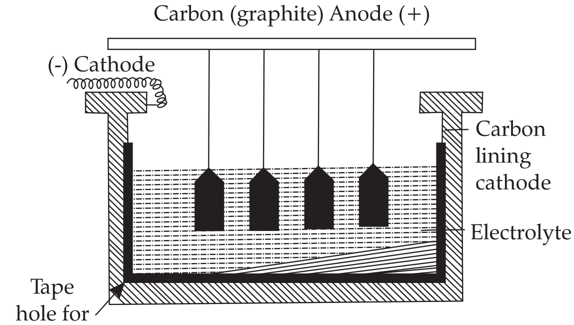
➢ **Common Ores of Iron, Aluminium and Zinc**

Ores of Al	Chemical Name	Formula
(a) Ores of Al		
Bauxite	Hydrated aluminium oxide	$Al_2O_3 . 2H_2O$
Cryolite	Sodium aluminium fluoride	Na_3AlF_6
Corundum	Anhydrous aluminium oxide	Al_2O_3
(b) Ores of Fe		
Red haematite	Anhydrous ferric oxide	Fe_2O_3
Brown haematite	Hydrated ferric oxide	$2Fe_2O_3 . 3H_2O$
Magnetite	Triferric tetraoxide	Fe_3O_4
Iron pyrite	Iron disulphide	FeS_2
Siderite	Ferrous carbonate	$FeCO_3$
(c) Ores of Zn		
Zinc blende	Zinc sulphide	ZnS
Zincite	Zinc oxide	ZnO
Calamine	Zinc carbonate	$ZnCO_3$

➢ **Metallurgy of Aluminium**

(i) **Occurrence:** It is a highly electropositive metal and it does not occur in free state.

(ii) **Purification of Ore:** Most of aluminium is extracted from bauxite which contains ferric oxide (Fe_2O_3) and silica (SiO_2) as impurities crushed ore is subjected to electromagnetic separation to remove ferric oxide and then concentrated by Bayer's process or Hall's process.



Extraction of Aluminium

(iii) Hall-Heroult's Process: (Bayer's Process)

(iv) Electrolytic Vessel: Iron tank lined with heat resistant material like carbon with a sloping floor for removal of molten aluminium.

(v) Electrolyte: It is a molten mixture of alumina, cryolite, fluorspar.

(vi) Electrodes — Anode: Thick carbon rods

Cathode: Tank with carbon lining.

(vii) Temperature: 950°C

A layer of powdered coke is sprinkled over the surface of the electrolytic mixture. This reduces the heat loss by radiation and prevents carbon anode from burning in air.

(viii) Reactions:

Alumina

$$Al_2O_3 \rightleftharpoons 2Al^{3+} + 3O^{2-}$$

At cathode: Carbon lining (gas carbon) of the cell.

$$4Al^{3+} + 12\,e^- \longrightarrow 4Al$$

At anode: Thick rods of graphite are suspended into the fused electrolyte.

$$6O^{2-} - 12\,e^- \longrightarrow 6[O]$$

$$3O + 3O \longrightarrow 3O_2$$

Anode is oxidised to carbon monoxide and then to carbon dioxide.

$$2C + O_2 \longrightarrow 2CO$$

$$2CO + O_2 \longrightarrow 2CO_2$$

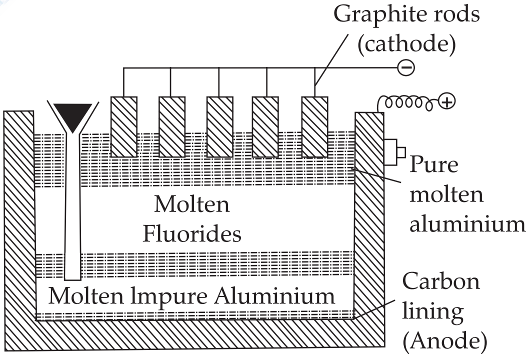
The oxygen evolved at the anode escapes as a gas or reacts with carbon anode. The carbon anode is thus oxidised. The carbon anode is, hence consumed and renewed periodically after a certain period of usage. Further purification can be done by electrolysis.

- **Refining of Aluminium (Hoope's Electrolytic process) :**

The process uses an electrolytic cell which contains three layer of molten substance of differing specific gravity. Molten impure aluminium forms the bottom layer. The bottom layer has carbon lining and serves as anode. Pure molten aluminium with carbon electrodes serves as cathode in the top layer. The middle layer consists of a mixture of fluorides of sodium barium and aluminium. Lower layer consists of impure Al at bottom along with carbon lining.

Anode: $\underset{\text{(Impure)}}{Al} - 3e^- \rightarrow Al^{3+}$

Cathode: $Al^{3+} + 3e^- \rightarrow \underset{\text{(Pure)}}{Al}$



Refining of Aluminium

- **Alloy:** Alloy is a homogeneous mixture of two or more metals or of one or more metals with certain non-metallic elements.

- **Common Alloys, their Compositions, Properties and Uses:**

Principal metal	Alloy's name	Composition	Properties	Used for making
Aluminium	1. Duralumin	95% Al 4% Cu 0.5% Mg 0.5% Mn	1. Light but as strong as steel. 2. Hard and resistant to corrosion. 3. Highly ductile.	1. Bodies of aircraft, buses and tube trains. 2. Light tools 3. Pressure cooker.
	2. Magnalium	90-95% Al 10-5% Mg	1. Resists corrosion 2. Light 3. Strong	1. Aircraft 2. Scientific instruments 3. Metal mirrors 4. Light tools 5. Beams of balance 6. Household appliances

	3. Alnico	Al,Ni,Co,Fe	1. Light 2. Shiny 3. Resists corrosion	Magnets
Iron	1. Stainless steel	73% Fe, 18% Cr, 8% Ni, 1% C	1. Resists corrosion 2. Lustrous, hard 3. Resistant to acids and alkalis	1. Utensils 2. Cutlery 3. Ornamental pieces 4. Surgical instruments
	2. Manganese steel	85% Fe, 1% C, 14% Mn	1. Durable, tough and hard	1. Safes 2. Rock drills 3. Armour plates
	3. Tungsten	84% Fe, 5% W, 1%C,	1. Very hard	1. Cutting tools for high speed lathes
	4. Nickel steel	95-98%Fe 5-3% Ni	1. Hard and elastic 2. Resistant to corrosion	1. Electric wire cables 2. Automobile parts
	5. Invar	Fe 63%, Ni 36% C 1%	1. Negligible expansion	1. Metre scales 2. Scientific instruments
Zinc and copper	1. Brass	60-70% Cu 40-30% Zn	1. Malleable and ductile. 2. Can be easily cast. 3. Resists corrosion. 4. Yellow/silvery in colour.	1. Decorative hardware, utensils. 2. Screws and handles. 3. Cartridge containers. 4. Parts of watches . 5. Musical instruments. 6. Electrical goods.
	2. Bronze	80% Cu 18% Sn 2% Zn	1. Hard and easily cast. 2. Can take up polish. 3. Resists corrosion.	1. Medals 2. Statues 3. Utensils 4. Bearings and 5. Coins
	3. German silver	50% Cu 30% Sn 20% Zn	1. White and light like silver. 2. Malleable and ductile. 3. High electrical resistance.	1. Decorative articles. 2. Electric heaters, rheostats. 3. Resistors
	4. Bell metal	78% Cu 22% Sn	1. Sonorous (produces sound). 2. Hard and brittle.	1. Bell, gongs. 2. Statues.
	5. Gun metal	Cu 88%, Sn 8%, Zn 1%, Pb 1%	1. Hard and brittle 2. Easily cut	1. Barrels of cannons. 2. Bearings, gears, etc.
Lead	1. Solder or Fuse metal	Pb, Sn	1. Low melting point, high tensile strength	1. Welding 2. Fuse
	2. Type metal	75%Pb, 15% Sb, 10% Sn	1. Low melting point, easily cast.	1. For printing blocks.

Mnemonics

1. Concept: Ores of Iron

Mnemonics:

RB **He**ma **Ma**si is my **si**ster

Interpretation:

R: Red Haematite

B: Brown

He: Haematite

Ma: Magnetite

Si: Siderite

2. Concept: Ores of zinc

Mnemonics:

z z z......

Interpretation:

Zinc blende

Zinc calamine

Zincite

Key Words

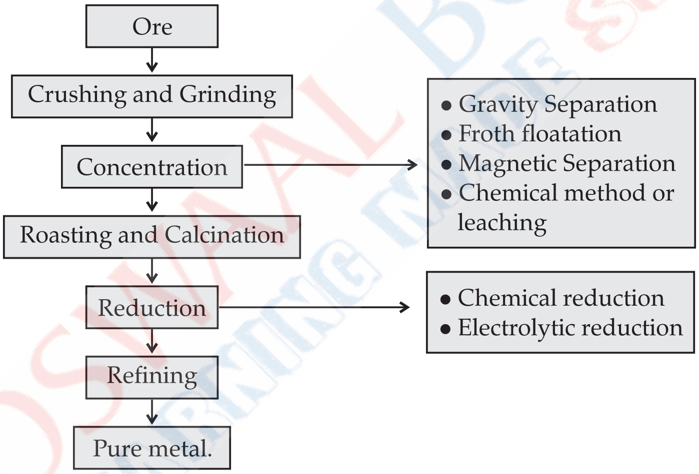
- **Metallurgy:** The process used for the extraction of metals in their pure form from their ores is referred to as metallurgy. It also deals with the production and purification of metals and manufacture of alloys.
- **Minerals:** The naturally occurring compounds of metals which are generally mixed with other matter such as soil, sand, limestone and rocks are known as minerals.
- **Ores:** These are the minerals from which the metals can be extracted conveniently and economically.
- **Flux:** It is a substance added to the charge in a furnace during smelting (or reduction) to remove gangue. The flux normally added in any metallurgical process is lime (CaO).
- **Slag:** It is a fusible product formed when flux combines with gangue during the extraction of metals.

  For example: $\text{Gangue} + \text{Flux} \longrightarrow \text{Slag}$

  $$SiO_2 + CaO \longrightarrow CaSiO_3$$
- **Fusible alloy:** An alloy melting in the range of about 57ºC to 260ºC, usually contains bismuth, lead, tin, etc. These alloys are called fusible alloys.
- **Amalgam:** A mixture or an alloy of mercury with a number of metals alloys such as sodium, zinc, gold and silver as well as with some non-metals is known as amalgam.

Key Terms

- **Flow Chart for extraction of metal from its ore:**



- Sulphide ores like Zinc blende (ZnS) and Galena (PbS) are lighter than the impurities present. They are concentrated by froth flotation process.
- The selection of reducing agents depends upon the position of the metal in the reactivity series.
- Oxides of highly active metals like potassium, sodium, calcium, magnesium and aluminium have great affinity towards oxygen and so cannot be reduced by common reducing agents like coke (carbon), carbon monoxide or hydrogen.
- Reactive metals can not be extracted from their aqueous salt solutions by electrolysis as they can react with water.
- The highly reactive metals can be used as reducing agents because they can displace metals of lower reactivity from their compounds . For example, in order to obtain manganese, its oxide is heated with aluminium powder.

  $$3\,MnO_2\,(s) + 4Al\,(s) \longrightarrow 3Mn\,(l) + 2Al_2O_3\,(s) + \text{Heat.}$$
- Aluminium is a powerful used as reducing agent . When the mixture of aluminium powder and iron oxide is ignited, the latter is reduced to metal. This process is called aluminothermy.

  $$Fe_2O_3 + 2Al \longrightarrow 2Fe + Al_2O_3 + \text{Heat.}$$
- Refining is the process by which crust metal is purified.
- Aluminium is the most abundant metal in the earth crust.
- Aluminium is extracted from its main ore bauxite $Al_2O_3.2H_2O$. Bauxite contains 60% Al_2O_3 the rest bring sand, ferric oxide and titanium oxide.
- Cryolite lowers the fusion temperature from 2050°C to 950°C and enhances conductivity.

- Fluorspar and cryolite act as a solvent for the electrolytic mixture and increases its conductivity since pure alumina is almost a non-conductor of electricity.
- Powdered coke is sprinkled over the surface of the electrolytic mixture. It reduces heat loss by radiation and prevent the burning of anode.
- An alloy melting in the range of about 51°C to 260°C, usually contains bismuth, lead, tin, etc. These alloys are called fusible alloys.
- The purpose of an alloy is to improve specific usefulness of the primary component and not to adulterate or degrade it.
- **Flow Chart for extraction of aluminium:**

Ore - Bauxite $Al_2O_3.2H_2O$

↓

Concentration by NaOH to obtain Al_2O_3

$$Al_2O_3.2H_2O + 2NaOH \xrightarrow{140°C–150°C} 2NaAlO_2 + 3H_2O$$

$$NaAlO_2 + 2H_2O \xrightarrow{50°C} NaOH + Al(OH)_3 \downarrow$$

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

↓

Electrolytic reduction of alumina

Electrolyte: Alumina, Cryolite, Fluorspar (1: 3: 1)

Cathode: $4Al^{3+} + 12e^- \longrightarrow 4Al$

Anode: $6O^{2-} - 12e^- \longrightarrow 3O_2$

$C + O_2 \longrightarrow CO_2$

↓

Purification by electrolysis

Cathode: $Al^{3+} + 3e^- \longrightarrow Al$

Anode: $Al - 3e^- \longrightarrow Al^{3+}$

❑❑

CHAPTER-8
STUDY OF COMPOUNDS

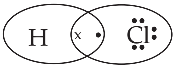
Topic-1

Hydrogen Chloride Gas

Concepts covered: • *Preparation of hydrogen chloride gas in laboratory,* • *Physical properties of hydrogen chloride gas*

Revision Notes

- Hydrogen chloride gas was prepared by Glauber in 1648 by heating common salt (NaCl) with conc. H_2SO_4. Lavoisier named it muriatic acid. Davy (1810) named it as hydrochloric acid.
- It has a polar covalent bond.



- It is synthesised from its elements in the presence of diffused sunlight.

$$H_2 + Cl_2 \xrightarrow[\text{sunlight}]{\text{diffused}} 2HCl$$

- **Preparation of Hydrogen Chloride in Laboratory**

  Hydrogen chloride is prepared in laboratory by the reaction of metallic chloride with concentrated sulphuric acid (Fig. 1)

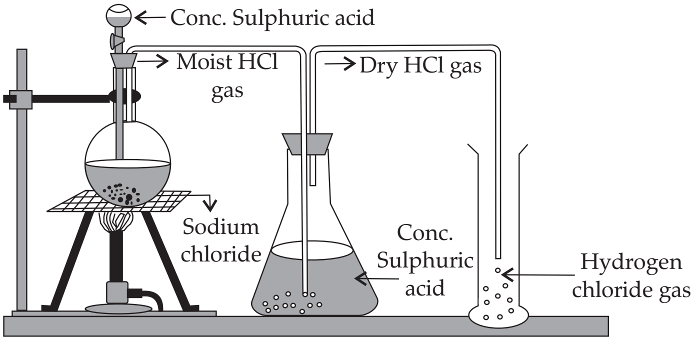


Fig. 1: Preparation of hydrogen chloride gas

Reactants used for the preparation of hydrogen chloride gas are sodium chloride and concentrated sulphuric acid. Sodium chloride is preferred over other metallic chlorides as it is easily and cheaply available.

$$\underset{\text{Rock salt}}{NaCl} + H_2SO_4(\text{conc}) \xrightarrow[200°C]{\text{below}} \underset{\substack{\text{Sodium}\\ \text{bisulphate}}}{NaHSO_4} + \underset{\substack{\text{Hydrogen}\\ \text{chloride gas}}}{HCl}$$

$$\underset{\text{Rock salt}}{2NaCl} + H_2SO_4(\text{conc}) \xrightarrow[200°C]{\text{above}} \underset{\substack{\text{Sodium}\\ \text{sulphate}}}{Na_2SO_4} + \underset{\substack{\text{Hydrogen}\\ \text{chloride gas}}}{2HCl}$$

➢ **Precautions observed during the laboratory preparation of hydrogen chloride gas.**

(i) The reaction mixture should not be heated beyond 200°C. At above 200°C, a sticky mass of sodium sulphate is formed which sticks to glass apparatus and is difficult to remove.

(ii) Heat energy is wasted if heated above 200°C.

- Hydrogen chloride gas is dried by passing through concentrated sulphuric acid. It is not dried by passing through phosphorous pentaoxide and calcium oxide as both of these drying agents undergo chemical reaction with hydrogen chloride gas.

$$2P_2O_5 + 3HCl \rightarrow POCl_3 + 3HPO_3$$

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

- Hydrogen chloride gas is collected by upward displacement of air as the gas is heavier than air and it is not collected over water as it is highly or extremely soluble in water. Therefore, it forms hydrochloric acid.
- When the gas jar is completely filled with the gas then dense white fumes appear at the mouth of the jar.
- In order to know whether the gas jar is full of hydrogen chloride gas, bring a glass rod dipped in ammonium hydroxide near the mouth of the jar. If dense white fumes appear immediately, then it shows that the gas jar is full of hydrogen chloride gas.
- Hydrogen chloride gas is dissolved in water with the help of special arrangement called **funnel arrangement** to prevent the back suction of water and gives greater surface area for the absorption of gas.

➢ **The physical properties of Hydrogen chloride gas are**

(a) It is a colourless gas having pungent suffocating smell which gives dense fumes in moist air.

(b) It is highly or extremely soluble in water.

The extreme solubility of hydrogen chloride gas is demonstrated by fountain experiment. (Fig. 2)

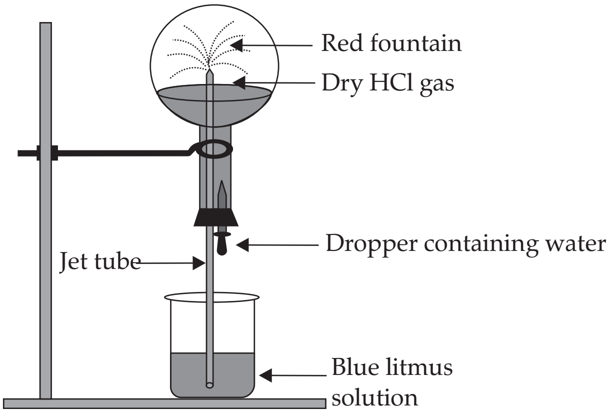


Fig. 2: Fountain experiment to demonstrate extreme solubility of HCl gas

(c) Hydrogen chloride gas is heavier than air. Set up the apparatus as shown in fig. 3

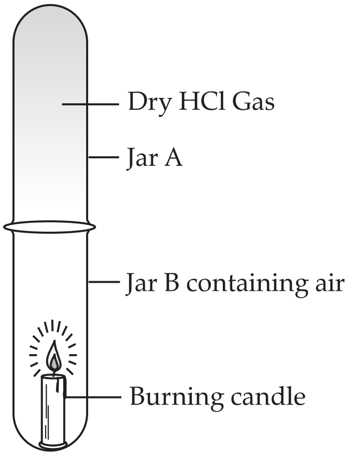


Fig. 3: Showing hydrogen chloride gas is heavier than air

It is seen that the dense white fumes appear more closer to the hydrogen chloride gas suggesting that the gas is heavier than air as it has travelled less distance as compared to air (Fig. 4).

- Hydrogen chloride gas is neither combustible nor it is a supporter of combustion. It extinguishes the burning splinter when brought near to it.
- Hydrogen chloride gas is thermally decomposed to give chlorine.

$$2HCl \xrightarrow{500°C} H_2 + Cl_2$$

- Metals which are lying above hydrogen in the metal activity series displace hydrogen when heated with hydrogen chloride gas.

$$Mg + 2HCl \xrightarrow{\Delta} MgCl_2 + H_2$$

$$Zn + 2HCl \xrightarrow{\Delta} ZnCl_2 + H_2$$

$$Fe + 2HCl \xrightarrow{\Delta} FeCl_2 + H_2$$

$$Ca + 2HCl \xrightarrow{\Delta} CaCl_2 + H_2$$

- Hydrogen chloride gas reacts with ammonia to form dense white fumes of ammonium chloride.

$$NH_3 + HCl \rightarrow \underset{\text{Dense white fumes}}{NH_4Cl}$$

- Hydrogen chloride gas is a polar covalent compound which on dissolving in water produces ions.
- Hydrogen chloride gas on dissolving in water produces strong, monobasic acid (Hydrochloric acid).

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

- Dry hydrogen chloride gas and liquefied hydrogen chloride gas has no effect on litmus, showing the neutral (non-acidic) character of the dry gas.

Key Word

- **Polar Covalent Bond:** A type of chemical bond where a pair of electrons is unequally shared between two atoms.

Key Terms

- Sodium chloride is cheap and therefore it is preferred for preparation of HCl over other metal chlorides.
- Conc. Nitric acid is not used during the preparation of HCl because it is volatile and may volatilise out along with hydrogen chloride.
- When hydrogen chloride gas is exposed in air, it gives white fumes, due to the formation of hydrochloric acid on reacting with atmospheric water vapour.
- The blue litmus solution turns red due to the acidic nature of hydrogen chloride gas.

Mnemonics

Concept: Physical properties of HCl.

Mnemonics:

Call **G**auri **P**hone **S**e **ESHA**

Interpretation:

C – Colourless, **G** – Gas, **P** – Pungent, **S** – Smell, **E** – Extremely, **S** – Soluble (In water), **H** – Heavier than, **A** –Air

Topic-2 Hydrochloric Acid

Concepts covered: • *Preparation of hydrochloric acid,* • *Properties of hydrochloric acid*

Revision Notes

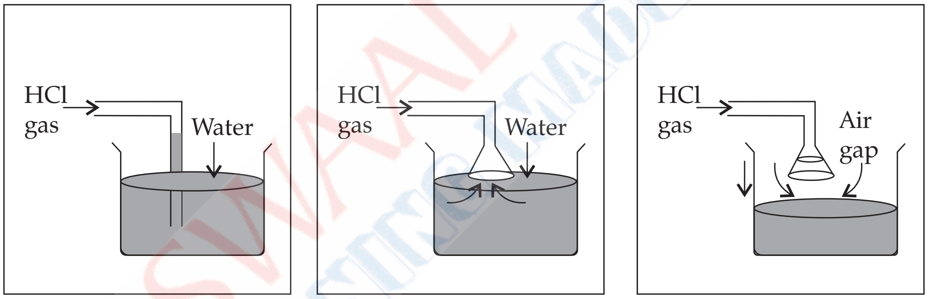
- Hydrogen chloride gas when dissolved in water produces hydrochloric acid.

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

Hence, hydrochloric acid is a solution of hydrogen chloride in water.

- **Preparation of Hydrochloric acid:**

Procedure: Hydrochloric acid is prepared by dissolving hydrogen chloride gas in water using a special funnel arrangement as shown in figure B.



A B(I) B(II)

Fig. To show funnel arrangement

Since, hydrogen chloride gas is extremely soluble in water and if the delivery tube through which HCl gas is passed directly immersed in water, then the partial vacuum is created in the tube because rate of absorption of HCl gas is high. The pressure outside being higher causes the water to be pushed up into the delivery tube. This is called back- suction.

- **Mechanism by which back-suction is avoided or minimised:**

The funnel arrangement prevents or minimises back-suction of water. And it also provides a large surface area for the absorption of HCl gas.

The rim of the funnel is placed so that it just touches through containing water. If back-suction occurs, the water rises up the funnel and the level outside the funnel falls creating an air gap between the rim of the funnel and the surface of water.

The pressure outside and inside equalise and the water which had raised in the funnel falls down again.

- **Precaution:** An empty flask (anti-suction device) is put between the generative flask and the water trough. In case, the back-suction occurs, the water will collect in it and will not reach the generating flask.

Properties of Hydrochloric Acid:

Physical Properties

(i) Colour, odour and taste: Colourless, pungent choking smell and acidic.
(ii) Physiological action: Concentrated acid which is corrosive.
(iii) Solubility: Readily soluble in water.
(iv) Boiling point: 110°C

(v) Acidic nature: The presence of H^+ in HCl imparts acidic properties. It is monobasic in nature.

$$HCl \xrightleftharpoons{H_2O} H^+(aq) + Cl^-(aq)$$

Chemical properties

(i) Action on metals: Hydrochloric acid reacts with metals which are above hydrogen in the activity series and form metal chlorides and hydrogen.

$$Mg + 2HCl \rightarrow MgCl_2 + H_2$$

(ii) Action on oxides and hydroxides: Hydrochloric acid reacts with oxides and hydroxides to form salt and water only.

$$ZnO + 2HCl \rightarrow ZnCl_2 + H_2O$$

$$Zn(OH)_2 + 2HCl \rightarrow ZnCl_2 + 2H_2O$$

(iii) With salts of weaker acids: HCl acid decomposes salts of weaker acids, e.g., carbonates, bicarbonates, sulphates, sulphides.

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

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

$$Na_2SO_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2\uparrow$$

$$FeS + 2HCl \rightarrow FeCl_2 + H_2S\uparrow$$

(iv) Action on thiosulphates: It reacts with thiosulphate to produce SO_2 gas and yellow sulphur is precipitated.

$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2 + S\downarrow$$

(v) Reaction with Nitrates: Lead nitrate and mercury**(I)** nitrate react with hydrochloric acid to give white precipitate of lead and mercury**(II)** chloride.

$$Pb(NO_3)_2 + 2HCl \rightarrow \underset{\text{white}}{PbCl_2\downarrow} + 2HNO_3$$

$$Hg_2(NO_3)_2 + 2HCl \rightarrow \underset{\text{white}}{Hg_2Cl_2\downarrow} + 2HNO_3$$

Silver nitrate gives thick curdy white precipitate of silver chloride.

$$AgNO_3 + HCl \rightarrow AgCl\downarrow + HNO_3$$

$$AgCl + 2NH_4OH \rightarrow \underset{\substack{\text{Diammine}\\ \text{silver(I)chloride}}}{[Ag(NH_3)_2]^+Cl^-} + 2H_2O$$

$$[Ag(NH_3)_2]^+Cl^- + HNO_3 \rightarrow AgCl\downarrow$$

$$2AgCl \xrightarrow{\text{Sunlight}} 2Ag + Cl_2$$

Oxidation of Hydrochloric acid

Powerful oxidising agents such as manganese dioxide (MnO_2), lead oxide (PbO_2), red lead (Pb_3O_4), potassium permanganate ($KMnO_4$) and potassium dichromate ($K_2Cr_2O_7$) oxidise conc. HCl liberating chlorine gas.

$$MnO_2 + 4HCl \xrightarrow{\Delta} MnCl_2 + 2H_2O + Cl_2$$

$$PbO_2 + 4HCl \xrightarrow{\Delta} PbCl_2 + 2H_2O + Cl_2$$

$$Pb_3O_4 + 8HCl \xrightarrow{\Delta} 3PbCl_2 + 4H_2O + Cl_2$$

$$2KMnO_4 + 16HCl \xrightarrow{\Delta} 2KCl + 2MnCl_2 + 8H_2O + 5Cl_2$$

$$K_2Cr_2O_7 + 14HCl \xrightarrow{\Delta} 2KCl + 2CrCl_3 + 7H_2O + 3Cl_2$$

Formation of Aqua-regia

Mixture of 3 parts of conc. HCl and 1 part of conc. HNO_3 is called **aqua-regia.**

$$\underset{\text{Conc.}}{3HCl} + \underset{\text{Conc.}}{HNO_3} \rightarrow \underset{\text{Nitrosyl chloride}}{NOCl} + 2H_2O + \underset{\text{Nascent chlorine}}{2[Cl]}$$

Nascent chlorine reacts with noble metals like gold and platinum to give their soluble chlorides.

$$Au + 3[Cl] \rightarrow \underset{\text{Gold(III) chloride}}{AuCl_3}$$

$$Pt + 4[Cl] \rightarrow \underset{\text{Platinum (IV) chloride}}{PtCl_4}$$

Test for Hydrogen Chloride and Hydrochloric Acid

HCl gas gives thick white fumes of ammonium chloride (NH_4Cl), when a glass rod dipped in NH_3 is held near the mouth of the tube.

$$NH_3 + HCl \rightarrow NH_4Cl$$

With silver nitrate solution both give white precipitate of silver chloride.

$$AgNO_3 + HCl \rightarrow AgCl\downarrow + HNO_3$$

Precipitate is insoluble in nitric acid but soluble in ammonium hydroxide. When hydrochloric acid is heated with manganese dioxide, then greenish yellow gas, i.e., chlorine is evolved which turns moist iodide paper blue black.

$$MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$$

Key Words

- **Back Suction:** The effect in which the pressure in the delivery tube and flask is reduced and the atmospheric pressure from outside forces the water back upto the delivery tube is called back suction.
- **Pickling of metals:** It is a process of removal of oxide before they are painted, electroplated or galvanised.

Key Terms

- When hydrogen chloride gas is dissolved in water, hydrochloric acid is formed.
- HCl ionises in water due to its polar nature.

  $HCl + H_2O \rightarrow H_3O^+ + Cl^-$
- Liquified hydrogen chloride does not conduct electricity. It shows covalent nature of hydrogen chloride.
- Dry hydrogen chloride gas and liquefied hydrogen chloride do not turn blue litmus paper red, showing non-acidic character of the dry gas.
- The aqueous solution of HCl gas is called hydrochloric acid.
- A constant boiling mixture or azeotrope is a solution which boils without any change in its composition. HCl acid form constant boiling mixture at 110°C.
- Hydrochloric acid is used as:
  - a laboratory reagent.
  - in the manufacture of chlorine, chlorides, dyes, drugs, etc.
  - in industry to pickle steel
  - to remove rust from iron sheets
  - in tanning and calico printing industry
  - to decrease activity of gastric juice in patients.

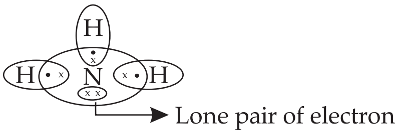
Topic-3

Ammonia

Concepts covered: • *Preparation of ammonia,* • *Properties of ammonia*

Revision Notes

- The molecular formula of ammonia is NH_3. The relative molecular mass is 17.
- Ammonia is a polar covalent compound.



Electron dot diagram of Ammonia

- Ammonia is found in free state in traces.
- In combined state ammonia is found in the form of ammonium salts like ammonium chloride, ammonium sulphate, etc.
- The smell in toilets is due to the bacterial decomposition of urea present in urine. As a result, ammonia gas is released.

$$NH_2CONH_2 + 2H_2O \rightarrow 2NH_3 + H_2O + CO_2$$

Preparation of Ammonia:

- In laboratory, ammonia is prepared by heating ammonium salts (except ammonium nitrate) with caustic alkalies like sodium hydroxide, potassium hydroxide or calcium hydroxide. (Fig. 1).

$$\underset{\text{Calcium hydroxide}}{Ca(OH)_2} + \underset{\text{Ammonium chloride}}{2NH_4Cl} \xrightarrow{\Delta} \underset{\text{Calcium chloride}}{CaCl_2} + \underset{\text{Ammonia}}{2NH_3\uparrow} + \underset{\text{Water}}{2H_2O}$$

$$\underset{\text{Sodium hydroxide}}{NaOH} + \underset{\text{Ammonium chloride}}{NH_4Cl} \xrightarrow{\Delta} \underset{\text{Sodium chloride}}{NaCl} + \underset{\text{Ammonia}}{NH_3\uparrow} + \underset{\text{Water}}{H_2O}$$

(i) The reactants are finely ground and then taken in a round bottom flask. The round bottom flask is fitted in a slanting position bending in the downward direction.

(ii) Ammonia is dried by passing over quick lime, i.e., calcium oxide. It is not dried by passing through conventional drying agents like conc. sulphuric acid, anhydrous calcium chloride, phosphorus pentaoxide because these drying agents undergo chemical reaction with ammonia.

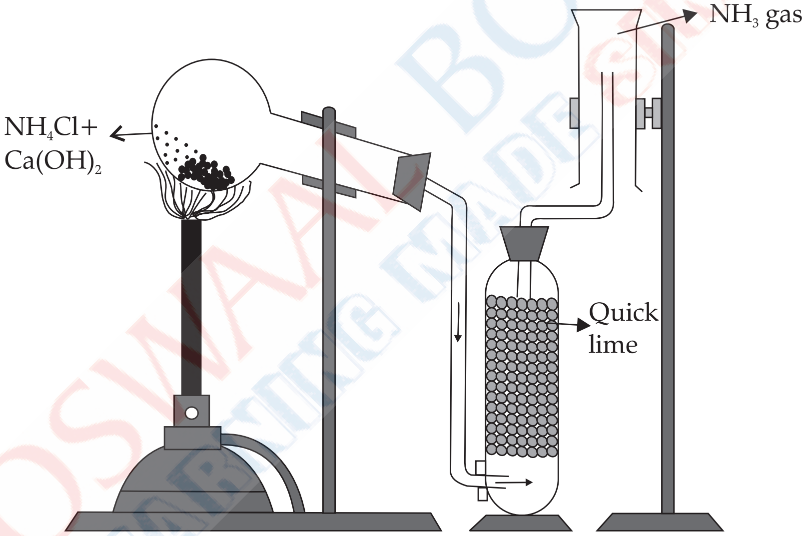


Fig. 1: Laboratory preparation of ammonia by ammonium chloride and calcium hydroxide

$$2NH_3 + H_2SO_4 \rightarrow (NH_4)_2SO_4$$

$$CaCl_2 + 8NH_3 \rightarrow CaCl_2.8NH_3$$

$$6NH_3 + 3H_2O + P_2O_5 \rightarrow 2(NH_4)_3PO_4$$

(iii) Ammonia is collected by downward displacement of air as the gas is lighter than air and highly soluble in water.

(iv) Ammonium nitrate is not used for the preparation of ammonia as it is explosive and gives nitrous oxide and water.

$$NH_4NO_3 \rightarrow N_2O + 2H_2O$$

- **Action of warm water on metallic nitrides (Fig.2)**

Magnesium nitride, calcium nitride and aluminium nitride on warming with water produces their respective metallic hydroxide with the liberation of ammonia.

$$Mg_3N_2 + 6H_2O \xrightarrow{\text{Warm}} 3Mg(OH)_2 + 2NH_3$$

$$Ca_3N_2 + 6H_2O \xrightarrow{\text{Warm}} 3Ca(OH)_2 + 2NH_3$$

$$AIN + 3H_2O \xrightarrow{\text{Warm}} Al(OH)_3 + NH_3$$

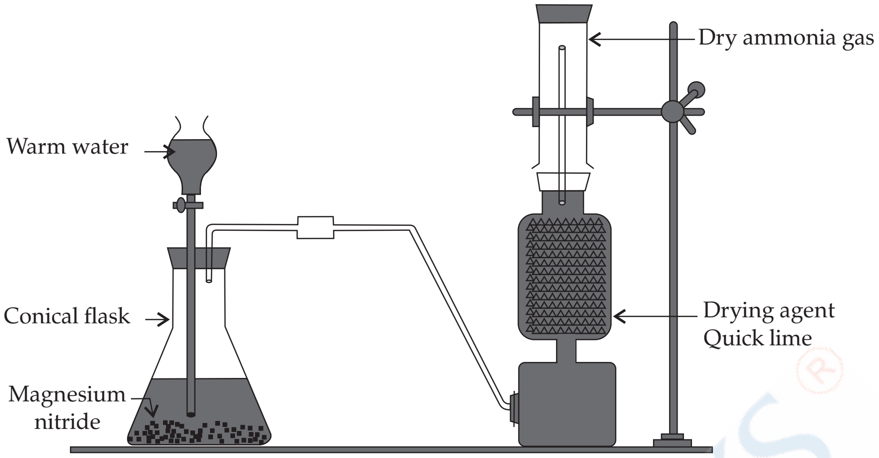


Fig.2. Laboratory preparation of ammonia gas from magnesium nitride

- **Manufacture by Ammonia- Haber's Process (Fig.3)**
  - **(i)** Ammonia is manufactured by Haber's process. The ratio by volume of nitrogen and hydrogen is 1:3.
  - **(ii)** Nitrogen is obtained by the fractional distillation of liquefied air. Hydrogen is obtained by Bosch process.
  - **(iii)** Ammonia is separated from unreacted nitrogen and hydrogen by
    - **(1) Liquefaction:** Ammonia can be easily liquefied in comparison to nitrogen and hydrogen.
    - **(2) By absorbing ammonia in water:** As ammonia is highly soluble in water where as nitrogen and hydrogen are insoluble in water.
  - **(iv)** The speed of the reaction can be enhanced by taking finely divided iron as the catalyst. The efficiency of a catalyst is increased by using a promoter which is either molybdenum or aluminium oxide.

    The reaction is reversible and exothermic.

$$N_2 + 3H_2 \rightleftharpoons 2NH_3 + \text{Heat}$$

The favourable conditions for the reaction are

Catalyst	Finely divided iron
Promoter	Molybdenum
Temperature	450-500 °C
Atmospheric pressure	200-1000 atm.

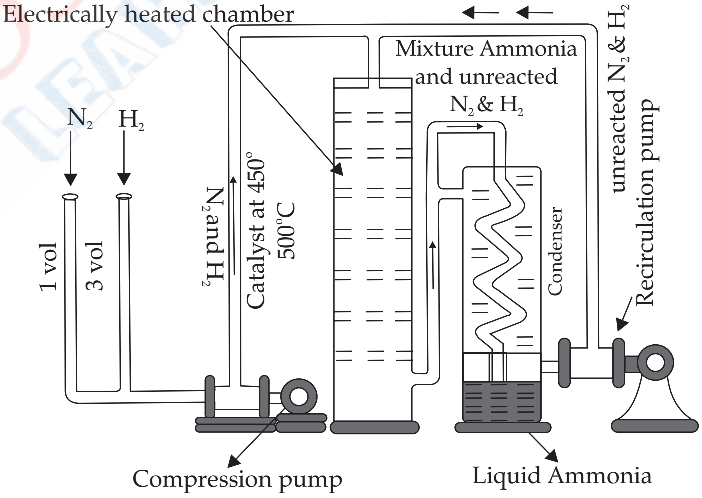


Fig.3: Haber's process of manufacture of ammonia

The physical properties of ammonia are:

(i) It is a colourless gas having pungent irritating odour.

(ii) It is lighter than air.

(iii) It is highly or extremely soluble in water. The extreme solubility of ammonia is demonstrated by fountain experiment. (Fig. 4).

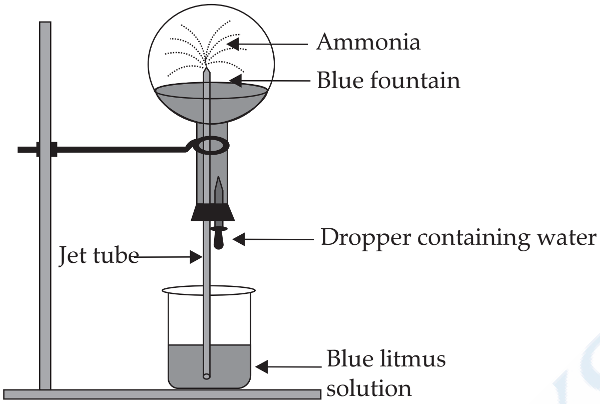


Fig. 4: Fountain experiment to demonstrate extreme solubility of NH_3 gas

Ammonia is dissolved in water with the help of funnel arrangement so as to prevent back suction of water as the gas is highly soluble in water. Ammonia when dissolved in water produces ammonium hydroxide which is alkaline in nature.

$$NH_3 + H_2O \rightarrow \underset{\text{Ammonium hydroxide}}{NH_4OH}$$

$$NH_4OH \rightarrow \underset{\text{Ammonium ion}}{NH_4^+} + \underset{\text{Hydroxide ion}}{OH^-}$$

The chemical properties of ammonia are as follows:

➢ **Basic nature:**

(i) It on dissolving in water produces hydroxyl ions as the only negatively charged particles.

$$NH_3 + H_2O \rightarrow NH_4OH \rightleftharpoons NH_4^+ + OH^-$$

(ii) Ammonia reacts with acids to form salts.

$$NH_3 + \underset{\text{Hydrochloric acid}}{HCl} \rightarrow \underset{\text{Ammonium chloride (Dense white fumes)}}{NH_4Cl}$$

$$NH_3 + \underset{\text{Nitric acid}}{HNO_3} \rightarrow \underset{\text{Ammonium nitrate}}{NH_4NO_3}$$

$$2NH_3 + \underset{\text{Sulphuric acid}}{H_2SO_4} \rightarrow \underset{\text{Ammonium sulphate}}{(NH_4)_2SO_4}$$

$$2NH_4OH + H_2SO_4 \rightarrow (NH_4)_2SO_4 + 2H_2O$$

$$NH_4OH + \underset{\text{Nitric acid}}{HNO_3} \rightarrow \underset{\text{Ammonium nitrate}}{NH_4NO_3} + H_2O$$

(iii) As ammonia on dissolving in water, produces hydroxyl ions as the only negatively charged particle thus the aqueous solution of ammonia called ammonium hydroxide which is alkaline in nature and it shows characteristic colour changes with indicators.

Red litmus solution — blue

Phenolphthalein — turns pink

Methyl orange — yellow

➢ **Burning of Ammonia in Oxygen:**

Ammonia is neither combustible nor it is a supporter of combustion. However, if jet of ammonia is ignited in atmosphere of oxygen, it burns with yellowish green flame.

$$4NH_3 + 3O_2 \rightarrow 2N_2 + 6H_2O$$

➢ **Catalytic oxidation of ammonia:**

Ammonia reacts with oxygen at 800°C in the presence of platinum catalyst to give nitric oxide and water vapour.

$$4NH_3 + 5O_2 \xrightarrow[800°C]{Pt} 6H_2O + 4NO\uparrow + \text{Heat}$$

$$2NO + O_2 \longrightarrow \underset{\text{Brown gas}}{2NO_2}$$

Procedure: Pass dry ammonia gas and oxygen gas through inlets over heated Pt placed in combustion tube, which emits a reddish glow. Reddish brown vapours of NO_2 are seen in the flask due to the oxidation of NO.

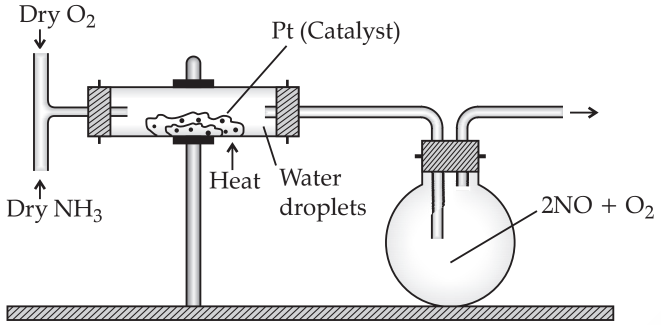


Fig.5: Catalytic oxidation of ammonia

The reaction is exothermic in nature.

- **Reducing Nature of Ammonia:**
  (i) Ammonia reduces heated metallic oxides such as copper oxide to give metal, water vapour and nitrogen.

$$2NH_3 + \underset{\text{black solid}}{3CuO} \longrightarrow \underset{\text{reddish brown solid}}{3Cu} + 3H_2O + N_2\uparrow$$

Procedure: Pass ammonia gas overheated CuO in hard glass tube. The black copper oxide in reduced to reddish brown copper. Nitrogen gas in collected over water in a gas jar. The water formed is collected in the U-tube and is tested with an hydrous $CuSO_4$ which turns blue.

This reaction proves that ammonia is made up of nitrogen and hydrogen and so, it is a nitrogen hydride.

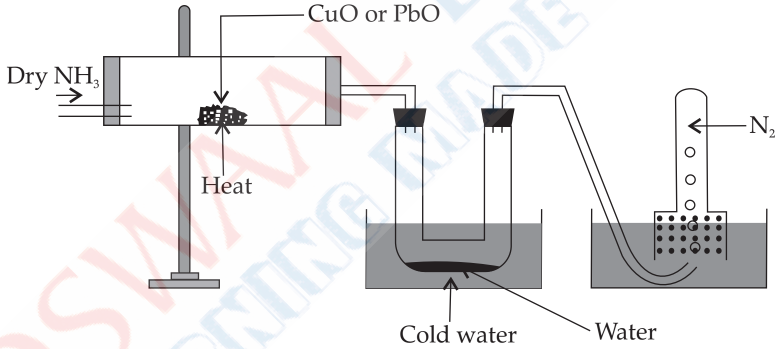


Fig. 6: Showing reducing nature of NH_3

(ii) $3CaOCl_2 + 2NH_3 \rightarrow 3CaCl_2 + N_2 + 3H_2O$

(iii) Reduction of Chlorine:

When ammonia is in excess: Greenish yellow chlorine disappears to give dense white fumes of ammonium chloride.

$$\underset{\text{Excess}}{8NH_3} + 3Cl_2 \rightarrow 6NH_4Cl + N_2$$

When chlorine is in excess:

$$NH_3 + \underset{\text{Excess}}{3Cl_2} \rightarrow NCl_3 + 3HCl$$

These reactions show that.

(i.) Ammonia is a reducing agent.

(ii.) Chlorine has strong affinity for hydrogen.

- Ammonia reacts with carbon dioxide to form urea which is a very important nitrogenous fertilizer containing 46.66% of nitrogen.

$$2NH_3 + CO_2 \xrightarrow[150\,atm]{150^\circ C} NH_2CONH_2 + H_2O$$

- **Aqueous solution of ammonia precipitates metallic hydroxides from their soluble salts.**

$$FeCl_3 + 3NH_4OH \rightarrow \underset{\substack{\text{Ferric}\\\text{hydroxide}\\\text{(Reddish}\\\text{brown ppt.)}}}{Fe(OH)_3\downarrow} + 3NH_4Cl$$

$$FeSO_4 + 2NH_4OH \rightarrow \underset{\substack{\text{Ferrous}\\ \text{hydroxide}\\ \text{(Dirty green ppt.)}}}{Fe(OH)_2}\downarrow + (NH_4)_2SO_4$$

$$Pb(NO_3)_2 + 2NH_4OH \rightarrow \underset{\substack{\text{Lead}\\ \text{hydroxide}\\ \text{(White ppt.)}}}{Pb(OH)_2}\downarrow + 2NH_4NO_3$$

$$Zn(NO_3)_2 + 2NH_4OH \rightarrow \underset{\substack{\text{Zinc}\\ \text{hydroxide}\\ \text{(White gelatinous}\\ \text{ppt.)}}}{Zn(OH)_2}\downarrow + 2NH_4NO_3$$

$$Zn(OH)_2 + 4NH_4OH \rightarrow \underset{\substack{\text{Tetraammine zinc}\\ \text{hydroxide}}}{[Zn(NH_3)_4](OH)_2} + 4H_2O$$

$$Cu(NO_3)_2 + 2NH_4OH \rightarrow \underset{\substack{\text{Copper}\\ \text{hydroxide}\\ \text{(Pale blue ppt.)}}}{Cu(OH)_2}\downarrow + 2NH_4NO_3$$

$$Cu(OH)_2 + 4NH_4OH \rightarrow \underset{\substack{\text{Tetraammine copper}\\ \text{hydroxide}}}{[Cu(NH_3)_4](OH)_2} + 4H_2O$$

Metallic salt solution	Colour of the ppt (in small quantity)	Nature of ppt (Soluble / Insoluble) in excess
(i) Iron (III) chloride	Reddish brown	Insoluble
(ii) Iron (II) sulphate	Dirty green	Insoluble
(iii) Lead nitrate	White	Insoluble
(iv) Zinc nitrate	White	Soluble
(v) Copper sulphate	Pale blue or bluish white	Soluble

Tests for Ammonia:

(a) Ammonia gives dense white fumes with concentrated Hydrochloric acid.

$$NH_3 + HCl \rightarrow NH_4Cl$$

(b) Ammonia turns Nessler's reagent brown.

(c) When ammonia is passed through copper sulphate solution first a little then a bluish white precipitate is formed which dissolves in excess of ammonia to give deep blue solution or inky blue solution or Prussian blue solution.

(d) As ammonia is basic in nature therefore it turns moist red litmus blue, phenolphthalein from colourless to pink.

Ammonia is extensively used in the manufacture of nitrogenous fertilizers, nitric acid and other explosives. Generally, it is used as a refrigerant and as a cleansing agent (removes grease).

Mnemonics

1. **Concept:** Conditions for Haber's Process
   Mnemonics:
   CaFé Promo
   Interpretation:
   Ca: Catalyst
   Fe: Iron
   Pro: Promoter
   Mo: Molybdenum
2. **Concept:** Colour change with different indicators in ammonia:
   Mnemonics:
   Rohan **L**aaya **B**illi **P**ar **P**apa
   Mumma **O**utrageously **Y**elled
   Interpretation:
   R: Red
   L: Litmus solution—
   B: blue
   Par: Phenolphthalein—turns
   P: pink
   M: Methyl
   O: orange—
   Y: yellow
   Red litmus solution — blue
   Phenolphthalein — turns pink
   Methyl orange — yellow
3. **Concept:** Metallic Salt Solution Colours:
   Mnemonics:
   I **C**an't **R**ead **B**ible.
   Interpretation:
   I: Iron
   C: chloride
   R: Reddish
   B: brown

Key Word

- **Nessler's Solution:** It is a slightly alkaline solution of potassium mercuric iodide made by adding KOH. Its chemical formula is K_2HgI_4.

Key Terms

- Ammonia and ammonium compounds being highly soluble in water, do not occur as minerals.
- Drying of ammonia gas is done by passing it through a drying tower containing lumps of quicklime (CaO).
- Othe drying agents like Conc. H_2SO_4, P_2O_5 and anhydrous $CaCl_2$ are not used, as ammonia being basic, reacts with them.

$$2NH_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4$$

$$6NH_3 + P_2O_5 + 3H_2O \longrightarrow 2(NH_4)_3PO_4$$

$$CaCl_2 + 4NH_3 \longrightarrow CaCl_2.\ 4NH_3$$

- Ammonia gas is collected in inverted gas jar by the downward displacement of air. Its reason is that it is lighter than air and highly soluble in water, so, it can not be collected over water.
- Ammonia is liquefied easily as compared to nitrogen and hydrogen.
- Ammonia burns in oxygen with yellowish green flame and produces water vapours and nitrogen.
- Ammonia reduces heated yellow lead monoxide to greyish metallic lead.

$$\underset{\text{(yellow)}}{3PbO} + 2NH_3 \longrightarrow \underset{\text{(greyish)}}{3Pb} + 3H_2O + N_2$$

- Anhydrous ammonia is a clear, colourless liquid under pressure. It evaporates rapidly and produces cooling effect. This makes ammonia a good refrigerant.
- Aqueous ammonia emulsifies or dissolves fats, grease, etc.
- Ammonia reacts with CO_2 at 150°C and 150 atm. pressure to give urea which is a valuable nitrogenous fertiliser.

$$2NH_3 + CO_2 \xrightarrow[\text{150 atm}]{\text{150°C}} NH_2CONH_2 + H_2O$$

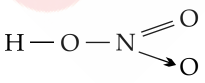
Topic-4

Nitric Acid

Concepts covered: • *Formation of nitric acid in atmosphere,* • *Laboratory preparation of nitric acid,* • *Properties of nitric acid*

Revision Notes

- Molecular formula: HNO_3 Molecular mass: 63
- **Structure of nitric acid**



- Nitric acid was initially called 'aqua-fortis'.
- Nitric acid occurs in the free state and in the combined state.

Formation of Nitric Acid in Atmosphere

- **Step 1:** Nitrogen present in the atmosphere reacts with oxygen to form nitric oxide

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g)$$

- **Step 2:** Nitric oxide is further oxidises to nitrogen dioxide.

$$2NO + O_2 \rightarrow 2NO_2(g)$$

- **Step 3:** This nitrogen dioxide dissolves in rain water.

$$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$$

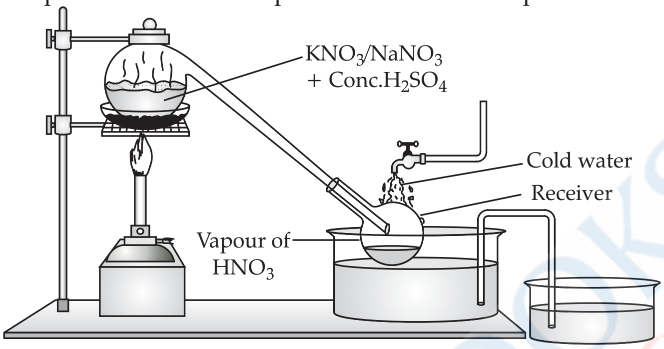
Laboratory Preparation of Nitric Acid

- **Reactants:** Distilling a mixture of potassium or sodium nitrate with concentrated sulphuric acid.

$$\underset{}{KNO_3} + \underset{\text{Conc.}}{H_2SO_4} \xrightarrow{<200^\circ C} \underset{\substack{\text{Potassium}\\ \text{bisulphate}}}{KHSO_4} + HNO_3$$

$$NaNO_3 + H_2SO_4 \xrightarrow{<200^\circ C} \underset{\substack{\text{sodium}\\ \text{bisulphate}}}{NaHSO_4} + HNO_3$$

- **Products:** Potassium bisulphate or sodium bisulphate and nitric acid vapours.



Laboratory preparation of nitric acid

- **Procedure:** A mixture of equal parts by weight of sodium nitrate or potassium nitrate and concentrated sulphuric acid are heated gently in the glass retort.
- **Observation:** On heating the mixture in glass retort, the volatile nitric acid is displaced and the vapours are collected in the receiver which is cooled from outside with cold water.
- **Collection:** Vapours of nitric acid are condensed to a light yellow liquid. The yellow colour is due to the dissolution of NO_2 gas.

$$4HNO_3 \rightarrow 2H_2O + 4NO_2 + O_2$$

The yellow colour of the acid is removed by passing dry air or CO_2 in it.

- **Manufacture of Nitric Acid (Ostwald Process)**

The process is explained in three steps:

Step 1: Catalytic Oxidation of Ammonia

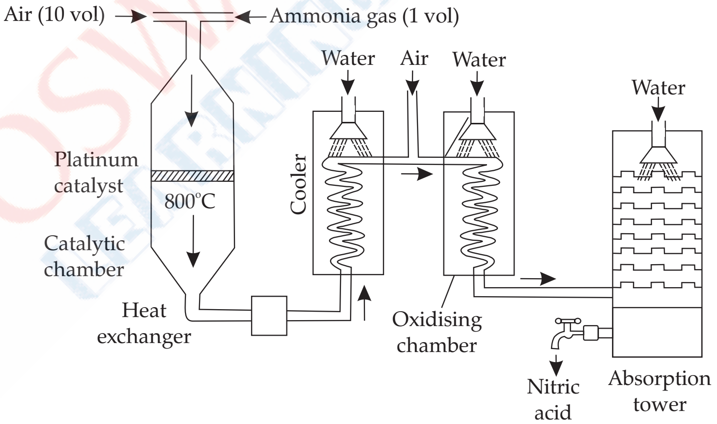


Fig. Manufacture of nitric acid by Ostwald process

- Mixture of dry air and dry ammonia in the ratio 1: 10 is compressed first and then passed into the catalytic chamber.
- Oxidation of ammonia into nitrogen monoxide takes place.

$$4NH_3 + 5O_2 \xrightarrow[800^\circ C]{Pt} 4NO + 6H_2O + \text{Heat}$$

- Hot gases passed through a heat exchanger, mixed with air and passed into another cooling chamber called oxidising chamber.

Step 2: Oxidation of Nitric oxide in oxidation chamber

$$2NO + O_2(g) \xrightarrow{50^\circ C} 2NO_2(g)$$

Step 3: Absorption of nitrogen dioxide in water: The nitrogen dioxide is passed through the absorption tower, from the top of which warm water trickles.

$$4NO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 4HNO_3(aq)$$

➢ **Chemical Properties**

1. **Stability**

- Pure nitric acid is colourless and unstable and decomposes slightly even at ordinary temperature and in the presence of sunlight.

$$4HNO_3 \xrightarrow[\text{Sunlight}]{\Delta} \underset{\text{Brown colour}}{4NO_2} + 2H_2O + O_2$$

- Thus, the nitric acid stored in a plain glass bottle turns yellow. To avoid the decomposition, nitric acid is generally stored in coloured bottles.

2. **Acidic Properties**

- It is a strong monobasic acid. It ionises completely in aqueous solution.

$$HNO_3(aq) \longrightarrow H^+ + NO_3^-$$

- It turns blue litmus to red, methyl orange to pink and phenolphthalein remains colourless.
- **Reaction with Alkalies:** Neutralises alkalies to form salt and water. Metallic oxides and hydroxides react with dilute HNO_3 to form salt and water.

$$Na_2O + 2HNO_3 \rightarrow 2NaNO_3 + H_2O$$

$$ZnO + 2HNO_3 \rightarrow Zn(NO_3)_2 + H_2O$$

$$NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$$

$$Fe(OH)_3 + 3HNO_3 \rightarrow Fe(NO_3)_3 + 3H_2O$$

$$Mg(OH)_2 + 2HNO_3 \rightarrow Mg(NO_3)_2 + 2H_2O$$

- **Reaction with Carbonates and Bicarbonates:** These react with dil. HNO_3 to give salt, water and carbon dioxide.

$$Na_2CO_3 + 2HNO_3 \rightarrow 2NaNO_3 + H_2O + CO_2\uparrow$$

$$NaHCO_3 + HNO_3 \rightarrow NaNO_3 + H_2O + CO_2\uparrow$$

$$CaCO_3 + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O + CO_2\uparrow$$

Reaction with carbonates and bicarbonates: These react with dil. HNO_3 to form soluble metallic nitrates, water and SO_2 gas.

3. **Oxidising Properties**

- Oxidising properties are due to nascent oxygen which it gives on decomposition.

$$2HNO_3(\text{Conc.}) \rightarrow 2NO_2 + H_2O + [O]$$

$$2HNO_3(\text{Dil.}) \rightarrow 2NO + H_2O + 3[O]$$

(i) Action on Non-metals:

$$\underset{\text{Carbon}}{C} + 4HNO_3 \rightarrow CO_2 + 2H_2O + 4NO_2$$

$$\underset{\text{Sulphur}}{S} + 6HNO_3 \rightarrow H_2SO_4 + 2H_2O + 6NO_2$$

$$\underset{\text{Phosphorus}}{P_4} + 20HNO_3 \rightarrow 4H_3PO_4 + 4H_2O + 20NO_2$$

(ii) Action on Metals: Nitric acid reacts with all metals except gold and platinum . Cold and dilute nitric acid oxidises metal to their nitrates and liberate nitric oxide.

$$\underset{\text{Copper}}{3Cu} + 8HNO_3 \rightarrow 3Cu(NO_3)_2 + 4H_2O + 2NO$$

$$\underset{\text{Zinc}}{3Zn} + 8HNO_3 \rightarrow 3Zn(NO_3)_2 + 4H_2O + 2NO$$

$$\underset{\text{Iron}}{3Fe} + 8HNO_3 \rightarrow 3Fe(NO_3)_2 + 4H_2O + 2NO$$

- Concentrated nitric acid oxidises metal to their nitrates and liberates nitrogen dioxide.

$$Cu + 4HNO_3 \rightarrow Cu(NO_3)_2 + 2H_2O + 2NO_2$$

$$Zn + 4HNO_3 \rightarrow Zn(NO_3)_2 + 2H_2O + 2NO_2$$

$$Fe + 6HNO_3 \rightarrow Fe(NO_3)_2 + 2H_2O + 3NO_2$$

- Metals like Fe, Al, Co and Ni become passive (inert) when treated with pure concentrated nitric acid because of the formation of extremely thin layer of insoluble metallic oxide which stops the reaction.
- Very dilute nitric acid reacts with magnesium and manganese metals.

$$Mg + 2HNO_3 \rightarrow Mg(NO_3)_2 + H_2$$

$$Mn + 2HNO_3 \rightarrow Mn(NO_3)_2 + H_2$$

Test for Nitric Acid and Nitrates:

➢ Concentrated nitric acid gives brown fumes on heating

$$4HNO_3 \xrightarrow{\Delta} 2H_2O + \underset{\text{Brown fumes}}{4NO_2} + O_2$$

➢ Nitrates (other than potassium, sodium and ammonium) produce reddish brown fumes of nitrogen dioxide [NO_2] are evolved, when copper reacts with nitric acid.

$$Cu + 4HNO_3 \xrightarrow{\Delta} Cu(NO_3)_2 + 2H_2O + 2NO_2$$

$$Cu + 4NaNO_3 + 4H_2SO_4 \xrightarrow{\Delta} 4NaHSO_4 + Cu(NO_3)_2 + 2H_2O + 2NO_2$$

Brown Ring Test

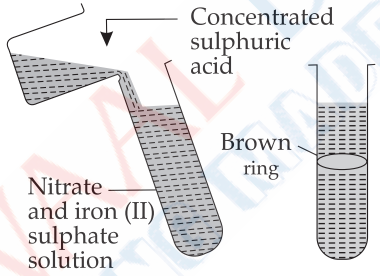
➢ **Procedure:** Take an aqueous solution of nitrate or nitric acid in a test tube.

(i) Add freshly prepared saturated solution of iron [II] sulphate.

(ii) Now add concentrated sulphuric acid carefully from the sides of the test tube, it means that it should not fall dropwise in the test tube.

(iii) Cool the test tube in water.

(iv) A brown ring appears at the junction of the two liquids.



Brown ring test

Reaction: $6FeSO_4 + 3H_2SO_4 + 2HNO_3 \rightarrow 3Fe_2(SO_4)_3 + 4H_2O + 2NO$

$$FeSO_4 + 6H_2O \rightarrow [Fe_2(H_2O)_6]SO_4$$

$$[Fe(H_2O)_6]SO_4 + NO \rightarrow \underset{\text{Pentaaqua−nitroso iron (I) sulphate}}{[Fe(H_2O)_5NO]\ SO_4} + H_2O$$

Key Words

➢ **Nitrogen Fixation:** The conversion of free atmospheric nitrogen into useful nitrogenous compounds in the soil is called nitrogen fixation.

➢ **Aqua Regia:** It is a mixture of conc. nitric acid (1 part by volume) and conc. hydrochloric acid (3 parts by volume). (1: 3) It mean royal water.

Key Terms

➢ Chile saltpetre: $NaNO_3$

➢ During lightning discharge, the nitrogen present in the atmosphere reacts with the oxygen to form nitric oxide.

$$N_2 + O_2 \rightleftharpoons 2NO$$

➢ Nitric acid was formerly known as **aqua fortis** meaning strong water. It is due to the fact that it reacts with nearly all metal. It can even dissolve silver.

➢ Nitric acid upto 98% (fuming nitric acid) is obtained by distilling 68% HNO_3 over conc. H_2SO_4.

- An aqueous solution of nitric acid (68% concentration) forms a constant boiling mixture at 121°C.
- Nitric acid is non-poisonous. It has a corrosive action on the skin and causes painful blisters. It stains the skin yellow as it reacts with protein of the skin and forms xanthoproteic acid.
- Nitric acid stored in a bottle turns yellow. This colour is due to dissolved NO_2 in HNO_3. To avoid the decomposition, nitric acid is normally stored in coloured bottles.
- Nitric acid oxidises hydrochloric acid to chlorine. Aqua regia reacts even with noble metals like gold and platinum to give their chlorides. Aqua regia contains nascent chlorine which attacks these metals.

$$Pt + 4[Cl] \longrightarrow \underset{\text{(Soluble)}}{PtCl_4}$$

$$Au + 3[Cl] \longrightarrow \underset{\text{(Soluble)}}{AuCl_3}$$

$$HCl + AuCl_3 \longrightarrow H^+ [AuCl_4]^-$$

- In Brown ring test, a freshly prepared ferrous sulphate solution is used, because on exposure to the atmosphere, it is oxidised to ferric sulphate which will not give the brown ring.
- **Effect of Heat on Nitrates:**

$$2NaNO_3 \xrightarrow{\Delta} 2NaNO_2 + O_2 \uparrow$$

$$2KNO_3 \xrightarrow{\Delta} 2KNO_2 + O_2 \uparrow$$

$$2Ca(NO_3)_2 \xrightarrow{\Delta} 2CaO + \underset{\substack{\text{Reddish}\\\text{brown gas}}}{4NO_2} + O_2$$

$$2Zn(NO_3)_2 \xrightarrow{\Delta} \underset{\substack{\text{Yellow (when hot)}\\\text{White (when cold)}}}{2ZnO} + 4NO_2 + O_2$$

$$2Cu(NO_3)_2 \xrightarrow{\Delta} \underset{\text{Black}}{2CuO} + 4NO_2 + O_2$$

$$2AgNO_3 \xrightarrow{\Delta} \underset{\text{Silver grey}}{2Ag} + 2NO_2 + O_2$$

$$NH_4NO_3 \xrightarrow{\Delta} N_2O(g) + 2H_2O(g)$$

Topic-5

Sulphuric Acid

Concepts covered: • *Manufacturing sulphuric acid,* • *Properties of sulphuric acid*

Revision Notes

- Sulphuric acid is called as king of chemicals. It is commonly called as **oil of vitriol.**
- It was prepared during the **distillation** of **green vitriol** ($FeSO_4.7H_2O$).

$$2FeSO_4.7H_2O \xrightarrow{\Delta} Fe_2O_3 + SO_2 + 13H_2O + H_2SO_4$$

- Sulphuric acid is manufactured by Contact process.
  - **(a)** Catalytic oxidation of sulphur dioxide in catalytic chamber:

    The gases entering the catalytic chamber must be pure, otherwise it would poison the catalyst.

$$\underset{\text{Sulphur dioxide}}{2SO_2 + O_2} \xrightarrow[450^\circ C]{\text{Vanadium pentaoxide}} \underset{\text{Sulphur trioxide}}{2SO_3}$$

The catalyst glows red hot because the reaction is exothermic in nature. So, only initial heating of the catalyst is required.

  - **(b)** **Absorption tower:**

    SO_3 formed in catalytic chamber is not directly absorbed in water because:
    - **(i)** The reaction is highly exothermic in nature.
    - **(ii)** It forms a homogeneous mixture. A dense mist of minute particles of sulphuric acid is formed which is not easily condensed. Instead, sulphur trioxide formed is absorbed in concentrated sulphuric acid to form Pyrosulphuric acid or Oleum ($H_2S_2O_7$).

$$SO_3 + \underset{\text{(conc.)}}{H_2SO_4} \to \underset{\substack{\text{pyrosulphuric acid}\\ \text{or}\\ \text{Oleum}}}{H_2S_2O_7}$$

(c) **Dilution of Oleum:** It is diluted by adding calculated amount of water to obtain concentrated sulphuric acid of desired concentration.

$$H_2S_2O_7 + \underset{\substack{\text{Calculated}\\ \text{amount}}}{H_2O} \to \underset{\text{Concentrated}}{2H_2SO_4}$$

- Concentrated sulphuric acid is colourless, odourless, viscous, hygroscopic liquid which is soluble in water in all proportions.
- It is a strong dibasic acid. The salts of sulphuric acid are called sulphuricates and bisulphates. Dilute sulphuric acid shows the typical properties of dilute acids.

(a) **Reaction with bases:**

It forms salt and water. It undergoes neutralisation reaction.

$$\underset{\substack{\text{Potassium}\\ \text{hydroxide}}}{2KOH} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Potassium}\\ \text{sulphate}}}{K_2SO_4} + 2H_2O$$

$$\underset{\substack{\text{Sodium}\\ \text{hydroxide}}}{2NaOH} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Sodium}\\ \text{sulphate}}}{Na_2SO_4} + 2H_2O$$

$$\underset{\substack{\text{Copper}\\ \text{hydroxide}}}{Cu(OH)_2} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Copper}\\ \text{sulphate}}}{CuSO_4} + 2H_2O$$

$$\underset{\substack{\text{Ammonium}\\ \text{hydroxide}}}{2NH_4OH} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Ammonium}\\ \text{sulphate}}}{(NH_4)_2SO_4} + 2H_2O$$

(b) **Reaction with metallic carbonates and bicarbonates:**

It liberates carbon dioxide.

$$\underset{\substack{\text{Potassium}\\ \text{carbonate}}}{K_2CO_3} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Potassium}\\ \text{sulphate}}}{K_2SO_4} + H_2O + CO_2\uparrow$$

$$\underset{\substack{\text{Potassium}\\ \text{bicarbonate}}}{KHCO_3} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Potassium}\\ \text{bisulphate}}}{KHSO_4} + H_2O + CO_2\uparrow$$

$$\underset{\substack{\text{Sodium}\\ \text{carbonate}}}{Na_2CO_3} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Sodium}\\ \text{sulphate}}}{Na_2SO_4} + H_2O + CO_2\uparrow$$

$$\underset{\substack{\text{Sodium}\\ \text{bicarbonate}}}{NaHCO_3} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{sodium}\\ \text{bisulphate}}}{NaHSO_4} + H_2O + CO_2\uparrow$$

$$\underset{\substack{\text{Sodium}\\ \text{bicarbonate}}}{2NaHCO_3} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{sodium}\\ \text{sulphate}}}{Na_2SO_4} + 2H_2O + 2CO_2\uparrow$$

(c) **Reaction with Active metals:** On reaction of active metals with dilute acids hydroxide gas is liberated.

$$Zn + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\text{Zinc sulphate}}{ZnSO_4} + H_2\uparrow$$

$$Mg + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Magnesium}\\ \text{sulphate}}}{MgSO_4} + H_2\uparrow$$

$$Fe + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Ferrous}\\ \text{sulphate}}}{FeSO_4} + H_2\uparrow$$

(d) **Reaction with metallic sulphites and bisulphites:** On reaction of active metals with dilute acids, Sulphur dioxide gas is liberated.

$$\underset{\substack{\text{potassium}\\ \text{sulphite}}}{K_2SO_3} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Potassium}\\ \text{sulphate}}}{K_2SO_4} + H_2O + \underset{\substack{\text{Sulphur}\\ \text{dioxide}}}{SO_2}\uparrow$$

$$\underset{\substack{\text{potassium}\\ \text{bisulphite}}}{KHSO_3} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Potassium}\\ \text{bisulphate}}}{KHSO_4} + H_2O + \underset{\substack{\text{Sulphur}\\ \text{dioxide}}}{SO_2}\uparrow$$

$$\underset{\substack{\text{Sodium}\\ \text{sulphite}}}{Na_2SO_3} + \underset{\text{(dil.)}}{H_2SO_4} \to \underset{\substack{\text{Sodium}\\ \text{sulphate}}}{Na_2SO_4} + H_2O + \underset{\substack{\text{Sulphur}\\ \text{dioxide}}}{SO_2}\uparrow$$

$$\underset{\text{Sodium bisulphite}}{2NaHSO_3} + \underset{\text{(dil.)}}{H_2SO_4} \rightarrow \underset{\text{Sodium Sulphate}}{Na_2SO_4} + 2H_2O + \underset{\text{Sulphur dioxide}}{2SO_2}\uparrow$$

(e) Reaction with metallic sulphides: On reaction of metallic sulphides of dilute sulphuric acid, hydrogen sulphide gas is liberated.

$$\underset{\text{Zinc sulphide}}{ZnS} + \underset{\text{(dil.)}}{H_2SO_4} \rightarrow \underset{\text{Zinc sulphate}}{ZnSO_4} + \underset{\text{Hydrogen sulphide}}{H_2S}$$

$$\underset{\text{Iron(II) sulphide}}{FeS} + \underset{\text{(dil.)}}{H_2SO_4} \rightarrow \underset{\text{Iron(II) sulphate}}{FeSO_4} + \underset{\text{Hydrogen sulphide}}{H_2S}$$

(f) Reaction with metallic oxide:

It forms salt and water.

$$Al_2O_3 + \underset{\text{(dil.)}}{3H_2SO_4} \rightarrow Al_2(SO_4)_3 + 3H_2O$$

$$CuO + \underset{\text{(dil.)}}{H_2SO_4} \rightarrow CuSO_4 + H_2O$$

$$ZnO + \underset{\text{(dil.)}}{H_2SO_4} \rightarrow ZnSO_4 + H_2O$$

$$MgO + \underset{\text{(dil.)}}{H_2SO_4} \rightarrow MgSO_4 + H_2O$$

(g) It shows characteristic colour change with indicators:

Indicator	Colour change
Blue litmus	Red
Phenolphthalein	Remains colourless
Methyl orange	Red or Pink

➢ **Concentrated Sulphuric acid acts as**

(a) Least volatile acid: Nitrates and chlorides on reaction with concentrated sulphuric acid form their corresponding acids, which are more volatile than sulphuric acid.

$$NaCl + H_2SO_4(\text{conc.}) \xrightarrow[200°C]{\text{below}} NaHSO_4 + HCl$$

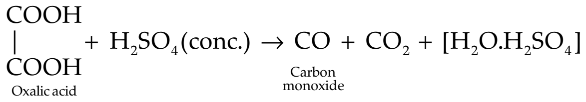
$$KNO_3 + H_2SO_4 \xrightarrow[200°C]{\text{below}} KHSO_4 + HNO_3$$

(b) Dehydrating agent: Concentrated Sulphuric acid acts as dehydrating agent as it has strong affinity for water. Dehydrating agent is a chemical compound which removes chemically combined elements of water, hydrogen and oxygen in the ratio of 2: 1.

(i) Dehydration of Formic acid:

$$\underset{\text{Formic acid}}{HCOOH} + H_2SO_4(\text{conc.}) \rightarrow \underset{\text{Carbon monoxide}}{CO} + [H_2O.H_2SO_4]$$

(ii) Dehydration of Oxalic acid:



$$\underset{\text{Oxalic acid}}{\begin{matrix}COOH\\ |\\ COOH\end{matrix}} + H_2SO_4(\text{conc.}) \rightarrow \underset{\text{Carbon monoxide}}{CO} + CO_2 + [H_2O.H_2SO_4]$$

(iii) Dehydration of ethanol:

$$\underset{\text{Ethanol}}{C_2H_5OH} + H_2SO_4(\text{conc.}) \rightarrow \underset{\text{Ethene}}{C_2H_4} + [H_2O.H_2SO_4]$$

(iv) Dehydration of Blue vitriol ($CuSO_4.5H_2O$):

Blue coloured crystalline copper sulphate on coming in contact with concentrated H_2SO_4 becomes white and crumbles down to form powder.

$$\underset{\substack{\text{Hydrated}\\\text{copper sulphate}\\\text{(Blue)}}}{CuSO_4.5H_2O} + H_2SO_4(\text{conc.}) \rightarrow \underset{\substack{\text{Anhydrous}\\\text{Copper sulphate}\\\text{(White)}}}{CuSO_4} + [5H_2O.H_2SO_4]$$

(v) **Dehydration of Sugar:**

On adding concentrated sulphuric acid to sugar, initially the crystals become brown, steam is released causing a lot of frothing and finally a black porous mass is left behind.

$$\underset{\text{Sugar}}{C_{12}H_{22}O_{11}} + H_2SO_4(\text{conc.}) \rightarrow \underset{\substack{\text{Black}\\\text{mass}}}{12C} + [11H_2O.H_2SO_4]$$

(c) **Oxidising agent: It oxidises**

(i) **Metals**

$$\underset{\text{Zinc}}{Zn} + \underset{\text{(conc.)}}{2H_2SO_4} \rightarrow \underset{\text{Zinc sulphate}}{ZnSO_4} + 2H_2O + SO_2$$

$$\underset{\text{Copper}}{Cu} + \underset{\text{(conc.)}}{2H_2SO_4} \rightarrow \underset{\substack{\text{Copper}\\\text{sulphate}}}{CuSO_4} + 2H_2O + SO_2$$

(ii) **Non-metals**

$$C + \underset{\text{(conc.)}}{2H_2SO_4} \rightarrow CO_2 + 2H_2O + 2SO_2$$

$$S + \underset{\text{(conc.)}}{2H_2SO_4} \rightarrow 2H_2O + 3SO_2$$

(iii) **Inorganic compounds**

$$H_2S + \underset{\text{(conc.)}}{H_2SO_4} \rightarrow S + 2H_2O + SO_2\uparrow$$

(d) **Drying agent:** Concentrated sulphuric acid acts as a drying agent, i.e., it is used to remove moisture from the gases and other compounds, without undergoing any chemical reaction.

Mnemonics

Concept: Role of Conc. Sulphuric Acid

Mnemonics:

LiVeD On Diet

Interpretation:

L: Least

V: Volatile

D: Dehydrating

O: Oxidizing

D: Drying

Key Words

- **King of Chemicals:** Sulphuric acid is called the king of chemicals.
- **Oil of vitriol:** Sulphuric acid was obtained as an oily viscous liquid by heating crystals of green vitriol. So, it is known as oil of vitriol.

Key Terms

- **Barytes:** $BaSO_4$ (Barium sulphate)
- **Gypsum:** $CaSO_4.2H_2O$
- **Kieserite:** $MgSO_4.H_2O$
- Water is never poured on acid to dilute it as large amount of heat is evolved which changes water to steam. The steam so formed causes spurting of acid which can cause burn injuries, so dilution's done by pouring acid on a given amount of water in a controlled manner by continuous stirring. The evolved heat is dissipated in water itself and so the spurting of the acid is minimised.

❑❑

CHAPTER-9
ORGANIC CHEMISTRY

Topic-1

Organic Compounds

Concepts covered: • *Unique nature of carbon atoms,* • *Characteristics of organic compounds,* • *Cycloalkanes,* • *Hydrocarbons*

Revision Notes

- The word "organic" means pertaining to life. Earlier, it was regarded that organic compounds can only be produced by nature under the influence of living force called **vital force**.
- The vital force theory was soon discarded when a German scientist, Friedrich Wohler, synthesize an organic compound urea in the laboratory, by heating ammonium cyanate.

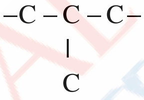
$$\underset{\text{Ammonium cyanate}}{NH_4CNO} \xrightarrow{\text{Heat}} \underset{\text{Urea}}{CO(NH_2)_2}$$

Later on, Kolbe prepared acetic acid (CH_3COOH) and Berthelot synthesised methane (CH_4) gas in the laboratory.

- All organic compounds essentially contain carbon atom. Carbon has 4 valence electrons. Therefore, to satisfy its valency carbon shares its electrons with other carbon atoms or with the atoms of other elements. As a result of sharing, it leads to the formation of straight chain, branched chain, closed chain or the ring structure.

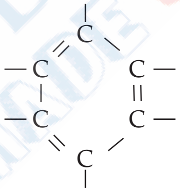
$-C-C-C-C-$

straight chain



$$-\underset{\underset{C}{|}}{C}-C-C-$$

Branched chain

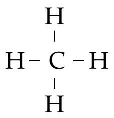


Closed chain or Ring structure

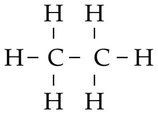
- **Unique nature of carbon atoms :**
  - **(i)** Carbon has four valence electrons. It can neither lose nor gain electrons to attain octet. It forms covalent bonds by sharing its four electrons with other atoms. It is known as **tetra valency** of the carbon atoms.
  - **(ii)** Carbon atom possesses a unique property to link with one another by means of covalent bonds to form long chains (or rings) of carbon atoms. This property of forming bonds with atoms of the same elements is called as **catenation**.
- **Characteristics of organic compounds are :**
  - **(i)** All organic compounds are covalent in nature.
  - **(ii)** Almost all the organic compounds are insoluble in water but soluble in organic solvents like benzene, ether, carbon tetrachloride.
  - **(iii)** All have relatively low melting point and boiling point.
  - **(iv)** All organic compounds are combustible in nature.
- Older chemists basically classified hydrocarbons as either aliphatic or aromatic. The classification was done on the basis of their source and their properties.
- **Cycloalkanes :** These hydrocarbons possess one or multiple carbon rings. The hydrogen atom is attached to the carbon ring.
- **Aromatic Hydrocarbons :** These are also called as arenes. Arenes are compounds which consist of at least one aromatic ring.
- **Hydrocarbons :** A compound made up of hydrogen and carbon only is called **hydrocarbon**. For example, CH_4, C_2H_2, C_2H_6, etc. The most important natural source of hydrocarbon is petroleum or crude oil. Hydrocarbons are further divided into two main groups:
  - **(i)** Aliphatic (open) and **(ii)** Cyclic (closed) chain compounds.

  The aliphatic compounds are further divided into saturated and unsaturated hydrocarbons.
- **Saturated hydrocarbons :** A hydrocarbon in which the carbon atoms are connected by only single bonds is called **saturated hydrocarbon**. It is represented by the general formula C_nH_{2n+2} where n is the number of carbon atoms.

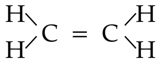
Methane CH_4



Ethane C_2H_6



- **Unsaturated hydrocarbons :** A hydrocarbon in which two carbon atoms are connected by a double bond or a triple bond is called as an **unsaturated hydrocarbon**. Alkenes are the hydrocarbons with double bond between two carbon atoms. Alkynes are the hydrocarbons with triple bond between two carbon atoms.



Ethene

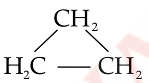
$H-C\equiv C-H$

Ethyne

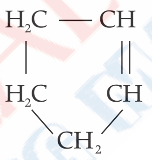
- **Difference between Saturated and Unsaturated Organic Compounds :**

Saturated Organic Compounds	Unsaturated Organic compounds
i. All the four valencies of each carbon atom are satisfied by forming single covalent bonds with carbon and with hydrogen atoms.	**1.** The valencies of at least two carbon atoms are not fully satisfied by the hydrogen atoms.
ii. Carbon atoms are joined only by a single covalent bond.	**2.** Carbon atoms are joined by double covalent bonds, or by triple covalent bonds.
3. They are less reactive due to the non-availability of electrons in the single covalent bond, and therefore they undergo substitution reaction.	**3.** They are non–reactive due to the presence of electrons in the double or the triple bond, and therefore, undergo reaction.

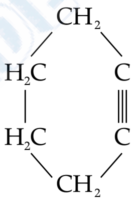
- **Carbocyclic compounds :** Cyclic or closed chain hydrocarbons contain three or more carbon atoms in their molecule. Cyclic compounds containing single, double and triple bonds are called cycloalkanes, cycloalkenes and cycloalkynes respectively.



Cyclopropane (C_3H_6)

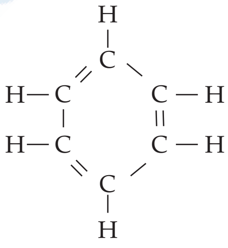


Cyclopentene C_5H_8



Cyclohexyne (C_6H_8)

Some hydrocarbon contains at least one benzene ring in their molecules. It is a ring of six carbon atom having C — C single and C = C double bond in alternate positions.



Benzene

- **Alkyl Group :** Alkyl group is represented by 'R'. The general formula of alkyl group is C_nH_{2n+1} (where *n* = number of carbon atoms). The group formed by the removal of one hydrogen atom from alkane molecules is called an alkyl group. An alkyl group is named by replacing the suffix 'ane' of the alkane with the suffix – yl.

$$\underset{\text{Methane}}{CH_4} \xrightarrow{-H} \underset{\text{Methyl}}{-CH_3}$$

$$\underset{\text{Ethane}}{C_2H_6} \xrightarrow{-H} \underset{\text{Ethyl}}{-C_2H_5}$$

- **Homologous Series :** When the organic compounds having similar structural formula, same functional group are arranged in order of increasing molecular weights, they form a homologous series.
- **Characteristics of a Homologous Series**
  - **(i)** They have similar general and structural formula and same chemical properties.
  - **(ii)** The two adjacent members of homologous series differ by CH_2 unit.

(iii) The molecular mass of two adjacent homologous differ by 14 amu.

(iv) The members of a homologous series can be prepared by similar methods of preparation.

- **Homologous Series of Alkanes :** (General formula C_nH_{2n+2})

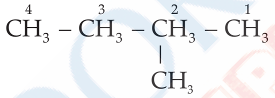
Alkane	Formula
1. Methane	CH_4
2. Ethane	C_2H_6
3. Propane	C_3H_8
4. Butane	C_4H_{10}
5. Pentane	C_5H_{12}

- **Importance of Homologous Series :**
  - (i) It helps in systematic study of organic compounds.
  - (ii) By knowing the properties of any member of a homologous series, we can predict the properties of other members of the series.
- **Isomerism :** Two or more compounds having the same molecular formula but different physical and chemical properties are called isomers and this phenomenon is known as isomerism.

Example - **(i)** $\overset{5}{C}H_3 - \overset{4}{C}H_2 - \overset{3}{C}H_2\ \overset{2}{C}H_2 - \overset{1}{C}H_3$

Pentane$(n-\text{pentane})$

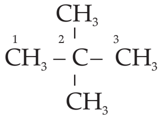
(ii)



$$\overset{4}{C}H_3 - \overset{3}{C}H_3 - \underset{\displaystyle CH_3}{\overset{2}{C}H_3} - \overset{1}{C}H_3$$

2-methyl butane (*iso* -pentane)

(iii)



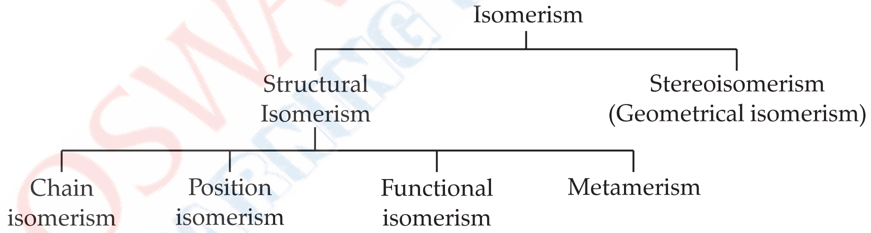
$$\overset{1}{C}H_3 - \underset{\displaystyle CH_3}{\overset{\displaystyle CH_3}{\overset{2}{C}}} - \overset{3}{C}H_3$$

2,2 dimethyl propane
(*neo* -pentane)

- **There are two types of isomerism :**

(1) **Structural isomerism :** Chain isomerism, position isomerism, functional isomerism, metamerism and tautomerism

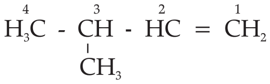
(2) **Stereo isomerism :** Optical and geometrical isomerism



- **Chain Isomerism :** When the same molecular formula represents two or more compounds which differ in the length of carbon chain without altering the position of double or triple bond then the isomerism is said to be chain isomerism. For example : C_5H_{10}

$$H_3\overset{5}{C} - H_2\overset{4}{C} - H_2\overset{3}{C} - \overset{2}{C}H = \overset{1}{C}H_2$$

Pent$-$1$-$ene



$$H_3\overset{4}{C} - \underset{\displaystyle CH_3}{\overset{3}{C}H} - H\overset{2}{C} = \overset{1}{C}H_2$$

3-Methyl but - 1- ene

- **Position Isomerism :** The isomerism in this case differ with respect to the position of the double bond and triple bond. For example : Butyne C_4H_6.

$$H_3\overset{4}{C} - \overset{3}{C}H_2 - \overset{2}{C} \equiv \overset{1}{C}H \qquad H_3\overset{4}{C} - \overset{3}{C} \equiv \overset{2}{C} - \overset{1}{C}H_3$$

(But - 1 - yne) (But - 2 - yne)

- **Functional group** : A **functional group** is an atom or a group of atoms which imparts characteristics properties to the organic compound.

Series	Functional Group	General Formula	Example
Alkane	Hydrocarbon chain	C_nH_{2n+2}	Methane, CH_4 Ethane, C_2H_6
Alkene	Double bond $\gt C = C \lt$	C_nH_{2n}	Ethene, C_2H_4 Propene, C_3H_6

Alkyne	Triple bond $-C \equiv C-$	C_nH_{2n-2}	Ethyne, C_2H_2 Propyne, C_3H_4
Alcohol	– OH group	$C_nH_{2n+1}OH$	Methanol, CH_3OH Ethanol, C_2H_5OH
Aldehyde	– CHO group	$C_nH_{2n+1}CHO$	Ethanal, CH_3CHO Propanal, C_2H_5CHO
Carboxylic acid	– COOH group	$C_nH_{2n+1}COOH$	Ethanoic acid, CH_3COOH Propanoic acid, C_2H_5COOH
Halides -			
Chloride	– Cl	$C_nH_{2n+1}Cl$	Chloromethane CH_3Cl Chloroethane C_2H_5Cl
Bromide	– Br	$C_nH_{2n+1}Br$	Bromomethane CH_3Br Bromoethane C_2H_5Br
Iodide	– I	$C_nH_{2n+1}I$	Iodomethane CH_3I Iodoethane C_2H_5I

➢ **Nomenclature of Organic Compounds :** Nomenclature is the system of assignment of names to organic compounds. Organic compounds have two names, common name or trivial system and IUPAC name.

Trivial System : The basic of naming organic compounds by the trivial system is its (a) Source **(b)** Properties **(c)** Latin or Greek origin.

IUPAC System : (International Union of Pure and Applied Chemistry)

IUPAC name takes up only one molecular structure of the compound and assign only one name to the compound.

According to this system, the name of an organic compound consists of three parts :

(i) Word Root **(ii)** Suffix **(iii)** Prefix

(i) **Word Root :** The Word root indicates the total number of carbon atoms present in the longest carbon chain belonging to the compound. For example, 'Meth' refers to a chain with 1 carbon atom and 'Hept' refers to a chain with 7 carbon atoms.

Number of carbon atoms	Word Root
C_1	Meth
C_2	Eth
C_3	Prop
C_4	But
C_5	Pent
C_6	Hex
C_7	Hept
C_8	Oct
C_9	Non
C_{10}	Dec

(ii) **Suffix** : The part of the name which appears after the word root.

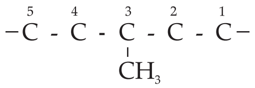
- **Primary Suffix :** It tells us about the nature of carbon chain i.e., whether saturated or unsaturated.

Name	Group	Suffix
Alkane	$>C-C<$	ane
Alkene	$>C=C<$	ene
Alkyne	$-C \equiv C-$	yne

- **Secondary Suffix** : It is written after the primary suffix for functional group present in the compound.

Name	Group	Suffix
Alcohol	– OH	ol
Aldehyde	– CHO	al
Carboxylic acid	– COOH	oic acid

(iii) Prefix : There are many groups which are not regarded as functional groups in the IUPAC system. These are regarded as side chains and represent as prefix. A prefix is placed before the word root while naming a particular compound.



$$-\overset{5}{C}-\overset{4}{C}-\underset{CH_3}{\overset{3}{C}}-\overset{2}{C}-\overset{1}{C}-$$

3-methyl

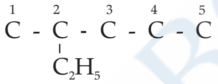
➢ **Rules for naming an Organic Compound :**

(i) Selection of carbon chain : The longest chain of carbon atoms in the structure of the compound is found first. The compound is then named as a derivative of the alkane hydrocarbon.

$$\overset{1}{C}-\overset{2}{C}-\overset{3}{C}-\overset{4}{C}-\overset{5}{C}$$

Longest chain of 5 carbon atoms, so word root is 'pent'.

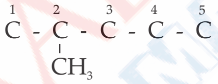
(ii) The alkyl group present as side chains (branches) are considered as substituent's and named separately as methyl (– CH_3) or ethyl (– C_2H_5) group.



$$\overset{1}{C}-\underset{C_2H_5}{\overset{2}{C}}-\overset{3}{C}-\overset{4}{C}-\overset{5}{C}$$

2-ethyl

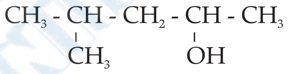
(iii) The carbon atoms of the longest carbon chain are numbered in such a way that the alkyl groups (substitutes) get the lowest possible number.



$$\overset{1}{C}-\underset{CH_3}{\overset{2}{C}}-\overset{3}{C}-\overset{4}{C}-\overset{5}{C}$$

2-methyl

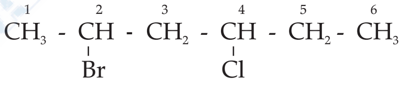
(iv) If the functional group is also present in the chain, then the carbon atoms are numbered in such a way that the functional group gets the smallest possible number.



$$CH_3-\underset{CH_3}{CH}-CH_2-\underset{OH}{CH}-CH_3$$

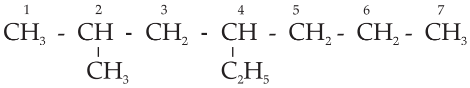
4-methyl pentan - 2- ol

(v) If different types of substituents are attached in the chain, they are named alphabetically.



$$\overset{1}{CH_3}-\underset{Br}{\overset{2}{CH}}-\overset{3}{CH_2}-\underset{Cl}{\overset{4}{CH}}-\overset{5}{CH_2}-\overset{6}{CH_3}$$

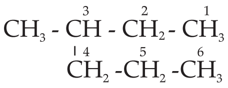
2-bromo-4-chlorohexane



$$\overset{1}{CH_3}-\underset{CH_3}{\overset{2}{CH}}-\overset{3}{CH_2}-\underset{C_2H_5}{\overset{4}{CH}}-\overset{5}{CH_2}-\overset{6}{CH_2}-\overset{7}{CH_3}$$

4-ethyl 2-methylheptane

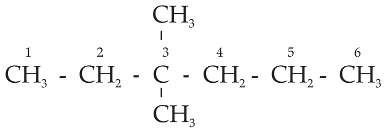
(vi) The IUPAC name of the compound is obtained by writing the position and name of alkyl group just before the name of parent 'hydrocarbon'.



$$CH_3-\overset{3}{CH}-\overset{2}{CH_2}-\overset{1}{CH_3}$$
$$|\,4\quad \overset{4}{CH_2}-\overset{5}{CH_2}-\overset{6}{CH_3}$$

3-methylhexane

(vii) Multiple alkyl groups are named as di, tri or tetra for two, three or four respectively.



$$\overset{1}{CH_3}-\overset{2}{CH_2}-\underset{CH_3}{\overset{CH_3}{\overset{3}{C}}}-\overset{4}{CH_2}-\overset{5}{CH_2}-\overset{6}{CH_3}$$

3,3-dimethyl hexane

Mnemonics

Concept : Homologous series of alkanes.

Mnemonics : **M**any **e**lephants **p**refer **b**lue **p**ineapples

Interpretation :

M – methane

E – ethane

P – propane

B – butane

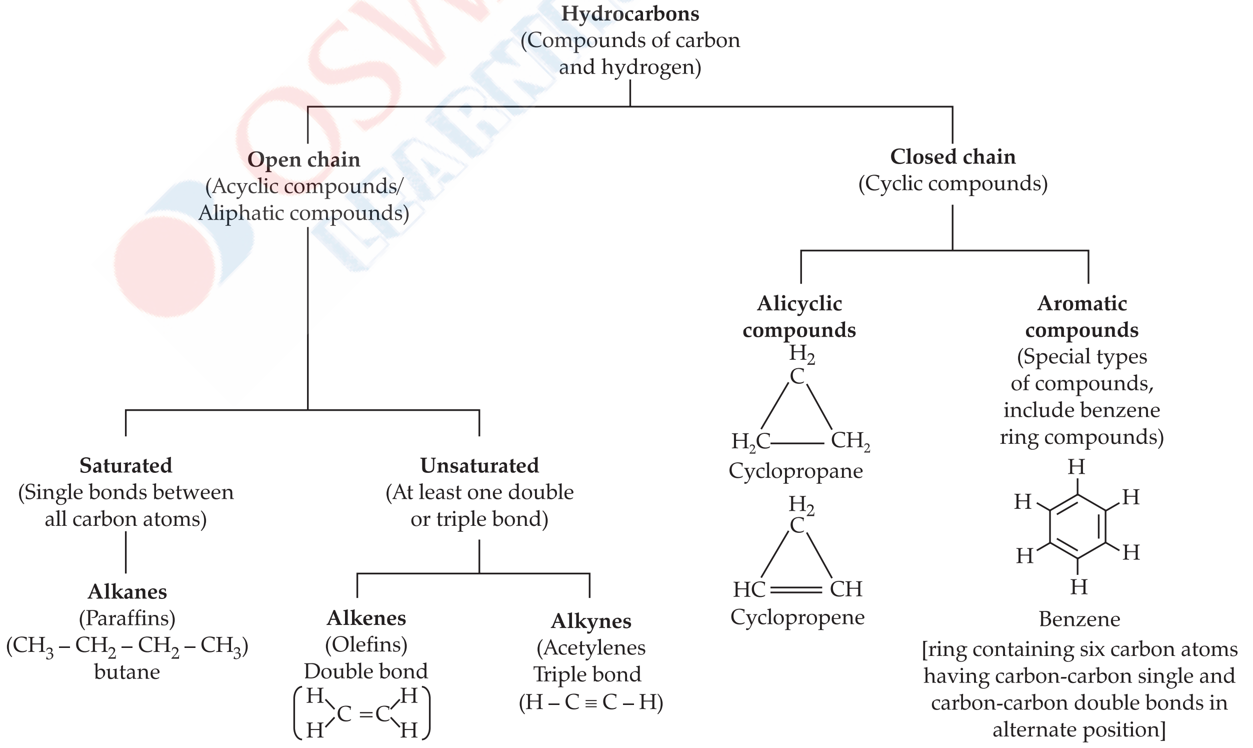
P – pentane

Key Words

- **Organic Chemistry :** It is the study of hydrocarbons and their derivatives.
- **Catenation :** It is the property by virtue of which atoms of the same element get linked together through covalent bonds so as to form long straight, branched or closed chain or rings.
- **Tetracovalency :** Carbon atom shows tetracovalency because it has four electrons in its valence shell.
- **Functional Group :** An atom or group of atoms or some other characteristics structural feature which gives special properties to a compound.
- **Homologous Series :** It is a series of compound having similar structural formulae, same functional group and hence similar chemical properties.
- **Structural Formula :** It gives up the relative arrangements of bonded atoms in a molecule.

Key Terms

- Carbon is a necessary element in every organic compound.
- The characteristic of the carbon atom by virtue of which it forms four covalent bonds, is known as tetravalency of carbon.
- The unique nature of carbon a atom, i.e., catenation and tetravalency gives rise to the formation of a large number of compounds.
- **Classification of Hydrocarbons**



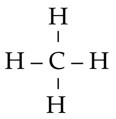
Topic-2

Hydrocarbons-Alkanes, Alkenes and Alkynes

Concepts covered: *Alkanes: • Structural formula, • Laboratory preparation of methane and ethane, • Properties of methane and ethane, • Alkenes, • Preparation of ethene, • Properties of alkenes, • Alkynes, • Laboratory preparation of ethyne, • Properties of alkynes.*

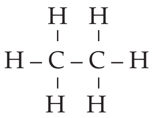
Revision Notes

- Alkanes are the saturated hydrocarbons which contain only single covalent bonds between two carbon atoms. They posses the general formula C_nH_{2n+2}, Where n = is the number of the series is methane CH_4 and second member (n=2) is ethane, C_2H_6.
- **Structural formula of Alkanes :**



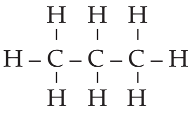
$$H-\underset{H}{\overset{H}{C}}-H$$

Methane



$$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H$$

Ethane

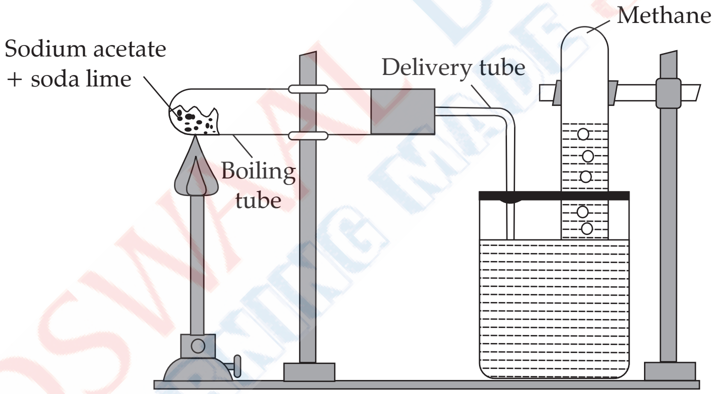


$$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H$$

Propane

- **Laboratory preparation of methane and ethane :** Methane is prepared by anhydrous sodium acetate (sodium ethanoate) with sodalime, NaOH + CaO.

$$\underset{\text{Sodium acetate}}{CH_3COONa(s)} + NaOH(s) \xrightarrow[\Delta]{CaO} Na_2CO_3(s) + \underset{\text{Methane}}{CH_4(g)\uparrow}$$



Preparation of methane (CH_4)

Ethane is prepared by heating anhydrous sodium propionate with sodalime.

$$\underset{\text{Sodium propionate}}{C_2H_5COONa(s)} + NaOH(s) \xrightarrow[\Delta]{CaO} Na_2CO_3(s) + \underset{\text{Ethane}}{C_2H_6(g)\uparrow}$$

- **Other methods of preparations of Methane :**
  (i) Methane can also be prepared by the action of water on aluminium carbide.

$$\underset{\text{Aluminium carbide}}{Al_4C_3(s)} + 12H_2O(l) \rightarrow 4Al(OH)_3(s) + \underset{\text{Methane}}{3CH_4(g)}$$

  (ii) Methane can also be prepared by the reduction of methyl iodide (iodo methane) with Zn-Cu couple Zn/HCl.

$$\underset{\text{Iodomethane}}{CH_3I} + 2[H] \xrightarrow{\text{Zn–Cu Couple}} \underset{\text{Methane}}{CH_4} + HI$$

- **Other methods of Preparation of Ethane :**
  (i) Ethane can also be prepared by the reduction of bromoethane with Zn-Cu couple or Zn/HCl.

$$\underset{\text{Bromoethane}}{C_2H_5Br} + 2[H] \xrightarrow{\text{Zn–Cu Couple}} \underset{\text{Ethane}}{C_2H_6} + HBr$$

  (ii) Ethane from alkyl halides - Methyl iodide or methyl bromide reacts with sodium metal in the presence of dry ether, than ethane gas is produced.

$$2CH_3I + 2Na \xrightarrow{\text{dry ether}} \underset{\text{Ethane}}{H_3C - CH_3} + 2NaI$$

- **Physical Properties :**
  1. Methane is colourless and odourless gas. Its melting point is - 183°C and boiling point is -162°C. It is insoluble in water but soluble in organic solvents.
  2. Ethane is colourless and odourless gas. Its boiling point is - 89°C and melting point is - 172°C. It is insoluble in water but soluble in organic solvents.
- **Chemical Properties :**

(i) Combustion of Alkanes : Methane and ethane burn in air to form carbon dioxide and water with the evolution of large amount of heat.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O + \text{Energy}$$

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O + \text{Energy}$$

(ii) Substitution Reactions :

Methane reacts with chlorine in the presence of diffused sunlight to form mono-chloromethane, CH_3Cl.

$$CH_4(g) + Cl_2 \rightarrow \underset{\text{Monochloromethane}}{CH_3Cl(g)} + HCl(g)$$

With excess of chlorine, the remaining three H atoms are successively replaced by Cl atoms to form dichloromethane, trichloromethane and tetrachloromethane.

$$CH_3Cl + Cl_2 \rightarrow \underset{\text{Dichloromethane}}{CH_2Cl_2} + HCl$$

$$CH_2Cl_2 + Cl_2 \rightarrow \underset{\text{Trichloromethane}}{CHCl_3} + HCl$$

$$CHCl_3 + Cl_2 \rightarrow \underset{\text{Tetrachlormethane}}{CCl_4} + HCl$$

These reactions are called **substitution rections** because chlorine atom successively replaces hydrogen atoms in the methane molecule.

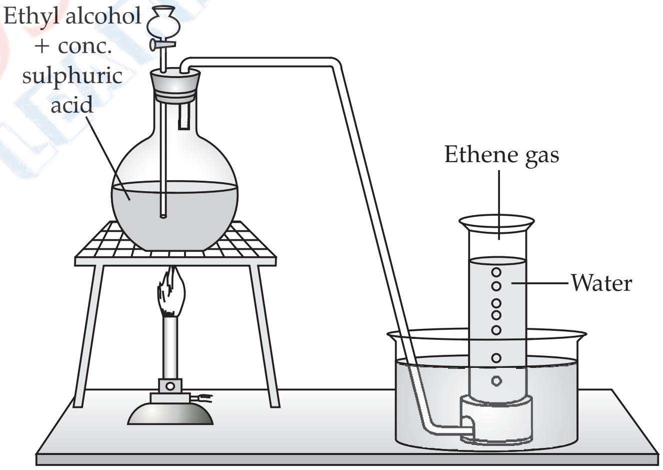
Similarly it will happen with C_2H_6

- **Alkenes :** Alkenes are also called olefins because the lower member of alkenes form oily products when they were treated with chlorine or bromine. Alkenes form a homologous series having the general formula C_nH_{2n}. Ethene is the first member of the alkene series.

Preparation of Ethene

i. **Dehydration of ethyl alcohol.**

Reactants : Ethanol and conc. sulphuric acid.



Laboratory Preparation of ethene

- **Reaction :**

$$\underset{\text{Ethyl alcohol}}{CH_3CH_2OH} + H_2SO_4 \xrightarrow{100^\circ C} \underset{\text{Ethyl hydrogen sulphate}}{CH_3CH_2HSO_4} + H_2O$$

$$CH_3CH_2HSO_4 \xrightarrow[170^\circ C]{\text{excess } H_2SO_4} \underset{\text{Ethene}}{CH_2 = CH_2} + H_2O$$

- **Collection :** The gas is collected by downward displacement of water because :
  - **(i)** It is an inflammable gas.
  - **(ii)** It is insoluble in water.
  - **(ii)** **By dehydration :** Industrial preparation:
    By passing ethanol vapours through a tube containing alumina (Al_2O_3) at 300°C.

$$C_2H_5OH \xrightarrow[300^\circ C]{Al_2O_3} C_2H_4 + H_2O$$

  - **(iii)** **Dehydrogenations :**
    When an alkyl halide is heated gently in an alcoholic medium, it forms corresponding alkene.

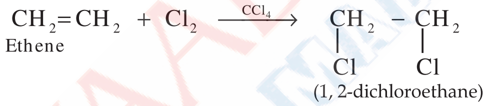
$$\underset{\text{Ethyl chloride}}{C_2H_5Cl} + \underset{\text{(alc.hot and conc.)}}{KOH} \rightarrow C_2H_4 + KCl + H_2O$$

$$\underset{\text{Ethyl bromade}}{C_2H_5Br} + \underset{\text{(alc.hot and conc)}}{KOH} \rightarrow C_2H_4 + KBr + H_2O$$

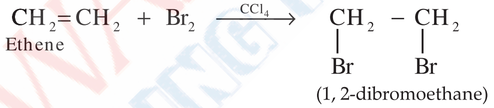
- **Physical properties of alkenes**
  Ethene is a colourless and inflammable gas with a peculiar odour. Its boiling is - 102°C and melting point is –169°C. It is sparingly soluble in water but highly soluble in organic solvents.
- **Chemical properties**
  - **(i)** Addition of hydrogen (hydrogenation) in the presence of catalyst such as platinum or palladium at ordinary temperature or nickel at 200°C.

$$\underset{\text{Ethene}}{C_2H_4} + H_2 \xrightarrow[200^\circ C]{Ni} \underset{\text{Ethane}}{C_2H_6}$$

  - **(ii)** **Addition of halogens (halogenation) :** Ethene reacts with halogens in presence of carbon tetrachloride as a solvent. The order of the reaction with halogens is $F_2 > Cl_2 > Br_2 > I_2$



$$\underset{\text{Ethene}}{CH_2{=}CH_2} + Cl_2 \xrightarrow{CCl_4} \underset{\text{(1, 2-dichloroethane)}}{\underset{Cl}{CH_2} - \underset{Cl}{CH_2}}$$



$$\underset{\text{Ethene}}{CH_2{=}CH_2} + Br_2 \xrightarrow{CCl_4} \underset{\text{(1, 2-dibromoethane)}}{\underset{Br}{CH_2} - \underset{Br}{CH_2}}$$

  - **(iii)** **Addition of water (hydration)**

$$CH_2 = CH_2 + H_2O \xrightarrow{H^+} \underset{\text{Ethyl alcohol}}{C_2H_5OH}$$

  - **(iv)** **Addition of HCl :** Ethene reacts with HCl at room temperature. The order of reaction of hydrogen halides with alkanes is HI > HBr > HCl > HF.

$$\underset{\text{Ethene}}{CH_2 = CH_2} + HCl_{(aq)} \longrightarrow \underset{\left(\begin{array}{c}\text{Ethyl chloride}\\ \text{Chloroethane}\end{array}\right)}{CH_3CH_2Cl}$$

  - **(v)** **Polymerization :** Ethene polymerises to produce polyethene.

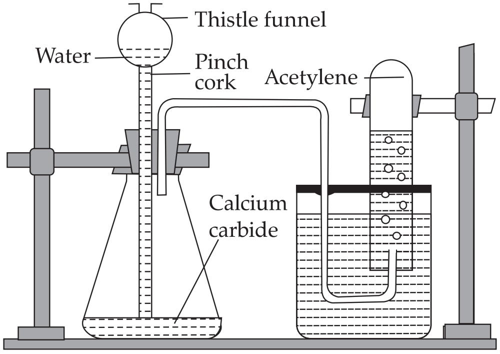
$$\underset{\text{Ethane}}{nH_2C = CH_2} \xrightarrow{\text{Polymerization}} \underset{\text{Polyethene}}{[H_2C - CH_2]_n}$$

  - **(vi)** **Combustion of ethene :** Ethene burns in air with a sooty flame producing a large amount of heat.

$$C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O + \text{Heat}$$

- **Uses of Ethene :**
  - **(i)** It is used for ripening of fruits.
  - **(ii)** It is used in making polythene.
  - **(iii)** It is used in making epoxy ethane.
- **Alkynes**
  - The aliphatic hydrocarbons, containing a triple bond (-C ≡ C-) between two carbon atoms are called alkynes. General formula for Alkynes is C_nH_{2n-2}. Ethyne is the first member of alkyne series.
  - Molecular formula of Ethyne is C_2H_2.

- **Laboratory Preparation of Ethyne (Acetylene)**

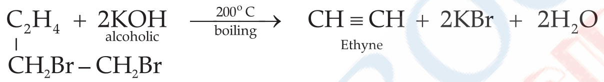


Laboratory preparation of ethyne

- **Reactants :** Water and Calcium carbide

$$\underset{\text{Calcium Carbide}}{CaC_2} + 2H_2O \rightarrow \underset{\text{Calcium hydroxide}}{Ca(OH)_2} + \underset{\text{Ethyne}}{C_2H_2\uparrow}$$

- **Collection :** The gas collected by downward displacement of water, since it is insoluble in water.
- **Preparation from 1,2-dibromoethane** :



$$\begin{array}{l} C_2H_4 \\ | \\ CH_2Br-CH_2Br \end{array} + \underset{\text{alcoholic}}{2KOH} \xrightarrow[\text{boiling}]{200^\circ C} \underset{\text{Ethyne}}{CH\equiv CH} + 2KBr + 2H_2O$$

- **Physical Properties**

It is a colourless gas with an ether like odour. Its boiling point is - 75°C. It liquefies at - 84°C. It is negligibly soluble in water but highly soluble in organic solvents.

- **Chemical Properties**
  - **(i) Oxidation of Ethyne:** Ethyne burns in excess air with a brilliant white flame to produce carbon dioxide, water vapours and a large amount of heat.

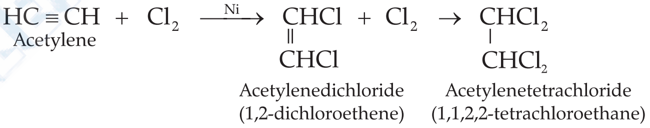
$$\underset{\text{Ethene}}{2CH=CH} + 5O_2 \rightarrow 4CO_2\uparrow + 2H_2O + \text{heat}$$

  - **(ii) Addition of hydrogen (catalytic hydrogenation) :** In the presence of nickel, platinum or palladium.

$$\underset{\text{Ethyne}}{C_2H_2} + H_2 \xrightarrow{Ni} \underset{\text{Ethylene}}{C_2H_4}$$

$$\underset{\text{Ethylene}}{C_2H_4} + H_2 \xrightarrow{Ni} \underset{\text{Ethane}}{C_2H_6}$$

  - **(iii) Reaction with chlorine :** Acetylene in an inert solvent reacts with chlorine to give first dichloroethene and then tetrachloroethane.



$$\underset{\text{Acetylene}}{HC\equiv CH} + Cl_2 \xrightarrow{Ni} \underset{\substack{\text{Acetylenedichloride}\\ \text{(1,2-dichloroethene)}}}{\begin{array}{c} CHCl \\ \| \\ CHCl \end{array}} + Cl_2 \rightarrow \underset{\substack{\text{Acetylenetetrachloride}\\ \text{(1,1,2,2-tetrachloroethane)}}}{\begin{array}{c} CHCl_2 \\ | \\ CHCl_2 \end{array}}$$

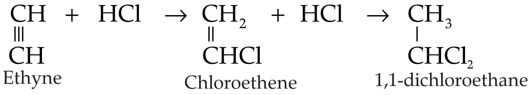
Acetylene reacts vigorously with chlorine gas in the presence of sunlight to give out flames.

$$C_2H_2 + Cl_2 \rightarrow 2C + 2HCl$$

  - **(iv) Reaction with Bromine :** Ethyne reacts with bromine in carbon tetrachloride to first form dibromoethene and then tetrabromoethane. During addition, the red - brown colour of bromine gets decolourized.

$$\underset{\text{Acetylene}}{C_2H_2} \xrightarrow{+Br_2} \underset{\text{Acetylene dibromide}}{C_2H_2Br_2} \xrightarrow{+Br_2} \underset{\text{Acetylene tetrabromide}}{C_2H_2Br_4}$$

  - **(v) Reaction with HCl :**



$$\underset{\text{Ethyne}}{\begin{array}{c} CH \\ ||| \\ CH \end{array}} + HCl \rightarrow \underset{\text{Chloroethene}}{\begin{array}{c} CH_2 \\ \| \\ CHCl \end{array}} + HCl \rightarrow \underset{\text{1,1-dichloroethane}}{\begin{array}{c} CH_3 \\ | \\ CHCl_2 \end{array}}$$

- **Uses**
  - **(i)** As an illuminant in oxy-acetylene lamp.
  - **(ii)** For artificial ripening and preservation of fruits.
  - **(iii)** For oxy-acetylene welding at very high temperature.

Mnemonics

Concept : Preparation of methane.
Mnemonics : SAW SaiL GuM
Interpretation :
S – sodium
A – acetate
W – with
S – soda
L – lime
G – gives
M – methane

Key Words

- **Alkanes :** These are the hydrocarbons in which all the linkages between the carbon atom are single covalent bonds.
- **Fire-damp :** It is called 90% methane found in cavities in coal.
- **Pyrolysis :** The decomposition of a compound by heat in the absence of air is known as Pyrolysis.
- **Cracking :** It is defined as a process in which pyrolysis occurs in alkanes.

Key Terms

- Alkanes are relatively unreactive under ordinary conditions so, they are called paraffins.
- Alkanes with more than three carbon atoms form isomers.
- Methane is considered as a green house gas. It is 20 times more effective in trapping heat in comparison to CO_2.
- Methane can not be prepared by Wurtz reaction as this reaction is not suitable for the preparation of alkanes with odd number of carbon atoms.
- Soot is used in the manufacture of printing inks and tyres.
- All alkanes react with chlorine, bromine and iodine in a similar manner, producing the corresponding substituted products.
- Alkenes are also known as olefins (oil-forming) because the lower members of alkenes form oily products on reacting with chlorine or bromine.
- Ethyne is used for oxy-acetylene welding at very high temperature. It is also used for artificial ripening and preservation of fruits.

❑❑