Module - 6

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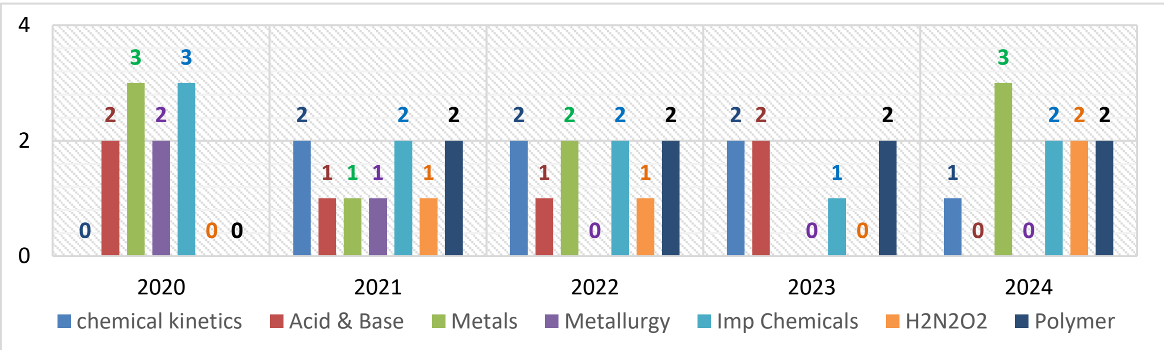
SYLLABUS

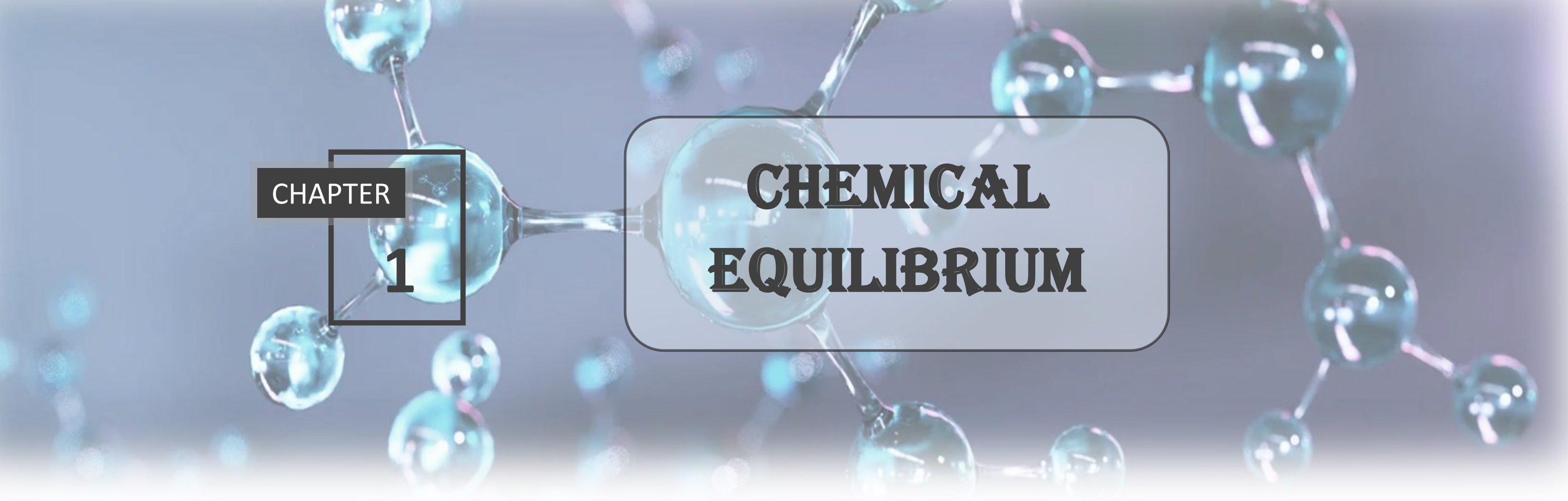
Unit	Syllabus
Unit - 1	**CHEMICAL EQUILIBRIUM** : Definition, types of Equilibrium, Factors Affecting Equilibrium, Le-Chatelier's Principle. **LAW OF MASS ACTION** : Introduction, Equilibrium Constant, Equilibrium Constant in Gaseous System, Factors Affecting Equilibrium Constant. **LE-CHATELIER'S PRINCIPLE**: Definition
Unit - 2	**CHEMICAL KINETICS** : Introduction, Rate of reaction, factors affecting rate of reaction, rate law, average rate of reaction, units of rate constant, order of reaction, half live period of reactions. **DIFFERENT TYPES OF REACTION** : reversible and irreversible reaction, endothermic & exothermic reaction, fast & slow reactions
Unit - 3	**ACIDS & BASES** : Introduction, properties and uses of acids & bases, different concepts of acids & bases (Arrhenius, Bronsted-Lowry, Lewis), conjugate acids & bases, HSAB concept. **pH SCALE** : pH discovery, pH of acids, bases & water, dissociation constant, some examples.
Unit - 4	**CHEMICAL COMPOUND** : water: properties and uses, hard & soft water, heavy water. **PREPARATION, PROPERTIES & USES OF** : washing soda, baking soda, bleaching powder, plaster of Paris, gypsum. **PREPARATION OF BUILDING MATERIALS** : lime, cement, glass, steel
Unit - 5	**METALS & THEIR PROPERTIES** : Introduction, position of metals in periodic table. **NON-METALS** : Introduction, position of non-metals in periodic table. **ORES & ALLOYS** : Types and examples.
Unit - 6	**METALLURGY** : Introduction, steps involved in the extraction of metals: concentration (gravity separation, magnetic separation, froth flotation), conversion of ores into oxide (calcination, roasting), reduction of ore (different processes). **METALLURGY OF COPPER & IRON** : Introduction & process **CORROSION OF METALS** : Introduction, electrochemical theory of rusting, factors affecting corrosion.
Unit - 7	**HYDROGEN** : Preparation, isotopes, types, properties and uses. **OXYGEN** : Preparation, properties an uses. **NITROGEN** : Preparation, properties an uses. **ALCOHOL** : Preparation, types, properties and uses. **ACETIC ACID** : Preparation, properties and uses.
Unit - 8	**POLYMER** : introduction, types rubber, biodegradable polymer, resin **SOAPS & DETERGENTS**

Module - 6

CONTENTS

Questions Distribution





CHAPTER 1

CHEMICAL EQUILIBRIUM

1.1 INTRODUCTION

The state of any reversible reaction in which rates of the forward and the backwards reactions are equal is called **chemical equilibrium**. In this state, the measurable properties of the system like concentration, temperature, colour, density etc. **remain constant with time**.

For a reaction : a + b ⇋ c + d

Here, a + b = forward reaction

c + d = backward reaction

Then, **according to law of mass action** :

rate of **forward reaction** (r_f) α [a] [b]

(r_f) = k_f [a] [b] (k_f = constant)

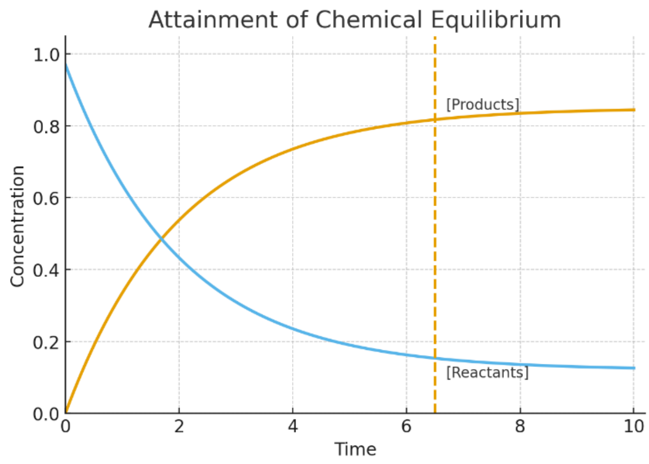
and rate of **backward reaction** (r_b) α [c] [d]

(r_b) = k_b [c] [d]

Now, equilibrium = (r_f) = (r_b)

k_f[a] [b] = k_b [c] [d]

$$\frac{K_f}{K_b} = \frac{[C]\,[D]}{[A]\,[B]} = k_c$$



Here k_c is known as the **Equilibrium Constant** and has a definite value for every chemical reaction at a particular temperature.

> **Note** : This equilibrium is **dynamic in nature**, as it consists of a forward reaction in which reactants give products and backward rection in which product gives original reactants. Even after equilibrium, the reactants & products are changing into each other and **this equilibrium state can be approached from both sides**.
>
> Ex: synthesis of ammonia by Haber's process.
>
> $N_2 + 3H_2 \leftrightharpoons 2NH_3$

This reaction also indicates that chemical reaction reaches a state of dynamic equilibrium, in which the rates of forward & backward reactions are equal and **there is no net change in composition**.

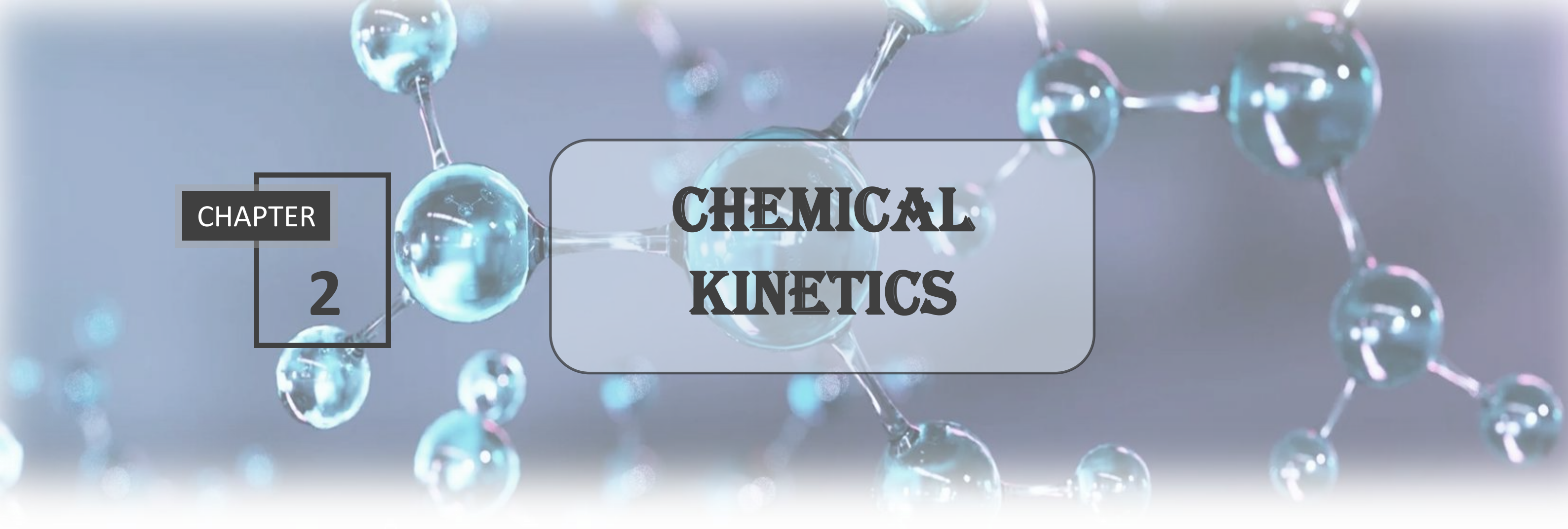
1.2 TYPES OF EQUILIBRIUM

- ***Homogenous equilibrium***

  A system where all the reactants and products are in ***same phase***.

  Ex – N_2 (g)+ $3H_2$ (g)⇋ 2 NH_3 (g)

- ***Heterogeneous equilibrium***



CHAPTER 2

CHEMICAL KINETICS

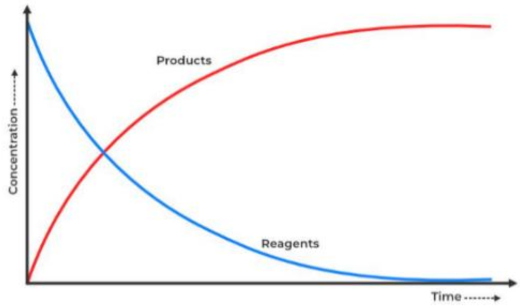
2.1 INTRODUCTION

Chemical kinetics = ***Kinesis*** (Greek word) = movement. ***Chemical kinetics*** is "the branch of chemistry which deals with the study of the rate of chemical reactions, the factors affecting the rate, and the mechanism by which the reactions proceed."

The **Rate of reaction** can be defined as the **change in concentration** of a reactant or product per mol in unit time. This means it is the speed at which reactants are converted into products –

(i) The rate of decrease in concentration of any reactant.

(ii) The rate of increase in concentration of any product.



Let's take a general equation at constant volume :

R→ P

At time t_1 = concentrations of R & P are $[R]_1$&$[P]_1$

And, at time t_2 = concentrations of R & P are $[R]_2$& $[P]_2$

Then rate of disappearance of R = (Decrease in concentration of R)/ (Time)

$= -\frac{\Delta[R]}{\Delta t}$ ----------------- (i)

And rate of appearance of P = (Increase in concentration of P)/ (Time)

$= +\frac{\Delta[P]}{\Delta t}$ -----------------(ii)

Here Δ[R] is taken negative because concentration of reactants is decreasing and Δ[P] is taken positive because concentration of products is increasing with time.

Example : $N_2 + 3H_2 \rightarrow 2NH_3$

(i) Rate of formation of ammonia = $+\frac{d[NH3]}{dt}$

(ii) Rate of disappearance of nitrogen = $-\frac{d[N2]}{dt}$

(iii) Rate of disappearance of hydrogen = $-\frac{d[H2]}{dt}$

Now, **rate of reaction** = $-\frac{d[N2]}{dt} = -\frac{1}{3}\frac{d[H2]}{dt} = +\frac{1}{2}\frac{d[NH3]}{dt}$

Thus, rate of reaction = $-\frac{d[N2]}{dt} = \frac{1}{2}\frac{d[NH3]}{dt}$

Or, rate of formation of ammonia = twice the rate of disappearance of nitrogen

i.e. $\frac{d[NH3]}{dt} = -\frac{2}{3}\frac{d[H2]}{dt}$

Topic	Rate law	Units of k	Example	Identification
Zero order	Rate = k	mol L^{-1} s^{-1}	Photochemical reactions at high intensity; surface-catalysed decompositions at saturation	Rate independent of concentration; linear decrease of [A] with time
First order	Rate = k[A]	s^{-1}	Radioactive decay (kinetically); acid-catalysed hydrolysis (at fixed acid); inversion of cane sugar (at fixed H^+)	Fraction left after t: $[A]_t = [A]_0 e^{(-kt)}$
Pseudo–first order	True: Rate = $k[A][B]^m$; with [B] > [A]; Rate = k′[A], where $k' = k[B]^m$	s^{-1} (for k′)	Ester hydrolysis in water (acid catalysed), inversion of sucrose (constant H^+)	One reactant present in excess; k′ changes with the excess reactant as k′ ∝ [B]^m

Exercise no 2.1

1. For the first order reaction, the time required for 99.9% completion of reaction is how many times that required for 50% completion? [Raj ACF 2018]

(a) 50 times
(b) 10 times
(c) 5 times
(d) 2.5 times

Solve : $t = \frac{2.303}{k} \log \frac{a}{a-x}$

$T_{99.9} = \frac{2.303}{k} \log \frac{100}{100-99.9} = = \frac{2.303}{k} \log \frac{100}{1}$

$= \frac{2.303}{k} \log_{10} 1000$---------(i)

Now, $T_{50} = \frac{2.303}{k} \log \frac{100}{100-50} = \frac{2.303}{k} \log_{10} 2$------(ii)

Now dividing both the equation: $= \frac{3.000}{0.3010} = 10$

2. The $t_{1/2}$ of reaction is doubled as the initial concentration of the reactant is doubled. What is the order of the reaction? [Raj ACF 2018]

(a) 3
(b) 2
(c) 1
(d) 0

Solve : we know that half -life is related to concentration as

$t_{1/2} \propto \frac{1}{a^{n-1}}$

according to question,

$\frac{t_{1/2}}{2t_{1/2}} = \frac{1/a^{n-1}}{1/2a^{n-1}}$

$½ = 2^{n-1}$

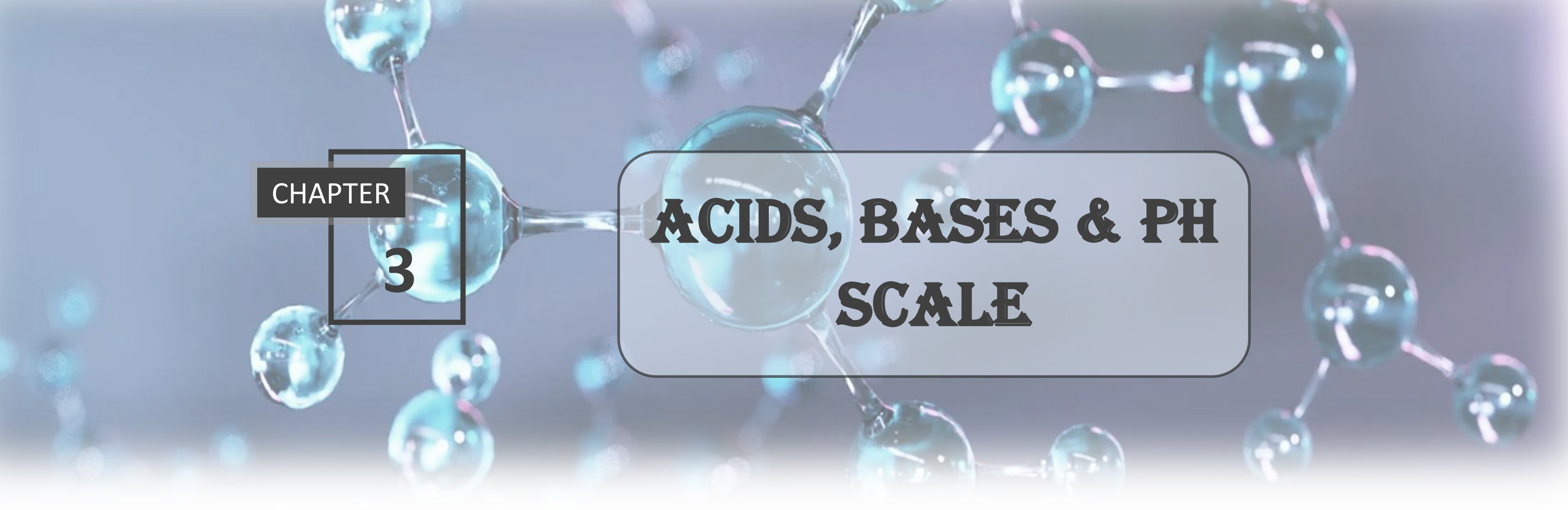
$2^{-1} = 2^{n-1}$

n-1 = -1

n=0, hence the reaction is of the zero order.

3. A first order reaction A → product has a first order rate constant $1.15 \times 10^{-3} s^{-1}$ how long it will take 8.0 g of A to reduce to 2.0 g? [Raj ACF 2018]

(a) 802 s
(b) 1205 s
(c) 601 s



CHAPTER 3

ACIDS, BASES & PH SCALE

3.1 ACIDS & BASES

The word Acid comes from a Latin word '**Acidus**' which means '**sour**.' In chemical terms, an **acid** is any hydrogen-containing substance, capable of **donating a proton (hydrogen ion)***** to another substance. Acids show several characteristic reactions; they turn blue litmus paper red***, are usually identified by their sour taste, and can react with some metals to liberate hydrogen gas.

A **base**, conversely, is a molecule or ion that can **accept a hydrogen ion***** **from an acid**. Bases are often recognized by their bitter taste and a slippery, soapy texture. They cause an opposite reaction in litmus paper compared to acids, turning red litmus paper blue***. It is also useful to understand the term '**alkali**', which refers to a base that is soluble in water. This leads to an important distinction: **all alkalis are bases, but not all bases are alkalis**, because not every base will dissolve in water.

PROPERTIES OF ACIDS

- Acids are corrosive in nature.
- They are good conductors of electricity.
- Their pH is always less than 7.
- Examples – Sulfuric acid (H_2SO_4), Hydrochloric acid (HCl), Acetic acid (CH_3COOH).

PROPERTIES OF BASES

- In their aqueous solutions, bases act as good conductors of electricity.
- Their pH value is always greater than 7.
- Bases release hydroxide ions (OH^-) when dissolved in water.
- Example – Sodium Hydroxide (NaOH), milk of magnesia [Mg $(OH)_2$], calcium hydroxide [Ca $(OH)_2$].

USES OF ACIDS & BASES

Acids :

- A diluted solution of **acetic acid**, called vinegar, has various household applications, and it primarily used as food preservative.
- **Sulphuric acid** (H_2SO_4) is widely used is batteries. The batteries used to start the engines of automobiles commonly contain this acid.
- Citric acid is an integral part of lemon juice and orange. it can also be used as food preservative.
- The industrial production of explosives, dyes, fertilizers, and paints involves the use of **nitric acid** and **sulphuric acid**.

CHAPTER 5

METALS AND THEIR GENERAL PROPERTIES

5.1 Metals

Metal, any of a class of substances characterized by high electrical and thermal conductivity, as well as by malleability, high reflectivity of light and ductility. Metals are the elements which have free electrons, so they form +ve ions (Cations) by donating electrons, means they are electro-positive. Typical examples – Na, Cu, Fe, Al.

General reaction for ion formation –

$M \rightarrow M^{+n} + ne^{-}$

(metal) (cation) (Electron)

Physical properties

- **Malleability** : Metals are malleable, *i.e.*, metals can be beaten into thin sheets without breaking it. Exceptions- Zinc, mercury and Antimony are non-malleable.
- **Ductility** : Metals are ductile *i.e.* metals can be drawn into wires. Exceptions- zinc, mercury and Antimony are non-ductile.
- **Lustre** : They are lustrous or shiny and can be polished. (Except Sodium).
- **Melting and Boiling points** : They have high melting and boiling points, (except sodium, potassium, mercury, and cesium).
- **Conductivity** : They are good conductor of heat and electricity.
  Exceptions: **Heat** – Lead, mercury, Titanium, Aluminium. **Electricity** – Mercury, Tungsten, Titanium, Aluminium.
- **Hardness** : They are generally hard and strong. (Except Sodium & Potassium).
- **Density** : Metals have high density, except Lithium, Sodium and Potassium.
- They are solid at room temperature. (Except Mercury, which exists in liquid state at room temperature).

Chemical Properties

- **Reaction with Oxygen** : When metals are burnt in air; They react with the Oxygen to form metals oxide –
  $4\,Na(S) + O_2(g) \rightarrow 2Na_2O(s)$ (Sodium Oxide)
  $2Mg + O_2 \rightarrow 2MgO$
  $4Al + 3O_2 \rightarrow 2Al_2O_3$
  Note : The aluminium oxide shows acidic as well as basic properties, and known as **Amphoteric oxide**. Zinc also forms same oxide. Amphoteric oxides react with acid and base to form salt and water. Some other examples of metals that form amphoteric oxides are lead, tin, iron, chromium, gallium, beryllium etc.

CHAPTER 6

METALLURGY

6.1 Metallurgy & it's types

The branch of chemistry which deals with the study and practice of extraction of metals from their ores, refining them for use, and creating alloys is called metallurgy. It is a crucial field that has played a pivotal role in the development of human civilization, shaping various industries and technological advancements.

Mineral

The various compounds of metals which occur in the earth's crust and are obtained by mining are called minerals***. In earth crust, order of abundance of elements is. O > Si > Al > Fe. A mineral may be single compound or a mixture of compounds having fixed chemical composition.

Gangue

The earthy undesirable impurities present in an ore are called gangue. It is also known as matrix.

Flux

flux refers to a substance or mixture used to promote the fusion of metals or minerals during the smelting process. The purpose of using flux is to lower the melting point of the raw materials, facilitating the removal of impurities, and promoting the separation of slag from the metal.

Types

depending upon the process, metallurgy has 4 types –

(a) **Pyro metallurgy** : Extraction of metal from ore by using heat energy. Steps involved are – Calcination, roasting, reduction etc. Ex. Less reactive metals: Cu, Fe, CO, Ni, Zn, Sn, Pb etc.

(b) **Hydro metallurgy** : (for Ag, Au) this is wet metallurgy process.

Cu $\longrightarrow$ Pyro + Hydro

Ag and Au $\longrightarrow$ By cyanide process.

(c) **Electrical metallurgy** : this process is used for highly electropositive materials (S-block & Al). Metal obtained by electrolysis of fused salt/anhydrous medium.

(d) **Ion exchange metallurgy** : trans-uranic (elements after uranium in periodic table) elements are obtained by this method.

CHAPTER 7

PREPARATION AND PROPERTIES OF HYDROGEN, OXYGEN, AND NITROGEN

7.1 HYDROGEN

Hydrogen (Z = 1) is the first and the lightest element in the periodic table. It was discovered by ***Henry Cavendish*** in the 18th century. It occurs rarely in free state because it is highly reactive, but is present in water, acids, alkalis, and organic matter. It is the most abundant element in the universe (70% of the total mass of the universe.), the earth's crust contains 1% of hydrogen by weight. it behaves anomalously in the periodic table, showing alkali-metal and halogen-like features; hence its "floating" position is discussed –

- Resembles Group 1 – forms H^+, ionic hydrides (NaH, CaH_2).
- Resembles Group 17 – exists as H_2, forms covalent molecules, forms H^- in metal hydrides.

Isotopes of hydrogen

Name	**Protium** (ordinary hydrogen)	**Deuterium** (heavy hydrogen)	**Tritium** (radioactive***)
Symbol*	$_1H^1$	$_1H^2$	$_1H^3$
Neutrons*	0	1	2
Protons*	1	1	1
Electrons*	1	1	1
Stability	Stable	Stable	Unstable (radioactive)
Electronic configuration	$1S^1$	$1S^1$	$1S^1$

Methods of preparation

There are several methods of preparing hydrogen –

- **By action of metals with acid** : The metals which are placed above H_2 in electrochemical series, react with dilute acids and liberate hydrogen.

  $Fe + H_2SO_4(dil) \rightarrow FeSO_4 + H_2$

  $Zn + 2HCl\ (dil) \rightarrow ZnCl_2 + H_2$

CHAPTER 8

POLYMERS, SOAPS & DETERGENTS

8.1 Polymer & it's types

The term polymer is used to describe a very large molecule that is made up of many repeating small molecular units. These small units are called monomers and the chemical reaction that combines the monomers together is called polymerization. The term 'polymer' is a Greek term which means- Polus (many) and Meros (part). This term was coined by **Berzelius**. Properties of polymers depend on composition (monomers), architecture (linear/branched/cross-linked), and intermolecular forces (elastomer ↔ fibre spectrum).

Homopolymers & Copolymers

Polymers which are formed by only one type of monomer are called homopolymers. And polymers which are formed by more than one type of monomers are known as copolymers. Some examples are as follows –

Homopolymer* **	**Monomer*** **
Starch	Glucose
Cellulose	Glucose
Polyethylene	Ethylene
Polyvinyl chloride	Vinyl chloride
Teflon	Tetrafluoro ethylene
Nylon-6	Caprolactam

Copolymer* **	**Monomer*** **
Saran	Vinyl chloride & vinylidene chloride
SAN	Styrene & acrylonitrile
ABS	Acrylonitrile, butadiene & styrene
Butyl rubber	Isobutylene & isoprene
Buna-S	Styrene & butadiene
Buna-N	Acrylonitrile & butadiene
Nylone-66	Hexamethylenediamine & adipic acid
Terylene	Terephthalic acid ethylene glycol

Classification of polymers

polymers are classified in following ways –

Classification based upon source

- **Natural polymers** : polymers which are obtained from animals and plants as natural polymers. They are generally monodispersed, so there **PDI (poly dispersity index) is 1**. For ex.

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