CLASS NOTES OF
"APPLIED CHEMISTRY-A"

Technical Classes

✅ Technical Classes के Course में उपलब्ध फीचर्स

1. सभी कक्षाएं स्मार्ट बोर्ड पर Live
2. विशेषज्ञ शिक्षको द्वारा पठन पाठन
3. Lecture के दौरान डाउट सॉल्विंग
4. Recorded Lecture (VOD)
5. प्रत्येक क्लास का PDF नोट्स
6. SBTE Exam की तैयारी के लिए ब्रह्मास्त्र क्लास
7. Laptop में क्लास देखने की सुविधा

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नोट :-

1. सभी ऑफलाइन कक्षाएं Technical Classes के कैंपस तथा सभी ऑनलाइन कक्षाएं Technical Classes के एप्लीकेशन पर चलेगी।

2. यह नोट्स टेक्निकल क्लासेस के स्टूडेंट्स के लिए है, तथा क्लास करने के बाद अधिक प्रभावी होगा।

I) **Course Curriculum Detailing:** This course curriculum detailing depicts learning outcomes at course level and session level and their attainment by the students through Classroom Instruction (CI), Laboratory Instruction (LI), Term Work (TW) and Self Learning (SL). Students are expected to demonstrate the attainment of Theory Session Outcomes (TSOs) and Lab Session Outcomes (LSOs) leading to attainment of Course Outcomes (COs) upon the completion of the course. While curriculum detailing, NEP 2020 related reforms like Green skills, Sustainability, Multidisciplinary aspects, Society connect, Indian Knowledge System (IKS) and others must be integrated appropriately.

J) **Theory Session Outcomes (TSOs) and Units: T2400103A**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO-1a Describe the three subatomic particles in an atom. *TSO-1b* Conclude Rutherford model of atom. *TSO-1c* Apply the different atomic theories and principles for structural illustration. *TSO-1d* Calculate uncertainty in position and momentum. *TSO-1e* Draw the shapes of s, p and d orbitals. *TSO-1f* Write the electronic configuration of different elements. *TSO-1g* Differentiate between ionic, covalent, and coordinate compounds based on the type of chemical bonding. *TSO-1h* Explain the unique behavior of water. *TSO-1i* Prepare the solution of given concentration.	**Unit-1.0 Atomic Structure and Chemical Bonding and Solutions:** 1.1 Atoms and its fundamental particles, 1.2 Rutherford Model of Atom, 1.3 Bohr's Theory, Hydrogen spectrum explanation based on Bohr's Model of Atom, 1.4 Wave Mechanical model of atom, de Broglie relationship, Heisenberg Uncertainty Principle 1.5 Quantum Numbers, Shapes of Atomic Orbitals, 1.6 Pauli's Exclusion Principle, Hund's Rule of Maximum Multiplicity, Aufbau Principle, Electronic Configuration (till atomic number 30). 1.7 Concept of Chemical bonding - Cause of chemical bonding, Types of Bonds: Ionic Bond (NaCl, CaCl2, MgO), Covalent Bond, Polar and Nonpolar Covalent Bonds (H2. F2. HF, HCl) & Co-ordinate Bond (CO, NH4+, O3, H2SO4),. 1.8 Dipole Moment (NH3, NF3), Hydrogen bonding. 1.9 Solution- (solute, solvent) and their strength- Molarity, Normality, Molality.	**CO1**
TSO-2a Classify hard and soft water based on their properties. *TSO-2b* List the impurities responsible for hardness. *TSO-2c* Calculate the hardness of water. *TSO-2d* Determine the hardness by EDTA method. *TSO-2e* Apply different water softening techniques to soften the hard water. *TSO-2f* Calculate the amount of lime and soda required for removal of hardness. *TSO-2g* Differentiate between BOD and COD. *TSO-2h* Use the Indian standard specification of drinking water.	**Unit-2.0 Water** 2.1 Introduction, Sources of Water. Hardness of Water- Temporary & Permanent hardness. 2.2 Degree of Hardness (In terms of CaCO3 equivalent), Unit of Hardness, Quantitative Measurement of Water Hardness by EDTA method. 2.3 Municipal supply of Water, Treatment of water, Water Softening Technique-Soda Lime Process, Zeolites method and ion exchange method, 2.4 Water Quality Index - Biological Oxygen Demand, Chemical Oxygen Demand, Determination of Dissolved Oxygen 2.5 Indian standard specification of drinking water.	**CO2**
TSO-3a List ores of metals. *TSO-3b* Describe ore, gangue, matrix. *TSO-3c* Select Appropriate metallurgical processes for concentration, extraction, and purification of given ore. *TSO-3d* Describe alloy with examples. *TSO-3e* Write the constituent of given alloy.	**Unit-3.0 Engineering materials** 3.1 Natural Occurrence of Metals- Minerals, ores. 3.2 Metallurgy - General principles of Metallurgy, Gangue, Flux and Slag, Steps involved in metallurgy. 3.3 Extraction of Aluminium, Iron and Copper from	**CO3**

Major Theory Session Outcomes (TSOs)	Units	Relevant COs Number(s)
TSO-3f Write the composition properties and uses of ferrous and non-ferrous alloys. *TSO-3g* Distinguish between homopolymer and copolymer. *TSO-3h* Write the monomers of given polymers. *TSO-3i* Explain vulcanization process. *TSO-3j* Explain cement & its manufacture. *TSO-3k* Differentiate among the different engineering materials based on their chemical composition and composition-based applications.	their important ores along with reactions, Properties and uses. 3.4 Alloys – Definition, Purpose of alloying, Ferrous and Non-Ferrous Alloy with suitable examples, Composition, Properties, and their applications. 3.5 Polymers-Homopolymers and Copolymers, Natural polymers and synthetic polymers, Addition and Condensation polymerization, Thermoplastic and Thermosetting plastic. 3.6 Monomers, applications, and synthesis of Polythene, PVC, Orlon, Terylene, Nylon 66, Nylon 6, Bakelite. 3.7 Natural Rubber and its vulcanization, advantages of vulcanized rubber. 3.8 Cement, Average composition of Portland cement, Raw material for manufacture of cement, Setting of Cement.	
TSO-4a Classify fuels. *TSO-4b* Describe HCV and LCV. *TSO-4c* Explain knocking, octane number and cetane number. *TSO-4d* Use different gaseous fuels based on their composition, calorific value, and other properties. *TSO-4e* Explain uses of NPK fertilizers. *TSO-4f* Select relevant lubricant based on their composition, calorific value, and other properties. *TSO-4g* Determine viscosity, flash, and fire point of given lubricant for its specific use. *TSO-4h* Explain Flash, Fire, Cloud & Pour point.	**Unit-4.0 Chemistry of Fuel and Lubricants** 4.1 Fuels, Characteristics of an Ideal Fuel. 4.2 Classification of Fuel- Solid, liquid and gas fuel, Calorific Values (HCV and LCV), 4.3 Petroleum and its fractional distillation. 4.4 Cracking, knocking, Fuel Rating (Octane Number, Cetane Number). 4.5 Composition, uses, advantages and disadvantages of LPG, CNG and Biogas. 4.6 Manures, NPK fertilizers (preparation and uses). 4.7 Fire Extinguishers and their types. 4.8 Lubricants- Classification of Lubricants with examples, Functions and Properties of Good Lubricant. 4.9 Viscosity &Viscosity Index. Flash point. Fire point, Cloud & Pour point	**CO4**
TSO-5a. Describe Electrolyte and Nonelectrolyte. *TSO-5b.* Describe Metallic and electrolytic conduction. *TSO-5c.* Explain the faraday law of electrolysis. *TSO-5d.* Calculate the mass of metal deposited after passing a certain amount of current. *TSO-5e.* Calculate the emf at different temperature, pressure, and molar concentration. *TSO-5f.* Predict the feasibility of a cell. *TSO-5g.* Explain the working of a cell. *TSO-5h.* Describe corrosion. *TSO-5i.* Explain the different methods to prevent corrosion.	**Unit-5.0 Electrochemistry** 5.1. Introduction, Electrolyte and Nonelectrolyte, Electrolytic and Metallic Conduction, Factors affecting Electrolytic Conductance. 5.2. Molar Conductivity and Equivalent Conductivity. Variation of Molar Conductivity, Kohlrausch's law. 5.3. Faraday's Laws of Electrolysis. 5.4. Galvanic Cell, Electrode Potential, Measurement of Electrode Potential SHE (Standard Hydrogen electrode), EMF, Electrochemical Series, Nernst Equation for Electrode Potential. 5.5. Batteries, Primary Cells-Dry cell, Secondary cell -Lead storage battery, Fuel cells. 5.6. Corrosion, their types (Dry & Wet corrosion) and prevention.	**CO5**

APPLIED CHEMISTRY-A

Based on New Syllabus
Session :- 2024-27

1st Semester

Unit-1.0 Atomic Structure and Chemical Bonding and Solutions:

Atomic Structure

↓

Structure of atom.

↓ Why(?)

Properties of matter

↓ Why?

Need / requirement of life.

Atom → The word atom is taken from a Greek word a-tomio which means indivisible or uncutable for smallest particles of matter by John Dalton.

a-tomio
↓ ↓
not divisible.
indivisible.

Dalton's Atomic Theory :- (1808)

[1.] Matter is made of atoms.

[2.] Atoms can be neither created nor destroyed in any chemical reaction.

e.g.:- $2Mg + O_2 \rightarrow 2MgO$

[3.] Atoms of the same element have identical properties and size.

[4.] Atoms of different elements have different properties and size.

[5.] Atoms can't be further divided.

[6.] Atoms rearrange in any chemical rxn.

*In nuclear rxn, atoms break.

(Imp. for obj.)

(Success) Merits of D.A.T. :→

Explain.

1. Law of mass conservation
2. Law of constant composition / definite proportion.
3. Law of multiple proportion.

Q. Which one of the following is the merit of Dalton's atomic theory.?

(a) Henry's law.

(b) Raoult's law

(c) Laws of mass conservation (explain)

(d) None of these.

(दोष)

Failure (Limitation) of D.A.T. →

It failed to explain

(a) internal structure of atom and assumes that atoms have no structure.

(b) how atoms combine together to form a molecule?

$Na + Cl_2 \longrightarrow NaCl$

(Highly reactive) (Suffocating gas) (common salt)

(c) different elements have different atomic mass.

Imp. for obj.

Electrical nature of matter:-

i.e. presence of charged particles in matter.

* Michael Faraday was the first scientist who confirmed the presence of charged particles in matter on the basis of electrolysis.

e.g.:- $NaCl(l) \xrightarrow{\text{electrolysis}} Na + Cl_2$

molten Sod. chloride → Na at (Cathode), Cl_2 (at anode)

Chemical rxn is possible only when charged particles are present.

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

Acid Base Salt water.

$$\boxed{H^+Cl^- + Na^+{}^-OH \rightarrow NaCl + H_2O}$$

$$H_2C = CH_2 + H_2 \xrightarrow{Pd} H_2C - CH_2$$

Ethene

Ethene.

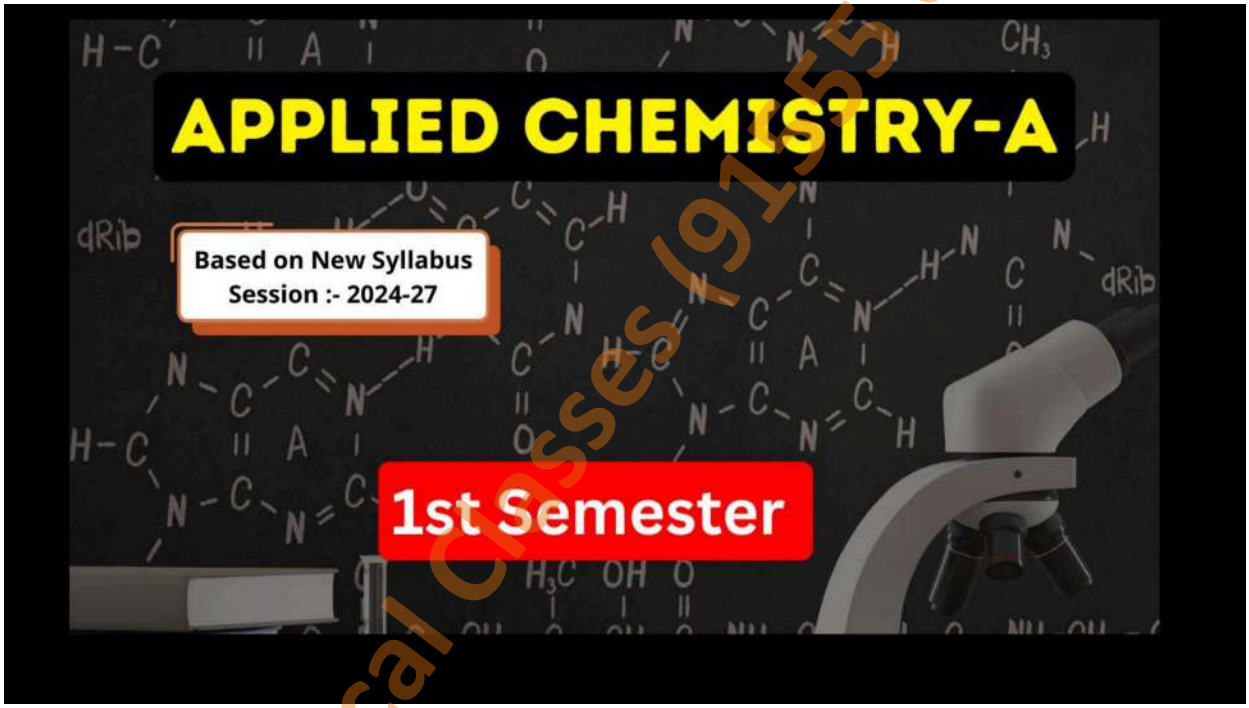
$$Mg + O_2 \xrightarrow{\Delta} MgO$$

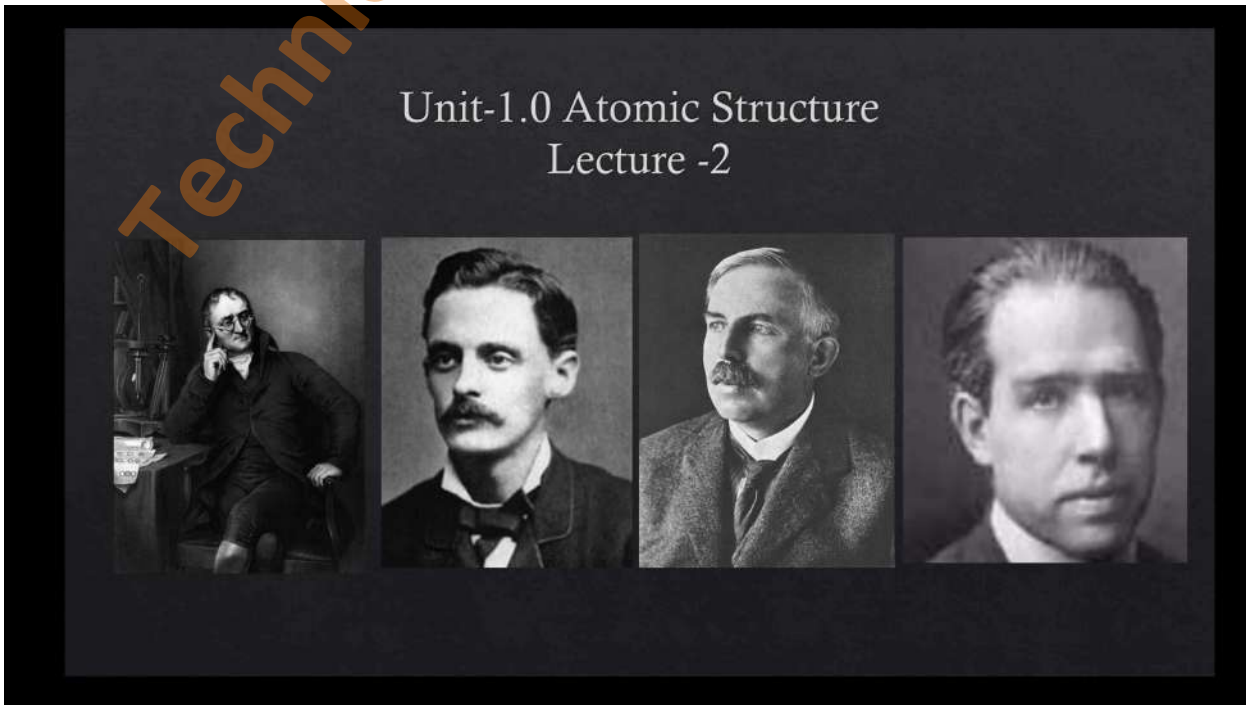
Air

Mg-ribbon.

magnesium oxide.

Thanks





Types of atoms

[1.] Metallic atoms:- * Atoms of metals are called metallic atom.

* It is also called electropositive atoms.

* They show tendency to loss e^-(s) to form positive ions.

e.g.:- $Na - 1e^- \rightarrow Na^+$

or, $Na \longrightarrow Na^+ + 1e^-$

$Mg - 2e^- \longrightarrow Mg^{2+}$

$Mg \longrightarrow Mg^{2+} + 2e^-$

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

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

[2.] Non-metallic atoms:-

* Atoms of non-metals are called non-metallic atoms.

* They have tendency to gain e^-(s) to form negative (-ve) ions.

* They are also called electronegative atoms.

$Cl + e^- \rightarrow Cl^-$

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

$N + 3e^- \rightarrow N^{3-}$

Imp:

* Atoms are electrically neutral.
  → No charge.

e.g:- Na_{11} → Atomic no.

$\boxed{\text{Atomic no. (Z)} = \text{no. of } e^-\text{s} = \text{no. of } p^+\text{s}}$

1 Na-atom contains 11 e^-s and 11 p^+s.

* Charge on 11 e^-s $= 11 \times (-1.6 \times 10^{-19} C)$
  Charge on 11 p^+s $= 11 \times (+1.6 \times 10^{-19} C)$
  → Total charge = 0

O_8

* 1 O-atom contains 8 e^- and 8 p^+s

* Charge on 8 e^-s $= 8 \times (-1.6 \times 10^{-19} C)$
  Charge on 8 p^+s $= 8 \times (+1.6 \times 10^{-19} C)$
  → Total charge = 0

* Atoms
  - gain of e^-s → −ve ion → no. of e^-s > no. of p^+s
  - Neutral → no. of e^-s = no. of p^+s
  - loss of e^-s → +ve ion → no. of e^-s < no. of p^+s

e.g:- Na_{11} — 11 e^-s, 11 p^+s

Na — $1e^-$ → Na^+

Na: 11 e^-s, 11 p^+s

Na^+: 10 e^-s, 11 p^+s

Ca_{20} — 20 e^-s, 20 p^+s.

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

or,

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

Ca	Ca^{2+}
20 e^-s	18 e^-s
20 p^+s	20 p^+s

* In all positive ions, no. of e^-s will be less than no. of p^+s.

$Cl-Cl$ Cl_2

$Cl_{17} \rightarrow 17e^-s$, $17 p^+s$

$Cl + 1e^- \rightarrow Cl^-$

$17e^-s$, $17p^+s$ → $18e^-s$, $17p^+s$

O_8 $8e^-s$, $8p^+s$

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

$8e^-s$, $8p^+s$ → $10e^-s$, $8p^+s$

Imp.

Chemical bond

- Metallic atom + non-metallic atom → Ionic bond
- Non-metall atom + non-metallic atom → Covalent bond
- Metallic atom + metallic atom → Metallic bond

[3.] Metalloid atoms:-

* Atoms of metalloids are called metalloid atoms.
* They have both tendencies to loss or gain e^-s.
* They have some properties of metals and some properties of non-metals.

e.g:- Ge (Metalloid)

$Ge - 4e^- \rightarrow Ge^{4+}$

or, $Ge \rightarrow Ge^{4+} + 4e^-$

$Ge + 4e^- \rightarrow Ge^{4-}$

(4.] Inert gas atoms:-

* Atoms of inert gas elements are called inert gas atoms.

He, Ne, Ar, Kr, Xe, Rn

* Generally, they don't show tendencies to either loss or gain e^-s.

Sub-atomic particles of atoms

Atoms → Microscopic particle

↓ further divided

Subatomic particles (about 35): electrons, protons, neutrons, neutrino, positron, negative meson, positive meson, God particle etc.

* Electrons, protons and neutrons are called fundamental particles bcoz they present in all atoms.

Exception:-

Isotopes of H → atoms of same element having same atomic no. but different mass no.

H_1^1 (Protium) H_1^2 (Deuterium) H_1^3 (Tritium)

* H-atom (Protium) contains $1e^-$ and $1p^+$ only.
* H-atoms don't contain neutrons.

Thanks

APPLIED CHEMISTRY

Based on New Syllabus
Session :- 2024-27

1st Semester

Fundamental particles of atoms

* Electrons, protons and neutrons are fundamental particles of all atoms except H-atom. → protium (H_1^1) → $1e^-$, $1p^+$, n^0 ✗

* Electrons are universal constituent of all atom i.e. e^-s are present in all matter.

Imp.

* Discovery of e^-s became as a result of conduction of electricity through gases at high voltage and low pressure.

Property	Electrons	Protons	Neutrons
[1.] Discovered by (Very Imp. for objective.)	J.J. Thomson	Goldstein	Chadwick
[2.] Represented by	e^-	p^+ or H^+	n^0
[3.] Nature	Negatively charged	Positively charged	Neutral particle.
[4.] Absolute charge	-1.6×10^{-19} C	$+1.6\times10^{-19}$ C	0
[5.] Relative charge	-1 unit	$+1$ unit	0
[6.] Absolute mass	9.11×10^{-31} kg	1.672×10^{-27} kg	1.675×10^{-27} kg
[7.] Relative mass.	$\frac{1}{1836}$ amu $= 0.00054$ amu	1.0072 amu	1.0083 amu
[8.] Specific charge (Charge/mass)	1.758×10^{11} C kg^{-1}	9.579×10^{7} C kg^{-1}	0

Absolute mass / Relative mass.

* $m_{e^-} < m_{p^+} < m_{n^0}$

mass of an e^- is negligible.

$m_{p^+} \sim m_{n^0}$ → 1.672×10^{-27} kg, 1.675×10^{-27} kg

* Electrons (−ve charge) are discovered in cathode rays.
* Protons are discovered in anode rays.
* Neutrons are discovered by nuclear rk^n.
* Electron name was given by Stoney for −vely charged particles present in Cathode rays.
* (Charge/mass) ratio :−

$e^- > p^+ > n^0$

Atomic Model

Atomic model represents position of fundamental particles in atoms.

[1.] Thomson's atomic model (assumption.)
(1st atomic model based on theory)

[2.] Rutherford's atomic model
(1st atomic model based on experiment)

[3.] Bohr's atomic model

[4.] Quantum mechanical model of atom.

Thomson's atomic model

* After discovery of e^-s and p+s, this model was given by Thomson to explain/represent position of these particles.
* A/c to this model, +vely charged particles (protons) are uniformly distributed and electrons are embeded in them to make the whole atom electrically neutral. This model was also called watermelon model.
* This model was also called Plum pudding model.

Merits of Thomson's atomic model :-

This model was accepted that time because it was able to explain —

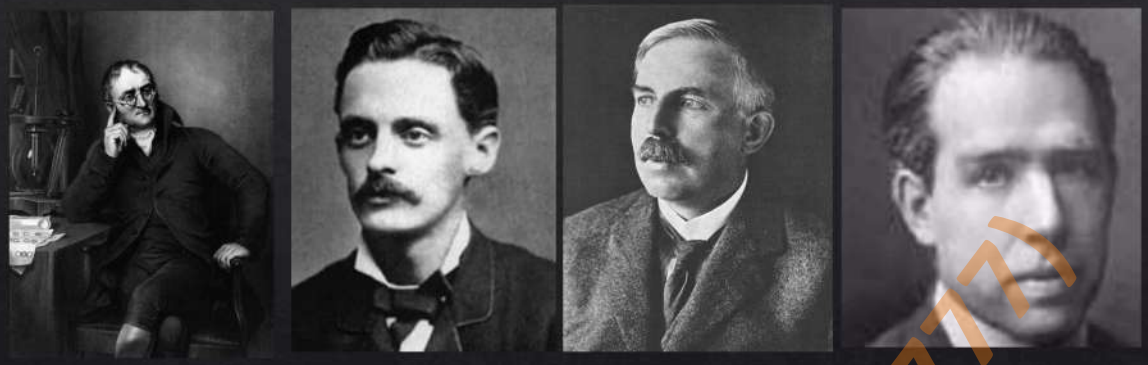
(a) Dalton's atomic theory.
(b) Laws of chemical combination.
(c) Ionisation of gas

Demerits/limitations of Thomson's atomic model :-

This model failed to explain α-particle scattering experiment performed by Rutherford.

Rutherford's atomic model.
(Based on α-particles exp.)

Unit-1.0 Atomic Structure and Chemical Bonding and Solutions:



Thanks

APPLIED CHEMISTRY-A

Based on New Syllabus
Session :- 2024-27

1st Semester

Unit-1.0 Atomic Structure, chemical bonding and solutions

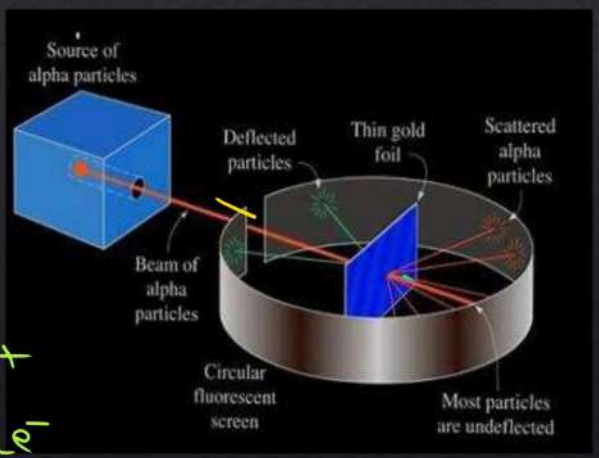
Lecture -4 Topics- α-Particles scattering experiments, R.A.M. and its failure, Atomic number and mass number

Alpha -Particles scattering experiment

*α-particle → He^{2+} ions are called α-particles.

*Radioactive substance.
Po, Ra etc.
emits → α-rays, β-rays, γ-rays

*α-particle He_2 or, $He - 2e^- \rightarrow He^{2+}$
$He \rightarrow He^{2+} + 2e^-$

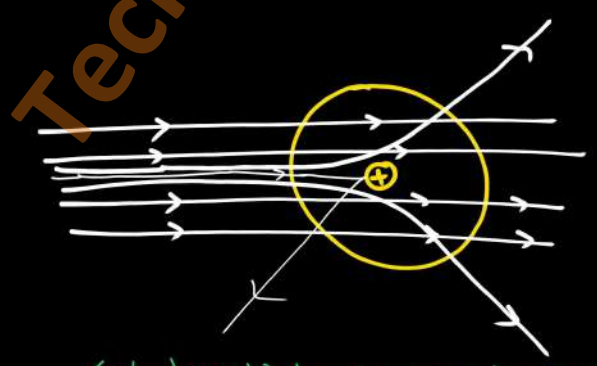


* R.A.M is based on α-particles scattering experiment.
* Rutherford performed α-particle scattering experiment.

Theory:- Rutherford projected beam of α-particles on a very thin foil of gold and observed the scattered α-particles on a moving disc which is coated by ZnS screen.

Observations and conclusions

Observation	Conclusion
[1.] Most of the α-particles passed through atoms without undergoing any deflection.	[1.] Most of the part of atom is empty.
[2.] Few α-particles deviated making some angle.	[2.] The centre of atoms has +vely charged body called nucleus.
[3.] Very few α-particles bounced back. (1 particle bounced back in 20,000 particles)	[3.] The centre (nucleus) of atom has considerable mass and the size is very small.



(α-particle scattering exp.)

Rutherford's atomic model

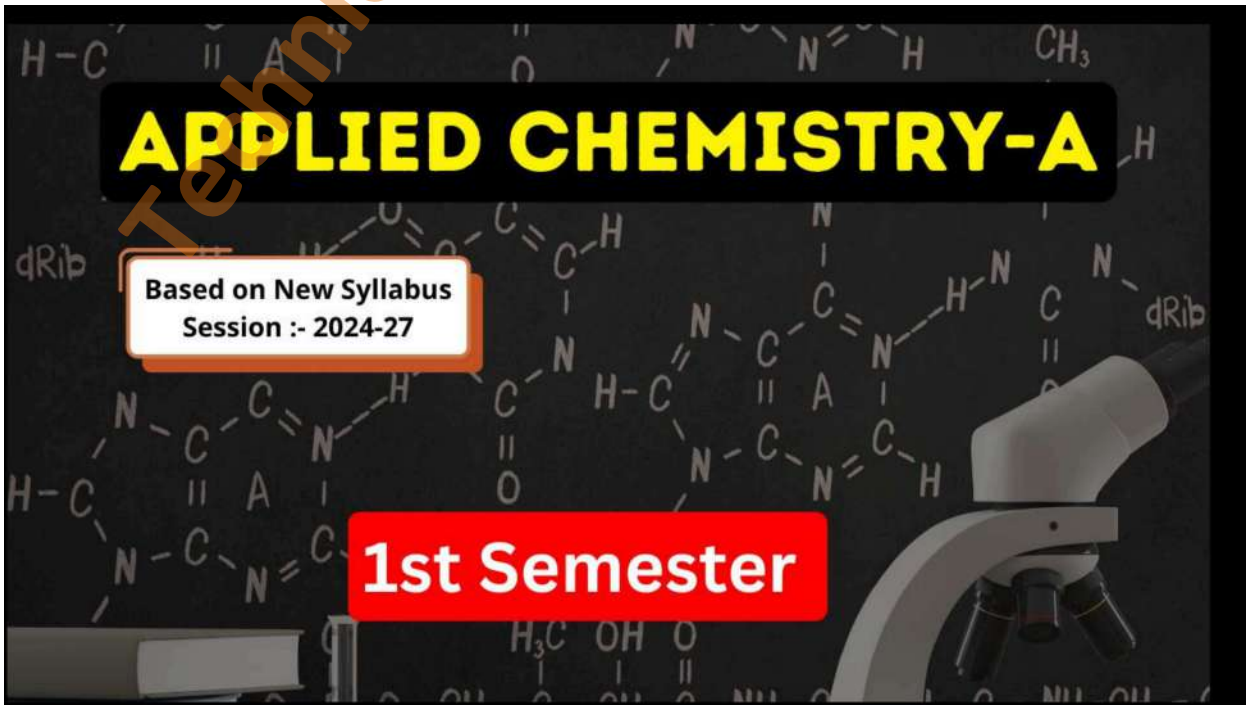
On the basis of conclusion of α-particle scattering exp. Rutherford proposed an atomic model called R.A.M.

[1.] An atoms has two parts.
(i) Nuclear part (ii) Extra-nuclear part.

[2.] Nuclear part contains protons and neutrons and its size is very very small as compared to an atom. It is +ve charged body. It has considerable mass.

[3.] In extra-nuclear part, e^-s revolve around nucleus like earth revolve around sun.

* It is also called planetary model of atom.



Charge on a nucleus :-

* Nucleus contains p^+s and n^os.
  - proton → +ve charged particle
  - neutron → Neutral particle.
* Charge of a nucleus depends on p^+s only

At. no. (Z)
Z = no. of p^+s
e^- → Symobol of electron
e → magnitude of charge of p^+

Charge of 1 p^+ = $+1.6\times10^{-19}$ C = +e

Charge on nucleus = No. of p^+s × Charge of 1 p^+
$= Z \times (+1.6\times10^{-19}\,C)$
$= Z\times(+e)$

$\boxed{\therefore \text{Charge on a nucleus} = +Z\times e}$

Charge on a nucleus of a C-atom :-

(a) C_6 At. no. (Z) = 6.
$\boxed{Z = \text{no. of } p^+\text{s} = 6\,p^+\text{s}}$

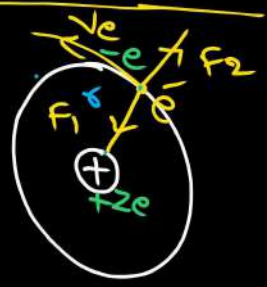
* Charge on a nucleus of C-atom $= +Z\times e$
$= +6\times1.6\times10^{-19}$ C.

(b) Ca_{20} At. no. (Z) = 20
no. of p^+s = 20 p^+s

Charge on a nucleus of Ca-atom $= +20\times1.6\times10^{-19}$ C

* Rutherford confirmed how an electron revolve around nucleus on a circular path on the basis of Newtonian mechanics/classical mechanics

Let us consider,
mass of an electron = m_{e^-}
Charg on an electron = -1.6×10^{-19} C = −e
|Charge on 1 e^-| = e
tangential vel. of moving electron = V_{e^-}
Charge on nucleus = +Z×e



Drawback of Rutherford's atomic model :-

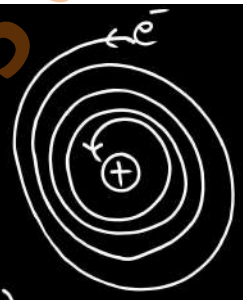
[1.] It failed to explain how e^-s are distributed around nucleus and what are their energies.

[2.] It failed to explain stability of nucleus against protonic repulsion.

[3.] It failed to explain atomic spectra.

main demerit (R.A.M.)

[4.] A/c to Maxwell's electrodynamic principle, an accelerated charged particle radiate energy continuously. If energy is emitted by moving e^- continuously then it loss energy and come closer to nucleus using spiral path. As a result, it finally falls in the nucleus. Actually it doesn't happen but it was not explained by Rutherford.



There are two forces act on moving electron.

(a) Centripetal force → (towards the centre) (F_1)

(b) Centrifugal force → (away from the centre) (F_2)

Electron move on circular path if

$\boxed{\text{Centripetal force} = \text{Centrifugal force}}$

$$\boxed{F_1 = F_2}$$

Physics (Formula)

$$\frac{1}{4\pi\epsilon_0} \times \frac{(Ze)\times(e)}{r^2} = \frac{m_e v^2}{r}$$

$$\boxed{\frac{1}{4\pi\epsilon_0} \times \frac{Ze^2}{r^2} = \frac{mv^2}{r}}$$

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1st Semester

Terms associated with nucleus:-

[1.] Atomic no. (Z) → It is no. of protons present in a nucleus of an atom.

* Atom – Electrically neutral
  no. of p^+s = no. of e^-s

Z = no. of p^+s = no. of e^-s

* This concept was given by Mosley on the basis of experiment.

e.g.:- C_6 $Z=6$ | N_7 $Z=7$

$6e^-$s, $6p^+$s | $7e^-$s, $7p^+$s

[2.] Mass no. (A) → It is the sum of total no. of protons and neutrons present in nucleus.

$\boxed{\text{Mass no. (A)} = \text{no. of pts} + \text{no. of n}^0\text{s}}$

* It is always a whole number.
* $\boxed{\text{At. mass}}$ and $\boxed{\text{mass no.}}$ both are not same.

e.g.:- C^{12}_{6} $\boxed{Z = 6}$

$A = 12$

$6e^-$s, 6 pts, $6n^0$

X^{A}_{Z} — A → mass no., Z → At. no., X = symbol of an atom

* No. of neutrons = Mass no. − At. no
= $A - Z$

[3.] Neutron no. (N) → It is total no. of neutrons present in a nucleus of an atom.

N^{14}_{7} $Z = 7$, $A = 14$ $(N = A - Z)$

$7e^-$s, 7 pt, $7n^0$ $\boxed{A > Z}$

* Properties of an atom varies when neutron no. change.

C^{12}_{6} C^{13}_{6} C^{14}_{6} (Isotopes of C-atom)

$6n^0$s $7n^0$s $8n^0$s

Isotopes

Atoms of the same element having same at. no. but different mass no. is called isotopes.

e.g.- Isotopes of H :-

	H^1_1	H^2_1	H^3_1
	(Protium)	(Deuterium)	(Tritium)
At. no. →	$Z = 1$	$Z = 1$	$Z = 1$
Mass no. →	$A = 1$	$A = 2$	$A = 3$
	$1e^-$, 1 pt	$1e^-$, 1 pt	$1e^-$, 1 pt
	no n^0	$1n^0$	$2n^0$s

e.g.:- Isotopes of carbon:-

C_6^{12} C_6^{13} C_6^{14}

At. no. → Z = 6 | Z = 6 | Z = 6

Mass no. → A = 12 | A = 13 | A = 14

Neutron no. → N = 6 | N = 7 | N = 8

e.g.:- Isotopes of chlorine:-

Cl_{17}^{35} Cl_{17}^{36} Cl_{17}^{37}

e.g.:- Isotopes of nitrogen:-

N_7^{14} N_7^{15} N_7^{16}

Isobar

Atoms of different elements have different at. no. but same mass no..

e.g.:- Ar_{18}^{40} K_{19}^{40} Ca_{20}^{40}

At. no. → Z = 18 | Z = 19 | Z = 20

Mass no. → A = 40 | A = 40 | A = 40

Neutron no. → (40 − 18) = 22 | (40 − 19) = 21 | (40 − 20) = 20

Isoelectronic

Those chemical species having same no. of e^-s are called isoelectronic species.

e.g.:- O^{2-}, Na^+, Mg^{2+}, F^-, Ne, Al^{3+}

O^{2-} → $10e^-$s, Na^+ → $10e^-$s, Mg^{2+} → $10e^-$s, F^- → $10e^-$s, Ne → $10e^-$s, Al^{3+} → $10e^-$s

Na_{11}
Mg_{12}
F_9
Ne_{10}
Al_{13}
O_8

Isotones

Those chemical species having same no. of neutrons.

e.g.:- $^{14}C_6$ $^{15}N_7$ $^{16}O_8$

no. of n°s → 8n°s 8n°s 8n°s

Isosters → Those chemical species having same no. of atoms and e^-s.

e.g.:- CO_2 N_2O

3 atoms 3 atoms

$6e^- + 2\times 8e^-$ $2\times 7e^- + 8e^-$

$= 22e^-$s $= 22e^-$s

Bohr's atomic model

* It was given by Bohr for H-like species which contains $1e^-$ only.

H-like species:-

$\underbrace{H, He^+, Li^{2+}, Be^{3+}}_{1e^-}$

$He_2 \rightarrow 2e^-$

$Li_3 \rightarrow 3e^-$

$Be_4 \rightarrow 4e^-$

* This model was based on R.A.M. and Planck's Quantum Theory. (P.Q.T.)

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Bohr's atomic model:-

* Valid for H-like species.

obs: H-atom, He^{+}, Li^{2+}, Be^{3+} ($2e^{-}$)

* Based on Rutherford's atomic model and Planck's Quantum Theory.

obs:

* A/c to Bohr's atomic model:-

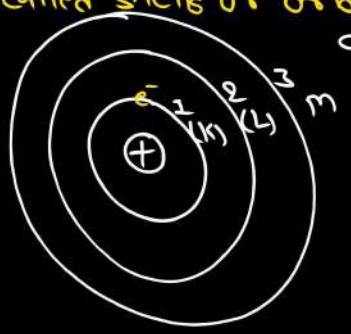
(1) Electron revolve in a fixed circular path around nucleus called shells or orbits.

orbit

$n = 1$ (1st orbit) (K)

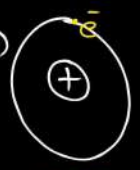
$n = 2$ (2nd orbit) (L)

$n = 3$ (3rd orbit) (M)



[2.] As long as possible, an electron revolve around nucleus in a certain orbit with loss or gain of energy.

[3.] When transition (jump) of an e^- takes place then energy can loss or gain by that e^-.



It doesn't loss or gain energy.

* Lower orbit → Higher orbit
(It happens when energy is absorbed by e^-.)

e.g.:- $n_1 \to n_2$, $n_1 \to n_3$, $n_1 \to n_4$ | $n_2 \to n_3$, $n_2 \to n_4$, $n_3 \to n_4$ | $n_3 \to n_5$

* Higher orbit → Lower orbit
(It happens when energy is released by that e^-)

e.g.:- $n_4 \to n_3$, $n_4 \to n_2$, $n_4 \to n_1$ | $n_3 \to n_2$, $n_3 \to n_1$ | $n_2 \to n_1$

Conclusion:-
* L.O. → H.O.
when energy is absorbed by e^-.
* H.O. → L.O.
when energy is released by e^-.

[4.] Electron revolve only in those orbits whose angular momentum (mvr) is integral multiple of $h/2\pi$.

Obs. → Angular momentum $= n \times \frac{h}{2\pi}$

$(m_e v_e r_n = n \times \frac{h}{2\pi})$

where m_e = mass of e^-
V_e = vel. of e^-
r_n = radius of nth orbit

where
$n = 1, 2, 3 - - -$
$h \to$ Planck's constant

e.g.:- $n=1$: $mvr = 1 \times \frac{h}{2\pi} = \frac{h}{2\pi}$
$n=2$: $mvr = 2 \times \frac{h}{2\pi} = \frac{h}{\pi}$

Transition Energy (ΔE)

It is the energy released or absorbed by an e^- when jumps (transition) from one orbit to another orbit.

$\boxed{\Delta E = E_f - E_i}$ where, E_f = energy of an e^- in final orbit

E_i = energy of an e^- in initial orbit.

Imp.

e.g.:- $n_2 \rightarrow n_4$ (L.O. → H.O)

$\boxed{\Delta E = E_4 - E_2}$

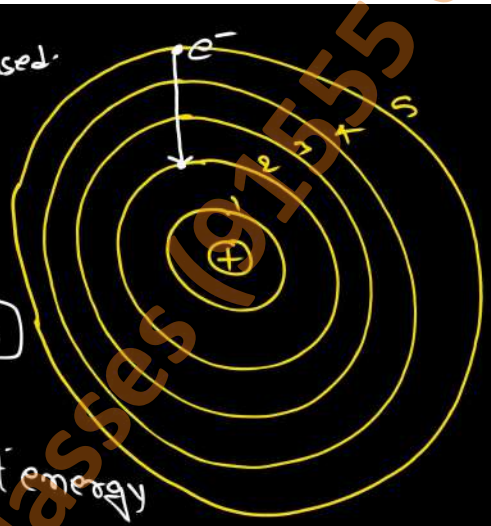
$\boxed{\Delta E = +ve}$

+ve sign indicates that energy is absorbed by e^-

---

energy is released.

$\boxed{H.O. \rightarrow L.O.}$



* $n_5 \rightarrow n_2$

$\Delta E = E_f - E_i$

$\boxed{\Delta E = E_2 - E_5}$

$\boxed{\Delta E = -ve}$

* −ve sign indicates that energy is released by e^-.

Obj. ΔE

$\boxed{\Delta E = +ve}$ → energy is absorbed → ($n_{L.O.} \rightarrow n_{H.O.}$)

$\boxed{\Delta E = -ve}$ → energy is released → ($n_{H.O.} \rightarrow n_{L.O.}$)

Obj.

* Energy of an e^- is maximum in infinite orbit ($n = \infty$) and minimum in 1st orbit ($n = 1$).

Obj. → $E_{max^m} = E_\infty$ (Energy of an e^- in ∞-orbit)

$E_{min^m} = E_1$ ( ), ( ) in 1st orbit

* Total energy of an e^- in nth orbit $= -13.6 \times \frac{Z^2}{n^2}$ eV/atom

–ve sign represents restoring energy.

* Restoring energy → If $13.6 \times \frac{Z^2}{n^2}$ eV atom^{-1} is supplied to an electron then e^- complete free from the attractive influence of nucleus.

$13.6 \times \frac{Z^2}{n^2}$ eV atom^{-1} is absorbed by e^-.

where Z = atomic no.
n = nth orbit.

(for H-atom)

$E_n = -13.6 \times \frac{Z^2}{n^2}$ eV atom^{-1}

e.g. (a) Energy of an e^- in 1st orbit

$E_1 = -13.6 \times \frac{(1)^2}{1^2}$ eV atom^{-1}

$E_1 = -13.6$ eV atom^{-1}

(b) For He^+-ion $Z = 2$ $E_1 = ?$, $E_2 = ?$

$E_1 = -13.6 \times \frac{2^2}{1^2}$ eV atom^{-1} $= -13.6 \times 4$ eV atom^{-1}

$E_2 = -13.6 \times \frac{2^2}{2^2}$ eV atom^{-1} $= -13.6 \times 1$ eV atom^{-1}

$E_3 = -13.6 \times \frac{2^2}{3^2}$ eV atom^{-1}

* When 13.6 eV/atom^{-1} energy is absorbed by an in e^- in H-atom then it becomes free from attractive influence of e^-.)

Q. Calculate energy of e^- in 1st, 2nd, 3rd and ∞-orbit of Li^{2+}-ion

Sol^n: For Li^{2+}-ion, $Z = 3$

$E_n = -13.6 \times \frac{Z^2}{n^2}$ eV atom^{-1}

$E_1 = -13.6 \times \frac{(3)^2}{1^2}$ eV atom^{-1} $= -13.6 \times 9$ eV atom^{-1}

$E_2 = -13.6 \times \frac{(3)^2}{2^2}$ eV atom^{-1}

$E_3 = -13.6 \times \frac{(3)^2}{(3)^2}$ eV atom^{-1}

$E_\infty = -13.6 \times \frac{(3)^2}{\infty^2}$ eV atom^{-1} $= 0$

Li-atom
At. no. = 3
Z = 3 pts

Li^{2+}-ion
$1e^-$ 3 pts

Constant/∞ = 0

$\frac{2}{\infty} = 0$, $\frac{2.31}{\infty} = 0$

* Energy of an e^- in ∞-orbit of H-like species (H-atom, He^+, Li^{2+}, Be^{3+}) is zero.

$Z=1$ $\quad Z=2 \quad Z=3 \quad Z=4$

V.I. obj.

$E_\infty = 0$

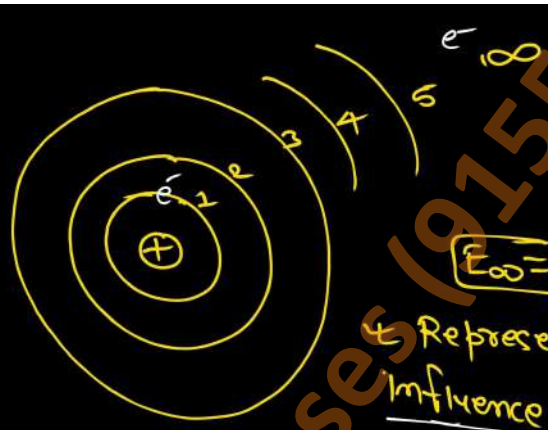
i.e. the e^- present in ∞-orbit of any H-like species doesn't experience attractive influence of nucleus.

Be-atom → $Z=4$

no. of pts $=4$

Be^{3+}-ion → $1e^-$, 4 pts

* It is assumption that max^m no. of orbits in any orbit is ∞.



$E_\infty = 0$ → Represents no attractive influence on e^- by nucleus.

* For H-atom ($n_{L.O.} \rightarrow n_{H.O.}$) $\quad n_1 \rightarrow n_3$ $\quad \Delta E = ?$

Energy is absorbed

$E_n = -13.6 \times \frac{Z^2}{n^2}$ eV atom^{-1}

$\Delta E = E_f - E_i$

$\Delta E = E_3 - E_1$

$= \left(-13.6 \times \frac{(1)^2}{(3^2)}\right) - \left(-13.6 \times \frac{1^2}{1^2}\right)$ eV atom^{-1}

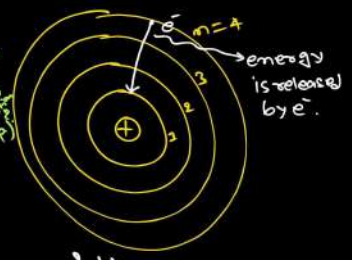
$= +13.6 \times \left(1 - \frac{1}{9}\right)$ eV atom^{-1} $= +\frac{8}{9} \times 13.6$ eV atom^{-1}

When $+\frac{8}{9} \times 13.6$ eV atom^{-1} energy is supplied to the e^- in 1st orbit of H-atom then e^- jumps to the 3rd orbit.

(For H-atom) $(Z=1)$

$n_{H.O.} \rightarrow n_{L.O.}$

* $\boxed{n_4 \rightarrow n_1}$ → How much energy is released in this transition (jump)



T.E., $\Delta E = ?$

$$\Delta E = E_f - E_i$$
$$= E_1 - E_4$$
$$= \left(\left(-13.6 \times \frac{1^2}{1^2}\right) - \left(-13.6 \times \frac{1^2}{4^2}\right)\right) eV\,atom^{-1}$$
$$= \left(13.6 \times \frac{1}{4} - 13.6 \times 1\right) eV\,atom^{-1}$$
$$= 13.6\left(\frac{1}{4} - 1\right) eV\,atom^{-1} = -13.6 \times \frac{3}{4}\, eV\,atom^{-1}$$

* When an e^- jumps from 4th orbit to 1st orbit in H-atom then $\left(13.6 \times \frac{3}{4}\, eV\,atom^{-1}\right)$ energy is released.

* E_m

* Radius of mth Bohr's orbit $= 0.529 \times \frac{n^2}{Z}\, \mathring{A}$

$$\boxed{r_m = 0.529 \times \frac{n^2}{Z}\, \mathring{A}}$$

V_m

(Next classes)

APPLIED CHEMISTRY

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Calculation of Bohr's atomic radius:-

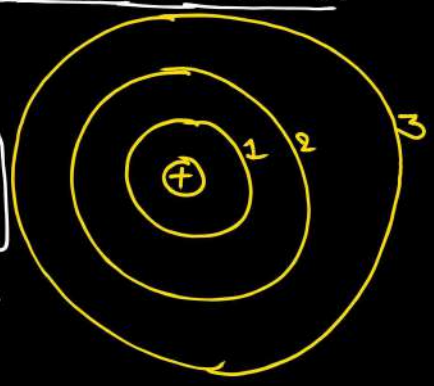
$1 \text{Å} = 10^{-10} m$

V.I.

Radius of nth Bohr's orbit $= 0.529 \times \frac{n^2}{Z} \text{Å}$

where $n = 1, 2, 3 \ldots$

Z = atomic no.



* H-atom, He^{+}-ion, Li^{2+}-ion, Be^{3+}-ion
$Z = 1$, $Z = 2$, $Z = 3$, $Z = 4$

Q. Calculate the radius of 1st, 2nd and 3rd Bohr's orbit of Li^{2+}-ion. [$1\,\mathring{A} = 10^{-10}\,m$]

Solⁿ:- For Li^{2+}-ion

$Z = 3$, $r_1 = ?$ $r_2 = ?$ $r_3 = ?$

$$r_n = 0.529 \times \frac{n^2}{Z}\,\mathring{A}$$

$$r_1 = 0.529 \times \frac{(1)^2}{3}\,\mathring{A} = \frac{0.529}{3}\,\mathring{A}$$

$$r_2 = 0.529 \times \frac{(2)^2}{3}\,\mathring{A} = 0.529 \times \frac{4}{3}\,\mathring{A}$$

$$r_3 = 0.529 \times \frac{(3)^2}{3}\,\mathring{A} = 0.529 \times 3\,\mathring{A}$$

Q. Compare radii of 2nd Bohr's orbit of He^+-ion and Li^{2+}-ion.

Solⁿ:- For He^+-ion: $Z = 2$, $r_2 = ?$ | For Li^{2+}-ion: $Z = 3$, $r_2 = ?$

$$r_n = 0.529 \times \frac{n^2}{Z}\,\mathring{A}$$

$$\frac{(r_2)_{He^+}}{(r_2)_{Li^{2+}}} = \frac{0.529 \times \frac{(2)^2}{2}\,\mathring{A}}{0.529 \times \frac{(2)^2}{3}\,\mathring{A}} = \frac{\frac{1}{2}}{\frac{1}{3}} = \frac{3}{2}$$

Calculation of velocity of an e^- in nth Bohr's orbit:-

$$\text{Vel. of an } e^- \text{ in nth Bohr's orbit} = 2.18 \times 10^6 \times \frac{Z}{n}\,ms^{-1}$$

Where Z = at. no.
$n = 1, 2, 3 \ldots$

Q. Calculate the velocity of an e^- in 3rd Bohr's orbit of Be^{3+}-ion?

($n = 3$)

Solⁿ:- For Be^{3+}-ion, $Z = 4$

$$V_3 = 2.18 \times 10^6 \times \frac{4}{3}\,ms^{-1}$$

Ionisation energy of H-like species:-

H-atom, He^+-ion, Li^{2+}, Be^{3+} — $1e^-$

I.E. → The minimum amount of energy required to complete remove an e^- from ground state to ∞-orbit.

$$n_1 \rightarrow n_\infty$$

$$I.E. = \Delta E = E_\infty - E_1 \quad \{E_\infty = 0\}$$

$$I.E. = \Delta E = (0) - \left(-13.6 \times \frac{Z^2}{n^2}\ eV\,atom^{-1}\right)$$

$$I.E. = +13.6 \times \frac{Z^2}{n^2}\ eV\,atom^{-1}$$

---

* **For H-atom:-** (1)

$$E_n = -13.6 \times \frac{Z^2}{n^2}\ eV\,atom^{-1}$$

$Z = 1$

$n_1 \rightarrow n_\infty$

Ionisation energy

$$I.E. = \Delta E = E_\infty - E_1$$

$$= (0) - \left(-13.6 \times \frac{1^2}{1^2}\right) eV\,atom^{-1}$$

$$I.E. = +13.6\ eV\,atom^{-1}$$

When 13.6 eV energy is supplied to one H-atom then e^- jumps from 1st orbit to ∞-orbit.

---

* **For He^+-ion** (2)

$Z = 2$

$n_1 \rightarrow n_\infty$

$$I.E. = \Delta E = E_\infty - E_1$$

$$I.E. = (0) - \left(-13.6 \times \frac{2^2}{1^2}\right) eV\,ion^{-1}$$

$$(I.E.)_{He^+} = +13.6 \times 4\ eV\,ion^{-1}$$

When $+13.6 \times 4$ eV energy is supplied to one He^+-ion then e^- jumps from 1st orbit to ∞-orbit.

* For Li^{2+}-ion. (3)

$Z = 3$

$n_1 \rightarrow n_\infty$

$I.E. = \Delta E = E_\infty - E_1$

$= (0) - \left(-13.6 \times \frac{3^2}{1^2}\right)$ eV ion^{-1}

$= +13.6 \times 9$ eV ion^{-1}

* When 13.6×9 eV energy is supplied to one Li^{2+}-ion then e^- jumps from 1st orbit to ∞-orbit.

* I.E. of H-like species $= +13.6 \times Z^2$ eV atom^{-1}

e.g.:- $(I.E.)_H = +13.6 \times 1^2$ eV atom^{-1}

$(I.E.)_{He^+} = +13.6 \times 2^2$ eV ion^{-1}

$(I.E.)_{Li^{2+}} = +13.6 \times 3^2$ eV ion^{-1}

$(I.E.)_{Be^{3+}} = +13.6 \times 4^2$ eV ion^{-1}

Success (merits) of Bohr's atomic model:-

This model was successful to calculate

(i) radius of nth Bohr's orbit

(ii) energy of an e^- in nth Bohr's orbit

(iii) velocity of an e^- in nth Bohr's orbit.

Limitation of Bohr's atomic model :-

[1.] It failed to explain atomic spectra of multielectrons atoms.

$He \rightarrow 2e^-$, $Li \rightarrow 3e^-$ — B.A.M. is invalid.

He^+, Li^{2+}, Be^{3+}, H — B.A.M. is valid.

[2.] It failed to explain Heisenberg's Uncertainty principle.

[3.] It failed to explain de-Broglie wavelength theory.

[4.] It failed to explain how atoms combine together to form molecules.

[5.] It failed to explain dual nature of electron.

[6.] It failed to explain splitting of atomic spectra in magnetic field (Zeeman effect) and in electric field (Stark effect.)

de-Broglie Wavelength theory :-

* Einstein

Light → Dual nature

- particle nature → Photons
- wave nature → propagate → Electromagnetic wave, $c = 3 \times 10^8\ ms^{-1}$
  - frequency (ν)
  - wavelength (λ)

de Broglie

Microscopic particles (e's) → Dual nature

- particle nature.
- wave nature → matter wave.
  - don't propagate, $c \neq 3 \times 10^8\ ms^{-1}$
  - wavelength associated with matter ($\lambda = ?$)

(2M).

A/c to de-Broglie wavelength theory, wavelength of microscopic particles like e^-s is inversely proportional to momentum of that particle.

Mathematically, wavelength $\propto \frac{1}{\text{Momentum}}$

$p = \text{mass} \times \text{vel.}$

$\boxed{p = m \times v}$

$\boxed{\lambda \propto \frac{1}{p}}$

$\boxed{\lambda = \frac{h}{p}}$

$\boxed{\lambda = \frac{h}{mv}}$

where h is proportionality constant.

h (Planck's constant)

$h = 6.6 \times 10^{-34}$ J-s

m = mass of microscopic particle

v = vel. of " "

$* \; K.E. = \frac{1}{2} m v^2$

$\Rightarrow m \times K.E. = \frac{1}{2} m^2 v^2$

$\Rightarrow 2 \times m \times K.E. = m^2 v^2 = (mv)^2$

$\boxed{\therefore mv = \sqrt{2 \times m \times K.E}}$

We know that $\lambda = \frac{h}{mv}$

$\Rightarrow \boxed{\lambda = \frac{h}{\sqrt{2 \times m \times K.E.}}}$

Imp. formula:

① $\lambda \propto \frac{1}{p}$ $\boxed{p = mv}$

② $\boxed{\lambda = \frac{h}{p}}$

* ③ $\boxed{\lambda = \frac{h}{mv}}$

* ④ $\boxed{\lambda = \frac{h}{\sqrt{2 \times m \times K.E.}}}$

Q. The mass of an e^- is 9.11×10^{-31} kg. Its given K.E. is 3×10^{-25} J. Calculate wavelength associated with e^-.

Soln:- Given:- $m_{e^-} = 9.11 \times 10^{-31}$ kg

$K.E. = 3 \times 10^{-25}$ J, $\lambda = ?$

We know that, $\lambda = \frac{h}{\sqrt{2 \times m \times K.E.}}$

$= \frac{6.6 \times 10^{-34} \text{ J-s}}{\sqrt{2 \times 9.11 \times 10^{-31} \text{ kg} \times 3 \times 10^{-25} \text{ J}}}$

$= \ldots\ldots\ldots$

Q. The vel. of an e^- in Bohr's orbit is $2.19 \times 10^6\ ms^{-1}$. Calculate the de-Broglie wavelength associated with it.

Solⁿ:- Given: $\begin{cases} V_{e^-} = 2.19 \times 10^6\ ms^{-1} \\ m_{e^-} = 9.11 \times 10^{-31}\ kg \end{cases}$

$\lambda = ?$

We know that, $\lambda = \frac{h}{mv}$

$$\lambda = \frac{6.6 \times 10^{-34}\ J\text{-}s}{9.11 \times 10^{-31}\ kg \times 2.19 \times 10^6\ ms^{-1}}$$

$\lambda = \ldots\ldots\ldots$

* When a charged particle of charge QC is accelerated by applying potential difference of V volt then K.E. of charged particle is QC × V volt.

$\therefore$ K.E. $= (Q \times V)\ J$ $\quad$ $1C \times 1\ volt = 1J$

* We know that, $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2 \times m \times K.E.}}$

$$\lambda = \frac{h}{\sqrt{2 \times m \times Q \times V}}$$

m → mass of particle. Q → Charge of particle V → pot. diff.

* For e^- → $m_{e^-} = 9.11 \times 10^{-31}\ kg$

$Q = |\text{Charge on } 1e^-| = 1.6 \times 10^{-19}\ C$

$$\lambda = \frac{h}{\sqrt{2 \times m \times Q \times V}}$$

$$\lambda = \frac{6.6 \times 10^{-34}\ J\text{-}s}{\sqrt{2 \times 9.11 \times 10^{-31}\ kg \times 1.6 \times 10^{-19}\ C \times V}}$$

$$\lambda = \frac{12.27}{\sqrt{V}}\ \mathring{A}$$

$1\mathring{A} = 10^{-10}\ m$

Q. If an e^- is accelerated by a p.d of 25 volt. Find the de-Broglie wavelength associated with it.

Solⁿ:-

$V = 25$ volt

$\lambda = ?$

$$\lambda = \frac{12.27}{\sqrt{25}} \text{ Å}$$

$$\lambda = \frac{12.27}{5} \text{ Å}$$ ans.

* For p^+ :-

$$\boxed{\lambda = \frac{0.286}{\sqrt{V}} \text{ Å}}$$

* For α-particle:-

$$\boxed{\lambda = \frac{0.101}{\sqrt{V}} \text{ Å}}$$

For e^- →

$$\boxed{\lambda = \frac{12.27}{\sqrt{V}} \text{ Å}}$$

$1 \text{ Å} = 10^{-10} m$

$1 nm = 10^{-9} m$

$1 pm = 10^{-12} m$

Heisenberg's Uncertainty principle:-

* Particle

→ macroscopic particle (ball) → trajectory/path can be traced. (?)

→ Bcoz their position and momentum both can be calculated simultaneously with accuracy at certain time.

→ microscopic particle. (e^-s, p^+s, n^0s etc.) → trajectory/path can't be traced. (?)

→ Bcoz their position and momentum both can't be calculated simultaneously with accuracy at certain time.

H.U.P.

(A)

* A/c to H.U.P., the exact (accurate) position and momentum of microscopic particles like e^-s can't be determined simultaneously with accuracy at certain time.

If we calculate exact position with accuracy then inaccuracy is observed in momentum and if momentum is calculated with accuracy then inaccuracy is observed in position at certain time for microscopic particle.

Uncertainty

H.U.P.

(B)

* The product of uncertainty in position (Δx) and uncertainty in momentum (Δp) is greater than or equal to $h/4\pi$

mathematically.

$$\Delta x \times \Delta p \geq \frac{h}{4\pi}$$

$$\Delta x \times m \times \Delta v \geq \frac{h}{4\pi}$$

$$\Delta x \times \Delta v \geq \frac{h}{4\pi m}$$

For minimum uncertainty.

$$\Delta x \times \Delta p = \frac{h}{4\pi}$$

* We know that $\Delta p = m \times \Delta v$

Δp: inaccuracy or uncertainty in momentum

m: mass of microscopic particle

Δv: inaccuracy or uncertainty in vel.

$$\Delta x \times m \times \Delta v = \frac{h}{4\pi}$$

$$\Delta x \times \Delta v = \frac{h}{4\pi m}$$

* Significance of H.U.P. →

H.U.P. concludes that the path/trajectories of microscopic particles is ruled out.

(Numericals based on H.U.P.)

APPLIED CHEMISTRY-A

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Line spectrum of H-atom:-

* Line spectrum of H-atom is produced due to excitation and de-excitation of electron.

* **Excitation of e^-**

L.O. → H.O
(When energy is supplied to the e^-)

e.g.:- $n_2 \rightarrow n_4$

T.E., $\boxed{\Delta E = +(E_4 - E_2)}$ — (1)

De-excitation of e^-

H.O. → L.O.
(Energy is released.)

e.g.:- $n_4 \rightarrow n_2$

$\Delta E' = E_2 - E_4$

$\boxed{\Delta E' = -(E_4 - E_2)}$ — (2)

From (1) and (2), $\boxed{\Delta E = -\Delta E'}$

* $\boxed{\Delta E = -\Delta E'}$

$n_2 \rightarrow n_4$
Energy required for this jump

$n_4 \rightarrow n_2$
Energy released for this jump

Imp. for obj:- $\boxed{n_2 \rightarrow n_4}$ excitation

$\boxed{n_4 \rightarrow n_2}$ de-excitation

Conclusion:-

* In H-like species, for the same transition, energy released must be equal to energy absorbed.

* When an e^- in H-like species absorb energy then gets excited and jumps to higher orbit. Electron doesn't remain in higher orbit and hence it jums from H.O. to L.O. releasing energy.

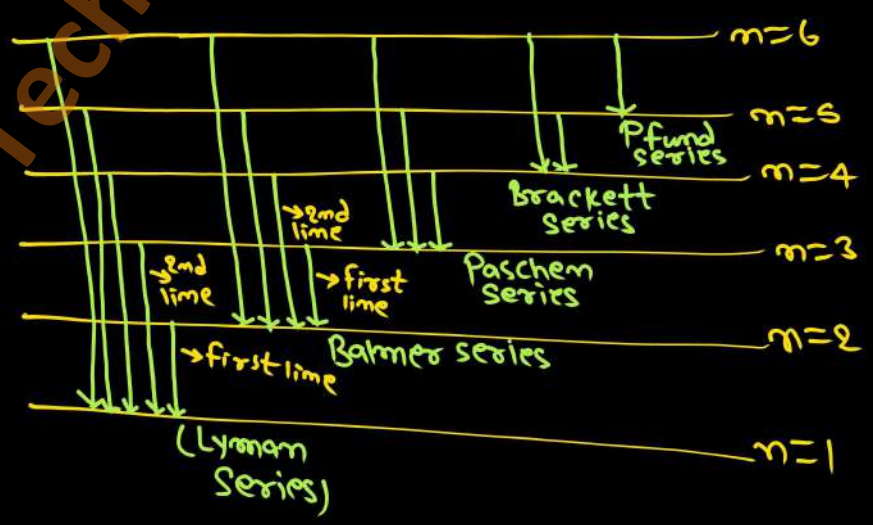
This energy is produced in form light which is analysed by spectroscopy then we obtain lines called line spectrum of H-like species.

* H.O. $\longrightarrow$ L.O.

$n_2 \longrightarrow n_1$

$\boxed{n_i \longrightarrow n_f}$ $\boxed{n_i > n_f}$

	n_i (H.O.)	n_f (L.O.)	Series
(a)	2, 3, 4, 5 ---- ∞	1	Lyman series
(b)	3, 4, 5, ---- ∞	2	Balmer series
(c)	4, 5, 6, ---- ∞	3	Paschem series
(d)	5, 6, 7, ---- ∞	4	Brackett series
(e)	6, 7, 8, ---- ∞	5	Pfund series.



Rydberg's formula:-

H.O. → L.O.

$n_i \rightarrow n_f$ $(n_i > n_f)$

$\Delta E = E_f - E_i$

$\boxed{\Delta E = -(E_i - E_f)}$

negative sign indicates that energy is released from $n_i \rightarrow n_f$.

$E_n = \frac{-13.6 \times Z^2}{n^2}$ eV atom^{-1}

$= -2.18 \times 10^{-18} \times \frac{Z^2}{n^2}$ J atom^{-1}

$\Delta E = \frac{hc}{\lambda}$

h → Planck's constant, c → speed of light, λ → wavelength

$\Delta E = E_i - E_f$

$\Delta E = \left(-2.18 \times 10^{-18} \times \frac{Z^2}{n_i^2}\right) - \left(-2.18 \times 10^{-18} \times \frac{Z^2}{n_f^2}\right)$ J atom^{-1}

$\Rightarrow \frac{hc}{\lambda} = 2.18 \times 10^{-18} \times Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$\boxed{\Rightarrow \frac{1}{\lambda} = \frac{2.18 \times 10^{-18}}{hc} \times Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)}$

$\boxed{\therefore \frac{1}{\lambda} = R_H \times Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)}$

$R_H = \frac{2.18 \times 10^{-18}\ J}{hc} = 1.09678 \times 10^7\ m^{-1}$

(Rydberg's Constant)

Q. Calculate the wavelength ($\lambda = ?$) for 2nd line of Balmer series of He^+-ion.

Solⁿ:- For He^+-ion, $Z = 2$

$\boxed{n_4 \rightarrow n_2}$ → For 2nd line of Balmer series

$\frac{1}{\lambda} = R_H \times Z^2 \left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$

$\frac{1}{\lambda} = R_H \times (2)^2 \left(\frac{1}{2^2} - \frac{1}{4^2}\right)$

$\frac{1}{\lambda} = R_H \times 4 \times \left(\frac{1}{4} - \frac{1}{16}\right)$

$\frac{1}{\lambda} = R_H \times 4 \times \left(\frac{4-1}{16}\right)$

$\frac{1}{\lambda} = R_H \times \cancel{4} \times \frac{3}{\cancel{16}\,4}$

$\boxed{\therefore \lambda = \frac{4}{3 \times R_H}}$

Concept of quantum number :-

* It is solution of Schrodinger's wave equation.
* Quantum no. is the set of four numbers which give information about electrons (address of e^-s).

Types of quantum no. :-

[1.] Principle Quantum no. (n) → orbit

[2.] Azimuthal / Subsidiary quantum no. (l) → Sub-orbit

[3.] Magnetic Quantum no. (m) → orbital

[4.] Spin quantum no. (s or m_s) → Spin motion of e^-

(my address.)

* India → Bihar → Patna → Danapur → Mamer block → Nawati mohalla.

Similarly.

orbit → Suborbit → orbital

(n) → value → n = 1, 2, 3 ----

(l) → value → l = (n−1)

(m) → value → m = −l to +l including zero

l = 0, s-suborbit
l = 1, p- ''
l = 2, d- ''
l = 3, f- ''

Suborbit

1s

e.g.:- (a) n = 1 (1st orbit) | n = 1, l = 0 (s) → 1 value
l = (1−1) = 0

(b) n = 2 (2nd orbit) | n = 2, l = 0, 1 (s, p) → 2 values — 2s, 2p
l = 0, 1

(c) n = 3 (3rd orbit) | n = 3, l = 0, 1, 2 (s, p, d) → 3 value — 3s, 3p, 3d
l = 0, 1, 2

(d) n = 4 (4th orbit) | n = 4, l = 0, 1, 2, 3 (s, p, d, f) → 4 value. — 4s, 4p, 4d, 4f
l = 0, 1, 2, 3

* No. of orbit = No. of suborbit.

Conclusion:-

orbit	Suborbit
n = 1	1s
n = 2	2s, 2p
n = 3	3s, 3p, 3d
n = 4	4s, 4p, 4d, 4f
n = 5	5s, 5p, 5d, 5f, 5g

1p ✗, 3d ✓, 2s ✓, 1d ✗, 3f ✗, 2p ✓, 2s ✓

* For given value of l, the value of m is (−l) to (+l) including zero.

Suborbit	orbital
l = 0 (s-suborbit)	m = 0
l = 1 (p-suborbit)	m = −1, 0, +1
l = 2 (d-suborbit)	m = −2, −1, 0, +1, +2
l = 3 (f-suborbit)	m = −3, −2, −1, 0, +1, +2, +3.

Conclusion:-

Suborbit	orbital	maxm no. of e⁻s
s-suborbit	□	s^2
p-suborbit	□□□	p^6
d-suborbit	□□□□□	d^{10}
f-suborbit	□□□□□□□	f^{14}

* Maximum no. of e⁻s in any orbital two.

To sum up:-

in orbit	Suborbit	orbital	no. of orbitals	Maxm no. of e⁻s
n=1	1s	□	1	2 e⁻s
n=2	2s, 2p	□, □□□	4	8 e⁻s
n=3	3s, 3p, 3d	□, □□□, □□□□□	9	18 e⁻s
n=4	4s, 4p, 4d, 4f	□, □□□, □□□□□, □□□□□□□	16	32 e⁻s

* Maxm no. of e⁻s in nth orbit $= 2n^2$

e.g:- Maxm no. of e⁻s 5th orbit $= 2 \times 5^2 = 50$

* No. of orbitals in nth orbit $= n^2$

e.g:- no. of orbitals in 5th orbit $= 25$

* no. of orbitals in suborbit $= (2l+1)$

e.g:- For d-suborbit $l = 2$

no. of orbitals in d-suborbit $= 2 \times 2 + 1 = 5$

Electronic configuration:-

e⁻s → configure/distribution

Distribution of e⁻s of an atom/ion in different orbits, suborbits and orbitals is called electronic configuration.

Rules to write E.C. →

[1.] Aufbau's principle

[2.] Pauli's exclusion principle

[3.] Hund's rule of maximum multiplicity.

[1.] Aufbau's principle

* Aufbau is a German word which mean build up i.e. filling of e^-s in different energy levels.
* It states that the e^-s are filled in diff. energy levels in order of their increasing energy levels.

Imp. * s^2, p^6, d^{10}, f^{14}

Order of energy levels:-

$1s < 2s < 2p < 3s < 3p < 4s <$
$3d < 4p < 5s < 4d < 5p <$
$6s < 4f < 5d < 6p < 7s$ ....

e.g.:- $H_1 \rightarrow 1s^1$

$He_2 \rightarrow 1s^2$

$Li_3 \rightarrow 1s^2 2s^1$

$Be_4 \rightarrow 1s^2 2s^2$

$B_5 \rightarrow 1s^2 2s^2 2p^1$

$C_6 \rightarrow 1s^2 2s^2 2p^2$

$N_7 \rightarrow 1s^2 2s^2 2p^3$

$O_8 \rightarrow 1s^2 2s^2 2p^4$

$F_9 \rightarrow 1s^2 2s^2 2p^5$

$Ne_{10} \rightarrow 1s^2 2s^2 2p^6$

* $1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p$ - - - - -

$Na_{11} \rightarrow 1s^2 2s^2 2p^6 3s^1$ or, $[Ne]_{10} 3s^1$

$Mg_{12} \rightarrow 1s^2 2s^2 2p^6 3s^2$ or, $[Ne]_{10} 3s^2$

$Al_{13} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^1$ or, $[Ne]_{10} 3s^2 3p^1$

$Si_{14} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^2$ or, $[Ne]_{10} 3s^2 3p^2$

$P_{15} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^3$ or, $[Ne]_{10} 3s^2 3p^3$

$S_{16} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^4$ or, $[Ne]_{10} 3s^2 3p^4$

$Cl_{17} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^5$ or, $[Ne]_{10} 3s^2 3p^5$

$Ar_{18} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6$ or, $[Ne]_{10} 3s^2 3p^6$

$K_{19} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$ or, $[Ar]_{18}\, 4s^1$

$Ca_{20} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ or, $[Ar]_{18}\, 4s^2$

= H.W. → 21 to 30 $\boxed{{}^{*}Cr_{24}, {}^{*}Cu_{29}}$ → Exception.

[2.] Pauli's exclusion principle –

* Maximum no. of e^-s in any orbital is two.
* No any two e^-s in an atom can have same set of quantum no.

e.g.:- $He_2 \rightarrow 1s^2$, $l = 0$, $\boxed{\uparrow\downarrow}$

$n=1, l=0, m=0, s=+1/2$

$n=1, l=0, m=0, s=-1/2$

(Recall) .....

Hund's rule:-

$\boxed{\uparrow}$ s^1 $\boxed{\uparrow\downarrow}$ s^2

$\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow\downarrow}$ p^6

$\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}$ d^{10}

Spin motion of e^-

$\uparrow$ → Clockwise spin motion of e^-

$\downarrow$ → anti clock-wise spin motion of e^-

Molality

* The no. of mol of solute per kg of solvent is called molality.
* It is denoted by m.
* Unit → $mol\,kg^{-1}$ or m
* 1m solution is called molal solution.
* 1m solution means $1\,mol\,kg^{-1}$.
  i.e. 1 mol solute is dissolved in 1 kg of solvent.
* 0.1m solution is called decimolal solution.
  i.e. $0.1\,mol\,kg^{-1}$ i.e. 0.1 mol solute per kg of solvent.
* 0.5m solution is called semi-molal solution.
  $0.5\,mol\,kg^{-1}$

Formula for molality:-

ωg of solute is dissolved in Wg of solvent.

Solute + Solvent = Solⁿ

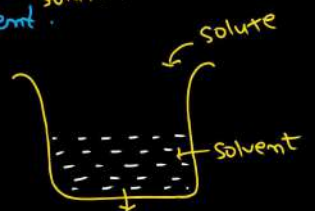
$n_{mol} = \frac{\omega}{MM}$ mol

$\therefore$ Wg solvent — $\frac{\omega}{MM}$ mol solute.

$\therefore$ $1g$ solvent — $\frac{\omega}{MM \times W}$ mol solute.

$\therefore$ $1000g$ solvent — $\frac{\omega \times 1000}{MM \times W}$ mol solute.

1Kg



Solute — Solvent

mass → ωg — Wg

molar mass → $MM\ g\,mol^{-1}$

no. of mol → $n_{solute} = \frac{\omega}{MM}$ mol

$$\therefore \text{Molality} = \frac{\omega_{solute}(g) \times 1000}{MM_{solute}(g\,mol^{-1}) \times W_{solvent}(g)}$$

[1] $\text{molality} = \frac{\omega_{solute}(g) \times 1000}{MM_{solute}(g\,mol^{-1}) \times W_{solvent}(g)}$

[2] $\text{Molality} = \frac{\omega_{solute}(g)}{MM_{solute}(g\,mol^{-1}) \times W_{solvent}(Kg)}$

$n_{solute} = \frac{\omega_{solute}(g)}{MM_{solute}(g\,mol^{-1})}$

[3] $\text{Molality} = \frac{n_{solute} \times 1000}{W_{solvent}(g)}$

[4] $\text{Molality} = \frac{n_{solute}}{W_{solvent}(Kg)}$

Q. 4g NaOH is added to 800g of water to form aq. solution of NaOH. Calculate molality of solution.

Solⁿ:- Given,

$\omega_{NaOH} = 4g$

$\omega_{H_2O} = 800g$

Molality = ?

$$\text{Molality} = \frac{\omega_{NaOH} \times 1000}{MM_{NaOH} \times W_{H_2O}} = \frac{\cancel{4} \times \cancel{1000}}{\cancel{40} \times \cancel{800}_{2}}\ mol\,Kg^{-1}$$

$= \frac{1}{8}\ mol\,Kg^{-1}$

$= \frac{1}{8}\ m$

Chemical bonding

the attractive force which holds two or more atoms together in a molecule is called chemical bonding.

* Metal + Metal → Metallic bond (Solid state.)
* Metal + Non-metal → Ionic bond
* Non-metal + Non-metal → Covalent bond

Note:→ * Metals have tendency to loss $e^-(s)$ to form +ve ion.
* Non-metals have tendency to gain $e^-(s)$ to form −ve ion.

Ionic Bond

Metal + Non-metal → Ionic bond
+ve ion −ve ion

$C^+ + a^- \longrightarrow Ca$

Ionic bond is formed by complete transfer of $e^-(s)$ from one atom to another atom.

* Complete transfer means transfer (removal) of e^- from outermost orbit to infinite orbit.

$Na_{11} \rightarrow 2, 8, \underbrace{1}_{V.E.}$

$n_3 \rightarrow n_\infty$
(complete transfer of e^-)

e.g.:- Formation of NaCl−

$Na(s) + Cl_2(g) \longrightarrow NaCl(s)$

$Na_{11} \rightarrow 2, 8, \underbrace{1}_{V.E.}$ | $Cl_{17} \rightarrow 2, 8, \underbrace{7}_{V.E.}$

lewis dot Symbol → $Na^{\cdot}$ $\cdot\ddot{Cl}:$

$Na^{\cdot} + \cdot\ddot{Cl}: \longrightarrow Na^+ + :\ddot{Cl}:^{\ominus}$

2,8,1 2,8,7 2,8 2,8,8

NaCl

Here, electrostatic attraction b/w Na^+-ion and Cl^--ion take place and thus ionic bond is formed.

* Formation of ionic bond in CaO :-

$Ca_{20} \rightarrow 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2$ | $O_8 \rightarrow 1s^2 2s^2 2p^4$

2, 8, 8, 2 (V.E.) | 2, 6 (V.E.)

Lewis dot symbol → Ca· | ·O·

$$Ca \cdot \; \cdot\ddot{O}: \longrightarrow Ca^{2+} + O^{2-}$$

or,

CaO

Calcium oxide.

* Formation of ionic bond in $AlCl_3$:-

$Al_{13} \rightarrow 2, 8, 3$ (V.E.) | $Cl_{17} \rightarrow 2, 8, 7$ (V.E.)

$$Al\cdot \; \cdot\ddot{Cl}: \; \cdot\ddot{Cl}: \; \cdot\ddot{Cl}: \longrightarrow Al^{3+} + \; :\ddot{Cl}:^{\ominus} \; :\ddot{Cl}:^{\ominus} \; :\ddot{Cl}:^{\ominus}$$

or, $Al^{3+}\ 3Cl^-$

or, $AlCl_3$

Formation of Ionic bond in $MgCl_2$ –

$Mg_{12} \rightarrow 2, 8, 2$ (V.E.) | $Cl_{17} \rightarrow 2, 8, 7$ (V.E.)

$$Mg\cdot \; \cdot\ddot{Cl}: \; \cdot\ddot{Cl}: \longrightarrow Mg^{2+} + \; :\ddot{Cl}:^{\ominus} \; :\ddot{Cl}:^{\ominus} \longrightarrow Mg^{2+}\ 2Cl^-$$

or

$MgCl_2$.

Covalent bond

Classical concept → By sharing of e^-(s) b/w atoms

Modern concept (VBT) → By overlapping of atomic orbitals.

V.B.T. → Valence bond theory.

* Covalent bond is formed by sharing of e^-(s) b/w atoms.

e.g.:- H_2

H—H

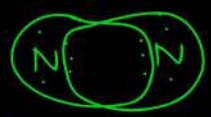
	L.D.S.
$H_1 \rightarrow 1s^1$	H·
$O_8 \rightarrow 2,6$	·O·
$N_7 \rightarrow 2,5$	·N·
$F_9 \rightarrow 2,7$	·F·
$C_6 \rightarrow 2,4$	·C·
$S_{16} \rightarrow 2,8,6$	·S·

Halogen family → F, Cl, Br, I (V.E. = 7)

O_2

:O=O:

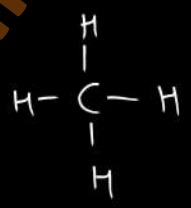
N_2



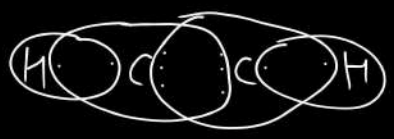
:N≡N:

* Single covalent bond (By sharing of one-one e^-)
* Double ,, ,, (,, ,, two-two e^-s).
* Triple ,, ,, (,, ,, three-three e^-s).

CH_4

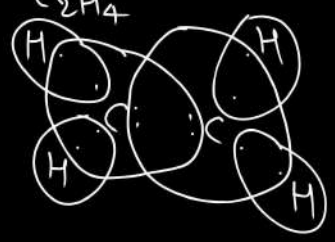


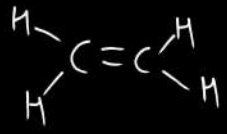
C_2H_2



H—C≡C—H

C_2H_4





H_2O

CO_2

:O=C=O:

Halogen acid (HX) where X = F, Cl, Br, I

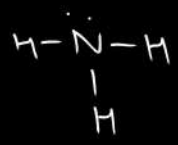
HF, HCl, HBr, HI

e.g.:-

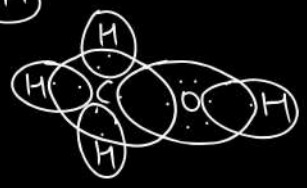
H–F: or, H–F

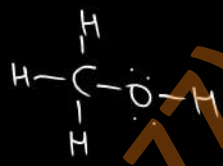
H–Cl, H–Br, H–I

NH_3



CH_3OH





Covalent bond

- Polar covalent bond ($\mu_R \neq 0$)
- Non-polar covalent bond ($\mu_R = 0$)

Dipole moment (μ)

e.g.:- HCl

$\overset{\delta+}{H} \rightarrow \overset{\delta-}{Cl}$

$\boxed{E_N(Cl) > E_N(H)}$

* Charge develop on H and Cl due to electronegativity difference i.e. polarity develop.

e.g.:- $\overset{\delta+}{H} \rightarrow \overset{\delta-}{F}$, $\overset{\delta+}{H} \rightarrow \overset{\delta-}{Br}$, $\overset{\delta+}{H} \rightarrow \overset{\delta-}{I}$

H_2 O O

H – H

* No charge develop because of no E_N difference.

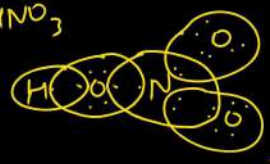
* O_2 O=O

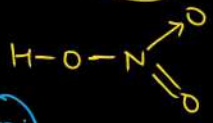
* N_2 N≡N

Co-ordinate bond / Dative bond

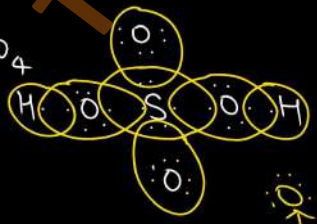
O_3

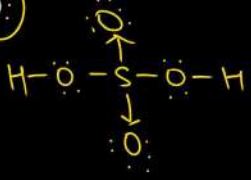
HNO_3



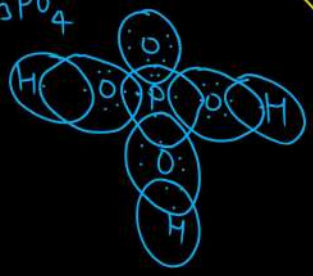


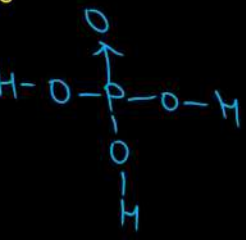
H_2SO_4

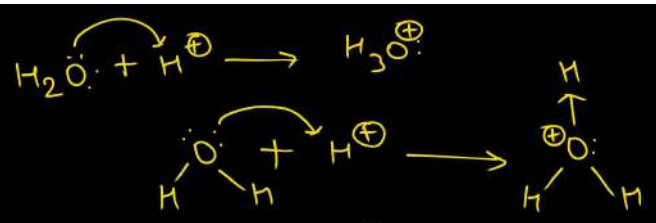




H_3PO_4







Co-ordinate bond is a type of covalent bond in which one atom supplies e^-s to other atom. It is combination of transfer and sharing of e^-(s).

* It is denoted by $\longrightarrow$.

Polarity of a bond :-

It is decided by dipole moment.

e.g.:- $\overset{\delta+}{A} \xrightarrow{} \overset{\delta-}{B}$ (d) | $E_N(B) > E_N(A)$

Dipole moment = Magnitude of charge × distance b/w centre of +ve and -ve charge

$$\boxed{\mu = \delta \times d}$$

Unit → C m | Unit of dipole moment → C-m or D.

* Dipole moment is a vector quantity.
* It is denoted by $\overset{\longrightarrow}{\mu}$.

* Dipole moment is the product b/w magnitude of charge and the distance b/w the centre of +ve and -ve charge.

e.g.:- $\overset{\delta+}{H} \xrightarrow{} \overset{\delta-}{F}$ | $E_N(F) > E_N(H)$

$$\boxed{\mu = \delta \times d}$$

δ → Mag. of charge; d → bond length.

Application of dipole moment :-

(i) If $\mu_R \neq 0$, molecule is said to be non-polar.

(ii) If $\mu_R = 0$, molecule is said to be polar.

Polarity of a bond :-

It is decided by dipole moment.

e.g.:- $\overset{\delta+}{A} \rightarrow \overset{\delta-}{B}$ | $E_N(B) > E_N(A)$

$\leftarrow d \rightarrow$ (d = Bond length, δ = magnitude of charge).

* Dipole moment is the product b/w magnitude of charge and distance b/w the centre of +ve and -ve charge.

* It is denoted by μ.

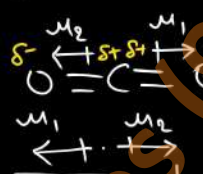
$$\boxed{\mu = \delta \times d}$$

* It is a vector quantity.
* It is represented by $\longrightarrow$

Application of dipole moment :-

[1.] If $\boxed{\mu_R = 0}$, molecule is said to be non-polar.

e.g.:- (a) CO_2



$\boxed{\mu_R = 0}$

| $E_N(O) > E_N(C)$

$\mu_R = \mu_1 + (-\mu_2)$
$= 0$

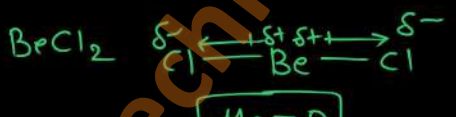
$\therefore$ CO_2 molecule is non-polar.

(b) BF_3

$\therefore$ BF_3 is non-polar molecule.

$\boxed{\mu_R = 0}$

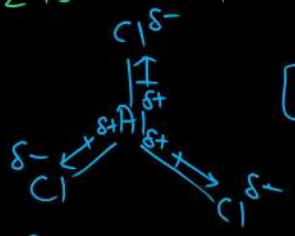
$BeCl_2$



$\boxed{\mu_R = 0}$

$\therefore$ $BeCl_2$ is a non-polar molecule.

$AlCl_3$



$\boxed{\mu_R = 0}$

$\therefore$ $AlCl_3$ is also a non-polar molecule.

$\underbrace{H_2, O_2, N_2, Cl_2}$

Homonuclear diatomic molecule.
$\downarrow$
Non-polar molecule.

$\mu_R = 0$

H — H

$\mu = 0 \times d$
$= 0$

Application of dipole moment

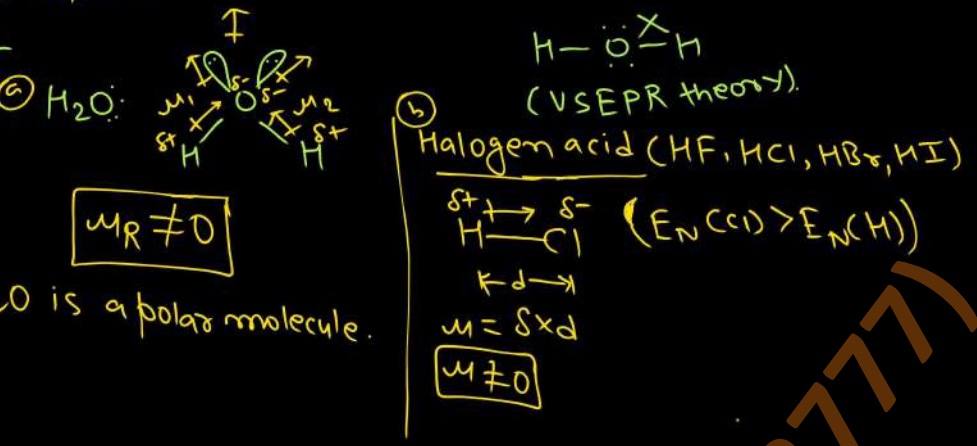
(ii) If $\mu_R \neq 0$, molecule is said to be polar.

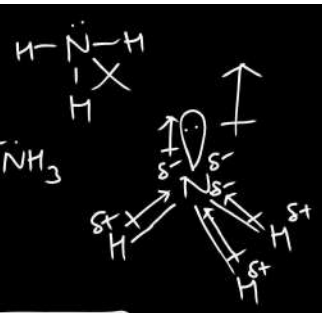
e.g.:-

(a) H_2O:

$\boxed{\mu_R \neq 0}$

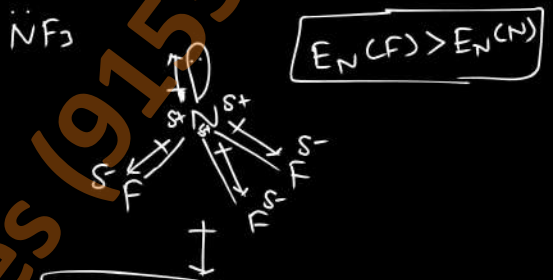
H_2O is a polar molecule.





$\boxed{\mu_R \neq 0}$

NH_3 is a polar molecule.



$\boxed{\mu_R \neq 0}$

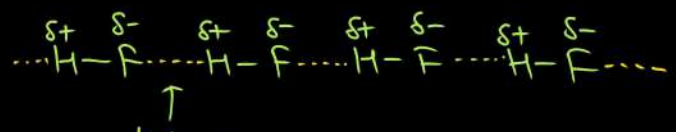
NF_3 is a polar molecule.

$\boxed{\mu_{NH_3} > \mu_{NF_3}}$

H-bonding

The attractive force b/w covalently bonded Hydrogen of one molecule and one of the more electronegative element like F, O, N of other molecule.

e.g.:- HF, HCl, HBr, HI



* H-bond is denoted by dotted line.

Conditions for formation of H-bonding:-

(i) Molecule should have covalently bonded hydrogen.

(ii) Other molecule must have more E_N element like F, O, N.

at. size less.

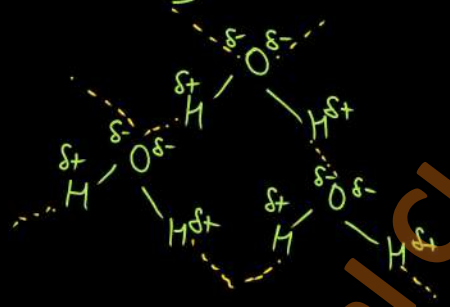
* HF HCl

F at. size less Cl-atomic size high.

Types of H-bonding:-

[1.] Intermolecular H-bonding:- H-bonding b/w (two or more than two) same or different molecules are called intermolecular H-bonding.

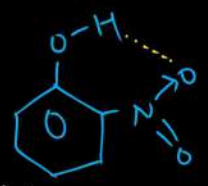
e.g:- H_2O, NH_3, HF.



(ii) Interamolecular H-bonding:-

H-bonding in a single molecule is called interamolecular H-bonding.

e.g:- o- nitrophenol



* Water is a liquid bcoz water molecules are associted by H-bonding.

* Ammonia (NH_3) is a liquid but phosphine is a gas. ?

H-bond + H-bond

* Ethanol dissolve in water due to formation of H-bonding b/w ethanol and water molecules.

Solution

The homogeneous mixture of two or more non-reacting species.

e.g.:- water + sugar → aq. solⁿ of sugar (1)
(Solvent) (Solute)

Solute + Solvent = Solution

* Solute → the component which is present in less amount is solute.

* Solvent → the component which is present in large amount is solvent.

Types of solution:- (On the basis of no. of components)

(i) Binary solution → It consist of two components only.

e.g.:- Sugar + Water → solⁿ (2)
Solute solvent

(ii) Ternary solution → It consist of three components only.

Sugar + salt + Water → solⁿ
(Solute) (NaCl) (Solute) (Solvent)

(iii) Quarternary solution → It consist of four components only.

Sugar + salt + lemon + water → solⁿ
(NaCl) juice (Solvent)

* Water is universal solvent.

* On the basis of nature of solvent –

(a) Aquous solution → The solution prepared in water is called aq. solution.

e.g:- aq. solution of sugar
" " " urea
" " " ethanol

(b) Non-aquous solution → The solution prepared in solvent other than water like benzene (C_6H_6), carbontetrachlorid (CCl_4), chloroform ($CHCl_3$), carbondisulphide (CS_2) etc.

e.g:- $CCl_4 + I_2$

③

* On the basis of amount of solute :-

[1] Dilute solution → the solution in which amount of solute is very less than solvent is called dilute solution.

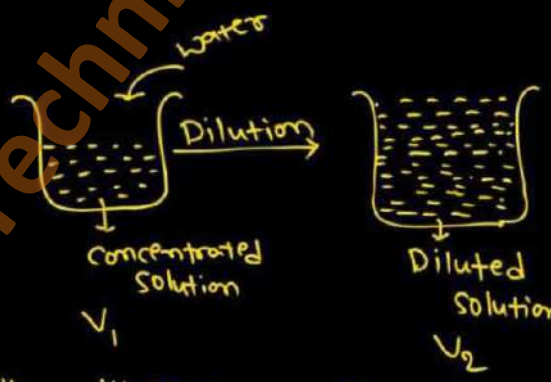
e.g:- 1000 mL water + 2 g sugar → dil. solution.

④

[2] Concentrated solution → the solution in which amount of solute is large in comparision to dilute solⁿ is called concentrated solⁿ

1000 g water + 15 g water → solⁿ

Dilution → the process of addition of water to concentrated solⁿ.



⑤

$(V_2 > V_1)$

* Upon dilution, vol. of solution increases but concentration of solution decreases.

* **Saturated solution** → No more solute dissolve in saturated solⁿ.

* **Super saturated solution** → When saturated solution is heated then more solute can dissolve thus super saturated solution is formed.

Concentration of solution → (6)

the unknown amount of solute is added to known amount of solvent or solution is called concentration of solution.

Units of concentration of solution:-

[1] Molarity [2] Mobility [3] Normality.

Molarity.

the no. of mol of solute dissolved in 1L of solution is called molarity.

* It is denoted by (M).
* Unit → $mol\,L^{-1}$ or M
* A solution whose concentration is (1M) called (molar solution) (7)

  1M solution = $1\,mol\,L^{-1}$ solution.

  i.e. 1 mol solute is dissolved in 1L of solution.
* A solution whose concentration is (0.1M) called (decimolar solution)

  i.e. $0.1\,mol\,L^{-1}$ solⁿ

  0.1 mol solute is dissolved in 1L solution.
* A solution whose conc^n is ($0.5\,mol\,L^{-1}$) called (semimolar solution.)

  i.e. ($0.5\,mol\,L^{-1}$)

Molarity of solution (8)

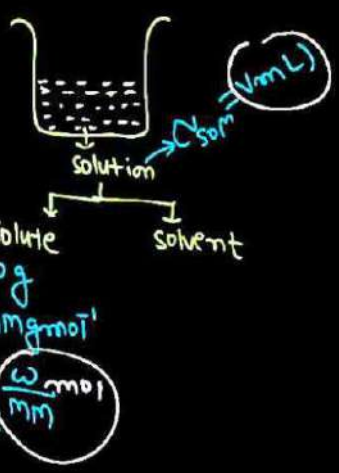
Let w g solute whose molar mass MM $g\,mol^{-1}$ is dissolved in V mL solution.

∵ (V mL) solⁿ contains ($\frac{w}{MM}$ mol) solute.

∴ 1 mL " " $\frac{w}{MM \times V}$ " ".

∴ (1000 mL) " " $\frac{w \times 1000}{MM \times V}$ " "

$$\therefore \text{Molarity} = \frac{w_{solute}(g) \times 1000}{MM_{solute}(g\,mol^{-1}) \times V_{soln}(mL)}$$



(1.) $M = \frac{\omega_{solute}(g) \times 1000}{mm_{solute}(g\,mol^{-1}) \times V_{som}(mL)}$

(2.) $M = \frac{\omega}{mm \times V_{som}(L)}$

(3.) $M = \frac{m_{solute}}{V_{som}(L)}$

(4.) $M = \frac{m_{solute} \times 1000}{V_{som}(mL)}$

9

Q. 500 mL aq. solution of NaOH contains 2g NaOH. Calculate molarity of solution.

Sol^n – $V_{som} = 500\,mL$

$\omega_{NaOH} = 2g$,

Molarity = ?

NaOH: 23 + 16 + 1 = 40 g mol^{-1}

$\therefore M = \frac{\omega_{NaOH} \times 1000}{mm_{NaOH} \times V_{som}(mL)} = \frac{\cancel{2} \times \cancel{1000}}{\cancel{40} \times \cancel{500}}\,mol\,L^{-1} = \frac{1}{10}\,mol\,L^{-1} = 0.1\,mol\,L^{-1}$

$\therefore$ Molarity of above som is $0.1\,mol\,L^{-1}$.

i.e. 0.1 mol NaOH is dissolved in 1 L of solution.

Normality

The no. of equivalent of solute present in 1L of solution is called normality.

* It is denoted by N.
* Unit → eqv. L^{-1} or g-eqv. L^{-1} or N
* 1 N solution is called normal solution.
* 1 N solution = 1 eqv. L^{-1}

  i.e. 1 eqv. of solute is present in 1L of solution.
* 0.1 N solution is called deci-normal solution.

  0.1 N solution = 0.1 eqv. L^{-1}

  i.e. 0.1 eqv. of solute present in 1L of solution.

* 0.5 N solution is called semi-normal solution.

  0.5 N solution.

  i.e. 0.5 eqv. L^{-1}

  0.5 eqv. of solute is present in 1L of solution.

* amount of solute
  - mass (g)
  - no. of mol: $n_{mol} = \frac{mass\,(g)}{Molar\,mass\,(g\,mol^{-1})}$
  - no. of eqv.: $n_{eq.} = \frac{\omega(g)}{Eq.\,mass\,(g\,eq^{-1})}$

Formula for normality

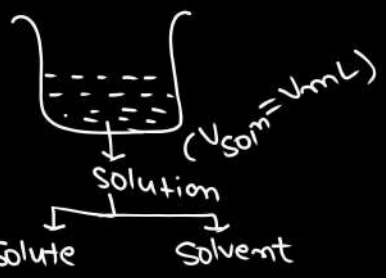
Let V mL solution contains ω g solute whose equivalent mass E_ω g eq^{-1}.

∴ V mL sol^n contains $\frac{\omega}{E_\omega}$ eqv. solute.

∴ 1 mL sol^n " $\frac{\omega}{E_\omega \times V}$ eqv. solute.

∴ 1000 mL (1 L) " " $\frac{\omega \times 1000}{E_\omega \times V}$ eqv. solute.

$$\therefore \text{Normality} = \frac{\omega_{solute}(g) \times 1000}{E_\omega (g\,eq^{-1}) \times V_{sol^n}(mL)}$$



mass → ω g

Eq. mass → E_ω g eq^{-1}

no. of eqv. → $n_{eq.} = \frac{\omega}{E_\omega}$ eq.

[1.] $N = \frac{\omega_{solute}(g) \times 1000}{E_\omega (g\,eq^{-1}) \times V_{sol^n}(mL)}$

[2.] $N = \frac{\omega}{E_\omega \times V_{sol^n}(L)}$

$$n_{eq.} = \frac{\omega(g)}{E_\omega (g\,eq^{-1})}$$

[3.] $N = \frac{n_{eq.}}{V_{sol^n}(L)}$

[4.] $N = \frac{n_{eq.} \times 1000}{V_{sol^n}(mL)}$

Q. 500 mL aq. solution of NaOH contains 4 g NaOH whose E_ω(NaOH) = 40 g eq^{-1}. Calculate normality of solution.

Sol^n Given, V_{sol^n} = 500 mL

ω_{NaOH} = 4 g

E_ω(NaOH) = 40 g eq^{-1}

N = ?

$$N = \frac{\omega_{solute}(g) \times 1000}{E_\omega (g\,eq^{-1}) \times V_{sol^n}(mL)}$$

$$= \frac{4 \times 1000}{40 \times 500}\ g\,eq^{-1} = 0.2\ eqv.\,L^{-1} \text{ or, } 0.2N$$

$E_\omega(\text{base}) = \frac{MM_{base}}{\text{Acidity}}$

$E_\omega(\text{Acid}) = \frac{MM_{Acid}}{\text{Basicity}}$

Molefraction (χ)

It is ratio of no. of mol of one component to the ratio of no. of mol of all components of solution.

e.g:- Sol^n → Solute, Solvent

no. of mol → n_1, n_2

mol fraction → χ_{solute}, $\chi_{solvent}$

$$\chi_{solute} = \frac{n_{solute}}{n_{solute}+n_{solvent}} = \frac{n_1}{n_1+n_2}$$

$$\chi_{solvent} = \frac{n_{solvent}}{n_{solute}+n_{solvent}} = \frac{n_2}{n_1+n_2}$$

$$\chi_{solute}+\chi_{solvent} = \frac{n_1+n_2}{n_1+n_2} = 1$$

* It has no unit.
* $\boxed{\chi_{solute}+\chi_{solvent}=1}$

Q. 2 g NaOH is added to 500 g water to form a solution. Calculate mole fraction of each component.

Sol^n:- Sol^n → NaOH, H_2O

mass → 2 g, 500 g

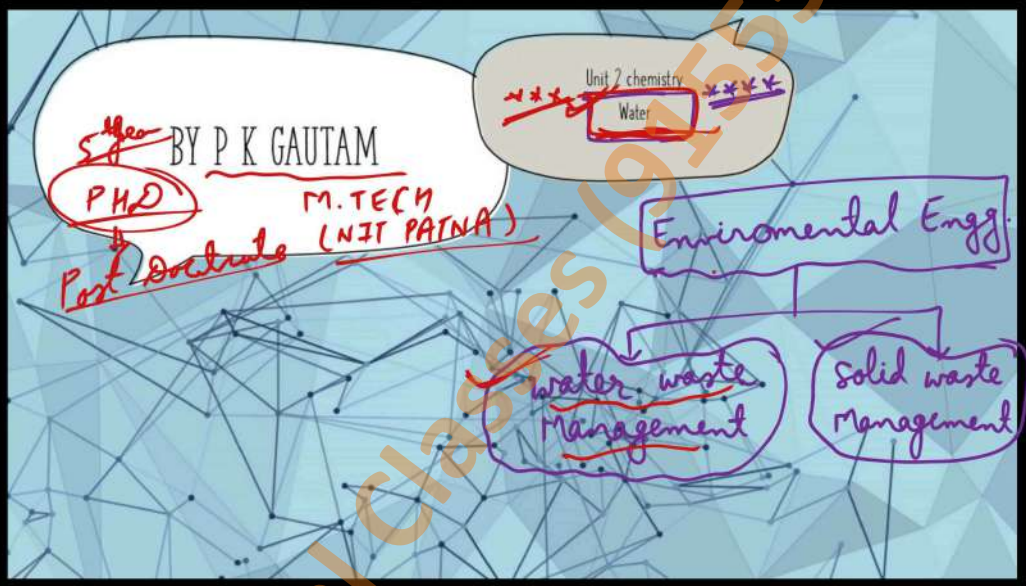
molar mass → $40\,g\,mol^{-1}$, $18\,g\,mol^{-1}$

NaOH: 23+16+1 = $40\,g\,mol^{-1}$

H_2O: 2×1+16 = $18\,g\,mol^{-1}$

Mole fraction of NaOH, $\chi_{NaOH} = \dfrac{\frac{2}{40}}{\frac{2}{40}+\frac{500}{18}}$

Similarly, $\chi_{H_2O} = \dfrac{\frac{500}{18}}{\frac{2}{40}+\frac{500}{18}}$, $\chi_{H_2O} = 1-\chi_{NaOH}$



SYLLABUS

Unit-2.0 Water	CO2
2.1 Introduction, Sources of Water, Hardness of Water- Temporary & Permanent hardness,	
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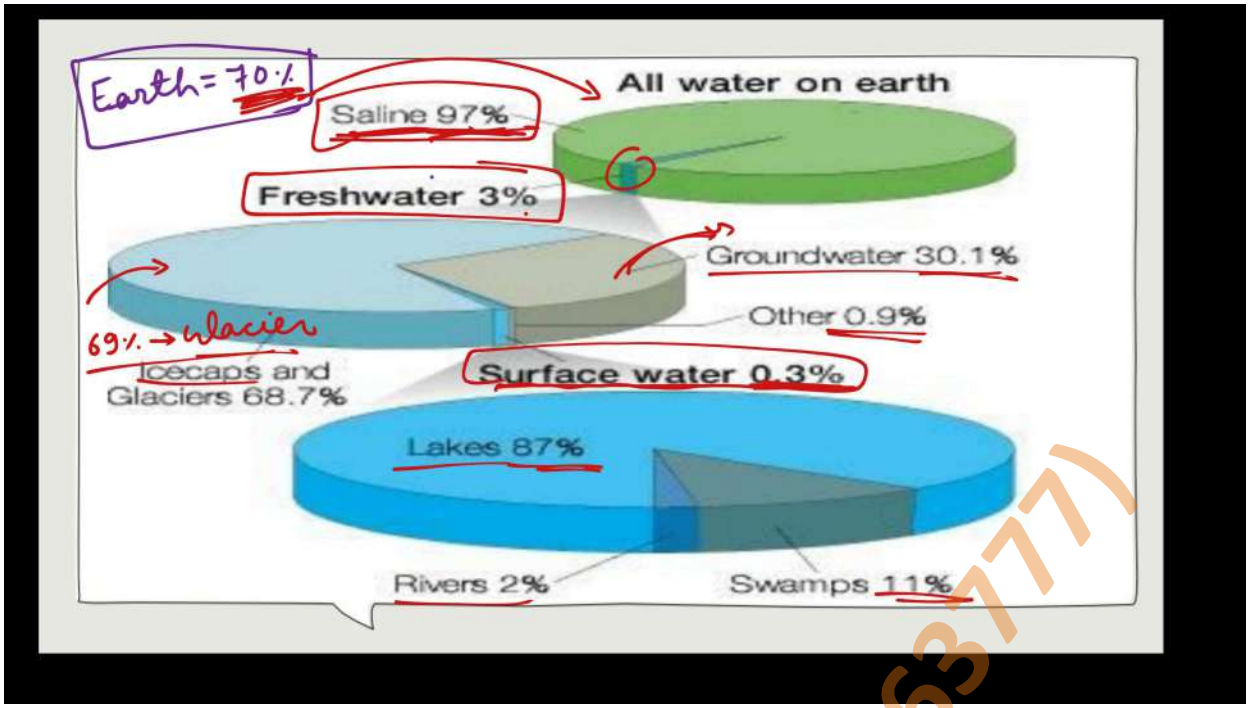
Numerical

BOD (COD)



2.1 INTRODUCTION

सबसे ज्यादा → जरूरी

- Water is the most abundant and essential natural resource.
- It covers nearly 70% of the earth surface .
- About 97% in the ocean and island which are not suitable for human consumption because of its high salt content.
- 2% is locked in the glacier and polar ice caps and only 1% is as available in fresh water in rivers, lakes, streams, reservoirs and grounds Water suitable for human consumption.

बर्फ

saline 97%
70%
70% पानी
R_e = 6370 km

- Water is composed of the chemical element hydrogen and oxygen and existing in liquid, Gas and Solid State. (ice)

H_2O ⇒ 2:1 → compound

River, water vapour

- Human beings, plants, animals and all other forms of life need water in one or more way and can't survive without it.

आर-पार देख सकते हैं → गंध नहीं, रंग

- Water (chemical formula H_2O) is an inorganic, transparent, odourless, and nearly colourless chemical substance, which is constituent of Earth's hydrosphere and the fluids of all known organism.

60-70%

$H_1 \rightarrow 1s^1$ (1)

$O_8 \rightarrow 1s^2\ 2s^2\ 2p^4$ (2, 6)

Hydrogen bond

H–O–H ⇒ H_2O

- Human body contains about 60% Water.
- It's PH value is 7. (Neutral) acidic < 7 < Basic

SOURCES OF WATER

The chief Source of water are :-

1. Surface water
2. Ground water
3. Rain water.

1. Surface water Sources:-

This includes lakes, ponds, reservoirs, streams, rivers, seas and oceans.

2. Underground water:-

This is the water source accumulated under the ground through the seepage. It obtained from wells, tube wells, Springs, etc.

Underground water is relatively free from suspended impurities because it is filtered as the water seepage through different layers Of soils. The filtration also remove the biological impurities.

3. Rain water:-

It is the purest form of water however rainwater during its downward path to the earth dissolves a considerable amount of industrial gases (like CO_2, SO_2, NO_2 etc) and suspended solid particles in the atmosphere.

- Use of water :- The different uses of water for industrial and domestic purposes are:-

1. Pharmaceutical industry:-These industries needs ultra pure water with should be colourless, tasteless odourless and free from pathogenic organism.
- Textile industry:-It needs frequent dyeing of cloths. So the water used by this industry should be soft and free from all type of organic matter.
- Boilers:-It require water of zero hardness otherwise efficient heat transfer is prevented by a scale formation.
- Laundries:-It require soft water, free from iron and colour. Because hardness consumption of soaps.
- Cooking:-
- Drinking:-
- Cleaning:-

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HARDNESS OF WATER

- Hardness in water is that characteristics." which prevents the lathering of soap".
- It is commonly defined as its shop consuming capacity.
- Generally soaps consist of sodium salt of higher fatty acids (soap = . C17H35COONa) (Sodium stearate).
- Consumption of soap by water is mainly due to the presence of dissolve calcium and magnesium ions.
- It is the concentration of multivalent cations in water.
- There are many multivalent Metallic ions in the water

Major source	Minor source
Ca2+ , Mg2+	Fe2+, Mn2+, Al3+ etc.

A typical reaction can be represented as following :-

$$\underset{\text{Soap}}{2C_{17}H_{35}COONa} + \underset{\text{(Hardness of water)}}{MgCl_2} \longrightarrow \underset{\text{White ppt.}}{(C_{17}H_{35}COO)_2Mg^{-}} + \underset{\text{Salt}}{2NaCl}$$

$$\underset{\text{Soap}}{2C_{17}H_{35}COONa} + \underset{\text{(Hardness of water)}}{CaCl_2} \longrightarrow \underset{\text{White ppt.}}{(C_{17}H_{35}COO)_2Ca^{-}} + \underset{\text{Salt}}{2NaCl}$$

TYPES OF HARDNESS

The hardness of water may be of two types:-

1. Temporary hardness (Bicarbonate hardness) Carbonate Hardness / Alkaline Hardness
2. Permanent hardness (Non carbonate hardness) or Non-Alkaline Hardness.

Boiling → × Slaked lime

Boiling → ✓ RO/ion-Exchange mtd/Zeolite Mtd.

TEMPORARY HARDNESS

This types of hardness is due to the presence of bicarbonate ions of calcium and magnesium.

It can be removed by —

$Ca(HCO_3)_2$

$Mg(HCO_3)_2$

1. Boiling :-

when water is boiled, bicarbonates are decomposed to carbonates and carbon dioxide which are deposited as a crust at the bottom of vessel.

$Ca(HCO_3)2 \rightarrow CaCO_3 + CO_2 + H_2O$

$Mg(HCO_3)2 \rightarrow MgCO_3 + CO_2 + H_2O$

$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3\downarrow\downarrow + CO_2\uparrow + H_2O$ (ppt)

$Mg(HCO_3)_2 \xrightarrow{\Delta} MgCO_3\downarrow\downarrow + CO_2\uparrow + H_2O$ (ppt) (gas)

*****

2. Clark 's process:- Clark's process is used to remove Temporary Hardness.

Calcium hydroxide is Clark's reagent. It removes the hardness of water by converting bicarbonates into carbonate.

Reaction:

$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2CaCO_3 + 2H_2O$

$Ca(OH)2$ (slaked lime) + $Ca(HCO_3)_2 \rightarrow 2CaCO_3 + 2H_2O$

2. PERMANENT HARDNESS

- This type of hardness is due to the presence of dissolved chloride and sulphates of calcium and magnesium .
- it cannot be removed by boiling but it can be removed by-

1. lime soda, 2. Zeolite 3. ion exchange and 4. Permutit methods.

E.g. $CaCl_2$, $MgCl_2$, $CaSO4$ $MgSO4$

$CaSO_4 / CaCl_2$

$MgSO_4 / MgCl_2$

Boil → $CaCO_3$, $MgCO_3$ ← $Ca(HCO_3)_2$, $Mg(HCO_3)_2$ → Temporary

Ca^{+2} Mg^{+2} → (HCO_3)

Ca^{+2} / Mg^{+2} → SO_4^{-2} / Cl^{-1} → Permanent

COMPARISON BETWEEN TEMPORARY HARDNESS AND PERMANENT HARDNESS:-

Temporary hardness	Permanent hardness
1. Carbonate or alkaline hardness	1Non-Carbonate hardness or Non-alkaline hardness
2. It is due to the presence of bicarbonate of ca/mg or Carbonate of Mg.	2.It is due to presence of dissolved chlorides, sulphates of ca/ Mg. .
3. It can be removed by boiling.	.3. It can not removed by boiling.
4. Hardness removal is cheap	4. Hardness removal is expensive

2.2

Degree of Hardnes :-

The concentration of hardness as well as none hardness constituting ions are usually expressed in terms of equivalent amount of calcium carbonate (CaCO3).

The reason for choosing calcium carbonate ($CaCO_3$)as the standard for reporting hardness of water is the ease in calculation as its molecular weight is exactly 100 and it is the most insoluble salt that can be precipitated in water treatment.

UNITS OF HARDNESS:-

- Hardness of water is expressed in one of the following units:-

1. Parts per million (ppm):-It is the parts of calcium carbonate(CaCO3) equivalent hardness per 10^-6 parts water.

2. Milligrams per litre(mg/L):-It is defined as the number of milligram of CaCO3 present in 1 litre of water.
3. Clarke's degree: It is part of (CaCO3) equivalent hardness per 70000 parts of water. 1°Clark =1 grain of (CaCO3). Equivalent hardness per gallon of water.

4. Degree French (Fr):-It is the part of (CaCO3). Equivalent hardness per 10^-5 parts of water.

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- Hardness in water is that characteristics." which prevents the lathering of soap".
- It is commonly defined as its shop consuming capacity.
- Generally soaps consist of sodium salt of higher fatty acids (soap = . C17H35COONa) (Sodium stearate).
- Consumption of soap by water is mainly due to the presence of dissolve calcium and magnesium ions.
- It is the concentration of multivalent cations in water.
- There are many multivalent Metallic ions in the water

Major source	Minor source
Ca2+ , Mg2+	Fe2+, Mn2+, Al3+ etc.

Ca^{+2}, Mg^{+2}

Bicarbonate

$C_{17}H_{35}COO^-Na$

Sodium stearate

TYPES OF HARDNESS

The hardness of water may be of two types:-

1. Temporary hardness (Bicarbonate hardness)
2. Permanent hardness (Non carbonate hardness)

TEMPORARY HARDNESS

This types of hardness is due to the presence of bicarbonate ions of calcium and magnesium.

It can be removed by

1. Boiling :-

$Ca(HCO_3)_2$
$Mg(HCO_3)_2$

when water is boiled, bicarbonates are decomposed to carbonates and carbon dioxide which are deposited as a crust at the bottom of vessel.

$Ca(HCO_3)_2 \xrightarrow{\Delta} CaCO_3 \downarrow + CO_2 \uparrow + H_2O$

soluble → insoluble (PPt)

$Ca(HCO_3)2 \rightarrow CaCO_3 + CO_2 + H_2O$

$Mg(HCO_3)2 \rightarrow MgCO_3 + CO_2 + H_2O$

2. Clark 's process:- Clark's process is used to remove Temporary Hardness.

Calcium hydroxide is Clark's reagent. It removes the hardness of water by converting bicarbonates into carbonate.

Reaction:

$Ca(OH)2$ (slaked lime) + $Ca(HCO_3)_2 \rightarrow 2CaCO_3 + 2H_2O$

2. PERMANENT HARDNESS

This type of hardness is due to the presence of dissolved chloride and sulphates of calcium and magnesium .

it cannot be removed by boiling but it can be removed by-

1. lime soda, 2. Zeolite and 3. ion exchange and 4. Permutit methods.

E.g. $CaCl_2$, $MgCl_2$, $CaSO_4$ $MgSO_4$

COMPARISON BETWEEN TEMPORARY HARDNESS AND PERMANENT HARDNESS:-

Temporary hardness	Permanent hardness
It is also known as —	It is also known as
1. Carbonate or alkaline hardness	1.Non-Carbonate hardness or Non-alkaline hardness
2. It is due to the presence of bicarbonate of ca/mg or Carbonate of Mg.	2.It is due to presence of dissolved chlorides, sulphates of ca/ Mg.
3. It can be removed by boiling.	3. It can not removed by boiling. → RO, ion exchange, zeolite
4. Hardness removal is cheap	4. Hardness removal is expensive

SYLLABUS

Unit-2.0 Water	CO2
2.1 Introduction, Sources of Water. Hardness of Water- Temporary & Permanent hardness.	
2.2 Degree of Hardness (In terms of CaCO3 equivalent), Unit of Hardness, Quantitative Measurement of Water Hardness by EDTA method.	
2.3 Municipal supply of Water, Treatment of water, Water Softening Technique-Soda Lime Process, Zeolites method and ion exchange method,	
2.4 Water Quality Index - Biological Oxygen Demand, Chemical Oxygen Demand, Determination of Dissolved Oxygen	
2.5 Indian standard specification of drinking water.	

COMPARISON BETWEEN TEMPORARY HARDNESS AND PERMANENT HARDNESS:-

Temporary hardness	Permanent hardness
1. Carbonate or alkaline hardness	1.Non-Carbonate hardness or Non-alkaline hardness
2. It is due to the presence of bicarbonate of ca/mg or Carbonate of Mg.	2..It is due to presence of dissolved chlorides, sulphates of ca/ Mg. .
3. It can be removed by boiling.	.3. It can not removed by boiling.
4. Hardness removal is cheap	4. Hardness removal is expensive

2.2

- DEGREE OF HARDNESS :- ($CaCO_3$)
- THE CONCENTRATION OF HARDNESS AS WELL AS NONE HARDNESS CONSTITUTING IONS ARE USUALLY EXPRESSED IN TERMS OF EQUIVALENT AMOUNT OF CALCIUM CARBONATE ($CaCO_3$).
- THE REASON FOR CHOOSING CALCIUM CARBONATE ($CaCO_3$) AS THE STANDARD FOR REPORTING HARDNESS OF WATER IS THE EASE IN CALCULATION AS ITS MOLECULAR WEIGHT IS EXACTLY 100 AND IT IS THE MOST INSOLUBLE SALT THAT CAN BE PRECIPITATED IN WATER TREATMENT.

$CaCO_3 \downarrow + CO_2 \uparrow + H_2O$

$CaCO_3$ — Insoluble

Molecular wt $= 40 + 12 + (16 \times 3)$
$= 40 + 12 + 48$
$= 100$

Equivalent wt $= \frac{100}{2} = 50$

$CaSO_4$, $CaCl_2$, $MgSO_4$, $MgCl_2$

UNITS OF HARDNESS:-

- HARDNESS OF WATER IS EXPRESSED IN ONE OF THE FOLLOWING UNITS:-
  1. PARTS PER MILLION (PPM):-IT IS THE PARTS OF CALCIUM CARBONATE($CaCO_3$) EQUIVALENT HARDNESS PER 10^6 PARTS WATER.
  2. MILLIGRAMS PER LITRE(MG/L):-IT IS DEFINED AS THE NUMBER OF MILLIGRAM OF $CaCO_3$ PRESENT IN 1 LITRE OF WATER.
  3. CLARKE'S DEGREE: IT IS PART OF ($CaCO_3$) EQUIVALENT HARDNESS PER 70000 PARTS OF WATER. 1°CLARK =1 GRAIN OF ($CaCO_3$). EQUIVALENT HARDNESS PER GALLON OF WATER.
  4. DEGREE FRENCH (FR):-IT IS THE PART OF ($CaCO_3$). EQUIVALENT HARDNESS PER 10^5 PARTS OF WATER.

$$\frac{?\,(CaCO_3)}{10^6 \text{ part of Hard water}} = \frac{mg\,(CaCO_3)}{1 \text{ lit of Hard water}} = \frac{?\,(CaCO_3)}{70{,}000 \text{ of Hard water part}} = \frac{?\,(CaCO_3)}{10^5 \text{ part of water}}$$

ppm, mg/lit, clarck, French

$$\frac{1}{10^6} = \frac{1}{10^5} F$$

$$\Rightarrow F = \frac{1}{10} \text{ ppm}$$

$$\boxed{F = 0.1 \text{ ppm}}$$

$$? \frac{1}{10^6} = \frac{1}{70{,}000}$$

$$? \text{ ppm} = \frac{10^6}{70{,}000}$$

$$C = \frac{10^6}{10{,}000} \text{ ppm}$$

$C = 0.07$ ppm

ppm

$$\frac{?\text{ of }(CaCO_3)}{10^6 \text{ part of Hard water}}$$

mg/lit

$$\frac{mg\text{ of }(CaCO_3)}{1 \text{ lit of Hard water}}$$

clarck

$$\frac{?\text{ of }(CaCO_3)}{70{,}000 \text{ part of Hard water}}$$

French

$$\frac{?\text{ of }(CaCO_3)}{10^5 \text{ part of Hard water}}$$

$$\boxed{F = P}$$

$$\frac{?\,(CaCO_3)}{10^5} = \frac{?\,(CaCO_3)}{10^6}$$

$$F = \frac{10^5}{10^6} P$$

$$F = 10^{-1} \text{ ppm} \Rightarrow \boxed{P = 10F}$$

$$\boxed{F = 0.1 \text{ ppm}}$$

$$\frac{\text{ppm}}{\frac{?\text{ of }(CaCO_3)}{10^6}} = \frac{C}{\frac{?\text{ of }(CaCO_3)}{70{,}000}}$$

$$\boxed{P = \frac{10^6}{70{,}000} C}$$

$$\Rightarrow C = \frac{70{,}000}{10^6} \text{ ppm}$$

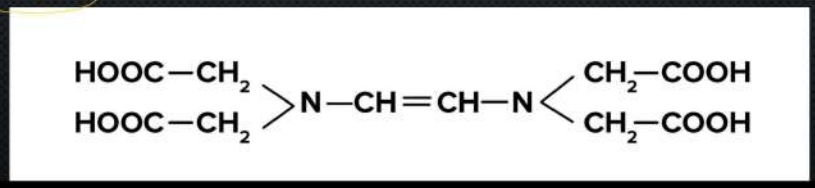
$$\boxed{C = 0.07 \text{ PPM}}$$

EDTA METHOD :-

EDTA EBT

- A METHOD WHICH IS USED TO DETERMINE THE TOTAL HARDNESS OF WATER.
- EDTA STANDS FOR ETHYLENE DIAMINE TETRA-ACETIC ACID.
- IT IS A STRONG COMPLEXING AGENT WHOSE STRUCTURE IS GIVEN BELOW:

EDTA



CHEMICAL USED IN EDTA PROCESS :-

- 1. SAMPLE OF HARD WATER
- 2. SAMPLE OF STANDARD WATER
- 3. EDTA
- 4. EBT (ERIOCHROME BLACK T)AS AN INDICATOR
- 5. BUFFER SOLUTION CONTAINING NH4CL-NH4OH OH PH 10

- EDTA DISSOLVE IN WATER WITH GREAT DIFFICULTY AND IN A VERY SMALL QUANTITY, HENCE FOR COMMON EXPERIMENT PURPOSE, IN PLACE OF EDTA , IT'S DISODIUM DERIVATIVE IS USED.

WORKING PROCESS

- VARIOUS STEPS INVOLVED IN THIS METHODS ARE:-

1. PREPARING OF STANDARD WATER SOLUTIONS:-ONE GM OF PURE CACO3 IS DISSOLVED IN MINIMUM QUANTITY OF HCL AND THE SOLUTION IS EVAPORATED TO DRYNESS OVER A HOT WATER BATH. THE RESIDUE DISSOLVED IN DISTILLED WATER AND THE SOLUTION IS MADE UP TO ONE LITRE.
2. PREPARING OF STANDARD BUFFER SOLUTIONS:-ADD 6.75 GM OF NH4CL TO 570 ML OF CONCENTRATED AMMONIA , MIX THE SOLUTION WELL AND THEN DILUTE TO 1 LITRE BY ADDING DISTILLED WATER.

- 3. PREPARING OF INDICATOR:- DISSOLVE 0.5GM OF EBT IN 100ML OF ALCOHGRAM
- 4.PREPARING OF STANDARDISATION OF EDTA SOLUTIONS:-DISSOLVE ABOUT 4 GRAM OF PURE EDTA CRYSTALS AND 0.1 GRAM OF MGCL2 IN ONE LITRE OF DISTILLED WATER RINESS AND FEEL THE BURETTE WITH EDTA SOLUTION. PIPETTE OUT 50 ML OF STANDARD HARD WATER IN A CANONICAL FLASK. ADD 10- 12 ML OF BUFFER SOLUTION AND 4-5 DROP OF THE INDICATOR WITH EDT SOLUTION TILL BINE RED COLOUR CHANGES TO BLUE .

- TITRATION OF PERMANENT HARDNESS:-TAKE 250 ML OF THE WATER SAMPLE IN A BEAKER. BOIL IT ,TILL THE VOLUME IS REDUCED TO ABOUT 50 ML [TO CONVERT ALL BICARBONATE TO CARBONATES]FILTER, WASH THE PRECIPITATED WITH DISTILLED WATE COLLECTING FILTRATE AND WASHING IN 250 ML MEASURING FLASK. FINALLY MAKE U THE VOLUME TO 250ML WITH DISTILLED WATER. TITRATE 50ML OF THIS SOLUTION AGAINST EDTA SOLUTION USING EBT AS INDICATOR LET V3 ML OF EDTA IS USED .

2.2

- DEGREE OF HARDNESS :-
- THE CONCENTRATION OF HARDNESS AS WELL AS NONE HARDNESS CONSTITUTING IONS ARE USUALLY EXPRESSED IN TERMS OF EQUIVALENT AMOUNT OF CALCIUM CARBONATE (CACO3).
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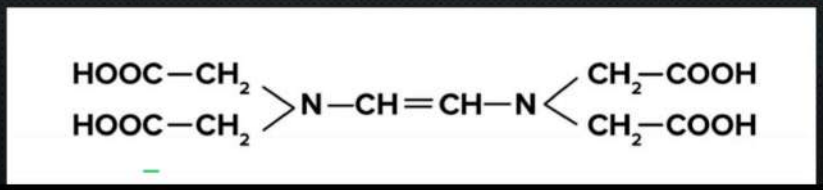
- 4. DEGREE FRENCH (FR):-IT IS THE PART OF (CACO3). EQUIVALENT HARDNESS PER 10^5 PARTS OF WATER.

EDTA METHOD :-

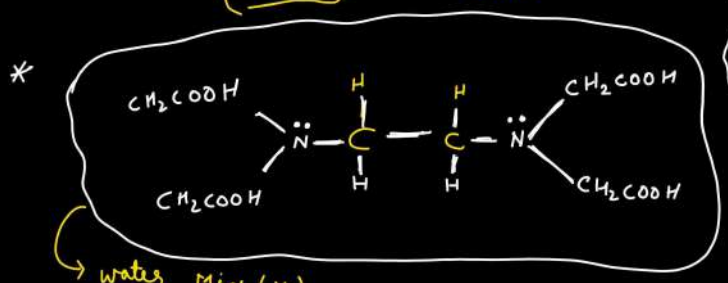
EDTA stands form
Ethylene Diamine Tetra Acetic acid
NH_2 (4) (CH_3COOH)

- A METHOD WHICH IS USED TO DETERMINE THE TOTAL HARDNESS OF WATER.
- EDTA STANDS FOR ETHYLENE DIAMINE TETRA-ACETIC ACID.
- IT IS A STRONG COMPLEXING AGENT WHOSE STRUCTURE IS GIVEN BELOW:



EDTA → Ethylene Diamine Tetra Acitic acid.

$CH_2 = CH_2$ — $-NH_2$ — $-CH_2-COOH$

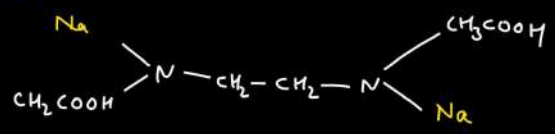


→ water Mix (X)

Na-salt EDTA

⇓

Soluble.



- It is a Titration mtd.
- It is used for calculation of hardness.
- In EDTA four types of solⁿ is used -

(I) Standard Hard water solⁿ.

($1g\ CaCO_3$ + Hcl = (very small amount)

dry powder → Hot water boiled → 1lit Distilled water

(II) EDTA solⁿ → Distilled water + 3-4 ml EDTA

(III) Indicator solution → EBT → $P_H = 10$

(IV) Buffer solution

Acid ($P_H < 7$) — P_H ~~change~~ — Base ($P_H > 7$)

P_H X change

$NH_4Cl + NH_4OH + EBT + EDTA$

originally water = colorless

+ EBT ⇒ Blue (Hardness)

+ EDTA ⇒ Red wine (Hardness) X

CHEMICAL USED IN EDTA PROCESS :-

- 1. SAMPLE OF HARD WATER
- 2. SAMPLE OF STANDARD WATER
- 3. EDTA
- 4. EBT (ERIOCHROME BLACK T) AS AN INDICATOR
- 5. BUFFER SOLUTION CONTAINING NH4CL-NH4OH OF PH 10

- EDTA DISSOLVE IN WATER WITH GREAT DIFFICULTY AND IN A VERY SMALL QUANTITY, HENCE FOR COMMON EXPERIMENT PURPOSE, IN PLACE OF EDTA , IT'S DISODIUM DERIVATIVE IS USED.

WORKING PROCESS

- VARIOUS STEPS INVOLVED IN THIS METHODS ARE:-

1. PREPARING OF STANDARD WATER SOLUTIONS:-ONE GM OF PURE CACO3 IS DISSOLVED IN MINIMUM QUANTITY OF HCL AND THE SOLUTION IS EVAPORATED TO DRYNESS OVER A HOT WATER BATH. THE RESIDUE DISSOLVED IN DISTILLED WATER AND THE SOLUTION IS MADE UP TO ONE LITRE.
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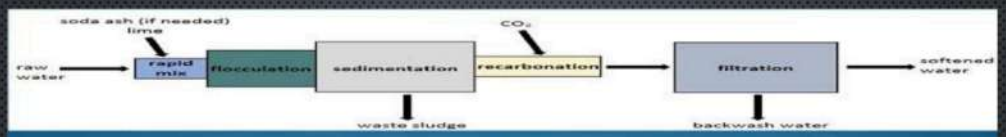
- TITRATION OF PERMANENT HARDNESS:-TAKE 250 ML OF THE WATER SAMPLE IN A BEAKER. BOIL IT ,TILL THE VOLUME IS REDUCED TO ABOUT 50 ML [TO CONVERT ALL BICARBONATE TO CARBONATES]FILTER, WASH THE PRECIPITATED WITH DISTILLED WATE COLLECTING FILTRATE AND WASHING IN 250 ML MEASURING FLASK. FINALLY MAKE U THE VOLUME TO 250ML WITH DISTILLED WATER. TITRATE 50ML OF THIS SOLUTION AGAINST EDTA SOLUTION USING EBT AS INDICATOR LET V3 ML OF EDTA IS USED .

METHODS USED IN PERMANENT HARDNESS:-

1. **LIME SODA PROCESS. :-**

- **LIME SODA PROCESS IS A METHOD OF SOFTENING HARD WATER.**
- **THIS PROCESS IS NOW OBSOLETE BUT WAS VERY USEFUL FOR THE TREATMENT OF LARGE VOLUMES OF HARD WATER.**
- **IN THIS PROCESS CALCIUM AND MAGNESIUM IONS ARE PRECIPITATED BY THE ADDITION OF LIME (CA(OH)2) AND SODA ASH (NA2CO3).**



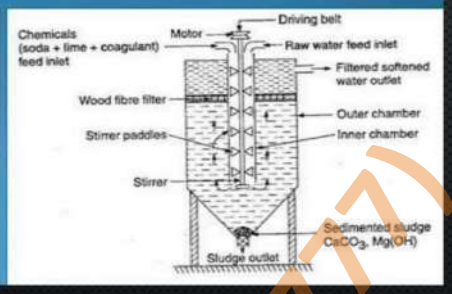
Lime Soda Process

$$MgSO_4 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaSO_4$$

$$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + Na_2SO_4$$

$$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3\downarrow + 2NaCl$$

$$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaCl_2$$



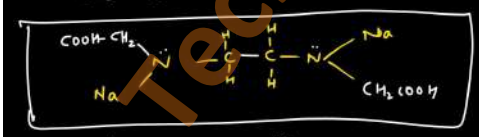
SYLLABUS

Unit-2.0 Water	CO2
2.1 Introduction, Sources of Water. Hardness of Water- Temporary & Permanent hardness.	
2.2 Degree of Hardness (In terms of CaCO3 equivalent), Unit of Hardness, Quantitative Measurement of Water Hardness by EDTA method.	
2.3 Municipal supply of Water, Treatment of water, Water Softening Technique-Soda Lime Process, Zeolites method and ion exchange method,	
2.4 Water Quality Index - Biological Oxygen Demand, Chemical Oxygen Demand, Determination of Dissolved Oxygen	
2.5 Indian standard specification of drinking water.	

EDTA Method :-

Ethylene Diamine Tetra acetic acid

$CH_2 = CH_2$ $\quad$ $2\,NH_3$ $\quad$ $4\,CH_3COOH$



Bi-Sodium-EDTA salt

Titration

(i) EDTA (standard)

(ii) EBT solution (Indicator solⁿ)

Eriochrome Black-T

$P_H = 10$

Hardness + EBT = Red wine

Hardness + EBT = Blue

(iii) Buffer solⁿ

(NH_4Cl + $NH_4(OH)$ + EBT + EDTA)

acid $\quad$ Base $\quad$ (P_H = const.)

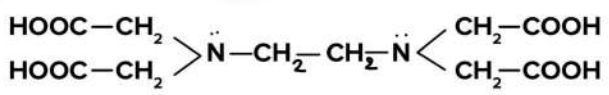
(iv) Hard water

EDTA METHOD :-

- A METHOD WHICH IS USED TO DETERMINE THE TOTAL HARDNESS OF WATER.
- EDTA STANDS FOR ETHYLENE DIAMINE TETRA-ACETIC ACID
- IT IS A STRONG COMPLEXING AGENT WHOSE STRUCTURE IS GIVEN BELOW:

Titration

EDTA

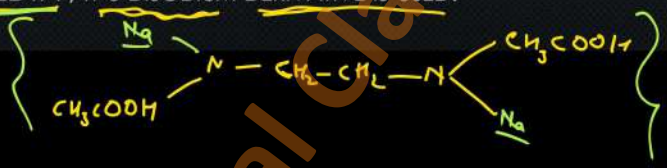


CHEMICAL USED IN EDTA PROCESS :-

1. SAMPLE OF HARD WATER
2. SAMPLE OF STANDARD WATER
3. EDTA
4. EBT (ERIOCHROME BLACK T) AS AN INDICATOR — PH = 10 — Blue — Hardness = Redwine
5. BUFFER SOLUTION CONTAINING NH4CL-NH4OH — PH 10 → constant

NH_4Cl, NH_4OH, EDTA, EBT

- EDTA DISSOLVE IN WATER WITH GREAT DIFFICULTY AND IN A VERY SMALL QUANTITY, HENCE FOR COMMON EXPERIMENT PURPOSE, IN PLACE OF EDTA , IT'S DISODIUM DERIVATIVE IS USED.



WORKING PROCESS

1g $CaCO_3$ + HCl → Powder → Hot water

- VARIOUS STEPS INVOLVED IN THIS METHODS ARE:-

1. PREPARING OF STANDARD WATER SOLUTIONS:-ONE GM OF PURE CACO3 IS DISSOLVED IN MINIMUM QUANTITY OF HCL AND THE SOLUTION IS EVAPORATED TO DRYNESS OVER A HOT WATER BATH. THE RESIDUE DISSOLVED IN DISTILLED WATER AND THE SOLUTION IS MADE UP TO ONE LITRE. 1 lit.

   $CaCO_3$

2. PREPARING OF STANDARD BUFFER SOLUTIONS:-ADD 6.75 GM OF NH4CL TO 570 ML OF CONCENTRATED AMMONIA, MIX THE SOLUTION WELL AND THEN DILUTE TO 1 LITRE BY ADDING DISTILLED WATER.

Buffer sol^n ⇒ P_H = const.

- NH_4Cl → 6.75 gm
- NH_4OH → 570 ml
- EBT
- EDTA

Distilled water = 1 lit

① Preparation of standard solⁿ:-

1g $CaCO_3$ + Minᵐ(HCl) = dry → Evaporate

Solid lid Hot water bath

dry + Distilled water

⇓

1 lit

⇓

standard solⁿ

- 3. PREPARING OF INDICATOR:- DISSOLVE 0.5GM OF EBT IN 100ML OF ALCOHOLAM

EBT = 0.5g + 100ml

- 4.PREPARING OF STANDARDISATION OF EDTA SOLUTIONS:-DISSOLVE ABOUT 4 GRAM OF PURE EDTA CRYSTALS AND 0.1 GRAM OF MGCL2 IN ONE LITRE OF DISTILLED WATER RINESS AND FEEL THE BURETTE WITH EDTA SOLUTION. PIPETTE OUT 50 ML OF STANDARD HARD WATER IN A CANONICAL FLASK. ADD 10- 12 ML OF BUFFER SOLUTION AND 4-5 DROP OF THE INDICATOR WITH EDT SOLUTION TILL BINE RED COLOUR CHANGES TO BLUE .

4gm EDTA + 0.1 $MgCl_2$ = 1lit Distilled

10-12 gm

4-5 drop (EBT)

TITRATION OF PERMANENT HARDNESS:-TAKE 250 ML OF THE WATER SAMPLE IN A BEAKER. BOIL IT ,TILL THE VOLUME IS REDUCED TO ABOUT 50 ML [TO CONVERT ALL BICARBONATE TO CARBONATES]FILTER, WASH THE PRECIPITATED WITH DISTILLED WATER, COLLECTING FILTRATE AND WASHING IN 250 ML MEASURING FLASK. FINALLY MAKE UP THE VOLUME TO 250ML WITH DISTILLED WATER. TITRATE 50ML OF THIS SOLUTION AGAINST EDTA SOLUTION USING EBT AS INDICATOR LET V3 ML OF EDTA IS USED .

Calculation

STEP-1

Standardisation of EDTA solution :- since 1 ml of standard hard water contains 1 mg of hardness causing substance in terms of CaCO3. 50 ml of standard hard water contains 50 mg of CaCO, So,50 ml of standard hard water V, ml of EDTA solution V, mi of EDTA solution=50 mg of CaCO, 1ml of EDTA solution=50/V, mg of $CaCO_3$.

Step-2

Determination of total hardness of water :- Since 1ml of EDTA solution=50/V, mg of $CaCO_3$ V2ml of EDTA solution=50° V2/V_1mg of CaCO Thus 50 ml Of water sample contains 50 V2/V_1mg of CaCO 1000 ml of water contains=50" V 2*1000/V,*50mg of CaCO Total Hardness =V2/V, 1000 ppm

- Step-3
- Determination of parmanent hardness of water:- Now applying the above steps and replacing V2 by V3 We get permanent hardness $=V2/V_1$ *1000 ppm
- Step :- 4
- Determination of temporary hardness:-
- We know, Temporary Hardness Total Hardness-Permanent hardness Temporary Hardness (V2/V1)* 1000-(V3/v1)*1000 , ppm.

Methods used in permanent hardness:-

1. Lime soda process. :-

- Lime Soda process is a method of softening hard water.
- This process is now obsolete but was very useful for the treatment of large volumes of hard water.
- In this process Calcium and Magnesium ions are precipitated by the addition of lime (Ca(OH)2) and soda ash (Na2CO3).

SYLLABUS

Unit-2.0 Water

2.1 Introduction, Sources of Water. Hardness of Water- Temporary & Permanent hardness.

2.2 Degree of Hardness*(In terms of CaCO3 equivalent), Unit of Hardness, Quantitative Measurement of Water Hardness by EDTA method,

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2.4 Water Quality Index - Biological Oxygen Demand, Chemical Oxygen Demand, Determination of Dissolved Oxygen

2.5 Indian standard specification of drinking water

2.3 MUNICIPAL SUPPLY OF WATER

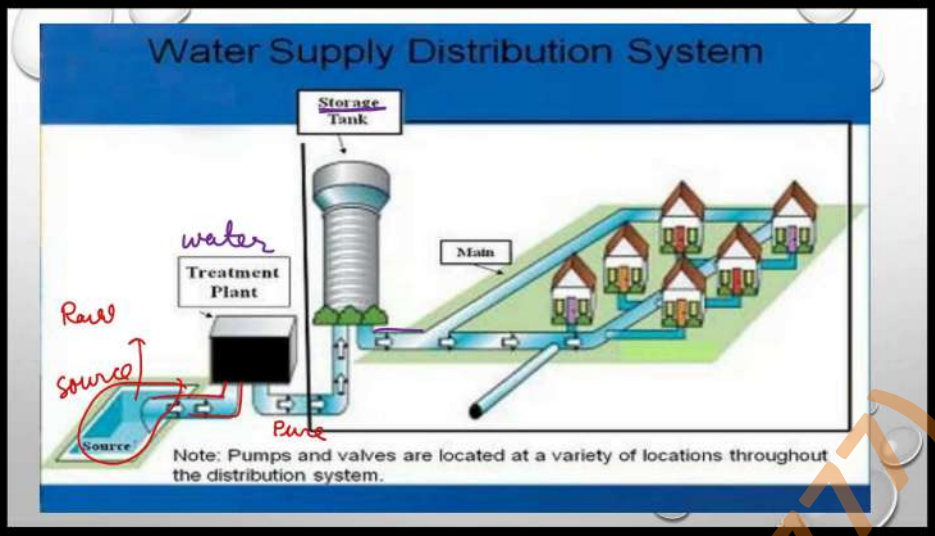
- THE COMMON REQUIREMENTS FOR POTABLE WATER ARE –
  - IT SHOULD BE CLEAR, COLOURLESS, FREE FROM SOLIDS.
  - IT SHOULD HAVE GOOD TASTE AND SHOULD BE ODOURLESS.
  - IT SHOULD BE SOFT
  - IT SHOULD BE ABUNDANT AND CHEAP.
  - ORGANISM AND DISEASE PRODUCING BACTERIA SHOULD NOT BE PRESENT
  - IT SHOULD NOT HAVE OBJECTIONABLE DISSOLVED GASES BUT SUFFICIENT DISSOLVED OXYGEN SHOULD BE PRESENT
  - IT SHOULD BE FREE FROM HARMFUL METALLIC
  - RADIOACTIVE SUBSTANCE SHOULD NOT BE PRESENT
  - IT SHOULD BE FREE FROM FLUORIDES, CHLORIDES AND PHENOLIC COMPOUNDS
  - CORROSIVE METALS SHOULD NOT EXIST

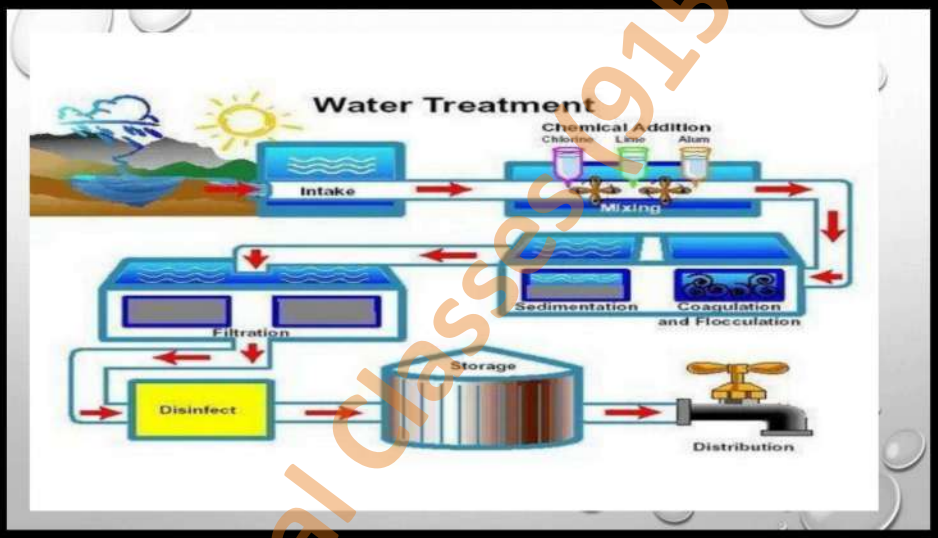
WHY WE NEED MUNICIPAL SUPPLY

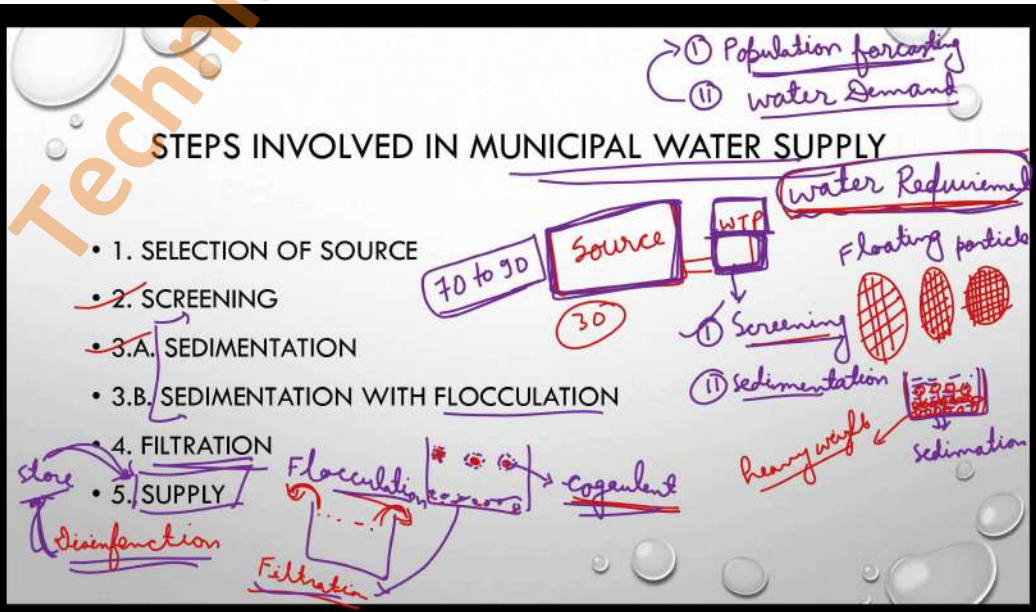
- VILLAGE – LESS POPULATION - LESS REQUIREMENT- TUBE WELLS
- TOWN – MORE POPULATION DENSITY- HIGH WATER REQUIREMENT- MUNICIPAL SUPPLY IS NEEDED.

MUNICIPAL WATER SUPPLY SYSTEM:-

- MUNICIPAL WATER SUPPLY SYSTEM IS ALSO KNOWN AS PUBLIC WATER SUPPLY SYSTEM
- IT INCLUDES WATER TREATMENT FACILITIES, WATER STORAGE FACILITY AND A PIPE NETWORK FOR DISTRIBUTING THE TREATED WATER TO CONSUMERS INCLUDING RESIDENTIAL, INDUSTRIAL OR COMMERCIAL PURPOSES.







1. SOURCE

- SOURCE REFERS TO SOURCE OF WATER SUCH AS RIVERS, STREAM, LAKES, RESERVOIRS, SPRING AND GROUND WATER THAT PROVIDE WATER TO SUPPLY.
- Source are selected such that they can full fill the water demand for at least 50 to 70 years.

8 to 10

SYLLABUS

Unit-2.0 Water

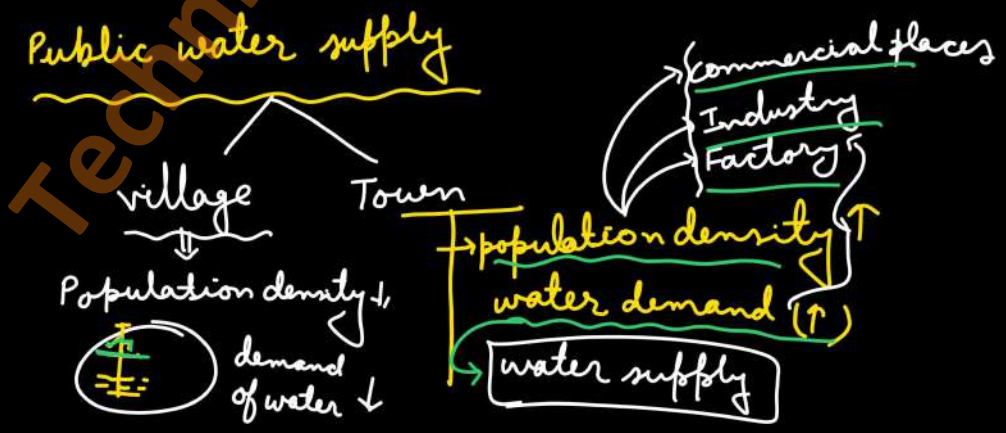
2.1 Introduction, Sources of Water. Hardness of Water- Temporary & Permanent hardness.

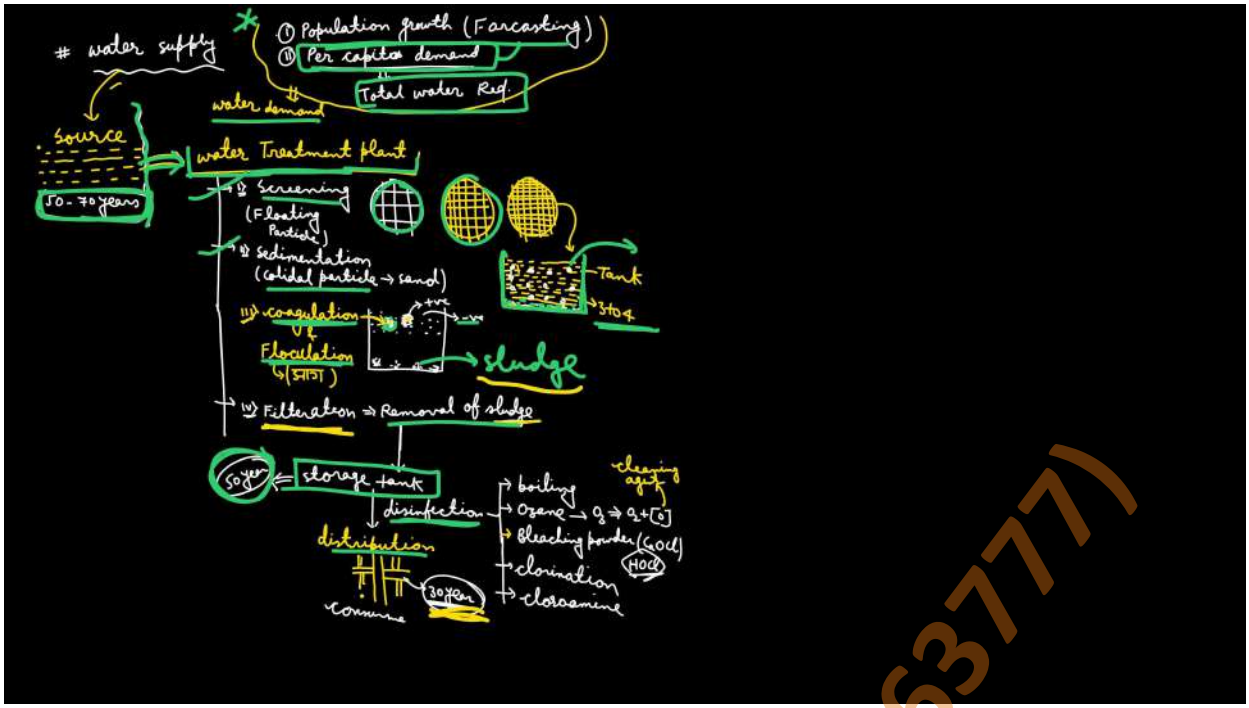
2.2 Degree of Hardness (In terms of $CaCO_3$ equivalent), Unit of Hardness, Quantitative Measurement of Water Hardness by EDTA method.

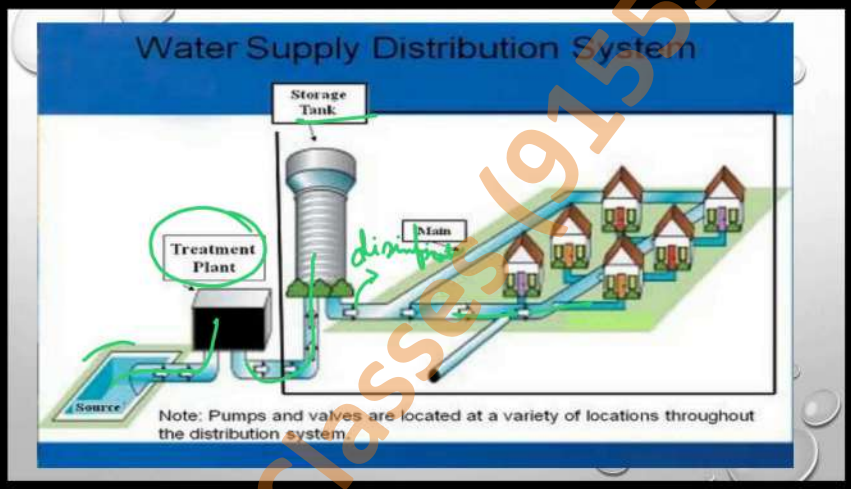
2.3 Municipal supply of Water, Treatment of water, Water Softening Technique-Soda Lime Process, Zeolites method and ion exchange method,

2.4 Water Quality Index - Biological Oxygen Demand, Chemical Oxygen Demand, Determination of Dissolved Oxygen

2.5 Indian standard specification of drinking water







STEPS INVOLVED IN MUNICIPAL WATER SUPPLY

- 1. SELECTION OF SOURCE
- 2. SCREENING
- 3.A. SEDIMENTATION
- 3.B. SEDIMENTATION WITH FLOCCULATION → sludge
- 4. FILTRATION
- 5. SUPPLY

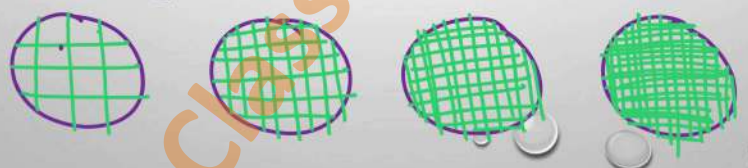
1. SOURCE

- SOURCE REFERS TO SOURCE OF WATER SUCH AS RIVERS, STREAM, LAKES, RESERVOIRS, SPRING AND GROUND WATER THAT PROVIDE WATER TO SUPPLY.

life→50 - 70 years

2. SCREENING

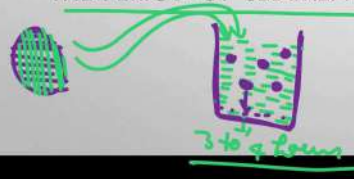
- IT IS THE PHYSICAL TREATMENT PROCESS.
- IT IS THE PROCESS OF REMOVING FLOATING MATERIALS FROM WATER.
- IT IS THE FIRST AND ESSENTIAL STEP OF TREATMENT OF WATER.



3. SEDIMENTATION

(sand)

- IT IS THE PROCESS OF REMOVING FINE SUSPENDED COLLOIDAL IMPURITIES BY ALLOWING WATER STAND IN BIG DEEP TANK MOST OF THE SUSPENDED PARTICLES SETTLE DOWN AT THE BOTTOM DUE TO FORCE OF GRAVITY.
- •THE PERIOD OF SEDIMENTATION IS UP TO 3 TO 5 HOURS.



SEDIMENTATION WITH COAGULATION

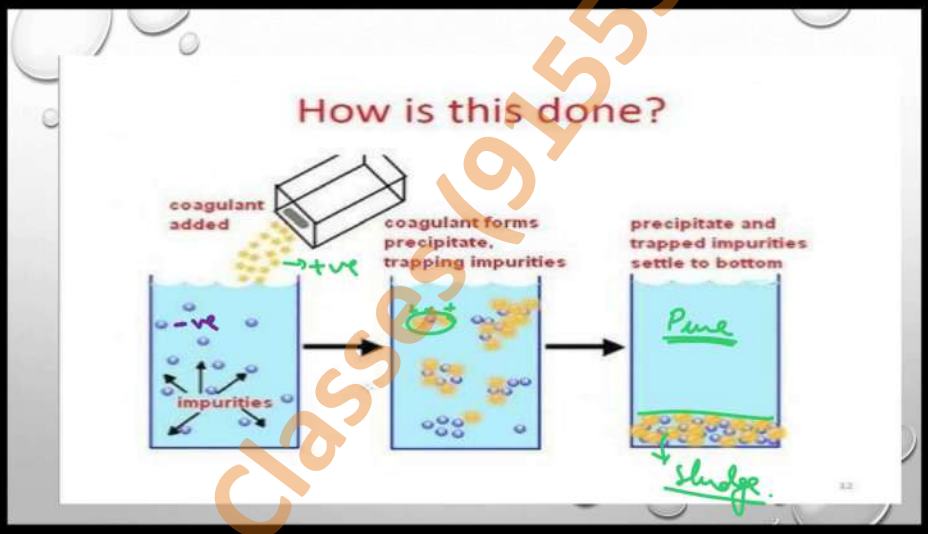
coagulant → Alum

- IT IS THE PROCESS OF REMOVAL SUSPENDED IMPURITIES IN WATER BY THE USE OF CHEMICAL AGENTS IS KNOWN AS COAGULATION.
- COAGULANTS-ALUMINIUM SULPHATE [AL2(SO4)3], FERROUS SULPHATE(FESO4), FERRIC SULPHATE [FE2(SO4)3] AND FERRIC CHLORIDES (FECL3) ETC ARE USED.

$Al_2(SO_4)_3$ $FeSO_4$ $FeCl_3$ $Fe_2(SO_4)_3$

- COAGULANTS ARE +VE CHARGED PARTICLES.

Impurities → -ve



4. FILTRATION

(2μ) clay particle

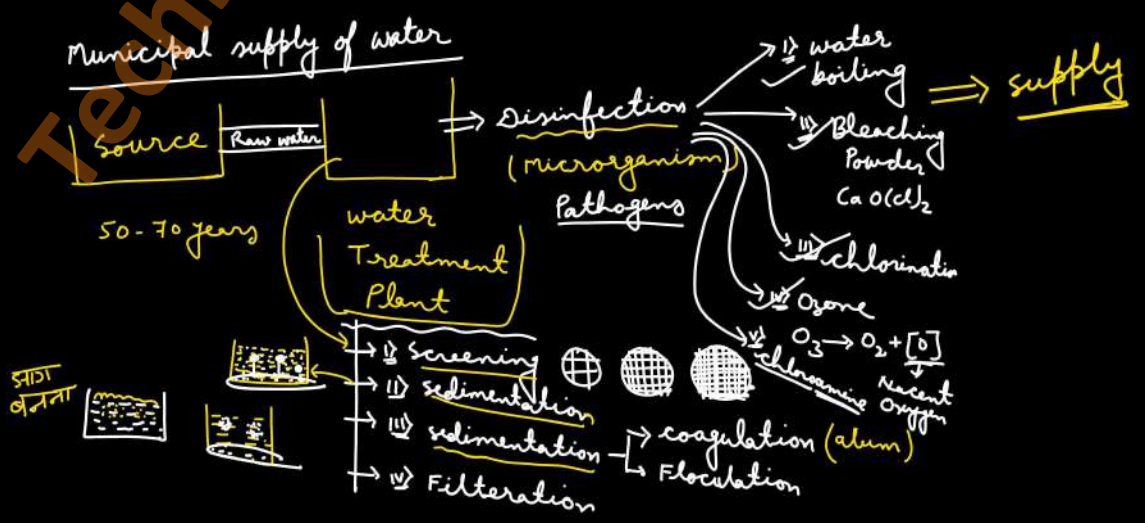
- WHEN FORMATION OF SLUDGE ETC AFTER COAGULATION HAS SETTLE DOWN FILTRATION IS CARRIED OUT.
- IT IS THE PROCESS OF SEPARATING SUSPENDED SLUDGE/IMPURITIES FROM WATER PASSING THROUGH POROUS BED MADE OF FINE AND PROPER SIZED GRANULAR MATERIALS.

5. SUPPLY

- IT IS THE LAST STEP OF MUNICIPAL WATER SUPPLY SYSTEM IN THIS WATER IS DISTRIBUTED TO CONSUMER THROUGH PIPE NETWORK.

TREATMENTS OF WATER

- WATER ARE TREATED BEFORE SUPPLYING.
- FOLLOWING ARE THE METHODS WHICH ARE USED TO WATER SOFTENING
  - 1.SODA LIME PROCESS,
  - 2. ZEOLITES METHOD AND
  - 3. ION EXCHANGE METHOD



TREATMENTS OF WATER

- WATER ARE TREATED BEFORE SUPPLYING.
- FOLLOWING ARE THE METHODS WHICH ARE USED TO WATER SOFTENING
- 1.SODA LIME PROCESS,
- 2. ZEOLITES METHOD AND
- 3. ION EXCHANGE METHOD

LIME SODA PROCESS

- LIME SOFTENING (ALSO KNOWN AS LIME BUTTERING, LIME-SODA TREATMENT, OR CLARK'S PROCESS) IS A TYPE OF WATER TREATMENT USED FOR WATER SOFTENING, WHICH USES THE ADDITION OF LIMEWATER (CALCIUM HYDROXIDE) TO REMOVE HARDNESS (DEPOSITS OF CALCIUM AND MAGNESIUM SALTS) BY PRECIPITATION.
- THIS PROCESS IS NOW OBSOLETE BUT WAS VERY USEFUL FOR THE TREATMENT OF LARGE VOLUMES OF HARD WATER.
- THE ADDITION OF LIME (CAO) AND SODA NA2C03 TO THE HARD WATER PRECIPITATES CALCIUM AS THE CARBONATE, MAGNESIUM AS ITS AND HYDROXIDE. THE AMOUNTS OF THE TWO CHEMICALS REQUIRED ARE EASILY CALCULATED FROM THE ANALYSIS OF THE WATER AND STOICHIOMETRY OF THE REACTIONS.

$Ca(OH)_2$

Lime $Ca(OH)_2$ + Soda Na_2CO_3

CaO

$CaO + H_2O \rightarrow Ca(OH)_2$

$Ca(HCO_3)_2$

$Mg(HCO_3)_2$

Boiler ⇒ Blade

$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + H_2O$ (ppt) (Lime water)

$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCO_3\downarrow\downarrow + H_2O$ (Lime water)

Lime- soda Process

CaO ⇓ $CaO + H_2O \rightarrow Ca(OH)_2$ ⇓ Lime water

Na_2CO_3

Hard water + Lime water ⟶ calcium carbonate | Magnisium Hydroxide (PPt) ↓↓ + soft water

Ca^{+2} $Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow CaCO_3\downarrow + H_2O$ (Insoluble)

Mg^{+2} $Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2\downarrow + CaCO_3\downarrow + H_2O$ (ppt)

$$Ca(HCO_3)_2 + Ca(OH)_2 = 2CaCO_3 \downarrow + 2H_2O$$

calcium bicarbonate + calcium hydroxide = calcium carbonate + water

PPt

Soft

Insoluble in water

$$Mg(HCO_3)_2 + 2Ca(OH)_2 = Mg(OH)_2 + 2CaCO_3 \downarrow + 2H_2O$$

magnesium bicarbonate + calcium hydroxide = magnesium hydroxide + calcium carbonate + water

PPt Insoluble

Soft

2. ZEOLITE METHOD

- ZEOLITE SOFTENING PROCESS IS THE PROCESS OF REMOVING PERMANENT AS WELL AS TEMPORARY HARDNESS OF THE WATER. ZEOLITE SOFTENING OCCURS WHEN MAGNESIUM (MG) AND CALCIUM (CA) ZEOLITES (INSOLUBLE) IN WATER GET PRECIPITATED.
- IN THIS ZEOLITE SOFTENING PROCESS, ZEOLITE WORKS AS A CATALYST WHICH HELPS IN EXCHANGING IONS FROM CA2+ OR MG2+ WITH SODIUM IONS.
- CERTAIN COMPLEX INORGANIC SALTS POSSESS THE PROPERTY OF EXCHANGING CALCIUM AND MAGNESIUM IONS PRESENT IN HARD WATER FOR NA2+ IONS. AN IMPORTANT SALT OF THIS TYPE IS SODIUM ALUMINIUM ORTHOSILICATE OR SODIUM ZEOLITE (NA2AL2SI2O8.XH2O), COMMONLY KNOWN AS PERMUTIT (ARTIFICIALLY SYNTHESIZED ZEOLITE). THIS SODIUM ZEOLITE SALT BELONGS TO A FAMILY OF COMPLEX SALTS KNOWN AS ZEOLITES.

WATER

UNIT 2

SYLLABUS

Unit-2.0 Water

8825339898

2.1 Introduction, Sources of Water. Hardness of Water- Temporary & Permanent hardness.

2.2 Degree of Hardness (In terms of $CaCO_3$ equivalent), Unit of Hardness, Quantitative Measurement of Water Hardness by EDTA method.

2.3 Municipal supply of Water, Treatment of water, Water Softening Technique-Soda Lime Process, Zeolites method and ion exchange method,

2.4 Water Quality Index - Biological Oxygen Demand, Chemical Oxygen Demand, Determination of Dissolved Oxygen

2.5 Indian standard specification of drinking water

Numerical + PYQ + Imp Q.

objective -

(i) Full form → EDTA / BOD / COD
- Barine sol
- zeolite / sheep

(ii) Temporary hardness & Permanent hardness.

(iii) BOD < COD ⇒ Potassium Dicromate
BOD: 5 days, 20°C; COD: 3 days

(4) marks-
(i) EDTA method (ii) lime soda method
(6) (iii) zealite method / Ion exchange method
(iv) BOD & COD difference.
(iv) How we can remove Temporary & permanent Hardness.
(v) Municipal supply of water.

(9) Numerical
→ Hardness (T.H / P.H / Total hardness)
→ BOD / COD calculation)

RTI - 2005

IS 10500 : 2012

Name

Indian standard

Publishing year

भारतीय मानक

पीने का पानी — विशिष्टि

(दूसरा पुनरीक्षण)

Indian Standard

DRINKING WATER — SPECIFICATION

(Second Revision)

ICS 13.060.20

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

May 2012 Price Group 6

Indian Standard

DRINKING WATER — SPECIFICATION

(Second Revision)

1 SCOPE

This standard prescribes the requirements and the methods of sampling and test for drinking water.

2 REFERENCES

The standards listed in Annex A contain provisions which through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated in Annex A.

3 TERMINOLOGY

For the purpose of this standard the following definition shall apply.

3.1 Drinking Water — Drinking water is water intended for human consumption as potable and cooking purposes from any source. It includes water treated or untreated supplied by any means for human consumption.

4 REQUIREMENTS

Drinking water shall comply with the requirements given in Tables 1 to 4. The analysis of pesticide residues given in Table 5 shall be conducted by a recognized laboratory using internationally established test method meeting the residue limits as given in Table 5.

Drinking water shall also comply with bacteriological requirements (see **4.1**), virological requirements (see **4.2**) and biological requirements (see **4.3**).

4.1 Bacteriological Requirements

4.1.1 *Water in Distribution System*

Ideally, all samples taken from the distribution system including consumers' premises, should be free from coliform organisms and the following bacteriological quality of drinking water collected in the distribution system, as given in Table 6 is, therefore specified when tested in accordance with IS 1622.

4.2 Virological Requirements

4.2.1 Ideally, all samples taken from the distribution

Table 1 Organoleptic and Physical Parameters
(*Foreword* and *Clause* 4)

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to Part of IS 3025	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Colour, Hazen units, Max	5	15	Part 4	Extended to 15 only, if toxic substances are not suspected in absence of alternate sources a) Test cold and water mixed b) Test at several dilutions
ii)	Odour	Agreeable	Agreeable	Part 5	
iii)	Taste	Agreeable	No relaxation	Part 11	
iv)	Turbidity, NTU, Max	1	5	Part 10	
v)	Total dissolved solids, mg/l, Max	500	2 000	Part 16	

TDS

NOTE — It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'Acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

Table 2 General Parameters Concerning Substances Undesirable in Excessive Amounts
(*Foreword* and *Clause* 4)

Sl No.	Characteristic	Requirement (Acceptable Limit)	Permissible Limit in the Absence of Alternate Source	Method of Test, Ref to	Remarks
(1)	(2)	(3)	(4)	(5)	(6)
i)	Aluminium (as Al), mg/l, Max	0.03	0.2	IS 3025 (Part 55)	—
ii)	Ammonia (as total ammonia N), mg/l, Max	0.5	No relaxation	IS 3025 (Part 34)	—
iii)	Anionic detergents (as MBAS), mg/l, Max	0.2	1.0	Annex K of IS 13428	—
iv)	Barium (as Ba), mg/l, Max	0.7	No relaxation	Annex F of IS 13428* or IS 15302	—
v)	Boron (as B), mg/l, Max	0.5	1.0	IS 3025 (Part 57)	—
vi)	Calcium (as Ca), mg/l, Max	75	200	IS 3025 (Part 40)	—
vii)	Chloramines (as Cl_2), mg/l, Max	4.0	No relaxation	IS 3025 (Part 26)* or APHA 4500-Cl G	—
viii)	Chloride (as Cl), mg/l, Max	250	1 000	IS 3025 (Part 32)	—
ix)	Copper (as Cu), mg/l, Max	0.05	1.5	IS 3025 (Part 42)	—
x)	Fluoride (as F), mg/l, Max	1.0	1.5	IS 3025 (Part 60)	—
xi)	Free residual chlorine, mg/l, Min	0.2	1	IS 3025 (Part 26)	To be applicable only when water is chlorinated. Tested at consumer end. When protection against viral infection is required, it should be minimum 0.5 mg/l
xii)	Iron (as Fe), mg/l, Max	0.3	No relaxation	IS 3025 (Part 53)	Total concentration of manganese (as Mn) and iron (as Fe) shall not exceed 0.3 mg/l
xiii)	Magnesium (as Mg), mg/l, Max	30	100	IS 3025 (Part 46)	—
xiv)	Manganese (as Mn), mg/l, Max	0.1	0.3	IS 3025 (Part 59)	Total concentration of manganese (as Mn) and iron (as Fe) shall not exceed 0.3 mg/l
xv)	Mineral oil, mg/l, Max	0.5	No relaxation	Clause 8 of IS 3025 (Part 39) Infrared partition method	—
xvi)	Nitrate (as NO_3), mg/l, Max	45	No relaxation	IS 3025 (Part 34)	—
xvii)	Phenolic compounds (as C_6H_5OH), mg/l, Max	0.001	0.002	IS 3025 (Part 43)	—
xviii)	Selenium (as Se), mg/l, Max	0.01	No relaxation	IS 3025 (Part 56) or IS 13360*	—
xix)	Silver (as Ag), mg/l, Max	0.1	No relaxation	Annex J of IS 13428	—
xx)	Sulphate (as SO_4), mg/l, Max	200	400	IS 3025 (Part 24)	May be extended to 400 provided that Magnesium does not exceed 30
xxi)	Sulphide (as H_2S), mg/l, Max	0.05	No relaxation	IS 3025 (Part 29)	—
xxii)	Total alkalinity as calcium carbonate, mg/l, Max	200	600	IS 3025 (Part 23)	—
xxiii)	Total hardness (as $CaCO_3$), mg/l, Max	200	600	IS 3025 (Part 21)	—
xxiv)	Zinc (as Zn), mg/l, Max	5	15	IS 3025 (Part 49)	—

blue baby

NOTES

1 In case of dispute, the method indicated by '*' shall be the referee method.

2 It is recommended that the acceptable limit is to be implemented. Values in excess of those mentioned under 'acceptable' render the water not suitable, but still may be tolerated in the absence of an alternative source but up to the limits indicated under 'permissible limit in the absence of alternate source' in col 4, above which the sources will have to be rejected.

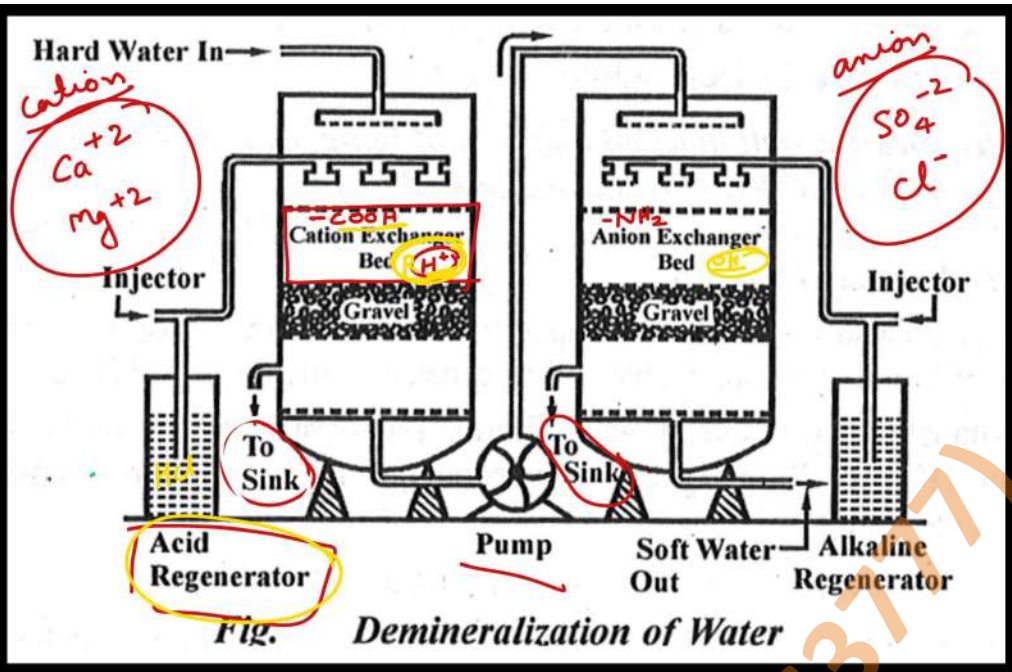


Fig. *Demineralization of Water*

- cations like Ca^{2+} and Mg^{2+} and anions like SO_4^{2-} and Cl^- can be removed by cation and anion exchange resins.
- cation resins – (-COOH, $-SO_3H$) are capable for exchanging their H^+ ions to cationic portion of hard water.
- Anion resins – ($-NH_2$, $-NHCH_3$) are capable for exchanging the anionic portion of the hard water.

Process :–

- Hard water is pass through cation and anion exchanger bed respectively.
- water coming out side from anion exchanger bed is completely free from cations and anions.
- It is known as "deionised water". and it is as pure as distilled water.

Regeneration :-

- cation exchange Resins are regenerated by passing a dilute solution of Hcl through them.

$$RCa + 2HCl \longrightarrow RH_2 + CaCl_2$$

- Anion exchange Resins are generated by passing a dilute solution of NaOH.

$$R'Cl_2 + 2NaOH \longrightarrow R'(OH)_2 + 2NaCl$$

Advantage :-

(i) Highly acidic or alkaline water can be treated.
(ii) water of nearly zero hardness can be obtained.

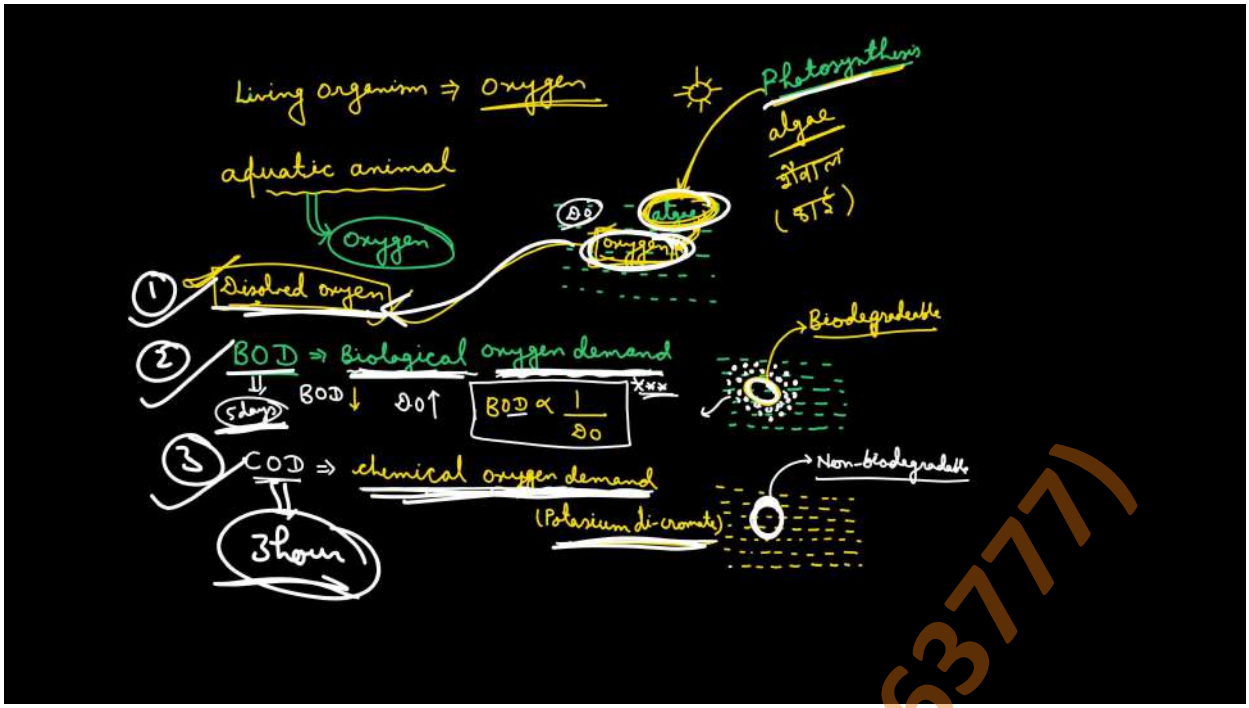
Disadvantage :-

(i) Equipment is costly.
(ii) expensive chemicals are used.
(iii) If water contains turbidity the the output of process is reduce.

2.4 water quality Index :-

waste water Treament

- D.O ⇒ (Dissolved oxygen)
- B.O.D ⇒ (Biological oxygen demand or Bio-chemical oxygen demand)
- C.O.D → chemical oxygen demand.



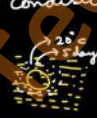
① Dissolved oxygen (D.O) :-

The amount of oxygen dissolved in water is known as dissolved oxygen (D.O.).

- The oxygen is dissolved in water via photosynthesis by the algae or the aquatic plant which produces oxygen during their photosynthesis.
- The oxygen produces gets mixed with water which is known as dissolved oxygen.
- Fisher or any other aquatic animals uses these D.O. for their breathing.

2) B.O.D (Biological oxygen demand) :-

Amount of free oxygen in water required for the biological oxidation of organic matter under aerobics conditions at 20°c and for the period of 5 days.



- B.O.D. is measured in PPm or mg/lit.
- $B.O.D = (D_1 - D_2) \times \text{Dilution factor}$

$$= (D_1 - D_2) \times \frac{\text{volume of sample after dilution}}{\text{volume of sample before dilution}}$$

where -

D_1 = Dissolve oxygen of diluted water sample after preparation
= Oxygen decreases in sample.

D_2 = Dissolve oxygen of diluted water sample after incubation
= Oxygen decreases in blank.

C.O.D. (chemical oxygen demand):-

COD is the amount of oxygen demanded to oxidised (decompose) biodegradeable organic matter as well as non-biodegradeable matter present in waste water using strong chemical oxidant such as potassium dicromat.

- COD represent both biological active and inactive organic matter.
- It is also measured in PPm / (mg/lt).
- COD > BOD
- It generally takes 3 to 4 hours.
- $$COD = \frac{(V_b - V_s) \times N \times 800}{V}$$

V_b = volume of blank titration
V_s = volume of unreacted titration
N = Normality
V = volume of water sample.

PYQ. ⇒ Last 4 to 5 + NOTES

60 to 70 % | 30 to 40 %

80 ⇒ 70+

unit → 01 :-
Subh → NOTES.
PYQ → 60 to 70 %

Difference B/w B.O.D & COD :-

BOD	COD
(i) BOD stands for biological oxygen demand.	(i) COD stands for chemical oxygen demand.
(ii) Def^n	(ii) Def^n -
(iii) Formula	(iii) Formula
(iv) BOD. is always less than COD	(iv) COD is greater than BOD
(v) It takes 5 days (more time than COD).	(v) It takes 3 to 4 hours (less than the BOD).
(vi) It is cheaper.	(vi) It is costlear.
(vii) No extra chemicals are used.	(vii) chemicals like Potassium dicromate are used.
(viii) It is used only for the biodegradeable matters.	(viii) It is used for both bio-degradeable and Non-biodegradeable matter.

2. ZEOLITE METHOD

- ZEOLITE SOFTENING PROCESS IS THE PROCESS OF REMOVING PERMANENT AS WELL AS TEMPORARY HARDNESS OF THE WATER. ZEOLITE SOFTENING OCCURS WHEN MAGNESIUM (MG) AND CALCIUM (CA) ZEOLITES (INSOLUBLE) IN WATER GET PRECIPITATED.

$Ca^{2+} + Ze \rightarrow CaZe + Na^+$ | $Mg^{2+} + Ze \rightarrow MgZe + Na^+$

- IN THIS ZEOLITE SOFTENING PROCESS, ZEOLITE WORKS AS A CATALYST WHICH HELPS IN EXCHANGING IONS FROM CA2+ OR MG2+ WITH SODIUM IONS.
- CERTAIN COMPLEX INORGANIC SALTS POSSESS THE PROPERTY OF EXCHANGING CALCIUM AND MAGNESIUM IONS PRESENT IN HARD WATER FOR NA2+ IONS. AN IMPORTANT SALT OF THIS TYPE IS SODIUM ALUMINIUM ORTHOSILICATE OR SODIUM ZEOLITE (NA2AL2SI2O8.XH2O), COMMONLY KNOWN AS PERMUTIT (ARTIFICIALLY SYNTHESIZED ZEOLITE). THIS SODIUM ZEOLITE SALT BELONGS TO A FAMILY OF COMPLEX SALTS KNOWN AS ZEOLITES.

- ZEOLITE SOFTENING PROCESS OF WATER

Na^{2+} CaZe

- WHEN HARD WATER CONTAINING MAGNESIUM AND CALCIUM IONS PASSES THROUGH A ZEOLITE BED OF SODIUM, THEN SODIUM (NA2+) IONS GET DISPLACED OR REPLACED BY THE IONS OF MG2+ AND CA2+ AND WHEN THE REPLACEMENT IS COMPLETE I.E. ALL THE SODIUM IONS GET REPLACED BY MG2+ AND CA2+ IONS THEN THE ZEOLITE GET INACTIVATED. THIS ZEOLITE THEN GETS REGENERATED BY PASSING BRINE SOLUTION (NaCl) THROUGH THE INACTIVE ZEOLITE BED. THIS PROCESS OF SOFTENING WATER IS MAINLY USED IN LAUNDRY.

Ca^{2+}/Mg^{2+}

Zeolite

$Na_2Al_2Si_2O_8 \cdot xH_2O$ ⇓ Zeolite

Reactions involved;

Ca^{2+} Mg^{2+}

$$Ca^{2+} + Na_2Al_2Si_2O_8.xH_2O \rightarrow CaAl_2Si_2O_8.xH_2O + 2Na^+$$

PPt

$$Mg^{2+} + Na_2Al_2Si_2O_8.xH_2O \rightarrow MgAl_2Si_2O_8.xH_2O + 2Na^+$$

PPt

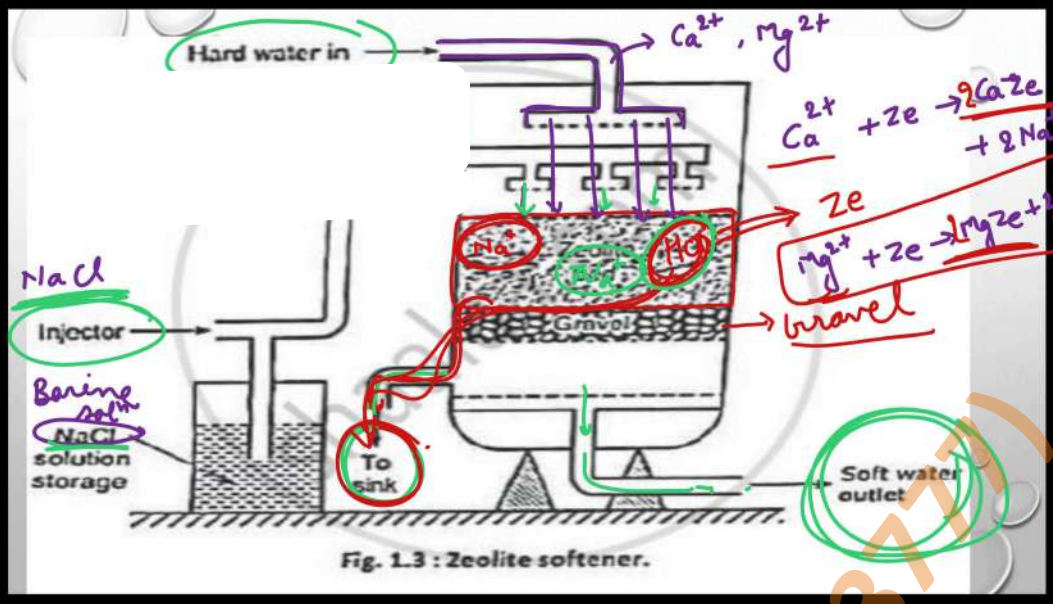


Fig. 1.3 : Zeolite softener.

- ADVANTAGES
- CLEAN AND EASY PROCESS.
- THE EQUIPMENT OCCUPIES LESS SPACE AS WELL AS IT IS COMPACT.
- TIME EFFECTIVE I.E. IT DOES NOT REQUIRE MUCH TIME FOR WATER SOFTENING.
- EASY TO MAINTAIN.
- NO PRECIPITATION OF IMPURITIES OCCURS.

- LIMITATIONS
- IN CASE OF TURBID WATER SUPPLY, THE SUSPENDED MATTER HAS TO BE REMOVED BY PROCESSES LIKE COAGULATION, FILTRATION OR OTHERS BEFORE ITS ADMINISTRATION TO THE ZEOLITE BED AS IT MAY CAUSE CLOGGING.
- THE PRESENCE OF LARGE QUANTITIES OF MN2+ OR FE2+ COLOURED IONS HAS TO BE REMOVED FROM WATER AS THEY MAY PRODUCE THEIR OWN ZEOLITES.
- SODA ACID MUST NEUTRALISE THE MINERAL ACIDS AS THEY MAY DESTROY THE BED OF ZEOLITES.

3. ION EXCHANGE METHOD

Engineering materials

Natural occurance of metals — Minerals and ores

occurance of metal–

(a) Im free state → metals which have low reactivity generally found im free state.

e.g.:- Gold (Au), Platinum (Pt)

(ii) Im combined state → Metals which are highly reactive occur im combined form as sulphide, carbonate, sulphate, oxide, phosphide, nitrate etc.

e.g.:- Al, Fe, Cu.

Minerals → The naturally occuring chemical substances that found im earth's crust which are obtained by mining are called minerals.

Earth's crust → Outermost layer of earth

Ore → The minerals from which a particula metal can be extracted convienetly and economically are called ores.

Imp. (Memories).

Principal ores of some metals:-

		Ore	Formula
[1]	Iron	Haemetite	Fe_2O_3
		Magnetite	Fe_3O_4
		Siderite	$FeCO_3$
		Iron pyrite	FeS_2
[2]	Copper	Copper pyrite	$CuFeS_2$
		Malachite	$CuCO_3 \cdot Cu(OH)_2$
		Copper glance	Cu_2S
[3]	Aluminium	Cuprite	Cu_2O
		Bauxite	$Al_2O_3 \cdot 2H_2O$
[4]	Zinc	Zinc blende	ZnS
		Calamine	$ZnCO_3$
		Zincite	ZnO

* Gangue → the earthy materials (impurities) present in ores are called gangue.

Metallurgy

The scientific and technological process used for isolation (extraction) of pure metal from ores are called metallurgy.

Process involved in metallurgy:-

(i) Concentration of ore
(ii) Isolation of metals from concentrated ore.
(iii) Refining or purification of metals.

(i) Concentration of ore

the process of removal of unwanted materials (gangue) is called concentration of ore.

Methods of concentration of ore:-

(i) Crushing and grinding (ii) Gravity separation
(iii) Magnetic separation (iv) Froth floatation process
(v) Leaching.

(i) Crushing and grinding →

pulverisation
- Jaw crusher → huge lumps convert to small pieces
- Ball mill → small pieces convert to powdered form.

(ii) Gravity separation → powdered ore is washed with stream of water under high pressure, light impurities are washed away whereas heavy ore are left.

e.g.:- Generally oxide and carbonate ore are concentrated by this method.

(iii) Magnetic separation:- It is based on difference in magnetic and non-magnetic properties of ore.

e.g.:- Haemetite.

Detail

(iv) Froth floatation process — wetting

It is based on prefrential properties of ore particles.

e.g.:- Sulphide ore of Zn, copper and lead are concentrated by this method.

(v) Leaching → It is used for such ore which is selectively dissolve in a solvent.

- Ore dissolve.
- Impurities not dissolved.

(ii) Extraction (Isolation) of metal from concentrated ore:-

The process used to obtain metals in free state from concentrated ore is called extraction of metal.

It involves two major steps:-

(a) Conversion of concentrated ore into metal oxide

(b) Reduction of ~~metal~~ oxide to metal.

I. Calcination II. Roasting.

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(b) Reduction of ~~metal~~ oxide to metal.

I. Calcination II. Roasting.

Conversion of concentrated ore into metal oxide :-

Calcination | Roasting.

* Calcination :- process of heating an ore below its m.pt. either in absence of air or limited supply of air.

Benefits
* Moisture removed
* Hydrated ore becomes anhydrated.

e.g.:- $Al_2O_3 \cdot 2H_2O \xrightarrow{\Delta} Al_2O_3 + 2H_2O$

Bauxite → Alumina

$Fe_2O_3 \cdot 3H_2O \xrightarrow{\Delta} Fe_2O_3 + 3H_2O$

Limonite

Calcination

* Carbonates are converted into their oxide.

e.g.:- Calcination

$ZnCO_3 \xrightarrow{\Delta} ZnO + CO_2(\uparrow)$

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

* **Roasting**:- the process of heating the ore below its m.pt. in excess of air.

Benifits
* Moisture removed.
* Non-metallic impurities such as sulphur, phosphorous are oxidiesed and are removed as volatile gases.

e.g.:- $S_8 + O_2 \xrightarrow{\Delta} SO_2(\uparrow)$

$P_4 + O_2 \xrightarrow{\Delta} P_2O_5$

* Sulphide ores are converted into metallic oxide.

Roasting
$ZnS + O_2 \xrightarrow{\Delta} ZnO + SO_2(\uparrow)$

$PbS + O_2 \xrightarrow{\Delta} PbO + SO_2(\uparrow)$

$Cu_2S + O_2 \xrightarrow{\Delta} Cu_2O + SO_2(\uparrow)$

(b) Reduction of oxide of metal:-

Metal oxide is heated with other R.A. like C, CO, Al, Mg etc.

* Common methods of reduction:-

(i) Auto-reduction → Extraction of Cu, Pb, Sb, Hg etc. are carried out by this process.

e.g.:- $Cu_2S + O_2 \longrightarrow Cu_2O + SO_2(\uparrow)$

$Cu_2S + Cu_2O \longrightarrow Cu + SO_2(\uparrow)$

(ii) V.I. Smelting → In this process metal oxide is reduced to metal with C or CO.

e.g.:- $Fe_2O_3 + C \xrightarrow{>1123K} Fe + CO(\uparrow)$

$Fe_2O_3 + CO \xrightarrow{1123K} Fe + CO_2(\uparrow)$

e.g.:- $ZnO + C \longrightarrow Zn + CO(\uparrow)$

$SnO_2 + C \longrightarrow Sn + CO(\uparrow)$

(iii) Aluminothermic reduction →

Reduction of metal oxide by Al is called aluminothermic reduction.

e.g.:- $MnO_4 + Al \longrightarrow Al_2O_3 + Mn$

$Cr_2O_3 + Al \longrightarrow Al_2O_3 + Cr$

Flux (V.I.) → A flux is a substance which when mixed with calcinated or roasted ore, chemically combine with impurities present to form an easily fusible material called slag.

Flux + Impurity → Slag

(Substance added.) (Calcinate or Roasted ore) (fusible material)

Slag → The compound formed on rxn of gangue (Impurities of ore) with flux is called slag.

* The slag is insoluble in molten metal and being lighter, floats over the surface of molten metal.

Types of flux –

(i) **Acidic flux** → For basic impurities like lime (CaO) present in the ore, acidic fluxes like silica are used.

$$CaO + SiO_2 \longrightarrow CaSiO_3$$

(basic impurity) (Acidic flux) (Fusible Slag)

(ii) **Basic flux** → For acidic impurities like silica present in the ore, basic fluxes like lime stone are used.

$$SiO_2 + CaCO_3 \longrightarrow CaSiO_3 + CO_2$$

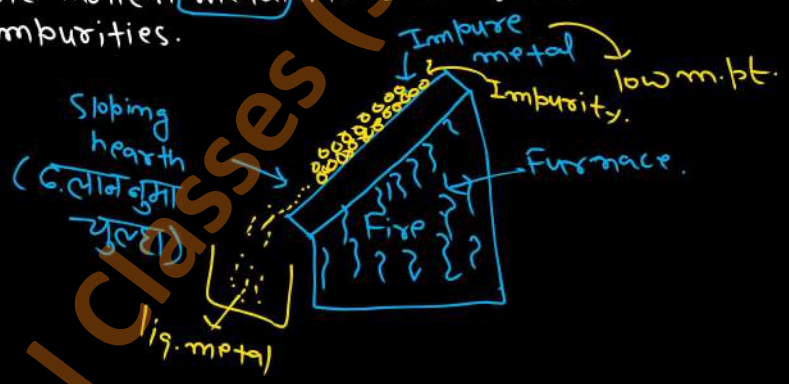
(Basic impurity) (Basic flux) fusible slag.

Refining or purification of metals :-

(a) **Distillation:-** * This method is used to remove the non-volatile impurities from volatile metals like Zn, Cd, Hg.

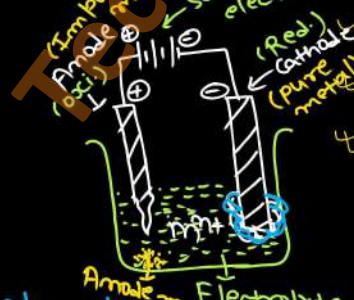
* The impure metal is heated in a retort when pure metal vaporieses and condense separately leaving behing the non-volatile impurities.

(b) **Liquiation** → It is useful for low melting metals like tin and lead. The impure metal is heated on the sloping hearth of a furnance when the molten metal flows away from infusible impurities.



(c) **Electrolytic refining:-** * It is based on electrolysis.

* It is carried out in electrolytic cell.
* The impure metal is made anode whereas pure metal is made cathode.
* Electrolytic solution is taken in electrolytic cell. It should be salt of metal.
* Electricity is passed in the electrolytic cell. Oxidation takes place at anode and reduction takes place at cathode.
* Impure metal (anode) get oxidies and metal ions are produced, these +ve metal ions move towards cathode. Thus, pure metal is obtained at cathode due to reduction of metal ion.



Oxi. at anode:-

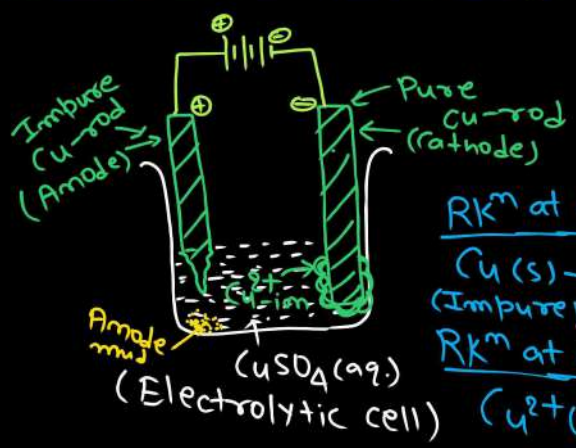
$$M(s) \rightarrow M^{n+}(aq.) + ne^-$$

Red. at cathode:-

$$M^{n+}(aq.) + ne^- \rightarrow M(s)$$

* The less electropositive impurities settle down below the anode is called anode mud.

Example of electrolytic refining:-



Rkⁿ at anode:- oxidation

$Cu(s) \rightarrow Cu^{2+}(aq.) + 2e^-$
(Impure)

Rkⁿ at cathode:- Reduction

$Cu^{2+}(aq.) + 2e^- \rightarrow Cu(s)$

(iv) Vapour phase refining:-

In this method, impure metal is converted into its vapour and collected. It is then thermally decompose to get pure metal. (i) Mond process (ii) van Arkel method.

(i) Mond process:- → In this process, Ni is heated in a stream of CO to form volatile complex, nickel tetracarbonyl.

$$Ni + 4CO \xrightarrow{330K-350K} Ni(CO)_4$$
(volatile form)

The vapour of $Ni(CO)_4$ is taken to decomposer chamber maintained at 450K-470K where it decomposes to give pure Ni.

$$Ni(CO)_4 \xrightarrow{450K-470K} Ni + 4CO(\uparrow)$$
(volatile form) (pure form)

(ii) van Arkel method:-

This method is useful for removing all oxygen and nitrogen present in form of impurity in certain metals like Zr and Ti. Impure metal is heated with iodine in evacuated vessel and the resultant tetraiodide is decomposed on a tungstun filament to get pure metal.

e.g.:- $Zr(s) + 2I_2(s) \xrightarrow{870K} ZrI_4 \xrightarrow[2075K]{\text{Tungstun filament}} Zr(s) + I_2(g)\uparrow$
Impure — Zirconium tetraiodide — (pure)

e.g.:- $Ti(s) + I_2 \xrightarrow{523K} TiI_4 \xrightarrow{1700K} Ti(s) + I_2(g)\uparrow$
Impure — Titanium tetraiodide — (pure)

Extraction of copper

Ore: $CuFeS_2$ (Copper pyrite) → concentration of ore by froth flotation method → concentrated ore

Roasting

$CuFeS_2 + O_2 \xrightarrow{\Delta} Cu_2S + FeS + SO_2(\uparrow)$

$FeS + O_2 \xrightarrow{\Delta} FeO + SO_2(\uparrow)$

FeO: Metallic oxide (Basic impurity)

$FeO + SiO_2 \rightarrow FeSiO_3$ (Slag) → molten form

FeO: Basic impurity; SiO_2: Acidic flux

Bassemerisation

$Cu_2S + O_2 \rightarrow Cu_2O + SO_2(\uparrow)$

$Cu_2O + Cu_2S \longrightarrow Cu + SO_2(\uparrow)$

Cu: Impure Cu

Purification

By electrolytic refining by taking impure Cu as anode, pure Cu as cathode and $CuSO_4$ soln as electrolyte

At anode → $Cu(s) \rightarrow Cu^{2+} + 2e^-$

At cathode → $Cu^{2+} + 2e^- \rightarrow Cu(s)$

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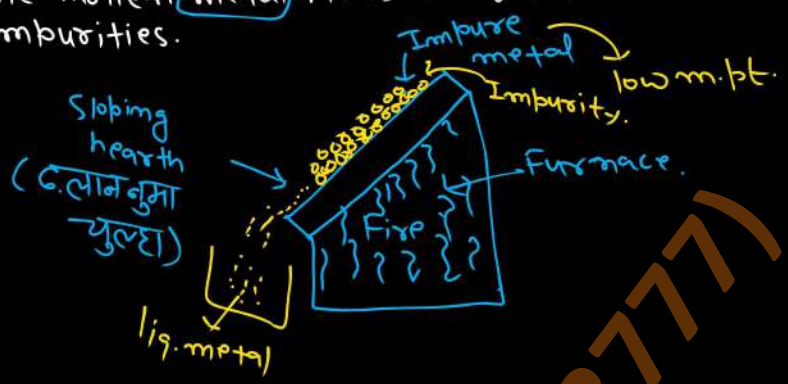
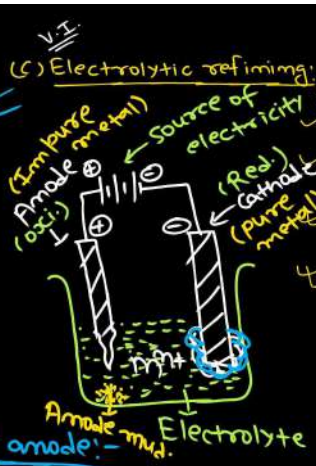


(c) Electrolytic refining:- V.I.



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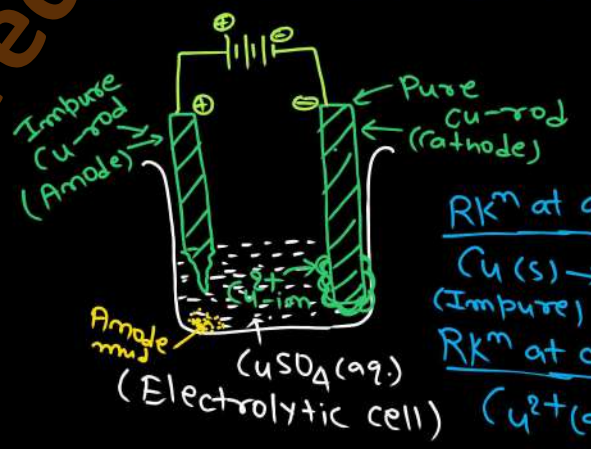

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Ore: $CuFeS_2$ Copper pyrite → concentration of ore by froth flotation method → concentrated ore → Roasting

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$$FeS + O_2 \xrightarrow{\Delta} FeO + SO_2(\uparrow)$$

Metallic oxide (Basic impurity)

$$FeO + SiO_2 \rightarrow FeSiO_3 \text{ (slag)}$$

Basic impurity, Acidic flux, molten form

Bassemerisation

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Impure Cu.

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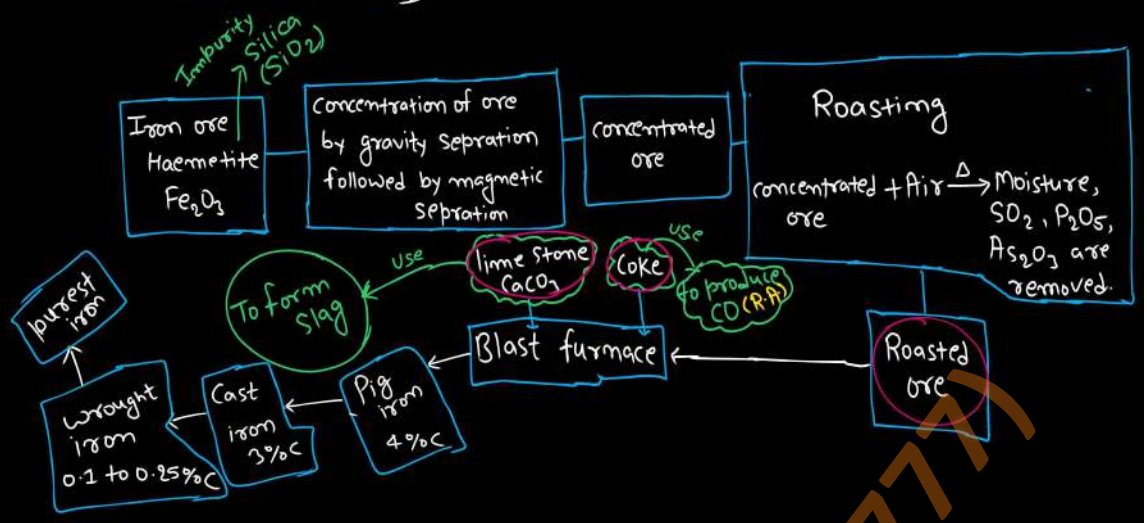
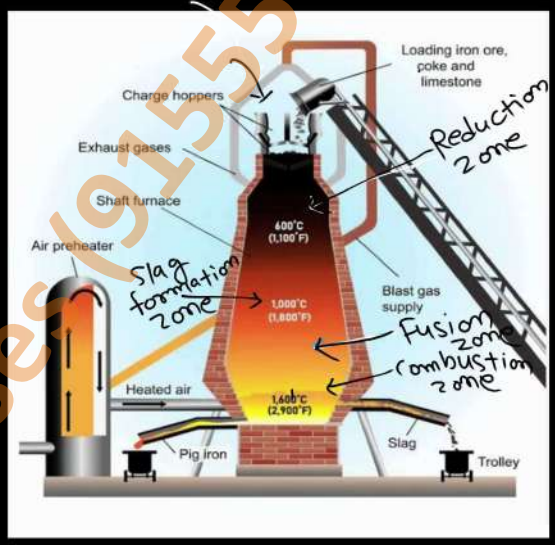
Extraction of iron from haemetite ore:-





[1] Combustion Zone:-

roasted ore + C + lime stone.

* Lowest part of furnance above hearth
* temp^r → 1500°C – 1600°C
* $C + O_2 \xrightarrow{1600°C} CO_2(g)$
  (Hot air)

This $CO_2(g)$ rises upwards and meets with red hot coke (C).

$$CO_2(g) + C \xrightarrow{1500°C} 2CO(g)$$

(pure C / coke) (R.A.)

[2.] Reduction zone :-

roasted ore + C + lime stone $CaCO_3$

iron oxide. CO

* Upper most part of furnace
* $\boxed{250^\circ C \text{ to } 700^\circ C}$
* Oxide ore is reduced to Fe in this zone.

O.N. decr. ⇒ Reduction

$$Fe_2O_3 + \underset{(R.A)}{CO} \xrightarrow{300-400^\circ C} Fe_3O_4 + CO_2\uparrow$$

$$Fe_3O_4 + \underset{(R.A)}{CO} \xrightarrow{500-600^\circ C} FeO + CO_2\uparrow$$

$$FeO + \underset{(R.A.)}{CO} \xrightarrow{700^\circ C} \underset{\text{Hot (Spongy iron)}}{Fe} + CO_2\uparrow$$

[3.] Slag formation zone :-

* Central zone
* $800^\circ C - 1000^\circ C$
* $CaCO_3(s) \xrightarrow{1000^\circ C} CaO + CO_2\uparrow$

  lime stone — (Basic flux)
* $CaO + SiO_2 \longrightarrow CaSiO_3$

  (Basic flux) — (silica as impurity in haemetite) — (fusible slag)

[4.] Zone of fusion :-

* Just above the zone of combustion
* $1200^\circ C - 1500^\circ C$
* Spongy iron melts at $1300^\circ C$ and collects at bottom of hearth.
* The slag which is being lighter floats over molten iron and prevents the oxidation of molten metal.
* Slag and molten metal are removed from respective holes. The molten metal is run into moulder and is allowed to solidify.

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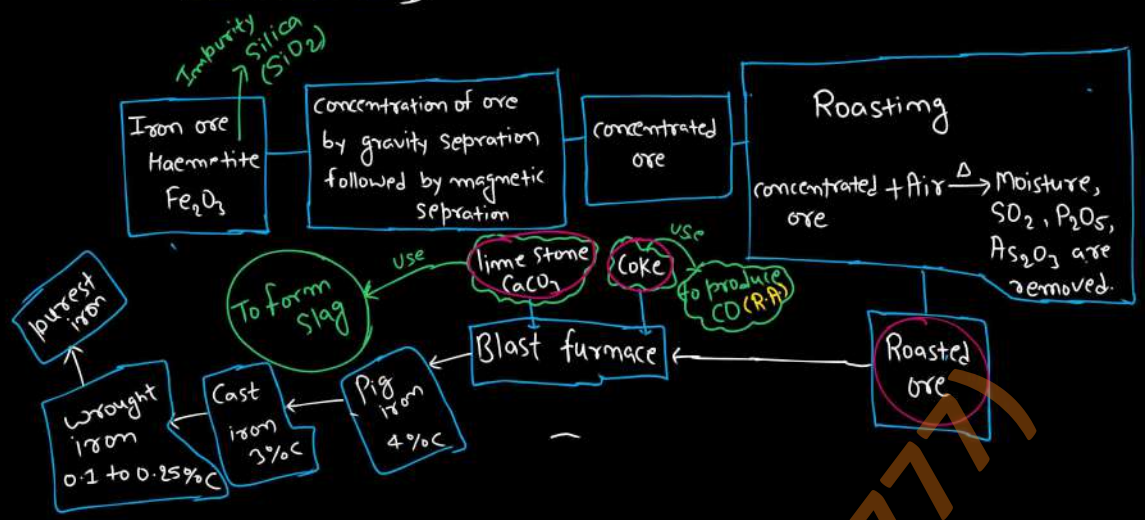

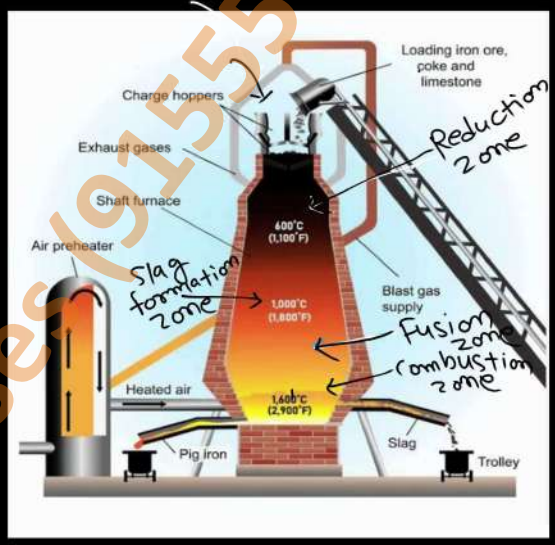

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$$Fe_2O_3 + 3CO(g) \xrightarrow{300-700^\circ C} \underset{\text{Hot spongy iron}}{Fe} + 3CO_2\uparrow$$

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* $\underset{\text{lime stone}}{CaCO_3(s)} \xrightarrow{1000^\circ C} \underset{\text{(Basic flux)}}{CaO} + CO_2\uparrow$
* $\underset{\text{(Basic flux)}}{CaO} + \underset{\text{(silica as impurity in haemetite)}}{SiO_2} \longrightarrow \underset{\text{(fusible slag)}}{CaSiO_3}$

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Extraction of Aluminium from Bauxite ore :-

$Al_2O_3 \cdot 2H_2O$ (Bauxite)

Bayer's process ↓ + NaOH (aq.)

Solution ($NaAlO_2$) + Residue (Fe_2O_3 and SiO_2)

↓ Rk^n with crystal of $Al(OH)_3$ followed by hydrolysis

ppt. of $Al(OH)_3$

↓ 1100°C

Al_2O_3 (Alumina)

↓

Electrolytic reduction (Hall heroult's process)

→ Cathode: Al (99%) → electrorefining → Pure Al (99.9%) (cathode)

→ Anode (oxygen)

Introduction

Polymer → macromolecules → molecular mass high.

* H_2O, NH_3, CH_4 → less no. of atom.
* macromolecules → very High no. of atoms. e.g.:- $C_{12}H_{22}O_{11}$ 45-atom

* Addition of repeating unit of monomer forms macromolecules having high molecular mass called polymer.
* Polymerisation is the process of conversion of monomer into polymer.

Etheme $\xrightarrow{\text{Polymerisation}}$ Polytheme

$$n\,CH_2=CH_2 \xrightarrow{\text{Polymerisation}} \underset{\text{(Polytheme) Polymer}}{-(CH_2-CH_2)-_n}$$

(Monomer)

$n(CH_2=CH_2$ Etheme (monomer)

$-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-$ repeating unit

$-(CH_2-CH_2)-_n$ Polytheme Polymer

Classification of polymers –

I. On the basis of source:-

(a) Natural polymer → Those polymers which are obtained from nature i.e. plants and animals.
e.g.:- Cellulose, protein, starch, Rubber, Nucelic acid etc.

(b) Synthetic polymer → Those polymers which are prepared in lab called synthetic polymer.
e.g.:- Polythene, Teflon, Nylon etc.

(c) Semi-Synthetic polymer → When natural polymer is modified to make high quality polymer is called semi-synthetic polymer.
e.g.:- Cellulose nitrate, Cellulose acetate etc.

* On the basis of structure –

(a) Linear polymers → Polymers having long straight chain.

e.g.:- Polythene (HDP), PVC etc.

(b) Branched chain polymer → Linear polymers having some branches.

e.g.:- Amylopectin, LDP (Low density polythene)

(c) Cross-linked or network polymer → Polymers in which various monomers chains are joined by covalent bond.

e.g.:-

On the basis of Molecular force:-

[1.] Elastomer [2.] Fibres [3.] Thermoplastic polymer (V.I.) [4.] Thermosetting polymer (V.I.)

[1.] Elastomer.

* Those polymers in which chains are held together by weak intermolecular force.
* Degree of elasticity is very high.

e.g.:- Buna-N, Buna-S, Neoprene etc.

[2.] Fibres

* Those polymers in which chains are held together by strong intermolecular force.
* Very high tensile strength

e.g.:- Nylon, Terylene etc.

(V.I.)

Thermoplastic polymer	Thermosetting polymer.
(i) On heating, it soften and melts	(i) On heating, it becomes hard.
(ii) It can be remoulded.	(ii) It can't be remoulded.
(iii) Soluble in organic solvent	(iii) Insolube in organic solvent
(iv) Less brittle	(iv) More brittle.
(v) By addition polymerisation	(v) By condensation polymerisation.
(vi) Polythene, PVC, Teflon, Nylon etc.	(vi) Bakelite, Urea-formaldehyde resin
(vii) Linear or slightly branced long chain	(vii) 3-D cross-linked str.

Types of polymerisation reaction:-

[1] Addition or chain growth polymerisation

[2] Condensation or step growth polymerisation.

[1] Addition or chain growth polymerisation

* b/w molecules containing double or triple bond
* involves successive addition of monomer
* R.I. – Carbocation, carbanion, free radicles.
* Ethylene, Propylene, Butadiene, vinyl chloride etc

$H_2C=CH_2$ $CH_3-CH=CH_2$ $H_2\overset{1}{C}=\overset{2}{C}H-\overset{3}{C}H=\overset{4}{C}H_2$ (Buta-1,3-diene), $CH_2=CH-Cl$

V.I. → Single type of monomer involved.

Homopolymer → The addition polymers formed by polymerisation of a single monomeric species called homopolymer.

e.g:- Polythene

V.I. → two diff. types of monomers are used.

Co-polymer → The addition polymers formed by polymerisation of two different polymers are called co-polymer.

e.g:- Butadiene-styrene copolymer [Buna-S]

Some Important Addition polymers:-

(A) Polythen

LDP → Low density polythene

* By heating ethylene at 333K-343K and 6-7 atm in presence of catalyst like triethylaluminium and titanium tetrachloride.
* Addition homopolymer
* Linear molecule, closely packed.
* High density High m.pt.
* Translucent
* Chemically inert, quite harder and greater tensile strength
* Used for making pipes, containers, house wares etc.

HDP → High density polythene.

* By heating ethylene under high pressure (1000-2000 atm) at tempr of 350-570K in presence of traces of O_2 or peroxide.
* Addition homopolymer
* Highly branched polymer
* Low density, Low m.pt.
* Transparent
* Chemically inert, tough but flexible and moderate tensile strength.
* Used for packaging, insulation, manufacture of pipe, toys, bottle etc

(B) Teflon (Polytetrafluoroethane)

$$n\,CF_2=CF_2 \xrightarrow[\text{High pressure}]{\text{Peroxide catalyst}} [CF_2-CF_2]_n$$

Tetrafluoroethene (Monomer) → Teflon (Polymer)

* Chemically inert and resistant to attack by corrosive reagents
* Used for making non-stick surface coated utensils

$$-F_2C-CF_2-CF_2-CF_2-CF_2-CF_2-CF_2-$$

Repeating unit

(C) Polyacrylonitrile (orlon)

$$H_2C=CH-CN \xrightarrow[\text{Catalyst}]{\text{Peroxide}} [CH_2-\underset{}{\overset{CN}{CH}}]_n$$

Acrylonitrile (Monomer) → Polyacrylonitrile (PAN) (Polymer)

* Used as a substitute for wool in making commercial fibre as orlon.

$$-H_2C-\overset{CN}{CH}-CH_2-\overset{CN}{CH}-CH_2-\overset{CN}{CH}-CH_2-\overset{CN}{CH}-$$

Repeating unit

[2] Condensation or Step growth polymerisation –

* The process of formation of polymers by repeated condensation of bifunctional monomer molecules is called condensation polymerisation.
* It involves elimination of small molecules like water, alcohol, HCl etc.

e.g.:- Nylon 6,6
Nylon 6
Terylene

Some Important condensation polymers :-

(A) Nylon 6, 6 –

* Formed by condensation of adipic acid with hexamethylenediamine

$$HO-\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-OH + H-\underset{H}{N}-(CH_2)_6-NH_2 \xrightarrow[\text{High pressure}]{553K} \left[\overset{O}{\overset{\|}{C}}-(CH_2)_4-\overset{O}{\overset{\|}{C}}-\underset{H}{N}-(CH_2)_6-NH\right]_n$$

Adipic acid (Moner) — hexamethylenediamine (monomer) — Nylon 6,6

* Used in making bristles of toothbrush, climbing ropes, fishing nets, parachute fabrics.

* High tensile strength

(B) Nylon 6 :-

Formed by self-condensation of caprolactum in presence of water by heating at a high temp$^{\circ}$.

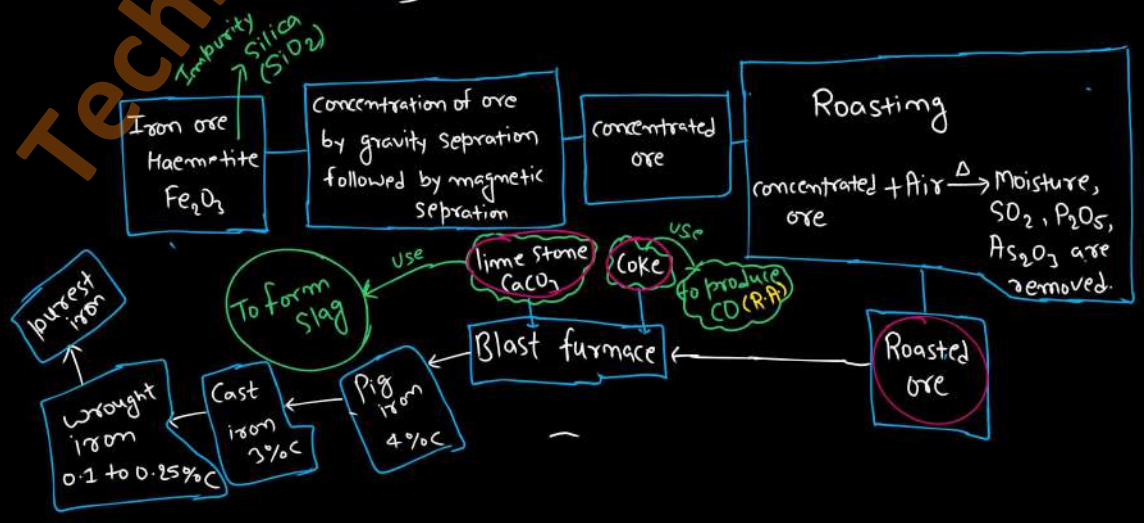
Caprolactum

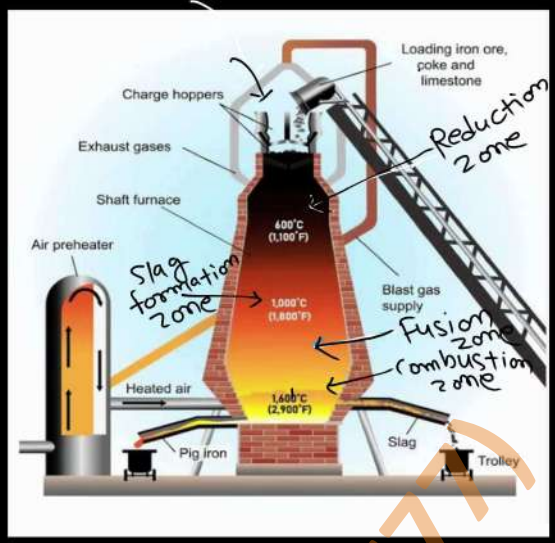
$$+ nH_2O \xrightarrow{533-593K} n\,HOOC-(CH_2)_5-NH_2 \xrightarrow{\Delta,\ \text{polymerisation}} \left[\overset{O}{\overset{\|}{C}}-(CH_2)_5-NH\right]_n$$

Aminocaproic acid — Nylon-6

* Used for making tyres cords, fabrics and ropes.

Extraction of iron from haemetite ore :-





[1] Combustion Zone:-

roasted ore + C + lime stone.

* Lowest part of furnance above hearth
* temp^r → 1500°C – 1600°C
* $C + O_2 \xrightarrow{1600°C} CO_2(g)$
  (Hot air)

This $CO_2(g)$ rises upwards and meets with red hot coke (C).

$$CO_2(g) + C \xrightarrow{1500°C} 2CO(g)$$

(pure C / coke) (R.A.)

[2] Reduction Zone:-

roasted ore + C + lime stone $CaCO_3$

iron oxide. CO

* Upper most part of furnace
* $\boxed{250°C \text{ to } 700°C}$
* Oxide ore is reduced to Fe in this zone.

O.N. decr. ↓ Reduction

$$Fe_2O_3 + \underset{(R.A.)}{CO} \xrightarrow{300-400°C} Fe_3O_4 + CO_2\uparrow$$

$$Fe_3O_4 + \underset{(R.A.)}{CO} \xrightarrow{500-600°C} FeO + CO_2\uparrow$$

$$FeO + \underset{(R.A.)}{CO} \xrightarrow{700°C} \underset{\text{Hot (Spongy iron)}}{Fe} + CO_2\uparrow$$

$$Fe_2O_3 + 3CO(g) \xrightarrow{300-700°C} \underset{\text{Hot Spongy iron}}{Fe} + 3CO_2\uparrow$$

[3.] Slag formation zone :-

* Central zone
* 800°C – 1000°C
* $CaCO_3(s) \xrightarrow{1000°C} CaO + CO_2 \uparrow$
  (lime stone) (Basic flux)
* $CaO + SiO_2 \longrightarrow CaSiO_3$
  (Basic flux) (silica as impurity in haemetite) (fusible slag)

[4.] Zone of fusion :-

* Just above the zone of combustion
* 1200°C – 1500°C
* Spongy iron melts at 1300°C and collects at bottom of hearth.
* The slag which is being lighter floats over molten iron and prevents the oxidation of molten metal.
* Slag and molten metal are removed from respective holes. The molten metal is run into moulder and is allowed to solidify.

Extraction of Aluminium from Bauxite ore :-

$Al_2O_3 \cdot 2H_2O$ (Bauxite)

Bayer's process ↓ + NaOH (aq.)

Solution ($NaAlO_2$) + Residue (Fe_2O_3 and SiO_2)

↓ Rkn with crystal of $Al(OH)_3$ followed by hydrolysis

ppt. of $Al(OH)_3$

↓ 1100°C

Al_2O_3 (Alumina)

↓

Electrolytic reduction (Hall heroult's process)

→ Cathode: Al (99%) $\xrightarrow{\text{electrorefining}}$ Pure Al (99.9%) (Cathode)

→ Anode (oxygen)

Introduction

Polymer
↓
macromolecules
↓
Molecular mass high.

* H_2O, NH_3, CH_4
↓
less no. of atom.

* Macromolecules.
↓
very High no. of atoms.
e.g.:- $C_{12}H_{22}O_{11}$
45-atom

* Addition of repeating unit of monomer forms macromolecules having high molecular mass called polymer.

* Polymerisation is the process of conversion of monomer into polymer.

Etheme $\xrightarrow{\text{Polymerisation}}$ Polytheme

$$n\,CH_2=CH_2 \xrightarrow{\text{Polymerisation}} -(CH_2-CH_2)-_n$$

(Monomer) (Polytheme) Polymer

$n(CH_2=CH_2$
Etheme
(monomer)

$-CH_2-CH_2-CH_2-CH_2-CH_2-CH_2-$
repeating unit

$-(CH_2-CH_2)-_n$
Polytheme
Polymer

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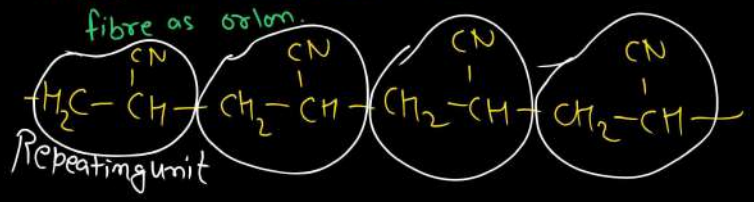

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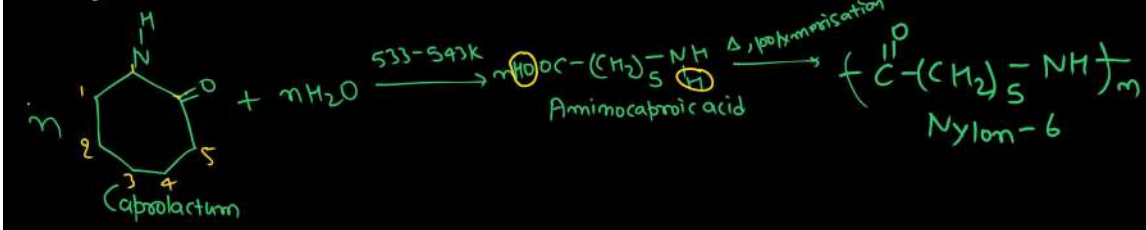
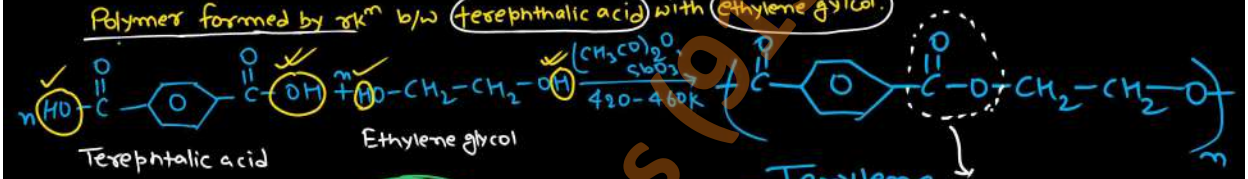
Formed by self-condensation of caprolactum in presence of water by heating at a high tempr.



* Used for making tyres cords, fabrics and ropes.

Terylene (Dacron) → This is an example of polyester.

Polymer formed by rxn b/w terephthalic acid with ethylene glycol.



Mixing

* Grease resistant * Used in blending with cotton and wool fibres

* Glass reinforcing materials in safety helmets.

* Polyester is a condensation polymer whic has ester linkage (-C(=O)-O-)

Rubber → Elastomer.

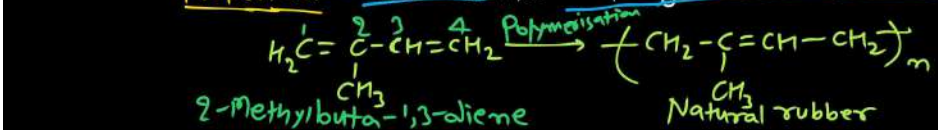
Natural rubber | Synthetic rubber

Regain its normal size, shape or length when the force is removed.

Natural rubber → Rubber obtained from natural sources is called natural rubber.

Preparation - The milky sap obtained from rubber plant is called latex. The latex is coagulated with acetic acid. The coagulated mass is then squeezed.

Properties :- Stretched like a spring and exhibit elastic property.



Vulcanisation

* Raw rubber doesn't possess the characteristic of rubber.
* Vulcanisation of the rubber is process of converting natural rubber to more strong and elastic form.
* Natural rubber is mixed with 3–5 % sulphur and heated at 100 to 150°C.

Uses:- * For making shoes, water proof coats, golf balls etc.
* Vulcanised rubber is used for making rubber bands, gloves, tubes, conveyer belts and car tyres.

Synthetic rubber

Rubber prepared in lab is called synthetic rubber.
e.g:- Neoprene, thiokol, Buna-S, Buna-N etc.

(a) Neoprene- * First synthetic rubber
* Polymer of chloroprene
* Non-inflammable
* Resistant to action of acids, alkalies, oils, sunlight, O_3 etc.

$$n\,\overset{1}{H_2C}=\overset{2}{\underset{Cl}{C}}-\overset{3}{CH}=\overset{4}{CH_2} \xrightarrow{\text{Polymerisation}} \left(CH_2-\underset{Cl}{C}=CH-CH_2\right)_n$$

Chloroprene (2-chlorobuta-1,3-diene) → Neoprene

Uses:- In manufacturing of conveyer belts, gaskets and hoses etc.

Buna-N

It is obtained by co-polymerisation of 1,3-butadiene and acrylonitrile in presence of peroxide catalyst.

$$n\,\overset{1}{CH_2}=\overset{2}{CH}-\overset{3}{CH}=\overset{4}{CH_2} + n\,CH_2=CH-CN \xrightarrow{\text{Peroxide catalyst}} \left(CH_2-CH=CH-CH_2-CH_2-\overset{CN}{\underset{|}{CH}}\right)_n$$

Buta-1,3-diene + Acrylonitrile → Buna-N

Properties- * Very rigid and resistent to petrol, lubricating oil and organic solvents
* Used in making oil seals, tank lining etc.

Cement

* Imp. material of construction → Building, Bridge, tower, Road etc.
* Used as a binder
* Finely powderd mixture of calcium silicate and aluminate along with small amount of gysum.
* It becomes hard when treated with water.

Ave. composition of portland cement :-

Lime (CaO)	50% – 60%
Silica (SiO_2)	20% – 25%
Alumina (Al_2O_3)	5% – 10%
Magnesium oxide (MgO)	2% – 3%
Ferric oxide (Fe_2O_3)	1% – 2%
Sulphur trioxide (SO_3)	1% – 2%

Raw material for cement

[1] Lime stone ($CaCO_3$)
Calcium carbonate

[2] Gypsum ($CaSO_4 \cdot 2H_2O$)
Calcium sulphate dihydrate

[3] Clay (SiO_2 and Al_2O_3)
(Mitti) — SiO_2 → Silica, Al_2O_3 → Alumina

* MgO and Fe_2O_3 used in small amount → To impart suitable colour to cement

Manufacture of cement

Wet process

Raw slurry → गारा या घोल

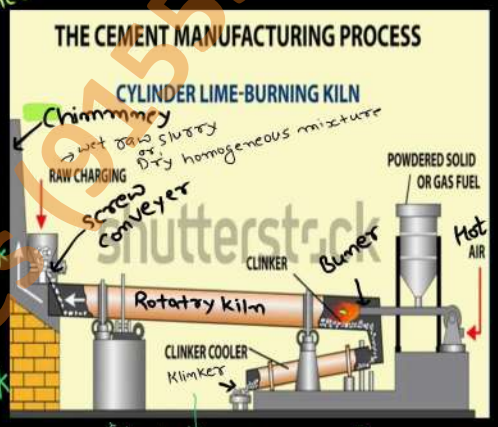
* Raw material soft
* Clay is washed with water to remove impurities and then mixed with lime stone and crushed to make fine powder
* Resultant mass is converted to homogeneous raw slurry. → गारा

Dry process

* Raw material hard
* Raw material mixed with lime stone and crushed to make fine powder.
* Mixture is converted to fine powder.

Following changes takes place in kiln (Furnance) :-

* Temp^r in upper region of kiln → 1000 – 1100K
  (Water content of mixture evaporates.)
* Temp^r in middle region of kiln → 1100 – 1200K
  (thermal decomposition of lime stone).
  $CaCO_3 \xrightarrow{\Delta} CaO + CO_2$
* Temp^r in lower region of kiln → 1770 – 1870K
  (Various combination r^k^{n} takes place b/w CaO and Clay.



* key ingredients of cement
* dark grey in colour
* It is ground in fine powder and mixed with gypsum.

Main compounds in portland cement

$2CaO + SiO_2 \rightarrow 2CaO \cdot SiO_2$ — Dicalcium silicate

$3CaO + SiO_2 \rightarrow 3CaO \cdot SiO_2$ — Tricalcium silicate

$2CaO + Al_2O_3 \rightarrow 2CaO \cdot Al_2O_3$ — Dicalcium aluminate

$3CaO + Al_2O_3 \rightarrow 3CaO \cdot Al_2O_3$ — Tricalcium aluminate

$4CaO + Al_2O_3 + Fe_2O_3 \rightarrow 4CaO \cdot Al_2O_3 \cdot Fe_2O_3$ — Tetracalcium aluminoferrite

* Due to very high temperature in lower region, about 25-30% mass melts and combine with solid mass to form climkers.

* The hot climkers are cooled by cold air and mixed it with gypsum.

* The climkers are converted into fine powder in grinding machine.

* Fine powder is portland cement.

Setting of cement

* It is the process by which cement paste transforms from a fluid to a solid state.

* It is exothermic rkn.

It takes place in two phases :-

[1.] Initial setting
↓
cement mixture starts lossing its plasticity.
Softness.

[2.] Final setting.
↓
cement continue to harden and gain strength.

KEY STAGES IN SETTING OF CEMENT

Mixing (cement with water and aggregate.)
↓
Hydration (Water initiate the hydration rkn) calcium silicate hydrate and calcium hydroxide is formed.
↓
Initial set (cement mixture lossing its plasticity.) → few hours
↓
Final set (Cement continues to harden and gain strength.) → 24 hours
↓
Curing (After setting, maintain moisture and tempr condition for complete hydration for strength development.

Unit - 4

FUELS AND LUBRICANTS

FUEL

Combustion

* Combustible substance which burns in air and produce large amount of heat that is used economically for domestic and industrial purposes.
* Heat is evolved due to chemical rxn so these fuels are called chemical fuels.

  e.g.:- Natural gas, Petrol, Diesel, kerosene oil, wood, coal etc.

Characteristics of ideal fuels :-

[1.] High calorific value → Higher the amount of heat per unit mass or volume, better is fuel.

[2.] Moderate ignition temp^r →

[3.] Low moisture (water) content →

[4.] Moderate rate of combustion →

[5.] Availability at low ~~con~~ cost →

[6.] Easy to transport →

[7.] Harmless combustion product → Combustion should not be harmful by emitting CO, SO_2, H_2S gas and other poisionous gas.

Classification of fuels:-

[I.] On the basis of their occurance:-

(a) Natural fuel or Primary fuel
↓
Fuels which are found in nature.
e.g.:- Wood, coal, petrolium and natural gases.

(b) Artificial fuel or Secondary fuel
↓
Fuels which are prepared artificially from primary fuels.
e.g.:- Coke, kerosen oil, petrol, coal gas, producer gas etc.

[II.] On the basis of physical state:-

Type	Natural fuel	Artificial fuel
(a) Solid	Wood, dung, Coal	Charcoal, coke
(b) Liquid	Crude petroleum	kerosene, Petrol, diesel
(c) Gas	Natural gas	LPG, coal gas, oil gas, bio gas, water gas

Petroleum
↓
Dark coloured viscous oil found deep in earth's crust.

Classification :-

(i) Paraffinic base type → Composition → Hydrocarbons (Alkane का G.F. → C_nH_{2n+2})
(CH_4 to $C_{35}H_{72}$)

(ii) Asphaltic base type → Composition → Cycloparaffins or naphthalene with small amount of paraffins.

(iii) Mixed base type → composition → Both paraffinic and asphaltic hydrocarbon.
↓
Semi-solid wax

Origin of petroleum :-

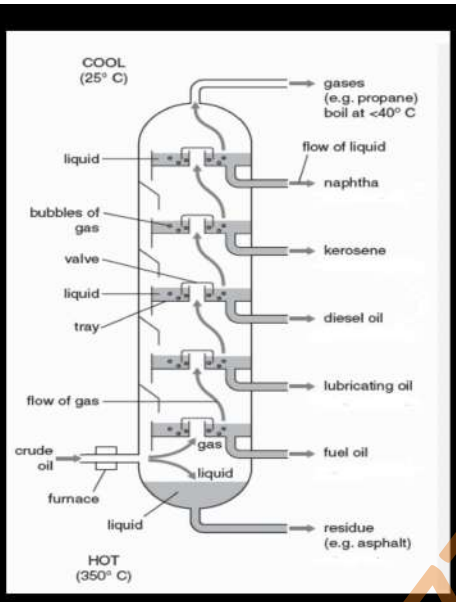
Due to earthquake, marine animals and plants got buried under the crust of earth. Because of prolonged action of pressure and heat in the interior of earth for ages, biological matter decompose into petroleum.

Mining of petroleum

* By drilling holes in earth's crust and sinking pipe in the oil bearing porous rock, we do mining of petrolem.
* The crude oil thus obtained is conveyed by pipe line to refineries which are located at long distance.

Refining of petroleum

* It is done by fractional distillation of petroleum in fractionating column made of steel.
* It contains large no. of horizontal stainless steel tray.
* The process of dividing petroleum into different useful fractions with different boiling range is called refining of petroleum.
* Crude oil is heated from bottom above 400°C.
* Vapours of oil rise up in fractionating column and condensed at the tray.
* The uncondesed gases escape at the top of column. These liquified to give L.P.G.
* LPG consisting mainly methane, ethane, propane and butane is supplied in cylinder at high pressure.



Composition and uses of main petroleum fractions:-

Name of fraction	Boiling range	composition (in terms of C	Application
(1.) Uncondensed gas	upto 30°c	C_1-C_4	Used as domenstic fuel or industrial fuel.
[2.] Petroleum ether	40-80°c	C_5-C_7	as solvent
[3.] Gasoline	40-120°C	C_5-C_9	as motor fuel
[4.] Naphtha	120-180°C	C_9-C_{10}	as solvent
[5.] Kerosene	180-250°c	$C_{10}-C_{16}$	For lighting purpose
[6.] Diesel oil	250-320°C	$C_{17}-C_{30}$	as diesel engine fuel.

Cracking

the process of decomposition of higher mm hydrocarbon having high boiling point to lower molecular mass hydrocarbon of low boiling points

$$C_{10}H_{22} \xrightarrow{\text{Cracking}} C_5H_{12} + C_5H_{10}$$

Decane — n-Pentane — Pentene

b.p. → 174°c — 36°c

Types of cracking:-

[1.] Thermal cracking
↓
When cracking is done by heating under pressure.

[2.] Catalytic cracking
↓
When cracking is carried out in presence of catalyst like alumina or aluminium silicate.

→ It doesn't require high bressure.
→ Quality of petrol is better.
→ yield of petrol is better.

KNOCKING

In an internal combustion engine, a mixture of fuel and air ignited in a cylinder.

- Petrol engine → Ignition is done by electric spark.
- Diesel engine → " " compresed air.

The gas evolved during ignition create high pressure and force the piston down providing the power stoke to IC engine.

* IC engine → It is a heat engine where the combustion of a fuel occur with an oxidiser (air) in a combustion Chamber.

* The efficiency of an IC engine depends on compression ratio.

Compression ratio → The ratio of gaseous vol. in cylinder at the end of suction stroke to the vol. at the end of compression stroke.

* Higher the compression ratio, higher the efficiency of engine.

Knocking

In certain circumstances, compression ratio exceeds a certain limit so that the last portion of fuel–air mixture get ignited instantaneously, producing an explosive violence called Knocking.

LPG

* Liquified petroleum gas
* By product during cracking of heavy oils
* Flammable mixture of propane and butane
* Used as a fuel in cooking.
* It is supplied under pressure in cylinder
* Calorific value → 28000 Kcal/m^3

Advantanges of LPG:-

* low cost
* High calorific fuel
* Burn consistently
* Stored with cleanliness
* Burn completely without smoking
* Easily transported.

CNG

* Compressed natural gas.
* By compressing natural gas.
* Odourless, tasteless, non-toxic
* Composition:- Methane (93.05 %)
  - Ethane, butane, propane are also present.
  - N_2, CO_2, H_2S and traces of water are also present.
* It is used in place of petrol, diesel, LPG.
* CNG combustion produces very less undesirable gases than other gases.

Biogas / Gobar gas

* Renewable energy source
* Mixture of gases produced by break down of organic matter like plant materials, food waste, muncipal waste, agricultural waste.

Ave. composition:-

Methane	50-75%
Carbondioxide	25-50%
Nitrogen	0-10%
Hydrogen	0-1%

Uses of biogas:-

* Domestic fuel
* For lighting and running water pump.
* Generate organic fertiliser

Advantage of biogas:-

* Reduce soil and water pollution
* Clean and renewable energy source
* Prevents health problems
* Healthy cooking alternative

Manure

* It is natural organic fertiliser made from decomposed plant and animal waste.
* It is applied to soil to improve soil fertility and crop productivity.
* It added nutrients to soil like nitrogen, phosphorous and potassium which are vital for plant growth.

Significant role in agriculture:-

* Nutrient supply → N, P, K.
* Microbial activity → Incr
* Soil structure improvement → Water retention, aeration incr.
* Environmental benefits →
  It reduce the need for chemical fertilizer which minimies potential environmental pollution.

Types of manures:-

[1] Farmyard manure → A mixture of cattle dung and urine

[2] Green manure → It consist of green plants and crops.

[3] Compost → Decomposed organic material from kitchen waste, garden refuse and other organic material.

[4] Vermicompost → Produced using earthworm to decompose organic matter.

NPK fertilizers

It is a synthetic fertilizer that contain three nutrients required for plant growth.

- N → Essential for leaf growth and photosynthesis
- P → Imp. for root development, flowering, fruiting.
- K → Helps in overall plant health, disease resistance, and water regulation.

Properties of NPK fertiliser

[1.] Nutrient content → NPK ratio
10 – 10 – 10
Equal proportion

[2.] Solubility → Highly soluble in water

[3.] Granuel uniformity → consistent nutrient supply

[4.] Self - Stability → Stable under normal storage condition
(less risk of nutrient degradation

Uses of NPK fertilizers

(i) Plant Nutrition –

(ii) Soil fertility improvement –

(iii) Crop yield enhancement –

(iv) Commerical and home gardening –

(v) Application flexibility.

Application methods

[1.] Broadcasting → Spreading fertilizer over soil

[2.] Side-dressing → Applying fertilizers beside the growing plants.

[3.] Foliar feeding → Spraying a dilute solution of fertilizer onto plants.

[4.] Incorporation → Mixing fertilizer into soil during planting.

Manufacturing of NPK fertilizer:-

[1.] Raw materials →

* N → Urea, Ammonium chloride, Ammonium sulphate, Calcium nitrate
* P → Monoammonium phosphate; $(NH_4)H_2PO_4$
  Diammonium phosphate; $(NH_4)_2HPO_4$
  Triple super phosphate; $(NH_4)_3PO_4$
* K → Potassium chloride (KCl)
  Potassium sulphate (K_2SO_4)

[2.] Mixing raw materials → A/c to desired NPK ratio.

[3.] Granulation → Mixture is processed in granulator. → Granuels.

[4.] Drying and cooling → To solidify granuels.

[5.] Screening → To get uniform size granuels.

[6.] Packing → For transport to markets and farms.

Fire Extinguisher

* A portable device that is used to control or put out small fire.
* It is not meant to be used on fire that are out of controll.

Types of Fire extinguisher

[1.] Water extinguisher →

Use → Effective on class A fire; ordinary solid combustion like wood, paper and cloth.

Not for → Electrical fires, flammable liquids or metal.

[2.] Foam extinguisher →

Use → Suitable for class A and B fire ;

Flammable liquids such as alcohol, ether, oil

Not for → Electrical fires

[3.] Dry powder extinguisher →

Use → Suitable for class A, B and C fire.

gases such as butane and propane

Not for → Confined space

[4.] CO_2 extinguisher →

Use → Effective on class B and electrical fires.

Not for → Class A fire

[5.] Wet chemical extinguisher -

Use → for class K fire like cooking oils and fats.

Not for → General use on class A, B or C fire.

Uses for fire extinguisher

(PASS technique)

- Pull → Pull the pin of the extinguishe
- Aim → Aim at the base of fire
- Squeeze → Squeeze the lever slowly
- Sweep → sweep from side to side

Lubricants

* A substance which reduces the friction b/w two moving surfaces.
* The process of applying the lubricants in b/w two moving surfaces is called lubrication.

Function of lubrication

[1.] Reduce friction

[2.] Prevent corrosion

[3.] Protect agimst surface deformation →

[4.] Heat transfer →

[5.] As a coolent →

Properties of lubricants

[1.] Flash points and Fire points:-

Flash points	Fire points
the lowest tempr at which vapour produced by a lubricant ignites when comes in contact with flame.	the lowest tempr at which vapour produced by a lubricant burn continuously for at least five seconds when comes in contact with flame

* The fire point is usually 20–30° higher than flash point.
* Lubricants should not be used in environements that are hotter than fire points.
* We should use lubricants having high flash point and fire point.

[2.] Oiliness → A good lubricant should have high oiliness so that it maintain continuous film b/w moving surface reducing friction.
layer.

[3.] Volatility → Tempr ↑ | volatility ↑ | Reuse of lubricant | Expensive

Good lubricant should have low volatility.

[4.] Carbon residue → Lubricants evaporate and pyrolyse under a prescribed set of conditions and carbon residue is obtained.

Good lubricant should deposit least amount of carbon.

[5.] Ash content → It is measure of the inorganic impurities in a lubricant like sand, aluminium, silicon, Sodium, nickel and vanadium.

* Range of ash content → 0.03 % – 0.07 % by mass.

[6.] Anilime point → It is the minimum tempr at which equal volume of anilime and lubricant oil are miscible.

* Lower anilime point → Higher % of aromatic hydrocarbon.
* Higher anilime point → Lower % of aromatic hydrocarbon.
* Aromatic hydrocarbons have tendency to dissolve natural rubber and certain synthetic rubbers.
* A good lubricants should have high anilime point.

[7.] Cloud and pour point →

Cloud point → tempr at which lubricants begins to form waxy solids and appear cloudy.

* Viscosity ↑ Fluidity decr.

Pour point → tempr at which a lubricant solidifies and losses its flow property.

For

* Machine working at low tempr. lubricants should have much lower cloud point and pour point.

Classification of lubricants

- Lubricating oil
  - Animal or vegetable oil
  - Petroleum or mineral oil
  - Blended oil → By adding additive in lubricating oil
- Grease or Semi-solid lubricant → Combining lubricating oil with thickening agent
- Solid lubricants → Graphite, Molbdenum disulphite
  - oils and grease can't be used in high tempr and high load.

Electrochemistry

[1.] Electrolysis, Faraday's law of electrolysis

[2.] Galvanic cell, Electrode pot., SHE, value of electrode pot. of an electrode using SHE. EMF, ECS, Nernst eqn

[3.] Molar conducitity, Equivalent conductivity, Kohrausch's law.

[4.] Battery.

[5.] Corrosion, types, prevention

(6) Electrolyte, Non-electrolyte etc.

Electrochemistry

Electro + chemistry

Electro → Electrons → Flow → Electricity → Electrical energy

chemistry → chemical change (Process) → chemical rxn → Chemical energy

Red. + oxi. → Redox (Simultaneously)

Red. → Reduction → Gain of e^-s

oxi. → oxidation → loss of e^-s

* Interconversion: Chemical energy $\underset{\text{Electrolytic cell}}{\overset{\text{Galvanic cell}}{\rightleftarrows}}$ Electrical energy

* Branch of physical chemistry in which we study interconversion b/w chemical and electrical energy.

Electrolysis :→

When electricity is passed through aq. or molten form of electrolyte (aq. NaCl, molten NaCl) then corresponding ions are produced which get discharged at anode and cathode to give neutral product. This proces is called electrolysis.

* The device in which process of electrolysis is carried out is called electrolytic cell.

* Electrolytic cell → Electricity passed → Chemical rxn → Ions produced $\xrightarrow{\text{Discharge}}$ Anode and Cathod

Electrolysis of moltem NaCl :-

When electricity is passed through moltem NaCl then corresponding ions Na^+-ions and Cl^--ions are produced. Now Na^+-ions move towards negatively charged cathode and reduction takes place.

$NaCl^{(s)} + water \rightarrow aq.\ NaCl$

$NaCl(s) \xrightarrow{\Delta} NaCl(l)$ (moltem)

Cl^--ions move towards anode (+ve charged) and oxidation takes place.

Rkn at anode:- (oxi.)

$2Cl^- \longrightarrow Cl_2^{(g)} + 2e^-$ (At anode)

Rkn at cathode:- (Red.) $Na^+ + e^- \rightarrow Na(l)$

or, $2Na^+ + 2e^- \rightarrow 2Na(l)$ (moltem)

* $NaCl(l) \xrightarrow{\text{Electrolysis}} Na(l) + Cl_2(g)$

moltem NaCl — (At cathode) — (At anode)

* Im electrolyti cell, the electrode which is connected to +ve pole of battery is called anode and the electrode connected to -ve pole of battery is called cathode.

* Im electrolysis, metal is obtained at cathode and non-metal is obtained at anode.

e.g:- Electrolysis of moltem $AlCl_3$ →

$AlCl_3(l) \xrightarrow{\text{Electrolysis}} Al(l) + \frac{3}{2}Cl_2(g)$

(moltem) — (At cathode) — (At anode)

e.g:- $Al_2O_3(l) \xrightarrow{\text{Electrolysis}} Al(l) + O_2(g)$

(moltem) — (at cathode) — (at anode)

Quantitative aspects of electrolysis:-

mag. of charge on $1e^- = 1.6 \times 10^{-19}$ C

mag. of charge on 1 mol e^-s $= 6.022 \times 10^{23} \times 1.6 \times 10^{-19}$ C

$= 96,490$ C

$\simeq 96,500$ C (1 Faraday)

$1\ mol = 6.022 \times 10^{23}$ → Avogadro's constant → N_A

Conclusion:-

* Charge on 1 mol e^-s $= 96,500C = 1F$

Similarly, " 2 mol e^-s $= 2 \times 96,500C = 2F$

$$\boxed{\text{Charge on } n\ mol\ e^-s = n \times 96,500C = nF}$$

* When 1 mol Na^+-ions obtain 1 mol e^-s then 1 mol Na is formed.

e.g.- $Na^+ + e^- \rightarrow Na$

1 mol, 1 mol → 96,500C, 1 mol → 23g.

* When 1 mol Ca^{2+}-ions obtain 2 mol e^-s then 1 mol Ca is formed.

e.g.- $Ca^{2+} + 2e^- \rightarrow Ca$

1 mol, 2 mol → 2×96,500C, 1 mol → 40g.

* When 1 mol Al^{3+}-ions obtain 3 mol e^-s then 1 mol Al is formed.

e.g.- $Al^{3+} + 3e^- \rightarrow Al$

1 mol, 3 mol → 3×96,500C, 1 mol → 27g

Faraday's law of electrolysis:-

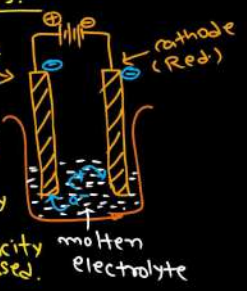
Faraday studied quantitative relation b/w quantity of electricity passed and amount of substance deposited on electrode. This relation is called Faraday's law of electrolysis.

[1.] Faraday's 1st law of electrolysis

[2.] Faraday's 2nd law of electrolysis

Faraday's 1st law of electrolysis:-

It states that amount of substance deposited at electrode is directly proportionat to quantity of electricity passed.



Mathematically, amount of substance deposite $\propto$ Quantity of electricity passed.

$\Rightarrow \omega \propto Q$

$\boxed{\omega = Z \times Q}$

It is proportionality constant called electrochemical equivalent.

Quantity of electricity passed = Current in Ampere × Time in sec.

$\boxed{Q\,C = I\,A \times t\ sec.}$

$\therefore \boxed{Q = I \times t}$

We know that,

$w = z \times Q$ — (1)

and $Q = I \times t$ — (2)

From (1) and (2), $\boxed{w = z \times I \times t}$ $\boxed{w = z \times Q}$

let $I = 1A$, $t = 1$ sec. then $Q = 1A \times 1$ sec.

$\therefore Q = 1C$

$\boxed{w = z}$

Electrochemical equivalent of a substance is equal to amount of substance deposited when 1C electricity is passed.

Problems based on Faraday's 1st law of electrolysis:-

$\boxed{w = z \times Q}$ $\boxed{Q = I \times t}$

$\boxed{w = z \times I \times t}$

MnO_4^-: $x + 4 \times (-2) = -1$, $\boxed{x = +7}$

1 Q. How much $\boxed{\text{charge is required}}$ for following reductions?

(i) 1 mol Al^{3+} to Al (ii) 1 mol Cu^{2+} to Cu (iii) 1 mol MnO_4^- to Mn^{2+}

Solⁿ:- (i) $Al^{3+} + 3e^- \rightarrow Al$

1 mol, 3 mol e^-s → $3 \times 96{,}500C = 3F$; 1 mol → 27g

(ii) $Cu^{2+} + 2e^- \rightarrow Cu$

1 mol, 2 mol → $2 \times 96{,}500C = 2F$; 1 mol → 63.5g

(iii) $MnO_4^- + 5e^- + 8H^+ \rightarrow Mn^{2+} + 4H_2O$

(+7) → (+2)

1 mol, 5 mol → $5 \times 96{,}500C = 5F$; 1 mol

* Charge on 1 mol e^-s = 96,500C = 1F

" " 2 mol e^-s = 2 × 96,500C = 2F.

Q. A solution of $Ni(NO_3)_2$ was electrolysed b/w Pt electrodes using a current of $\boxed{2.5 \text{ amp}}$ for 40 minute. What is mass of $\boxed{\text{Ni deposited}}$?

Solⁿ:- Given: $I = 2.5$ amp $t = 40 \times 60$ sec. $= 2400$ sec.

Rkⁿ at cathod:- $Ni^{2+} + 2e^- \rightarrow Ni$

1 mol, 2 mol → $2 \times 96{,}500C$, 1 mol → 58.5g

At. mass of Ni = 58.5

$Q = I \times t = 2.5 \times 2400C = 6000C$

$2 \times 96{,}500C \rightarrow 58.5g$

$1C \rightarrow \frac{58.5}{2 \times 96{,}500}$ g

$6000C \rightarrow \frac{58.5 \times 6000}{2 \times 96{,}500}$ g

$\therefore$ Mass of Ni deposited at cathode $= \frac{58.5 \times 6000}{2 \times 96{,}500}$ g

V.I 2nd method:-

$w = z \times I \times t$

$w = \frac{\text{At. mass}}{n \times 96{,}500} \times I \times t$

$\therefore w = \frac{58.5 \times 2.5 \times 2400}{2 \times 96{,}500}$ g

3. Q. When a current of 0.75 A is passed through $CuSO_4$ solution for 25 minute, 0.369 g of Cu is deposited at cathod?. Calculate at. mass of Cu ? $Cu^{2+} + 2e^- \rightarrow Cu$.

Solⁿ:- Given, $I = 0.75A$, $t = 25 \times 60$ sec. $= 1500$ sec.

$\omega_{Cu} = 0.369$ g, At. mass of Cu = ?

We know that, $\omega = Z \times I \times t$

$$Z = \frac{\text{At. mass}}{n \times 96{,}500}$$

$$\omega = \frac{\text{At. mass} \times I \times t}{n \times 96{,}500}$$

$$\Rightarrow \text{At. mass} = \frac{\omega \times n \times 96{,}500}{I \times t}$$

$$= \frac{0.369 \times 2 \times 96{,}500}{0.75 \times 1500} \quad \text{Ans.}$$

(4.) An electric current of 5A is passed through fused $CaCl_2$ for 2 hr. Write down electrode reaction and amount of product deposited at cathode? (At. mass of Ca = 40)

Solⁿ:- $I = 5A$, $t = 2hr = 2 \times 60 \times 60$ sec. $= 7200$ sec.

Rkⁿ at cathode:- $Ca^{2+} + 2e^- \rightarrow Ca$.

$$\omega_{Ca} = \frac{\text{At. mass} \times I \times t}{n \times 96{,}500}$$

$$\omega_{Ca} = \frac{40 \times 5 \times 7200}{2 \times 96{,}500} \text{ g}$$

(2.) Faraday's 2nd law of electrolysis:-

When same quantity of electricity is passed through different electrolytic solutions connected in series then amount of substance deposited at their electrode is proportional to equivalent mass.

A/c 2nd law. Mathematically,

mass of substance deposite $\propto$ Eq. mass of that substance.

$$\omega \propto E$$

$$\Rightarrow \omega = C \times E$$

For 1st electrolytic solution, $\omega_1 = C \times E_1$ — (1)

For 2nd electrolytic solution, $\omega_2 = C \times E_2$ — (2)

From (1) by (2), we get

$$\frac{\omega_1}{\omega_2} = \frac{E_1}{E_2}$$

* $\boxed{\frac{\omega_1}{\omega_2} = \frac{E_1}{E_2}}$ — (1)

We know that $\omega = z \times I \times t$

In 1st electrolytic cell, $\omega_1 = z_1 \times I \times t$

In 2nd electrolytic cell, $\omega_2 = z_2 \times I \times t$

Now from (1), $\frac{z_1 \times \cancel{I} \times \cancel{t}}{z_2 \times \cancel{I} \times \cancel{t}} = \frac{E_1}{E_2}$

$\boxed{\frac{z_1}{z_2} = \frac{E_1}{E_2}}$

z = Electrochemical equivalent

E = Eq. mass

i.e. Electrochemical equivalent is directly proportional to eq. mass of substance.

Q. An electric current is passed through $CuSO_4$ and $AgNO_3$ solution connected in series. If at any time 0.7 gm of Cu is deposited then how much Ag will be deposited?

(Cu = 63.5, Ag = 108)

Sol^n:- From 2nd law of electrolysis, $\frac{\omega_1}{\omega_2} = \frac{E_1}{E_2}$

$\Rightarrow \frac{\omega_{Cu}}{\omega_{Ag}} = \frac{E_{Cu}}{E_{Ag}}$

$\Rightarrow \frac{0.7}{\omega_{Ag}} = \frac{63.5/2}{108}$

$\therefore \omega_{Ag} = \frac{0.7 \times 108 \times 2}{63.5}$ g

Rk^n at cathode:-

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

$\boxed{n=2}$

$Ag^+ + e^- \rightarrow Ag$

$\boxed{n=1}$

Eq. mass (Atom) = $\frac{\text{At. mass}}{\text{Valency}}$

$E_{Cu} = \frac{\text{At. mass of Cu}}{\text{Valency}} = \frac{63.5}{2}$

$E_{Ag} = \frac{108}{1} = 108$

Application of electrolysis in industry:-

[1] Electroplating —

[2.] Electrorefining —

[3.] Electrotyping —

[4.] Electrometallurgy. —

Redox reaction

Direct redox rkn

(oxidation and reduction both take place in a single beaker.)

Chemical change → Chemical energy → Heat energy

Zn rod in $CuSO_4$ soln

Indirect redox rkn → Galvanic cell

(oxidation takes place in one beaker and reduction takes place in other beaker.)

Chemical change → Chemical energy → Electrical energy

Examples of direct redox rkn :-

We immerse Zn-rod in aq. solution of $CuSO_4(aq)$.

$$Zn(s) + CuSO_4(aq) \longrightarrow ZnSO_4(aq) + Cu(s) \quad \boxed{\text{Exothermic rkn}}$$

(Blue) (colourless)

$$Zn(s) + Cu^{2+}(aq) + \cancel{SO_4^{2-}(aq)} \longrightarrow Zn^{2+}(aq) + \cancel{SO_4^{2-}(aq)} + Cu(s)$$

Spectator ion = SO_4^{2-}

(Ions which don't undergo chemical change during rkn).

Gain of $2e^-$ (Reduction)

$$Zn(s) + Cu^{2+}(aq) \longrightarrow Zn^{2+}(aq) + Cu(s)$$

loss of $2e^-$ (oxidation)

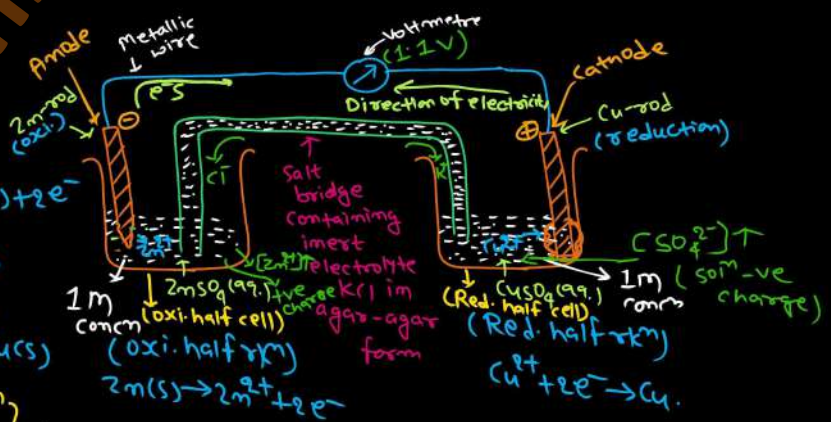
When Zn-rod is dipped in aq. $CuSO_4$ solution then $ZnSO_4(aq.)$ and $Cu(s)$ is formed. During this rkⁿ, Zn gets oxidiesed to Zn^{2+}-ions and Cu^{2+}-ions present in solution get reduced to Cu. Thus oxidation and reduction both rkⁿ take place in a single beaker. That's why this is an example of direct redox rkⁿ. In this rkⁿ heat is released.

V.I Galvanic cell

* It is a device in which indirect redox reaction takes place in such a way that chemical energy of rkⁿ gets converted to electrical energy.

Construction of Galvanic cell –

* We add Zn-rod in $ZnSO_4(aq.)$ solⁿ in one beaker and Cu-rod in $CuSO_4$ solution in another beaker. Now both rods are connected by a metallic wire which passes through a voltmetre. Both solutions are connected by inverted U-shaped tube called salt bridge. It contains inter electrolyte which maintain electrical neutrality in both beaker.
* Zn-rod is called anode (-ve charged) and Cu-rod is called cathode.
* Oxidation takes place on Zn-rod and reduction takes place on Cu-rod.
* Electrons flow from Zn-rod to Cu-rod and thus electricity is produced whose direction is from Cu-rod to Zn-rod.



Rkⁿ at Zn-rod (anode) →

$Zn(s) \rightarrow Zn^{2+}(aq.) + 2e^-$

(oxi. half rkⁿ)

$Zn(s) \rightarrow Zn^{2+} + 2e^-$

Rkⁿ at cathode → (Cu-rod)

$Cu^{2+}(aq.) + 2e^- \rightarrow Cu(s)$

(Red. half rkⁿ)

$Cu^{2+} + 2e^- \rightarrow Cu.$

overall redox rkⁿ or cell rkⁿ →

$$Zn(s) \rightarrow Zn^{2+}(aq.) + \cancel{2e^-}$$

$$Cu^{2+}(aq.) + \cancel{2e^-} \rightarrow Cu(s)$$

$$Zn(s) + Cu^{2+}(aq.) \rightarrow Zn^{2+}(aq.) + Cu(s)$$

Cell representation:-

* Cell reactions → Rkn taking place in Galvanic cell.
* Cell reactions are represented by cell representation.

$$M(s) \,|\, M^{n+}(aq.) \,||\, M^{n+}(aq.) \,|\, M(s)$$

Anode (−ve charged) Oxidation left — Salt bridge — Cathode (+ve charged) Reduction Right

(flow of e^-s)

flow of electricity

e.g.:- Cell rkn

$$Zn(s) + Cu^{2+}(aq.) \longrightarrow Zn^{2+}(aq.) + Cu(s)$$

Cell representation:-

$$Zn(s) \,|\, Zn^{2+}(aq.) \,||\, Cu^{2+}(aq.) \,|\, Cu(s)$$

Anode (oxi.) — Cathode (red.)

e.g.:- Cell reaction:-

gain of $2e^-$s (red.)

$$Ni(s) + 2Ag^+(aq.) \longrightarrow Ni^{2+}(aq.) + 2Ag(s).$$

loss of $2e^-$s (oxi.)

Cell representation:-

$$Ni(s) \,|\, Ni^{2+}(aq.) \,||\, Ag^+(aq.) \,|\, Ag(s)$$

Anode — e^-s — Cathode

Oxi. left — electricity — Red. Right

Cell reaction:

$$Cr(s) + 3Cd^{2+}(aq.) \longrightarrow 2Cr^{3+}(aq.) + Cd(s)$$

Cell representation:-

$$Cr(s) \,|\, Cr^{3+}(aq.) \,||\, Cd^{2+}(aq.) \,|\, Cd(s)$$

Anode — Cathode

or, $Cr \,|\, Cr^{3+}(c_1) \,||\, Cd^{2+}(c_2) \,|\, Cd(s)$

V.I.

* **Salt bridge:-** It is inverted U-shaped tube containing intert electrolyte to maintain electrical neutrality in both oxidation and reduction half beaker.

Function of salt bridge:-

To maintain electrical neutrality in both beaker.

Electrode potential (E) [Potential = ~~क्षमता~~ (ability, capacity)

"The tendency (capacity or) of an electrode to loss or gain e^-(s) when it is dipped in its own salt solution."

Types:

[1] Oxidation electrode potential (E_{oxi}) — tendency of an electrode to loss e^-(s)

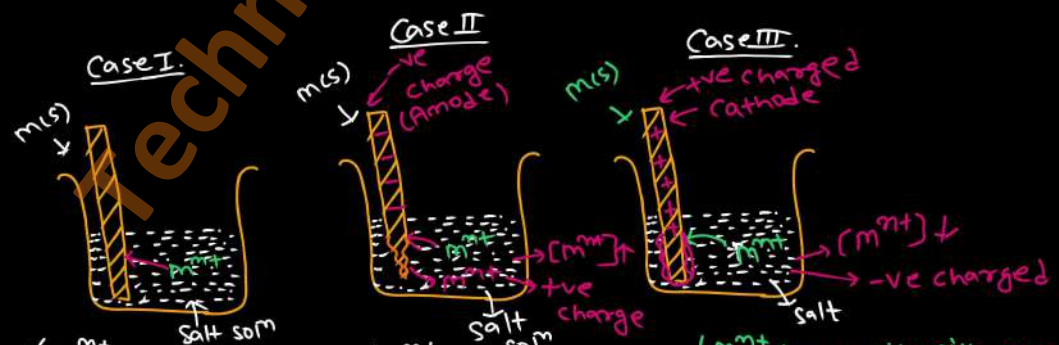
[2] Reduction electrode potential (E_{red}) — tendency of an electrode to gain e^-(s).

e.g.:- Cell representation:- $Zn(s) | Zn^{2+}(c_1) || Cu^{2+}(c_2) | Cu(s)$

Anode ($\ominus$) | Cathode ($\oplus$)

$E_{Zn/Zn^{2+}}$ = oxi. electrode pot. of Zn-electrode (E_{oxi})

$E_{Cu^{2+}/Cu}$ = Red. electrode pot of Cu-electrode. (E_{red})



Case I: (M^{n+}-ions collide with metal rod) → No change.

Case II: (M^{n+}-ions collide with metal rod then metal rod get oxidiesed i.e. M^{n+}-ions are produced (Oxidation)

$M(s) \rightarrow M^{n+}(aq) + ne^-$

Case III: (M^{n+}-ions collide with metal rod then M^{n+}-ions get reduced and deposited at metal rod thus reduction takes place.

$M^{n+}(aq) + ne^- \rightarrow M(s)$

* Due to charge difference produced b/w metal rod (electrode) and electrolyte, potential difference is set up b/w electrode and electrolyte is called electrode potential (E).

* V.I. When electrode potential is calculated at standard condition (i.e. 298K temp^r and 1 atm pressure) then the value is called Standard electrode potential (E°).

Electrode pot. (E)
- E_{oxi}
- E_{red}

Standard electrode pot. (E°)
- E°_{oxi} (Standard oxi. electrode pot.)
- E°_{red} (Standard reduction electrode potential)

e.g.:- 298K, 1 atm

$Zn(s) + Cu^{2+}(aq) \rightarrow Zn^{2+}(aq) + Cu(s)$

$Zn|Zn^{2+}||Cu^{2+}|Cu$.

$E^\circ_{Zn/Zn^{2+}}$ → Standard oxi. electrode pot. of Zn

$E^\circ_{Cu^{2+}/Cu}$ → Standard red. electrode pot. of Cu.

* Imp. The electrode potential of a single electrode can't be calculated bcoz neither oxidation nor reduction takes place alone.

* Electrode potential of a single electrode is calculated using refference electrod like SHE.

* Reffference electrode →
- SHE (Standar hydrogen electrode).
- or.
- NHE (Normal hydrogen electrode)

Note:- Both oxidation and reduction potential have equal magnitude but opposite sign.

Consider a cell rxn (Under standard condition)

$Zn(s) + Cu^{2+}(aq.) \rightarrow Zn^{2+}(aq.) + Cu(s)$

Zn-rod (Anode) → left

Cu-rod (Cathode) → Right

Cell representation:- $\boxed{Zn(s)|Zn^{2+}(C_1)||Cu^{2+}(C_2)|Cu(s)}$

oxi. half cell

Red. half cell

$Zn(s)|Zn^{2+}(C_1)$, $Zn(s) \rightarrow Zn^{2+}(C_1) + 2e^-$; $E^\circ_{Zn/Zn^{2+}} = E^\circ_{oxi}$

$Cu^{2+}(C_2)|Cu(s)$, $Cu^{2+}(C_2) + 2e^- \rightarrow Cu(s)$; $E^\circ_{Cu^{2+}/Cu} = E^\circ_{red}$

Imp:- $E^\circ_{Zn/Zn^{2+}} = -E^\circ_{Zn^{2+}/Zn}$

$E^\circ_{Cu^{2+}/Cu} = -E_{Cu/Cu^{2+}}$

e.g.:

$E^\circ_{Zn^{2+}/Zn} = -0.76V$

E°_{red} (standard red. pot. of Zn)

$E^\circ_{Zn/Zn^{2+}} = +0.76V$

E°_{oxi} (standard oxi. pot. of Zn)

$E^\circ_{Cu^{2+}/Cu} = +0.34V$

E°_{red} (Standard red. pot. of Cu)

$E^\circ_{Cu/Cu^{2+}} = -0.34V$

E°_{oxi} (Standard oxi. pot. of Cu)

Reduction half rxn

* $Ag^+(aq.) + e^- \rightarrow Ag(s)$

$E^\circ_{Ag^+/Ag} = +0.80V$ — (1)

Standard red. pot of silver

$E^\circ_{Ag/Ag^+} = -0.80V$ — (2)

Standard oxi. pot of silver

From (1) and (2), we have.

$E^\circ_{Ag^+/Ag} = -E^\circ_{Ag/Ag^+}$

Conclusion:-

* $E^\circ_{red} = -E^\circ_{oxi}$

* $E^\circ_{oxi} = -E^\circ_{red}$

EMF of cell the cell :-

Electromotive force of the cell

Electrons — motivate — Force.
Flow

The force which is responsible for flow of e^-s from anode to cathode is called emf of the cell.

$$\boxed{\text{EMF of the cell} = (E_{oxi})_{anode} + (E_{red})_{cathode}}$$

$$(E_{oxi})_{anode} = -(E_{red})_{anode}$$

$$E_{cell} = (E_{red})_{cathode} - (E_{red})_{anode}$$

$$\boxed{E_{cell} = E_{Right} - E_{Left}}$$

e.g.:- $Zn(s) + Cu^{2+}(aq.) \rightarrow Zn^{2+}(aq.) + Cu(s)$. [cell rxn]

$= Zn(s) | Zn^{2+}(c_1) || Cu^{2+}(c_2) | Cu(s)$. [cell representation]

Left — Right

$$\boxed{E_{cell} = E_{Cu^{2+}/Cu} - E_{Zn^{2+}/Zn}}$$

Under standard condition,

$$\boxed{E^\circ_{cell} = E^\circ_{Cu^{2+}/Cu} - E^\circ_{Zn^{2+}/Zn}}$$

Standard emf of the cell →

* When emf of the cell is calculated under standard condition then it is called standard emf of the cell.

* It is represented by E°_{cell}.

$$\boxed{E^\circ_{cell} = E^\circ_{Right} - E^\circ_{Left}}$$

e.g.:- For cell representation:- Under (Standard condition)

$Zn | Zn^{2+}_{(1M)} | Cu^{2+}_{(1M)} | Cu$.

L R

$E^\circ_{cell} = ?$

298 K
1 bar
1M

$E^\circ_{cell} = E^\circ_R - E^\circ_L$

$= E^\circ_{Cu^{2+}/Cu} - E^\circ_{Zn^{2+}/Zn}$

$= (+0.34V) - (-0.76V)$

$= +0.34V + 0.76V$

$= +1.1V$

$E^\circ_{cell} = ?$

Q. Calculate Standard emf of the cell :-

Cell rxn: $Cu(s) + Ag^+(aq) \rightarrow Cu^{2+}(aq.) + Ag(s)$

Under standard condition.

Cell representation:-

$Cu(s) | Cu^{2+}(1M) || Ag^+(1M) | Ag(s)$.

L R

$E^\circ_{cell} = E^\circ_R - E^\circ_L$ (Both should be interms of red)

$= E^\circ_{Ag^+/Ag} - E^\circ_{Cu^{2+}/Cu}$.

$= (0.80V) - (0.34V)$

$= +0.46V$

Standar condition:-
298K temp^r
1 bar pressure
1M concn

$E^\circ_{Cu^{2+}/Cu} = +0.34V$

$E^\circ_{Cu/Cu^{2+}} = -0.34V$

Nernst equation

* Nernst has established a relation b/w E_{cell} and E°_{cell} called Nernst equation.

* It relates concentration of ions involved in rxn and E_{cell}.

Consider a hypothetical reduction half rxn :-

$M^{n+}(aq.) + ne^- \rightarrow M(s)$.

From thermodynamics (B.Sc.) we know that

$$E_{M^{n+}/M} = E^\circ_{M^{n+}/M} - \frac{RT}{nF} \ln \frac{[M(s)]}{[M^{n+}(aq)]}$$

Where, $E_{M^{n+}/M}$ = emf of the cell (at given conc^n and T)

$E^\circ_{M^{n+}/M}$ = Standard emf of the cell.

R = Gas constant ($8.314\ J\ K^{-1} mol^{-1}$)

T = Temp^r (298K)

n = no. of e^-'s involved

F = Faraday's constant ($96,500\ C\ mol^{-1}$)

$[M^{n+}]$ = Molar concentration of M^{n+} ions.

$$\ln y = 2.303 \times \log_{10} y$$

$$[M(s)] = 1 \qquad \ln \frac{1}{x} = -\ln x$$

We know that

$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF} \ln \frac{1}{[M^{n+}]}$$

$$E_{cell} = E^\circ_{cell} - \frac{2.303 \times RT}{nF} \log_{10} \frac{1}{[M^{n+}]}$$

Put the value of R, T and F, we have.

$$\frac{2.303 \times RT}{nF} = \frac{0.0591}{n}$$

$$\therefore E_{M^{n+}/M} = E^\circ_{M^{n+}/M} - \frac{0.0591}{n} \log \frac{1}{[M^{n+}]}$$

e.g.:- (a) $Zn^{2+}(aq.) + 2e^- \rightarrow Zn(s)$

$$E_{Zn^{2+}/Zn} = E^\circ_{Zn^{2+}/Zn} - \frac{0.0591}{2} \log \frac{1}{[Zn^{2+}]}$$

e.g.:-

(b) $Cu^{2+} + 2e^- \rightarrow Cu$.

$$E_{Cu^{2+}/Cu} = E^\circ_{Cu^{2+}/Cu} - \frac{0.0591}{2} \log \frac{1}{[Cu^{2+}]}$$

(c) $Ag^+ + e^- \rightarrow Ag(s)$

$$E_{Ag^+/Ag} = E^\circ_{Ag^+/Ag} - \frac{0.0591}{1} \log \frac{1}{[Ag^+]}$$

Nernst equation for cell rxn

Consider a cell rxn at 298K temp^r,

$Zn(s) + Cu^{2+}(aq.) \longrightarrow Zn^{2+}(aq.) + Cu(s)$.

Cell representation :- $Zn(s) | Zn^{2+}(aq.) || Cu^{2+}(aq.) | Cu(s)$.

(L: anode (oxi.); R: cathode (Red.))

$\ln a - \ln b = \ln \frac{a}{b}$

For red. half cell → $Cu^{2+}|Cu$; $Cu^{2+} + 2e^- \rightarrow Cu$

$$E_{Cu^{2+}/Cu} = E^\circ_{Cu^{2+}/Cu} - \frac{RT}{nF} \ln \frac{1}{[Cu^{2+}]} \quad \text{— (1) (Nernst eqn for } Cu^{2+}/Cu)$$

For oxi. half cell → Zn/Zn^{2+} Zn^{2+}/Zn ; $Zn^{2+} + 2e^- \rightarrow Zn$

$$E_{Zn^{2+}/Zn} = E^\circ_{Zn^{2+}/Zn} - \frac{RT}{nF} \ln \frac{1}{[Zn^{2+}]} \quad \text{— (2) (Nernst eqn for } Zn^{2+}/Zn)$$

From (1) - (2), we get,

$$E_{Cu^{2+}/Cu} - E_{Zn^{2+}/Zn} = \left(E^\circ_{Cu^{2+}/Cu} - \frac{RT}{nF} \ln \frac{1}{[Cu^{2+}]}\right) - \left(E^\circ_{Zn^{2+}/Zn} - \frac{RT}{nF} \ln \frac{1}{[Zn^{2+}]}\right)$$

$$\Rightarrow E_{cell} = \left(E^\circ_{Cu^{2+}/Cu} - E^\circ_{Zn^{2+}/Zn}\right) - \frac{RT}{nF} \ln \frac{1}{[Cu^{2+}]} + \frac{RT}{nF} \ln \frac{1}{[Zn^{2+}]}$$

$$\Rightarrow E_{cell} = E^\circ_{cell} - \frac{RT}{nF} \left(\ln \frac{1}{[Cu^{2+}]} - \ln \frac{1}{[Zn^{2+}]}\right)$$

$$\Rightarrow E_{cell} = E^\circ_{cell} - \frac{RT}{nF} \left(\ln \frac{1}{[Cu^{2+}]} \Big/ \frac{1}{[Zn^{2+}]}\right)$$

$$\Rightarrow E_{cell} = E^\circ_{cell} - \frac{RT}{nF} \ln \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

$$\Rightarrow E_{cell} = E^\circ_{cell} - \frac{2.303 \times RT}{nF} \log \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{n} \log \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

Nernst eqn for cell rxn

In general, Consider a hypothetical cell rxn:-

$$aA + bB \xrightarrow{ne^-} cC + dD$$

Nernst eqn ; $E_{cell} = E^\circ_{cell} - \frac{0.0591}{n} \log_{10} \frac{[C]^c \times [D]^d}{[A]^a \times [B]^b}$

Under standard condition:-

$$Cu(s) + 2Ag^+ \longrightarrow Cu^{2+}(aq.) + 2Ag(s)$$

temp^r → 298 K
pressure → 1 bar
conc^n → 1 M

Nernst eqn,

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{2} \log_{10} \frac{[Cu^{2+}]}{[Ag^+]^2}$$

Problems based on Nernst equation:-

Q. Calculate emf of the cell in which following reaction takes place:

$$Ni(s) + 2Ag^+(0.002M) \longrightarrow Ni^{2+}(0.160M) + 2Ag(s).$$

Given that $E^\circ_{cell} = 1.05V$

Sol^n:-

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{2} \log \frac{[Ni^{2+}]}{[Ag^+]^2}$$

$$= 1.05 - \frac{0.0591}{2} \log \frac{0.160}{(0.002)^2}$$

$$= 1.05 - \frac{0.0591}{2} \log \frac{160 \times 10^{-3} \times 10^6}{}$$

$$= 1.05 - \frac{0.0591}{2} \log(4 \times 10^4) \text{ V}$$

$$= 1.05 - \frac{0.0591}{2} \times (4.6021)$$

$$= (1.05 - 0.14)V$$

$$= 0.91V \text{ Ans.}$$

$\log 10 = 1$

$\log a \times b = \log a + \log b.$

$\log a^b = b \log a$

$\log(4 \times 10^4) = \log 4 + \log 10^4$

$= \log 2^2 + 4 \log 10$

$= 2 \times \log 2 + 4 \times 1$

Note:- Both oxidation and reduction potential have equal magnitude but opposite sign.

Consider a cell rxn (Under standard condition)

$$Zn(s) + Cu^{2+}(aq.) \longrightarrow Zn^{2+}(aq.) + Cu(s)$$

Zn-rod (Anode) → left

Cu-rod (Cathode) → Right

Cell representation:- $Zn(s) | Zn^{2+}(C_1) || Cu^{2+}(C_2) | Cu(s)$.

oxi. half cell — Red. half cell

$Zn(s) | Zn^{2+}(C_1)$, $Zn(s) \longrightarrow Zn^{2+}(C_1) + 2e^-$; $E^\circ_{Zn/Zn^{2+}} = E^\circ_{oxi}$

$Cu^{2+}(C_2) | Cu(s)$, $Cu^{2+}(C_2) + 2e^- \longrightarrow Cu(s)$; $E^\circ_{Cu^{2+}/Cu} = E^\circ_{red}$

Imp:- $E^\circ_{Zn/Zn^{2+}} = -E^\circ_{Zn^{2+}/Zn}$

$E^\circ_{Cu^{2+}/Cu} = -E_{Cu/Cu^{2+}}$

e.g.:

$E^\circ_{Zn^{2+}/Zn} = -0.76V$

E°_{red} (standard red. pot. of Zn)

$E^\circ_{Zn/Zn^{2+}} = +0.76V$

E°_{oxi} (standard oxi. pot. of Zn)

$E^\circ_{Cu^{2+}/Cu} = +0.34V$

E°_{red} (standard red. pot. of Cu)

$E^\circ_{Cu/Cu^{2+}} = -0.34V$

E°_{oxi} (standard oxi. pot. of Cu)

Reduction half rxn

* $Ag^+(aq.) + e^- \rightarrow Ag(s)$

$E^\circ_{Ag^+/Ag} = +0.80V$ — (1)

Standard red. pot of silver

$E^\circ_{Ag/Ag^+} = -0.80V$ — (2)

Standard oxi pot of silver

From (1) and (2), we have.

$E^\circ_{Ag^+/Ag} = -E^\circ_{Ag/Ag^+}$

Conclusion:-

* $E^\circ_{red} = -E^\circ_{oxi}$

* $E^\circ_{oxi} = -E^\circ_{red}$

EMF of cell the cell:-

Electromotive force of the cell

Electrons motivate Flow Force.

The force which is responsible for flow of e⁻s from anode to cathode is called emf of the cell.

$EMF \text{ of the cell} = (E_{oxi})_{anode} + (E_{red})_{cathode}$

$(E_{oxi})_{anode} = -(E_{red})_{anode}$

$E_{cell} = (E_{red})_{cathode} - (E_{red})_{anode}$

or $E_{cell} = E_{Right} - E_{Left}$

e.g.:- $Zn(s) + Cu^{2+}(aq.) \rightarrow Zn^{2+}(aq.) + Cu(s)$. [cell rxn]

$Zn(s) | Zn^{2+}(c_1) || Cu^{2+}(c_2) | Cu(s)$ [cell representation]

Left Right

$E_{cell} = E_{Cu^{2+}/Cu} - E_{Zn^{2+}/Zn}$

under standard condition

$E^\circ_{cell} = E^\circ_{Cu^{2+}/Cu} - E^\circ_{Zn^{2+}/Zn}$

Standard emf of the cell →

* When emf of the cell is calculated under standard condition then it is called standard emf of the cell.

* It is represented by E°_{cell}.

$E^\circ_{cell} = E^\circ_{Right} - E^\circ_{Left}$

e.g.:- For cell representation:- Under

$Zn | Zn^{2+}_{(1M)} || Cu^{2+}_{(1M)} | Cu$. (Standard condition)

L R

$E^\circ_{cell} = ?$

298K
1 bar
1M

$E^\circ_{cell} = E^\circ_R - E^\circ_L$

$= E^\circ_{Cu^{2+}/Cu} - E^\circ_{Zn^{2+}/Zn}$

$= (+0.34V) - (-0.76V)$

$= +0.34V + 0.76V$

$= +1.1V$

$E^\circ_{cell} = ?$

Q. Calculate Standard emf of the cell :-

$$Cu(s) + Ag^+(aq) \rightarrow Cu^{2+}(aq) + Ag(s)$$

Under standard condition.

Standar condition:-
298K temp^r
1 bar pressure
1M conc^n

Cell representation:-

$$Cu(s) \,|\, Cu^{2+}(1M) \,||\, Ag^+(1M) \,|\, Ag(s).$$

$$E^\circ_{cell} = E^\circ_R - E^\circ_L \quad \text{(Both should be interms of red)}$$

$$= E^\circ_{Ag^+/Ag} - E^\circ_{Cu^{2+}/Cu}$$

$$= (0.80V) - (0.34V)$$

$$= +0.46V$$

$$E^\circ_{Cu^{2+}/Cu} = +0.34V$$

$$E^\circ_{Cu/Cu^{2+}} = -0.34V$$

Nernst equation

* Nernst has established a relation b/w E_{cell} and E°_{cell} called Nernst equation.

* It relates concentration of ions involved in rk^n and E_{cell}.

Consider a hypothetical reduction half rk^n:-

$$M^{n+}(aq) + ne^- \rightarrow M(s).$$

From thermodynamics B.Sc. we know that

$$E_{M^{n+}/M} = E^\circ_{M^{n+}/M} - \frac{RT}{nF} \ln \frac{[M(s)]}{[M^{n+}(aq)]}$$

Where, $E_{M^{n+}/M}$ = emf of the cell (at given conc^n and T)

$E^\circ_{M^{n+}/M}$ = Standard emf of the cell.

R = Gas constant ($8.314 J K^{-1} mol^{-1}$)

T = Temp^r (298K)

n = no. of e^-s involved

F = Faraday's constant ($96,500 C mol^{-1}$)

$[M^{n+}]$ = Molar concentration of M^{n+}-ions.

$$[M(s)] = 1$$

$$\ln y = 2.303 \times \log_{10} y$$

$$\ln \frac{1}{x} = -\ln x$$

We know that

$$E_{cell} = E^\circ_{cell} - \frac{RT}{nF} \ln \frac{1}{[M^{n+}]}$$

$$E_{cell} = E^\circ_{cell} - 2.303 \times \frac{RT}{nF} \log_{10} \frac{1}{[M^{n+}]}$$

Put the value of R, T and F, we have.

$$2.303 \times \frac{RT}{nF} = \frac{0.0591}{n}$$

$$\therefore E_{M^{n+}/M} = E^\circ_{M^{n+}/M} - \frac{0.0591}{n} \log \frac{1}{[M^{n+}]}$$

e.g.:- (a) $Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$

$$E_{Zn^{2+}/Zn} = E^\circ_{Zn^{2+}/Zn} - \frac{0.0591}{2} \log \frac{1}{[Zn^{2+}]}$$

e.g.:-

(b) $Cu^{2+} + 2e^- \rightarrow Cu.$

$$E_{Cu^{2+}/Cu} = E^\circ_{Cu^{2+}/Cu} - \frac{0.0591}{2} \log \frac{1}{[Cu^{2+}]}$$

(c) $Ag^+ + e^- \rightarrow Ag(s)$

$$E_{Ag^+/Ag} = E^\circ_{Ag^+/Ag} - \frac{0.0591}{1} \log \frac{1}{[Ag^+]}$$

Nernst equation for cell rxn

Consider a cell rxn at 298K temp^r,

$$Zn(s) + Cu^{2+}(aq.) \longrightarrow Zn^{2+}(aq.) + Cu(s).$$

Cell representation:- $Zn(s) \,|\, Zn^{2+}(aq.) \,||\, Cu^{2+}(aq.) \,|\, Cu(s).$

anode (oxi.) — cathode (Red.)

$\ln a - \ln b = \ln \frac{a}{b}$

For red half cell → $Cu^{2+}|Cu$; $Cu^{2+} + 2e^- \rightarrow Cu$

$$E_{Cu^{2+}/Cu} = E^\circ_{Cu^{2+}/Cu} - \frac{RT}{nF} \ln \frac{1}{[Cu^{2+}]} \quad \text{— (1) (Nernst eqn for } Cu^{2+}/Cu)$$

For oxi. half cell → (Zn/Zn^{2+}) Zn^{2+}/Zn ; $Zn^{2+} + 2e^- \rightarrow Zn$

$$E_{Zn^{2+}/Zn} = E^\circ_{Zn^{2+}/Zn} - \frac{RT}{nF} \ln \frac{1}{[Zn^{2+}]} \quad \text{— (2) (Nernst eqn for } Zn^{2+}/Zn)$$

From (1) - (2), we get,

$$E_{Cu^{2+}/Cu} - E_{Zn^{2+}/Zn} = \left(E^\circ_{Cu^{2+}/Cu} - \frac{RT}{nF} \ln \frac{1}{[Cu^{2+}]}\right) - \left(E^\circ_{Zn^{2+}/Zn} - \frac{RT}{nF} \ln \frac{1}{[Zn^{2+}]}\right)$$

$$\Rightarrow E_{cell} = \left(E^\circ_{Cu^{2+}/Cu} - E^\circ_{Zn^{2+}/Zn}\right) - \frac{RT}{nF} \ln \frac{1}{[Cu^{2+}]} + \frac{RT}{nF} \ln \frac{1}{[Zn^{2+}]}$$

$$\Rightarrow E_{cell} = E^\circ_{cell} - \frac{RT}{nF}\left(\ln \frac{1}{[Cu^{2+}]} - \ln \frac{1}{[Zn^{2+}]}\right)$$

$$\Rightarrow E_{cell} = E^\circ_{cell} - \frac{RT}{nF}\left(\ln \frac{\frac{1}{[Cu^{2+}]}}{\frac{1}{[Zn^{2+}]}}\right)$$

$$\Rightarrow E_{cell} = E^\circ_{cell} - \frac{RT}{nF} \ln \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

$$\Rightarrow E_{cell} = E^\circ_{cell} - 2.303 \times \frac{RT}{nF} \log \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{n} \log \frac{[Zn^{2+}]}{[Cu^{2+}]}$$

Nernst eqn for cell rxn

In general.

Consider a hypothetical cell rxn:-

$$aA + bB \xrightarrow{ne^-} cC + dD$$

Nernst eqn ; $$E_{cell} = E^\circ_{cell} - \frac{0.0591}{n} \log_{10} \frac{[C]^c \times [D]^d}{[A]^a \times [B]^b}$$

Under standar condition:-

$$Cu(s) + 2Ag^+ \longrightarrow Cu^{2+}(aq.) + 2Ag(s)$$

temp^r → 298 K
pressure → 1 bar
Conc^n → 1 M

Nernst eqn,

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{2} \log_{10} \frac{[Cu^{2+}]}{[Ag^+]^2}$$

Problems based on Nernst equation:-

Q. Calculate emf of the cell in which following reaction takes place:

$$Ni(s) + 2Ag^+(0.002M) \longrightarrow Ni^{2+}(0.160M) + 2Ag(s).$$

Given that $E^\circ_{cell} = 1.05V$

Sol^n:-

$$E_{cell} = E^\circ_{cell} - \frac{0.0591}{2} \log \frac{[Ni^{2+}]}{[Ag^+]^2}$$

$$= 1.05 - \frac{0.0591}{2} \log \frac{0.160}{(0.002)^2}$$

$$= 1.05 - \frac{0.0591}{2} \log \frac{160 \times 10^{-3} \times 10^6}{4}$$

$$= 1.05 - \frac{0.0591}{2} \log(4 \times 10^4)\ V$$

$$= 1.05 - \frac{0.0591}{2} \times (4.6021)$$

$$= (1.05 - 0.14)V$$

$$= 0.91V \text{ Ans.}$$

$\log 10 = 1$

$\log a \times b = \log a + \log b.$

$\log a^b = b \log a$

$\log(4 \times 10^4) = \log 4 + \log 10^4$

$= \log 2^2 + 4 \log 10$

$= 2 \times \log 2 + 4 \times 1$

Measurement of electrode potential

The electrode pot. of half-cell can't be determined alone. It is determined using reference electrode.

* Refference electrode → The electrode of known potential is used to determine the electrode potential of unknown electrode is called refference electrode.

e.g.:- SHE or NHE

Standard hydrogen electrode (SHE)

In SHE (V.I.), hydrogen gas is passed at 1 atm in 1M HCl solution in which platinised Pt electrode is immersed. Its standard potential is arbitrarily assigned as 0.0V by international convention system.

* SHE can act as either anode or cathode w.r.t. other electrode.

* If SHE acts as anode, oxidation takes place.

$$H_2(g) \longrightarrow 2H^+(aq.) + 2e^-$$

i.e. some $H_2(g)$ change to H^+-ions.

SHE (Anode)

* If SHE acts as cathode, reduction takes place.

$$2H^+(aq.) + 2e^- \longrightarrow H_2(g)$$

i.e. Some H^+ ions change into H_2 gas.

SHE (cathode)

$E^\circ_{red} = -ve$ → Anode

SHE → Cathode

e.g.:- $E^\circ_{Zn^{2+}/Zn} = -0.76V$ → Zn-electrode → Anode

SHE → Cathode.

$E^\circ_{red} = -ve$.

Note-1: The negative sign of (Standard red. potential) indicates that an electrode when joined with SHE acts as (anode)

$E^\circ_{red} = +ve$

Note-2: The positive sign of (Standard red. potential) indicates that an electrode when joined with SHE acts as (cathode)

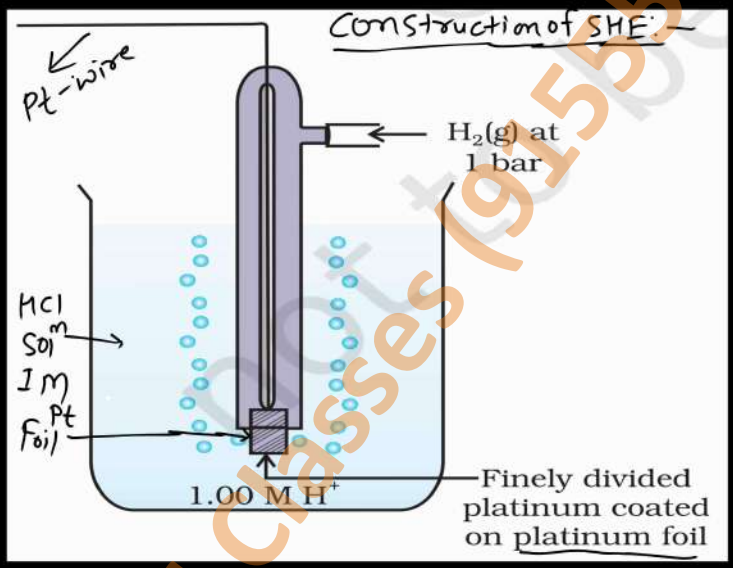
$E^\circ_{red} = +ve$ → Cathode

SHE → Anode.

$E^\circ_{Cu^{2+}/Cu} = +0.34V$ → Cu-electrode → Cathode

SHE → Anode.

Construction of SHE:-



Electrochemical Series (ECS)

When standard reduction electrode potential of different electrodes are arranged in decreasing order then this arrangement is called electrochemical series.

$E^\circ_{Cu^{2+}/Cu} = +0.34V$

$E^\circ_{Zn^{2+}/Zn} = -0.76V$

Reaction (Oxidised form + ne⁻	→ Reduced form)	E°/V
$F_2(g) + 2e^-$	$\rightarrow 2F^-$	2.87
$Co^{3+} + e^-$	$\rightarrow Co^{2+}$	1.81
$H_2O_2 + 2H^+ + 2e^-$	$\rightarrow 2H_2O$	1.78
$MnO_4^- + 8H^+ + 5e^-$	$\rightarrow Mn^{2+} + 4H_2O$	1.51
$Au^{3+} + 3e^-$	$\rightarrow Au(s)$	1.40
$Cl_2(g) + 2e^-$	$\rightarrow 2Cl^-$	1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightarrow 2Cr^{3+} + 7H_2O$	1.33
$O_2(g) + 4H^+ + 4e^-$	$\rightarrow 2H_2O$	1.23
$MnO_2(s) + 4H^+ + 2e^-$	$\rightarrow Mn^{2+} + 2H_2O$	1.23
$Br_2 + 2e^-$	$\rightarrow 2Br^-$	1.09
$NO_3^- + 4H^+ + 3e^-$	$\rightarrow NO(g) + 2H_2O$	0.97
$2Hg^{2+} + 2e^-$	$\rightarrow Hg_2^{2+}$	0.92
$Ag^+ + e^-$	$\rightarrow Ag(s)$	0.80
$Fe^{3+} + e^-$	$\rightarrow Fe^{2+}$	0.77
$O_2(g) + 2H^+ + 2e^-$	$\rightarrow H_2O_2$	0.68
$I_2 + 2e^-$	$\rightarrow 2I^-$	0.54
$Cu^+ + e^-$	$\rightarrow Cu(s)$	0.52
$Cu^{2+} + 2e^-$	$\rightarrow Cu(s)$	0.34
$AgCl(s) + e^-$	$\rightarrow Ag(s) + Cl^-$	0.22
$AgBr(s) + e^-$	$\rightarrow Ag(s) + Br^-$	0.10
$2H^+ + 2e^-$	$\rightarrow H_2(g)$	0.00
$Pb^{2+} + 2e^-$	$\rightarrow Pb(s)$	−0.13
$Sn^{2+} + 2e^-$	$\rightarrow Sn(s)$	−0.14
$Ni^{2+} + 2e^-$	$\rightarrow Ni(s)$	−0.25
$Fe^{2+} + 2e^-$	$\rightarrow Fe(s)$	−0.44
$Cr^{3+} + 3e^-$	$\rightarrow Cr(s)$	−0.74
$Zn^{2+} + 2e^-$	$\rightarrow Zn(s)$	−0.76
$2H_2O + 2e^-$	$\rightarrow H_2(g) + 2OH^-(aq)$	−0.83
$Al^{3+} + 3e^-$	$\rightarrow Al(s)$	−1.66
$Mg^{2+} + 2e^-$	$\rightarrow Mg(s)$	−2.36
$Na^+ + e^-$	$\rightarrow Na(s)$	−2.71
$Ca^{2+} + 2e^-$	$\rightarrow Ca(s)$	−2.87
$K^+ + e^-$	$\rightarrow K(s)$	−2.93
$Li^+ + e^-$	$\rightarrow Li(s)$	−3.05

Increasing strength of oxidising agent ↑

Increasing strength of reducing agent ↓

Application of ECS:-

[1.] To predict whether a metal reacts with an acid to give $H_2(g)$:-

$E^\circ_{red} = -ve$	$E^\circ_{red} = +ve$
↓ Metal	↓ Metal
$E^\circ_{Zn^{2+}/Zn} = -0.76V$ (SRP of Zn)	$E^\circ_{Cu^{2+}/Cu} = +0.34V$ (SRP of Cu)
$Zn(s) + dil.\ HCl(aq.) \rightarrow ZnCl_2(aq.) + H_2(g)\uparrow$	$Cu(s) + dil.\ HCl \rightarrow$ no rxn

* Metals having SRP is -ve, reacts with dil. acid to liberate $H_2(g)$.
* Metals having SRP is +ve, don't reacts with dil. HCl to produce $H_2(g)$.

[2.] To calculate E°_{cell}:-

Under standard condition ⇒ $E^\circ_{cell} = E^\circ_{Right} - E^\circ_{Left}$

Cell rxn ⇒ $E^\circ_{cell} = E^\circ_{cathod} - E^\circ_{anode}$

→ Both should be in terms of reduction.

$$Zn(s) + Cu^{2+}(aq.) \longrightarrow Zn^{2+}(aq.) + Cu(s)$$

Cell representation:-

$$\underset{\text{Anode}}{Zn|Zn^{2+}(2m)}\,||\,\underset{\text{Cathode}}{Cu^{2+}(1m)|Cu(s)}$$

$$E^\circ_{cell} = E^\circ_{Cu^{2+}/Cu} - E^\circ_{Zn^{2+}/Zn}$$
$$= (+0.34V) - (-0.76V)$$
$$= +1.1V$$

[3.] To predict the spontaneity or feasibility of rxn:-

* If $E^\circ_{cell} = +ve$, rxn is said to feasible.
* If $E^\circ_{cell} = -ve$, rxn is not feasible.

$Cu(s) + ZnSO_4(aq.) \longrightarrow$ no rxn

$Cu + Zn^{2+} \longrightarrow Cu^{2+} + Zn$ (✗)

$Cu|Cu^{2+}||Zn^{2+}|Zn$

$E^\circ_{cell} = E^\circ_R - E^\circ_L = E^\circ_{Zn^{2+}/Zn} - E^\circ_{Cu^{2+}/Cu}$

$E^\circ_{cell} = (-0.76V) - (+0.34V)$

$= -0.76V - 0.34V$

$E^\circ_{cell} = -1.1V$

-ve sign indicates that rxn is not feasible b/w Cu and $ZnSO_4(aq.)$.

(Zn is more reactive than Cu).

e.g.:- $Zn(s) + CuSO_4(aq.) \longrightarrow ZnSO_4(aq.) + Cu(s)$.

⇒ $Zn(s) + Cu^{2+}(aq.) \longrightarrow Zn^{2+}(aq.) + Cu(s)$.

$E^\circ_{cell} = +1.1V$

+ve sign indicates that rxn is feasible b/w Zn and $CuSO_4$ Solution.

Application of electrochemical series:-

* $Cu + dil.\ H_2SO_4 \longrightarrow$ No rxn

$Cu + conc.\ H_2SO_4 \longrightarrow CuSO_4 + SO_2 + H_2O$.

[4.] To compare oxidising and reducing power:-

Reductant / Reducing agent ← Oxi. → loss of e^-(s)

Oxidant / oxidising agent ← Red. → gain of e^-(s)

$$\underset{(R.A.)}{Zn} + \underset{(O.A.)}{Cu^{2+}} \longrightarrow Zn^{2+} + Cu$$

Red.

Oxi.

R.A. ← Oxi. → tendency to loss of e^-s

E°_{red} ↓	E°_{oxi} ↑	tendency to loss e^-(s) incr.	power of R.A incr.	power of oxidising agent decr.

Conclusion →
- E°_{red} ↓ ⇒ Reducing power incr. Oxidising power decr.
- E°_{red} ↑ ⇒ Reducing power decr. Oxidising power incr.

O.A. ← Red. → tendency to gain e^-(s)

E°_{oxi} ↓	E°_{red} ↑	tendency to gain e^-(s) incr.	power of O.A. incr.	power of R.A. decr.

conclusion →
- E°_{red} ↑ ⇒ Oxidising power incr. Reducing power decr.
- E°_{red} ↓ ⇒ Oxidising power decr. Reducing power incr.

Overall conclusion:-
- E°_{red} incr. Reducing power decr.
- E°_{red} decr. Reducing power incr.

→ Memories

Q. Given SRP, $E^\circ_{K^+/K} = -2.93V$ (सबसे कम), $E^\circ_{Ag^+/Ag} = +0.80V$ (सबसे ज्यादा), $E^\circ_{Hg^{2+}/Hg} = +0.79V$

$E^\circ_{Mg^{2+}/Mg} = -2.37V$, $E^\circ_{Cr^{3+}/Cr} = -0.74V$

Arrange these metals in their increasing order of reducing power.

Sol^n Plan:- E°_{red} ↓ Reducing power incr.

$$Ag < Hg < Cr < Mg < K$$

Order of reducing power.

Q Given. $E^\circ_{Cr^{3+}/Cr} = -0.74V$

$E^\circ_{MnO_4^-/Mn^{2+}} = +1.51V$

$E^\circ_{Cr_2O_7^{2-}/Cr^{3+}} = +1.33V$

$E^\circ_{Cl/Cl^-} = +1.36V$

based on the data given above, strongest O.A. will be

(a) Mn^{2+} (b) MnO_4^- (c) Cl^- (d) Cr^{3+}

Hints:- $E^\circ_{red}\uparrow$ Oxidising power $\uparrow$

[5.] E°_{red} (metal) $\geq 0.79V$ → Such metal oxide on heating produce metal and oxygen.

(a) $HgO \xrightarrow{\Delta} Hg + \frac{1}{2}O_2$; $E^\circ_{Hg^{2+}/Hg} = +0.86V$

(b) $Al_2O_3 \not\xrightarrow{\Delta} 2Al + \frac{3}{2}O_2$; $E^\circ_{Al^{3+}/Al} = -1.66V$

(c) $Na_2O \not\xrightarrow{\Delta} 2Na + \frac{1}{2}O_2$; $E^\circ_{Na^+/Na} = -2.71V$

(d) $BaO \not\xrightarrow{\Delta} Ba + \frac{1}{2}O_2$; $E^\circ_{Ba^{2+}/Ba} = -2.91V$

In extraction of metal:-

[6.] Metals having low SRP can displace those metals which has high SRP from their salt.

$E^\circ_{Zn^{2+}/Zn} = -0.76V$

$E^\circ_{Cu^{2+}/Cu} = +0.34V$.

here SRP of Zn is less than Cu.

(a) $Cu + ZnSO_4 \not\rightarrow CuSO_4 + Zn$

(b) $Zn + CuSO_4 \longrightarrow ZnSO_4 + Cu$.

(Zn is more reactive than Cu.)

SRP of Zn is low as compared to Cu.

Electrolyte and non-electrolyte:-

* Those substance whose aquous solution allow to pass electricity is called electrolyte

e.g.:- aq. solution of NaCl
aq. solution of KCl
aq. solution of K_2SO_4 etc.

* Those substance whose aquous solution don't allow to conduct electricity is called non-electrolyte.

e.g.:- aq. solution of sugar
aq. solution of alcohol
Glycerol etc.

Types of electrolyte:-

[1] Strong electrolyte

Electrolytes which completely dissociate in water into corresponding ions are called strong electrolyte.

e.g.:- (a) strong acid → HCl, H_2SO_4, HNO_3 etc.
(b) strong base → $NaOH$, KOH, $Mg(OH)_2$, $Ca(OH)_2$ etc.
(c) Generally, all salts are strong electrolytes.
e.g.:- NaCl, KCl, $NaNO_3$, K_2SO_4 etc.

[2] Weak electrolyte.

Electrolyte which partially dissociate in water into corresponding ions are called weak electrolyte.

e.g.:- (a) Weak acid (all organic acid)
e.g.:- CH_3COOH, oxalic acid etc.
(b) Weak base, (Most organic base)
e.g.:- Alkylamine
(c) $AgCl_2$, lead acetate

Difference b/w resistance and conductance:-

Resistance	Conductance (G)
(1) Obstruction in the flow of electric current.	(1) Ease in the flow of electric current.
(2) Representation → R	(2) Representation → G
(3) Unit → ohm or Ω	(3) Unit → ohm^{-1} / Ω^{-1} / mho / ℧ / Siemens
(4) $R \propto l$ — (1)	(4) It is reciprocal of resistance.
$R \propto \frac{1}{A}$ — (2)	$G = \frac{1}{R}$ — (1)
$\therefore R \propto l/A$	$\frac{1}{R} = \frac{1}{\rho} \times \frac{A}{l}$ — (2)
$R = \rho \times \frac{l}{A}$	From (1) and (2), $G = \frac{1}{\rho} \times \frac{A}{l}$
proportionality constant called specific resistance or resistivity.	$G = k \times \frac{A}{l}$
	k → specific conductance or conductivity.

$\frac{1}{\rho} = k$ (specific conductance or conductivity) (Kappa)

Specific resistance or Resistivity (ρ)

* $R = \rho \times l/A$

If $l = 1m$ and $A = 1m^2$ then

Resistance $R = \rho$ Resistivity

* Resistivity of a conductor is equal to resistance when length of conductor is 1m and its cross-sectional area is $1m^2$.

* Unit:- $\rho = R \times \frac{A}{l}$

$= ohm \times \frac{m^2}{m}$

$= ohm\ m$

or

Ωm or $S m$

Specific conductance or Conductivity (κ)

* $G = \kappa \times \frac{A}{l}$

If $l = 1m$ and $A = 1m^2$ then $G = \kappa$.

$G = \kappa$

Conductance conductivity

* Conductivity of a conductor is equal to conductance when length of conductor is 1m and it cross-sectional area is $1m^2$.

Unit:- $\kappa = G \times l/A$

$= \Omega^{-1} \times \frac{1m}{1m^2}$

$= \Omega^{-1} m^{-1}$ or, $ohm^{-1} m^{-1}$ or $mho\ m^{-1}$ or $S m^{-1}$.

Types of conductivity

[1.] Metallic Conductivity or, Electronic conductivity

In metals, free mobile e^-s carrying current electricity called electronic conductivity.

Factors:
* Nature and str. of metal
* no. of v.E. per atom

no. of v.e^-s per atom incr., metallic conductivity incr.

* on incr. temp^r, metallic conductivity decreases.

[2.] Electrolytic conductivity or, Ionic conductivity

Conductivity of an electrolytic solution is called ionic conductivity.

Factors:
* Nature of electrolytic solution
* Nature of solvent
* on incr. temp^r, electrolytic conductivity increases.

Molar conductivity

To compare conductivities of electrolytes

* Conductivity of solution containing 1 mol of electrolyte in a given volume is called molar conductivity.

* Molar conductivity = Specific conductance × V_{sol^n} containing 1 mol of electrolyte

* $\Lambda_m = \kappa \times V$

* $\Lambda_m = \frac{\kappa \times 1000}{C}$

$\Lambda_m = \frac{\kappa \times 1000}{Molarity}$

Imp.

Variation of conductivity and molar conductivity with concentration:-

(1) * Conductivity of strong and weak electrolyte decr. with dilution.

Reason:- Because no. of current carrying particles i.e. ions per mL of solution become less.

(2) * Molar conductivity increases with dilution.

$$\Lambda_m = \kappa \times V$$

κ → kappa → conductivity; V → V_{soln}

Very Imp.

(1) conductivity (κ) ↓ Dilution ↑

(2) Molar conductivity (Λ_m) ↑ Dilution ↑

With dilution, first factor decreases while the other incr. The incr. in 2nd factor is much more than the dec. in first factor.

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* Molar conductivity increases with dilution and finally attain a max^m value at infinite dilution.

$$\Lambda_m = \kappa \times V$$

Incr. decr Incr.

Dilution → Addition of water

Dilution incr. → vol incr. → conc^n decr.

* Conductivity decr.
Molar conductivity incr.

Dilution ↑ conc^n ↓

Dilution → ∞ conc^n → 0

Limiting molar conductivity:- (dilution → ∞)

* The value of molar conductivity at infinite dilution is called limiting molar conductivity.
* It is denoted by Λ_m^0 or Λ_m^∞.

Dilution → ∞ , conc^n → 0

* Λ_m^0 can be calculated for strong electrolyte but can't be calculated for weak electrolyte.
* Λ_m^0 for weak electrolyte is calculated by Kohlrausch's law.

Kohlrausch's law (V.I.)

Limiting molar conductivity of an electrolyte is the sum of limiting ionic conductivity of cation and anion each multiplied with no. of ions present in one formula unit of electrolyte.

e.g.:- $\boxed{\Lambda^0_m (A_xB_y) = x\lambda^0_{A^{y+}} + y\lambda^0_{B^{x-}}}$

$\Lambda^\infty_m (NaCl)$ or, $\Lambda^0_m (NaCl) = \lambda^0_{Na^+} + \lambda^0_{Cl^-}$

$\Lambda^\infty_m (BaCl_2)$ or, $\Lambda^0_m (BaCl_2) = \lambda^0_{Ba^{2+}} + 2\times\lambda^0_{Cl^-}$

$\Lambda^0_m (Al_2(SO_4)_3) = 2\lambda^0_{Al^{3+}} + 3\lambda^0_{SO_4^{2-}}$

$NaCl \xrightarrow{aq.} Na^+ + Cl^-$

$CaCl_2 \xrightarrow{aq.} Ca^{2+} + 2Cl^-$

$AlCl_3 \xrightarrow{aq} Al^{3+} + 3Cl^-$

cation, anion

$A_xB_y \xrightarrow{aq.} xA^{y+} + yB^{x-}$

Application of Kohlrausch's law:-

I. In determination of Λ^0_m for weak electrolyte.

Imp. Q. Λ^0_m for NaCl, HCl and CH_3COONa are 126.4, 425.9 and 91 $S\,cm^2\,mol^{-1}$ respectively. Calculate $\Lambda^0_m(CH_3COOH)$. (weak electrolyte) → CH_3COO^-, H^+

Given. strong electrolyte

$\Lambda^0_m(NaCl) = 126.4\ S\,cm^2\,mol^{-1}$

$\Lambda^0_m(HCl) = 425.9\ S\,cm^2\,mol^{-1}$

$\Lambda^0_m(CH_3COONa) = 91\ S\,cm^2\,mol^{-1}$

Rough:

$NaCl \xrightarrow{aq.} Na^+ + Cl^-$ — (1)

$HCl \xrightarrow{aq.} H^+ + Cl^-$ — (2)

$CH_3COONa \xrightarrow{aq.} CH_3COO^- + Na^+$ — (3)

$\Lambda^0_m(CH_3COOH) = (\lambda^0_{H^+} + \lambda^0_{Cl^-}) + (\lambda^0_{CH_3COO^-} + \lambda^0_{Na^+}) - (\lambda^0_{Na^+} + \lambda^0_{Cl^-})$

$= \Lambda^0_m(HCl) + \Lambda^0_m(CH_3COONa) - \Lambda^0_m(NaCl)$

$= (425.9 + 91 - 126.4)\ S\,cm^2\,mol^{-1}$

(2) In application of d.o.d. →

$\boxed{\alpha = \frac{\Lambda^c_m}{\Lambda^\infty_m}}$

where, Λ^c_m = molar conductivity at conc^n C

Λ^0_m or, Λ^∞_m = molar conductivity at infinite dilution.

(3.) In determination of dissociation constant for weak electrolyte:-

$$\boxed{K_a = \frac{C\alpha^2}{(1-\alpha)}}$$

Where K_a = dissociation constant for weak electrolyte

C = initial conc^n

α = D.O.D.

Q: The conductivity of $0.001028\ mol\,L^{-1}$ acetic acid is $4.95\times10^{-5}\ S\,cm^{-1}$. Calculate its dissociation constant if Λ^{o}_{m} for acetic acid is $390.5\ S\,cm^{2}\,mol^{-1}$.

Solⁿ:- Given,
- molarity $= 0.001028\ mol\,L^{-1}$
- conductivity $(\kappa) = 4.95\times10^{-5}\ S\,cm^{-1}$
- $\Lambda^{o}_{m}(CH_3COOH) = 390.5\ S\,cm^{2}\,mol^{-1}$

$K_a(CH_3COOH) = ?$

$$\Lambda^{c}_{m} = \frac{\kappa\times1000}{\text{Molarity}} = \frac{4.95\times10^{-5}\times1000}{0.001028}\ S\,cm^{2}\,mol^{-1} = 48.15\ S\,cm^{2}\,mol^{-1}$$

$$D.O.D.\ (\alpha) = \frac{\Lambda^{c}_{m}}{\Lambda^{o}_{m}} = \frac{48.15\ S\,cm^{2}\,mol^{-1}}{390.5\ S\,cm^{2}\,mol^{-1}} = 0.1233$$

Dissociation constant, $$K_a(CH_3COOH) = \frac{C\alpha^2}{(1-\alpha)} = \frac{0.001028\times(0.1233)^2}{(1-0.1233)}\ \text{Ans.}$$

Application of electrochemical series:-

* $Cu + \text{dil. } H_2SO_4 \longrightarrow$ No rxⁿ

$$Cu + \text{conc. } H_2SO_4 \longrightarrow CuSO_4 + SO_2 + H_2O.$$

[4.] To compare oxidising and reducing power:-

Reductant / Reducing agent ← Oxi. → loss of e^-(s)

Oxidant / oxidising agent ← Red. → gain of e^-(s)

$$\underset{(R.A.)}{Zn} + \overset{Red.}{\underset{(O.A.)}{Cu^{2+}}} \longrightarrow \underset{oxi.}{Zn^{2+}} + Cu.$$

R.A. ← Oxi. → tendency to loss of e^-s

$E^\circ_{red}\downarrow$	$E^\circ_{oxi}\uparrow$	tendency to loss e^-(s) incr.	power of R.A incr.	power of oxidising agent decr.

Conclusion →
- $E^\circ_{red}\downarrow$ ∝ Reducing power incr. Oxidising power decr.
- $E^\circ_{red}\uparrow$ ∝ Reducing power decr. Oxidising power incr.

O.A. ← Red. → tendency to gain e^-(s)

$E^\circ_{oxi}\downarrow$	$E^\circ_{red}\uparrow$	tendency to gain e^-(s) incr.	power of O.A. incr.	power of R.A. decr.

conclusion →
- $E^\circ_{red}\uparrow$ ∝ Oxidising power incr. Reducing power decr.
- $E^\circ_{red}\downarrow$ ∝ Oxidising power decr. Reducing power incr.

Overall conclusion:- E°_{red} incr. Reducing power decr. → Memories

E°_{red} decr. Reducing power incr.

Q. Given SRP, $E^\circ_{K^+/K} = -2.93V$ (सबसे कम), $E^\circ_{Ag^+/Ag} = +0.80V$ (सबसे ज्यादा), $E^\circ_{Hg^{2+}/Hg} = +0.79V$

$E^\circ_{Mg^{2+}/Mg} = -2.37V$, $E^\circ_{Cr^{3+}/Cr} = -0.74V$

Arrange these metals in their increasing order of reducing power.

Sol^n:- Plan:- $E^\circ_{red}\downarrow$ Reducing power incr.

$Ag < Hg < Cr < Mg < K$

Order of reducing power.

Q. Given: $E^\circ_{Cr^{3+}/Cr} = -0.74V$

$E^\circ_{MnO_4^-/Mn^{2+}} = +1.51V$

$E^\circ_{Cr_2O_7^{2-}/Cr^{3+}} = +1.33V$

$E^\circ_{Cl/Cl^-} = +1.36V$

based on the data given above, strongest O.A. will be

Hints:- (a) Mn^{2+} (b) MnO_4^- (c) Cl^- (d) Cr^{3+}

$E^\circ_{red}\uparrow$ Oxidising power ↑

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(a) $HgO \xrightarrow{\Delta} Hg + \frac{1}{2}O_2$; $E^{\circ}_{Hg^{2+}/Hg} = +0.86V$

(b) $Al_2O_3 \not\xrightarrow{\Delta} 2Al + \frac{3}{2}O_2$; $E^{\circ}_{Al^{3+}/Al} = -1.66V$

(c) $Na_2O \not\xrightarrow{\Delta} 2Na + \frac{1}{2}O_2$; $E^{\circ}_{Na^{+}/Na} = -2.71V$

(d) $BaO \not\xrightarrow{\Delta} Ba + \frac{1}{2}O_2$; $E^{\circ}_{Ba^{2+}/Ba} = -2.91V$

In extraction of metal:-

[6.] Metals having low SRP can displace those metals which has high SRP from their salt.

$E^{\circ}_{Zn^{2+}/Zn} = -0.76V$
$E^{\circ}_{Cu^{2+}/Cu} = +0.34V$.

here SRP of Zn is less than Cu.

(a) $Cu + ZnSO_4 \not\rightarrow CuSO_4 + Zn$

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(Zn is more reactive than Cu.)
SRP of Zn is low as compared to Cu.

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* Those substance whose aquous solution allow to pass electricity is called electrolyte

e.g.:- aq. solution of NaCl, aq. solution of KCl, aq. solution of K_2SO_4 etc.

* Those substance whose aquous solution don't allow to conduct electricity is called non-electrolyte.

e.g.:- aq. solution of sugar, aq. solution of alcohol, Glycerol etc.

Types of electrolyte :-

[1] Strong electrolyte

Electrolytes which completely dissociate in water into corresponding ions are called strong electrolyte.

e.g.:- (a) strong acid → HCl, H_2SO_4, HNO_3 etc.

(b) Strong base → $NaOH$, KOH, $Mg(OH)_2$, $Ca(OH)_2$ etc.

(c) Generally, all salts are strong electrolytes.
e.g.:- $NaCl$, KCl, $NaNO_3$, K_2SO_4 etc.

[2] Weak electrolyte.

Electrolyte which partially dissociate in water into corresponding ions are called weak electrolyte.

e.g.:- (a) Weak acid (all organic acid)
e.g.:- CH_3COOH, oxalic acid etc.

(b) Weak base, (Most organic base)
e.g.:- Alkylamine

(c) $HgCl_2$, lead acetate,

Difference b/w resistance and conductance :-

Resistance	Conductance (G)
(1) Obstruction in the flow of electric current.	(1) Ease in the flow of electric current.
(2) Representation → R	(2) Representation → G
(3) Unit → ohm or Ω	(3) Unit → ohm^{-1} / Ω^{-1} / mho / ℧ / Siemens
(4) $R \propto l$ — (1)	(4) It is reciprocal of resistance.
$R \propto \frac{1}{A}$ — (2)	$G = \frac{1}{R}$ — (1)
$\therefore R \propto l/A$	$\frac{1}{\rho} = \kappa$ (specific conductance or conductivity)
$R = \rho \times \frac{l}{A}$	$R = \frac{1}{\rho} \times \frac{A}{l}$ — (2)
proportionality constant called specific resistance or resistivity.	from (1) and (2), $G = \frac{1}{\rho} \times \frac{A}{l}$
	$G = \kappa \times \frac{A}{l}$
	specific conductance or conductivity.

Specific resistance or Resistivity (ρ)

* $R = \rho \times l/A$

If $l = 1m$ and $A = 1m^2$ then $R = \rho$

Resistance → Resistivity

* Resistivity of a conductor is equal to resistance when length of conductor is 1m and its cross-sectional area is $1m^2$.

* Unit :- $\rho = R \times \frac{A}{l}$

$= ohm \times \frac{m^2}{m}$

$= ohm\ m$ or Ωm or $S m$

Specific conductance or Conductivity (κ)

* $G = \kappa \times \frac{A}{l}$

If $l = 1m$ and $A = 1m^2$ then $G = \kappa$.

$G = \kappa$

conductance → conductivity

* Conductivity of a conductor is equal to conductance when length of conductor is 1m and it cross-sectional area is $1m^2$.

Unit :- $\kappa = G \times l/A$

$= \Omega^{-1} \times \frac{1m}{1m^2}$

$= \Omega^{-1} m^{-1}$ or, $ohm^{-1} m^{-1}$ or $mho\ m^{-1}$ or $S m^{-1}$.

Types of conductivity

[1.] Metallic Conductivity
or, Electronic conductivity

In metals, free mobile e^-s carrying current electricity called electronic conductivity.

Factors
* Nature and str. of metal
* no. of v.E. per atom
  no. of v.e^-s per atom incr., metallic conductivity incr.
* on incr. tempr, metallic conductivity decreases.

[2.] Electrolytic conductivity
or, Ionic conductivity

Conductivity of an electrolytic solution is called ionic conductivity.

Factors
* Nature of electrolytic solution
* Nature of solvent
* On incr. tempr, electrolytic conductivity increases.

Molar conductivity

To compare conductivities of electrolytes

* Conductivity of solution containing 1 mol of electrolyte in a given volume is called molar conductivity.
* Molar conductivity = Specific conductance × V_{sol^n} containing 1 mol of electrolyte

* $\Lambda_m = K \times V$
* $\Lambda_m = \frac{K \times 1000}{C}$

$\Lambda_m = \frac{K \times 1000}{\text{Molarity}}$

Imp.
Variation of conductivity and molar conductivity with concentration:-

(1) * Conductivity of strong and weak electrolyte decr. with dilution.

Reason:- Because no. of current carrying particles i.e. ions per mL of solution become less.

(2) * Molar conductivity increases with dilution.

$\Lambda_m = K \times V$
(K → kappa → conductivity; V → V_{sol^n})

Very Imp.
(1) Conductivity (K) ↓ Dilution ↑
(2) Molar conductivity (Λ_m) ↑ Dilution ↑

With dilution, first factor decreases while the other incr. The incr. in 2nd factor is much more than the dec. in first factor.

* Molar conductivity increases with dilution and finally attain a max^m value at infinite dilution.

$$\Lambda_m = \kappa \times V$$

Incr. decr Incr.

Dilution
↓
Addition of water

Dilution incr. → vol incr
→ conc^n decr
* Conductivity decr.
Molar conductivity incr.

Dilution ↑ conc^n ↓

Dilution → ∞ conc^n → 0

Limiting molar conductivity:- (dilution → ∞)

* The value of molar conductivity at infinite dilution is called limiting molar conductivity.
* It is denoted by Λ_m^0 or Λ_m^∞.

Dilution → ∞ , conc^n → 0

* Λ_m^0 can be calculated for strong electrolyte but can't be calculated for weak electrolyte.
* Λ_m^0 for weak electrolyte is calculated by Kohlrausch's law.

Kohlrausch's law (V.I.)

Limiting molar conductivity of an electrolyte is the sum of limiting ionic conductivity of cation and anion each multiplied with no. of ions present in one formula unit of electrolyte.

e.g.:- $\Lambda_m^0 (A_xB_y) = x\lambda^0_{A^{y+}} + y\lambda^0_{B^{x-}}$

$\Lambda_m^\infty (NaCl)$ or, $\Lambda_m^0 (NaCl) = \lambda^0_{Na^+} + \lambda^0_{Cl^-}$

$\Lambda_m^\infty (BaCl_2)$ or, $\Lambda_m^0 (BaCl_2) = \lambda^0_{Ba^{2+}} + 2\times\lambda^0_{Cl^-}$

$\Lambda_m^0 (Al_2(SO_4)_3) = 2\lambda^0_{Al^{3+}} + 3\lambda^0_{SO_4^{2-}}$

$NaCl \xrightarrow{aq.} Na^+ + Cl^-$

$CaCl_2 \xrightarrow{aq.} Ca^{2+} + 2Cl^-$

$AlCl_3 \xrightarrow{aq} Al^{3+} + 3Cl^-$

cation anion

$A_xB_y \xrightarrow{aq.} xA^{y+} + yB^{x-}$

Application of Kohlrausch's law :-

I. In determination of Λ°_m for weak electrolyte.

Imp. Q. Λ°_m for NaCl, HCl and CH_3COONa are 126.4, 425.9 and 91 $S\,cm^2\,mol^{-1}$ respectively. Calculate $\Lambda^\circ_m(CH_3COOH)$.

Given. strong electrolyte

$\Lambda^\circ_m(NaCl) = 126.4\ S\,cm^2\,mol^{-1}$

$\Lambda^\circ_m(HCl) = 425.9\ S\,cm^2\,mol^{-1}$

$\Lambda^\circ_m(CH_3COONa) = 91\ S\,cm^2\,mol^{-1}$

Rough.

$NaCl \xrightarrow{aq.} Na^+ + Cl^-$ — (1)

$HCl \xrightarrow{aq.} H^+ + Cl^-$ — (2)

$CH_3COONa \xrightarrow{aq.} CH_3COO^- + Na^+$ — (3)

weak electrolyte. CH_3COO^-, H^+

$$\Lambda^\circ_m(CH_3COOH) = (\lambda^\circ_{H^+} + \lambda^\circ_{Cl^-}) + (\lambda^\circ_{CH_3COO^-} + \lambda^\circ_{Na^+}) - (\lambda^\circ_{Na^+} + \lambda^\circ_{Cl^-})$$

$$= \Lambda^\circ_m(HCl) + \Lambda^\circ_m(CH_3COONa) - \Lambda^\circ_m(NaCl)$$

$$= (425.9 + 91 - 126.4)\ S\,cm^2\,mol^{-1}$$

(2.) In application of d.o.d. →

$$\boxed{\alpha = \frac{\Lambda^c_m}{\Lambda^\infty_m}}$$

where, Λ^c_m = molar conductivity at conc^n C

Λ°_m or, Λ^∞_m = molar conductivity at infinite dilution.

(3.) In determination of dissociation constant for weak electrolyte :-

$$\boxed{K_a = \frac{C\alpha^2}{(1-\alpha)}}$$

Where K_a = dissociation constant for weak electrolyte

C = initial conc^n

α = D.O.D.

Q. The conductivity of 0.001028 $mol\,L^{-1}$ acetic acid is $4.95 \times 10^{-5}\ S\,cm^{-1}$. Calculate its dissociation constant if Λ°_m for acetic acid is $390.5\ S\,cm^2\,mol^{-1}$.

Sol^n :- Given,

molarity = $0.001028\ mol\,L^{-1}$

conductivity (K) = $4.95 \times 10^{-5}\ S\,cm^{-1}$.

$\Lambda^\circ_m(CH_3COOH) = 390.5\ S\,cm^2\,mol^{-1}$.

$K_a(CH_3COOH) = ?$

$$\Lambda^c_m = \frac{K \times 1000}{\text{Molarity}} = \frac{4.95 \times 10^{-5} \times 1000}{0.001028}\ S\,cm^2\,mol^{-1} = 48.15\ S\,cm^2\,mol^{-1}$$

$$D.O.D.\ (\alpha) = \frac{\Lambda^c_m}{\Lambda^\infty_m} = \frac{48.15\ S\,cm^2\,mol^{-1}}{390.5\ S\,cm^2\,mol^{-1}} = 0.1233$$

Dissociation constant, $K_a(CH_3COOH) = \frac{C\alpha^2}{(1-\alpha)} = \frac{0.001028 \times (0.1233)^2}{(1-0.1233)}$ Ans.

Battery

Battery consist of two or more than two galvanic cell connected in series where chemical energy of redox rxn is converted to electrical energy.

Types of batter

[1.] Primary batteries

These are not chargeable because electrode reaction occurs only once and it become dead and can't be reused again.

e.g:- Dry cell

[2.] Secondary batteries

These are rechargeable and can be used again and again. It is recharged by passing current.

e.g:- Lead Storage battery.

Dry cell

It consist of Zn-container which act as anode and cathode is a graphite rod surrounded by powdered MnO_2 and C. The space b/w anode and cathode is filled by a moist paste of NH_4Cl and $ZnCl_2$. → electrolyte.

Rxn at anode:- $Zn \longrightarrow Zn^{2+} + 2e^-$

Complicated reaction

Rxn at cathod:- $MnO_4 + \overset{\oplus}{N}H_4 + e^- \rightarrow MnO(OH) + NH_3$

* It has potential of 1.5V
* Dry cell is used in watch, radio, calculator etc.

Dry cell

Anode → Zn container.

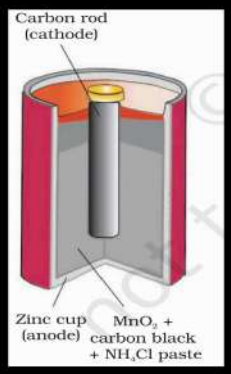
Cathode → Graphite rod. (Surrounded by powdered of MnO_2 and C)

Electrolyte → paste of NH_4Cl and $ZnCl_2$

Rxn at anode → $Zn \rightarrow Zn^{2+} + 2e^-$

& Rxn at cathod → यातें कठिन (complicated)

1.1V, watch, calculator, radio etc



Lead storage battery

It consist of lead anode and a grid of lead packed with lead oxide (PbO_2) as cathode. A 38% H_2SO_4 solution is used as an electrolyte.

The cell rxn when battery is in use, are:-

oxi. Anode :- $Pb^{(s)} + SO_4^{2-} \longrightarrow PbSO_4^{(s)} + 2e^-$

(+) red Cathode :- $PbO_2^{(s)} + SO_4^{2-} + 4H^+ + 2e^- \longrightarrow PbSO_4^{(s)} + 2H_2O(l)$

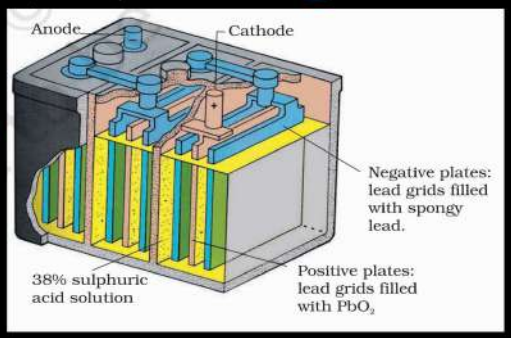
Overall rxn :- $Pb(s) + PbO_2(s) + 2H_2SO_4(aq.) \longrightarrow 2PbSO_4(s) + 2H_2O(l)$

On recharging the cell, operated like an electrolytic cell, the rxn is reversed and $PbSO_4(s)$ on anode and cathode is converted to Pb and PbO_2 respectively.

Rxn at anode :- $PbSO_4 + 2H_2O \longrightarrow PbO_2 + SO_4^{2-} + 2H^+ + 2e^-$

Rxn at cathode :- $PbSO_4 + 2e^- \longrightarrow Pb + SO_4^{2-}$

Lead storage battery →



Fuel cell

* Fuel cells are those cells which produce electrical energy directly from combustion of fuels like H_2, CO and CH_4.

* e.g. H_2-O_2 fuel cell → It utilises the reaction b/w H_2 and O_2 to produce water. $H_2(g)$ and $O_2(g)$ are bubbled through a porous carbon electrode in the cell into concentrated aq. NaOH solution.

Rxn at anode:- $2H_2(g) + 4^-OH \longrightarrow 4H_2O(l) + 4e^-$

Rxn at cathode:- $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4^-OH(aq.)$

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$$

Advantages of fuel cells:-

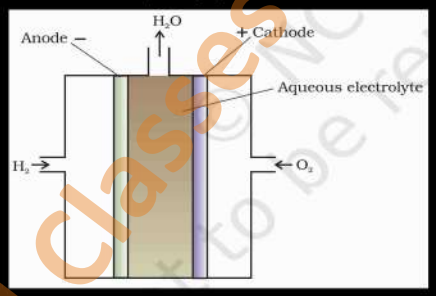
(i) Pollution free device, no harmful products are produced.

(ii) Efficiency → 75 %

(iii) Light in wt. as compared to electrical generator

(iv) It is continuous source of energy when supply of gases is maintained.

Fuel cell →



Corrosion

(Eat up → नष्ट करना / खाना)

* Process of slow eating up of metals by gases (CO_2, SO_2) and water (moisture) vapour present in atmosphere due to formation of certain compounds like oxide, sulphide, carbonates etc. is called corrosion.

* It is electrochemical phenomenon.

* Site (working place) of corrosion behave like electrochemical cell.

* Pure iron act as anode, impure surface act as cathode and moisture having dissolved CO_2 or oxygen behave as electrolyte.

At anode:- $Fe \rightarrow Fe^{2+} + 2e^-$ —— (1)

At cathode:- e^-s pick up by H^+-ions which are produced by H_2CO_3 (formed due to dissolution of CO_2 in water).

$$H_2CO_3 \rightleftharpoons 2H^+ + CO_3^{2-}$$

$$2H^+ + 2e^- \rightarrow 2H$$

The H-atoms thus formed reduces the dissolved oxygen and net reaction at cathodic area is

$$2H^+ + \frac{1}{2}O_2 + 2e^- \rightarrow H_2O. \quad \text{—— (2)}$$

Overall rxn of corrosion cell $\rightarrow$ $Fe + 2H^+ + \frac{1}{2}O_2 \rightarrow Fe^{2+} + H_2O$

(Ferrous ion)

* The ferrous ion so formed moves through water and come at the surface where these are further oxidiesed by atmospheric oxygen to ferric ions and form rust.

* Rust is hydrated ferric oxide.

$$2Fe^{2+} + \frac{1}{2}O_2 + 2H_2O \rightarrow Fe_2O_3 + 4H^+$$

(Ferrous ion) Ferric oxide

$$Fe_2O_3 + xH_2O \rightarrow Fe_2O_3 \cdot xH_2O$$

Rust.

Prevention of corrosion:-

[1.] Barrier protection :-

[2.] Sacrificial protection

[3.] Electrical protection.

(i) Barrier protection

a thin layer of barrier is introduced b/w iron and atmospheric oxygen, CO_2 and moisture.

(a) By covering metal surface by paint or grease.

(b) By electroplating iron with some non-corrosive metal like Ni, Cr, Cu etc.

(2.) Sacrificial protection

In this method

* Iron surface is coverd with more reactive metal than iron
* Zn is more reactive than Fe. Hence Fe is coated with Zn and this process is called galvanisation.
* Zn metal is sacrificed at the cost of iron, hence this is protection is called sacrificial protection.

(Zn ने Fe को Protect करने के लिए खुद को Sacrifice कर देता है।)

(3.) Electrical protection/Cathodic protection

* It is also a case of sacrifical protection.
* This method is used for protection of underground pipe or water tank.
* In this method, exposed surface of iron is protected by connecting it to a block of more active metal like Mg, Al, Zn etc
* The more active metal act as anode and iron act as cathode.
* More reactive metal is consumed (sacrificed) gradually and thus Fe remain protected.