

SURFACE CHEMISTRY

// COMPLETE NCERT
- No part of syllabus removed

by Apmi Kaksha

Class XII Board Exams

- Verified by CBSE
Science Topper's

- All PYQ's
Integrated

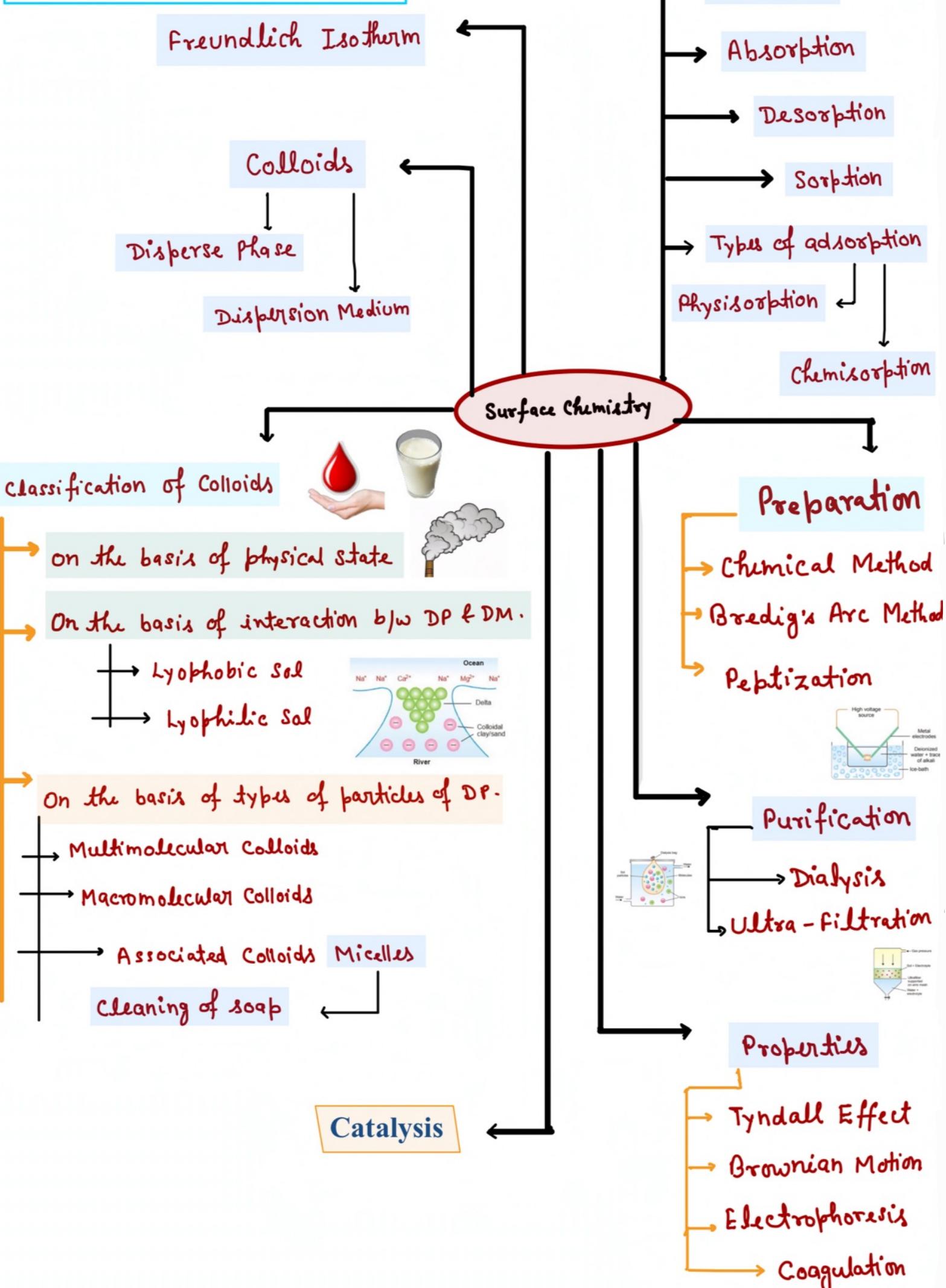
- **BEST NOTES**
for Class XII
Board
Exams



Raman Dhattarwal

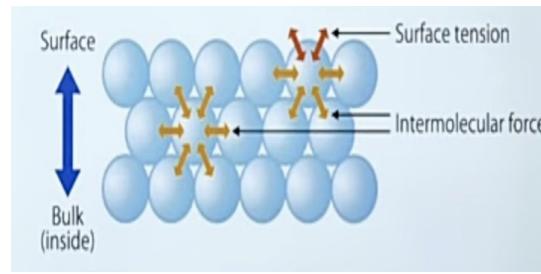
Flow Chart Of Complete Chapter

Freundlich Isotherm



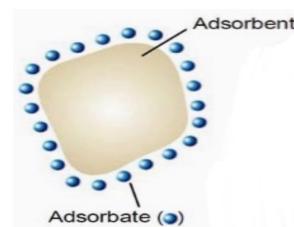
Surface Chemistry

- Surface chemistry deals with phenomena that occur at the surface or interface.
- The surface or interface is represented by separating the bulk phases by a hyphen or slash. For example -:
 - i) Interface between a solid and gas → Solid-gas or $\frac{\text{Solid}}{\text{gas}}$
 - ii) Interface between liquid and liquid → Liquid-liquid
 - iii) But there is no interface between two gases, due to complete miscibility.
- Molecules on surface experiences unbalanced attractive force resulting in a net inward pull. This produces surface tension.
- Molecules in bulk phases experiences balanced forces from all the directions and are in state of equilibrium.



Adsorption -: The accumulation of molecular species at the surface rather than in bulk of a solid or liquid is termed adsorption. [Delhi 2015C, 2014C | CBSE 2013] 1M

Adsorbate -: The molecular species or substance which concentrate or accumulates at the surface is termed adsorbate.



Adsorbent -: The material on the surface of which the adsorption takes place is called adsorbent.

Apni Kaksha :-

Example → Silica gel, charcoal, colloids.

Absorption vs Adsorption

[Delhi 2016 | CBSE 2010C] 1M

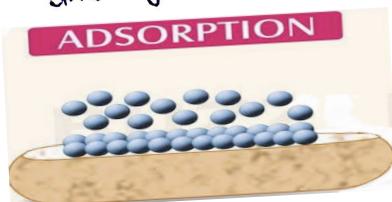
Absorption

i) The substance is uniformly distributed throughout the bulk of solid.



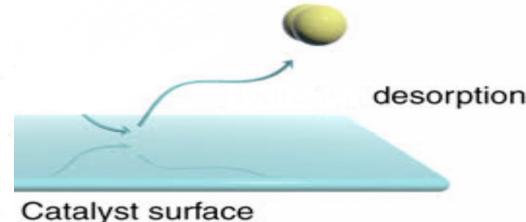
Adsorption

i) The substance is concentrated only at the surface and does not penetrate through surface to the bulk of adsorbent.



Desorption -: The process of removing an adsorbed substance from a surface. [Reverse of adsorption]

[Delhi 2011] 1M



Sorption :- When adsorption and absorption take place simultaneously. [Delhi 2014 Q1] 1M

Thermodynamics of adsorption :- [Why is adsorption always exothermic?]

- During adsorption there is always a decrease in residual forces of surface, there is a decrease in surface energy, which appears as heat. That's why adsorption is an exothermic process. [$\Delta H = \text{Ove}$] 1M [Delhi 2014 / CBSE 2010]
- After adsorption randomness of the system decreases. So for adsorption $\Delta S = \text{Ove}$.
- For adsorption, thermodynamic requirement is that at constant T and P, ΔH must be negative. [$\Delta H = \text{Ove}$]

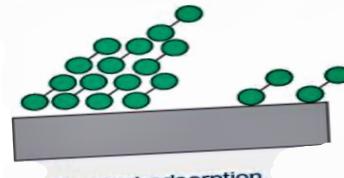
$$\Delta G = \Delta H - T \Delta S$$

Ove value ← ↓ More Ove value → +ve value

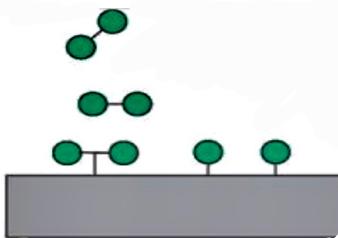
(1M) [Delhi 2010 / 2012 C]

Types of adsorption :-

i) Physical Adsorption :- When the particles of adsorbate are held to the surface of adsorbent by physical forces such as Vander waal's forces. Then adsorption is called physical adsorption.



ii) Chemical Adsorption :- When the molecules of adsorbate are held to the surface of the adsorbent by chemical forces. the adsorption is known as chemical adsorption. [Delhi 2011 C] 1M



→ Difference between physisorption and chemisorption

Physisorption

[Delhi 2013] 2M [CBSE 2015 / 2012] 3M

Chemisorption

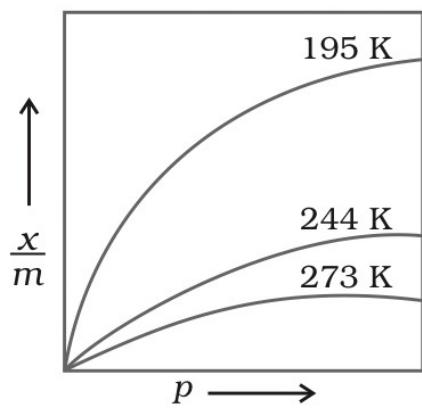
- i) Example → Adsorption of SO_2 on charcoal
- ii) Lack of specificity :- A given surface of an adsorbent does not show any preference for a particular gas.
- iii) It arises due to Vander waal force.
- iv) It is reversible in nature.
- v) As the surface of adsorbent increases physisorption increases.
- vi) Enthalpy of adsorption is low due to weak force of attraction between adsorbent and adsorbate.
- i) Example → Adsorption of H_2 on platinum.
- ii) High specificity :- It will only occur if there is some possibility of chemical bonding between adsorbent and adsorbate.
- iii) It is caused by chemical bond formation.
- iv) It is irreversible in nature.
- v) As the surface area of adsorbent increased chemisorption increases.
- vi) Enthalpy of adsorption is relatively high due to bond formation [strong attractive force]

Absorption Isotherms :- The graph between amount of gas adsorbed and pressure at constant temperature is known as absorption isotherm.

$x \rightarrow$ mass of gas adsorbed.

$m \rightarrow$ mass of adsorbent.

(3M)
[CBSE 2010 / 2010 C]



Freundlich adsorption isotherm :-

→ Empirical relationship between quantity of gas adsorbed and pressure at constant temperature.

$$\frac{x}{m} = K P^{\frac{1}{n}} \quad [0 < n \leq 1]$$

[CBSE 2014] (1M)

Apni Kaksha :-

→ K and n are constants which depends on nature of adsorbent and gas.

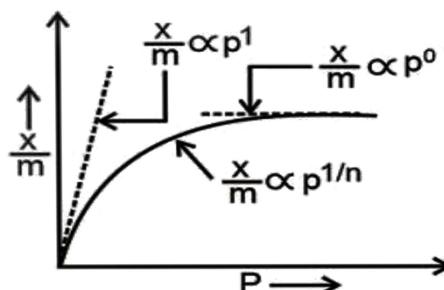
→ From Graph : i) As temperature increases extent of adsorption decreases.

ii) At low pressure : $\frac{x}{m} \propto P^1$

iii) At high pressure : $\frac{x}{m} \propto P^0$: curve seem to approach saturation at high pressure.

iv) At moderate pressure : $\frac{x}{m} \propto P^{\frac{1}{n}}$ where $[0 < n \leq 1]$

Taking log of $\frac{x}{m} = K P^{\frac{1}{n}}$:

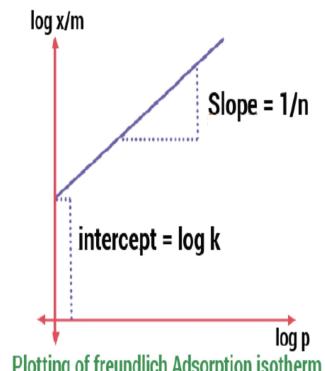


$$\log \frac{x}{m} = \log K + \frac{1}{n} \log P$$

$$y = c + m \cdot x$$

$$\text{Slope } [m] = \frac{1}{n}$$

$$\text{Intercept } [c] = \log K$$



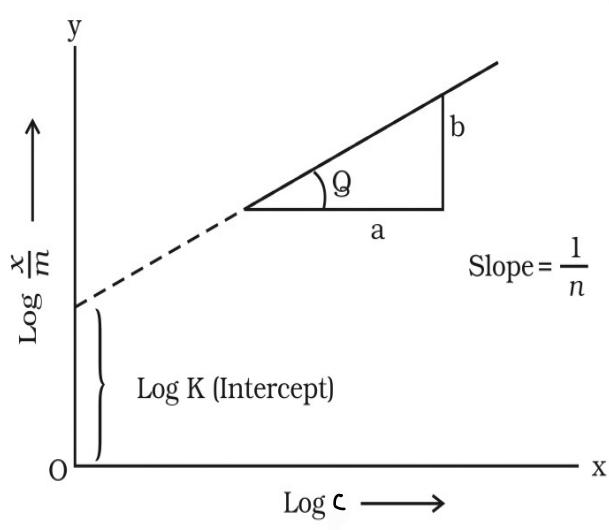
Absorption from solution phase :- Solids can adsorb solutes from solutions. Freundlich equation approximately describes the behaviour of adsorption from solution with a difference that instead of pressure, concentration of solution is taken into account.

$$\rightarrow \frac{x}{m} = K c^{\frac{1}{n}}$$

$$\rightarrow \log \frac{x}{m} = \frac{1}{n} \log c + \log K$$

$$\downarrow \quad \downarrow \quad \downarrow \quad \downarrow$$

$$y = m x + c$$

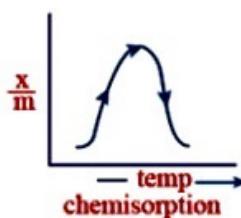
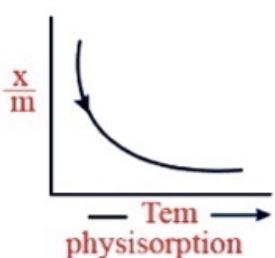


Question :- What is the effect of temperature on physisorption and chemisorption?

CBSE 2019
Delhi 2019
1M

Answer :- As temperature ↑
 \downarrow

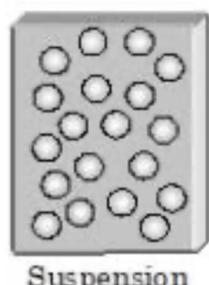
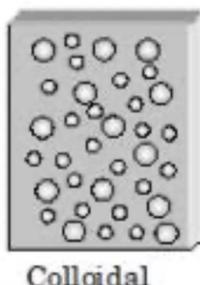
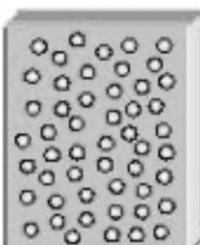
physisorption ↓.



- Chemisorption first increases and then decreases with increase in temperature.

[Delhi 2019] 1M

Colloids



→ The colloidal solutions are intermediate between true solutions and suspensions.

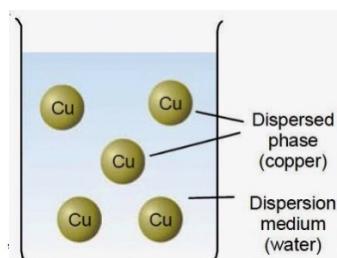
→ Colloidal solution = Dispersed phase + Dispersion medium.

→ Size of colloidal particles = 1 to 1000 nm.

Disperse Phase -: The phase which is distributed (or dispersed) through the medium is called disperse phase [DP].

Dispersion Medium -: A medium in which colloidal particles are dispersed is called continuous phase or dispersion medium [DM].

For example -: Gold sol \rightarrow Gold particles are D.P. and water is DM.



Classification of Colloids

i) On the basis of physical state of DP and DM :- [Most important]



Dispersed phase	Dispersion medium	Type of colloid	Examples
Solid	Solid	Solid sol	Some coloured glasses and gem stones
Solid	Liquid	Sol	Paints, cell fluids
Solid	Gas	Aerosol	Smoke, dust
Liquid	Solid	Gel	Cheese, jellies
Liquid	Liquid	Emulsion	Milk, hair cream, butter
Liquid	Gas	Aerosol	Fog, mist, cloud, insecticide sprays
Gas	Solid	Solid sol	Pumice stone, foam rubber
Gas	Liquid	Foam	Froth, whipped cream, soap lather



(ii) On the basis of interaction between DP and DM :- [CBSE 2013] [Delhi 2014C] [3M]

Lyophilic colloids

i) Lyophilic means liquid loving.

ii) Colloidal solution in which the particles of dispersed phase (solute) have great affinity for dispersion medium (solvent).

iii) Example → Glue, gelatin, starch, protein with a suitable liquid.

iv) It is a reversible sol means that if DM is separated from DP, the sol can be reconstituted by simply mixing of DM and DP.

[CBSE 2010] 1M

v) It is a stable colloid. It can not be precipitated easily.

Lyophobic colloids

i) Lyophobic means liquid hating.

ii) Colloidal solution in which the particles of the dispersed phase have no affinity for DM.

iii) Example → Solution of metals [Ag, Au]
[CBSE 2014] 1M → Gold sol.

iv) It is an irreversible sol means that it can not be prepared just by mixing of DP and DM. It can be prepared only by special methods.

v) It is an unstable colloid. So this sol needs stabilising agent for preservation.

On the basis of types of particles of the D.P. :-

a) Multimolecular Colloids -: On dissociation, a large no. of atoms or molecules of

[CBSE 2013]

a substance aggregate together to form species having size in colloidal range. The species thus formed are called multimolecular colloid. Example → Gold sol and sulphur [S₈] sol.

1M [Delhi 2013
2010]

b) Macromolecular Colloids -: Macromolecules [polymers] in suitable solvents form solution in which the size of macromolecules may be in colloidal range. Such systems are called macromolecular colloids.

Example → Polymers [like starch, cellulose, proteins, enzymes, polythene etc.]

1M [CBSE 2013 / Delhi 2012
2010]

c) Associated Colloids -: There are some substances which at low concentrations behave as normal strong electrolytes, but at higher concentrations exhibit colloidal behaviour due to formation of aggregates.

[CBSE 2013 / Delhi 2010/2012
2019]

→ The aggregated particles are called micelles or associated colloids.

Example → Soap | Detergents

→ The formation of micelles takes place only above a particular temperature called Kraft temperature (T_K) and above a particular concentration called CMC means Critical micelle Concentration.

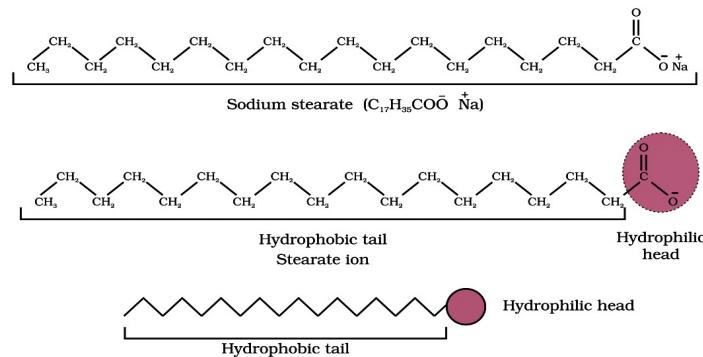
Mechanism of micelle formation :-

→ To understand the mechanism, let us take an example of soap solution.

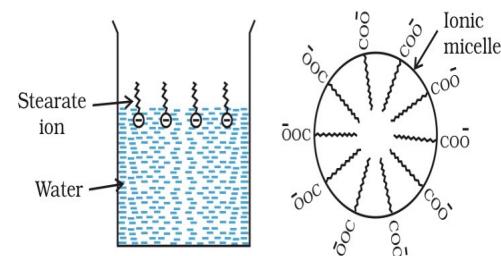
→ Soap : Sodium or potassium stearate

→ Sodium stearate has two parts

- Hydrophobic part [water repelling] : A long hydrocarbon chain (Non-polar tail)
- Hydrophilic part [water loving] : $-COO^-$ group (polar-ionic head) $[C_{17}H_{35}COO^-]$



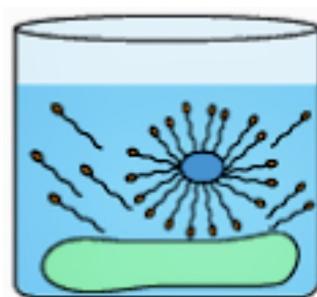
→ The $C_{17}H_{35}COO^-$ ions are present on the surface with their COO^- group in water and the hydrocarbon chains [$C_{17}H_{35}$] staying away from it and remain at the surface.



→ But at CMC, the anions are pulled into the bulk of solution and aggregate to form a spherical shape with their hydrocarbon chains pointing towards the centre of sphere with COO^- part remaining outward on the surface of sphere. This spherical aggregate is known as ionic micelle.

→ Detergents : sodium laurylsulphate $[CH_3(CH_2)_10SO_4^{\ominus} Na^{\oplus}]$

Cleaning action of soap :- The cleaning action of soap is due to the fact that soap particles form micelle around the oil droplet in such a way that hydrophobic part of the stearate ions is in oil droplet and hydrophilic part projects out of the grease droplet. Because hydrophilic part is outside of oil droplet, so it can interact with water due to polarity.



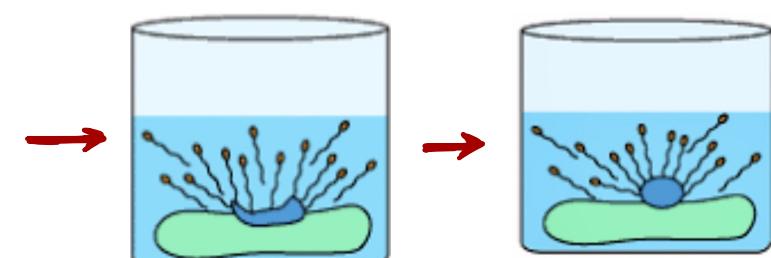
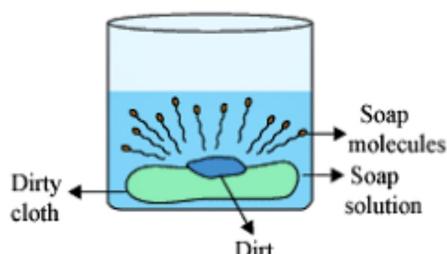
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Kaksha



→ The oil droplet surrounded by stearate ions is now pulled in water and removed from dirty surface.

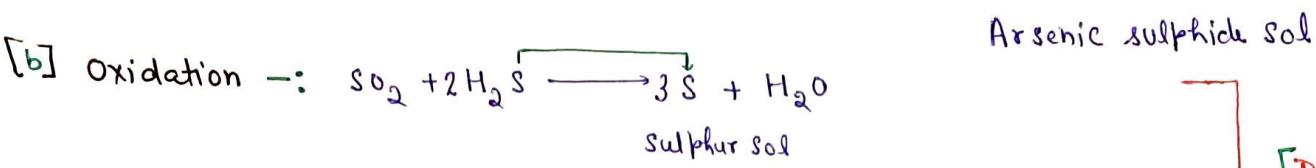
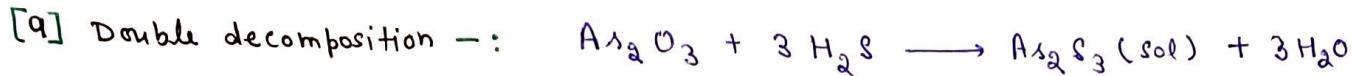
[CBSE 2012]

2M



Preparation of colloids

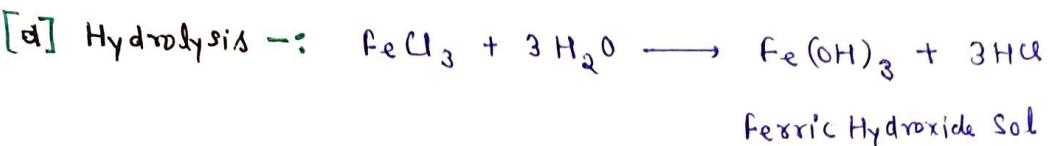
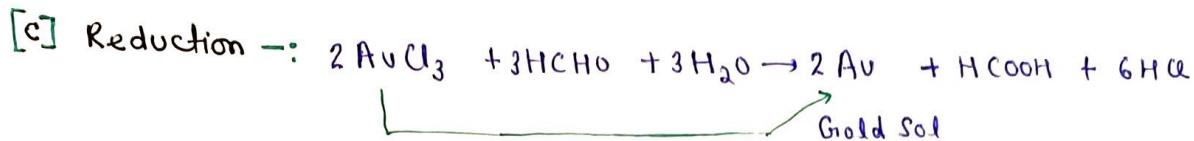
(i) Chemical Methods -:



Arsenic sulphide sol

[Delhi 2013]

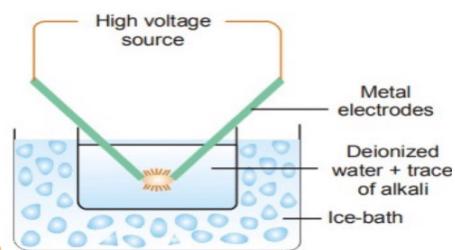
2M



(ii) Bredig's Arc Method -: [Electrical Disintegration]

By using electric arc, we can disintegrate (vapourise) the metal electrode [gold, silver, platinum etc.] which then condense to form particles of colloidal size.

→ This process involves dispersion as well as condensation.



(iii) Peptization -: Process of converting a precipitate into colloidal sol, by shaking it with DM in presence of a small amount of electrolyte.

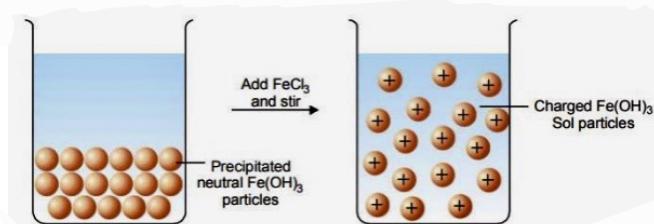
[CBSE 2010 | 2013]

[Delhi 2011 | 2013 | 2014C]

→ The electrolyte used for this purpose is called peptizing agent.

→ During peptization the ppt adsorbs one of the ions of electrolyte on its surface. This causes the development of positive or negative charge on ppt, which ultimately break up into smaller particles of size of a colloid.

$$\text{ppt} + \text{Electrolyte} = \text{Colloidal Solution}$$

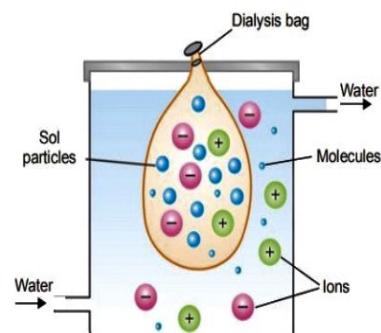


Purification of colloidal solution

(i) Dialysis -: It is process of removing a dissolved substance from a colloidal solution by means of diffusion through suitable membrane.

[CBSE 2011] 1M

→ True solution can pass through this membrane but not colloidal particles.

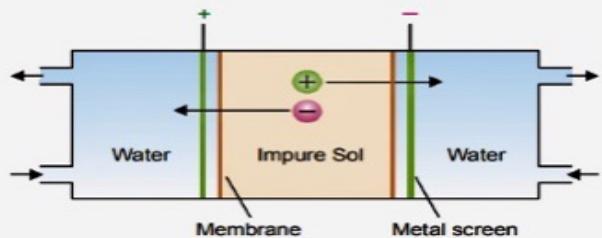


→ A bag of semipermeable membrane containing the colloidal solution is suspended in a vessel through which fresh water is continuous flowing. The molecules and ions diffuse through membrane into the outer water and pure colloidal solution is left behind.

(ii)

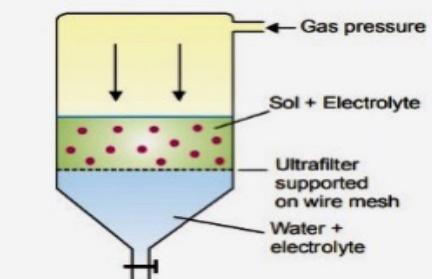
Electro-dialysis :-

→ Dialysis can be made faster by applying an electric field.



(iii) Ultra-filtration :- Ordinary filter paper have very large pore size. So it can pass both impurities and colloidal particles.

→ In such condition, we use ultrafilter paper which is designed in such a way that it can allows only the true solution to pass through. The pure colloid left on filter paper.

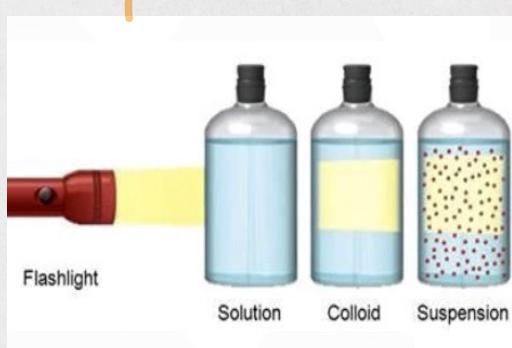


Properties of colloidal solutions

i Optical Property [Tyndall effect]

→ Scattering of light by colloidal particles is called Tyndall effect. [CBSE 2015C | 2011 | Delhi 2014C]

1M



Condition for Tyndall effect :- i) size of the colloidal particles should be approximately similar to the wavelength of light used.

ii) The difference in refractive indices of D.P. and D.M. should be large.

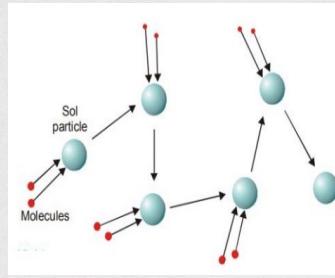
→ As the size of particles changes colour of colloidal solution changes.

ii Brownian Motion :- [Kinetic Property]

→ Continuous random motion / zig-zag motion of the colloidal particles is known as Brownian motion.

→ The Brownian movement has been explained to be due to the unbalanced bombardment of the particles by the molecules of the DM.

→ This motion stabilizes the colloidal solution as it does not allow the DP to settle down.



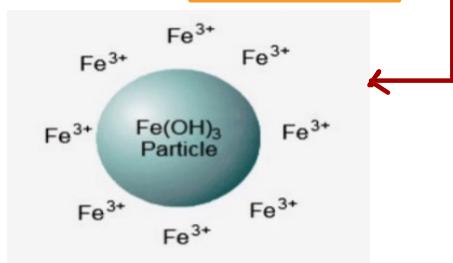
iii Electrical Properties :-

Charge on colloidal Particles :- Colloidal particles always carry an electric charge. The nature of this charge is same for all the particles in a given colloidal solution.

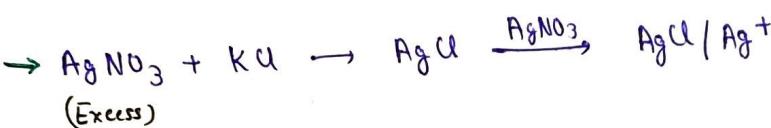
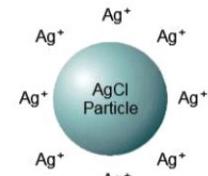
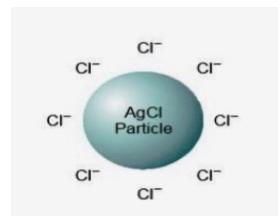
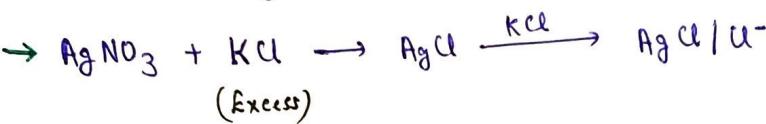
Positively charged sols	Negatively charged sols
Hydrated metallic oxides, e.g., $\text{Al}_2\text{O}_3 \cdot x\text{H}_2\text{O}$, $\text{CrO}_3 \cdot x\text{H}_2\text{O}$ and $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$, etc.	Metals, e.g., copper, silver, gold sols.
Basic dye stuffs, e.g., methylene blue sol.	Metallic sulphides, e.g., As_2S_3 , Sb_2S_3 , CdS sols.
Haemoglobin (blood)	Acid dye stuffs, e.g., eosin, congo red sols.
Oxides, e.g., TiO_2 sol.	Sols of starch, gum, gelatin, clay, charcoal, etc.

→ Preferential adsorption of ions create charge on colloidal particles.

→ The charge on sol particles originates by selective adsorption of ions common to the particles from the dispersion medium.



→ In some cases, particles may adsorb the anions or cations whichever are in excess and acquire the corresponding charge.

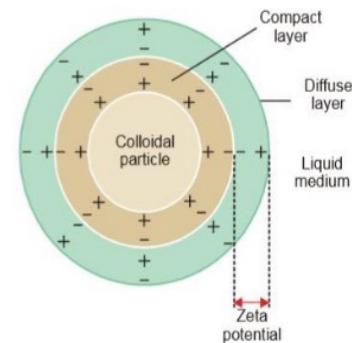
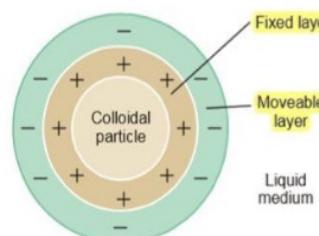


AgU / Ag^+

Zeta Potential [Electrokinetic Potential]

Potential difference between fixed layer and diffused layer = Zeta potential.

[CBSE 2015C] 1M



Electrophoresis :- The existence of charge on colloidal particles is confirmed by

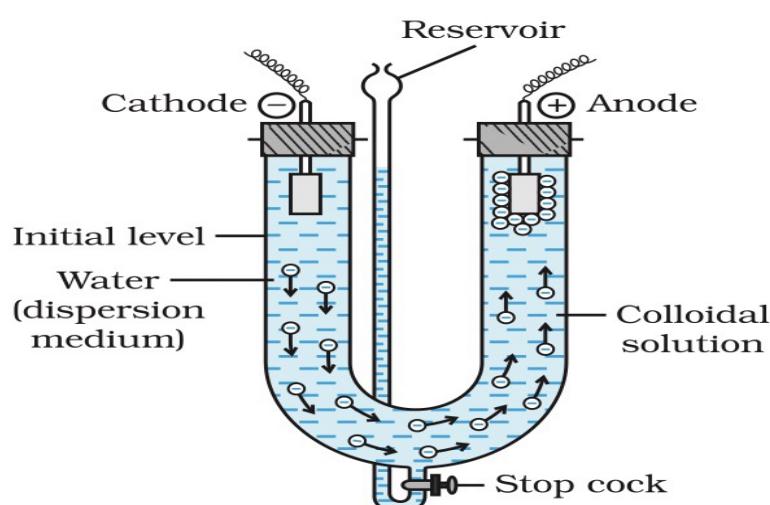
[Delhi 2011] [Delhi 2015C] electrophoresis experiment.

1M

→ The movement of sol particles under electric potential is called cataphoresis or electrophoresis.

→ +ve particles moves towards cathode.

→ -ve particles moves towards anode.



iv Coagulation [Precipitation] :- The process of settling of colloidal particles is called coagulation of the sol.

- The stability of lyophobic sols is due to the presence of charge on colloidal particles. If charge is removed by same method, the particles will come nearer to each other to form aggregates and settle down under the force of gravity.
- Coagulation of lyophobic sols can be carried out by following ways :-
 - ① By Electrophoresis
 - ② By Boiling
 - ③ By addition of electrolyte
 - ④ By mixing of two oppositely charged sols.

[Delhi 2012 / CBSE 2010]

1M

Hardy - Schulze Law :- The precipitating effect of an ion on DP of opposite charge increases with charge of ion.

- Coagulation Power \propto Charge on ion
- For coagulation of Fe(OH)_3 sol : Order of coagulation power : $[\text{Fe}(\text{CN})_6]^{4-} > \text{SO}_4^{2-} > \text{Cl}^-$
- For oxely charged sol : Order of coagulation power : $\text{Al}^{3+} > \text{Ba}^{2+} > \text{Na}^+$

Coagulation value :- Minimum concentration of an electrolyte [millimoles per litre] required to cause precipitation of a sol is called coagulation value.

→ Coagulation Power $\propto \frac{1}{\text{Coagulation value}}$

Protection of colloids :- Lyophilic sols are more stable than lyophobic sols.

because lyophilic sols are extensively solvated by DM. [Delhi 2015] 1M

- Due to its stability, lyophilic sols are used to protect the lyophobic sols from precipitation [coagulation]. Lyophilic sol form a protective layer around lyophobic sol particles and thus protect from electrolyte.

Gold Number :- Protective power of lyophilic sol is expressed in term of gold no.

- "The no. of milligrams of a hydrophilic colloid that will just prevent the precipitation of 10 ml of a gold sol, on the addition of 1 ml of 10% NaCl solution."

Protecting Power $\propto \frac{1}{\text{Gold Number}}$

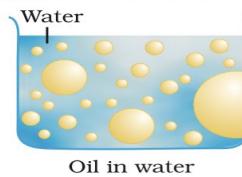
- These are liquid - liquid colloidal systems.
- In other words an emulsion may be defined as a dispersion / distribution of finely divided liquid droplets in another liquid.

There are two types of emulsions:

i) Oil in water type [O/W type]

DP → Oil

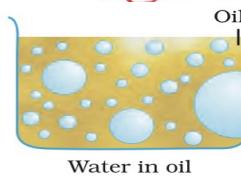
DM → Water



ii) Water in oil type [W/O type]

DP → Water

DM → Oil



Example → Milk | Cream | Soap | Gums

Example → Heavy metal salts of fatty acids.

Emulsifying Agent :- Water and oil are immiscible and they form unstable emulsions [Delhi 2010] 1M or sometime they separate in two layers. To stabilize the emulsion and to make them homogeneous, we add emulsifying agent.

Example → Soap | Detergents : Emulsifier

Casein (protein) in milk : Emulsifying agent.

→ Emulsions can be broken into constituent liquids by heating, freezing and centrifuging etc. This process is called De-emulsification.

1M

Question :- Leather gets hardened after tanning, Why?

[CBSE 2019 | Delhi 2015]

Answer :- Because colloidal nature of animal-skin having positively charged particles whereas tannin consists of negatively charged colloidal particles, which when combine leather get hardened.

1M

Question :- Why are medicines more effective in colloidal state? [Delhi 2019]

Answer :- Because they have large surface area per unit mass. So they are easily assimilated in the body.

Question :- Some substance can act both as colloid and crystalloids. Explain?

[Delhi 2012C | 2013C]

Answer :- When size of the particle lies between 1 to 1000 nm \Rightarrow Colloid.

1M

When size of the particle is less than 1 nm (true solution range) \Rightarrow Crystalloid

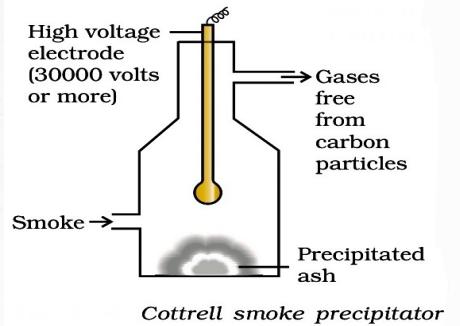
Example → NaCl in water : Colloid ; NaCl in benzene : Crystalloid.

Applications of colloids :-

[CBSE 2012 C]

1M

i) Electrical precipitation of smoke :- Smoke is a colloidal solution of solid particles such as carbon arsenic compounds, dust etc, in air.



→ Cottrell Precipitator :- a chamber containing plates having a charge opposite to that carried by smoke particles. The particles on coming in contact with these plates lose their charge and get precipitated.

ii) coagulation of blood :- blood is a colloidal particle which get precipitated by using alum (electrolyte).

Formation of Delta :-

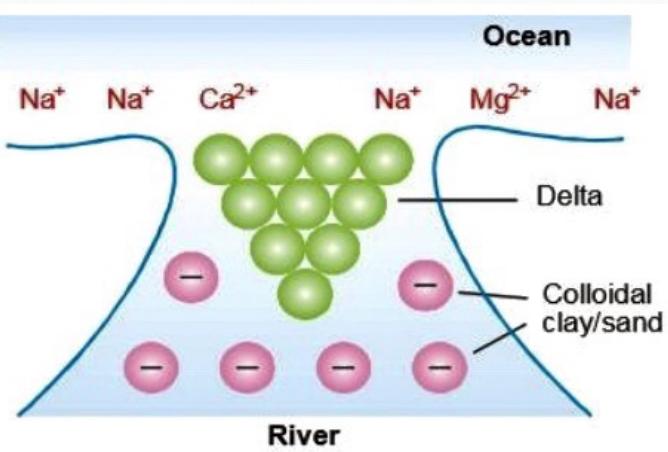
→ Due to precipitation of clay (which is colloidal in nature), delta's are formed at junction of river and sea.

Question :- Why is a finely divided substance more effective as an adsorbent?

Answer :- finely divided substance has more surface area, so more adsorption occurs.

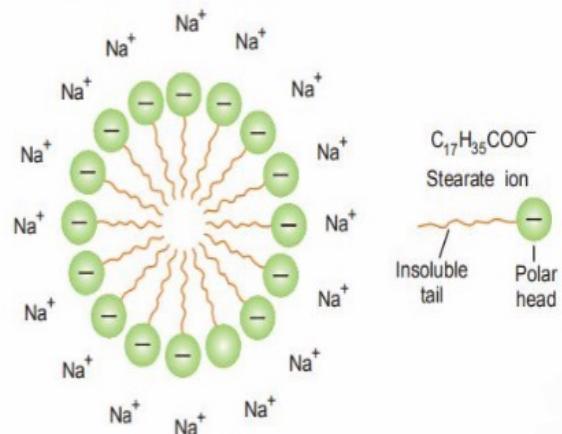
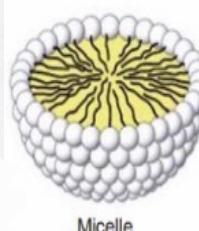
[Delhi 2010 C / CBSE 2011C]

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Delta formation

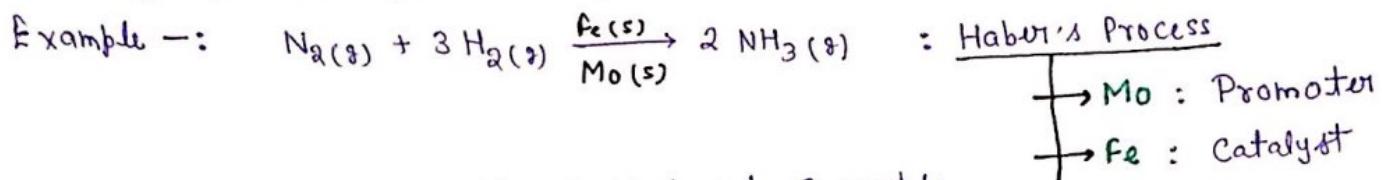
Micelle formation



Catalysis

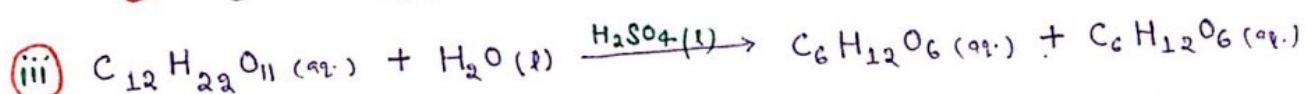
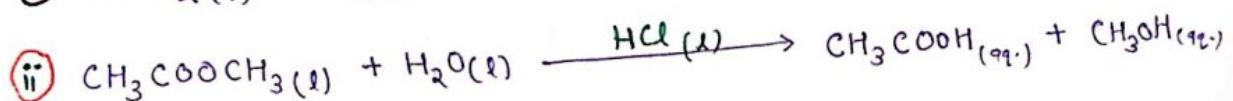
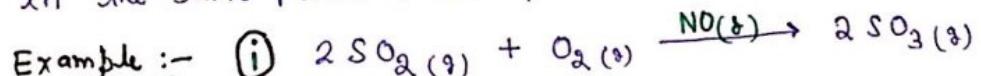
→ Substances, which alter the rate of a chemical reaction and themselves remain chemically and quantitatively unchanged after the reaction, are known as **catalyst** and phenomenon is known as **catalysis**.

Promoters and poisons :- Promoters are substances that enhance the activity of a catalyst while poisons decrease the activity of a catalyst.



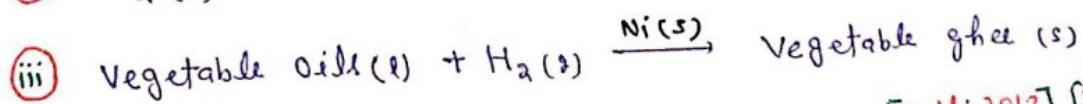
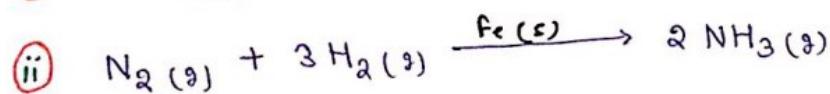
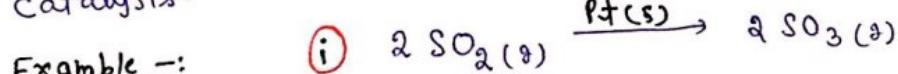
→ Catalysis can be broadly divided into 2 groups.

a) **Homogeneous catalysis** :- When the reactants and the catalyst are in the same phase, the process is said to be homogeneous catalysis.



b) **Heterogeneous catalysis** :- The catalytic process in which reactants and the catalyst are in different phases is known as heterogeneous catalysis.

Apni Kaksha



[Delhi 2012] 2M

Adsorption Theory of heterogeneous catalysis :-

According to modern adsorption theory - The catalytic activity is localised on the surface of the catalyst and mechanism involves five steps :-

- i) Diffusion of reactants to the surface of the catalyst.
- ii) Adsorption of reactant molecules on the surface of the catalyst.
- iii) Occurrence of chemical reaction on the catalyst's surface through

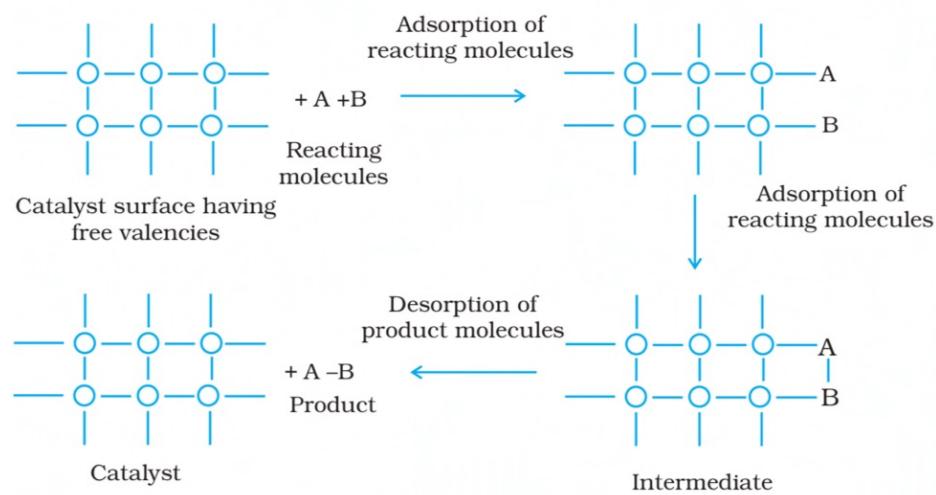
formation of an intermediate.

(iv) Desorption of reaction products from the catalyst surface, and so making the surface available again for more reaction to occur.

(v) Diffusion of reaction products away from catalyst's surface.

→ This theory explains why the catalyst remains unchanged in mass and chemical composition at the end of the reaction and is effective even in small quantities.

→ This theory does not explain the action of catalytic promoters and poisons.



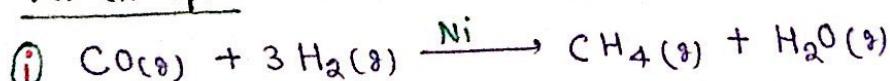
Important features of solid Catalysts :-

Activity :- The activity of a catalyst depends upon the strength of chemisorption to a large extent. The reactants must get adsorbed reasonably strongly on to the catalyst to become active.

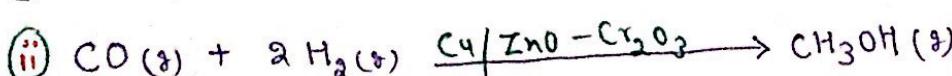


Selectivity :- The selectivity of a catalyst is its ability to direct a reaction to yield a particular product.

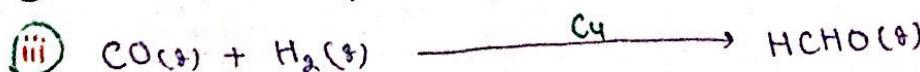
for example → Reactants H₂ and CO Different Catalyst, Different Products.



[CBSE 2018]

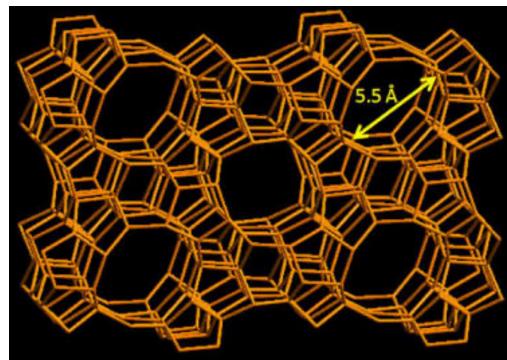


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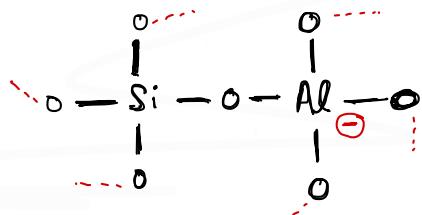
Shape Selective Catalysis :- The catalytic reaction that depends upon pore structure of the catalyst and size of the reactant and product molecules is called shape-selective catalysis.

Example -: Zeolites are microporous aluminosilicates 3 D network of silicates in which some silicon atoms are replaced by Al atoms giving Al-O-Si framework . They are good shape selective catalysts because of their honeycomb like structures.



→ Alcohols $\xrightarrow{\text{ZSM-5}}$ Gasoline [Petrol]

1M [Delhi 2011/2014 | CBSE 2011/2012]
2010



Enzymes :— Enzymes are complex nitrogenous organic compounds. They are usually protein molecules of high molecular mass. [CBSE 2014C] LM

→ Many reactions that occur in the bodies of animals and plants to maintain the life process are catalysed by enzymes. The enzymes are termed as biochemical catalysts and the phenomenon is called biochemical catalysis.

b) $C_{12}H_{22}O_{11} \text{ (s)} + H_2O \text{ (l)} \longrightarrow 2 C_6H_{12}O_6 \text{ (aq)}$

Glucose

Maltose

fructose

→ characteristics of enzyme catalysis: Enzymes are highly efficient, highly specific in nature and highly active under optimum temperature and optimum pH.

→ The enzymatic activity is increased in the presence of certain substances known as co-enzymes.

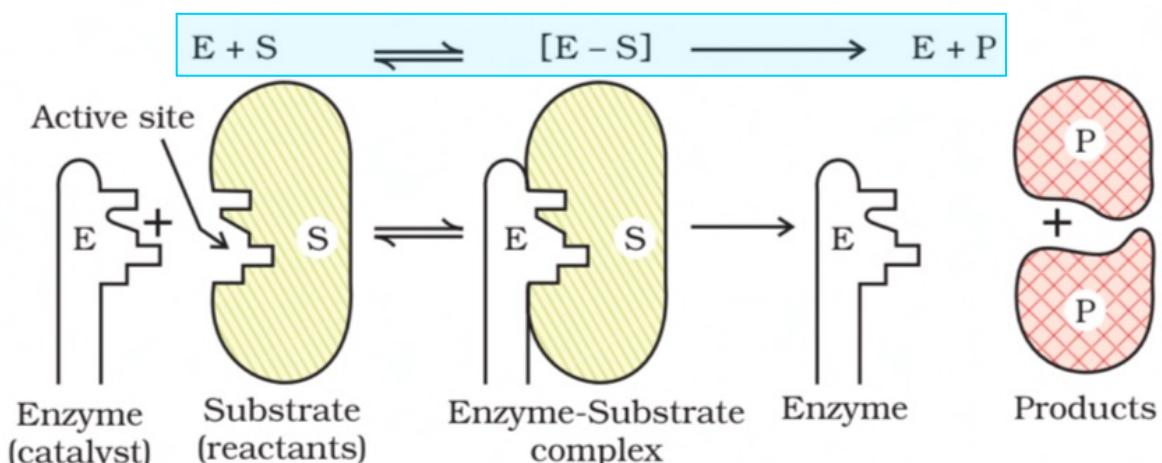
→ Certain substances known as inhibitors or poisons reduce or completely destroy the catalytic activity of the enzymes.

→ Mechanism of enzyme catalysis :-

Step 1 : Binding of enzyme to substrate to form an activated complex.



Step 2 : Decomposition of activated complex to form product.



Some Industrial Catalytic Processes

Process	Catalyst
1. Haber's process for the manufacture of ammonia $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$	Finely divided iron, molybdenum as promoter; conditions: 200 bar pressure and 723-773K temperature.
2. Ostwald's process for the manufacture of nitric acid. $4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$ $2NO(g) + O_2(g) \rightarrow 2NO_2(g)$ $4NO_2(g) + 2H_2O(l) + O_2(g) \rightarrow 4HNO_3(aq)$	Platinised asbestos; temperature 573K.
3. Contact process for the manufacture of sulphuric acid. $2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$ $SO_3(g) + H_2SO_4(aq) \rightarrow H_2S_2O_7(l)$ oleum $H_2S_2O_7(l) + H_2O(l) \rightarrow 2H_2SO_4(aq)$	Platinised asbestos or vanadium pentoxide (V_2O_5); temperature 673-723K.