

## Chemistry : Adsorption and Colloids

### INTRODUCTION

- ❑ The term adsorption was first used by H. Kayser in 1881 and it refers strictly to the existence of higher concentration of any particular component at the surface of a solid or liquid substance.
- ❑ The branch of physical chemistry, which deals with the nature of surfaces and also with chemical and physical process which takes place on the surfaces, is called **surface chemistry**.
- ❑ In surface chemistry, we study the phenomenon of adsorption, catalysis and colloidal properties.

### ADSORPTION

- ❑ **Adsorption is a surface phenomenon.**
- ❑ The phenomenon of accumulation of a substance forming higher concentrated layer on the surface of adsorbing substance is known as **adsorption**.
- ❑ It is the change in concentration at the interfacial layer between two phases of system when two different are brought in contact with each other.
- ❑ The phenomenon of higher concentration of molecular species (gases or liquids) on the surface of a solid in the bulk is called **adsorption**.
- ❑ It is specific and selective in nature.
- ❑ It is accompanied by decrease in free energy of the system, when  $\Delta G$  becomes zero, adsorption equilibrium is established.
- ❑ Adsorption is an exothermic process therefore  $\Delta H$  as negative sign.

- e.g. i. Adsorption of  $H_2$  gas on nickel
- ii. Adsorption of  $O_2$  gas on mercury
- iii. Adsorption of acetic acid on charcoal

#### • **Absorption**

- ❑ Absorption is a **bulk phenomenon**.
- ❑ **Absorption** : The phenomenon of penetration of one substance through the surface and get distributed through out the body of other substance is known as absorption.

OR

It is defined as a process due to which there is uniform diffusion of one substance throughout the bulk of another substance.

e.g. Absorption of water by sponge, Absorption of water by blotting paper.

- ❑ Adsorption usually takes place two immiscible i.e. Heterogenous phases are come in contact. There are three cases of adsorption.

1. **Gas - solid** - Adsorption of gas on charcoal
2. **Liq -solid** - Adsorption of acetic acid
3. **Solid - solid** - Adsorption of gas on Hg.

#### • **Adsorbent :**

- ❑ The surface on which adsorption takes place is known as **adsorbent** e.g. Charcoal.

## Distinguish between Adsorption and Absorption

Adsorption	Absorption
<ul style="list-style-type: none"><li>It is surface phenomenon.</li><li>It depends upon the surface area of adsorbent. It is an exothermic process.</li><li>It is reversible process.</li><li>It depends upon the temperature and pressure.</li><li>It is fast process.</li><li>The adsorbed substances get collected only</li><li>The surface of adsorbent, e.g. Adsorption of a gas by activated charcoal.</li><li>Equilibrium will be reached slowly, e.g. Adsorption of acetic acid on charcoal</li></ul>	<ul style="list-style-type: none"><li>It is bulk phenomenon.</li><li>It does depends upon the porous nature of absorbent.</li><li>It is neither exothermic nor endothermic.</li><li>It is irreversible process.</li><li>It is independent of temperature and pressure.</li><li>It is comparatively slow process.</li><li>One substance get penetrate through other substance on and uniformly distributed through out the body of adsorbent.</li><li>Equilibrium will be reached rapidly, e.g. Absorption ink by chalk .</li></ul>

- **Adsorbate :**

- The substance which gets adsorbed on solid surface is known as **adsorbate** e.g. Acetic acid.
- The process of removal of an adsorbed substance from the surface is known as **desorption**.

- **Sorption :** When both adsorption and absorption occur simultaneously, it is known as sorption, e.g. When a chalk is dipped in ink, the ink molecules are adsorbed at the surface of the chalk while the solvent of the ink gas deeper into the chalk due to absorption.

- **Demonstration of adsorption :**

Take 10 ml of water in test tube. Add small quantity of  $\text{CuSO}_4$  crystals in it. Shake well. The solution becomes blue colour. Then add 1 gm. of alumina in it and shake well for some time. Alumina settle down and solution becomes colourless. The coloured matter of  $\text{CuSO}_4$  is adsorbed by  $\text{Al}_2\text{O}_3$ .

## TYPES OF ADSORPTION

It is divided into two types.

1. **Physical adsorption (Physisorption):** A process in which the particles of the adsorbate are held to the surface of the adsorbent by physical forces such as van der Waals' forces.
2. **Chemical adsorption (Chemisorption):** A process in which the molecules of the adsorbate are held to the surface of the adsorbent by chemical forces.

## FACTORS AFFECTING ADSORPTION

The following are the factors affecting adsorption.

1. Nature of adsorbate and Nature of adsorbent
2. Temperature
3. Pressure
4. Concentration of adsorbate
5. Surface area of adsorbent
6. Activation of the solid adsorbent

• **Distinguish between Physical Adsorption and Chemical Adsorption**

Physical adsorption :	Chemical adsorption :
<ul style="list-style-type: none"> <li><input type="checkbox"/> The forces of attraction are weak vander waal's forces</li> <li><input type="checkbox"/> Low heat of adsorption. (<math>\Delta H</math> is 20 to 40 KJ/Mol)</li> <li><input type="checkbox"/> It is non specific.</li> <li><input type="checkbox"/> It is a reversible.</li> <li><input type="checkbox"/> It is multi-molecular in nature.</li> <li><input type="checkbox"/> Does not require activation energy.</li> <li><input type="checkbox"/> Rate is very fast.</li> <li><input type="checkbox"/> It occurs at Low temperature.</li> <li><input type="checkbox"/> It is also called Van der waal's adsorption.</li> <li><input type="checkbox"/> The Chemical identity of adsorbate does not change e.g. Adsorption of <math>H_2</math> on charcoal.</li> </ul>	<ul style="list-style-type: none"> <li>The forces of attraction are chemical forces. High heat of adsorption. (<math>\Delta H</math> is 200 to 400 kJ/mol)</li> <li>It is specific in nature.</li> <li>It is a irreversible.</li> <li>It is uni-molecular in nature.</li> <li>Activation energy is involved in this process.</li> <li>Rate is relatively slow.</li> <li>It occurs at high temperature.</li> <li>It is also known as <b>Langmuir adsorption</b>. The Chemical identity of adsorbate changes due to the formation of surface compound, e.g. Adsorption of <math>O_2</math> on tungsten.</li> </ul>

1. **Nature of adsorbate and Nature of adsorbent**

- ☐ The extent of adsorption depends on the nature of the adsorbate and adsorbent:
- ☐ It is observed that the gases which can be most easily liquified and which are highly soluble are the most easily adsorbed.
- ☐ Gases that liquified gases as  $HCl$ ,  $NH_3$ ,  $H_2S$ ,  $Cl_2$ ,  $SO_2$  and  $CO_2$  get adsorbed to greater extent than gases like  $H_2$ ,  $N_2$ ,  $O_2$  etc.

2. **Temperature :**

- ☐ Adsorption is an exothermic process involving equilibrium.  
Gas (Adsorbate) + Solid (adsorbent)  $\rightleftharpoons$  Gas adsorbed on solid + Heat
- ☐ According to Le-chatelier principle, increase in temperature decreases adsorption and vice versa.

3. **Pressure :**

- ☐ At constant temperature, as pressure increases, adsorption increases.

4. **Concentration of Adsorbate :**

- ☐ As the concentration of adsorbate in the solution increases, the rate of adsorption increases.

5. **Surface area of adsorbent :**

- ☐ Greater the surface area, greater would be the adsorption.

6. **Activation of solid adsorbent :**

- ☐ Activation of solid adsorbent that is increasing the adsorbing power of the solid adsorbent. This is accompanied by removing the adsorbed gases at solid adsorbent on passing super heated steam.

- ☐ The gas with higher critical temperature has stronger vander waal's forces of attraction and hence greater would be the adsorption.

### ADSORPTION ISOTHERM

- ☐ The plots of extent of adsorption ( $x/m$ ) vs. Pressure at constant. Temperature is called as adsorption , isotherm.

• **Freundlich adsorption Isotherm :**

- ☐ The variation of extent of adsorption ( $x/m$ ) with pressure ( $p$ ) was given Mathematically by freundlich.

- ☐ At low pressure  $\frac{x}{m} \propto P$

$$\text{or } \frac{x}{m} = kP \quad \text{---(i)}$$

where K is constant

- ☐ At high press  $\frac{x}{m} = \text{constant}$

$$\text{or } \frac{x}{m} \propto P^0$$

$$\text{or } \frac{x}{m} = kP^0 \quad \text{---(ii)}$$

- ☐ In the intermediate range of press  $\frac{x}{m} \propto P^{1/n}$

$$\text{or } = kP^{1/n} \quad \text{---(iii)}$$

'n' can take any whole number value which depends upon the nature of adsorbate and adsorbent. The above relation is also called of **Freundlich's adsorption isotherm**.

- Calculation of K and n can be determined as taking log both side for equation number (3) we get

$$\text{i.e. } \log \frac{x}{m} = \log k + \frac{1}{n} \log P$$

Therefore If we plot a graph between  $\log (x/m)$  vs  $\log P$  a straight line will be obtained. The slope of line is equal to  $1/n$  and intercept is equal to  $\log k$ .

- It states that, an empirical relationship between amount of adsorbate adsorbed by adsorbent per gram at constant temperature against equilibrium pressure or concentration.

#### • Adsorption from solutions

- Extent of adsorption increase with increase in concentration of solute in solution.
- Extent of adsorption decreases with increase in temperature.
- Extent of adsorption increase with increase in surface area of adsorbent Adsorption isotherm.

$$\frac{x}{m} = kC^{1/n} \text{ or } \log \frac{x}{m} = \log k + \frac{1}{n} \log C$$

- From graph between  $\log (x/m)$  and  $\log C$ , k and n can be calculated.

### APPLICATION OF ADSORPTION

The Phenomenon adsorption Finds a number of applications. Important ones are listed here.

- **Production of high vacuum**: The remaining traces of air can be adsorbed by charcoal from a vessel evacuated by a vacuum pump to give a very high vacuum.
- **Gas masks**: Gas mask (a device which consists of activated charcoal or mixture of adsorbent) is usually used for breathing in coal mines to adsorb poisonous gases.
- **Control of humidity**: Silica and aluminium gels are used as adsorbent for removing moisture and controlling humidity.
- **Removal of colouring matter from solution**: Animal charcoal removes colours of solutions by adsorbing coloured impurities.
- **Heterogeneous catalysis**: Adsorption of reactants on the solid surface of the catalysts increases the rate of reaction. There are many gaseous reaction of industrial importance involving solid catalysts. Manufacture of ammonia using Iron as a catalyst,

Manufacture of  $H_2SO_4$  by contact process and use of finely divided nickel in the hydrogenation of oils are excellent examples of heterogeneous catalysis.

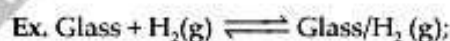
- **Separation of inert gases**: Due to the difference in degree of adsorption of gases by charcoal, a mixture of noble gases can be separated by adsorption on coconut charcoal at different temperature.
- **In curing diseases**: A number of drugs are used to kill germs by getting adsorbed on them.
- **Froth Floatation Process**: A low grade sulphide ore is concentrated by separating it from silica and other earthy matter by this method, using pine oils and frothing agent.
- **Adsorption indicators**: Surfaces of certain precipitates such as silver halides have the property of adsorbing some dyes like eosin, fluorescein, etc. and thereby producing a characteristic colour at the end point.

#### □ Chromatographies analysis:

Chromatographies analysis based on the phenomenon of adsorption finds a number of applications in analytical and industrial fields.

#### • Key points:

- Generally adsorption is exothermic process but an example of chemical adsorption is endothermic.



(Exception)  $\Delta H = \text{Positive}$

- Freundlich adsorption isotherm explains Physical adsorption upto moderate pressure but fails at high pressure.

Occulsion Adsorption of gases on metal surface voids is called occulsion.

### CATALYSIS

Catalyst is a substance which can change the speed of a reaction without being used up in that reaction.

#### • Types of catalyst,

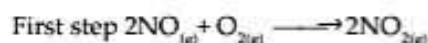
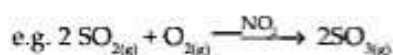
##### 1 Homogeneous catalyst:

When the catalyst is present in the same phase at the reactants and products it is called homogeneous Catalyst. And process is called homogeneous catalyst reaction.

#### • Mechanism:

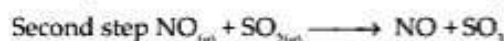
- First catalyst combines with reactant to form an intermediate.
- Intermediate either decomposes or combines with other reactant to form the product and the catalyst is regenerated.





Catalyst

Intermediate step

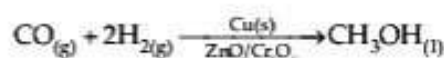
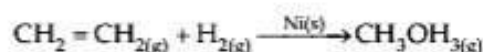
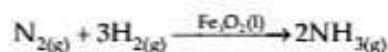


Catalyst Product

### • Heterogeneous catalyst :

When the catalyst is different in phase than the

reactants, is called heterogeneous catalyst.



Mechanism: Modern absorption theory

## Catalyst

### Positive catalyst

(If a catalyst increases the rate of reaction)

### Negative catalyst

(If a catalyst decreases the rate of reaction)

### Auto catalyst

(When one of the product act as catalyst)

### Induced catalyst

(One of the reactants act as catalyst)

## ADSORPTION THEORY OF HETEROGENEOUS CATALYSIS

- ☐ Diffusion of reactants toward the surface of the catalyst.
- ☐ Adsorption of reactant molecules on surface of the catalyst.
- ☐ Occurrence of chemical reaction on the catalyst surface and formation of an intermediate.
- ☐ Formation of products.
- ☐ Desorption of reaction products from the catalyst surface. Products leave catalyst surface.

The steps involved can be shown as:

Diffusion → Adsorption → intermediate formation  
→ Desorption → Product formation.

### • Catalytic poisoning or inhibitors :

- ☐ The phenomenon in which presence of a substance in small amounts even decreases the activity of catalyst, e.g. (i) CO acts as Poison for Fe in Haber process for  $\text{NH}_3$

(ii) As acts as poison for Pt contact process for  $\text{H}_2\text{SO}_4$

### • Poisoning is of two types :

#### • Temporary poisoning :

- ☐ The poisoners are held at active centers by weak forces.
- ☐ Catalyst surface is regenerated by scratching the surface.

#### • Permanent poisoning :

- ☐ The poisoners are held on active centers by free valences.

- ☐ Catalyst surface is regenerated only by chemical treatment.

### • Important features of solid catalysts

#### • Catalytic activity :

- ☐ Activity is the ability of catalyst to accelerate chemical reactions. It can be as high as  $10^{10}$  times in certain reactions.

- ☐ The metals which lie close to the middle of the d-block are most active catalysts.

- ☐ The d-block metals such as Fe, V and Cr show strong activity for the gases like  $\text{O}_2$ ,  $\text{C}_2\text{H}_2$ ,  $\text{C}_2\text{H}_4$ , CO,  $\text{H}_2$ ,  $\text{CO}_2$ ,  $\text{N}_2$  etc.

- ☐ Mn and Cu are unable to adsorb  $\text{N}_2$  and  $\text{CO}_2$ .

- ☐ The metals such as Mg and Li can adsorb only  $\text{O}_2$ .

#### • Promoters :

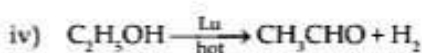
- ☐ The phenomenon in which presence of a substance in small amounts increases the activity of catalyst, e.g. Mo acts as promoter for Fe in Haber process, of  $\text{NH}_3$ .

$\text{Cr}_2\text{O}_3$  acts as promoter for  $\text{Fe}_2\text{O}_3$  in Bosch process of  $\text{H}_2$ .

- ☐  $\text{As}_2\text{O}_3$ ,  $\text{ThO}_2$  act as promoter for Ni, CO in synthesis of petrol.

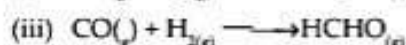
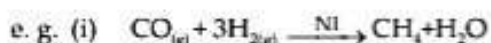
- ☐  $\text{Cr}_2\text{O}_3$  acts as promoter for ZnO in preparation of  $\text{CH}_3\text{OH}$ .

- ☐ The action of promoters is probably due to the formation of loose compound in increasing adsorption of the reactants.



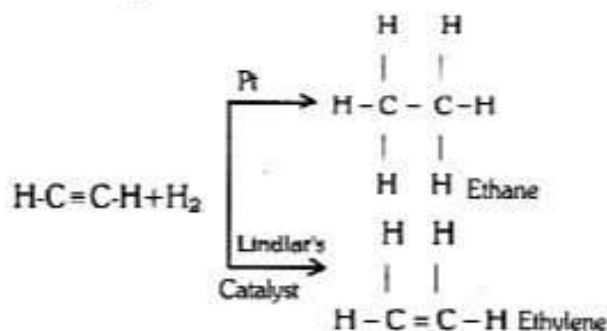
#### • Catalytic selectivity :

- The ability of a catalyst to direct a reaction to give a particular product is called selectivity,

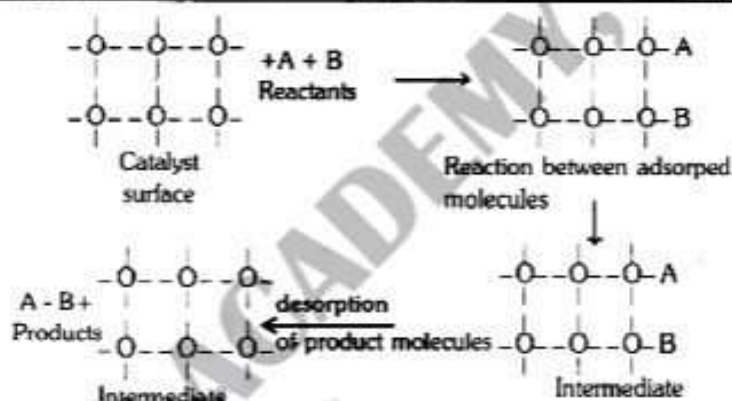


- Zeolite is a shape selective catalyst zeolites :  $\text{M}_x/\text{n} [(\text{AlO}_2)_x (\text{SiO}_2)_y] \text{M}_2\text{O} \cdot \text{M}$  may be  $\text{Na}^+$   $\text{K}^+$  or  $\text{Ca}^{2+}$

The reaction selectivity of zeolite depends upon the size of cavities, pores and distribution of pores in structure. Pore size in zeolite varies from 260 pm to 740 pm.



Sr.No.	Process	Product	Catalyst
1.	$2\text{SO}_2 + \text{O}_2 \rightarrow 2\text{SO}_3$	$\text{SO}_{3(g)}$	$\text{NO}_{(g)}$
2.	Oxidation of $\text{CO}_{(g)}$	$\text{CO}_{2(g)}$	$\text{NO}_{(g)}$
3.	Inversion of sucrose solution	Glucose and fructose	$\text{H}^+_{(aq)}$
4.	Hydrolysis of ester	acid and alcohol	$\text{H}^+_{(aq)}$



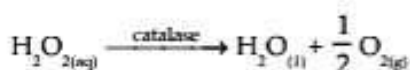
- Lindlar's catalyst (pd, partially inactivated by quinoline or heavy metal ion)

• **Enzyme catalysis :**

- Enzymes are complex, biological, nitrogenous, macromolecular derived from living organisms.

- Examples enzyme catalyzed reactions

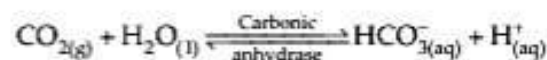
- (i) Enzyme catalysis is used as catalyst for the % decomposition of



- (ii)  $\text{Fe}^{2+}$  ion is oxidised to  $\text{Fe}^{3+}$  ion using . Ferroxiase enzyme as catalyst



- (iii) In human body, enzyme carbonic anhydrase catalyses the reaction of  $\text{CO}_2$  with water.



- iv) Conversion of Milk into curd Milk  $\xrightarrow{\text{Lactic bacilli}}$  Curd

• **Enzyme catalysis Mechanism :**

- Enzyme catalyzed reactions are highly specific. Step I : Binding enzyme with substrate



Enzyme Substrate      Enzyme-Substrate complex

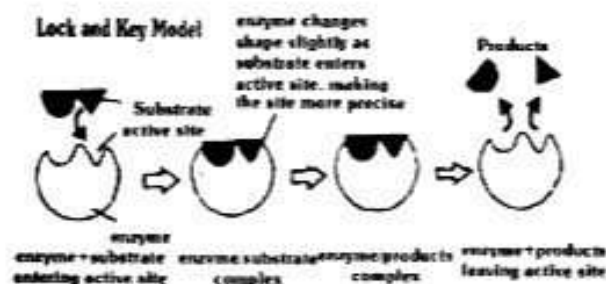
Step II: Dissociation of ES complex



Enzyme      enzyme      enzyme product

substrate      product

complex      association



Sr.No.	Enzyme	Source	Enzymatic reaction
1.	Invertase	yeast	sucrose $\rightarrow$ Glucose + fructose
2.	Urease	Soyabean	urea $\rightarrow$ $\text{CO}_2 + \text{NH}_3$
3.	Pepsin	Stomach	proteins $\rightarrow$ amino acid
4.	Amylase	Saliva	starch $\rightarrow$ Glucose
5.	Zymase	Yeast	Maltose $\rightarrow$ Glucose

## COLLOIDS

Thomson Graham (1861) studied the process of diffusion of dissolved substances through a parchment paper or on animal membrane and divided the substances into two classes : - 1) Crystalloid 2) Colloid

But this classification soon proved to be wrong since a crystalloid could behave as a colloid under different conditions and vice-versa for example: NaCl behaves as a crystalloid in aqueous medium and behaves as a colloid in benzene medium where as soap behaves as a typical colloid in water and behaves as a crystalloid in alcohol.

### Crystalloidal Particles :

○○○○○  
○○○○○  
○○○○○ Smaller Particles < 1 nm.

### Colloidal Particles :

○○○○○  
○○○○○

Particles Size 1 nm to 1000 nm

### Suspensions Particles :

○○○○○  
○○○○○

Particles having size bigger than 1000 nm.

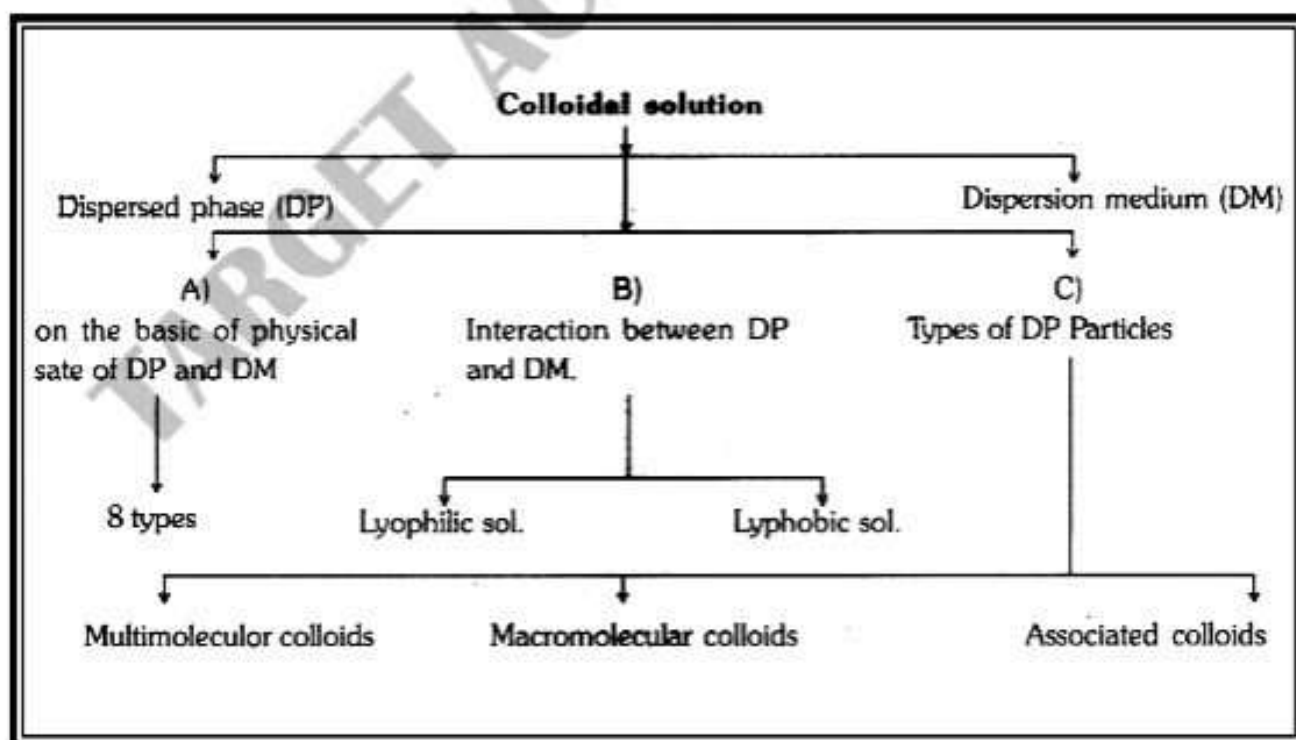
A colloidal system is made of two phases. The substance distributed as the colloidal particles is called dispersed phase or internal phase or the discontinuous phase. The continuous phase in which the colloidal particles are dispersed is called dispersion medium. For example for a colloidal solution of copper in water, copper particles constitute the dispersed phase and water the dispersion medium.

Depending on the dispersed phase or dispersion medium, colloidal solutions can be classified by 3 way-

❑ Comparison of true solutions, colloids and suspension :

Sr. No.	Property	True solution or Crystalloid	Colloid	Suspension
1.	Partical size	< 1 nm	1 nm to 1000 nm	> 1000 nm
2.	Visibility	Not visible with any of ite optical means.	May be visible with ultramicroscope.	Visible with naked eye.
3.	Seperation a) with filter paper b) with membranes (ultrafiltration)	Not possible Not possible	Not possible possible	possible possible
4.	Diffusion	Diffuses rapidly	Diffuse very slowly	Does not diffuse
5.	Settling	Does not settle	Does not settle due to gravity, but it may settle under	settle due to gravity.
6.	Nature	Homogeneous	Heterogeneous	Hetrogeneous
7.	Tyndall effect and Brownian moment	does not show	Shows	May or may not show

Types of colloidal solutions :





- Classification of colloidal systems Based on Dispersed phase and dispersion medium :

Internal phase or (Dispersed Phase)	External Phase or (dispersion medium)	Colloidal Name	Examples.
Solid	Solid	Solid sols	Alloys, ruby-glass, gems or precious stones, marbles optical and vision glasses.
	Liquid	sols	Muddy water, gold sol, protein, starch agar, gelatin in water smoke, Storm.
	Gases	Aerosols of solids	
Liquid	Solid	Gels	Cheese, Jams, Jellies, Curd, Plants, Fruits, Vegetables, butter.
	Liquid	Emulsions	Milk, blood, cosmetics Products e.g. Shampoo creams, emulsified oils polish and medicines.
	Gases	Aerosols of liquids	Fog, Clouds, mist.
Gases	Solid	Solid Foams	Pumice stone, styrene Foam, rubber, Porous Pot, rubber Pillows and mattresses.
	Liquid	Foam	Froths, Soap suds, air bubble
	Gases	Homogeneous system	-

Sr. No.	D.m.	Name of solution
i.	Water	Hydrosol or aquosol
ii.	Benzene	Benzosol
iii.	Alcohol	Alcosol
iv.	Air	Aerosol

- Classification of colloids :

Based on the nature of interaction between the dispersed phase and the dispersion medium,

- Lyophilic colloids :**

These are liquid loving colloids and are formed directly by mixing.

Substances like gelatin, starch etc.

These are more stable and cannot be easily coagulated.

- Lyophobic colloids :**

These are liquids hating colloids and are usually formed by metals, metal sulphide etc.

These are prepared by special method like chemical methods, Bredig's arc method, etc.

These are also called irreversible sols because once they are precipitated it is difficult to convert them back to colloidal solution.

- Based on type of particles of dispersed Phase

Multimolecular colloids	Macromolecular colloids	Associated colloids
A Large number of atoms/molecules /ions aggregate together to form colloids, e.g. gold sol, sulphur sol.	Macromolecules like protein, starch, enzyme, etc form colloidal solution, e.g. Starch, cellulose, protein etc.	(micelles) These colloids behave as a strong electrolyte at low concentration but behave as colloids at high concentration due to association of particles called micelles, e.g. soap & detergent

**Note :** Micelles are formed only at a particular temperature called Kraft temperature ( $T_k$ ) and concentration called critical micelle concentration (CMC), e.g. cleansing action of soap.

Differences between Lyophilic and Lyophobic sols are given in the table :

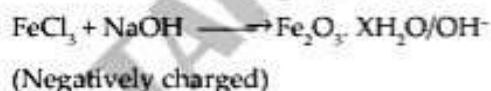
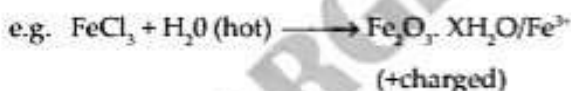
Sr. No.	Property	Lyophilic Solts	Lyophobic Sols
1.	Nature	DP has more affinity for DM, if DM is water then hydrophilic.	Less affinity, if DM is water, hydrophobic
2.	Preparation	As soon as DP comes in contact with DM, sol are formed.	Special method are required.
3.		More concentration of DP in sol.	less concentration of DP in sol.
4.	Stability	More stable	less stable
5.	Size of sol particles	small	large.
6.	Viscosity	More viscous than DM.	same as of DM.
7.	Surface tension	Much less than DM.	same as of DM.
8.	Reversibility	Reversible with temperature	Irreversible.
9.	Charge	The charge on sol particles depends upon pH of medium.	Independent of pH.
10.	Tyndal effect	less scattering	more scattering
11.	Solvation	Higher degree of solvation.	Lower degree of solvation.
12.	General example	Mostly of organic nature., e.g. Gelatin, starch, Gum, Albumin and cellulose solution.	Mostly of Inorganic nature. e.g. Transition metal salt like gold etc.

• **Cleansing action of soap :**

❑ The hydrophobic part (hydrocarbon) of soap, is attached to dirt particles while the hydrophilic part is projected towards water forming micelles.

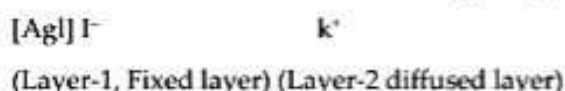
❑ The micelle along with dirt particle is pulled away towards water due to emulsification and washed away, cmc of soap  $10^{-4}$  to  $10^{-3}$  mol  $L^{-1}$ .

a) **Theory of preferential adsorption of Ions :** When two or more ions are present in the dispersion medium, the colloidal particles prefer to adsorb the ion common among them.



b) **Helmholtz electrical double layer :**

The charged colloidal particles layer after preferential adsorption, further attracts oppositely charged ions from dispersion medium forming a second layer called Helmholtz electrical double layer, e.g.



❑ The potential difference between the fixed layer and diffused layer is called electrokinetic potential or zeta potential.

• **Properties of colloids : General Properties :**

❑ Colloidal systems are heterogeneous and consist of two Phases disperse Phase and dispersion medium.

❑ The disperse phase particles pass slowly through parchment membrane

❑ The colloidal particles readily pass through most of the ordinary filter paper.

❑ The particles cannot be detected even with the help of powerful microscope.

❑ The colour of the sol depends on the size of colloidal particles.

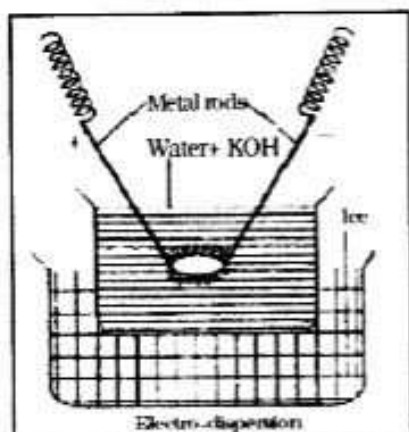
For example, the gold sol changes its colour gradually from red to blue as the particle size increases.

• **Preparation of colloids :**

• **Chemical method :** In these method chemical reactions are carried out and products formed associated leading to the formation of colloidal solution.



• **Bredig's arc method :** Colloidal solution of metals like Au, Ag, Pt etc. are prepared by this method. Metal electrodes are dipped in dispersion medium and high voltage is provided. Metal atoms are vaporised due to intense heat, which are then condensed to form colloidal solution.



**Fig. Bredig's arc method**

- **Peptisation** : Precipitates are converted back to colloidal solution by shaking it in dispersion medium with the help of small amount of electrolyte, e.g.

- $\text{AgI} \downarrow + \text{AgNO}_3 \rightarrow [\text{AgI}] \text{Ag}^+ : \text{NO}_3^-$
- $\text{AgI} \downarrow + \text{KI} \rightarrow [\text{AgI}] \text{I}^- : \text{K}^+$
- $\text{Fe}(\text{OH})_3 \downarrow + \text{FeCl}_3 \rightarrow [\text{Fe}(\text{OH})_3] \text{Fe}^{3+} : 3\text{Cl}^-$
- $\text{Fe}(\text{OH})_3 \downarrow + \text{NaOH} \rightarrow [\text{Fe}(\text{OH})_3] \text{OH}^- : \text{Na}^+$
- $\text{CdS} \downarrow + \text{H}_2\text{S} \rightarrow [\text{CdS}] \text{S}^{2-} : 2 \text{H}^+$

- **Note** : Gold number It is defined as the minimum weight of protective colloid in milligrams which must be added to 10 mL of a substance (red gold sol) so that no coagulation of the gold sol takes place when 1 mL of 10% NaCl solution is rapidly added to it.

- **Gold number of some hydrophilic colloids:**

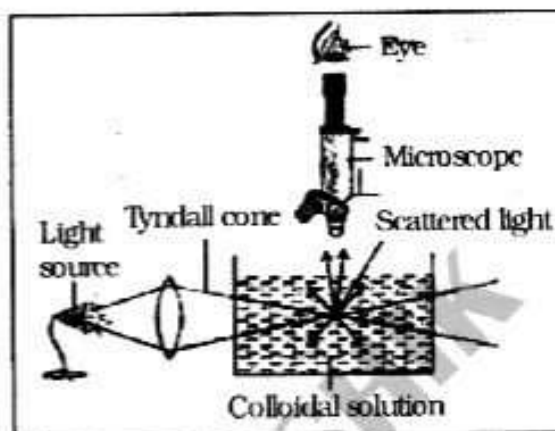
Lyophilic colloid	Gold Number
Gelatin	0.005 – 0.01
Egg albumen	0.08 – 0.1
Gum arabic	0.10 – 0.15
Potato-Starch	25
Hamoglobin	0.15 – 0.25
Sodium oleate	0.4 – 1.0

$$\text{Gold number} = 10 \times \frac{\text{Mass of Lyophilic sol (mg)}}{\text{volume of Lyophobic sol (mL)}}$$

$$\text{Protection capacity} \propto \frac{1}{(\text{Gold number})}$$

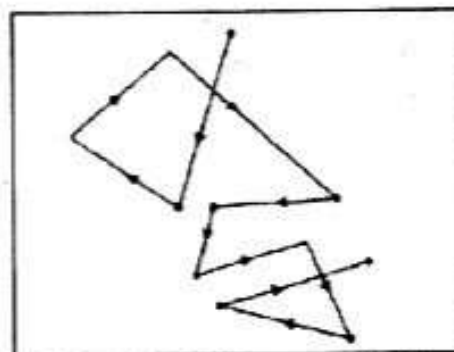
Gelatin and starch have the maximum and minimum protective power respectively.

- **Properties of colloidal solution :**
- **Tyndall effect** : Colloidal solutions show Tyndall effect due to scattering of light by colloidal particles in all directions in space.



**Fig. Tyndall effect**

- Tyndall effect is observed only under the following conditions.
  - 1) The diameter of the colloids should not be much smaller than the wavelength of light used.
  - 2) The refractive indices of the dispersed Phase and the dispersion medium should differ greatly in magnitude.
- **Colour** : The colour of colloidal solution depends on wavelength of light scattered by dispersed particles size and nature of colloidal particles and direction of observation.
- **Brownian movement** : Colloidal particles show a continuous zig-zag motion which is independent of nature of particles but small sized particles show faster movement.

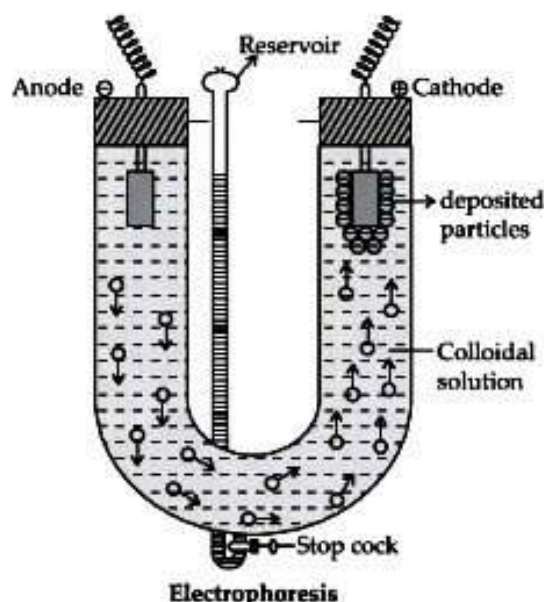


**Fig. Brownian movement**

- **Charge on Colloidal Particles** : Each Colloidal particles of a solution are either positively or negatively charged, the reason for this charge is best explained by preferential adsorption of ions from solution.



- **Positively charged sols** : Sols of haemoglobin, hydrated metallic oxides like  $\text{Al}_2\text{O}_3$ ,  $\text{XH}_2\text{O}$ ,  $\text{CrO}_3$ ,  $\text{XH}_2\text{O}$ ,  $\text{Fe}_2\text{O}_3$ ,  $\text{XH}_2\text{O}$  etc. basic dye like methylene blue, oxides like  $\text{TiO}_2$  etc.
- **Negatively charged sols** : Sols of starch gum, gelatin, clay, charcoal, acid dyes like eosin, congo red sols etc Metals like Cu, Ag, Au etc. metallic sulphides like  $\text{As}_2\text{S}_3$ ,  $\text{Sb}_2\text{S}_3$ ,  $\text{Cds}$  etc.
- **Coagulation (Precipitation) of colloidal Particles** :



- **Coagulation of Lyophobic Sols** :
- ❑ These are coagulated by **electrophoresis**, mixing two oppositely charged sols, boiling or persistent dialysis etc.
- ❑ A positively charged ion causes the precipitation of a negatively charged sol and vice-versa.

**Electro-osmosis** : The medium will move in opposite direction to the dispersed phase under the influence of applied electric potential. The movement of dispersion medium under the influence of applied potential is known as 'Electro-osmosis'. (In presence of plasma membrane)

- **Hardy-Schulze rule** : According to this rule, higher the charge on the flocculating ion added for coagulation higher is the coagulation of the ion.
- ❑ For the coagulation of positively charged sol, the coagulation power of different negatively charged ions is



- ❑ For the coagulation of negatively charged sol, the coagulation power of different positively charged ion is  $\text{Al}^{3+} > \text{Ba}^{2+} > \text{Na}^+$

- **Coagulation of Lyophilic sols** :

- ❑ These sols having high solvation energy and charge are more stable than lyophobic sols.

These are coagulated by adding an electrolyte and a suitable solvent like Alcohol, Acetone etc.

- **Coagulation or Flocculation value** :

- ❑ The minimum concentration of an electrolyte which is required to cause the coagulation or flocculation of a sol is known as flocculation value.

Sol	Electrolyte	Flocculation value (mM)
	NaCl	51.0
	KCl	49.5
	$\text{CaCl}_2$	0.65
$\text{As}_2\text{S}_3$	$\text{MgCl}_2$	0.72
(-vely Charged)	$\text{MgSO}_4$	0.81
	$\text{Al}(\text{NO}_3)_3$	0.095
	$\text{Al}_2(\text{SO}_4)_3$	0.096
	$\text{AlCl}_3$	0.093

Sol	Electrolyte	Flocculation value (mM)
	$\text{BaCl}_2$	9.3
$\text{Fe}(\text{OH})_3$	KCl	9.5
(+vely Charged)	$\text{K}_2\text{SO}_4$	0.20
	$\text{MgSO}_4$	0.22

- **Emulsions (Liquid, Liquid colloid system)**:

When two immiscible or partially miscible liquids are mixed and shaken together, one liquid is dispersed over another forming a colloidal system called emulsions.

- **Types of Emulsion** :

- Oil dispersed in water (O/W) type** : In this type, water acts as a dispersion medium, e.g. Milk
- Water dispersed in oil (W/O) type** : In this type, oil acts as a dispersion medium, e.g. butter, cream etc.

- ❑ **Emulsifying agent**: Oil in water type emulsion is unstable due to their Lyophobic nature and hence required an emulsifying agent for their stabilisation. e.g.- Proteins, gums, long chain alcohols, heavy metal salts, fatty acids, soaps etc.

- **Purification of colloidal system** :

- Dialysis** : It is the process of separating particles of colloidal dimensions by means of diffusion through a suitable membrane.
- Electrodialysis** : In this process, electric field is applied during dialysis.
- Filterability** : Colloidal particles pass through an ordinary filter paper but do not pass through parchment and other fine membrane.



- **Applications of colloids :**

Colloids have many important applications such as.

- ☐ Electrical precipitation of pollutants present in smoke.
  - ☐ Purification of drinking water by co-agulating suspended particles.
  - ☐ Colloids medicines are more effective due to the large surface area of colloids in dispersion medium. Cleansing action of soaps and detergents due to micelle formation.
  - ☐ Photographic film is an emulsion of light sensitive Ag Br in gelatin.
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