Revision Notes

Class – 12 Chemistry

Chapter 5 – Surface Chemistry

1. GENERAL INTRODUCTION

Surface chemistry is the discipline of chemistry that studies events that occur at the surface or interface, that is, at the boundary separating two bulk phases.

Pure chemicals or solutions can make up the two bulk phases.

A hyphen or a slash between the two bulk phases involved, such as solid-liquid or solid/liquid, is used to signify the interface. Because gases are entirely miscible, there is no interface between them. Dissolution, crystallisation, corrosion, heterogeneous catalysis, electrode processes, and other important phenomena occur at the interface.

2. ADSORPTION

2.1 Definition

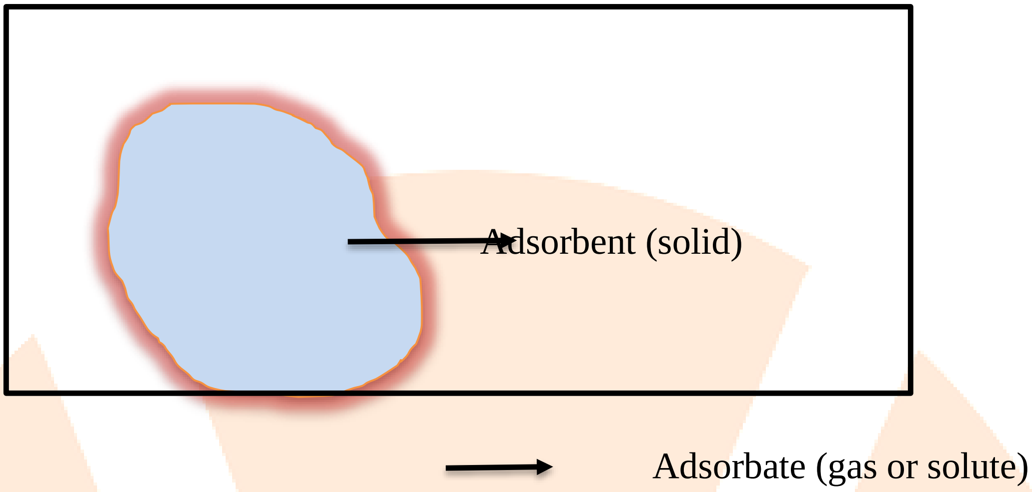
Adsorption is the process of attracting and holding a substance's molecules on the surface of a liquid or solid, resulting in a larger concentration of molecules on the surface. Occlusion is the process of gases adsorbing on a metal surface.

2.2 Adsorbate and Adsorbent

Adsorbate refers to a material that is adsorbed on any surface. For example, if a gas is adsorbed on the surface of a solid, the gas is referred to as the adsorbate.

Adsorbent is the substance on the surface of which adsorption occurs.

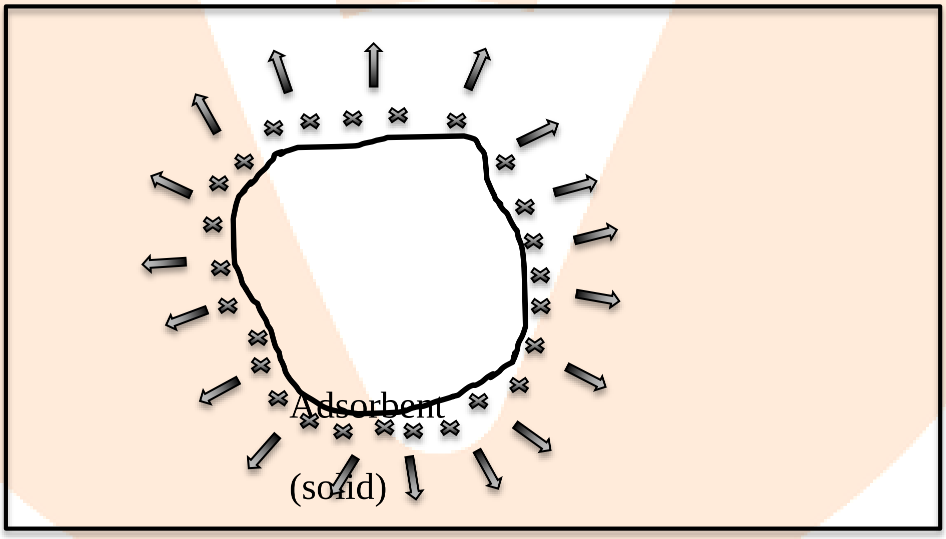
The adsorbent might be either solid or liquid. Metal powders, powdered charcoal, animal charcoal, silica powder, and other adsorbents are often employed.



Adsorbent and Adsorbate

2.3 Desorption

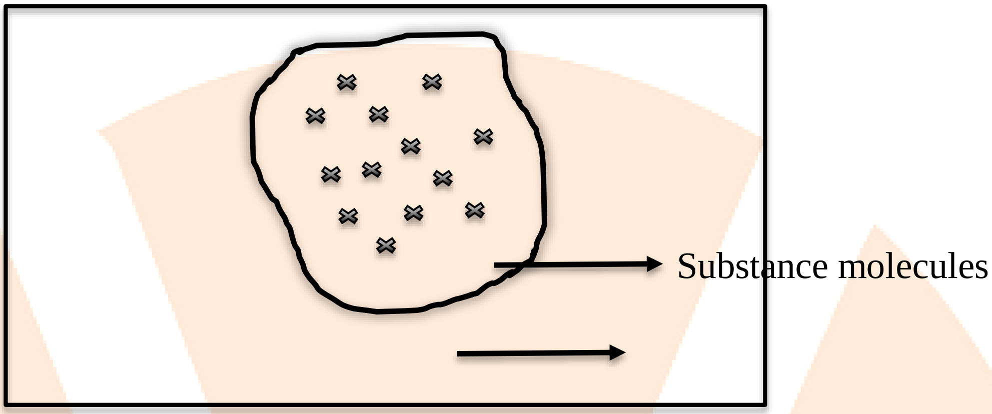
Desorption is the process of removing an adsorbed material from a surface. This can be accomplished by increasing or decreasing the system's pressure.



Removal of Adsorbate

2.4 Absorption

The phenomenon of absorption occurs when the molecules of a substance are consistently distributed throughout the body of a solid or liquid.

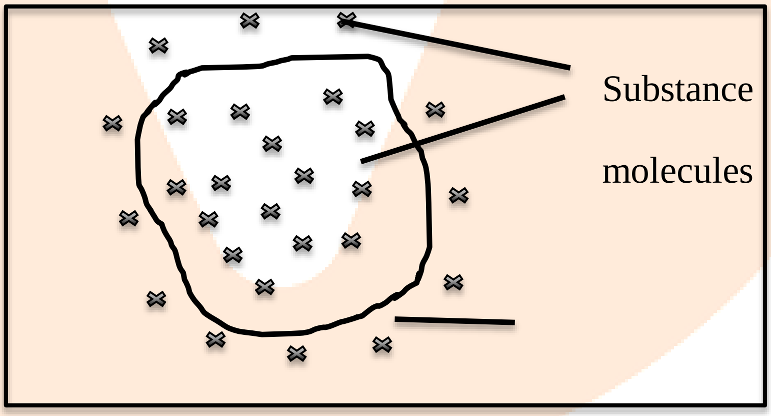


Body of solid (liquid)

2.5 Sorption

Sorption is a phenomenon in which adsorption and absorption occur at the same time. Cotton fibre absorbs dyes just as well as other fibres.

Adsorption is a fast, instantaneous process, whereas absorption is a lengthy process.



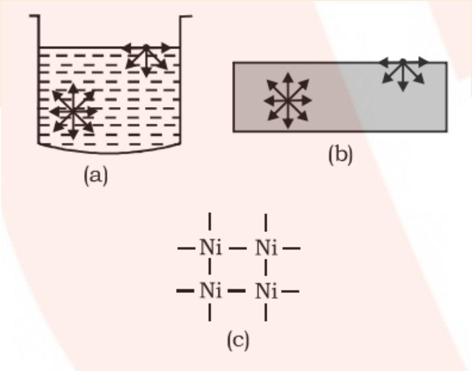
Body of Solid

2.6 Difference between Adsorption and Absorption

The following are the main points of distinction between adsorption and absorption.

Adsorption	Absorption
1. It's a purely physical phenomenon. 2. The substance is only kept on the surface and does not penetrate the solid or liquid's bulk or interior. 3. At the free phase, the concentration of adsorbed molecules is always higher. 4. It starts off fast and then slows down to reach equilibrium. **Examples** (i) $CaCl_2$ adsorbes water vapours in the first place. (ii) Charcoal adsorbes ammonia. (iii) Activated or animal charcoal is used to decolorize sugar solution. (iv) Blotting paper absorbs the ink.	1. It is concerned with the absorbent's entire mass. 2. It denotes that a component is evenly distributed throughout the solid or liquid's body. 3. It has a low concentration. 4. It happens at a constant rate. **Examples** (i) Anhydrous silica gel absorbs water vapours; (ii) NH_3 is absorbed in water and forms NH_4OH

2.7 Mechanism of adsorption



In the case of (a) liquid (b) solid (c) metal with unbound valencies, molecules at the surface experience a net inward force of attraction.

Adsorption occurs only when an adsorbent's surface atoms are active. Unbalanced forces of various types, such as Vander Waal's forces and chemical bond forces, exist in these atoms (free valencies).

Liquids and solids can attract and keep the molecules of a gas or dissolved material on their surface due to residual or imbalanced inward forces of attraction or free valancies at the surface.

2.8 Characteristics of adsorption

2.8.1 The presence of a larger concentration of any given component at the surface of a liquid or solid phase is referred to as adsorption.

2.8.2 Adsorption is always followed by the release of heat, making it an exothermic reaction. To put it another way, the adsorption H is always negative.

2.8.3 When a gas is adsorbed, the molecules' freedom of movement is restricted. As a result, the entropy of the gas after adsorption decreases, i.e. S is negative.

Adsorption is consequently accompanied with a decrease in the system's enthalpy as well as entropy, and hence G decreases.

2.8.5 The thermodynamic criteria for a process to be spontaneous is that G must be negative, i.e. there must be a drop in free energy. G can be negative if H has a sufficiently high negative value and $T\Delta S$ has a positive value, according to Gibb's Helmholtz equation [$\Delta G = \Delta H - T\Delta S$]

2.9 Classification of adsorption

Adsorption is divided into two groups, as shown below.

2.9.1 Physical adsorption: Physical adsorption occurs when the forces of attraction between the adsorbate and the adsorbent are Vander Waal's forces. Physisorption, or Vander Waal's adsorption, is another name for this type of adsorption. By increasing or reducing the pressure, it can be readily reversed.

2.9.2 Chemical adsorption: Chemical adsorption occurs when the forces of attraction between adsorbate particles and the adsorbent are almost equal in strength to chemical bonds. Adsorption of this sort is also known as chemisorption Langmuir adsorption. This form of adsorption is difficult to reverse.

COMPARISON BETWEEN PHYSISORPTION AND CHEMISORPTION

Physisorption (Vander Waal's adsorption)	**Chemisorption (Langmuir adsorption)**
1. Adsorption heat is normally in the 20-40 kJ/mol range.	1. Adsorption heat in the range of 50-400 kJ mol.
2. Vander Waal's forces are forces of attraction.	2. Chemical bond forces are forces of attraction.
3.It's also reversible.	3. It is unavoidable.
4. It frequently occurs at low temperatures and lessens as the temperature rises.	4. It takes place in a hot environment.
5. It has something to do with the liquification of gas.	5. It has nothing to do with each other
6. Multimolecular layers are formed.	6. Monomolecular layers are formed.
7. It does not necessitate the use of any activation energy.	7. It necessitates a large amount of activation energy.
8. High pressure is advantageous. Desorption occurs when pressure drops.	8. High pressure is advantageous. Desorption is not caused by a decrease in pressure.
9. It lacks specificity.	9. It's quite particular.

Note: Physical adsorption reduces after a period due to the creation of multilayers.

Both chemisorption and physisorption are exothermic processes.

2.10 Aspects that influence the amount of adsorption on a solid surface

The following are some of the elements that influence gas adsorption on solid surfaces.

(i) In comparison to hard non-porous materials, porous and finely powdered solids, such as charcoal and fullers earth, absorb more. Powdered charcoal is utilised in coal mine gas masks because of this feature.

(ii) When compared to gases with lower critical temperatures, gases with higher critical temperatures are adsorbed to a greater extent.

2.10.1 Nature of the adsorbate (gas) and adsorbent (solid)

Volumes of gases adsorbed by 1g of charcoal at 288 k at N.T.P.

Gas	H_2	N_2	CO	CH_4	CO_2	HCl	NH_3	SO_2
Volume adsorbed (mL)	4.7	8.0	9.3	16.2	48	72	181	380
Critical temp (K)	33	126	134	190	304	324	406	430

Critical temperature increases →

Ease of liquefaction increases →

Adsorption increases →

2.10.2 Surface area of the solid adsorbent

The extent of adsorption is directly proportional to the adsorbent's surface area; that is, the larger the adsorbent's surface area, the greater the extent of adsorption.

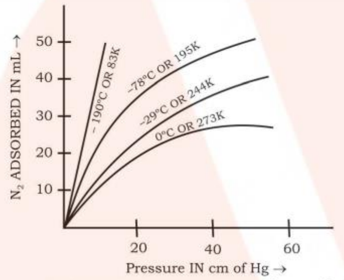
2.10.3 Effect of pressure on the adsorbate gas

The extent of adsorption increases as the pressure of the adsorbate gas rises.

The extent of adsorption increases significantly with pressure at low temperatures.

The degree of adsorption is found to be closely related to the pressure at low pressure.

Adsorption tends to reach a limiting value at high pressure (near to the gas's saturated vapour pressure).



Variation of adsorption of N_2 on charcoal with pressure at different constant temperatures

2.10.4 Effect of temperature

Adsorption is accompanied by the evolution of heat, the amplitude of adsorption should decrease as temperature rises, according to the Le-principle. Chatelier's

The heat of adsorption is the quantity of heat produced when one mole of gas is adsorbed on the adsorbent.

2.11 Adsorption Isotherms

Adsorption isotherms are mathematical equations that describe the relationship between the pressure (p) of the gaseous adsorbate and the extent of adsorption at any given temperature.

As a result, if x g of adsorbate is adsorbed on m g of adsorbent,

Extent of adsorption $= \frac{x}{m}$

2.11.1 Freundlich adsorption isotherm

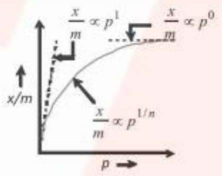
Adsorptions where the adsorbate forms a monomolecular layer on the surface of the adsorbent obey the isotherm.

$$\boxed{\frac{x}{m} = kP^{\frac{1}{n}}} \qquad \text{or} \qquad \boxed{\log\frac{x}{m} = \log k + \frac{1}{n}\log P}$$

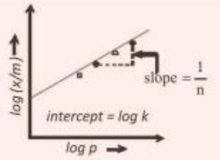
where x denotes the quantity of gas adsorbed by the adsorbent per gm (unit mass), k and n are constant at a given temperature and for a certain adsorbent and adsorbate (gas), and n is always greater than one, showing that the amount of gas adsorbed does not grow as quickly as the pressure.

The degree of adsorption varies linearly with pressure at low pressure.

$$\frac{x}{m}\alpha P^{1}$$



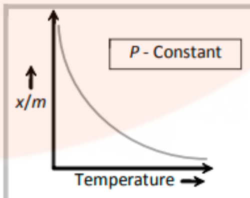
Freundlich adsorption isotherm : plot of x/m against p



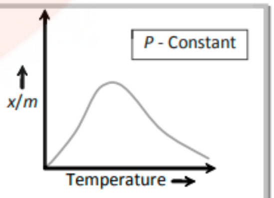
Plot of log x/m against log p for the adsorption of a gas on a solid

2.12 Adsorption Isobar

The adsorption isobar is a graph formed between the amount of gas adsorbed per gramme of adsorbent (x/m) and temperature 't' at a fixed equilibrium pressure of adsorbate gas.



Physical adsorption



Chemical adsorption

The physical adsorption isobar displays a drop in x/m as temperature rises, whereas the chemisorption isobar exhibits an initial increase and subsequently the expected fall as temperature rises. The initial increase is due to the heat provided acting as the activation energy required in chemisorption (like chemical reactions).

2.13 Adsorption from Solutions

Adsorbing solutes from solutions is another capability of solid surfaces. Here are a few examples:

When litmus solution is agitated with charcoal, the dye in the litmus solution is adsorbed by the charcoal, and the colour of the litmus solution fades.

When Mg(OH)2 is precipitated in the presence of magneson reagent, it is colourless (a blue coloured dye). Because the dye is adsorbed on the solid precipitate, it turns blue.

The Freundlich isotherm can be used to indicate the extent of adsorption from solution, which is dependent on the concentration of the solute in the solution $\frac{x}{m}=kc^{\frac{1}{n}}$. For adsorption from solution, the Freundlich adsorption isotherm is, where x is the mass of the solute adsorbed, m is the mass of the solid adsorbent, c is the equilibrium concentration of the solute in the solution, and n is a constant with a value greater than one. (The value of k varies on the nature of the solid, its particle size, temperature, and the type of the solute and solvent, among other things.) The curve of x/m vs c resembles that of the Freundlich adsorption isotherm. The preceding equations can be expressed as follows, where c is the solute's equilibrium concentration in the solution. $\log\frac{x}{m}=\log k+\frac{1}{n}\log\ c$

2.14 Factors affecting adsorption from solution

The adsorption of solid adsorbents from solutions is found to be dependent on the following factors:

2.14.1 Nature of the adsorbate and adsorbent.

2.14.2 As the temperature rises, the adsorption decreases.

2.14.3 Adsorption is proportional to the adsorbent's surface area.

2.14.4 Solute concentration in the solution

2.15 Positive and Negative Adsorption

When solids adsorb solutes from solutions, the solute is predominantly adsorbed on the surface of the solid adsorbent, resulting in a higher concentration of solute on the surface of the adsorbent than in the bulk. However, the solvent from the solution may be absorbed by the adsorbent in some situations, causing the solution's concentration to rise above its initial concentration.

Positive adsorption occurs when the concentration of the adsorbate is higher on the surface of the adsorbent than in the bulk. Negative adsorption occurs when the concentration of the adsorbate in the bulk increases after adsorption.

Blood solution + Conc. KCl solution $\rightarrow$ Positive adsorption

Blood solution + dilute KCl solution $\rightarrow$ Negative adsorption

2.16 Applications of Adsorption

The adsorption phenomenon has a wide range of uses. The following are some of the most important applications.

2.16.1 Production of high vacuum

A bulk of charcoal that has been cooled in liquid air is attached to a vessel that has already been vacuumed as much as feasible. The remaining air is absorbed by the charcoal, resulting in an extremely high vacuum.

2.16.2 In the case of gas masks: It's an adsorbent device made of activated charcoal or a combination of adsorbents. In coal mines, this system is used to adsorb harmful gases (e.g. $\mathrm{Cl_2}$, CO, sulphur oxide, etc.) and so purify the air for breathing.

2.16.3 Desiccation or dehumidification: Certain substances, such as silica and alumina (Al2 O3), have a significant tendency to absorb water. Water vapours or moisture in the air can be reduced or removed using these compounds.

In electrical equipment, silica gel is also utilised for dehumidification.

2.16.4 Color removal from solutions: Animal charcoal adsorbs coloured impurities to remove colour from solutions. It's also employed in the production of cane sugar as a decolorizer.

Heterogeneous catalysis: Heterogeneous catalytic processes are characterised by the adsorption of gaseous reactants on a solid catalyst.

The hydrogenation of oils is done with finely powdered nickel.

In the contact method to produce sulphuric acid, finely divided vanadium pentaoxide (V2 O5) is utilised.

Pt and Pd are utilised as catalysts in a variety of industrial processes.

Ammonia production utilising iron as a catalyst.

2.16.6 Separation of inert gases: A mixture of inert gases can be separated by adsorption on coconut charcoal at different low temperatures due to the difference in degree of adsorption of gases by charcoal.

2.16.7 Hard water softening: The hard water is forced to travel through a zeolite-filled column (sodium aluminium silicate)

2.16.8 Water de-ionisation: Water can be de-ionised for softening by eliminating all dissolved salts using cation and anion-exchanger resin.

2.16.9 In the treatment of diseases, a variety of medications are adsorbed on germs, killing them, or on tissues, heating them.

2.16.10 Cleaning substances: Soap and detergents adsorb on the contact, lowering the surface tension between the filth and the cloth, allowing the dirt to be removed.

2.16.11 Froth flotation process: This method concentrates a low-grade sulphide ore by separating it from silica and other earthy materials.

The finely split ore is mixed with pine oil and a foaming ingredient in water.

The mixture is suffused with air bubbles.

The resulting foam rises to the surface, where mineral particles that have been wetted with oil are absorbed, while earthy debris sinks to the bottom.

2.16.12 Adsorption indicators include: Certain precipitates, such as silver halide, can adsorb dyes such as eosin and fluorescein. The indicator is adsorbed at the end point in precipitation titrations (for example, $AgNO_3$ Versus $NaCl$), resulting in a distinct colour on the precipitate.

2.16.13 Chromatographic analysis: The phenomena of adsorption has given rise to chromatographic analysis, a good technique of analysis. The method has a wide range of applications in both analytical and industrial settings.

Differential adsorption of distinct elements of a mixture is the basis of the chromatographic process.

2.16.14 When dyeing, many dyes adsorb to the textile, either directly or by the application of mordants.

Catalyst is a material that may speed up and slow down a chemical reaction without being consumed at the conclusion of the process, a phenomenon known as catalysis.

3.1 Types of catalysis

The following types of catalytic reactions can be generally classified:

3.1.1 When the reactants and catalyst are in the same phase, it is called homogeneous catalysis (i.e. solid, liquid or gas). It is claimed that the catalysis is homogenous. Some examples of homogeneous catalysis are listed below.

In the lead chamber method, sulphur dioxide is oxidised to sulphur trioxide with oxygen in the presence of nitrogen oxides as a catalyst.

$$2SO_2(g)+(g)_2 \xrightarrow{NO(g)} 2SO_3(g)$$

The reactants, products, and catalyst are all in the same phase, or gaseous state.

H+ ions supplied by hydrochloric acid catalyse the hydrolysis of methyl acetate.

$$CH_3COOCH_3(\ell) + H_2O(\ell) \xrightarrow{HCl(g)} CH3COOH(\ell)\ CH_3OH(\ell)$$

Sugar hydrolysis is catalysed by H+ ions produced by sulphuric acid.

$$C_{12}H_{22}O_{11}(\ell) + H_2O(\ell) \xrightarrow{H_2SO_4(g)} C_6H_{12}O_6(\ell) + C_6H_{12}O_6(\ell)$$

3.1.2 Heterogeneous catalysis refers to a catalytic process in which the reactants and catalyst are in different phases at the same time. The following are some examples of heterogeneous catalysis.

In the contact process for the synthesis of sulphuric acid, oxidation of sulphur dioxide into sulphur trioxide in the presence of platinum metal or vanadium pentaoxide as catalyst. The reactants are in gaseous form, whilst the catalyst is solid.

$$2SO_2(g) + (g)_2 \xrightarrow{Pt(s)} 2SO_3(g)$$

In Haber's method, nitrogen and hydrogen combine to generate ammonia in the presence of finely split iron.

$$N_2(g) + 3H_2(g) \xrightarrow{Fe(s)} 2NH_3(g)$$

In Ostwald's procedure, ammonia is converted to nitric oxide in the presence of platinum gauze as a catalyst.

$$4NH_3(g) + 5O_2(g) \xrightarrow{Pt(s)} 4NO(g) + 6H_2O(g)$$

Vegetable oils are hydrogenated in the presence of finely divided nickel as a catalyst.

$$\text{Vegetable oils}(l) + H_2(g) \xrightarrow{Ni(s)} \text{Vegetable Ghee}(g)$$

3.1.3 Positive catalysis: When a foreign material accelerates the pace of a reaction, it is called a positive catalyst and the phenomenon is known as positive catalysis. Below are some examples of positive catalysis.

In the presence of colloidal platinum, $2H_2$ decomposes.

$$2H_2\ O_2(\ell) \xrightarrow{Pt} 2H_2O_2(\ell) + O_2(g)$$

3.1.4 Negative catalysis refers to substances that, when added to a reaction mixture, slow down rather than speed up the reaction rate. Negative catalysts or inhibitors are used in this process, which is known as negative catalysis. The following are some examples.

If some alcohol is added to chloroform, the oxidation by air is slowed.

$$2CHCl_2(\ell) + O_2(g) \xrightarrow{Alcohol(\ell)} 2COCl_2(g) + 2HCl(g)$$

3.1.5 Auto-catalysis: One of the products acts as a catalyst in some processes. The reaction is slow in the beginning, but after the products are formed, the rate of reaction accelerates. Autocatalysis is the term for this type of event. The following are some examples:

As the reaction develops, the rate of oxidation of oxalic acid by acidified potassium permanganate increases. The existence of $2Mn$ ions, which are generated during the process, causes this acceleration. As a result, two Mn ions serve as an auto-catalyst.

$$5H_2C_2O_4 + 2KMnO_4 + 3H_2SO_4 \rightarrow 2MnSO_4 + K_2SO_4 + 10CO_2 + 8H_2O$$

When nitric acid is poured on copper, the reaction is slow at first, but it quickly speeds up due to the creation of nitrous acid, which works as an auto-catalyst during the process.

Acetic acid and ethyl alcohol are generated during the hydrolysis of ethyl acetate. The reaction is slow at first, but it picks more speed as time goes on. This is because acetic acid is formed, which acts as an auto-catalyst in the reaction.

3.1.6 Catalysis that is induced: Induced catalysis occurs when one reaction influences the pace of another reaction in a way that does not happen under normal circumstances.

The following are some examples:

The reduction of mercuric chloride ($HgCl_2$) by oxalic acid is sluggish, but potassium permanganate can be reduced quickly. When oxalic acid is added to a mixture of potassium permanganate and $HgCl_2$, both these elements are reduced at the same time. As a result of the reduction of potassium permanganate, mercuric chloride is reduced.

(3.1.7): Acid-base catalysis H+ or OH– ions, according to Arrhenius and Ostwald, operate as catalysts. Hydrolysis of an ester, for example.

$$CH_3COOC_2H_5(\ell) + H_2O(\ell) \xrightarrow{H^+ or OH^-} CH3COOH(\ell)\ C_2H_5OH(\ell)$$

Sugar cane inversion,

$$C_{12}H_{22}O_{11}(\ell) + H_2 \xrightarrow{H^+} C_6H_{12}O_6(\ell) + C_6H_{12}O_6(\ell)$$

Sugar Fructose Glucose

Acetone is converted to diacetone alcohol.

$$CH_3COCH_3(\ell) + CH_3COCH_3(\ell) \xrightarrow{OH^-} CH_3COCH_3C(CH_3)_2OH(\ell)$$

Nitramide decomposition,

$$NH_2NO_2(l) \xrightarrow{OH^-} N_2O\ (g) + H_2O\ (l)$$

3.2 Characteristics of catalysis

The following are the properties that most catalytic reactions have in common.

3.2.1 At the end of the reaction, the mass and chemical composition of a catalyst remain unaltered.

3.2.2 The catalyst cannot start the reaction: The catalyst's role is to change the rate of the reaction rather than to initiate it.

3.2.3 The catalyst is usually very specific: A catalyst is a material that speeds up the rate of a process.

Different catalysts for the same reactant may produce different products if they fail to catalyse the other reaction.

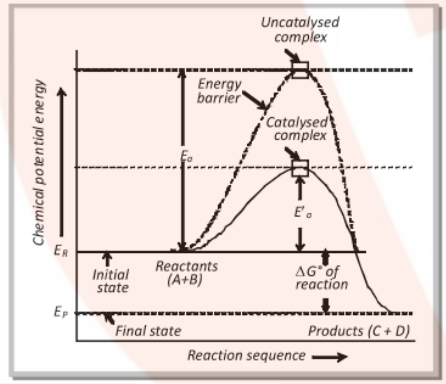
3.2.4 The catalyst has no effect on the equilibrium constant: In a reversible process, the catalyst catalyses both forward and backward reactions to the same extent, therefore it has no effect on the equilibrium constant.

3.2.5 Catalytic promoters: Promoters or activators are substances that are not catalysts themselves but boost the efficacy of catalysts when mixed in small amounts with them.

3.2.6 Catalytic poisons: Catalytic poisons are substances that, simply by being present, disrupt the catalyst's activity.

3.2.7 Changes in temperature affect the rate of catalytic reactions in the same way that they occur in the absence of a catalyst: The catalytic power of a catalyst increases as the temperature rises, but after a particular temperature, its power begins to decline. As a result, a catalyst has a maximal catalytic activity at a specific temperature. This is referred to as the optimal temperature.

The activation energy is reduced by using a positive catalyst.



3.3 Theories of Catalysis

3.3.1 Homogeneous Catalysis Collision Theory: A reaction happens because of effective collisions between the reacting molecules, according to the collision theory. The molecules must have a minimum level of energy known as activation energy (Ea) to collide effectively. Following the collision, the molecules form an activated complex, which then dissociates to reveal the product molecules. The catalyst creates a novel pathway that requires less activation energy. Hence,

$$\boxed{Ea} \Rightarrow \frac{Ea}{RT} \Rightarrow -\frac{Ea}{RT} \Rightarrow \boxed{e^{-Ea/RT}} \Rightarrow \boxed{k} \Rightarrow \boxed{\text{Reaction speeds up}}$$

3.3.2 Heterogeneous Catalysis Adsorption Theory:

Adsorption of reactants on the surface of the catalyst is common in heterogeneous catalytic processes.

The diffusion theory of catalysis can be used to describe the mechanism of such surface reactions. For gaseous processes on a solid surface, this theory proposes the following sequence.

Diffusion of the reactants to the surface is the first step.

Adsorption of the reactant molecules onto the surface is the second step.

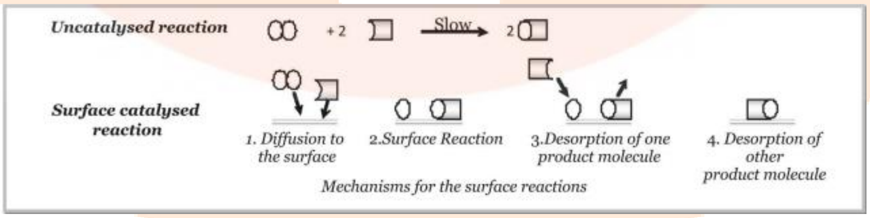
(iii) The actual chemical reaction on the surface

Step: (iv) Product desorption from the surface.

Step: (v) Product diffusion away from the surface.

Generally speaking,

Step (iii) determines the rate of reaction in general. Steps (ii) and (iv) may, however, be rate determining.



Mechanisms for the surface reactions

3.3.3 Modern adsorption theory's advantages: The following can be explained using this theory:

Because the catalyst is regenerated repeatedly, a small amount of the catalyst is sufficient.

The catalyst participates in the process but is created at the end of it unchanged in mass and chemical composition.

If catalytic poisons are present, they are preferentially adsorbed on the catalyst surface, preventing the reactant molecules from adsorbing. As a result, the catalyst's action is slowed.

However, this idea falls short of explaining how catalytic promoter’s work.

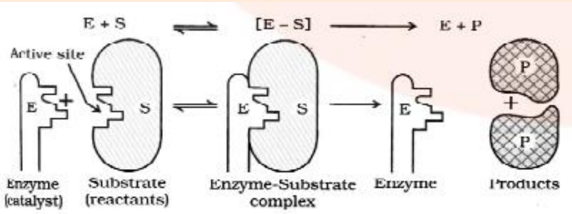
3.4 Enzyme catalysis

Low forms of plants and organisms secrete enzymes, which are complex nitrogenous compounds. Protein molecules with a larger molecular mass are known as enzymes. (between 15,000 and 1,000,000 g/mol) Enzymes are particularly good catalysts because they produce colloidal solutions in water. They catalyse a wide range of reactions, particularly those related to natural processes. To keep the life process going, animals and plants go through a series of reactions. Enzymes are responsible for catalysing these processes. As a result, enzymes are referred to as biochemical catalysts, and the phenomena is referred to as biochemical catalysis. Example,

Nitrogenase is an enzyme that catalyses the conversion of atmospheric N_2 to NH_3 and is found in bacteria on the root nodules of leguminous plants like peas and beans. The enzyme carbonic anhydrase catalyses the reaction of CO_2 with H_2O in the human body.

$$CO_2(aq) + H_2O(\ell) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

The forward reaction occurs when CO_2 is taken up by the blood in the tissues, and the reverse reaction occurs when CO_2 is released by the blood in the lungs.



$E \quad + \quad S \quad \rightleftharpoons \quad ES$ (Fast and Reversible)

Enzyme Substrate Enzyme Substrate complex

Step 2: The enzyme-substrate complex is dissociated to yield the products.

$E \rightarrow [EP] \rightarrow E + P$ (Slow and Rate determining)

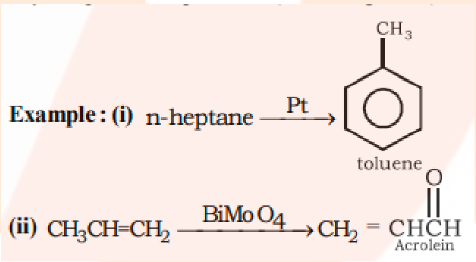
Enzyme Substrate complex	Enzyme-Product association	Enzyme (Regenerated)	Product

The rate of product production is determined by the concentration of ES.

3.5 Activity and selectivity

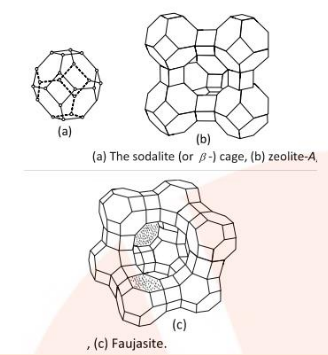
3.5.1 Activity: Activity refers to a catalyst's ability to speed up chemical reactions. In some reactions, the degree of acceleration might be as high as 10^{10} times. For example, in the presence of platinum as a catalyst, the reaction between H_2 and O_2 to create $2OH$ occurs with explosive violence. H_2 and O_2 can be held indefinitely without undergoing any reactions in the absence of a catalyst.

3.5.2 Selectivity: Catalysts' ability to steer reactions to produce certain products (excluding other).



3.6 Zeolites (shape selective catalysis)

Zeolites are alumino–silicates with the generic formula $Mn,[AlO_2]x.(SiO_2)y.mH_2O$, where M is a simple cation such as Na^+, K^+ or Ca^{2+} n is the charge on the simple cation, and m is the number of crystallisation water molecules. They have a cage that looks like a honeycomb. The shape and size of the reactant and product molecules influence the processes catalysed by zeolites. Therefore these reactions are referred to as shape selective catalysis.



(a) The sodalite (or β-) cage, (b) zeolite-A,

, (c) Faujasite.

In the petrochemical industry, zeolites are frequently utilised as catalysts for hydrocarbon cracking and isomerization. ZSM–5*** (Zeolite Sieve of Molecular Porosity 5) is a popular zeolite catalyst in the petroleum sector. It transforms alcohols straight into gasoline (petrol) by dehydrating them first, resulting in a mixture of hydrocarbons.

$$\text{Alcohols} \xrightarrow[\text{Dehydration}]{\text{ZSM-5}} \text{Hydrocarbons}$$

In the softening of hard water, hydrated zeolites are utilised as "ion-exchangers."

3.7 Catalysis used in Industries

SOME INDUSTRIAL CATALYTIC PROCESSES

Process	Reactions with catalyst and other conditions
Haber's process for the manufacture of ammonia process	$N_2(g) + 3H_2(g) \xrightarrow[\text{Molydenum (Promoter) 200 bar pressure 723 773 K temp}]{\text{Finely divided iron (catalyst)}} 2\,NH_3(g)$
Ostwald's process for the manufacture of nitric acid	$4NH_3(g) + 5O_2(g) \xrightarrow[\text{asbestos}]{\text{Platinised}} 4NO(g) + 6H_2O(g)$ $4NO(g) + O_2(g) \xrightarrow{573K} 2NO_2(g)$

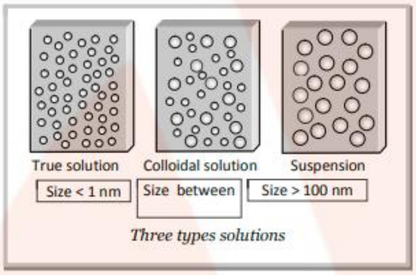
	$4NO(g)+2\,H_2O(\ell)+O_2(g)\rightarrow 4HNO_3(\ell)$
Contact process for the manufacture of sulphuric acid	$4SO_2(g)+O_2(g)\qquad 2SO_3(g)$ $SO_3(g)+H_2SO_4(l)\xrightarrow{673\ 723K}H_2S_4O_7(l)\xrightarrow{+H_2O(l\ )}2H_2SO_4(aq)$
Deacon's process for the manufacture of chlorine	$4HCl(g)+O_2(g)\frac{CuCl_2}{773K}>2H_2O(\ell)2\ Cl_2(g)$
Synthesis of methanol	$CO(g)2H_2(g)\xrightarrow[200\text{ bar }432\text{ K}]{ZnO+Cr_2O_3}CH_3OH(\ell)$
Hydrogenation of vegetable oil	$Oil(\ell)H_2(g)\frac{\text{Finely divided Ni}}{423\text{–}473K\text{ High pressure}}>\text{Vanaspati ghee }(s)$

4. COLLOIDAL STATE

The size of the particles determines the colloidal condition. It's thought to be a halfway point between full solution and suspension.

4.1 True solution

Because the size of the particles of solute in real solutions is so minute that they can't be recognised by any optical means and freely diffuse through membranes, they can't be detected by any optical methods. It's a one-of-a-kind system.

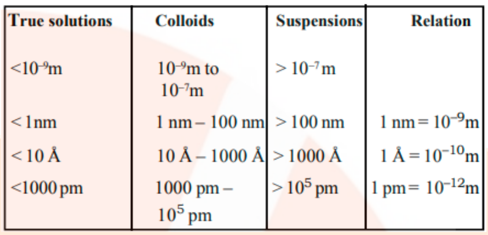


Three types solutions

4.2 Suspension

Particles are large enough to be seen with the naked eye and do not pass-through filter paper. It's a complicated system.

Different solutions' sizes are sometimes stated in different units, as shown below:



True solutions	Colloids	Suspensions	Relation
$<10^{-9}$m	10^{-9}m to 10^{-7}m	$> 10^{-7}$ m	
< 1nm	1 nm – 100 nm	> 100 nm	1 nm = 10^{-9}m
< 10 Å	10 Å – 1000 Å	> 1000 Å	1 Å = 10^{-10}m
<1000 pm	1000 pm – 10^5 pm	> 10^5 pm	1 pm = 10^{-12}m

CHARACTERISTICS OF TRUE SOLUTIONS, COLLOIDAL SOLUTIONS AND SUSPENSIONS

S.No	Property	True Solutions	Colloidal Solutions	Suspensions
1	Nature	Homogeneous	Heterogeneous	Heterogeneous
2	Particle size (diameters)	Less than 10–9 m or 1 nm (i.e., < 10 Å)	Between 10–9 to 10–6m or 1 nm to 1000 nm	More than 10–6m or 1000 nm (i.e., > 10000Å
3	Filtrability	Pass through both regular filter paper and animal membrane.	Animal membrane will not pass-through regular filter paper.	Filter paper and animal membrane are not to be used.
4	Settling	Don't give up.	Don't give up.	Decide to stand.
5	Visibility	Particles are imperceptible to the naked eye.	Under an ultra-microscope, light scattering by the particles is observed.	Particles can be seen with the naked eye or via a microscope.
6	Diffusion	Diffusion is quick	Diffusion is very slow	Diffusion does not take place

7	Appearance	transparent and clear	Transluscent	Opaque

4.3 Dispersed phase and Dispersion Medium

4.3.1 Dispersed phase (Discontinuous phase): This is a component that exists in small amounts and behaves similarly to a solute in a solution. For instance, in a colloidal silver solution in water (silver acts as a dispersed phase)

4.3.2 Dispersion medium (continuous phase): This is the component that is usually present in excess and functions similarly to a solvent in a solution. For instance, in a colloidal silver solution in water. The dispersion medium is water.

4.4 Classification of Colloids

4.4.1 Dispersion phase and dispersion medium classification based on physical state There are eight different types of colloidal systems depending on the physical state of the dispersed phase and the dispersion medium, which might be solids, liquids, or gases.

DIFFERENT TYPES OF COLLOIDAL SYSTEMS

Sr. No	Dispersed Phase	Dispersion	Colloidal System	Examples
1	Liquid	Gas	Aerosol of liquids	Fine pesticide sprays, fogs, clouds, and mists
2	Solid	Gas	Aerosol of liquids	Foam or froth Soap lather Smoke, volcanic dust, haze
3	Gas	Liquid		frothy lemonade, foam, whipped cream, and soda water
4	Liquid	Liquid	Emulsions	Medicines, emulsified oils, and milk

5	Solid	Liquid	Sols	Most paints, water-soluble starch, proteins, gold sol, arsenic sulphide sol, and ink
6	Gas	Solid	Solid foam	Styrene rubber, pumice stone, and foam rubber
7	Liquid	Solid	Gels	Butter, cheese, boot polish, jelly, and curd
8	Solid	Solid	Solid sols (coloured glass)	Some gem stones and alloys, as well as ruby glass

4.4.2 Classification based on the nature of the dispersed phase's interaction with the dispersion medium:

Water-loving colloids are known as lyophilic colloids. "Lyophilic colloids are colloidal solutions in which the particles of the dispersed phase have a strong affinity for the dispersion medium."

"The colloidal solutions in which there is no affinity between particles of the dispersed phase and the dispersion medium are called lyophobic colloids,"

"The colloidal solutions in which there is no affinity between particles of the dispersed phase and the dispersion medium are called lyophobic colloids,"

DISTINCTION BETWEEN LYOPHILIC AND LYOPHOBIC SOLS

Sr. No	Property	Lyophilic (suspensiod)	Lyophobic Sols (Emulsoid)
1	Surface tension	In comparison to the medium, it is lower.	Identical to that of the medium
2	Viscosity	Much higher than the medium's.	Identical to that of the medium

3	Reversibility	Reversible	Irreversible
4	Stability	More stable	Less stable
5	Visibility	Even under an ultramicroscope, particles are undetectable.	Under an ultramicroscope, particles can be seen.
6	Migration	Because particles do not carry any charge, they can migrate in either direction or do not migrate at all in an electric field.	Because particles carry charge, they migrate towards the cathode or the anode in an electric field.
7	Action of electrolyte	The addition of a modest amount of electrolyte has no effect.	Coagulation takes place
8	Hydration examples	There is a lot of hydration going on. Gum, gelatin, starch, proteins, rubber, and other similar substances	No hydration

4.4.3 Classification based on dispersed phase particle types: The colloids are categorised as follows based on the sort of particles in the dispersed phase.

Colloids made up of several molecules. Multimolecular colloids are generated when atoms or smaller molecules of substances gather together during dissolution to form particles of colloidal size. The dispersed phase in these sols is made up of clumps of atoms or molecules with a molecular size of less than 1 nm. Sols of gold atoms and sulphur molecules, for example. Vander Waal's forces hold the particles together in these colloids. They are typically lyophilic in nature.

Macromolecular colloids: These are substances with large molecules (called macromolecules) that dissolve to produce colloidal particles. Macromolecular colloids are the name given to such things.

These distributed macromolecules are often polymers with extremely large molecular masses.

Starch, cellulose, proteins, enzymes, gelatin, and other naturally occurring macromolecules are examples. Synthetic polymers such as nylon, polythene, plastics, and polystyrene are examples of artificial macromolecules. Their answers are highly stable and, in many ways, resemble actual solutions. They usually have a lyophobic personality. The molecules are malleable, allowing them to take on any shape.

Associated colloids are chemicals that, when dissolved in a medium, behave as conventional electrolytes at low concentrations but, due to the production of aggregated particles, behave as colloidal particles at larger concentrations.

Micelles are the aggregated particles that result from this process.

Both lyophilic and lyophobic groups can be found in their molecules. The creation of aggregates or clusters in solutions causes such compounds to behave colloidally. Micelles are microscopic aggregates of particles.

DIFFERENCE BETWEEN DIFFERENT TYPES OF COLLOIDS

Multimolecular colloids	**Macromolecular colloids**	**Associated colloids**
1. They are created by the aggregation of a high number of atoms or molecules with diameters smaller than 1 nm, such as gold, sulphur, and other metal sols.	They are big molecules, such as polymers like rubber, nylon, starch, proteins, and so on.	They are created by the amplification of many ions in a concentrated solution, such as soap solution.
2. Their molecular masses aren't particularly large.	They have a large molecular weight.	Their molecular masses are usually very large.

3. Weak van der Waals forces hold their atoms or molecules together.	The van der Waals forces that hold them together are considerably stronger due to the long chain.	The van der Waals forces increase as concentration increases.

4.5 Micelles

Micelles are clumps or aggregated particles generated through colloid association in solution. Soaps and detergents are common examples of micelles. Micelles develop at a certain temperature, known as the Kraft temperature (Tk), and at a certain concentration, known as the crucial micellization concentration (CMC). They can produce ions. Micelles can have up to 100 molecules in them. A classic example of this type of molecule is sodium stearate $(C_{17}H_{35}COONa)$

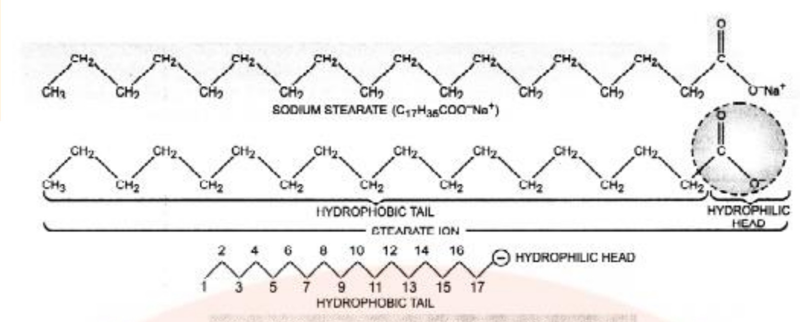
A classic example of this type of molecule is sodium stearate $(C_{17}H_{35}COONa)$

The ions $Na+$ and $C_{17}H_{35}COO-$ are produced when sodium stearate is dissolved in water.

$$C_{17}H_{35}COONa \rightleftharpoons C_{17}H_{35}COO^{-} + Na^{+}$$

The stearate ions combine to produce colloidal-sized ionic micelles.

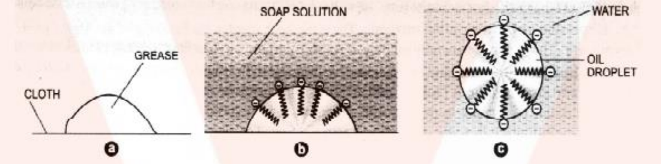
The $C_{17}H_{35}$ radical has a lengthy hydrocarbon component. COO^{-} component is lyophilic while LYO– part is lyophobic.



Hydrophobic tail and hydrophilic head of stearate ion

When an oil droplet comes into contact with a soap solution, the stearate ions organise themselves around it in such a way that the hydrophobic sections of the stearate ions are in the oil (or grease) and the hydrophilic parts are in the soap solution.

These polar groups can interact with the water molecules present around the oil droplet because the hydrophilic part is polar. As a result, the oil droplet is drawn away from the cloth's surface and into water, where it forms an ionic micelle that is rinsed away with the surplus water.



(a) Grease or oil on surface of cloth (b) Stearate ions arranged around the oil droplet (c) Ionic micelle formed surrounded by sheath of negative charge.

In reality, the stearate ions in soap molecules aid in the formation of a stable oil-water emulsion that is washed away by excess water. It's worth noting that a negative charge sheath forms around the oil globule.

Similarly, the polar group is OSO^-_3 together with the lengthy hydrocarbon chain in detergents, such as sodium lauryl sulphate $CH_3(CH_2)_{11}OSO^-_3\,Na^+$ It's an anionic detergent in the sense that anions bind together to create an ionic micelle, comparable to soap. Cetyl trimethyl ammonium bromide, $CH_3(CH_2)_{15}(CH_3)_3\,N^+Br^-$, is a well-known example of a cationic detergent that forms an associated colloid.

4.6 General Methods of preparation of Colloids

Different methods are used to create lyophilic and lyophobic colloidal solutions (or sols). The following are some of the most prevalent methods:

4.6.1 Preparation of Lyophilic colloids:

The dispersed phase particles and the dispersion medium have a great affinity for lyophilic colloids. Under normal conditions, colloidal solutions can be easily created by simply mixing the dispersed phase and dispersion medium.

Gelatin, gum, starch, egg, albumin, and other substances, for example, rapidly dissolve in water to form colloidal solution.

Because they can be precipitated and changed straight into colloidal state, they are reversible in nature.

4.6.2 Preparation of Lyophobic colloids4.6.2.1 By oxidation: A colloidal sulphur solution can be made by bubbling oxygen (or any other oxidising agent such as HNO_3, Br_2 etc.) through a hydrogen sulphide in water solution.

$$2H_2S+O_2(\text{or any oxidizing agent}) \rightarrow 2H_2+2S$$

4.6.2.2 By reduction: Aqueous solutions of metal salts have been treated with a suitable reducing agent such as formaldehyde, phenyl hydrazine, hydrogen peroxide, stannous chloride, and so on to obtain colloidal metals such as silver, gold, and platinum.

$$2AuCl_3+3SnCl_2 \rightarrow 3SnCl_4+2Au$$

$$AuCl_3+3HCHO+3H_2 \rightarrow 2Au+3HCOOH+6HCl$$

The purple colour of the gold sol obtained in this manner is known as cassius purple.

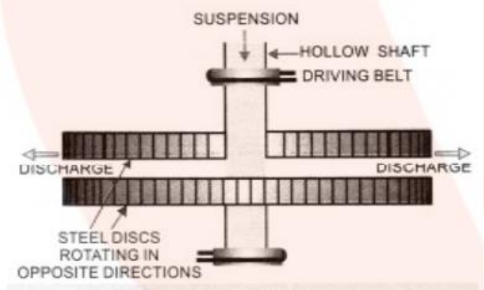
4.6.2.3 By hydrolysis: Many salt solutions are rapidly hydrolyzed when their salts are boiled in dilute solutions. Boiling solutions of the respective chlorides, for example, yield ferric hydroxide and aluminium hydroxide sols. $FeCl_3+3H_2O \rightarrow Fe(OH)_3+3HCl$

Similarly, sodium silicate is hydrolyzed to produce silicic acid sol.

$$As_2O_3+3H_2S \rightarrow As_2S_3+3H_2$$

4.6.2.5 Mechanical dispersion: The substance is initially pulverised to coarse particles in this approach. The suspension is then made by mixing it with the dispersion medium. After that, the suspension is ground in a colloidal mill. It is made up of two metallic discs that are virtually touching and rotate at a high speed of roughly 7000 revolutions per minute in opposite directions. The gap between the mill's discs is controlled such that coarse suspension is subjected to a high shearing force, resulting in colloidal particles.

This process is used to make colloidal solutions of black ink, paints, varnishes, dyes, and other materials.



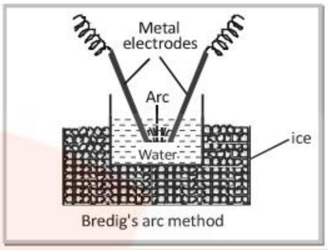
Colloid Mill

4.6.2.6 Bredig's arc technique or electrical dispersion:

This process is used to make platinum, silver, copper, and gold sols.

The metal to be manufactured as a sol is made up of two electrodes immersed in a dispersion media such as water. Ice is used to keep the dispersion medium chilly.

Between the electrodes, an electric arc is formed. This process generates a lot of heat, which results in colloidal solution. A tiny amount of KOH is added to the colloidal solution to stabilise it.

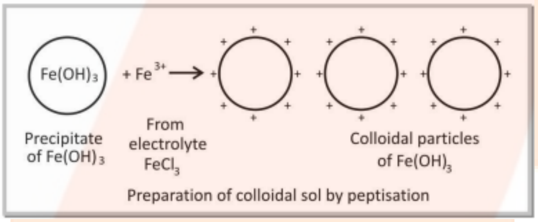


Bredig's arc method

4.6.2.7 By Peptization: Peptization is the process of turning a freshly formed precipitate into colloidal form by adding a suitable electrolyte. Peptizing agent or stabilising agent is the electrolyte utilised for this purpose. The adsorption of the electrolyte's ions by the particles of the precipitate causes peptisation. Sugar, gum, gelatin, and electrolytes are all important peptizing agents.

By shaking freshly synthesised ferric hydroxide with water containing 3 Fe or OH ions, i.e. Fe^{3+} OH^- $FeCl_3$ NH_4OH, it can be transformed to a colloidal state.

$$Fe(OH)_3 + FeCl_3 \rightarrow \left[Fe(OH)_3 Fe\right]^{3+} + 3Cl^-$$

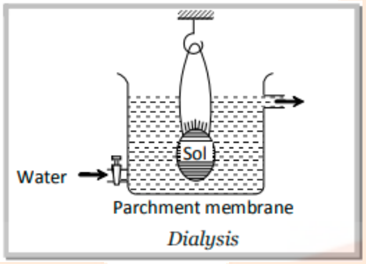


Preparation of colloidal sol by peptisation

4.7 Purification of colloidal solution

Impurities, particularly electrolytes, are commonly found in colloidal solutions generated using the procedures described above, which might destabilise the sols. To make colloidal solutions stable, these contaminants must be removed. The methods listed below are routinely used to purify colloidal solutions.

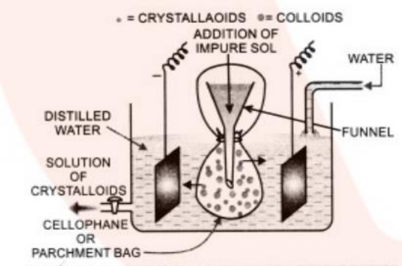
4.7.1 Dialysis is the process of separating colloid from crystalloid particles by diffusion via a suitable membrane. Its theory is since colloidal particles are unable to pass through a parchment or cellophane barrier, whereas electrolyte ions may.



Dialysis

A bag (parchment paper) is used to transport the colloidal solution. In fresh water, the bag is suspended. Impurities gradually diffused out of the bag, leaving only pure colloidal solution behind. The distilled water is changed often to prevent the crystalloids from accumulating and diffusing back into the bag. For eliminating HCl from ferric hydroxide sol, dialysis can be employed.

4.7.2 Electrodialysis is a type of electrodialysis that involves the use of electricity Dialysis is a slow process in its normal state. The dialysis is carried out using an electric field to speed up the purification process. Electrodialysis is the name for this procedure. The kidneys in the human body operate as dialysers, purifying colloidal blood. The dialysis method has a significant application in the artificial kidney machine, which is used to purify the blood of patients who have renal failure.The kidneys have stopped working. The gizmo that replaces your kidneys. It is based on the dialysis principle.



Electro-dialyser

4.7.3 Ultra-filtration: Sol particles pass through standard filter paper without being filtered because their pores are larger (more than 1 or 1000) than the size of sol particles (less than 200 m). If the pores of regular filter paper are reduced by soaking it in a gelatin or colloidion solution and then hardened by soaking it in formaldehyde, the treated filter paper may trap colloidal particles while allowing real solution particles to escape. Ultra-filter paper is used to separate colloids, and ultra-filtration is the process of using ultra-filters to separate colloids.

4.7.4 Ultra-centrifugation: The kinetic collisions of the medium molecules prohibit the sol particles from setting out under gravity's influence. High-speed centrifugal machines with 15,000 or more revolutions per minute can increase the setting force. Ultra–centrifuges are the name for such machines.

4.8 Properties of colloidal solutions

The following are the main characteristics of colloidal solutions.

4.8.1 Physical characteristics:

Nature of Colloidal Sols: Colloidal sols are heterogeneous by nature. The Dispersed Phase and the Dispersion Medium are the two phases.

The colloidal solutions have a very stable character. Their particles are in a state of motion and do not settle to the container's bottom.

Filterability: Colloidal particles flow through standard filter sheets with ease. Special filters known as ultrafilters can, however, keep them out (parchment paper)

4.8.2 Colligative properties:

The observed values of colligative qualities such as relative decrease in vapour pressure, elevation in boiling point, depression in freezing point, and osmotic pressure are smaller than expected due to the creation of linked molecules.

In comparison to the real solution, the number of particles in a colloidal sol will be very small.

4.8.3 Mechanical properties:

Brownian movement: The colloidal particles are moving in a zig-zag pattern at random. Brownian motion is the name for this sort of motion.

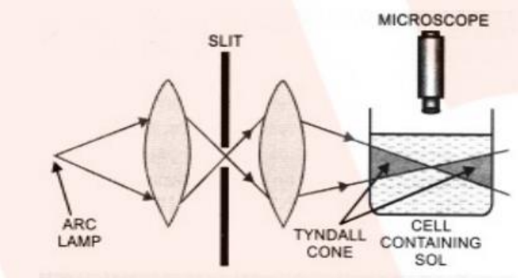
Brownian motion is caused by the molecules of the dispersion medium colliding with the particles of the dispersed phase on a regular basis.

Diffusion: Sol particles diffuse from a region of higher concentration to a region of lower concentration. However, because of their larger size, they diffuse at a slower rate.

Sedimentation: Under the action of gravity, colloidal particles settle down at a very slow rate. The molecular mass of macromolecules is determined using this phenomenon.

4.8.4 Optical properties : Tyandall effect:

Because light is scattered by particles as it passes through a sol, its path becomes apparent. It's known as the Tyndall effect. Tyndall was the first to investigate this phenomenon. Tyndall cone refers to the lit path of the beam. There are no particles with a big enough diameter to scatter light in a real solution, hence there is no Tyndall effect. A device known as an ultra – microscope has also been used to investigate the Tyndall phenomenon.



Tyndall effect

4.8.5 Electrical properties: Colloidal particles have an electric charge, whereas the dispersion medium has an equal and opposite charge, making the system electrically neutral. Because mutual forces of repulsion between similarly charged particles prevent them from coalescing and coagulating when they get closer to one another, the existence of equal and similar charges on colloidal particles is largely responsible for the system's stability.

4.9 Origin of the charge on colloidal particles

The charge on the sol particles is caused by the preferential adsorption of positive or negative ions on their surface in most situations. The electrical charge on the sol particles is acquired in one or more of the following methods.

4.9.1 Due to the dissociation of the surface molecules: The dissociation / ionisation of the surface molecules causes some colloidal particles to develop an electrical charge. The oppositely charged ions in the sol balance the charge on the colloidal particles. An aqueous solution of soap (sodium palmitate) that dissociates into ions is an example.

$$C_{17}H_{35}COONa \rightleftharpoons C_{17}H_{35}COO^{-} + Na^{+}$$

The anions $C_{17}H_{35}COO^{-}$ tend to congregate due to weak attractive forces inherent in the hydrocarbon chains, whilst the cations (Na^{+}) flow into solution.

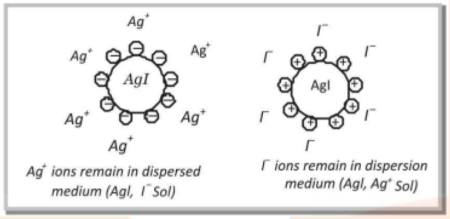
4.9.2 Frictional electrification: Frictional electrification is thought to occur when dispersed phase particles scrape against the dispersion medium, resulting in a charge on the colloidal particles. Because of the friction, the dispersion medium must also receive some charge. The theory does not appear to be valid because it does not carry any charge.

4.9.3 Because of selective ion adsorption: The particles that make up the dispersed phase selectively adsorb only those ions that are common with their own lattice ions.

When a tiny amount of silver nitrate ($AgNO_3$) solution is introduced to a large amount of potassium iodide (KI)(solution, the colloidal particles of silver iodide adsorb I^- from the solution, becoming negatively charged (at this point, KI is in excess, and I^- is common to AgI)

However, when a small amount of potassium iodide KI)(solution is added to a large amount of silver nitrate solution ($AgNO_3$), the colloidal silver iodide particles adsorb Ag from the solution and become positively charged ($AgNO_3$) is in excess at this point, and Ag^+ is common to AgI).

$$AgI+Ag^+ \rightarrow (AgI)Ag^+$$



Similarly, the adsorption of Fe^{3+} ions from the solution causes the ferric hydroxide colloidal particles to generate a positive charge.

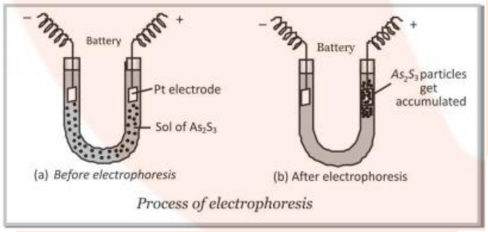
Due to the adsorption of OH^- ferric hydroxide colloidal particles acquire a negative charge.

$$Fe(OH)_3 + OH^- \rightarrow Fe(OH)_3.OH^-$$

$$Fe(OH)_3 + Cl^- \rightarrow Fe(OH)_3.Cl^-$$

4.10 Electrophoresis

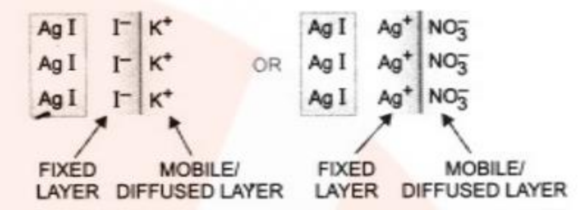
Electrophoresis is the movement of colloidal particles in the presence of an electric field. The charge on the particles is positive if they collect near the negative electrode. The charge on the sol particles, on the other hand, is negative if they collect near the positive electrode.



(a) *Before electrophoresis* (b) After electrophoresis

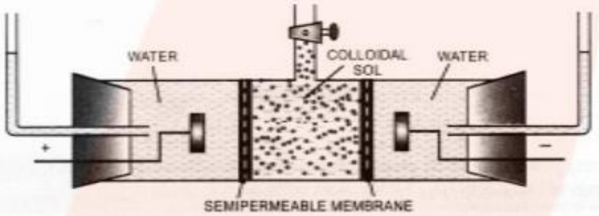
Process of electrophoresis

4.10.1 Electrical double layer theory: Electrical double layer theory can also be used to describe the electrical properties of colloids. A double layer of ions appears at the surface of a solid, according to this idea. The ion that is preferentially adsorbed is held in a fixed portion and gives colloidal particles charge. A diffused mobile ion layer makes up the second component. Both types of charges are present in the second layer. On the second layer, the net charge is the same as on the fixed section. The presence of the opposing sign on the fixed and diffuse regions of the double layer causes a potential difference known as zeta potential or electrokinetic potential to arise. When an electric field is used, the particles now move (electrophoresis)



Formation of electrical double layer

4.10.2 Electro-osmosis: In this process, a semipermeable membrane prevents scattered particles from migrating. The phenomena of electro-osmosis occurs when a dispersion medium is permitted to move under the influence of an electrical field while colloidal particles are not allowed to move. The occurrence of electro-osmosis suggests that when liquid is driven through a porous material or a capillary tube, a potential difference known as streaming potential exists between the two sides.



Electro-osmosis

4.11 Stability of sols

Sols are thermodynamically unstable, and due to Vander Waal's attractive forces, the dispersed phase (colloidal particles) tends to separate apart over time.

4.11.1, sols tend to be more stable. Stronger repulsive forces between particles with identical charges: In any sol, all colloidal particles have the same charge. As a result of electrostatic repulsion, they are unable to draw closer together and form aggregates. Thus, in a sol, larger repulsive forces between similarly charged particles promote stability.

4.11.2 Particle-solvent interactions: Colloidal particles become substantially solvated because of strong particle solvent (dispersion medium) interactions. The effective distance between colloidal particles rises because of solvation, while the Vander Waal's force of attraction decreases. The particles are unable to form aggregates as a result. Due to strong contacts between the sol particles and the dispersion medium, lyophilic sols are primarily maintained by solvation processes.

4.12 Coagulation or Flocculation or Precipitation

"The phenomena of coagulation or flocculation is the precipitation of a colloidal solution by the addition of an excess of an electrolyte."

4.12.1 Electrophoresis (electrophoresis): Colloidal particles travel towards the oppositely charged electrode in electrophoresis. These are released and precipitated when they come into prolonged contact with the electrode.

4.12.2 By combining two sols with opposite charges: The charges of oppositely charged sols are neutralised when they are blended in almost equal proportions.

Because ferric hydroxide (+ve sol) and arsenious sulphide (–ve sol) are mixed, both sols can be partially or totally precipitated.

4.12.3 When a sol is boiled, the adsorbed layer is disrupted due to increased collisions with the dispersion medium molecules. The charge on the particles is reduced, and they eventually settle down to form a precipitate.

4.12.4 By long-term dialysis: Long-term dialysis removes practically all traces of the electrolyte contained in the sol, making the colloids unstable.

4.12.5 By adding electrolytes: The dispersed phase particles, i.e. colloids, have a charge. When an electrolyte is put to a sol, the colloidal particles absorb ions from the electrolyte that have the opposite charge.

As a result, their charge is neutralised, causing the uncharged particles to clump together and coagulate or precipitate. When $BaCl_2$ solution is added to As_2S_3 sol, for example, the Ba^{2+} ions are attracted to the negatively charged sol particles and their charge is neutralised. Coagulation occurs as a result of this.

4.12.6 Rule of Hardy Schulze:

Various electrolytes have different coagulation capacities.

The flocculating ion, which is the ion carrying charge opposite to the charge on the colloidal particles, relies on the valency of the active ion. The coagulating capacity of an active ion or flocculating ion is proportional to its valency."

An electrolyte's coagulating power is proportional to its surface area proportional to the valency of active ions (ions that cause damage coagulation). To coagulate negative As_2S_3 sol, for example, the

The ability of different cations to coagulate has been discovered drop in order as follows: 3 2 Al Mg Na

To coagulate a positive sol, such as $Fe(OH)_3$, follow the same procedure, the ability of certain anions to coagulate blood has been discovered to reduction in the order

$\left[Fe(CN)_6\right]^{4-} > PO_4^{3-} > SO_4^{2-} > Cl^-$

4.12.7 Coagulation or flocculation value

"Flocculation value refers to the minimal concentration of an electrolyte required to cause coagulation or flocculation of a sol."

or "The flocculation value is the number of millimoles of an electrolyte necessary to cause coagulation of one litre of a colloidal solution."

As a result, a better flocculating agent will have a lower flocculating value.

FLOCCULATION VALUES OF SOME ELECTROLYTES

Sol	**Electrolyte value (mM)**	**Flocculation**	**Sol Electrolyte**	**Flocculation value (mM)**	
As_2S_3 (–vely charged)	NaCl KCl $CaCl_2$ $MgCl_2$ $MgSO_4$ $AlCl_3$ $Al_2(SO_4)_3$ $Al(NO_3)_3$	51.0 49.5 0.65 0.72 0.81 0.093 0.096 0.095	$Fe(OH)_3$ (+vely charged)	KCl $BaCl_2$ K_2SO_4 $MgSO_4$	9.5 9.3 0.20 0.22

Note: Coagulating value or flocculating value $\alpha \dfrac{1}{\text{coagulating power}}$

Coagulation of lyophilic sols (4.12.8): The stability of lyophilic sols is determined by two factors. The charge and solvation of colloidal particles is these parameters.

A lyophilic sol can be coagulated when these two components are removed. This is accomplished by combining electrolyte and a suitable solvent. Dehydration of the dispersion phase happens when solvents such as alcohol and acetone are applied to hydrophilic sols. A modest amount of electrolyte can cause coagulation in this situation.

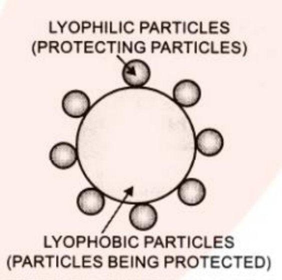
4.13 Protection of colloids and Gold number

Lyophilic and lyophobic sols are more stable than lyophilic and lyophobic sols.

By adding a little amount of an electrolyte to lyophobic sols, they can easily coagulate. Any lyophobic sol becomes less sensitive to electrolytes when a lyophilic sol is added to it. As a result, lyophilic colloids can prohibit any lyophobic sol from coagulating.

“The phenomena of adding a lyophilic colloid to a lyophobic sol to keep it from coagulating is known as sol protection or colloids protection.” Varied protective (lyophilic) colloids have different levels of protection. Any protective colloid's effectiveness is measured in gold numbers.

4.13.1 Gold number: To explain the protective capacity of different colloids, Zsigmondy coined the phrase "gold number." "Weight of the dried protective agent in milligrammes, which when added to 10 ml of a standard gold sol (0.0053 to 0.0058 percent) is just sufficient to prevent a colour change from red to blue when 1 ml of 10% sodium chloride solution is added, is equal to the gold number of that protective colloid," says the definition.



Protection of colloids

$$\text{Protective power } \alpha \ \frac{1}{\text{gold number}}$$

GOLD NUMBERS OF SOME HYDROPHILLC SUBSTANCES

Sr. No	Hydrophilic Substance	Gold Number	Hydrophilic Substance	Gold Number
1	Gelatin	0.005-0.01	Sodium oleate	0.4 – 1.0
2	Sodium caseinate	0.01	Gum tragacanth	2
3	Haemoglobin	0.03-0.07	Potato starch	25
4	Gum arabic	0.15-0.25		

Protective colloids serve an important function in the stabilisation of non–aqueous dispersions like paints and printing inks.

Congo rubin number: 4.13.2 To account for the protective characteristics of colloids, Ostwald created the Congo Rubin Number. "The amount of protective colloid in milligrammes that prevents colour change in 100 ml of 0.01 percent congo rubin dye to which 0.16 g equivalent of KCl is added," according to the definition.

4.14 Application of colloids

4.14.1 Alum (coagulation) purification of water: Alum, which produces three Al ions, is added to water to coagulate the negatively charged clay particles.

4.14.2 Coagulation and mutual coagulation in the rubber and tanning industries: Rubber plating, chrome tanning, dyeing, lubrication, and other industrial operations are colloidal in nature.

Rubber plating uses electrophoresis to cause negatively charged rubber (latex) particles to deposit on wires or handles of various tools. Anode refers to the material that will be used to deposit rubber.

Positively charged colloidal particles of skins and leather are coagulated in tanning by impregnating them in negatively charged tanning ingredients (found in tree bark).

Chrome salts are the most often used tanning agent for the coagulation of hide material, and the process is known as chrome tanning.

4.14.3 Artificial rains: Electrified sand or silver iodide can be thrown from an aeroplane to coagulate the mist hanging in the air, resulting in artificial rain.

4.14.4 Smoke Precipitation (Coagulation): Smoke is a negative sol made up of scattered carbon particles in the air.

By passing through a chamber with a highly positively charged metallic knob, these particles are eliminated.

4.14.5 Delta Formation (Coagulation): River water is made up of negatively charged colloidal clay particles. When a river empties into the sea, the clay particles are coagulated by the positive 2MgKNa ions and other ions present in the water, resulting in the formation of new lands known as deltas.

Blood is made up of negatively charged colloidal particles, which clots. The colloidal structure of blood explains why putting a ferric chloride solution to a cut stops bleeding. In fact, ferric chloride solution causes blood to coagulate and form a clot, which prevents additional bleeding.

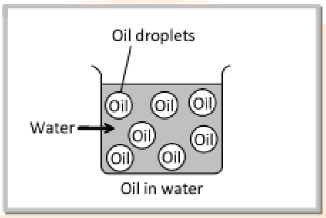
4.14.7 Colloidal medicine: The eye creams argyrol and protargyrol are colloidal silver solutions. As a disinfectant, colloidal sulphur is utilised. Tonics include colloidal gold, calcium, and iron.

4.14.8 Photographic plates: These are thin glass plates coated with gelatin and a fine silver bromide suspension. Silver bromide particles are colloidal in nature.

5. EMULSIONS

"Colloid solutions in which both the dispersed phase and the dispersion medium are liquids are known as emulsions."

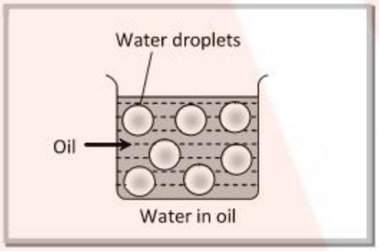
Milk, in which fat globules are spread in water, is a nice example of an emulsion. The emulsified globules are usually on the range of 10–6m in size. Emulsions have several qualities that are like lyophobic sols.



5.1 Types of Emulsion

The emulsions are classed as; depending on the nature of the dispersed phase, the emulsions are classified as; 5.1.1 Oil-in-water emulsions (O/W): An oil-in-water emulsion is one in which oil serves as the dispersed phase and water serves as the dispersion medium (continuous phase).

A good example of an oil-in-water emulsion is milk. Liquid fat globules in milk are distributed in water. Other examples are disappearing cream and others.



5.1.2 W/O emulsion (water-in-oil): A water-in-oil emulsion is an emulsion in which water serves as the dispersed phase and the oil serves as the dispersion medium. Oil emulsions are another name for these emulsions. Emulsions such as butter and cold cream are common examples. Other examples are cod liver oil and so on.

5.2 Preparation of Emulsions

Emulsions are made by vigorously churning a mixture of the necessary oil and water, either using a high-speed mixer or with ultrasonic vibrators. Simple mechanical stirring produces emulsions that are unstable. The two constituents (oil and water) tend to separate. A appropriate stabilising agent is usually added to achieve a stable emulsion. Emulsifier or emulsifying agent is the stabilising chemical. At first, the emulsifier is mixed in with the oil and water. Soaps, detergents, long-chain sulphonic acid, and lyophilic colloids such as gelatin, albumin, and casein, for example, can all operate as emulsifiers.

5.3 Nature of emulsifier

In the event of a certain emulsion, different emulsifiers may behave differently.

Sodium oleate, for example, is used to make oil-in-water (O/W) emulsions.

Water-in-oil (W/O) emulsions are made with magnesium and calcium oleates. When calcium oleate is introduced to a sodium oleate-stabilized emulsion, the system's stability suffers. The oil-in-water emulsion becomes unstable with a ratio of 2 Na : Ca. If the concentration of the two Ca ions is increased rapidly enough, the emulsion type is reversed, and the oil-in-water emulsion becomes a water-in-oil emulsion.

5.4 Identification of emulsions

There are several methods for determining whether an emulsion is an oil-in-water emulsion. The following are the characteristics of an emulsion.

5.4.1 Dilution test: Dilute the emulsion with water. If the emulsion can be diluted with water, water serves as the dispersion medium, and the emulsion is an oil-in-water emulsion. If the oil isn't diluted, it functions as a dispersion medium, and the result is a water-in-oil emulsion.

5.4.2 Dye test: The emulsion is shaken with an oil soluble appropriate dye. It is an oil-in-water type emulsion if colour is visible while gazing at a drop of the emulsion. It is an example of water-in-oil type if the entire background is coloured.

5.4.3 Conductivity test: To the emulsion, add a tiny amount of an electrolyte (e.g. KCl). Water is the dispersion medium if this renders the emulsion electrically conductive.

If the dispersed phase is not water.

5.5 Properties of emulsion

5.5.1 Emulsions exhibit all the properties of colloidal solution, including Brownian movement, Tyndall effect, and electrophoresis, among others.

5.5.2 The addition of electrolytes containing polyvalent metal ions coagulates the globules, demonstrating their negative charge.

5.5.3 Emulsion dispersed particles are larger than sol dispersed particles. It is in the range of 1000 to 10,000.

However, the particles are smaller than those found in suspensions.

5.5.4 By heating, centrifuging, freezing, and other methods, emulsions can be separated into two liquids. Demulsification is another name for this process.

5.6 Applications of emulsions

5.6.1 In metallurgy, ore concentration

In medicine,

5.6.2 (Emulsion water-in-oil type)

5.6.3 Soap's cleansing function

5.6.4 Milk is a fat-in-water emulsion, which is an important part of our nutrition.

5.6.5 Emulsification is used to digest lipids in the gut.