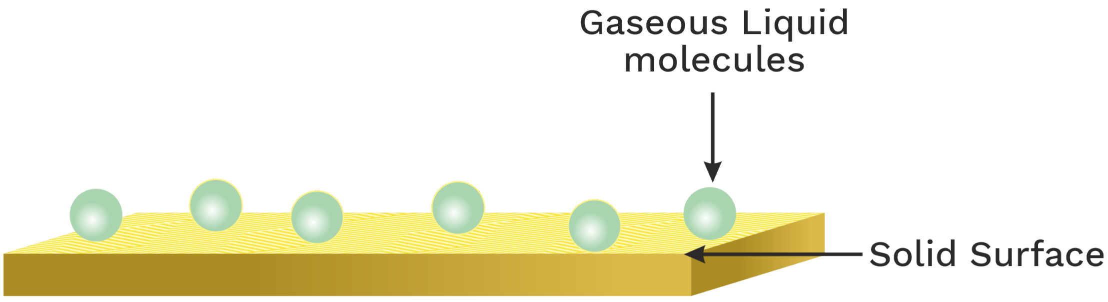
Surface Chemistry

Adsorption

- The term adsorption was introduced by Scheele during the discovery of uptake of gases by charcoal.
- It was discovered by Raymonds and Kayser.
- The substance on which the other substance is adsorbed is called an adsorbent or interface, for example, charcoal, solid Al_2O_3, silica gel, metals, colloids and clay in finely divided states.
- The substance which gets adsorbed on the adsorbent is called adsorbate.

Definitions

The phenomenon of adherence of liquid or gaseous molecules on the surface of a solid by physical or chemical processes is termed as adsorption.



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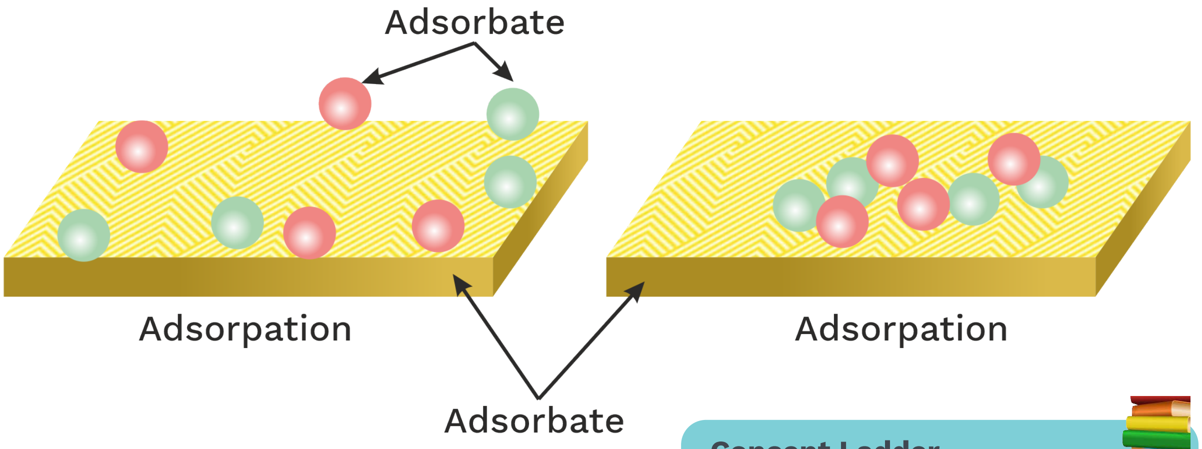

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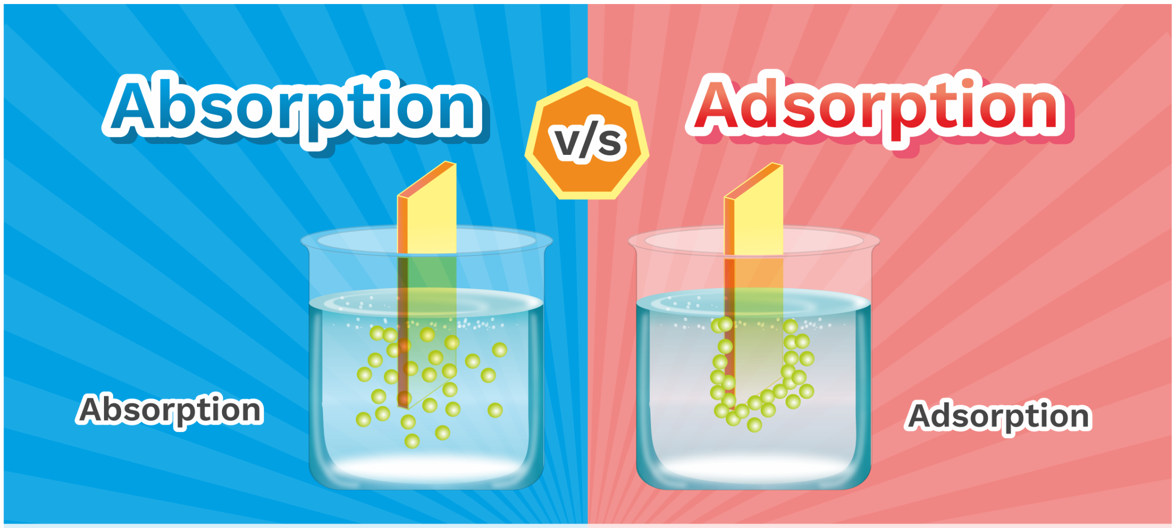
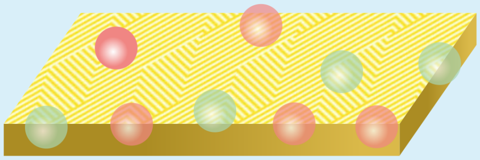
Features of Adsorption

- Adsorption is highly specific and selective in nature.

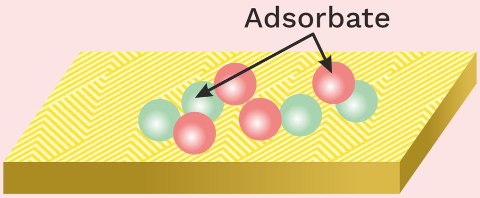
Concept Ladder

- Air becomes dry (moisture free) when silica gel as silica gel adsorbs H_2O molecules.





Absorption



Adsorpation

Absorption is the distribution of a certain substance through out the volume of another substance.

Absorbed materials can be separated between different phases due to their chemical characteristics.

Materials get absorbed into other material through the availability of space and also due to the properties of each material

Absorbed materials remain within the space of the absorbent wwithout having a chemical relationship being perfectly intact as when it is free

Adsorption is the attachment of a certain substance onto the surface of another substrate

Adsorption can be used to separate out certain material by adsorbing them onto one surface.

The vacant surface of the adsorbent has extra energy that stimulates the attachment of foreign molecules on to it

Adsorbates bind onto the surface of the adsorbent most commonly through van der waals interactions through or covalent bonds.

- It is a spontaneous process, so ΔH, ΔS, ΔG are negative.
- When absorption and adsorption occur simultaneously it is called sorption
- Adsorption is fast and exothermic. For example, inert gases, SO_2, Cl_2, CO_2, NH_3 get adsorbed on charcoal and silica gel adsorbs H_2O.
- Dyes can be adsorbed on animal charcoal.

Absorption

It occurs throughout the body of absorbing material and hence it is a slower process.

It is an endothermic process (ΔH is positive). For example, anhydrous $CaCl_2$ absorbs water, followed by a decrease in temperature.

Occlusion

Adsorption of gases on surface of metal is known as occlusion. For example, H_2 gas on Pd (palladium) surface.

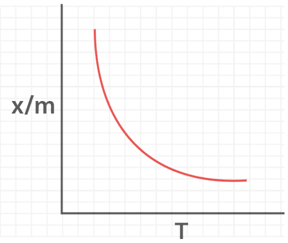
Types of Adsorption

Physical adsorption

- Here molecules are attracted to the surface by weak van der Waals forces.
- e.g., Charcoal adsorbs SO_2.
- It is less specific as all gases are adsorbed on metals to some extent.
- It is reversible in nature.

$$\text{Solid} + \text{Gas} \rightleftharpoons \text{Gas / Solid} + \text{Heat}$$

- Adsorption ∝ Liquification of gases.
- It is exothermic in nature. So observed at low temperatures.
- Here, adsorption energy is low. (20–40) kJ/Mole.
- It decreases with temperature.



Concept Ladder

- In positive adsorption, the concentration of the adsorbate is more on the surface of the adsorbent than in bulk.
- In negative adsorption, the concentration of the adsorbate is less relative to its concentration in bulk.

Definitions

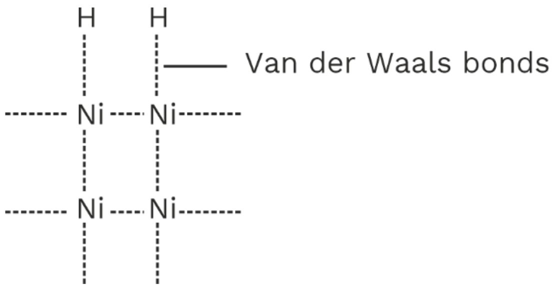
Desorption

It is reverse of adsorption, that is, removal of adsorbed substance from the surface of the adsorbent.

Rack your Brain

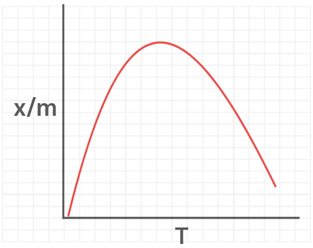
What is relation between Adsorption and liquification of gas?

- Here, multiple layers are formed.
- Here, adsorption $\propto$ surface area
- Here, activation energy barrier is absent. e.g., Adsorption of N_2 on Mica.



Chemical Adsorption/ Activated Adsorption

- In this process,the molecules are held on the surface by strong chemical bonds. e.g., H_2 adsorbed on metals due to hydride formation.
- It is very specific in nature.
- It is irreversible in nature.
- Adsorption energy is high in this case. (80–240 kJ/Mole)
- It is an endothermic process.
- Initially, it increases with increase in temperature then decreases.



- Adsorption $\propto$ Surface area
- In this, a unimolecular layer is formed.
- For this process to take place, Activation energy is needed to be overcome for this process to occur. Adsorption of O_2 on Tungsten, H_2 on Nickel.

Concept Ladder

That is why finely divided metals and porous substances are good adsorbents due to larger surface area

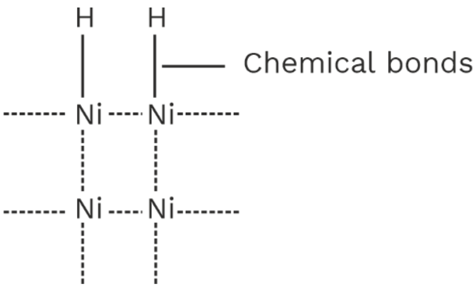
Rack your Brain

Where does chemical adsorption occur?

Previous Year's Question

Which one of the following characteristics is associated with adsorption? **[NEET]**

(1) ΔG and ΔH are negative but ΔS is positive.
(2) ΔG and ΔS are negative but ΔH is positive.
(3) ΔG is negative ΔH and ΔS are positive.
(4) ΔG, ΔH and ΔS all are negative.



Factors Affecting Adsorption

Effect of temperature

$$\text{Adsorption} \propto \frac{1}{\text{Temperature}}$$

Effect of pressure

At constant temperature:

$$\text{Adsorption} \propto \text{Pressure}$$

Nature of gas or adsorbent

Adsorption $\propto$ Critical temperature of the gas α Liquation of the Gas

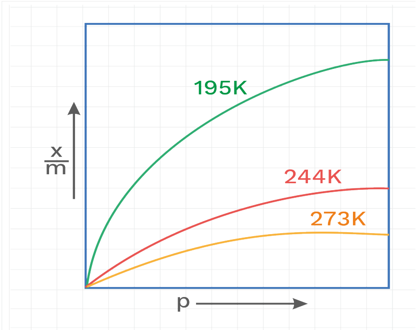
For example, [NH_3, Cl_2, HCl] > [N_2, O_2, H_2]

Surface area of Adsorbent: Larger is the surface area of adsorbent, more will be the number of active centres and faster will be the rate of adsorption.

Activation of solid adsorbent: When adsorbent is subdivided or already adsorbed gases are removed, the adsorbent becomes activated and the rate of adsorption increases.

Adsorption isotherm: The plot between extent of adsorption (x/m) vs pressure at constant temperature.

Here, x = Mass of gas adsorbed
m = Mass of adsorbent



Adsorption Isotherm

Concept Ladder

Rate of adsorption is high at the begning and then decreases till equilibrium is attained.

Previous Year's Question

Which is not correct regarding the adsorption of a gas on surface of a solid? **[AIPMT]**

(1) On increasing temperature adsorption increases continuously.
(2) Enthalpy and entropy change is negative
(3) Adsorption is more for some specific substance.
(4) it is a reversible reaction.

Freundlich Adsorption isotherm

At low pressure, graph is almost straight

$$\frac{x}{m} \propto P$$

$$\frac{x}{m} = KP$$

Here, K = Constant.

At high pressure $\frac{x}{m}$ becomes almost constant and does not change with pressure

$$\frac{x}{m} \propto P^{\circ} \text{ or } \frac{x}{m} = KP^{\circ}$$

At intermediate value of pressure

$$\frac{x}{m} \propto P^{\frac{1}{n}}$$

$$\frac{x}{m} = KP^{\frac{1}{n}}$$

$(n > 1)$

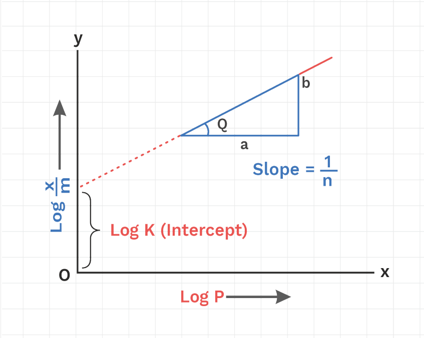
n is constant, which only depends upon nature of adsorbent and adsorbate.

Value of n and K are be determined as follows: On taking logarithm of equation (1), we get

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

Thus, on plotting a graph between $\log_e$ x/m and $\log_e$ P, a straight line is obtained.

Here, slope $= 1/n\left(\frac{1}{n} = 0 \text{ to } 1\right)$; Intercept = $\log_e$ K



Freundlich isotherm

Concept Ladder

Freundlich adsorption applicable only for physical adsorption because it considers multimolecular layer of adsorption.

Rack your Brain

Why Freundlich adsorption is unable to explain the degree of adsorption is constant at higher pressure?

Previous Year's Question

The correct option representing a Freundlich adsorption isotherm is **[NEET]**

(1) $\frac{x}{m} = kp^{0.3}$

(2) $\frac{x}{m} = kp^{2.5}$

(3) $\frac{x}{m} = kp^{-0.5}$

(4) $\frac{x}{m} = kp^{-1}$

If concentration is used in place of pressure

$$\frac{x}{m} = KC^{\frac{1}{n}}$$

Langmuir adsorption isotherm

$$\frac{x}{m} = \frac{a\,P}{1 + b\,P}$$

$$\frac{x}{m} / P = \frac{a\,P}{1 + b\,P}$$

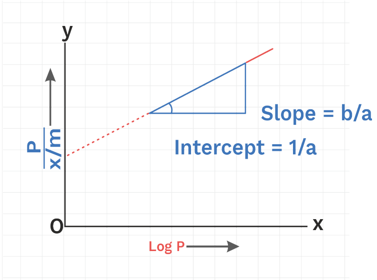
On reversing the equation, we get,

$$\frac{P}{x/m} = \frac{1 + b\,P}{a} = \frac{1}{a} + \frac{b}{a}P$$

Here a and b are constants when graph is plotted between

$$\frac{P}{x/m} \text{ and } P$$

It is a straight line, in which slope is equal to b/a while the intercept is equal to 1/a.



Freundlich isotherm

The plots between x/m and temperature at constant pressure are called adsorption isobars.

Uses of Adsorption

1. Silica and alumina gel are used to remove moisture and for controlling humidity.
2. Charcoal is used in production of high vacuum.
3. Animal charcoal removes the colour of solution by adsorbing coloured impurities.
4. In preparation of gas masks using activated charcoal to avoid poisonous gases like CO, CH_4.
5. Coconut charcoal is used for separating mixture of inert gas.

Previous Year's Question

In Freundlich adsorption isotherm, the value of 1/n is **[AIPMT]**

(1) between 0 and 1 in all cases
(2) between 2 and 4 in all cases
(3) 1 in case of physical absorption
(4) 1 in case of chemisorption.

Rack your Brain

Which purification technique will be used to purify pigments and hormones?

Concept Ladder

Froth floatation method used for concentration of sulphide ores, is based on adsorption.

6. Zeolite ($Na_2Al_2Si_2O_8.xH_2O$) softens water by adsorbing $CaCl_2$.
7. Adsorption chromatography is used for purification and separation of pigments, hormones
8. Many drugs are used to kill germs by getting absorbed on them.

Definitions

Catalyst is a substance which changes the rate of any reaction and this phenomenon is called catalysis.

Catalysts

- The term catalyst was coined by Berzilius.
- A catalyst never initiates or completes a reaction.
- A catalyst is effective in small amount.

For example,

$$2KClO_3 \xrightarrow[\text{Catalyst } MnO_2]{600K} 2KCl + 3O_2$$

Rack your Brain

Explain optimum temprature?

Homogenous Catalysis

In this, reagents and catalyst have same physical state or phase.

$$2SO_2(g) + O_2(g) \xrightarrow{NO(g)} 2SO_3(g)$$

$$CH_3COOCH_3(l) + H_2O(l) \xrightarrow{HCl(l)} CH_3COOH(l) + CH_3OH(l)$$

Surface Catalysis

In this, reagents and catalyst have different physical state or phase. In this, catalyst is always in a solid powderous form and catalysis is known as surface catalysis.

For example,

$$2SO_2(g) + O_2(g) \xrightarrow{Pt(s)} 2SO_3(g)$$

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

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

Concept Ladder

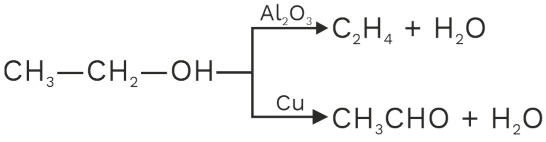
A catalyst affects the rate of a reaction but itself remains unchanged in mass and properties at the end of the reaction.

Properties of a Catalyst

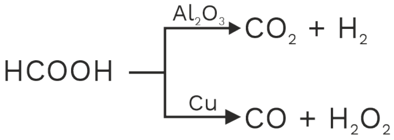
- A catalyst doesn't change in mass, chemical composition at the end of a reaction.
- The activity of a catalyst depends upon the extent of chemical adsorption, that is,

adsorption should always be moderately strong but not extremely strong.

- It is highly specific in nature, which means, catlyst can catalyse a given reaction but can be ineffective for other reactions. This is called specificity of catalyst.
  For example, invertase enzyme can catalyse hydrolysis of sucrose, but not that of maltose.



$$CH_3-CH_2-OH \xrightarrow{Al_2O_3} C_2H_4 + H_2O$$
$$CH_3-CH_2-OH \xrightarrow{Cu} CH_3CHO + H_2O$$



$$HCOOH \xrightarrow{Al_2O_3} CO_2 + H_2$$
$$HCOOH \xrightarrow{Cu} CO + H_2O_2$$

- Catalyst is most effective in solid powderous form due to a larger surface area, that means, more number of active centres.
- Catalyst is more effective at a particular temperature which is called optimum temperature.
- After addition of catalyst, reaction takes an alternataive path by changing the activation energy.

Catalyst Promoter or Activators

A promoter (an activator) in itself is not a catalyst, however its presence increases the effectivity of a catalyst. For example, in the given reaction Cr_2O_3 and copper act as catalyst promoters respectively.

$$CO + 2H_2 \xrightarrow[Cr_2O_3]{ZnO(C)} CH_3OH$$

$$\text{Vegetable oil} \xrightarrow[Cu]{Ni(C)} \text{Vegetable ghee}$$

Catalyst Poison

It is not a catalyst as such but it decreases the activity of a catalyst. For example,Mercury and Sulphur.

Concept Ladder

A catalyst is effective in small quantity, for example, 1 g colloidal platinum can catalyse the degradation of 108 litres of H_2O_2.

Definitions

It is the ability of a catalyst to direct the reaction in such a way so that only one particular product is formed, this is called selectivity of a catalyst.

Concept Ladder

A catalyst cannot affect the position of equilibrium but can set up equilibrium quickly.

Types of Catalysts

Positive Catalyst: Positive catalyst increases rate of a reaction by decreasing activation energy requirement for a reaction by making reaction proceed via an alternative path. Few examples which show this behaviour are listed below:

$$2H_2O \xrightarrow{Pt} 2H_2O + O_2$$

$$2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2$$

$$4NH_3 + 5O_2 \xrightarrow[300°C]{Pt} 4NO + 6H_2O$$

$$2SO_2 + O_2 \xrightarrow{NO} 2SO_3$$

$$2SO_2 + O_2 \xrightarrow[Pt]{V_2O_5} 2SO_3$$

$$4HCl + O_2 \xrightarrow[45^{\circ}C]{Cu_2Cl_2} 2Cl_2 + 2H_2O$$

$$CO + 3H_2 \xrightarrow{Ni} CH_4 + H_2O$$

$$\text{Vegetable oil} \xrightarrow[Cu]{Ni} \text{Vegetable ghee}$$

$$CO + 2H_2 \xrightarrow[Cr_2O_3]{ZnO} CH_3OH$$

Negative Catalyst: It decreases rate of a reaction by following an alternative path with higher activation energy requirement. Few examples are given below:

$$2Na_2SO_3 + O_2 \xrightarrow[\text{or acetanilide}]{\text{Alchol}} 2Na_2SO_4$$

$$2H_2O_2 \xrightarrow{\text{Glycerine}} 2H_2O + O_2$$

$$2C_6H_5 - CHO + O_2 \xrightarrow{\text{Diphenylamine}} 2C_6H_5 - COOH$$

$$2CHCl_3 + O_2 \longrightarrow 2COCl_2 + 2HCl_2$$

Here, C_2H_5OH acts as negative catalyst to check oxidation of chloroform. It also converts poisonous phosgene into non-poisonous diethyl carbonate.

Auto Catalysts: In certain reactions, one of the product acts as a catalyst. Such reactions are slow in start but become faster as they proceed. For example,

Concept Ladder

Presence of As_2O_3 reduces the Pt–Asbestos activity in contact process for the manufacture of H_2SO_4.

Previous Year's Question

Which one of the following statements is not correct? **[NEET]**

(1) The value of equilibrium constant is changed in the presence of a catalyst in the reaction at equilibrium.
(2) enzymes catalyse mainly biochemical reactions.
(3) Coenzymes increase the catalytic activity of enzyme.
(4) Catalyst does not initiate any reaction.

Rack your Brain

What is the role of ethyl alcohol to detect the oxidation of chloroform?

$$CH_3COOC_2H_5 + HOH \xrightarrow{} \underset{\text{Auto catalyst}}{CH_3COOH} + C_2H_5OH$$

$$5H_2C_2O_4 + 2KMnO_4 + 3H_2SO_4 \xrightarrow{} \underset{\text{Auto catalyst}}{2MnSO_4} + K_2SO_4 + 10CO_2 + 8H_2O$$

$$2Cu + 2HNO_3 \xrightarrow{} Cu_2O + \underset{\text{Auto catalyst}}{HNO_2}$$

Induced catalyst: In some cases,a reaction acts as catalyst for another reaction, for example, Na_2AsO_3 acts as an induced catalyst for oxidation of Na_2AsO_3.

Concept Ladder

H_2S or CO reduces activity of iron catalyst in Haber process.

$$Na_2AsO_3 + O_2 \xrightarrow{} \text{(No Reaction)}$$

$$\text{But, } 2Na_2SO_3 + O_2 \xrightarrow{} 2Na_2SO_4$$

$$\text{So, } Na_2AsO_3 + Na_2SO_3 + O_2 \xrightarrow{} Na_2AsO_4 + Na_2SO_4$$

Acid base catalysts: H^+ and OH^- ions also act as catalyst, so these are known as acid and base catalysts respectively, for example,

$$\underset{\text{Sugar}}{C_{12}H_{22}O_{11}} + H_2O \xrightarrow{H^+} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

$$\underset{\text{Acetaldehyde}}{CH_3CHO} + H.CH_2CHO \xrightarrow{OH^-} \underset{\beta\text{–hydroxy butyric aldehyde}}{CH_3 - CH(OH)CH_2 - CHO}$$

Shape selective catalysts or zeolites: Zeolites are the most common type of shape selective catalysts. The shape selectivity depends upon pore structure of the catalyst. Pore size varies between 260 to 740 pico metres.

Rack your Brain

What is the substance that retards the oxidation of sodium sulphid in the presence of air?

1. ZSM(5) is, zeolite sieve of porosity 5 is
   $H_x\ (AlO_2)_x\ (SiO_2)_{96-x}\ .16\ H_2O$
   It is used to convert alcohols into hydrocarbons. (Gasoline)
2. Germiniliti $[Na_2Ca(AlO_2)_2(SiO_2)_4.6H_2O]$
3. Erionite $[Na_2K_2Ca\ Mg\ (AlO_2)_2\ (SiO_2)_2\ .6H_2O]$

Theories of Catalysis

Compound formation theory: According to this, one of the reactants combines with catalyst to form an intermediate product, which carries out remaining part of reaction.

$A + C \longrightarrow AC$ (Intermediate compound)

$AC + B \longrightarrow AB + C$

$A + B + C \longrightarrow AB + C$

Here, A & B are reactants, C is catalyst and AC is intermediate product. Few examples are given below:

$4KClO_3 + 2MnO_2 \longrightarrow 2KMnO_4 + 2KCl + Cl_2 + 4\,O_2$

$2KMnO_4 \longrightarrow K_2MnO_4 + MnO_2 + O_2$

$K_2MnO_4 + Cl_2 \longrightarrow 2KCl + MnO_2 + O_2$

or $2KClO_3 \xrightarrow{MnO_2} 2KCl + 3O_2$

More examples:

1. Freidel Crafts reaction

$R - Cl + AlCl_3 \longrightarrow (R^+)(AlCl_4)^-$

$(R^+)(AlCl_4)^- \xrightarrow{C_6H_5-H} R - Cl + AlCl_3$

2. $R - OH + H.HSO_4 \longrightarrow R - HSO_4 \xrightarrow[R-OH]{} R - O - R + H_2SO_4$

3. $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

$NO_2(g) + SO_2(g) \longrightarrow SO_3 + NO$

4. $2MnO_2 + 2KCl \longrightarrow 2KMnO_4 + Cl_2 + O_2$

$2KMnO_2 \longrightarrow K_2MnO_2 + MnO_2 + O_2$

$K_2MnO_4 \xrightarrow{Cl_2} 2KCl + MnO_2 + O_2$

Adsorption Theory: According to the theory, reactants are adsorbed on surface of catalyst and forms a film. Due to high concentration of reactants on film, reaction proceeds at a very fast rate.

As most of the catalysts are used in solid-powderous form and they have a large surface area on which active centers are present. At these centres, reactant molecules get collected and form unstable bonds. Soon, reactants molecules undergo chemical combination to give desired products. Products leave surface as soon as they are formed, so that new reactant molecules can be adsorbed on catalyst surface. In this

Concept Ladder

The general formula of a zeolite is:

$M_{x/n}$ $[(AlO_2)_x(SiO_2)_y]$, H_2O

Here M = Metal ions like K^+ or M^{+2}, Ca^{+2}

n = Valency of metal cation

m = Number of molecules of water of crystallization.

Previous Year's Question

According to the adsorption theory of catalysis, the speed of the reaction increases becasue. **[AIPMT]**

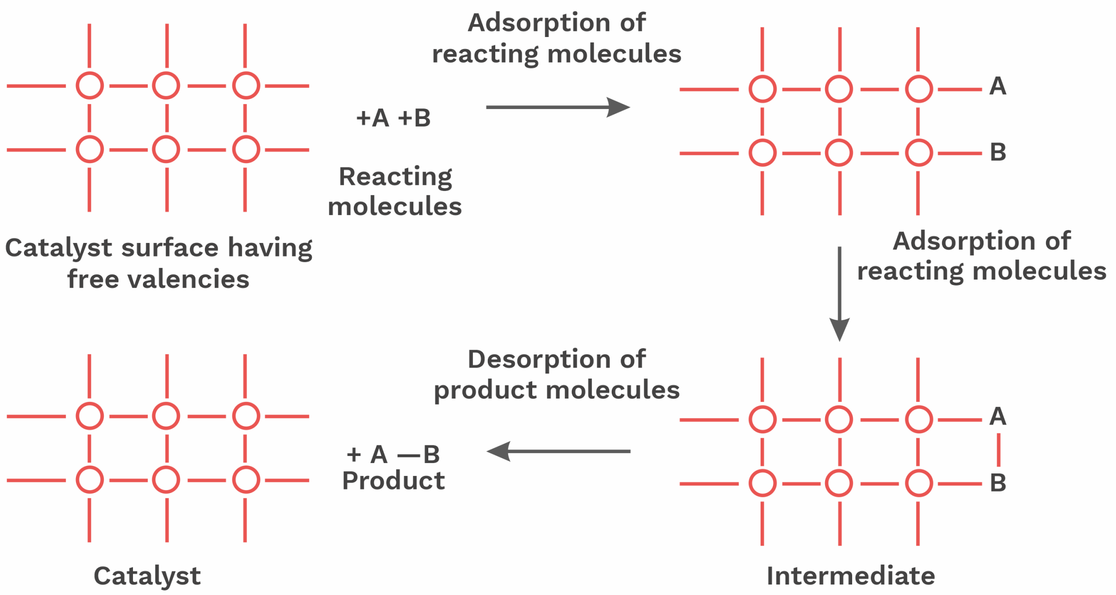
(1) the concentration of reactant molecules at the active centres of the catalyst becomes high due to adsorption.

(2) In the process of adsorption, the activation energy of the molecules becomes large.

(3) Adsorption produces heat which increases the speed of the reaction.

(4) Adsorption lowers the activation energy of the reaction.

way, process goes on till reaction is complete or attains equilibrium.



Adsorption of reacting molecules, formation of intermediate and desorption of products

Modern adsorption theory: According to this, reactants are adsorbed at active centers, that is, free vacancies on solid surface of catalyst and form an activated complex, which under strain, forms new molecules and leaves the surface.

Energy of activation theory: A catalyst lowers the value of activation energy needed for reaction, which can now be easily crossed by reactants and consequently products are formed.

Enzyme Catalyst or Biochemical Catalyst

- Enzymes are complex organic nitrogen compounds produced by living plants or animals in their cells.

Rack your Brain

Why a finely divided catalyst has greater activity?

- These are high molecular mass, globular protein molecules.
- Enzymes are highly efficient and increase the rate of reaction by $10^8 - 10^{20}$ times.
- Enzyme catalysts are highly specific in nature. For example, urea's enzyme can catalyse hydrolysis of urea but not of n-methyl urea.
- Enzyme catalysts are more effective at
- a constant temperature (37°C) and at a constant pH 7.4.
- Enzymes act like catalyst in many chemical and biochemical process.
- Optimum temperature range is 298 – 310 k and pH range is (5 – 7).

Concept Ladder

The non-protein component of an enzyme is called a co-factor.

A few examples:

1. $$\underset{\text{Cane Sugar}}{C_{12}H_{22}O_{11}} \xrightarrow{\text{Invertase}} \underset{\text{Glucose}}{C_6H_{12}O_6} + \underset{\text{Fructose}}{C_6H_{12}O_6}$$

$$C_6H_{12}O_6 \xrightarrow{\text{Zymase}} 2C_2H_5OH + 2CO_2$$

2. $$\underset{\text{Starch}}{2(C_6H_{10}O_5)n} + H_2O \xrightarrow[\text{Maltose}]{\text{Diastase}} nC_{12}H_{22}O_{11}$$

3. $$C_{12}H_{22}O_{11} \xrightarrow[\text{Maltase}]{H_2O} C_6H_{12}O_6$$

$$C_2H_5OH + O_2 \xrightarrow[\text{aceti}]{\text{Mycoderma}} CH_3COOH + H_2O$$

4. $$\text{Milk} \xrightarrow{\text{Lactobacilli}} \text{Curd}$$

Rack your Brain

Can a catalyst increase the yield of the reaction?

Q.1 How is adsorption of a gas related to its critical temperature?

A.1 Higher is the value of T_c (critical temperature) of a gas, greater is the ease of liquefaction, i.e., greater are the van der Waals forces of attraction and hence greater is the adsorption.

Q.2 Name two physical quantities that remain unaffected when a reversible reaction is carried out in the presence of a catalyst.

A.2 Equilibrium constant and enthalpy change.

Some Industrial Catalytic Process

S.NO	Process	Catalyst used
1.	Haber's process for manufacture of ammonia. $N_2 + 3H_2 \rightleftharpoons 2NH_3$	Finely divided iron as catalyst, Molybdenum as promoter. Conditions: 450–500°C temperature and 200 atmosphere pressure.
2.	Ostwald process for manufacture of nitric acid $4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$ $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$ $4NO_2(g) + 2H_2O(l) + O_2(g) \longrightarrow 4HNO_3(l)$	Platinized asbestos. Temperature required is 300°C
3.	Lead chamber process for manufacturing sulphuric acid. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $SO_3(g) + H_2O(l) \longrightarrow H_2SO_4(l)$	Nitric oxide
4.	Contact process for manufacture of sulphuric acid. $SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$ $SO_3(g) + H_2SO_4(l) \longrightarrow \underset{\text{Oleum}}{H_2S_2O_7(l)}$ $H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4(l)$	Platinized asbestos or vanadium pentoxide (V_2O_5). Temperature 400°C–450°C
5.	Deacon process for manufacture of chlorine. $4HCl(g) + O_2(g) \longrightarrow 2H_2O(l) + 2Cl_2(g)$	Cupric chloride ($CuCl_2$) Temperature 500°C
6.	Bosch process for manufacture of H_2. $CO + H_2 + H_2O(g) \longrightarrow CO_2(g) + 2H_2(g)$ Water gas	(Fe_2O_3) as catalyst + Cr_2O_3 as a promoter. Temperature 400°C–600°C.

S.NO	Process	Catalyst used
7.	Synthesis of methanol. $CO(g) + 2H_2(g) \longrightarrow CH_3OH(l)$	Zinc oxide (ZnO) + Cr_2O_3 act as promoter. Pressure 200 atm & temp. 250°C
8.	Hydrogenation of vegetable oils. $\text{Vegetable oil}(l) + H_2(g) \longrightarrow \text{Vegetable ghee}(s)$	Nickel (very finely divided) as catalyst + Cu as promoter. Temp. 150–200°C and high pressure.
9.	Manufacture of ethyl alcohol by fermentation of molasses (sugar solution).	Invertase enzyme and Zymase (yeast) enzyme. Temp. (25°C–30°C) Conversion occurs in 2 or 3 days.
10.	Manufacture of ethyl alcohol from starch. $\text{Starch} \xrightarrow{\text{Diastase}} \text{Maltose}$ $\text{Maltose} \xrightarrow{\text{Maltose}} \text{Glucose} \xrightarrow{\text{Zymase}} \text{Alchol}$	Germinated barley (diastase enzyme) Temperature 50°C–60°C. Yeast (maltase and zymase enzymes). Temperature 25°C–30°C.
11.	Manufacture of acetic acid from ethyl alcohol. $C_2H_5OH(l) + O_2(g) \longrightarrow CH_3COOH(l) + H_2O(l)$	Mycoderma acetic. (Temp. 25°C–30°C).
12.	Bergius process for the synthesis of petrol form coal. $\text{Coal} + H_2(g) \longrightarrow \text{Mixture of hydrocarbons}$	Ferric oxide (Fe_2O_3) (Temp. 475°C)

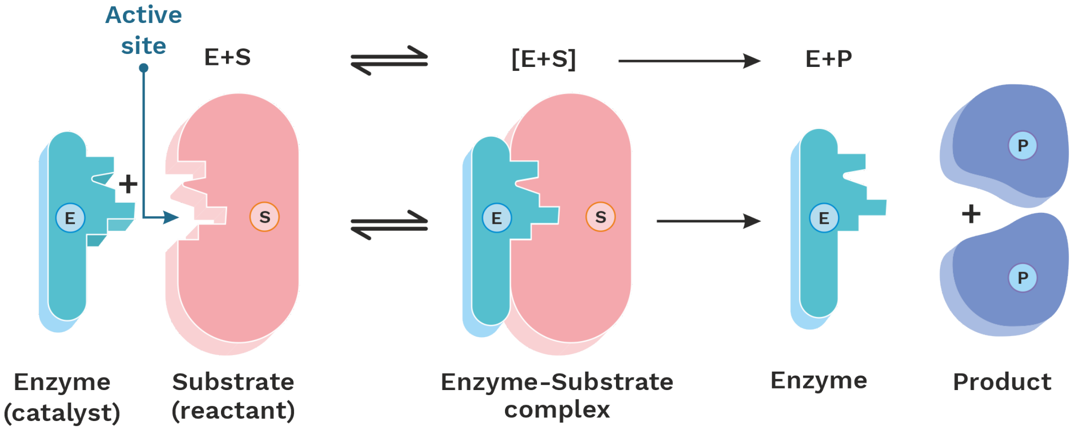
Co-enzyme: It increases activity of enzyme catalysis and is not a catalyst. Metal ions like Na^+, O^{2+}, Cu^{2+}, Mn^{2+} act as co-enzymes.

Lock and key hypothesis as a mechanism of enzyme action: A number of cavities are present on the surface of enzymes. These cavities have specific shapes and groups like $-NH_2$ $-COOH$, $-OH$ etc. These are active centres on enzyme surfaces. Here, 'key' (reagent or substrate) fits in 'lock', that is, active site of catalyst to produce an intermediate complex, which gets converted into product and enzyme catalyst is released.

Concept Ladder

Co-enzyme is a small non-protein (Vitamin) is present along in enzyme, and this enhanced the catalytic activity.

$$E + S \rightleftharpoons E - S \xrightarrow{R} E + \underset{\text{Activated Complex}}{P}$$



Mechanism of enzyme catalysed reaction

Q.3 Why is the ester hydrolysis slow in the beginning and becomes faster after some time?

A.3 The ester hydrolysis takes place as follows:

$$\underset{\text{Ester}}{RCOOR'} + \underset{\text{Waster}}{H_2O} \rightleftharpoons \underset{\text{Acid}}{RCOOH} + \underset{\text{Alcohol}}{R'OH}$$

Acid produced in reaction acts as catalyst (autocatalyst) for reaction. Hence, reaction becomes faster after some time.

Source	Enzyme	Enzymatic reaction
Invertase	Yeast	Sucrose → Glucose and fructose
Zymase	Yeast	Glucose → Ethyl alcohol and carbon dioxide
Diastase	Malt	Starch → Maltose
Maltase	Yeast	Maltose → Glucose
Urease	Soyabean	Urea → Ammonia and carbon dioxide
Pepsin	Stomach	Proteins → Amino acids

Colloidal State

Graham (1862) studied process of diffusion. Study of dissolved substances through animal membrane and a parchment paper and divided substances into two classes was done by him.

1. Crystalloids
2. Colloids

Concept Ladder

Substances like sugar, urea, common salt, which readily pass through the membrane while in the dissolved state are called crystalloids.

S.No.	Property	True solution	Colloidal state	Suspension
1.	Nature	Homogeneous	Heterogeneous	Heterogeneous
2.	Particle size	Less than 1 nm that is, 10^{-7} cm or 10Å	1 to 100 nm or 1 × 10^{-7} to 1 × 10^{-5} cm or 10–1000Å	More than 100 nm or more than 1 × 10^{-5} cm or 1000Å
3.	Effect of gravity on particles	No effect, particles do not settle.	No effect, particles do not settle	Particles settle when solution is left undisturbed

S.No.	Property	True solution	Colloidal state	Suspension
4.	Filterability	Passes unchanged through filter paper as well as animal or vegetable membranes	Pass unchanged through filter paper but not through animal or vegetable membranes	Does not pass through filter paper or animal and vegetable membranes
5.	Diffusion	Diffuses rapidly	Diffuse rapidly	Does not diffuse
6.	Visibility	Particles are completely invisible and thus do not scatter light	They are not visible to naked eye, but they scatter light	Particles are visible to naked eye and under a microscope and they scatter light
7.	Appearance of solution	Clear and transparent	Generally clear and transparent	Opaque
8.	Colligative properties	Affects colligative properties	Does not affect colligative properties	Does not affect colligative properties
9.	Tyndall effect	Not exhibited	Exhibited	Not exhibited
10.	Coagulation	They can be coagulated by adding suitable electrolytes	They can be coagulated by adding suitable electrolytes	They are not coagulated

- Substances like starch, gelatin, glue, which in dissolved state either do not pass at all or passed very slowly through membrane are called colloids.
- A colloid is a heterogeneous mixture of two immiscible phases, in which one is continuous phase and is called dispersion.

Concept Ladder

Colloidal state is an intermediate state between solution and suspension.

- medium (external phase) while other is a discontinuous phase called dispersed phase (internal phase).

Colloidal Systems

Dispersed phase	Dispersion medium	Colloidal system	Examples
Gas	Liquid	Foam or froth	Soap sols, lemonade froth, whipped cream
Gas	Solid	Solid foam	Pumice stone, styrene foam, foam rubber, Dried sea foam
Liquid	Gas	Aerosols of liquids	Fog, clouds, mist fine insecticide sprays
Liquid	Liquid	Emulsions	Milk, cold cream, tonics
Liquid	Solid	Gels	Cheese, butter, boot polish, table jellies
Solid	Gas	Aerosols of solids	Smoke, dust, haze
Solid	Liquid	Sols	paints, starch dispersed in water, gold sol, muddy water, inks
Solid	Solid	Solid sols	Ruby glass, gem stones, minerals.

Classification of Colloids

Colloids can be classified into a number of ways based upon some of important characteristics.

Based upon appearance

- A colloidal system in which dispersion medium is liquid or gas is called a sol. They are known as hydrosols or aquasols if dispersion medium is water.
- Colloidal systems in which the dispersion medium is a gas are called aerosols.

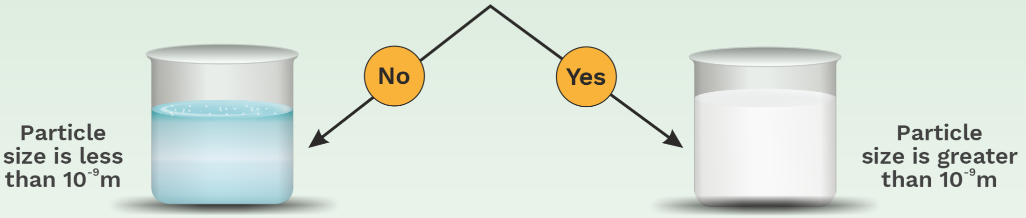
Concept Ladder

When the dispersion medium is alcohol or benzene, they are accordingly called alcosols or benzosol.

WHAT ARE COLLOIDS

Is Milk A Colloidal Solution ?

Partical size > 10^{-9}m



Particle size is less than 10^{-9}m

Salt Solution
(true Solution)

Particle size is greater than 10^{-9}m

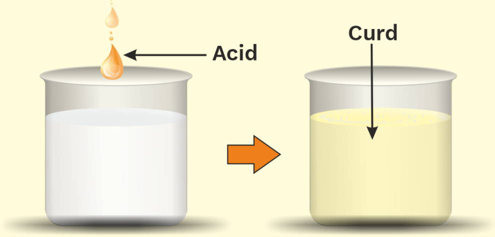
Milk
(Colloidal)

Colloids are everywhere around us

Colloids = dispersed phase + dispersed medium

How Curd Is Formed ?

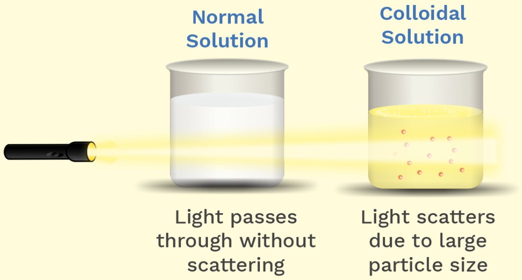
Coagulation : It is a process of forming precipitate by adding electrolyte to a colloidal solution.



Adding electrolytes to colloidal solution causes opposite charge to combine and form precipitate. Here acid is the electrolyte added and curd is the precipitate fomed.

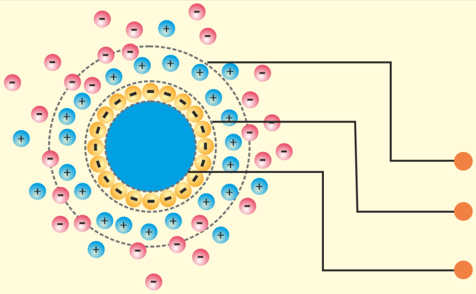
Tyndall Effect

Tyndall Tyndall effect is observed in morning, where sunlight scatters due to colloidal solution i.e. Fog.



Stability of colloids

Colloids are generally unstable. They are stabilised by forming a electric double layer.



- **Diffuse Layer :-** Diffuse layer consists of both the ions with higher concentration of counter ions
- **Stern Layer :-** Layer formed due to electrostatic attraction of opposite ions to the particle surface
- **Surface Charge :-** Formed by absorbing charged ions on particle.

A systems in which dispersion medium is a solid & is known as gels, for example, cheese.

Based upon charge

The colloids that can be classified into positive or negative colloids according to charge present on dispersed phase particle.

Based on interaction or affinity of phase

- **Lyophilic colloids (Suspensoid):** The colloidal systems in which the particle of dispersed phase have great affinity for the dispersion medium, are called lyophilic (solvent loving) colloids. Some common examples of lyophilic colloids are gum, gelatin, starch, rubber and protein.
- **Lyophobic colloids (Emulsoid):** A colloidal systems in which particles of dispersed phase have no affinity for dispersion medium are called lyophobic (solvent hating) colloids. Few examples of lyophobic colloids include sols of metals and their insoluble compounds like oxides and sulphides.
- **Based on molecular size:** Depending upon molecular size, colloidal system has been classified into three groups:
- **Multimolecular colloids:** The multimolecular colloidal particles consist of aggregate of atoms or small molecules with diameters less than 10^{-9} m or 1 nm. For example, gold sol, sulphur sol.
- **Macromolecular colloids:** Macromolecular colloidal particles themselves are very large molecules. They have high molecular masses varying from thousands to millions. Examples of naturally occurring macromolecules are starch, proteins and cellulose. Example of artificial macromolecules are polyethylene, nylon, dacron, synthetic rubber, polystyrene, and plastics.

Concept Ladder

Colloids of metal hydroxides are generally positively charged while colloids of metal sulphides are negatively charged.

Rack your Brain

What is Emulsoid?

Previous Year's Question

Fog is a colloidal solution of **[NEET]**

(1) solid in gas
(2) gas in gas
(3) liquid in gas
(4) gas in liquid

- **The associated colloids or micelles:** These type of colloids behave as normal electrolytes at low concentrations but behave as colloids at higher concentrations because at higher concentrations, (above C.M.C.) and above kraft temperature they form aggregated (associated) particles called miscellas. Soap and synthetic detergents are some examples of associated colloids. They produce ions which may have colloidal dimensions.

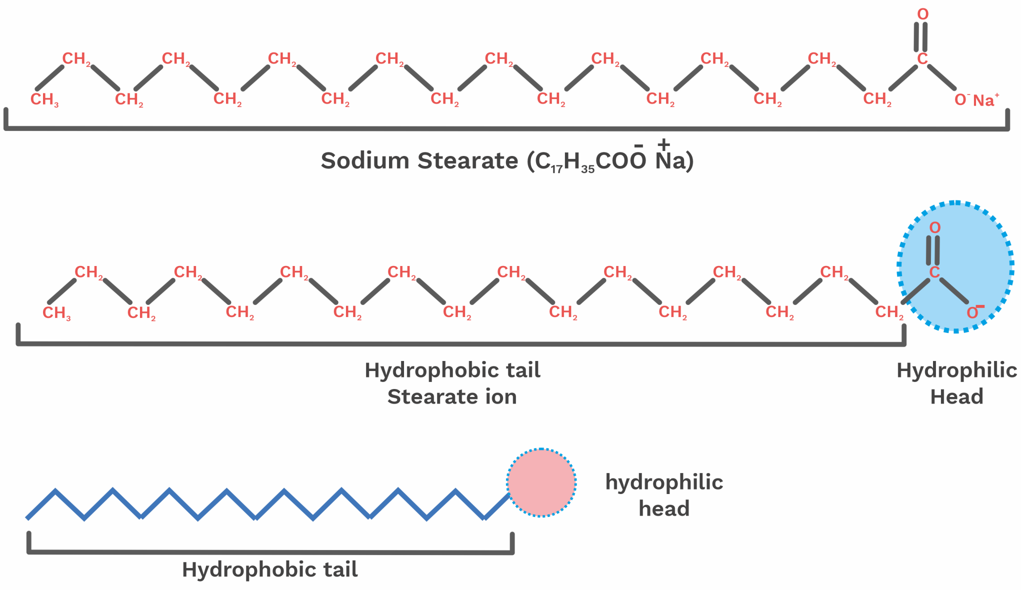
$$\mathrm{RCOONa} \rightleftharpoons \mathrm{RCOO^-} + \mathrm{Na^+}$$

Difference Between Lyophilic and Lyophobic Sols

S.No	Property	Lyophilic sols	Lyophobic sols
1.	Nature	Reversible	Irreversible
2.	Preparation	They can be prepared very easily by shaking or warming the substance with dispersion medium. They do not require any electrolyte for stabilization.	They can be prepared by special methods and addition of stabilizer is essential for their stability
3.	Stability	They are so stable that they are not easily coagulated by electrolytes.	They are generally unstable and get easily coagulated on addition of electrolytes
4.	Charge	Particles may carry no charge or very little charge depending upon the pH of the medium	Colloidal particles have characteristic charge (positive or negative).
5.	Viscosity	It is much higher than that of medium.	It is nearly same as that of medium.
6.	Surface tension	Surface tension is usually less than medium.	It is nearly same as that of the medium.

S.No	Property	Lyophilic sols	Lyophobic sols
7.	Migration in electric field	The particles may or may not migrate in an electric field	The colloidal particles migrate either towards cathode or anode in an electric field
8.	Solvation	Particles are highly solvated	Particles are not solvated
9.	Visibility	The particles cannot be seen under ultra-microscope	The particles though invisible, can be seen under ultra-microscope.
10.	Tyndall effect	Less distinct	More distinct
11.	Colligative electrolyte	They have relatively higher osmotic pressure, high depression of freezing point, high elevation in boiling point and high lowering of vapour pressure.	They have high osmotic pressure, small depression of freezing point, less elevation of boiling point, and less lowering of vapour pressure
12.	Action of electrolyte	Large amount of electrolyte is required to cause coagulation.	Small amount of electrolyte is sufficient to cause coagulation
13.	Conductivity	They show high conductivity which can be measured.	Due to their sensitivity in electrolyte, conductivity can rarely be measured over a considerable range of concentration
14.	Cataphoresis	The measurement of cataphoresis is difficult	It can be easily measured.
15.	Examples	Most of the organic substances for example, starch, gums, proteins, gelatin.	Generally inorganic substances for example, metal sols, sulphides and oxides sols.

The long-chain $RCOO^-$ ions combine or aggregate at higher concentration and form micelles and behave as colloids. They may contain 100 or more molecules. Some cationic surfactants like also behave micelles above **kraft temperature** and critical micelles concentration.



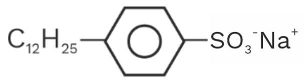
Hydrophobic and hydrophilic parts of stearate iond

For example,

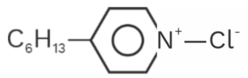
(1) Cetyl trimethyl ammonium bromide

$[CH_3(CH_2)_{15}N^+(CH_3)_3Br]$

(2) p-dodecyl benzene sulphonate



(3) Cetyl Pyridinium chloride



(4) Sodium lauryl sulphate

$CH_3(CH_2)_4\ SO_4\ Na$

Concept Ladder

Sodium stearate $C_{17}H_{35}COONa$ (Anionic Surfactant) is an example of an associated colloid. In water it gives Na^+ and stearate, $(C_{17}H_{35}COO^-)$ ions. These ions associate to form micelles of colloidal size.

Preparation of Lyophilic Sols

Substances which are coined as intrinsic colloids such as gelatin, starch and rubber, are converted into colloidal solutions when heated with water or some other suitable solvent. The colloidal solutions thus obtained are known as lyophilic sols. Such sols are reversible and are quite stable.

Preparation of Lyophobic Sols

Few substances which are termed as extrinsic colloids (such as metals), are not passed directly into a colloidal solution but are passed when they are treated with water or other solvents. These substances are converted into colloidal solutions by following two methods:

- Dispersion methods
- Condensation methods

Dispersion method

These methods are used to break down bigger particles to size of colloidal particles. The various dispersion methods used are:

1. **Mechanical dispersion method:** Coarse particles of substance to be dispersed are agitated with dispersion medium, i.e, water or some other liquid, to obtain a suspension. After that, suspension is passed through a mill (colloidal). For example, varnish , colloids of paint.
2. **Electro-disintegration method (Bredig's arc method):** Colloidal solution of metals like silver, gold or platinum are obtained by electro-disintegration method. (Bredig's arc method). In this, metals (Ag, Cu, Pt) whose colloidal solution is to be prepared are taken as electrodes and are dipped in the cold-water having KOH as stabilizer.

Concept Ladder

Blood is a colloidal solution. In case of kidney failure, blood cannot be purified. Under such condition, the blood is separated from dissolved toxic impurities by dialysis and re-introduced in the blood stream.

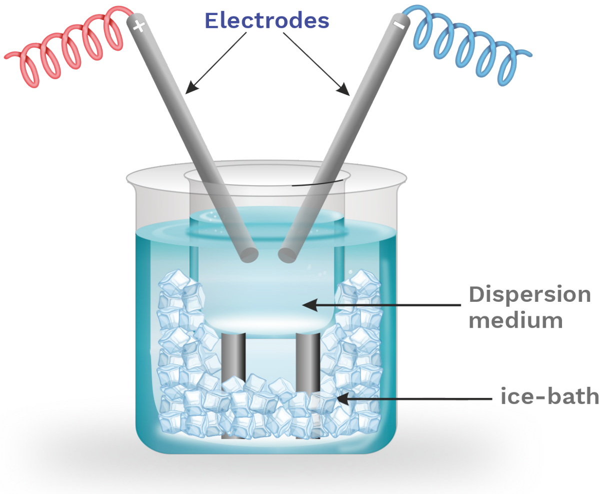
Rack your Brain

To which colloidal system does mist belong?

Previous Year's Question

Measuring zeta potential is useful in determining which property of colloidal solution? **[NEET]**

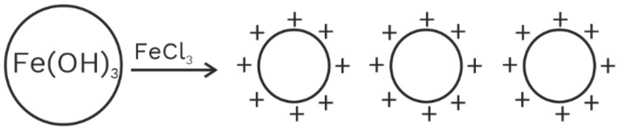
(1) Viscosity
(2) Solubility
(3) Stability of the colloidal particles
(4) Size of the colloidal particles



Bredig's Arc method

3. **Peptization:** This process involves conversion of fresh precipitates into colloidal solution is called peptization. Electrolyte which is added is known aspeptizing agent or dispersing agent.

- For example, to a freshly precipitated solution of ferric hydroxide converts into a colloid when small amount of electrolyte ferric chloride is added.



Freshly precipitated $Fe(OH)_3$ Colloidal particles of $Fe(OH)_3$

- Peptization may be carried out by the following ways:

(a) By dispersion medium
(b) By washing a precipitate
(c) By electrolyte

Cause of peptization: On adding electrolyte to freshly precipitated substance, particles of precipitate preferentially adsorb a particular type of ion of electrolyte and get dispersed due

Concept Ladder

Electro-dispersion method is not suitable when the dispersion medium is an organic lqiuid.

Rack your Brain

What are the causes of peptization?

Concept Ladder

The colloidal solution of silicic acid is also obtained by hydrolysis of dilute solution of sodium silicate with 4N hydrochloric acid which is added drop by drop with constant stringing.

to electrostatic repulsion. This produces particles of the colloid.

$$\underset{\text{Precipitate}}{Fe(OH)_3} + Fe^{3+} \longrightarrow \underset{\text{Colloidal sol}}{Fe(OH)_3Fe^{3+}}$$

Condensation methods: These type of methods involve growing of size of dispersed phase to size of colloidal particles. Various condensation methods used are:

- Physical methods
- Chemical methods

Chemical methods

1. **By double decomposition:** A colloidal solution of As_2S_3 may be obtained by passing hydrogen sulphide gas through cold dilute solution of arsenious oxide in water.

   $$As_2O_3 + 3H_2S \longrightarrow \underset{\text{Intense yellow colloidal solution}}{As_2S_3} + 3H_2O$$

   The solution of As_2S_3 is negatively charged because sulphide ions are absorbed on solution particles.

2. **By hydrolysis:** A deep red colloidal solution of is $Fe(OH)_3$ fomed by hydrolysis of ferric chloride when its dilute solution is boiled with water.

   $$FeCl_3 + 3H_2O \longrightarrow \underset{\text{Deep red colloidal solution}}{Fe(OH)_3} + 3HCl$$

3. **By oxidation:** A colloidal solution of sulphur is obtained by the oxidation of hydrogen sulphide with dilute nitric acid or bromine water or sulphur dioxide.

   $$H_2S + 2HNO_3 \longrightarrow 2H_2O + 2NO_2 + \underset{\text{Colloidal}}{S}$$

4. **By reduction:** A colloidal solution of Au(gold) is obtained by reduction of gold chloride with stannous chloride or formaldehyde or hydrazine.

   $$2AuCl_3 + 3SnCl_2 \longrightarrow \underset{\text{Purple of cassius}}{3SnCl_4} + 2Au$$

Concept Ladder

Lyophilic colloids such as starch, gelatin, etc., act as protective colloids.

Rack your Brain

Which property can be used to distinguish collidal solution from true solution?

Previous Year's Question

Which one of the following method is commonly used method for destruction of colloid? **[NEET]**

(1) Dialysis
(2) Condensation
(3) Filteration by animal membrane
(4) By adding electrolyte

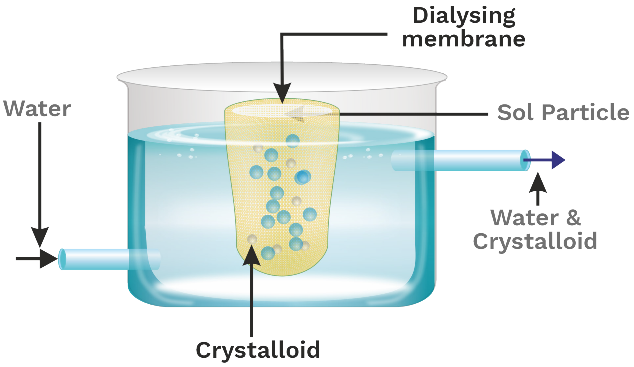
Physical methods

1. **By excess cooling:** Colloidal solution of ice in an organic solvent like ether or chloroform is obtained by freezing a solution of water in solvent.
2. **By exchange of solvent:** Substances like sulphur, phenolphthalein and resin which are highly soluble in alcohol or some other organic solvent yield colloidal solutions when their solutions in alcohol or other solvents are poured into water, in which substances are less soluble. Colloidal solutions thus obtained are less stable.
3. **By passing vapour of substance through solvent:** Colloidal solutions of substances like sulphur and mercury in water, are prepared by passing vapours of substance in cold water containing a little amount of ammonium citrate as a stabilizing agent.

Purification of Colloidal Solutions

The following methods are commonly used for the purification of a sol:

Dialysis: The process of removing a dissolved substance from the colloidal solution (system) by means of diffusion through a suitable membrane is called dialysis and the apparatus used for this purpose is known as dialyser (parchment paper or animal membrane).



Dialysis

Previous Year's Question

When a few typical solutes are separated by a particular selective membrane such as protein particles, blood corpuscles, this process is called. **[AIPMT]**

(1) transpiration
(2) endosmosis
(3) dialysis
(4) diffusion

Rack your Brain

Can a colloidal solution conduct electricity?

Previous Year's Question

Which mixture of the solutions will lead to the formation of negatively charged colloidal [AgI] sol? **[NEET]**

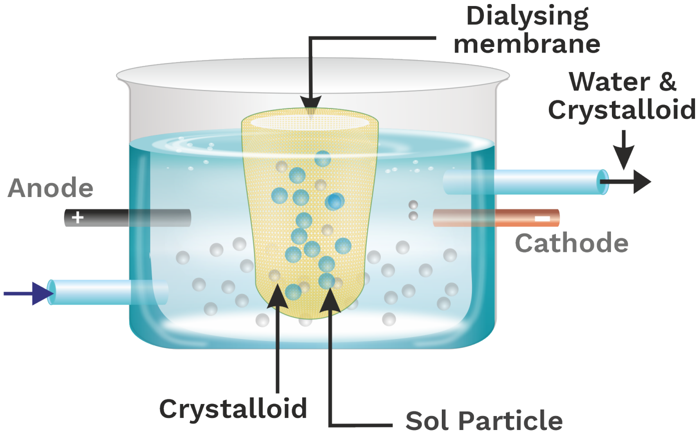
(1) 50 mL of 0.1 M $AgNO_3$ + 50 mL of 0.1 M KI
(2) 50 mL of 1 M $AgNO_3$ + 50 mL of 1.5 M KI
(3) 50 mL of 1 M $AgNO_3$ + 50 mL of 2 M KI
(4) 50 mL of 2 M $AgNO_3$ + 50 mL of 1.5 M KI

Electrodialysis : In electrodialysis, dialysis bag is surrounded by two electrodes. When a high potential is given, cation and anion of electrolyte are attracted by oppositely charged electrodes and impurities are easily and quickly removed from colloidal solution (sol). By this method, we can not remove non- electrolyte impurities.

Ultrafiltration: The process of separating the colloidal particles from the solvent and solute using specially prepared filters which are permeable to all substances present, except colloidal particles, is called ultrafiltration. For it, we use cellophone membrane (4% solution of Nitro cellulose in Alcohol and ether i.e., collodion solution)

Definitions

The process of dialysis can be accelerated by applying an electric field. This process is called Electrodialysis.



Electro-dialysis

Properties of Colloidal Solutions

The various properties of colloidal solutions are:

- Physical properties
- Mechanical properties
- Optical properties
- Electrical properties
- Colligative properties

Concept Ladder

Ultra filtration is a slow process. To speed up the process, pressure or suction is used.

Physical properties

1. **Heterogeneity:** Colloidal solutions are heterogeneous consisting of two phases, viz., dispersed phase and dispersion medium.
2. **Filterability:** Colloidal particles readily pass-through ordinary filter papers as the size of the pores of the filter paper is larger than that of the colloidal particles.
3. **Non-setting nature:** Colloidal solutions are quite stable as the colloidal particles remain suspended in the dispersion medium indefinitely, that is, there is no effect of gravity on the colloidal particles.
4. **Colour:** The colour of the colloidal solution is not always the same as the colour of the substances in the bulk. The colour of the colloidal solution depends upon the following factors:
   (a) Size and shape of colloidal particles
   (b) Wavelength of the source of light
   (c) Method of preparation of the colloidal solution
5. **Stability:** Colloidal solutions are quite stable. For example:
   (a) Finest gold is red in colour (has a very small particle size) as the size of particles increases, it becomes purple.
   (b) Dilute milk gives a bluish tinge in reflected light while it gives a reddish tinge in transmitted light.

Mechanical properties

1. **Brownian movement:** It is the dispersal medium in which the colloid particles exhibit swarming zig-zag and a ceaseless random motion. It was firstly shown by Robert Brown. Dispersed phase particles starts moving in the direction of net force when a colloid is formed between the dispersal medium particles and the dispersed phase particles. It increases the stability of colloids. It is far more smaller particle and in less viscous solvent.

Concept Ladder

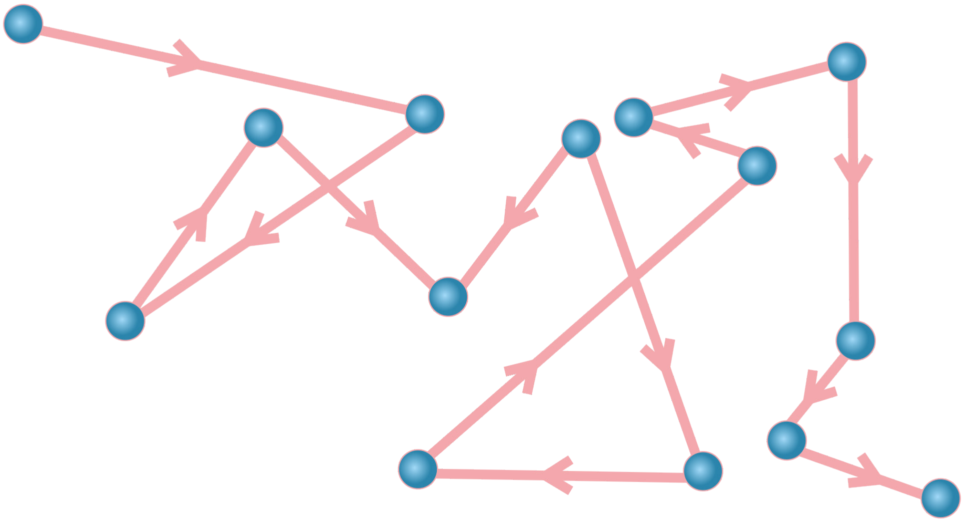
Experiments like dialysis and ultra-filtration indicate the heterogenous nature of the colloidal system.

Rack your Brain

The brownian movements is due to?

Concept Ladder

The way an observer receives the light, that is, whether by reflection or by transmission.



Brownian movement

2. **Sedimentation:** The heavier sol particles tend to settle down very slowly under the influence of gravity. This event is called sedimentation.
3. **Diffusion:** The colloidal particles have a tendency to diffuse from high concentration to a low concentration. The rate of diffusion of colloidal particles is less than that of true solutions.

Optical properties (Tyndall effect)

The path of a strong and conveying beam of light (wavelength between UV and visible region) becomes visible whenever it is passed through a colloidal solution and is viewed at right angles to the beam of light.

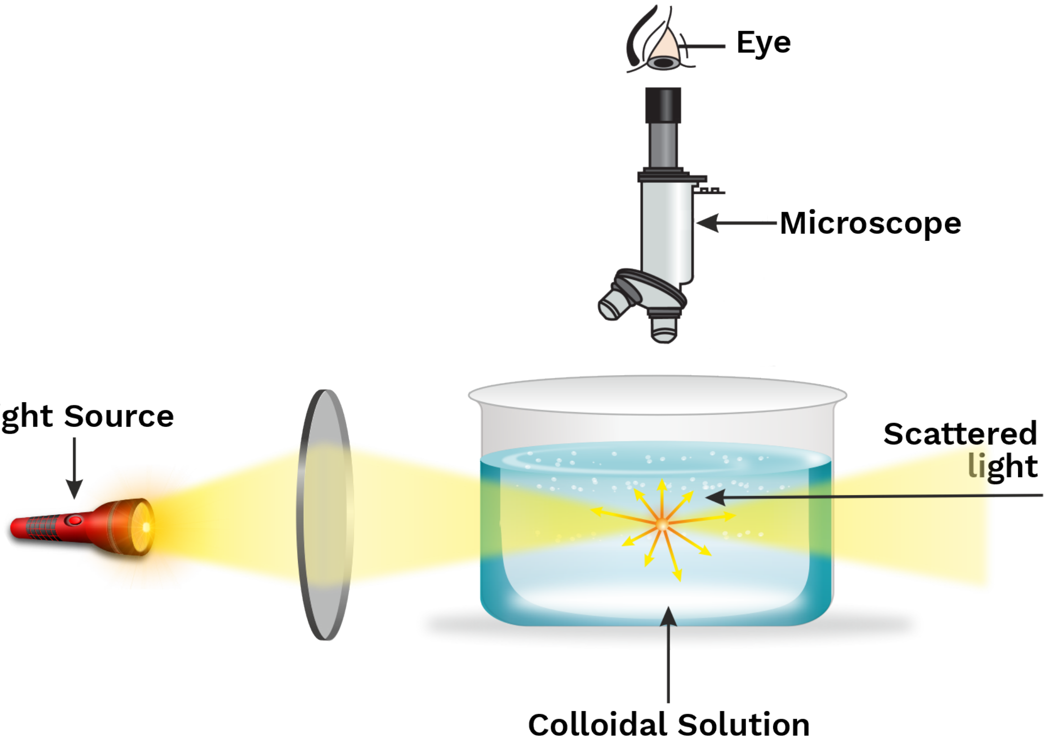
For devising the ultramicroscope, Tyndall effect was used by Siedentop and Zsigmondy.

The sky looks blue due to the scattering of light by colloid particles and also when a beam of light passes through a dark area dust particles are visible.

Previous Year's Question

Which property of colloidal solution is independent of charge on the colloidal particles? **[NEET]**

(1) Electroosmosis
(2) Coagulation
(3) Tyndall effect
(4) Electrophoresis

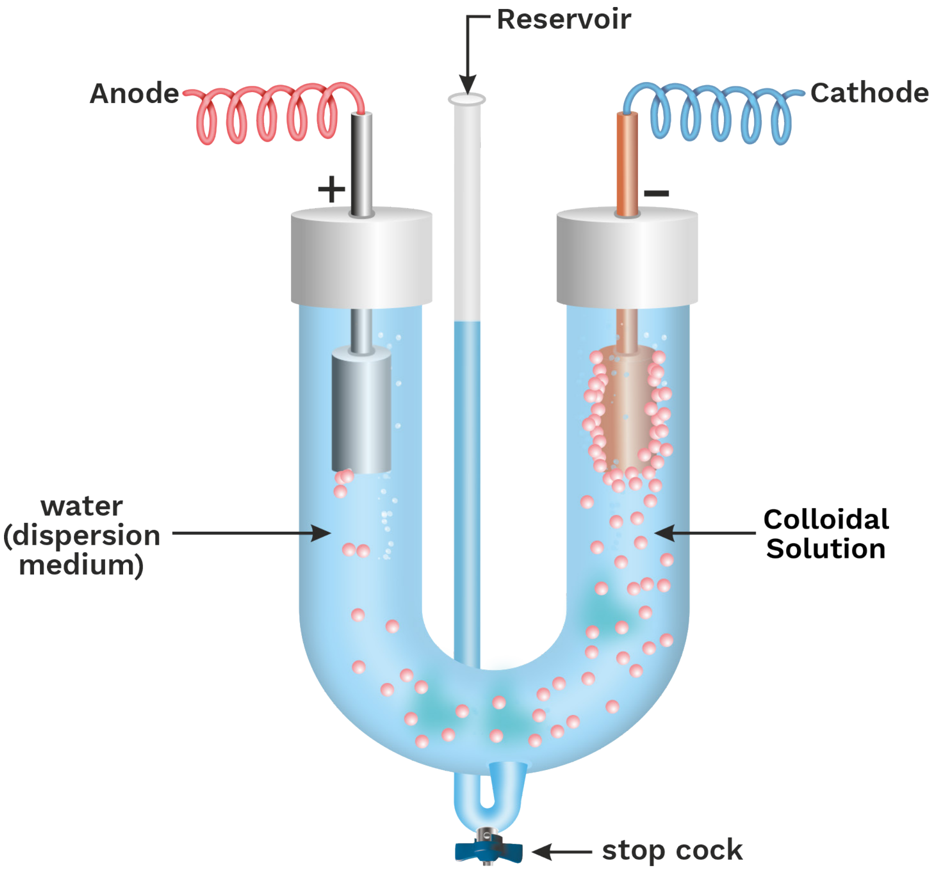


Electrical properties: The following are the two electrical properties of colloidal solutions:

1. **Electrophoresis or cataphoresis:** The phenomenon in which under the influence of electric field, the colloidal particles get migrated towards the oppositely charged electorde is known as electrophoresis or cataphoresis. It helps in finding charge on colloid particles.

Q.4 Why the sun looks red at the time of setting? Explain on the basis of colloidal properties.

A.4 The light emitted by the sun at the time of setting when the sun is at the horizon, has to travel a longer distance through the atmosphere. As a result, blue part of the light is scattered away by the dust particles in the atmosphere. Hence, the red part is visible.



Electrophoresis

2. **Electro-osmosis:** This involves the migration of the dispersion medium & not the colloidal particles under influence of an electric field. It helps in drying dye pastes, in removing water from peat, etc.

Origin of charge

Many reasons were given for the origin of charge on the colloidal particles. They can be followed as:

1. **Frictional electrification:** By rubbing of the dispersed phase particles with molecules of the medium, it is believed to be frictional.

Rack your Brain

What is the application of electro- osmosis?

2. **Dissociation of the surface molecules:** By dissociation, electric charges is formed on colloidal particles. For ex. dissociation of soap (sodium palmitate) into ions in an aqueous solution.

   $$\underset{\text{Sodium palmitate}}{C_{15}H_{31}COONa} \rightleftharpoons C_{15}H_{31}COO^{-} + Na^{+}$$

   The sodium ions pass into the solution while $C_{15}H_{31}COO^{-}$ ions have a tendency to form aggregates due to weaker forces of attraction present in the hydrocarbon chains. Therefore, the anions which are of collidal size carries negative charge.
3. **Preferential adsorption of ions from solution:** The colloidal particles can aquire electric charges by preferentially adsorbing positive or negative ions from the electrolyte. Silver chloride particles can absorb Cl^{-} ions from chloride solutions (KCl) and Ag^{+} ions from solution having Ag^{+} ions $AgNO_3$. In the first case the solution will be negatively charged whereas for second case it will be positively charged.

Sols with electrical charge

- **Positively charged sols:** Aluminium hydroxide, ferric hydroxide, basic dyes such as hydrated metallic oxides, haemoglobin, methylene blue.
- **Negatively charged sols:** Metals, such as gold, silver, platinum, metal sulphides like arsenius sulphide, starch, gum, gelatin, charcoal clay, salycylic acid, acid dyes (such as eosin).

Coagulation or flocculation: The presence of electric charges on the colloidal particles makes the colloidal sols stable. By electrical repulsion, the particles do not come close to one another for forming precipitates.

- The reciprocal of coagulation value is termed as the coagulating power.

Hardy–Schulz rule: This rule states that, “With increase in the valency of the active electrolyte ion, its power to precipitate the sol increases.”

Previous Year’s Question

On which of the following properties does the coagulating power of an ion depend? **[NEET]**

(1) the magnitude of the charge on the ion alone
(2) Size of the ion alone
(3) Both magnitude and sign of charge on the ion
(4) The sign of charge on the ion alone

Concept Ladder

The removal of charge by any means that lead to the aggregation of particles for precipitation is known as coagulation and the minimum amount of an electrolyte required to cause precipitation of one litre of a colloidal solution is called coagulation value or flocculation value of the electrolyte for the sol.

- $Si^{+4} > Al^{3+} > Mg^{2+} > Na^{+}$ is the order for coagulation power of cations for negatively charged colloids.

Concept Ladder

The coagulation power of anion for positively charged sol is

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

Protection and gold number: By using a protective lyophillic colloid, protections is involved in protecting the lyophobic colloid from co- agulation. The power of protection can be expressed as gold number.

The value of the protective colloid in milligrams (mg) needed to prevent the coagulation of a standard 10 mL gold sol when 1ml of 10% solution of NaCl is added to it, is termed as its gold number.

Gold number is inversly proportional to the protection power.

Colloid	Gelatin	Gum	Haemoglobin	Starch
Gold no.	0.005–0.01	0.15	0.03	25

e.g., Gelatin is added in ice creams to protect co-agulation of ice particles.

Colligative properties: Due to the large size of colloidal particles, the effect of colloidal particle on colligative properties is very small, except osmotic pressure.

Definitions

Colloidal solutions too exhibit colligative properties such as osmotic pressure, lowering of vapour pressure, depression in freezing point and elevation in boiling point.

Emulsions

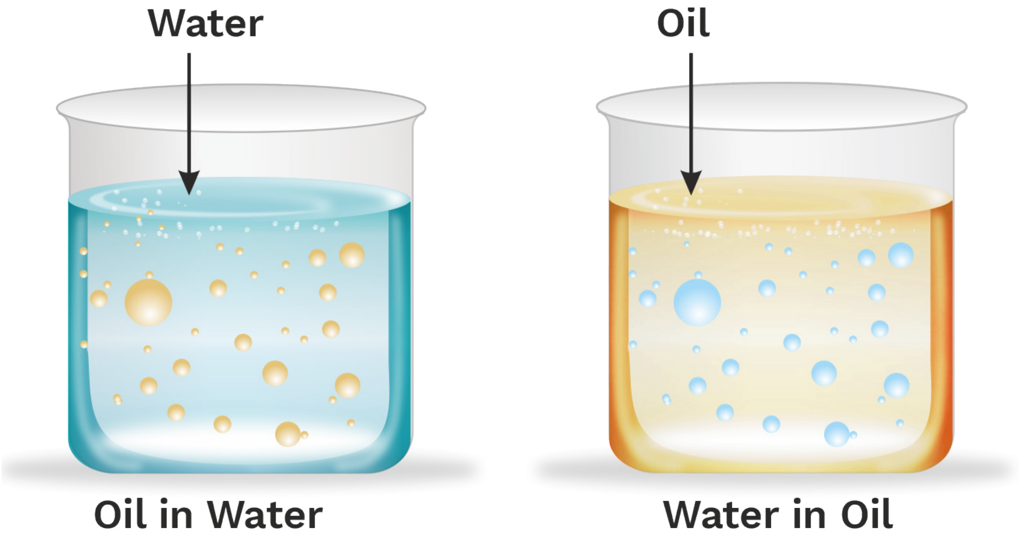
There are two types of emulsions: (a) water in oil, (b) oil in water emulsions.

To test the type of emulsion, either dye test or conductance measurement test may be performed.

- Hydrophilic emulsifiers: these emulsifiers are used to promote formation of oil-water emulsions like milk as they can dissolve better in water than in oil.
- Hydrophobic emulsifiers: on the other side, these emulsifiers can dissolve better in oil than in water and therefore these favour formation of water–oil emulsions as in cold cream.

Definitions

Emulsion is a colloidal solution of two immiscible liquids, in which the liquid acts as the dispersed phase as well as the dispersion medium.



Types Of Emulsions

Uses of emulsions

1. Many pharmaceutical preparations, medicines, ointments, creams and various lotion are emulsions. It is believed that medicines are more effective and easily assimilated by the body tissues when they are in colloidal form, that is, as emulsions.
2. All paints are emulsions.
3. Soaps and detergents remove dust and dirt from the dirty piece of cloth by making an oil in water emulsion.
4. Milk is an emulsion of liquid fats in water.
5. In froth floatation process, an oil is added to the finelydivided ore taken in water.
   The particles of ore go on to the surface due to the formation of foams while the other impurities are left at the bottom of the vessel.
6. The emulsion of asphalt in water is used in constructing roads and buildings.

Gels

Gels are that type of colloids in which dispersed phase and dispersion medium are made up of liquid and solid substance respectively.

Concept Ladder

The digestion of fat in the intestines is aided by emulsification. Fat present in food is emulsified by alkaline bile juices secreted from the small intestines, thus making it easier for the digestive enzymes to carry out their metabolic functions.

- Hydrophilic sols of agar-agar, gum-arabic, gamboges, mastic and gelatin can be converted by cooling them under moderate concentration condition into gels.
- Hydrophobic gels like aluminium hydroxide and silicic acid commonly known as alumina gel and silica gel, are prepared by method of double decomposition.
- Change of solvent method is also used for preparing hydrophobic gels, for ex. when C_2H_5OH is added rapidly to the solution of $C_4H_6CaO_4$ of fair concentration, gelation occurs after some time.

Elastic gels

- Elastic gels can swallow water when placed in it and causes swelling. This is known as swelling or imbibition. Examples of elastic gels are agar-agar, starch and gelatin.

Non-elastic gels

- These are irreversible gels, when hydrated, can be changed into powder or become glassy. They cannot be changed into their original form when hydration is followed by warming.
- Non-elastic gels cannot swellow water therefore they do not cause the swelling phenomenon.
- Alumina, silica and ferric oxide gels are important examples of non-elastic gels.
- When external pressure is applied on gel, it increases the rate of syneresis.

Thixotropy: Some of the gels, specially silica (irreversible) and gelatin (reversible) liquefy on shaking, changes to corresponding sols. The sol reverts back to gel. This process of sol–gel transformation is known as thixotropy.

Application of Colloids

Food

1. Mostly food items are colloidal in nature. For ex. casein is a lyophilic colloid.
2. For preserving smoothness of ice cream, gelatine is added as a protective colloid.

Rack your Brain

Write 5 examples of emulsion with dispersion phase and dispersion medium.

Definitions

Sols, when coagulated under some special conditions, change into semi-rigid mass, enclosing whole amount of liquid within itself. This semi-rigid mass is known as a gel.

Definitions

These are reversible gels. When partially dehydrated, they change into a solid mass. This mass changes back into its original form on simple addition of water, followed by slight heating.

Medicine

1. Colloidal gold and calcium are administered by injections for enhancing the vitality of the human body.
2. 2. Colloidal silver (protagol and argyrols) are used for eye lotions.
3. For insecticides, colloidal sulphure is used.
4. Emulsions such as dettol and phenyl are used as disinfectants.
5. Colloidal antimony is used to treat kala-azar.
6. Colloidal arsenic is used for treatment of eye diseases.

Industrial materials

1. Varnishes, enamels cellulose, paints, resins, glues, gums and other adhesives are colloidal in nature.
2. Latex is a suspension of negatively charged colloidal particles of rubber.

Rubber plating: By the process of electrophoresis, there is deposition of negatively charged particles of latex on handles of various tools or wires to insulate them. Anode is made by the particle which is to be rubber plated. Under the effect of an electrical field the rubber particles get migrated towards the anode and deposited on it.

Detergent action of soap: The addition of soap reduces the interfacial tension between grease and water & this causes emulsification of grease in water. Dirt is released by mechanical action.

Cleaning of water: Fine clay produces turbidity in water by its negatively charged particles. The addition of aluminium sulphate or potash-alum furnishes trivalent Al^{3+} ions causing coagulation of clay particles. By this coagulum settles downwards and thussuspensions are cleared from water.

Cottrell precipitator: The principle of electrophoresis is used for removal of dust and smoke particles from air.

Concept Ladder

Both elastic and non elastic gels undergo shrinking in volume when allowed to stand. This phenomenon is known as syneresis.

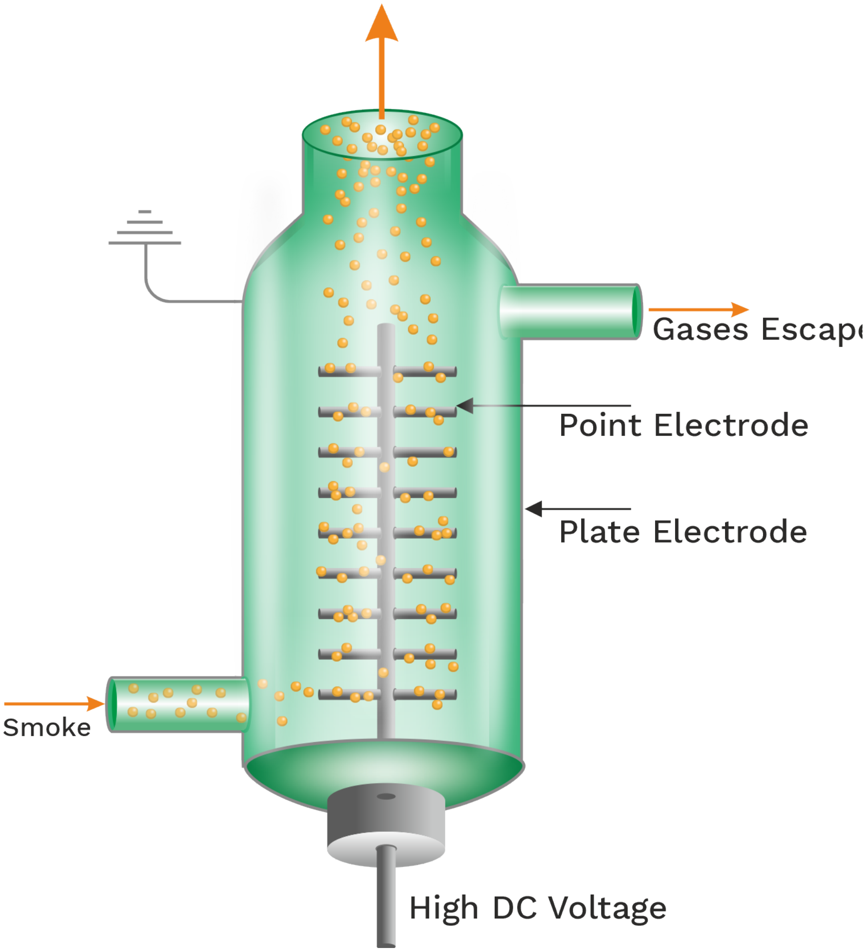
Rack your Brain

Why non-elastic gels do not undergo swelling?

Previous Year's Question

Which one of the following forms micelles in aqueous solution above certain concentration? **[AIPMT]**

(1) Dodecyl trimethyl ammonium chloride
(2) Glucose
(3) Urea
(4) Pyridinium chloride



Chrome-tanning: It is the process of penetrating positively charged particles of hydrated chromic oxide into leather.

Smoke screens: Titanium dioxide is used in smoke screen as it makes the smoke rapidly settle down.

Formation of deltas: There is formation of deltas, in the area where big rivers meet the sea.

By the salts present in the sea water the charged clay particles carried by river water as suspension are precipitated out.

Previous Year's Question

The protecting power of lyophilic colloidal sol is expressed in terms of **[NEET]**

(1) Coagulation value
(2) Gold number
(3) Critical micelle concentration
(4) Oxidation number

Q.5 Why do we add alum to purify water?

A.5 Muddy water contains mud particles which are colloidal in nature and carry charge. Alum provides Al^{3+} ions which bring about coagulation of mud particles which settle down.

Q.6 What is the 'coagulation' process?

A.6 Coagulation or precipitation of the solution is the process for settling of colloidal particles.

Q.7 What is meant by 'shape-selective catalysis' of reactions?

A.7 Shape-elective catalysis is the catalyst reaction in which small sized molecules are absorbed in the cavities and pores of selective adsorbents like zeolites.

Q.8 Out of NH_3 and CO_2 which gas will be adsorbed more readily on the surface of activated charcoal and why?

A.8 NH_3 gas has higher critical temperature than CO_2 and also it can be liquified easily therefore, it will be adsorbed more readily on activated charcoal. Its van der Waals forces are stronger.

Q.9 Write two applications of adsorption.

A.9 Applications of adsorption :

1. Charcoal, in gas masks is used which adsorbs poisonous gases in mines
2. In decolorisation of sugar.

Q.10 Why do true solutions not show Tyndall effect?

A.10 In true solution, the wavelength of the light used is much larger than the diameter of the dispersed particles, hence there is no scattering of light.

Q.11 Why is adsorption always exothermic?

A.11 Adsorption is accompanied by decrease of randomness. For the process to be spontaneous,
ΔG must be negative.
Hence, according to equation $\Delta G = \Delta H - T\Delta S$, ΔG can be -ve only if ΔH is negative.

Q.12 A delta is formed at the melting point of sea water and river water. Why?

A.12 On the meeting point of river water and sea water, delta is formed due to coagulation of colloidal clay particles.

Q.13 Write one similarity between physisorption and chemisorption.

A.13 Both physisorption and chemisorption increase with increase in pressure. Both increase with increase in surface area.

Q.14 Why do we see a beam coming from projector to screen in a cinema hall?

A.14 This is due to scattering of light coming from the projector by the particles of the dust present in the air and falling in the path of the beam of light.

Q.15 Why causes Brownian movement in a colloidal solution?

A.15 Brownian movement, i.e., zig-zig movement of the colloidal particles is due to hitting of these particles by molecules of dispersion medium with different forces from different directions.

Q.16 What type of solutions are formed on dissolving different concentrations of soap in water?

A.16 At low concentration, soap solution form a true solution. At concentrations above crirtical micelle concentration (cmc), it forms a colloidal sol.

Q.17 Why artificial rain can be caused by throwing common salt on the clouds?

A.17 Clouds are formed by colloidal dispersion of water particles in air. The colloidal water particles carry charge. On throwing common salt on the clouds coagulation of water particles takes place as common salt is an electroluyte.

Q.18 On the basis of Hardy-Schulze rule explain why coagulating power of phosphate is higher than chloride.

A.18 According to Hardy-Schulze rule, greater than valency of the flocculating ion added, greater is its power to cause coagulation or precipitiation. Phosphate ion (PO_4^{3-}) has greater charge than chloride ion (Cl^-). Hence, PO_4^{3-} ion has greater coagulating power.

Q.19 Why does bleeding stop by rubbing mois alum?

A.19 Moist alum coagulates the blood as it is a colloidal sol. and alum provides Al^{3+} ions. As a result, a clot of blood is formed. Hence, it stops bleeding.

Q.20 Do the vital functions of the body such as diagestion get affected dcuring fever? Explain your answer.

A.20 Yes, vital functions of the body are affected during fever. This is because biological reactions taking place in our body are catalysed by enzymes. These enzymes show maximum activity in the temperature range 298-310K. during fever, when temperature rises above 310K, enzuymatic activity becomes less.

Chapter Summary

1. When the collidal soltuion of cellulose nitrate is prepared in ethanol, then the solution is called as collodion.
2. The purification of blood by artifical kidney is performed by the process of dialysis.
3. By scattering of light due to colloidal dust particles dispersed in air the colour of sky appears to be blue.
4. Mutual coagulation is the process in which the solutions are percipitated simultaneously. For example when negatively charged As_2S_3 solution is added to positively charged $Fe(OH)_3$ solution in suitable amounts.
5. Flocculation value of an ion

$$\propto \frac{1}{\text{Coagulating power of the ion}}$$

6. For the contribution in colloidal chemistry, Zsigmondy was awarded the Nobel prize chemistry in 1925.
7. Ostwald introduced congo rubin number. Which is defined as “The amount of protective colloid in mg. That prevents colour change in 100ml of 0.01% congo rubin dye. From the addition of 0.16gn KCl.
8. In case of soaps and detergents C.M.C is 10^{-4} — 10^{-3} M/L
9. Fresh precipitates of CdS, HgS are peptized by H_2S.
10. Fresh precipitates of Stannic acid is peptized by $HCl_{(eq)}$ or $NH_{3(eq.)}$
11. Colloid solution of Graphite is called Aquadag.