SURFACE CHEMISTRY

CONTENTS

JEE(Advanced) Syllabus

Concepts : Elementary concepts of adsorption (excluding adsorption isotherms);
Colloids : Types, methods of preparation and general properties; Elementary ideas of emulsions, surfactants and micelles (only definitions and examples).

JEE(Main) Syllabus

Adsorption - Physisorption and chemisorption and their characteristics, factors affecting adsorption of gases on solids - Freundlich and Langmuir adsorption isotherms, adsorption from solutions.
Catalysis - Homogeneous and heterogeneous, activity and selectivity of solid catalysts, enzyme catalysis and its mechanism.
Colloidal state-distinction among true solutions, colloids and suspensions, classification of colloids-lyophilic, lyophobic; multi molecular, macromolecular and associated colloids (micelles), preparation and properties of colloids Tyndall effect, Brownian movement, electrophoresis, dialysis, coagulation and flocculation; Emulsions and their characteristics.

Surface Chemistry

INTRODUCTION :
Surface chemistry is that branch of chemistry which deals with study of the phenomena occurring at the surface or interface, i.e. at the boundary separating two bulk phases. In this chapter our main emphasis will be on three important topics related to surface chemistry, viz., adsorption, colloids and emulsions.

Section (A) : Adsorption
● **Adsorption :** The phenomenon of attracting and retaining the molecules of a substance on the surface of a liquid or a solid resulting into a higher concentration of the molecules on the surface is called adsorption. As a result of adsorption, there is a decrease of surface energy. The process of removal of an adsorbed substance from the surface on which it is adsorbed is called desorption. It is the reverse of adsorption and can be brought about by heating or by reducing the pressure.

● **Adsorbent and adsorbate :** The substance on the surface of which adsorption occurs is known as adsorbent. The substances that get adsorbed on the solid surface due to intermolecular attractions are called adsorbate. Charcoal, silica, gel, alumina gel are good adsorbents because they have highly porous structures and have large surface area. Colloids on account of their extremely small dimensions possess enoromous surface area per unit mass and are, therefore, also good adsorbents.

Examples of adsorption :
● **Adsorption of a gas by charcoal :** Finely divided activated charcoal has a tendency to adsorb a number of gases like ammonia, sulphur dioxide, chlorine, phosgene, etc. In this case, charcoal acts as an adsorbent while gas molecules act as adsorbate.

● **Adsorption of a dye by charcoal :** Animal charcoal is used for decolourising a number of organic substances in the form of their solutions. The discharge of the colour is due to the fact that the coloured component (generally an organic dye) gets adsorbed on the surface of the adsorbent (animal charcoal).

● **Sorption :** When both adsorption and absorption take place simultaneously.
      Eg : Dyes get adsorbed as well as absorbed in the cotton fibre i.e. sorption takes place.

Difference between adsorption and absorption :
The important points of distinction between adsorption and absorption

Absorption	Adsorption
It is the phenomenon in which the particles of gas or liquid get uniformly distributed throughout the body of the solid.	It is the phenomenon of higher concentration of gas or liquid on the surface than in the bulk of the solid.
The concentration is the same throughout the material.	The concentration on the surface of the adsorbent is different (has higher concentration) from that in the bulk.
It is a bulk phenomenon.	It is a surface phenomenon.
Absorption occurs at uniform rate.	Adsorption is rapid in the beginning and its rate slowly decreases
It is a slow process	*It is a fast process*

● **Thermodynamics of adsorption**
1. Adsorption involves attracting molecules of adsorbate on surface of the adsorbent. Due to this energy is released and thus heat of adsorption is negative i.e. adsorption is always exothemic
2. The molecules of adsorbate are held on surface of the solid adsorbent due to this entropy decreases i.e. ΔS is negative.
3. $\Delta G = \Delta H - T\Delta S$, Therefore adsorption will occur only when ΔG is negative and this is possible only if $|\Delta H| > |T\Delta S|$
4. As adsorption proceeds ΔH becomes less and less negative hence ΔH becomes equal to $T\Delta S$ and ΔG becomes zero. This is the state at which equilibrium is attained.

● **Enthalpy of adsorption** $\Delta H_{adsorption}$ **:** It is the amount of the heat released when 1 mole of an adsorbate gets adsorbed on a particular adsorbent at adsorption equilibrium. It depends upon the nature of both the adsorbate as well as adsorbent.

Types of adsorption : The adsorption is classified into two types :

(i) Physical adsorption (i.e. physisorption) : When the particles of the adsorbate are held to the surface of the adsorbent by the physical forces such as van der Waal's forces, the adsorption is called physical adsorption or vanderwaals adsorption.

(ii) Chemical adsorption (i.e. chemisorption) :
When the molecules of the adsorbate are held to the surface of the adsorbent by the chemical forces, the adsorption is called chemical adsorption.

Differences between Physical and Chemical Adsorption		
Property	**physical Adsorption**	**Chemical Adsorption**
Nature of adsorption	Weak	Strong
Enthalpy of adsorption	Low	High
Reversibility of adsorption	Reversible and occur rapidly	Irreversible and occurs slowly
Temp. at which adsorption is more pronounced	Low temp.	High temp.
Effect of change in temp.	Decreases with rise in temp.	Increases with rise in temp.
Specificity of adsorption	Not specific, generally take place on all surface	Highly specific, take place on specific surface
Nature of adsorbate layer	Multi-layered (at high pressure)	Mono-layered
Energy of activation	Very low	significantly high
Ease of desorption	Easy, since Vander-Waal's forces are involved	Not easy, since chemical forces are involved
Graph		

● **Competitive adsorption :** When an adsorbent is in contact with more than one species (adsorbate). There will be competition among them to get adsorbed on to the surface of the adsorbent. The one that is more strongly adsorbed gets deposited first in preference to the others. Further a strongly adsorbed substance may displace a weakly adsorbed substance.
Ex. NH_3 can displace O_2 or N_2 from the surface of charcoal.

Adsorption of gases on solids :
The extent of adsorption of a gas on a solid surface is affected by the following factors:

● **The nature of the gas (i.e. nature of the adsorbate).** The easily liquefiable gases such as HCl, NH_3, Cl_2 etc. are adsorbed more than the permanent gases such as H_2, N_2 and O_2.
extent of adsorption $\propto$ critical temperature of gas $\propto$ ease of liquification
Gas H_2 CH_4 CO_2 SO_2
T_C 33   190 K   304 K   330K

- **Nature of adsorbent.** The extent of adsorption of a gas depends upon the nature of adsorbent. Activated charcoal (i.e. activated carbon), metal oxides (silica gel and aluminium oxide) and clay can adsorb gases which are easily liquified. Gases such as H_2, N_2 and O_2 are generally adsorbed on finely divided transition metals Ni and Co.
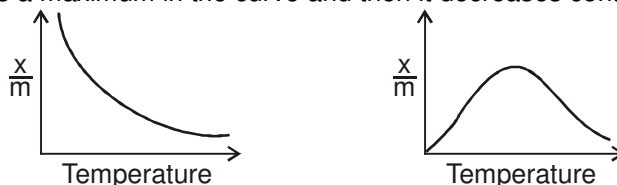 **Extent of adsorption $\propto$ surface area of solid.**

- **Activation of adsorbent :**
  (a) Metallic adsorbents are activated by mechanical rubbing or by subjecting it to some chemical reactions.
  (b) To increase the adsorbing power of adsorbents, they are sub-divided into smaller pieces. As a results, the surface area is increased and therefore, the adsorbing power increases.

- **Effect of temperature :** Mostly the process of adsorption is exothermic and the reverse process or desorption is endothermic. If the above equilibrium is subjected to increase in temperature, then according to Le-Chaterlier's principle, with increase in temperature, the desorption will be favoured. Physical adsorption decreases continuously with increase in temperature whereas chemisorption increases initially, shows a maximum in the curve and then it decreases continuously.

  The initial increase in chemisorption with increase in temperature is because of activation energy required.
  This is why the chemical adsorption is also known as "**Activated adsorption".**
  A graph between degree of adsorption (x/m) and temperature 't' at a constant pressure of adsorbate gas is known as **adsorption isobar.**

- **Effect of pressure.** The extent of adsorption of a gas per unit mass of adsorbent depends upon the pressure of the gas. The variation of extent of adsorption expressed as x/m (where x is the mole of adsorbate and m is the mass of the adsorbent) and the pressure is given as below. A graph between the amount of adsorption and gas pressure keeping the temperature constant is called an **adsorption isotherm.**

Figure-1

$$\frac{x}{m} \propto P$$
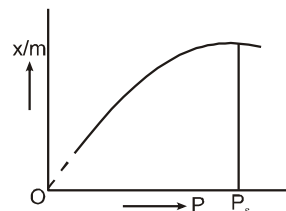
Where x = mass of adsorbate
M = mass of adsorbent

It is clear from the figure-1 that extent of adsorption (x/m) increases with pressure and becomes maximum corresponding to pressure P_s called saturation pressure.

Freundlich Adsorption isotherm

The variation of extent of adsorption (x/m) with pressure (P) was given mathematically by Freundlich.
Where n can take any whole number value which depends upon the nature of adsorbate and adsorbent. The above relationship is also called Freundlich's adsorption isotherm.

$$\left(\frac{x}{m}\right) = kp^{1/n}$$

Pressure	Graph	Relation
At low pressure	straight line	$\frac{x}{m} = kP$
At intermediate pressure	dependent on power of pressure	$(x/m) = kp^{1/n}$ $(0 < \frac{1}{n} < 1)$
At high pressure	Independent of pressure	$\frac{x}{m} = k$

where, x = Amount of gas adsorbed, m = Mass of adsorbent, K and n are adsorption constant, p is adsorption equilibrium pressure.

The constant k and n can be determined as explained below :

Taking logarithms on both sides

Eq. $(x/m) = kp^{1/n}$

we get $\log (x/m) = \log k + (1/n) \log p$.

☞ One of the drawbacks of Freundlich isotherm is that it fails at high pressure of the gas.

☞ This equation applicable only when adsorbate substance form unimolecular layer on adsorbent surface.

Langmuir Adsorption Isotherm :
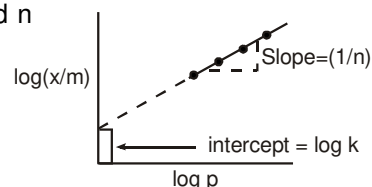
Assumptions :

1. Gas is considered to behave ideally.
2. A solid surface is considered as homogenous but contains a fixed number of adsorption sites on surface.
3. Each site adsorb a single molecule; means adsorption is monomolecular.
4. Rate of adsorption = Rate of desorption.
5. There is no lateral overlap between adsorbed molecules.

Derivation

Rate of adsorption α fraction of surface available for adsorption next line

α Pressure of gas.

If θ is covered fraction of surface covered. $(1 - \theta)$ is the free surface area.

Rate of adsorption $= K_aP(1 - \theta)$

Rate of desorption $= K_d\theta$

$K_aP(1 - \theta) = K_d\theta$

$K_aP - K_aP\theta = K_d\theta$

$$\frac{K_aP}{K_aP + K_d} = \theta; \qquad \theta = \frac{KP}{1 + KP} \qquad \text{where } K = \frac{K_a}{K_d}$$

Amount of gas adsorbed 'x' by given mass of adsorbent 'm' is proportional to θ

$$\frac{x}{m} \ \alpha \ \theta$$

$$\frac{x}{m} = \frac{KK_a/K_dP}{1 + K_a/K_dP}$$

$$\frac{x}{m} = \frac{aP}{1 + bP} \qquad\qquad ....(a)$$

$a = K_b, b = \dfrac{K_a}{K_b}$ where 'a' and 'b' are Langmuir parameter.

At very high pressure : $x/m = a/b$ ....(b)

At very low pressure : $x/m = ap$ .... (c)

For determination of the parameters 'a' and 'b', Eq. (a) may be written in its inverse form.

$$\frac{m}{x} = \frac{1 + bp}{ap} = \frac{b}{a} + \frac{1}{ap} \qquad .... (d)$$

A plot of m/x against 1/p gives a straight line with slope and intercept equal to 1/a and b/a respectively. At low pressure according to Eq. (c) x/m increases linearly with p. At high pressure according to Eq. (b) x/m becomes constant i.e. the surface is fully covered and change in pressure has no effect and no further adsorption takes place which is clear from the Figure-1.

Adsorption from solutions :

1. The extent of adsorption increases with increase in the surface area of adsorbent.
2. The extent of adsorption decreases with increase in temp.
3. The extent of adsorption is related to concentration of solution through this equation

Freundlich isotherm :

$(x/m) = k(c)^{1/n}$ $(n \geq 1)$ where c is the equilibrium concentration of the solute in solution.

Temperature dependence here also is similar to that for adsorption of gases and in place of equilibrium pressure, we use equilibrium concentrations of the adsorbates in the solution.

Applications of adsorption :

1. **In gas masks :** Activated charcoal is generally used in gas masks to adsorb poisonous and toxic gases from air. These masks are commonly used by the miners because there are poisonous gases like CO, CH_4 etc. in the atmosphere in coal mines.

2. **In dyeing of cloths :** Mordants such as alums are used in dyeing of cloths. They adsorb the dye particles which, otherwise, do not stick to the cloths.

3. **In dehumidizers :** Silica gel is commonly used to adsorb humidity or moisture from air.

4. **Removal of colouring matter :** Many substances such as sugar, juice and vegetable oils are coloured due to the presence of impurities. They can be decolourised by placing them in contact with adsorbents like activated charcoal or fuller's earth.

5. **Heterogeneous catalysis :** The phenomenon of adsorption is useful in the heterogeneous catalysis. The metals such as Fe, Ni, Pt, Pd, etc. are used in the manufacturing processes such as Contact process, Haber process and the hydrogenation of oils. Their use is based upon the phenomenon of adsorption.

6. **Refining Petroleum :** Silica gel is used as adsorbent in petroleum refining.

7. **Chromatography :** It is a method for separation of component and is based on preferential adsorption column is very common device used.

8. **Creating vacuum :** High vacuum can be created by removing gas by adsorption.

9. **Adsorption Indicators :** In volumetric analysis, adsorption indicator is used Surface of certain precipitates such as silver halide have the property of adsorbing some dye like eosin, fluorescein, etc In the case of precipitation titration ($AgNO_3$ vs NaCl) of the indicator is adsorbed at the end point producing a characteristic colour on the precipitate.

10. **In froth floatation process :** (in metallurgy).

11. **Softening of hard water :** Ion exchange resins used for softening of hard water is based upon selective and competive adsorption of ions on resins.

$$Na_2Z + Ca^{+2} \longrightarrow CaZ + 2 Na^+$$
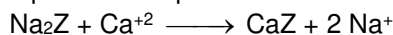
The organic polymers containing groups like –COOH, –SO_3H and –NH_2 etc. possess the property of selective adsorption of ions from solution. These are quite useful in the softening of water.

Solved Examples

Ex-1. A sample of charcoal weighing 6 g was brought into contact with a gas contained in a vessel of one litre capacity at 27ºC. The pressure of the gas was found to fall from 700 to 400 mm. Calculate the volume of the gas (reduced to STP) that is adsorbed per gram of the adsorbent under the condition of the experiment (density of charcoal sample is 1.5 g cm^3).

Sol. The adsorption is taking place in a closed vessel hence if pressure falls there is correspondingly increase in volume constant, excess of the volume of the gas would be adsorbed.

$$P_1V_1 = P_2V_2$$

$$V_2 = P_1 \frac{V_1}{P_2} = 700 \times \frac{1000}{400} = 1750 \text{ mL.}$$

Actual volume of the flask = 1000 – volume of charcoal = $1000 - \frac{6.00}{1.50} = 996$ mL.

Volume of the gas adsorbed = 1750 – 996 = 754 mL.

Volume of the gas adsorbed per gram at STP $\left(\text{Using} \frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2} \right) = \frac{125.67 \times 400 \times 273}{300 \times 760}$ **= 60.19 mL.**

Section (B) : Catalysis

● **Catalysts :** Berzillus in 1835 used the word catalyst first time for some substance which alter rate of chemical reaction and themselves remain chemically and quantitatively unchanged after the reaction and the phenomenon is known as catalysis.

Eg : Potassium chlorate when heated at 653K to 873K, it gives O_2, When MnO_2 is used in this reaction the O_2 is quickly released at the low temperature hence MnO_2 is a catalyst

$$2KClO_3 \rightarrow 2KCl + 3O_2$$

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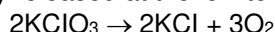
- **Homogeneous Catalysis :** When catalysts and reactants are in same phase then the process is said to be homogeneous catalysis and

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

  (ii) $CH_3COOCH_3(\ell) \xrightarrow{HCl(\ell)} CH_3COOH(aq)$

  (iii) $C_{12}H_{22}O_{11}(aq.) + H_2O(\ell) \xrightarrow{H_2SO_4(\ell)} C_6H_{12}O_6(aq.) + C_6H_{12}O_6(aq.)$
  Glucose Fructose
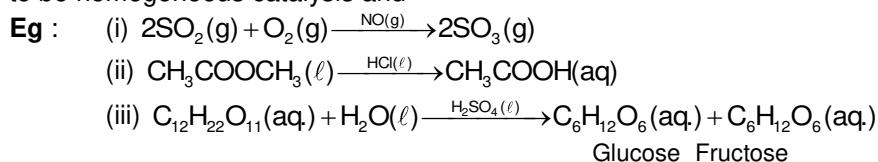
- **Heterogenous Catalysis :** When catalysts and reactants are in different phases, then process is know as heterogenous catalysis and catalyst is called heterogeneous catalyst

  Eg : (i) $2SO_3(g) + O_2(g) \xrightarrow{Pt(s)} 2SO_3(g)$

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

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

  (iv) Vegetable oils $(\ell) + H_2(g) \xrightarrow{Ni(s)}$ Vegetable ghee (s).

- **Types of Catalysis**

Positive	Negative	Auto	Induced
Substance which increase the rate of chemical reaction $2SO_2 + O_2 \xrightarrow{Pt} 2SO_3$	Substance which decrease the rate of chemical reaction $2H_2O_2 \xrightarrow[\text{negative catalyse}]{H_2O_2} 2H_2O^+$	One of Product behave as catalyst for that reaction and increase the rate of reaction, then this phenomena is called autocatalysis $CH_3COOC_2H_5 + H_2O$ $\Downarrow$ $CH_3COOH + C_2H_5OH$	When one reaction catalyses another reaction, then this phenomena is called as induced catalysis $Na_2SO_3 \rightarrow Na_2SO_4$

- **Promotors/Activators :** Substance which are not catalyst themselves but its presence can increase the catalytic activity of catalyst. Promotors increase the number of active sites on the surface Eg :

  (i) $N_2 + 3H_2 \xrightarrow[Mo(promotor)]{Fe(catalyst)} 2NH_3$
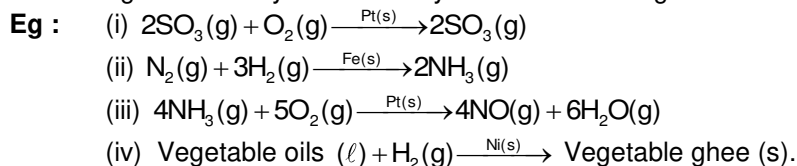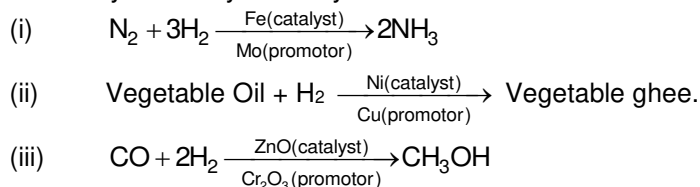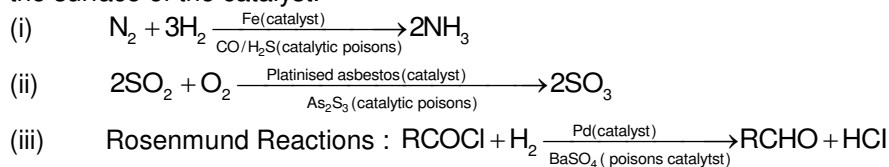
  (ii) Vegetable Oil + $H_2 \xrightarrow[Cu(promotor)]{Ni(catalyst)}$ Vegetable ghee.

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

- **Catalytic Poisons/Anti catalysts :** Substance which are not catalyst themselves but whose presence decrease the activity of the catalyst. Poisoning is due to preferential adsorption of poison on the surface of the catalyst.

  (i) $N_2 + 3H_2 \xrightarrow[CO/H_2S(catalytic poisons)]{Fe(catalyst)} 2NH_3$

  (ii) $2SO_2 + O_2 \xrightarrow[As_2S_3(catalytic poisons)]{Platinised asbestos(catalyst)} 2SO_3$

  (iii) Rosenmund Reactions : $RCOCl + H_2 \xrightarrow[BaSO_4(poisons catalytst)]{Pd(catalyst)} RCHO + HCl$

- **Characteristics of Catalysis :**
  (i) A Catalyst remains unchanged in mass and chemical compositions at the end of reactions. However its physical state can be changed.
  Eg : Granular MnO_2 during decomposition of $KClO_3$ is left as powder at the end of the reaction.
  (ii) **Highly efficient:** Finely devided state of catalyst is more efficient for the reactions because surface area increases and more adsorption take place.
  (iii) A catalyst cannot initiate the reaction. But some times the activation energy is so large that practically a reaction may not start until a catalyst lowers the activation energy significantly. For example, mixture of hydrogen and oxygen do not react at room temperature but the reaction occurs very rapid in presence of Pt black.

  $H_2 + O_2 \xrightarrow{room temperature}$ No reaction

  $H_2 + O_2 \xrightarrow{Pt black} H_2O$.
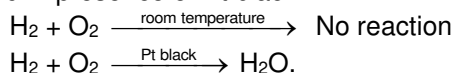
(iv) **Highly specific:** Catalyst are generally specific in nature. A substance which act as a catalyst in a particular reaction, fails to catalyse other reaction.

(v) Catalyst cannot change equilibrium state but it helps to attain equilibrium quickly.

(vi) A catalyst does not change the enthalpy, entropy and free energy of a reaction.

(vii) **Highly active under optimum temperature:** There is a particular temperature at which the efficiency of a catalyst is maximum, this temperature is known as optimum temperature. On either side of the optimum temperature, the activity of catalyst decreases. (Optimum range : 298 to 310 K).

(viii) **Highly active under optimum pH:** Range is pH 5 to 7.

(ix) Influence of Inhibitor or poison.

● **Adsorption Theory of Heterogeneous Catalyst :** This theory explains the mechanism of heterogeneous catalyst. This theory is combination of two theory, intermediate compound formation theory and the old adsorption theory, the catalytic activity is localised on the surface on the catalyst. The mechanism involves 5 steps.

(i) Diffusion of reactant to the surface of the catalyst of.

(ii) Adsorption of reactant molecules on the surface of the catalyst.

(iii) Formation of activated intermediate.

(iv) Formation of reactions product on the catalyst surface.

(v) Diffusion of reactions product from the catalyst surface or desorption.

Examples : Let us consider addition of H_2 gas to ethlene in presence of Ni catalyst, the reaction takes places as follows.
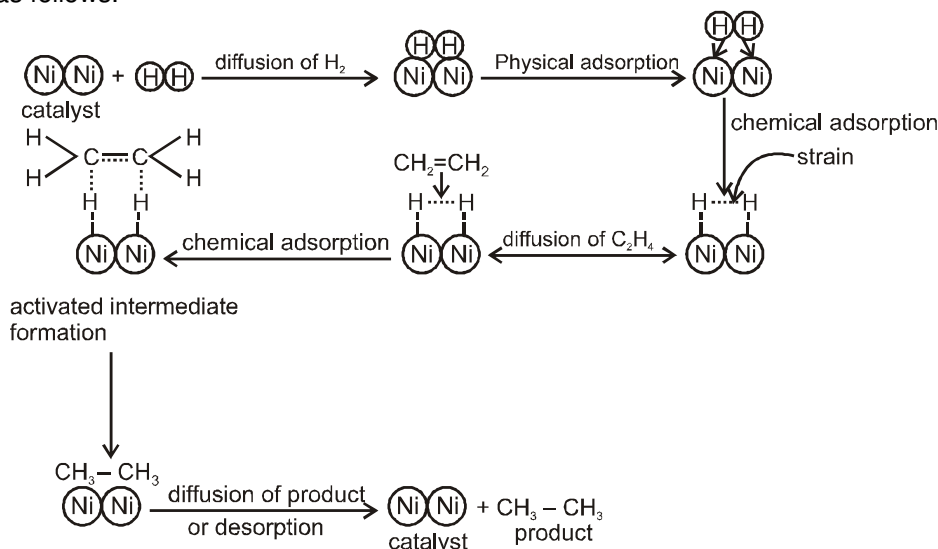
● **Factors Supporting Theory :**

(i) This theory explains the role of active centre, more free valency which provides the more space for more adsorption and concentration increases as a result of increase in rate of reaction.

(ii) Rough surface has more active centres and pores, there will be more free valency so more will be rate of reaction.

(iii) The theory explains the centre action of promoters which occupied the interstial void as a result surface area for the adsorption increases therefore rate of reaction increases.

(iv) The theory explains the function of poisons or inhibitors. In poisoning preferential adsorption of poisons takes place on the catalyst, surface area for the adsorption on the catalyst decreases hence rate of reaction decreases.

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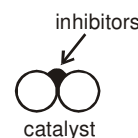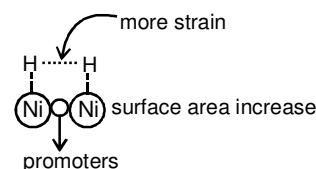
Some Industrial Catalytic reactions

S.N.	Process	Catalyst
1	Haber's Process for the manufacture of ammonia $N_2 + 3H_2 \rightarrow 2NH_3$	Finely divided iron, Molybdenum as promoter. **Conditions:** 200 atmospheric pressure and 450-500ºC temperature.
2	Ostwald's process for the manufacture of nitric acid. $4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$; $2NO + O_2 \rightarrow 2NO_2$ $4NO + 2H_2O + O_2 \rightarrow 4HNO_3$.	Platinised asbestos Temperature 300ºC
3	Lead chamber process for the manufacture of sulphuric acid $2SO_2 + O_2 \rightarrow 2SO_3$; $SO_3 + H_2O \rightarrow H_2SO_4$.	Nitric oxide.
4	Contact process for the manufacture of sulphuric acid $2SO_2 + O_2 \rightarrow 2SO_3$; $SO_3 + H_2SO_4 \rightarrow H_2S_2O_7$	Platinised asbestos or vanadium pentoxide(V_2O_5). Temperature 400–450ºC.

● **Shape selective catalysis**
   Catalysis action depends upon.
1. Shape of the catalyst (Pore structure or cavities)
2. Size of reactant and product.
   Zeolites
1. They are honey comb like structure i.e. shape selective catalysis.
2. They are microporous aluminium silicate with 3D silicate in which silicon atom are replaced by aluminum atoms i.e. Al–O–Si
3. The pore size is generally in range 260-740 pm.
4. General formula of zeolite is $Na_{x/n}[(AlO_2)_x(SiO_2)_y].zH_2O$
   Use of Zeolite
1. It is used as catalyst in petrolium industries for cracking hydrocarbon and isomerism i. e. ZSM-5.

$$R - OH \xrightarrow{\text{ZSM–5}} gasoline$$
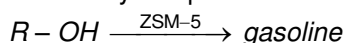
2. It convert alcohol directly into gasoline by dehydrating them to give a mixture of hydrocarbon.

Enzyme catalyst :
Enzyme are complex nitrogenous organic compound which are produced by living plants and animal the chracterstics of enzyme catalyst are.

1. Most highly efficient
2. Highly specific in nature
3. Highly active under optimum temperature
4. Highly active under optimum Ph.
5. Increase activity in presence of coenzyme
6. Influence of induce and poison

Section (C) : Classification and Preparation of Colloid
● **Colloid Solution :**
   Colloid State : A substance is said to be in colloidal state when the size of the particle of disperse phase is greater than particle of true solution and less than that of suspension solution particle, their range of diameters lie between 1 and 1000 nm (10^{-9} to 10^{-6} m).
   Colloid solution : It is a heterogeneous system consisting of 2 phase :
   (1) Disperse Phase (D.P) : The phase which is dispersed through the medium is called dispersed phase or discontinuous phase or internal phase.
   (2) Dispersion Medium (D.M) : A medium in which colloidal particles are dispersed is called dispersion medium. It is also known as continuous phase or outer phase or external phase.
   Colloidal solution = D.P. + D.M.
   Ex. In Gold sol, Gold is D.P and water is D.M.

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● **Differentiating point of colloids :**

(1) A colloid is a **heterogeneous system** in which one substance is dispersed (dispersed phase) as very fine particles in another substance called dispersion medium.

(2) The solution and colloid essentially differ from one another by particle size.

* In a solution, the particles are ions or small molecules.

* In a colloid, the dispersed phase may consist of particles of a single macromolecule (such as protein or synthetic polymer) or an aggregate of many atoms, ions or molecules.

(3) Colloidal particles are larger than simple molecules but small enough to remain suspended. They have a range of diameters between 1 and 1000 nm (10^{-9} to 10^{-6} m).

Classification of colloids :

1. **On the basis of physical state of D.P. and D.M.**

On the bases of physical state of D.P. and D.M. colloidal solution may be divided into eight system.

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

* Solution of gas in gas is not a colloidal system because it forms homogeneous mixture.

2. **On the basis of D.M. :** Colloidal solution are classified as

D.M.	Name of colloidal system
Water	Hydro sol or aqua sol
Alcohol	Alco sols
Benzene	Benzo sols
Air	Aero sols

* Aquadag & oildag are colloidal solution of graphite in water & oil respectively.
* Colloidal solution are often termed as sol.

3. **On the Basis of interaction of D.P. for D.M. :** There are two types-

(i) Lyophilic colloids / liquid loving sols / intrinsic colloid. The colloidal solution in which the particles of the dispersed phase have a great affinity (or love) for the dispersion medium, are called lyophilic colloids. These solutions are easily formed and the lyophilic colloids are reversible in nature. In case when water acts as the dispersion medium, the lyophilic colloid is called hydrophilic colloid. The common examples of lyophilic colloids are glue, gelatin, starch, proteins, egg albumin, rubber, etc.

(ii) Lyophobic colloids / solvent hating colloid / extrinsic colloid. The colloidal solutions in which there is no affinity between particles of the dispersed phase and the dispersion medium are called lyophobic colloids. Such solutions are formed with difficulty only by special methods. These sols are readily precipitated (or coagulated) upon addition of small amounts of electrolytes, by heating or by shaking and hence are not stable. Further, once precipitated, they do not give back the colloidal sol by simple addition of the dispersion medium. Hence these sols are also called irreversible sols. They need stabilising agents for their preservation. In case the dispersion medium is water, the lyophobic sol is called hydrophobic colloid. For example, the solution of metals like Ag and Au, hydroxides like Al $(OH)_3$, $Fe(OH)_3$, metal sulphides like As_2S_3 etc.

* **Lyophilic sols are more stable than lyophobic sols,** the additional stability is due presence of an envelope of the solvent layer (say water) around the colloidal particle, the process is known as hydration, To coagulate a hydrophilic sols we have to add a dehydrating agent in addition to electrolyte.

DISTINCTION BETWEEN LYOPHILIC AND LYOPHOBIC COLLOIDS

S.No.	Property	Lyophilic colloids	Lyophobic colloids
1	Ease of preparation	There are easily formed by direct mixing.	These are formed only by special methods
2	Reversible or irreversible nature	These are reversible in nature	These are irreversible in nature.
3	Particles nature	The particles of colloids are true molecules but are big in size	The particles are aggregates of many molecules
4	Stability	These are very stable	These are unstable and require traces of stabilizers
5	Action of electrolytes	No effect	The addition of small amount of electrolytes causes precipitation (called coagulation) of colloidal solution.
6	Charge on particles	*The particles do not carry any charge.*	The particles move in a specific direction either towards anode or cathode depending upon their charge in an electric field
7	Hydration	The particles of colloids are heavily hydrated due to the attraction for the solvent.	The particles of colloids are not appreciably hydrated.
8	*Viscosity*	*It is higher than that of dispersion medium*	*It is nearly same as that of dispersion medium*
9	*Tyndall effect*	*They do not show tyndall effect*	*They show tyndall effect.*
10	*Surface tension*	*Lower than dispersion medium*	*It is nearly same as that of dispersion medium*
11	*Coagulation of precipitation*	*Precipitated by high concentration of electrolyte*	*Precipitated by low concentration of electrolyte*
12	*Migration in electric field*	*May or may not migrate as they may not carry charge*	*Migrate toward anode or cathode as these particles carry charge*
13	*Example*	*Mostly organic nature; Starch and Gelatin*	*Inorganic nature; Transition metal salt in water, gold etc., Metal solution*

4. **On the basis of chemical composition :**
Inorganic Colloids
(i) Metal sols : Cu, Ag, Au, Pt Sols.
(ii) Non Metal sols : S, I_2, Graphite
(iii) Sol of oxide and hydroxide : SnO_2, TiO_2, Fe_2O_3, $Fe(OH)_3$, $Al(OH)_3$, $Cr(OH)_3$
(iv) Salt Sol - AgBr, AgI, As_2S_3, etc.

Organic Colloids
(i) Homopolar sol - In this type of colloid, particles carry similar type of charge. eg. Sol of rubber in benzene which contain - ve charge colloidal particle of latex.
(ii) Hydroxy Sol- Starch sol

5. **On the basis of charge on particles**
(i) Positive Sol
(a) Metal Oxide & Hydroxide - SnO_2, TiO_2, Fe_2O_3, $Al(OH)_3$, $Fe(OH)_3$, $Cr(OH)_3$.
(b) Basic Dyes Methylene blue, vismark brown.

(ii) Negative Sol
(a) Metal sol- Ag, Au, Pt, Cu   (b) Acidic dye - congo red, eosin
(c) Sulphide sol- CdS, HgS, As_2S_3, Sb_2S_3.
(d) Natural sol- Blood, clay, charcoal, latex rubber, dust particle in water, starch carbon particle in smoke, gum.

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6. **On the basis of type of particles of dispersed phase :**
Multimolecular, macromolecular and associated colloids

● **Multimolecular colloids :** In this type, the particles consist of an aggregate of atoms or small molecules size less than 1 nm. For example, sols of gold atoms and sulphur (S_8) molecules. In these colloids, the particles are held together by van der Waal's forces.

● **Macromolecular colloids:** In this types, the particles of the dispersed phase are sufficiently big in size (macro) to be of colloidal dimensions. These macromolecules forming the dispersed phase are generally polymers having very high molecular masses. These colloids are quite stable and resemble true solutions in many respects. Naturally occurring macromolecules are starch, cellulose, proteins, enzymes, gelatin, etc.

● **Associated colloids (Micelles):** These are the substances which behave as normal strong electrolytes at low concentration but behave as colloidal particles at higher concentration. These associated particles are also called micelles. Ex. Soap.

Micelles :
⇒ Micelles are relatively small, spherical structures composed of any where for a few to few thousand molecule that attract one another to reduce surface tension within a membrane of cell.
The formation of micelles takes place only at particular temp, that temperature is called **Kraft temperature**.
The concentration above which micelle formation becomes appreciable is termed is **critical micelles concentration**. Its value depend upon natures of D.P. and D.M. eg. Surface active agent (surfactants, which decrease the surface tension) like soaps and detergents form micelle beyond CMC ($\sim 10^{-3}$ mol/litre for soaps).
* Usually longer the hydrophobic chain, smaller is its CMC.
* Also CMC increase with decreasing polarity of the D.M.
* The micelles 'formation takes place only above a particular temperature called as Kraft Temperature (T_k).
*At CMC, the micelles are spherical in shape, but that start flattening with increase in concentration and ultimately form sheet or film like structures which have a thickness of two molecules. These are called **lamelar micelles** or **McBain Micelles.**

Mechanism of micelle formation: Let us take the example of soap solutions. Soap is sodium salt of a higher fatty acid and may be represented as $RCOO^-Na^+$ e.g., sodium stearate viz. $CH_3(CH_2)_{16}COO^-Na^+$ which is a major component of many bar soaps. When dissolved in water, it dissociates into $RCOO-$ and $Na+$ ions. The $RCOO^-$ ions, however, consist of two parts i.e., long hydrocarbon chain R (also called non-polar 'tail') which is hydrophobic (water repelling) and the polar group COO^- (also called polar-ionic 'head') which is hydrophilic (water loving). The $RCOO^-$ ions are, therefore, present on the surface with their COO^- groups in water and the hydrocarbon chains R staying away from it, and remain at the surface, but at higher concentration these are pulled into the bulk of the solution and aggregate in a spherical form with their hydrocarbon chains pointing towards the centre with COO^- part remaining outward on the surface. An aggregate thus formed is known as **'Ionic micelle'.** These micelles may contain as many as upto 100 such ions.

Aggregation of $RCOO^-$ ions to form an ionic micelle.
Similarly, in case of detergents, e.g., sodium lauryl sulphate viz. $CH_3(CH_2)_{11}SO_4^-Na^+$, the polar group is $-SO_4^-$ along with the long hydrocarbon chain. Hence, the mechanism of micelle formation is same as that of soaps.

Example of micelles :
(i) Sodium stearate $C_{17}H_{35}COO^-Na^+$(Soap).
(ii) Sodium lauryl sulphate $CH_3[CH_2]_{11}SO_4^-Na^+$ (Detergent).
(iii) Cetyl trimethyl ammonium bromide (Detergent). $CH_3(CH_2)_{15}N^+(CH_3)_3Br^-$.

The Cleansing Action of Soaps: It has been mentioned earlier that a micelle consists of a hydrophobic hydrocarbon like central core. The cleansing action of soap is due to these micelles, because oil and grease can be solubilised in their hydrocarbon, like centres which are not otherwise soluble in water. This is shown diagrammatically in Figure. The dirt goes out along with the soap micelles.

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Fig. : The cleansing action of soap.

(a) A sodium stearate molecule

(b) The simplified representation of the molecule that shows a hydrophilic head and a hydrophobic tail

(c) Grease (oily substance) is not soluble in water

(d) When soap is added to water, the non-polar tails of soap molecules dissolve in grease

(e) Finally, the grease is removed in the form of micelles containing grease.

*****Surfactants :** They can be ionic as well as non-ionic. The ionic are soaps and detergent. The surfactant gets adsorbed at the interface between the dispersed droplets and dispersion medium in the form of mono molecular layer and lowers the interfacial tension between oil and water so as to facilitate the mixing of two liquids.

Preparation of lyophobic colloidal sols :

[A]   Condensation methods :

In these methods particles of atomic or molecular size are induced to combine to form aggregates having colloidal dimensions. For this purpose chemical as well as physical methods can be applied.

(a) Chemical methods. Colloidal solutions can be prepared by chemical reactions leading to formation of molecules by double decomposition, oxidation, reduction or hydrolysis. These molecules then aggregate leading to formation of sols.

(i) Double decomposition : When a hot aqueous dilute solution of arsenous oxide (As_2O_3) is mixed with a saturated solution of H_2S in water, a colloidal sol of arsenous sulphide (As_2S_3) is obtained.

As_2O_3(in hot water) + $3H_2S$ (saturated solution in H_2O) $\xrightarrow{\text{Double decomposition}}$ As_2S_3(sol) + $3H_2O$

$$\begin{array}{l} \text{CH(OH)COOK} \\ | \\ \text{CH(OH)COO(SbO)} \end{array} + 3H_2S \rightarrow \begin{array}{l} \text{CH(OH)COOK} \\ | \\ \text{CH(OH)COOH} \end{array} + Sb_2S_3 \text{ (orange sol)} + 2H_2O$$

(ii) Oxidation : A colloidal sol of sulphur is obtained by passing H_2S into a solution of sulphur dioxide.

$$SO_2 + 2H_2S\text{(saturated solution in } H_2O) \xrightarrow{\text{Oxidation}} 3S\text{(sol)} + 2H_2O$$

Sulphur sol can also be obtained when H_2S is bubbled through Br_2 water or nitric acid (oxidizing agent).

$$2H_2S \text{ (aq.)} + Br_2 \text{ (aq.)} \longrightarrow 2HBr \text{ (aq.)} + S \text{ (sol).}$$

or   by bubbling O_2 (g) through a solution of H_2S : $2H_2S$ (aq.) + O_2 (g) $\longrightarrow$ $2H_2O$ (l) + 2S (sol).

(iii) Reduction : Colloidal sol of metals like gold, silver solution are obtained by following method.

$$2 AuCl_3 + 3 HCHO + 3H_2O \longrightarrow 2Au\text{(sol)} + 3HCOOH + 6HCl.$$
                                                              (purple of cassius)

$$2\ AuCl_3 + 3\ SnCl_2 \xrightarrow{\text{Reduction}} 3\ SnCl_4 + 2Au\text{(sol)}$$

$AgNO_3$ + tannic acid $\xrightarrow{\text{Reduction}}$ silver sol.

NH_2NH_2 can also be used as reducing agent.   *Sol of gold is also known as purple of cassius.

(iv) Hydrolysis : A colloidal sol of metal hydroxides like $Al(OH)_3$ or $Cr(OH)_3$ is obtained by boiling a dilute solution of $FeCl_3$, $AlCl_3$ or $CrCl_3$.

$FeCl_3 + 3H_2O \longrightarrow Fe(OH)_3$ (sol) + 3HCl ; $AlCl_3 + 3H_2O \longrightarrow Al(OH)_3$ (sol) + 3HCl

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The colloidal sol of sillicic acid is also obtained by hydrolysis of dilute solution of sodium silicate with hydrochloric acid. $Na_4SiO_4 + 4HCl \longrightarrow Si(OH)_4$ (sol) + 4NaCl.

(b) Physical methods : The following physical methods are used to prepare the colloidal solutions.

(i) By Exchange of solvent : When a true solution is mixed with an excess of the other solvent in which the solute is insoluble but solvent is miscible, a colloidal sol is obtained. For example,
• when a solution of sulphur in alcohol is poured in excess of water, a colloidal sol of sulphur is obtained.
• when a solution of phenolphthalein in alcohol is poured in excess of water a white sol of phenolphthalein is found.
• Phenolphthalein, I_2 , sulphur sol can be prepared by this methods.

(ii) Excessive cooling : Molecules of certain substance condense together on excess cooling to form colloidal size particle. The colloidal sol of ice in an organic solvent such as $CHCl_3$ or ether can be obtained by freezing a solution of water in the solvent. The molecules of water which can no longer be held in solution separately combine to form particles of colloidal size.

(iii) By condensing vapours of a substance into solvent : Substance like sulphur and Hg in water are prepared by passing their vapours in cold water containing small amount of stabilising agent like ammonium nitrate.

[B]   **Dispersion Methods :** In these methods large particles of the substance are broken into particles of colloidal dimensions in the presence of dispersion medium. These are stabilized by adding some suitable stabilizer. Some of the methods employed are given below :

(a) Mechanical dispersion (By colloidal mill):
Substance is first finely powdered.
↓
It is shaken with the D.M. to form a suspension.
↓
This suspension is passed through a colloidal mill.
↓
The simplest type of colloidal mill is disc mill which consists of two metal discs nearly touching each other & rotating in opposite.
↓
Direction at a high speed (7,000 revolutions per min.).
↓
The suspended particles are broken to produce colloidal size particle.
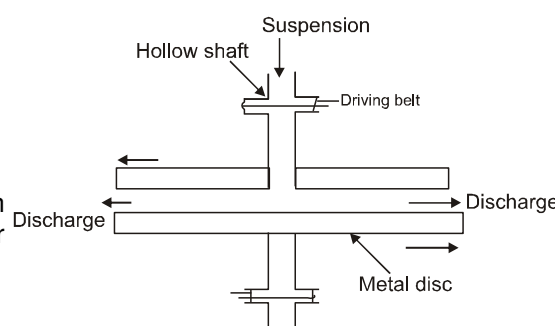* This method is used to prepare printing ink.

Fig. : A colloid mill

(b) Electrical disintegration or Bredig's Arc method : This process involves dispersion as well as condensation. Colloidal sols of less reactive metals such as gold, silver, platinum, copper, lead etc., can be prepared by this method. In this method, electric arc is struck between electrodes of the metal immersed in the dispersion medium as shown in fig. The intense heat produced vaporises the metal, which then condenses to form particles of colloidal size by surrounding cooling mixture (ice).
*A slight trace of KOH is added in water to stabilized colloidal solutions.

Fig. : Bredig's Arc method

(c) Ultrasonic dispersion : Ultrasonic vibration (having frequency larger than audible range) can bring about the transformation of coarse suspension or liquids like oil, mercury etc. into colloidal range.
*This is the latest method for preparation of metal oxides and metal sulphide sols from their coarse suspension.
*It is a suitable technique for oils also. This method also comprises both dispersion and condensation.
(d) Peptization: The term has originated from the digestion of proteins by the enzyme pepsin. Peptization may be defined as (the process of converting a precipitate into colloidal sol by shaking it with dispersion medium in the presence of a small amount of electrolyte).
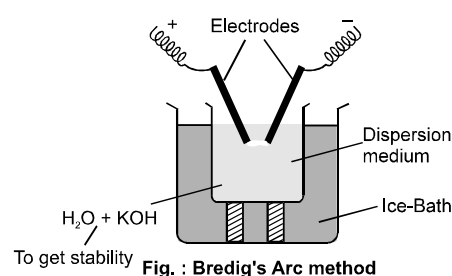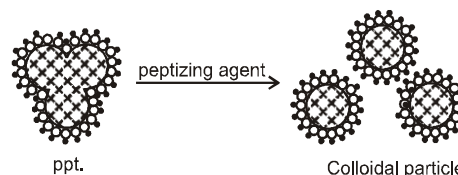
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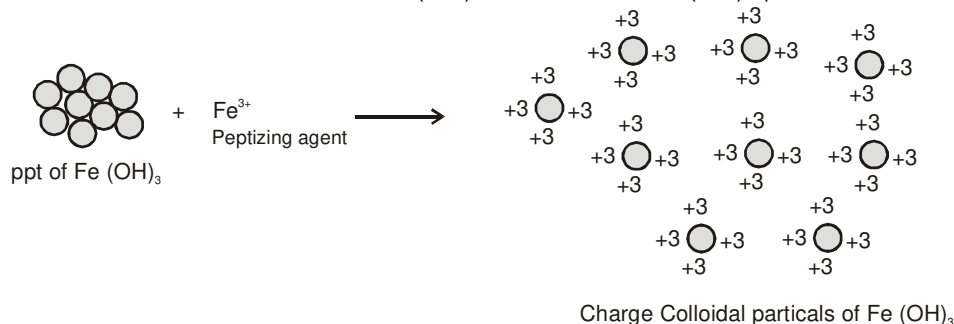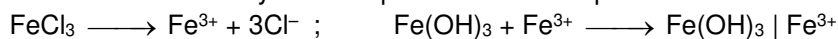ADVSC - 13

The electrolyte used for this purpose is called peptizing agent. This method is applied, generally, to convert a freshly prepared precipitate into a colloidal sol. During peptization, the precipitate adsorbs one of the ions of the electrolyte on its surface.

The ion adsorbed on the surface is common either with the anion or cation of the electrolyte. This causes the development of positive or negative charge on precipitates which ultimately break up into smaller particles having the dimensions of colloids.


ppt.   Colloidal particle

For example :

(i) When freshly precipitated $Fe(OH)_3$ is shaken with aqueous solution of $FeCl_3$ (peptizing agent) it adsorbs Fe^{3+} ions and thereby breaks up into small-sized particles.

$$FeCl_3 \longrightarrow Fe^{3+} + 3Cl^- \; ; \qquad Fe(OH)_3 + Fe^{3+} \longrightarrow Fe(OH)_3 \mid Fe^{3+}$$

ppt of Fe (OH)$_3$ +   Fe^{3+} Peptizing agent $\longrightarrow$ Charge Colloidal particals of Fe (OH)$_3$

(ii) Freshly prepared stannic oxide on treatment with a small amount of dilute hydrochloric acid forms a stable colloidal sol of stannic oxide, SnO_2 ; Sn^{4+} .

$$SnO_2 + 4HCl \rightarrow Sn^{4+} + 2H_2O + 4Cl^- \; ; \; SnO_2 + Sn^{4+} \rightarrow SnO_2 / Sn^{4+} \; .$$
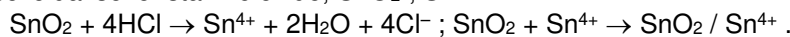
(iii) Freshly precipitated silver chloride can be converted into a colloidal sol by adding a small amount of hydrochloric acid, $AgCl : Cl^-$.

(iv) Cadmium sulphide can be peptised with the help of hydrogen sulphide, $CdS : S^{2-}$.

Section (D) : Purification and Properties of Colloid

Purification of Colloidal Sols : The colloidal sols obtained by various methods are impure and contain impurities of electrolytes and other soluble substances. These impurities may destabilise the sol. Hence, they have to be removed. A very important method of removal of soluble impurities from sols by a semipermeable membrane is known as dialysis.

A. Dialysis : It is a process of removing a dissolved substance from a colloidal solution by means diffusion through suitable membrane. Since particles in true solution (ions or smaller molecules) can pass through animal membrane or parchment paper or cellophane sheet but colloidal particle do not, the appratus used for this purpose is called Dialyser.

A bag of suitable membrane containing the colloidal solutions is suspended in a vessel through which fresh water continously flow. The molecules and ions (crystalloids) diffuse through membrane into the outer water & pure colloidal solution is left behind.
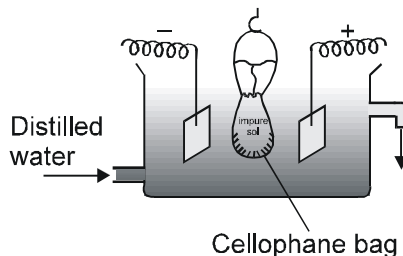

Distilled water

Cellophane bag

Fig. : An apparatus for electrodialysis.

Movement of ions across the membrane can be expedited by applying electric potential through two electrodes as shown in fig.

This method is faster than simple dialysis and is known as

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Electrodialysis.

*The most important applications of dialysis is in the purification of blood in the artificial kidney machine. 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 bloods stream.

*Dialysis is not applicable for non-electrolytes like glucose, sugar, etc.

B. Ultra Filtration : In this method, colloidal sols are purified by carrying out filtration through special type of graded filters called ultra-filters. These filter papers allow only the electrolytes to pass through. These filter papers are made of particular pore size by impregnating with colloidal solution and subsequently hardened by soaking in formaldehyde collodion. In order to accelerate the filtration through such filter papers, increased pressure or suction is employed.

Solved Examples

Ex-2. When SO_2 is bubbled into H_2S gas, colloidal sol is formed. What type of colloidal sol is it ?

Sol. $2H_2S + SO_2 \longrightarrow 2H_2O + 3S$ (colloidal).

Lyophobic colloidal sol of sulphur is formed.

Ex-3. A reddish brown positively charged sol is obtained by adding small quantity of $FeCl_3$ solution to freshly prepared and well washed $Fe(OH)_3$ precipitate. How does it take place ?

Sol. It is due to adsorptions of Fe^{3+} ions on the surface of $Fe(OH)_3$ which gives colloidal sol.

$Fe(OH)_3$ (ppt.) + Fe^{3+} (ions adsorbed) $\longrightarrow$ $[Fe(OH)_3]Fe^{3+}$ (colloidal sol).

Ex-4. Suppose we have a cube of 1.00 cm length. It is cut in all three directions, so as to produce eight cubes, each 0.50 cm on edge length. Then suppose these 0.50 cm cubes are each subdivided into eight cubes 0.25 cm on edge length, and so on. How many of these successive subdivisions are required before the cubes are reduced in size to colloidal dimensions of 100 nm.

Sol. We find that every division in two equal halves also reduces the size of edge lengths to one half.

In first subdivision 1 cm is reduceds to 0.5 cm = $\dfrac{1}{2}$ cm.

In second subdivision 0.5 cm is reduced to 0.25 cm = $\dfrac{1}{4}$ cm = $\left(\dfrac{1}{2}\right)^2$ cm

In n subdivision 1 cm is reduced to $\left(\dfrac{1}{2}\right)^n$. Size of colloidal particles lies between 1 to 1000 mm.

Thus to make n subdivision required particle size may be attained.

$$\left(\dfrac{1}{2}\right)^n = 100 \text{ nm} = 100 \times 10^{-9} \text{ m} = 100 \times 10^{-7} \text{ cm}.$$

∴ $n \log 2 = 5$

$n \times 0.3010 = 5$.

$n = \dfrac{5}{0.3010} = 16.61$ **= 17 subdivisions are required for dimension of 100 nm.**

Important properties of colloidal sols :

● **Heterogeneous character :**

Colloidal sols are heterogeneous in character as they consist of two phases.

(a) dispersed phase and   (b) dispersion medium.

● **Visibility :** Due to scattering caused by the colloidal particles, it will appear as a bright spot moving randomly.

● **Filterability :** Colloidal particles pass through an ordinary filter paper. However, the particle do not pass through other fine membranes.

● **Colligative Properties :** Colloidal sols show the colligative properties viz. relative lowering of vapour pressure, elevation in boiling point, depression in freezing point and osmotic pressure. However, due to high average molecular masses of colloidal particles, mole fraction of the dispersed phase is very low. Hence, the values of the colligative properties observed experimentally are very small. Only osmotic pressure measurements are used in determining the molecular mass of polymers.

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● **Optical Properties-Tyndall effect :** Tyndall, in 1869, observed that if a strong beam of light is passed through a colloidal sol placed in a dark place, the path of the beam gets illuminated. This phenomenon is called Tyndall effect, which is due to the scattering of light by the colloidal particles. The illuminated path of beam is called Tyndall cone. This phenomenon is due to scattering of light from the surface of colloidal particles. In a true solution there are no particles of sufficiently large diameter to scatter light & hence the beam is invisible.
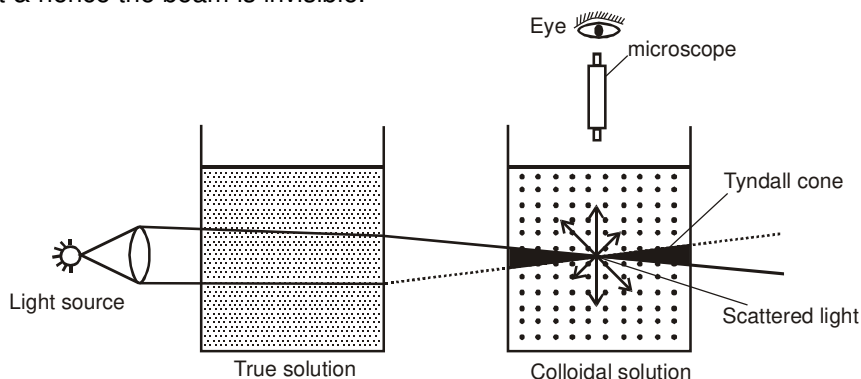
*The intensity of scattered light depends on the difference between the refractive indice of the D.P and D.M., In lyophobic colloids, this difference is appreciable and therefore the tyndal effect is quite well defined but in lyophilic sols the difference is very small and the tyndal effect is very weak. Thus in sols of silicic acid, blood serum, albumin, etc. there is little or no tyndal effect.

Example of Tyndall Effect
→   Blue colour of sky and sea water.
→   Visibility of tail of comets.
→   Light thrown from a projector in cinema hall.
→   Appearance of dust particle in a semi darked room.

● **Application of Tyndall Effect :**
(i)   In making ultramicroscopes.
(ii)   In finding heterogenity of solution.

Solved Examples

Ex-5.   Under what conditions is Tyndal effect observed ?
**Sol.**   Tydalls effect is applicable when :
(a) The diameter of the dispersed particles is not much smaller than the wavelength of the light used.
(b) The refractive indices of the dispersed phase and the dispersion medium must differ greatly in magnitude.

Ex-6.   In the lower layer of the atmosphere, there is a great deal of dust. When the weather is fine, it is possible to see the magnificent red colour of the setting sun. What have these observation to do with colloids ?
Sol.   Dust in the atmosphere is often colloidal. When the sun is low down on the horizon, light from it has to pass through a great deal of dust to reach your eyes. The blue part of the light is scattered away from your eyes. You see the red part of the spectrum, which remains. Red sunsets are the Tyndall effect on a large scale.

● **Mechanical Properties :**
Brownian movement: Robert Brown, a botanist, discovered in 1827 that pollen grains placed in water do not remain at rest but move about continuously and randomly. Later on, this phenomenon was observed in case of colloidal particles when they were seen under an ultramicroscope. The particles were seen to be in constant zig-zag motion as shown in fig. This zig-zag motion is called Brownian movement.
Brownian movement arises because of the impact of the molecules of the dispersion medium with the colloidal particles.
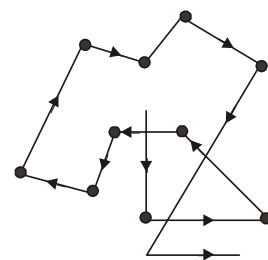
(Fig. Brownian movement)

Dependence :

(i) Size of colloidal particles : Mobility $\propto \dfrac{1}{\text{Size of the particle}}$

(ii) Viscosity of solution : Mobility $\propto \dfrac{1}{\text{Viscosity}}$

(iii) Temperature : Mobility $\propto$ Temperature

● **Factors Affecting Brownian Movement :**
(i) If particles is large then brownian movement becomes less.
(ii) Brownian movement increases with increasing temperature.
(iii) The brownian movement does not change with time & remains same for months or even for a year.

● **Important :**
(i) In confirmation of kinetic energy.
(ii) Determination of Avogadro numbers.
(iii) Stability of colloidal solution: Brownian movement does not allow the colloidal particles to settle down to gravity & thus is responsible for their stability.

● **Electrical Properties (Electrophoresis) :**
The existence of charge on colloidal particles is confirmed by electrophoresis experiment. When electric potential is applied across two platinum electrodes dipping in a colloidal solution, the colloidal particles move towards one or the other electrode. The movement of colloidal particles under on applied electric potential is called electrophoresis.
Positively charged particles move towards the cathode while negatively charged particles move towards the anode. Depending upon the direction a movement of particles towards cathode or anode electrophoresis can be called 'cataphoresis' or 'Anaphoresis'
Arsenious sulphide, gold, silver and platinum particles in their respective colloidal sole are negatively charged while particles of $Fe(OH)_3$, $Al(OH)_3$ are positively charged.
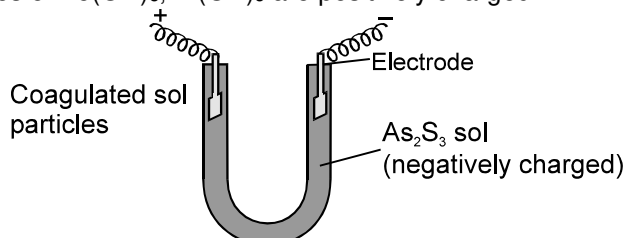
Coagulated sol particles

Electrode

As_2S_3 sol (negatively charged)

(Fig. : A set up for electrophoresis.)

The colloidal solution is placed in a U-tube fitted with platinum electrodes. On passing an electric current, the charged colloidal particles move towards the oppositely charged electrode. Thus, if arsenic sulphide sol is taken in the U-tube, in which negatively charge particle of arsenic sulphide move towards the anode.
*Earlier this process was called cataphoresis because most of the colloidal sols studied at that time were positively charged and moved towards cathode.

● **Electro osmosis:** When movement of colloidal particles is prevented by some suitable means (porous diaphragm or semi permeable membranes), it is observed that the D.M. begins to move in an electric field. This phenomenon is termed electrosmosis.

● **Sedimentation potential or Dorn potential :** When the charged colloidal particles are made to settle down under centrifugal field, there occurs a charge separation and a potential difference is developed. This effect is called **Dorn effect** and the potential difference thus developed is called Dorn potential or sedimentation potential. This process is **reverse of electrophoresis.**

● **Isoelectric point :** The H^+ concentration at which the colloidal particles have no charge is known as the isoelectric point. At this point stability of colloidal particles becomes very less & do not move under influence of electric field.

● **Streaming potential :** A potential difference is developed across a porous partition when the dispersion medium of a charged colloid is forced through it. This is called Streaming potential. This process is **reverse of electro-osmosis.**

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- **Charge on colloidal particles :** Colloidal particles are either positively charged or negatively charged. This charge is due to preferential adsorption of either positive or negative ions on their surface. There is adsorption of common ion present in excess.
    - $Fe(OH)_3$ sol prepared by the hydrolysis of $FeCl_3$ solution adsorbs Fe^{3+} and this is positively charged.
    $FeCl_3 + 3H_2O \rightleftharpoons Fe(OH)_3 + 3HCl$; $Fe(OH)_3 + FeCl_3 \rightarrow Fe(OH)_3$ Fe^{3+} : $3Cl^-$
    $$\text{Fixed part} \qquad \text{Diffused part.}$$
    Positive charge on colloidal sol is due to adsorption of Fe^{3+} ion (common ion between $Fe(OH)_3$ and $FeCl_3$).
    - As_2S_3 colloidal sol is obtained when As_2O_3 is saturated with H_2S :
        $As_2O_3 + 3H_2S \rightarrow As_2S_3 + 3H_2O$.
        As_2S_3 adsorbs S^{2-} ions (common between H_2S and As_2S_3 and thus is negatively charged).
        $As_2S_3 + H_2S \rightarrow As_2S_3$ S^{2-} : $2H^+$.
    - AgI in contact with $AgNO_3$ forms positively charged colloidal sol due to adsorption of Ag^+ ion.
    $AgI + AgNO_3 \rightarrow [AgI]Ag^+ : NO_3^-$, AgI in contact with KI forms negatively charged colloidal sol due to adsorption of I^- ion $AgI + KI \rightarrow AgI$ I^- : K^+.
    - SnO_2 in acidic medium forms positively charged colloidal sol due to adsorption of Sn^{4+} formed.
    $SnO_2 + 4H^+ \rightarrow Sn^{4+} + 2H_2O$ $SnO_2 + Sn^{4+} \rightarrow SnO_2$ Sn^{4+}
    SnO_2 in alkaline medium forms negatively charged colloidal sol due to adsorption of SnO_3^{2-} formed.
    $SnO_2 + 2OH^- \rightarrow SnO_3^{2-} + H_2O$ $SnO_2 + SnO_3^{2-} \rightarrow SnO_2$ SnO_3^{2-}
    Charge on colloidal particle may be due to some other reasons also e.g.
    *Due to electron capture by collidal particle during electro dispersion of metal.
    *Due to self dissociation.

- **Electric Double Layer Theory or Helm-holtz Electric double layer :**
Electric double layer Theory

- ❖ The combination of two layer of opposite charges (+ve and –ve charge) around colloidal particle is called Helm-Holtz electrical double layer.
- ❖ First layer of ions is firmly held and is termed as fixed layer.
- ❖ Secondary layer is mobile and is termed as diffused layer.
- ❖ The charges of opposite sign on fixed and diffused parts of double layer result in difference in potential between these layers.
- ❖ This potential difference between the fixed layer and diffused layer of opposite charges is called electrokinetic potential or zeta potential.

$$Z = \frac{4\pi\eta\mu}{D}$$

n = Viscosity coefficient

D = Dielectric constant of medium

μ = Velocity of colloidal particle when an electric field is applied.

e.g. $AgNO_3 + \underset{(excess)}{KI} \rightarrow AgI + KNO_3$

Solved Examples

**Ex-7.** Classify the following sols according to theirs charges :
  (a) gold sol   (b) ferric hydroxide sol   (c) gelatine   (d) blood
  (e) sulphur   (f) arsenious sulphide   (g) titanium oxide.

Sol. Negatively charged colloidal sol : (a), (c), (d), (e), (f).
  Positively charged colloidal sol : (b), (g).

Ex-8. SnO_2 forms positively charged colloidal sol in acidic medium and negatively charged colloidal sol in basic medium. Explain ?

Sol. SnO_2 is amphoteric reacting with acid and base both. In acidic medium (say HCl) Sn^{4+} ion is formed which is preferentially adsorbed on SnO_2 giving positively charged colloidal sol :

$$SnO_2 + 4HCl \longrightarrow SnCl_4 + 2H_2O \quad ;$$

$$SnO_2 + SnCl_4 \longrightarrow [SnO_2]Sn^{4+}(\text{positively charged}) + 4Cl^-.$$
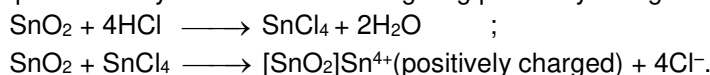
Section (E) : Coagulation, Protection And application of colloid

● **Coagulation/Flocculation : This process of aggregation of colloidal particles into an insoluble precipitate by the addition of some suitable electrolyte is known as coagulation.** At lower concentration of electrolytes, the aggregation of particles is called flocculation that can be reversed on shaking while at higher concentration of electrolyte, coagulation takes place and the same cannot be reversed simply by shaking. The stability of the lyophobic colloids is due to presence of charge on colloidal particles. If, somehow, the charge is removed, the particles will come near to each other to form aggregates and settle down under the force of gravity.

Coagulation value or Flocculation value: It needs to be noted that the coagulation of a colloidal solution by an electrolyte does not take place until the added electrolyte has certain minimum concentration in the solution. **The minimum concentration of electrolyte in millimoles required to cause coagulation of one litre of colloidal solution is called coagulation value.** It is express in terms of millimoles/litre.

$$Coagulation\ value = \frac{\text{millimoles of electrolyte}}{\text{volume of sol in litre}}$$

Neutralised
sol particles
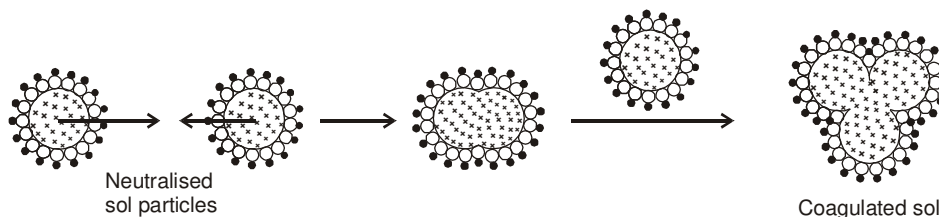
Coagulated sol

Coagulation of lyophobic sols can be carried out by the following methods.
(i) By electrophoresis
(ii) By mutual precipitation : It is a process in which oppositely charged sol are mixed in proper proportion to neutralise the charge of each other causing coagulation of both the sol.
Example : Positively charged $Fe(OH)_3$ and negatively charged As_2S_3 colloidal particle containing sol on mixing get coagulated.
(iii) By Prolonged Dialysis : On prolonged dialysis, traces of the electrolyte present in the sol are removed almost completely and the colloid becomes unstable and ultimately coagulate.
(iv) By Boiling : Sols such as sulphur and silver halides dispersed in water may be coagulated by boiling because increased collisions between sol particle and the water molecule removed the adsorbed electrolytes. This takes away the charge from the particles and helps them to coagulate.
(v) By cooling : Certain sol can also be coagulated by lowering temperature. For example, accumulation of cream on the surface of milk on cooling. This is because at lower temperature the dispersion medium molecules do not exert sufficient force on to the dispersed particles and hence the Brownian motion becomes less effective.
(vi) By the addition of electrolyte : When excess of an electrolyte is added, the colloidal particles are precipitated.

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- **Comparision of relative coagulating power of two electrolyte for the same colloidal solution :**
  The coagulation value decrease with increase in charge of the coagulating ion.

$$\text{Coagulating power} \propto \frac{1}{\text{coagulation value}}.$$

$$\frac{\text{coagulating power of electrolyte A}}{\text{coagulating power of electrolyte B}} = \frac{\text{coagulation value B}}{\text{coagulation value A}}.$$

- **Factor-Affecting Coagulations : (i) Nature of sols :** The lyophobic colloid can easily coagulate because it is a less stable colloid, but lyophilic colloids coagulate hardly by the addition of electrolyte due to protective layer of D.M. surrounding the colloidal particle.
  (ii) Nature of electrolyte : In equimolar electrolyte, strong electrolyte have greater coagulating power than weak electrolyte. Example : 0.1M NaCl > 0.1M CH_3COOH.

- **Hardy-Schulze Rule :** According to this rule greater is the valency of coagulating ion, greater its power to cause precipitation. This is known as Hardy-Schulze rule.
  In case of positive charged sol, the coagulating power of anion is in the order of $[Fe(CN)_6]^{4-} > PO_4^{3-} > SO_4^{2-} > Cl^-$
  In case of negative charged sol, the coagulating power of cation is in the order of $Al^{3+} > Ba^{2+} > Na^+$.

- The coagulating power of bivalent ion is 20-80 times higher than monovalent ion and coagulating power of trivalents is many times more than bivalent.

Solved Examples

Ex-9 The particles of a particular colloidal solution of arsenic trisulphide (As_2S_3) are negatively charged. Which 0.0005 M solution would be most effective in coagulating this colloidal solution. KCl, $MgCl_2$, $AlCl_3$ or Na_3PO_4? Explain.

Sol. Since As_2S_3 is a negatively charged colloidal sol hence positively charged ion will cause its coagulation. By Hardy-Schulze rule "greater the charge on ion, greater the coagulating power to coagulate oppositely charged colloidal sol", hence out of K^+, Mg^{2+}, Al^{3+} and Na^+, Al^{3+} would be most effective.

Protection of colloidal sols : Lyophilic colloidal sols are much more stable than lyophobic colloidal sols. This is due to the extensive solvation of lyophilic colloidal sols, which forms a protective layer outside it and thus prevents it from forming associated colloids. Lyophobic sols can easily precipitate by addition of small amount of an electrolyte. They can be prevented from coagulation by previous addition of some lyophilic colloid. This is due to formation of a protective layer by lyophilic sols outside lyophobic sols. Process of protecting the lyophobic colloid solution from precipitation by an electrolyte due to previous addition of some lyophilic colloid is called protection of colloid and lyophilic colloidal sols are called protective sols.

Eg : Gelatin, Sodium caseinate, Egg albumin, Gum arabic, Potato starch etc.,
Gelatin (lyophilic) protects gold sol (lyophobic) colloids is expressed in terms of gold number.

Gold Number : Zpsigmondy (1901) introduce a term called gold number it is defined as ''the minimum amount of the protective colloid in milligrams which when added to 10 ml of a standard gold sol is just sufficient to prevent a colour change from red to blue on the addition of 1 ml of 10% sodium chloride solution. It may be noted that smaller of the gold number, greater will be protecting power of the protective colloid.

$$\text{Protecting power} \propto \frac{1}{\text{gold number}}.$$

$$\text{Gold Number} = \frac{\text{weight of lyophilic sol in mg} \times 10}{\text{volume of gold sol in mL}}$$

Uses of protective action :
(i) Gelatin is added in the preparation of ice cream to protect the particle of ice.
(ii) Protargol and Argyrol, is a silver sol protected by organic material used as eye drop.

Applications of Colloids : Colloids including emulsions find a number of uses in our daily life and industry. Some of the uses are given below.

1. **In medicines :** A wide variety of medicinal and pharmaceutical preparations are emulsions. Colloidal medicines are easily adsorbed by the body tissue because of large surface area.
   * **Colloidal antimony** is used in curing **kalaazar.**

* **Milk of magnesia,** an emulsion, is used for **stomach disorder.**
* **Colloidal gold** is used for **intramuscular injection.**
* **Colloidal sulphur** are used as **Germicides.**
* **Argyrol** is a silver sol used as an **eye lotion.**
* **Colloidal Fe(OH)$_3$** is given to **arsenic poisoning** patients as it adsorbs arsenic and then gets omited out.

2. **Tanning**
3. **Photographic plate & Film**
4. **Rubber plating**
5. **Sewage disposal**
6. **Cottrell smoke precipitator :**

   Smoke is a dispersion of negatively charged colloidal particles of carbon in air and can be made free of these colloidal particles by passing it through cottrell precipitator as shown in fig. installed in the chimney of an industrial plant. It consists of two metal discs charged to a high potential. The carbon particles get discharged and precipitate, while gases come out from the chimney.
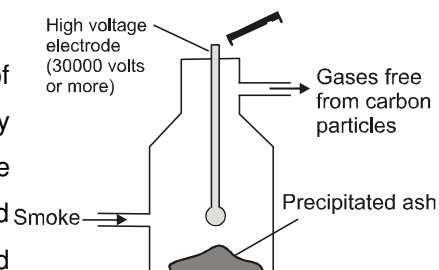
   Fig. : Cottrell smoke precipitator.

7. **Formation of deltas:** The river water contains colloidal particles of sand and clay which carry negative charge. The sea water contains +ve ions such as Na$^+$, Mg^{2+}, Ca^{2+} etc. As the river water meets sea water, these ions discharge the sand or clay particle which are precipitated in the form of delta.

8. **Artificial rain**
9. **Stop bleeding from a cut**
10. **Stop Screen**
11. **Preparation of nano-materials**
12. **In disinfectants :** The disinfectants such as dettol and lysol give emulsions of the oil-in-water type when mixed with water.

    STEM TECHNOLOGY : The size and shape of the colloidal particles is determined with the help of an electron microscope which has much more resolving power (of the order of 10^{-12}m.) The different techniques used to study the colloidal particles are :
    (i) Scanning electron microscope (SEM)
    (ii) Transmission electron microscope (TEM) and
    (iii) Scanning transmission electron microscope (STEM).

Section (F) : Emulsion and Gel

● **Emulsions :** Pair of immiscible liquid is called emulsion. Emulsion are unstable and some time they are separated into two layers on keeping still, for the stabilising of an emulsion, a third component is added called emulsifying-Agent form an interfacial film between D.P. and D.M.
Emulsion droplets are bigger than sol particles and can be seen under an ordinary microscope and sometimes even with a magnifying glass.
Example : Milk is an emulsion in which liquid fat is D.P. and liquid water is D.M. and **casein** is emulsifying agent.

☞ **Demulsification :** The separation of an emulsion into its constituent liquids is called demulsification. Various techniques employed for this are freezing, boiling, centrifugation, electrostatic precipitation or chemical methods which destroys the emulsifying agents.
Demulsification can be brought about by :
(i) Freezing   (ii) Heating
(iii) Centrifugal action (Separation of cream of milk done by centrifugation).
(iv) Removal of emulsifiers by adding a better solvent for them like alcohol, phenol etc, called demulsifiers.

Types of emulsions : Depending on the nature of the dispersed phase, the emulsions are classified as:
(a) Oil in water emulsions   (b) Water in oil emulsions

● **Inversion of phase :** The conversion of emulsion of oil in water (o/w) into water in oil (w/o) or vice versa is called the inversion of phase.

[A] Identification of the type of emulsion : These two types may be identified by :

● **Dilution test :** An emulsion can be diluted with any amount of the dispersion medium, while the dispersed liquid, if added, forms a separate layer. Thus if a few drops of water added to the emulsion are soluble in it, it is oil in water type and if immiscible, it is water in oil type.

● **Dye test :** If a small amount of oil soluble dye gives a uniform colour to the emulsion, it is water in oil type otherwise it is oil in water type.

● **Electrical conductivity test :** If conductivity of emulsion increases significantly by adding a very small amount of electrolyte, it is oil in water type and if there is no significant increase in conductivity, it is water in oil type.

[B] Applications of emulsions :

● Disinfactants like phenyl, dettol when mixed with water form emulsion.
● Digestion of fat in small intestine occurs easily due to emulsion.
● In metallurgical process the concentration of ore by froath floatation method is based upon emulsion.
● Milk is an emulsion of liquid fat in water in which casein emulsifying agent.
● Cleansing action of soap is due to formation of emulsions. Soaps and detergents emulsify the grease along with the adhering dirt and carry them away in the wash water.
● For concentrating ores, the finely powdered ore is treated with an oil. Oil forms emulsion with the ore particles. When air is bubbled into the mixture, emulsion containing the particles of the mineral are carried to the surface.

Gel :
Ex :   Gelatin dissolved in water forming a colloidal. Sol which when cooled sets into a gelly.
        ***Gel have honey-comb structure :**
Ex :   Sillicic acid, Gum arabic, Sodium oleate, Gelatin, Solid alcohol, etc.

Types of Gel :
(i) Elastic gel : Those gel which have elastic properties.   **Eg :** Gelatin, Starch, Agar-Agar etc.
(ii) Non- elastic gel : Those gel which are rigid.   **Eg :** Silica gel.

Properties of Gel :
1. **Syneresis/weeping of gel :** The spontaneous liberation of liquid from a gel is called syneresis or weeping of gels. It is reverse of swelling.
   Eg : Gelatin, Agar-Agar show syneresis at low concentration while sillicic acid shows it at high concentration.
2. **Imbibition or swelling of gel :** When gel is kept in a suitable liquid (water) it absorb large volume of liquid. The phenomenon is called, imbibition or swelling of gel.
3. **Thixotropic :** Some gels when shaken to form a sol, on keeping changes into gel are termed as thixotropic gel and phenomenon is called thixotropy.
   Eg : Gelatin and silica liquify on shaking changing into corresponding sol and the sol on keeping changes back into gel.

MISCELLANEOUS SOLVED PROBLEMS (MSPs)

1.*   Which of the following is (are) lyophobic colloids ?
      (A) Gold sol   (B) As_2S_3 sol   (C) Starch sol   (D) $Fe(OH)_3$ sol
Sol.   **(ABD)** Gold sol, As_2S_3 and $Fe(OH)_3$ are lyophobic colloid. Therefore, (A, B, D) are correct options.

2.   The presence of colloidal particles of dust in air imparts blue colour to the sky. This is due to
      (A) Absorption of the light   (B) Scattering of the light
      (C) Reflection of the light   (D) None of these
Sol.   **(B)** Due to scattering of the light. Therefore, (B) is correct option.

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3. The volume of nitrogen gas U_m (measured at STP) required to cover a sample of silica gel with a mono-molecular layer is 129 cm^3 g^{-1} of gel. Calculate the surface area per gram of the gel if each nitrogen molecule occupies 16.2×10^{-20} m^2.

Ans. 561.8 cm^3

Sol. 22400 cm^3 of N_2 at STP contain = 6.022×10^{23} molecules

$\therefore$ 129 cm^3 of N_2 at STP will contain = $\dfrac{6.022 \times 10^{23} \times 129}{22400}$ = 3.468×10^{21} molecules

Area occupied by a single molecule = 16.2×10^{-20} m^2

$\therefore$ Area occupied by 3.468×10^{21} molecules of nitrogen

= $(16.2 \times 10^{-20}) \times (3.468 \times 10^{21})$ m^2 = 561.8 m^2.

4. Which of the following has minimum gold number ?
(A) Potato starch   (B) Gum arabic   (C) Gelatin   (D) Albumin

Sol. **(C)** Gelatin has minimum gold number. Therefore, (C) is correct option.

5.* Which of the following are correctly matched ?
(A) Butter-gel   (B) Milk-emulsion   (C) Fog-aerosol   (D) Dust-solid sol

Sol. **(ABC)** are correct matches.

6. Explain the adsorption of nitrogen on iron.

Sol. When nitrogen gas is brought in contact with iron at 83 K, it is physisorbed on iron surface as nitrogen molecules, N_2. As the temperature is increased the amount of nitrogen adsorbed decreases rapidly and at room temperature, practically there is no adsorption of nitrogen on iron. At 773 K and above, nitrogen is chemisorbed on the iron surface as nitrogen atoms.

7. How do size of particles of adsorbent, pressure of gas and prevailing temperature influence the extent of adsorption of a gas on a solid ?

Sol. (a) Smaller the size of the particles of the adsorbent, greater is the surface area and hence greater is the adsorption
(b) At constant temperature, adsorption first increases with increase of pressure and then attains equilibrium.
(c) In physical adsorption, it decreases with increase of temperature but in chemisorption, first it increases and then decreases.

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

Sol. Higher is the critical temperature of a gas, greater the van der Waal's forces of attraction and hence greater is the adsorption.

9. Physical adsorption is essentially quite appreciable :
(A) at room temperature   (B) at higher temperature
(C) at lower temperature   (D) none of these

Sol. **(C)** Rate of physical adsorption decreases with increase in temperature (exothermic process). Therefore, (C) is correct option.

10. What type of colloidal sols are formed in the following ?
(i) Through cooled water, vapours of sulphur are passed.
(ii) White of an egg is mixed with water.

Sol. (i) Sulphur molecules associate together to form molecular sols.
(ii) Macromolecular sol because protein molecules present in the white of the egg are macromolecules & are soluble in water.

11. What happens when persistent dialysis of a colloidal solution is carried out.

Sol. The stability of a colloidal sol is due to the presence of a small amount of the electrolyte. On persistent dialysis, the electrolyte is completely removed. As a result, the colloidal sol becomes unstable and gets coagulated.

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Exercise-1

✍ **Marked questions are recommended for Revision.**

PART - I : SUBJECTIVE QUESTIONS

Section (A) : Adsorption

A-1. Why adsorption is always exothermic ?

A-2.✍ What is the difference between physical adsorption and chemisorption ?

A-3. What are the factors which influence the adsorption of a gas on a solid ?

A-4. What is an adsorption isotherm ?

A-5. What do you understand by activation of adsorbent ? How is it achieved ?

A-6. Which will be adsorbed more readily on the surface of charcoal and why– NH_3 or CO_2 ?

A-7.✍ In an Adsorption experiment a graph between log x/m versus log P was found to be linear with a slope of 45º the intercept of the log x/m was found to be 0.3010. Calculate the amount of gas adsorbed per gram of charcoal under a pressure of 0.6 bar.

A-8.✍ 1 gm of charcoal adsorbs 100 mL of 0.5 M CH_3COOH to form mono layer and there by the molarity of CH_3COOH reduces to 0.49 M. Calculate the surface area of the charcoal adsorbed by each molecule of CH_3COOH. Surface area of charcoal = 3.01×10^2 m^2/g.

A-9. What role does adsorption play in heterogeneous catalysis ?

A-10.✍ How many grams of gas would be adsorbed per gram of a substance at 8 atm by assuming Freundlich adsorption isotherm.

$$\frac{x}{m} = kp^{1/n} \qquad \text{and} \qquad k = 10^{-2} \text{ atm}^{-1/3} \qquad \& \qquad n = 3.$$

A-11. 10 mg of an adsorbate gets adsorbed on a surface. This causes the release of 3J of heat at constant pressure and at 27ºC. [Molar mass of adsorbate = 100 g/mol].
(i) Find $\Delta H_{adsorption}$.
(ii) Argue whether the adsorption is physical or chemical ?
(iii) If 20 mg of adsorbate is adsorbed at temperature T_0. Then compare T_0 and 27ºC :

Section (B) : Catalysis

B-1. Give two examples of heterogeneous catalysis.

B-2. Identify the correct order of steps in hetereogeneous catalysis.
(i) Adsorption of reactant molecules on the surface of the catalyst.
(ii) Diffusion of reactant to the surface of the catalyst.
(iii) Formation of reactions product on the catalyst surface.
(iv) Diffusion of reactions product from the catalyst surface or desorption.
(v) Formation of activated intermediate.

Section (C) : Classification and Preparation of Colloid

C-1. How are the colloidal solutions classified, on the basis of physical states of the dispersed phase and dispersion medium ?

C-2. Explain the following terms with suitable examples.
(a) Gel   (b) Liquid Aerosol   (c) Hydrosol

C-3.✍ How are associated colloids different from multimolecular and macromolecular colloids ?

C-4. Give one example of multimolecular and macromolecular colloids.

C-5. Describe a method each for the preparation of sols of sulphur and platinum in water

Section (D) : Purification and Properties of Colloid

D-1. Explain the following terms :
   (a) Peptization   (b) Electrophoresis   (c) Dialysis   (d) Brownian movement

D-2. Why the sun looks red at the time of setting ?

D-3. Why is osmotic pressure of a colloidal solution less than that of true solution ?

Section (E) : Coagulation, Protection And application of colloid

E-1. Which one of the following electrolytes is most effective for the coagulation of $Fe(OH)_3$ sol and why ?
   $NaCl$, Na_2SO_4, Na_3PO_4.

E-2. What do you understand by "isoelectric point" of a colloid ?

E-3. Rivers form delta on meeting with ocean, why ?

E-4. Artificial rain is made by spraying salt over clouds, why ?

Section (F) : Emulsion and Gel

F-1. Name two demulsifier.

F-2. What is the difference between sols and emulsions.

F-3. What is demulsification ?

F-4. What is phase inversion in emulsion ?

PART - II : ONLY ONE OPTION CORRECT TYPE

Section (A) : Adsorption

A-1. Which of the following statements about chemisorption is not applicable?
   (A) It involves chemical forces between adsorbent and absorbate
   (B) It is irreversible in nature
   (C) It involves high heat of adsorption
   (D) It does not require activation energy

A-2. Following is the variation of physical adsorption with temperature:
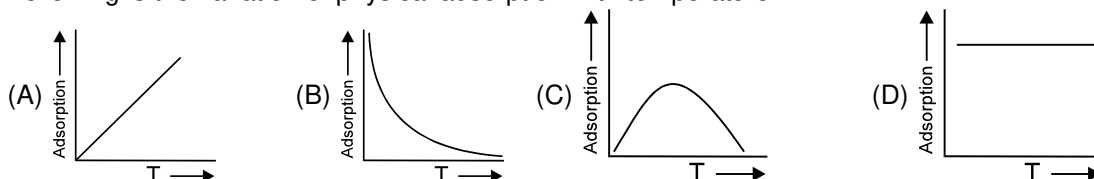
A-3. Adsorption is the phenomenon in which a substance:
   (A) accumulates on the surface of the other substance
   (B) goes into the body of the other substances
   (C) remains close to the other substance
   (D) none of these

A-4. Finely divided catalyst has greater surface area and has greater catalytic activity than the compact solid. If a total surface area of 6291456 cm^2 is required for adsorption in a catalysed gaseous reaction, then how many splits should be made to a cube of exactly 1 cm in length to achieve required surface area. (Given : One split of a cube gives eight cubes of same size)
   (A) 60   (B) 80   (C) 20   (D) 22

A-5. Volume of N_2 at NTP required to form a mono layer on the surface of iron catalyst is 8.15 ml/gram of the adsorbent. What will be the surface area of the adsorbent per gram if each nitrogen molecule occupies 16×10^{-22} m^2.
   (A) 16×10^{-16} cm^2 (B) 0.35 m^2/g (C) 39 m^2/g (D) 22400 cm^2

A-6. There is desorption of physical adsorption when :
   (A) temperature is increased   (B) temperature is decreased
   (C) pressure is increased   (D) concentration is increased

A-7. The rate of chemisorption :
(A) decreases with increase of pressure   (B) increases with increase of pressure
(C) is independent of pressure   (D) is independent of temperature

A-8. Softening of hard water is done using sodium aluminium silicate (zeolite). This causes :
(A) adsorption of Ca^{2+} and Mg^{2+} ions of hard water replacing Na^+ ions.
(B) adsorption of Ca^{2+} and Mg^{2+} ions of hard water replacing Al^{3+} ions
(C) both (A) and (B)
(D) none of these

Section (B) : Catalysis
B-1. Which one is false in the following statement ?
(A) A catalyst is specific in its action
(B) A very small amount of the catalyst can alter the rate of a reaction.
(C) The number of free valencies on the surface of the catalyst increases on sub-division
(D) Ni is used as a catalyst in the manufacture of ammonia

B-2. A catalyst increases rate of reaction by :
(A) Decreasing enthalpy   (B) Decreasing internal energy
(C) Decreasing activation energy   (D) Increasing activation energy

Section (C) : Classification and Preparation of Colloid
C-1. Colloidal solution of gold prepared by different methods of different colours because of :
(A) different diameters of colloidal gold particles
(B) variable valency of gold
(C) different concentration of gold particles
(D) impurities produced by different methods

C-2. At CMC, the surfactant molecules :
(A) Decomposes   (B) Become completely soluble
(C) Associate   (D) Dissociate

Section (D) : Purification and Properties of Colloid
D-1. A colloidal solution can be purified by the following method :
(A) dialysis   (B) peptization   (C) filtration   (D) oxidation

D-2. Peptisation is :
(A) conversion of a colloidal into precipitate form
(B) conversion of precipitate into colloidal sol
(C) conversion of metal into colloidal sol by passage of electric current
(D) conversion of colloidal sol into macromolecules

D-3. Bleeding is stopped by the application of ferric chloride. This is because :
(A) the blood starts flowing in opposite direction
(B) the blood reacts and forms a solid, which seals the blood vessel
(C) the blood is coagulated and thus the blood vessel is sealed
(D) the ferric chloride seals the blood vessel.

Section (E) : Coagulation, Protection And application of colloid
E-1. Gold number of a lyophilic sol is such property that:
(A) the larger its value, the greater is the peptising power
(B) the lower its value, the greater is the peptising power
(C) the lower its value, the greater is the protecting power
(D) the larger its value, the greater is the protecting power

E-2. Protective sols are :
(A) lyophilic   (B) lyophobic   (C) both (A) and (B)   (D) none of (A) and (B)

E-3. For the coagulation of 200 mL of As_2S_3 solution, 10 mL of 1 M NaCl is required. What is the coagulating value (number of milli moles of solute needed for coagulation of 1 liter of solution) of NaCl.
(A) 200   (B) 100   (C) 50   (D) 25

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E-4. Which of the following ions is most effective in the coagulation of an arsenious sulphide solution ?
(A) K^+ (B) Mg^{2+} (C) Al^{3+} (D) C

E-5. Which of the following ions is most effective in the coagulation of ferric hydroxide solution ?
(A) Cl^- (B) Br^- (C) NO_2^- (D) SO_4^{2-}

Section (F) : Emulsion and Gel

F-1. Small liquid droplets dispersd in another liquid is called :
(A) Suspension   (B) Emulsion   (C) Gel   (D) True solution

PART - III : MATCH THE COLUMN

1. Match list I with list II and select the correct answer :

	List-I		List-II
(P)	Mechanical property of colloid	(1)	Dialysis
(Q)	Purification	(2)	Peptization
(R)	Gold number	(3)	Brownian movement
(S)	Formation of a sol	(4)	Protection

Code:

	P	Q	R	S		P	Q	R	S
(A)	3	4	1	2	(B)	1	2	4	3
(C)	3	1	4	2	(D)	2	3	1	4

2. Match list I with list II and give the correct answer :

	List-I		List-II
(A)	Gold sol	(p)	Bredig's Arc method
(B)	Purification of colloidal solution	(q)	Negatively charged
(C)	As_2S_3 sol	(r)	Dialysis
(D)	Zeta potential	(s)	Electro kinetic potential
(E)	Casein	(t)	Double decomposition reaction
		(u)	Protective colloid

Exercise-2

🐦 **Marked questions are recommended for Revision**

PART - I : ONLY ONE OPTION CORRECT TYPE

1. Which of the following statements is correct for a lyophilic solution ?
(A) It is not easily solvated   (B) The coagulation of this sol is irreversible in nature
(C) It is unstable   (D) It is quite stable in a solvent

2. Liquid-liquid colloidal system is known as
(A) aerosol   (B) foam   (C) emulsion   (D) gel

3. The colloidal system consisting of a liquid dispersed in a solid dispersion medium is termed as :
(A) aerosol   (B) foam   (C) emulsion   (D) gel

4. Which of the following statements is not correct ?
(A) A colloidal solution is a heterogeneous two-phase system
(B) Silver sol in water is an example of lyophilic solution.
(C) Metal hydroxides in water are examples of lyophobic solution
(D) Liquid-liquid colloidal solution is not a stable system

5. Size of colloidal particles may range from :
(A) 1 to 1000 nm   (B) 10 to 100 pm   (C) 1 to 100 µm   (D) 1 to 10 mm

6. Which of the following represents a multimolecular colloidal particles?
(A) Starch   (B) A sol of gold   (C) Proteins   (D) Soaps

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7. Which of the following anions will have minimum flocculation value for the ferric oxide solution ?
(A) Cl^- (B) Br^- (C) SO_4^{2-} (D) $[Fe(CN)_6]^{3-}$

8. Which of the following represents a macromolecular colloidal particles ?
(A) Solution of gold   (B) Cellulose   (C) Soaps   (D) Synthetic detergents

9. Gold number of some lyophilic sols are :

I	Casein	0.01
II	Haemoglobin	0.03
III	Gum arabic	0.15
IV	Sodium oleate	0.40

Which has maximum protective power :
(A) I   (B) II   (C) III   (D) IV

10. Arsenic (III) sulphide forms a sol with a negative charge. Which of the following ionic substances should be most effective in coagulating the sol ?
(A) KCl   (B) $MgCl_2$ (C) $Al_2(SO_4)_3$ (D) Na_3PO_4

11. Smoke is a dispersion of :
(A) gas in gas   (B) gas in solid   (C) solid in gas   (D) liquid in gas

12. Smoke has generally blue tinge. It is due to :
(A) scattering   (B) coagulation   (C) Brownian motion   (D) electro-osmosis

13. Which one of the following statements is false for hydrophilic sols ?
(A) they do not require electrolytes for stability
(B) their viscosity is of the order of that of water
(C) their surface tension is usually lower than that of dispersion medium.
(D) none of these

14. Soaking of sponge by water is an example of :
(A) Simple adsorption   (B) Physical adsorption
(C) Chemisoption   (D) Absorption

15. Identify the appropriate graph between enthalpy and progress of physical adsorption.

(A)

(B)

(C)

(D)

16. Hydrolysis of ester in catalysed by acid. Rate of hydrolysis of ester were obtained initially and after some ester has been hydrolysed as R_0 and R_t then (same temp.)
(A) $R_0 = R_t$ (B) $R_0 < R_t$ (C) $R_0 > R_t$ (D) Cannot be determined

PART - II : SINGLE OR DOUBLE INTEGER TYPE

1. When a graph is plotted between log x/m and log p, it is straight line with an angle 45° and intercept 0.3010 on y-axis. If initial pressure is 0.3 atm, what will be the amount of gas adsorbed per gram of adsorbent : (Report your answer after multiplying by 10)

2. The volume of nitrogen gas (measured at STP) required to cover a sample of silica gel with a mono-molecular layer is $129 cm^3/g$ of gel. Calculate the surface area per gram of the gel if each nitrogen molecule occupies $16.2 \times 10^{-20} m^2$. (Report your answer after dividing by 10).

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3. How many of these reactions are homogeneously catalyzed?

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

(ii) $C_{12}H_{22}O_{11}(aq.) + H_2O(\ell) \xrightarrow{H_2SO_4(\ell)} C_6H_{12}O_6(aq.) + C_6H_{12}O_6(aq.)$
                                 Glucose   Fructose

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

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

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

(vi) $CH_3COOCH_3(\ell) \xrightarrow{HCl(\ell)} CH_3COOH(aq)$

(vii) Vegetable oils $(\ell) + H_2(g) \xrightarrow{Ni(s)}$ Vegetable ghee (s).

4. Coagulation value of the electrolytes $AlCl_3$ and NaCl for As_2S_3 sol are 0.093 and 52 repectively. How many times $AlCl_3$ has greater coagulating power than NaCl.

5. Among the following number of correct statements are :
(i) Stability of lyophilic colloids is mainly due to the strong interaction between dispersed particle and dispersion medium.
(ii) Entropy change for adsorption of gases over solid is positive.
(iii) Gelatin has considerably low value of gold number and is effective protective colloid.
(iv) Zeta potential is also responsible for stability of lyophobic colloid solution.
(v) Surface tension of lyophilic colloidal solution is lesser than that of dispersion medium.

6. For the just coagulation of 250 mL of $Fe(OH)_3$ sol, 2 mL of 1 M Na_2SO_4 electrolyte is required. What is the coagulating value of Na_2SO_4 electrolyte.

7. The minimum concentration of an electrolyte required to cause coagulation of a sol is called its flocculation value. It is expressed in millimoles per litre. If the flocculation value of $MgSO_4$ for standard As_2S_3 sol is 3.33. How many milligrams of $MgSO_4$ is to be added to 20 ml standard As_2S_3 sol so that flocculation just starts ?

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1. Which of the following statements about physical adsorption is correct ?
(A) It is always monolayer
(B) It is reversible in nature
(C) It involves van der Waals interactions between adsorbent and adsorbate
(D) It involves small enthalpy of adsorption as compared to chemisorption.

2. Which of the following statements regarding adsorption is correct ?
(A) Extent of adsorption of gases on charcoal increases with increase in pressure of the gas
(B) Extent of adsorption is independent of temperature
(C) Extent of chemisorption by a given mass of adsorbent is limited
(D) Extent of adsorption is dependent on the nature of adsorbent

3. Which of the following is characteristic of chemisorption?
(A) it is irreversible   (B) it is specific
(C) it is multilayer phenomenon   (D) heat of adsorption is generally around 80 – 240 kJ

4. Which is/are a purely surface phenomena :
(A) surface tension   (B) adsorption   (C) absorption   (D) none of these

5. Which of the following are correct statements ?
(A) Spontaneous adsorption of gases on solid surface is an exothermic process as entropy decreases during adsorption
(B) Formation of micelles takes place when temperature is below Kraft Temperature (T_k) and concentration is above critical micelle concentration (CMC)
(C) Longer the length of hydrophobic chain, smaller is the value of critical micelle concentration (CMC)
(D) According to Hardy-Schulze rule the coagulation (flocculating) value of Fe^{3+} ion will be more than Ba^{2+} or Na^+.

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6. Which of the following statements are true for physisorption?
(A) Extent of adsorption increases with increase in pressure.
(B) It needs activation energy
(C) It can be reversed easily
(D) It occurs at high temperature.

7. Identify the reactions that includes inhibtors in the reactions mixture.
(A) $N_2 + 3H_2 \xrightarrow[Mo]{Fe} 2NH_3$
(B) Vegetable Oil $+ H_2 \xrightarrow{Ni}$ Vegetable ghee.

(C) $N_2 + 3H_2 \xrightarrow[CO/H_2S]{Fe} 2NH_3$
(D) $RCOCl + H_2 \xrightarrow{Pd}{BaSO_4} RCHO + HCl$

8. Which of the following are the correct :
(A) A Catalyst remains unchanged in mass and chemical compositions at the end of reactions.
(B) Finely devided state of catalyst is more efficient for the reactions.
(C) Catalyst change equilibrium state of the reaction.
(D) A catalyst changes the entropy and the free energy of a reaction.

9. The diameter of colloidal particle is of the order :
(A) 10^{-3} m
(B) 10^{-6} m
(C) 10^{-15} m
(D) 10^{-7} m

10. Which of the following are examples of aerosols?
(A) Whipped cream
(B) Cloud
(C) Fog
(D) Soap lather

11. Which of the following are hydrophobic sols ?
(A) Protein sol
(B) Gold sol
(C) Gum sol
(D) $Fe(OH)_3$ sol.

12. Which of the following are multimolecular colloids ?
(A) Sulphur
(B) Egg albumin in water
(C) Gold sol
(D) Soap solution

13. The origin of charge on colloidal solution is
(A) Self dissociation (in soaps and detergents)
(B) Electron capture during Bredig's arc method
(C) Selective adsorption of ion on their surface
(D) It is due to addition of protective colloids

14. Which of the following is/are not true for lyophilic colloid ?
(A) These are prepared by special indirect methods.
(B) The particles must travel towards the anode or cathode under the influence of an electric field.
(C) These are called on intrinsic colloid
(D) Small quantity of electrolyte is sufficient to cause precipitation of these.

15. Which of the following are based on Tyndall effect.
(A) Tail of comets
(B) Deltas
(C) Blue colour of sky
(D) Coagulation

16. Which of the following statements is correct?
(A) Peptization is the process by which some fresh precipitates are converted into the colloidal state by addition of little suitable electrolyte.
(B) Metal sols of gold, silver and platinum can be prepared by Bredig's arc method.
(C) Impurities present in a solution makes it more stable.
(D) Dialysis is a process to remove impurities of ions and molecules from a solution.

17. Which is an example of coagulation?
(A) curdling of milk
(B) purification of water by addition of alum
(C) formation of deltas at the river beds
(D) formation of ice

18. When negatively charged colloids like As_2S_3 sol is added to positively charged $Fe(OH)_3$ sol in suitable amounts
(A) Both the sols are precipitated simultaneously .
(B) This process is called mutual coagulation.
(C) They become positively charged colloids.
(D) They become negatively charged colloids.

19. Which of the following are incorrect statements ?
(A) Hardy schulz rule is related to coagulation
(B) Brownian movement and Tyndall effect are the characteristic of colloids.
(C) In gel, the liquid is dispersed in liquid
(D) Higher the gold number, more is the protective power of lyophillic sols.

20. Which of the following sols is positively charged?
(A) Arsenious sulphide
(B) Aluminium hydroxide
(C) Ferric hydroxide
(D) Silver iodide in silver nitrate solution

PART - IV : COMPREHENSION

Read the following passage carefully and answer the questions.

Comprehension # 1

Many lyophilic sols and few lyophobic sols when coagulated under some special conditions changes into semi rigid mass, enclosing whole amount of liquid within itself, it is called gel and the process is called gelation. Gelatin Agar-agar, gum-Arabic can be converted into gels by cooling them under moderate concentration conditions. Hydrophobic sols like silicic acid. $Al(OH)_3$ are prepared by double decomposition and exchange of solvent method.

Types of Gel :
(i) **Elastic gel :** Those gel which have elastic properties.
Ex : Gelatin, Strach, Agar-Agar etc.

(ii) **Non- elastic gel :** Those gel which are rigid.
Ex: Silica gel.

Properties of Gel :
1. **Syneresis/weeping of gel :** The spontaneous liberation of liquid from a gel is called syneresis or weeping of gels. It is reverse of swelling.
Ex: Gelatin, Agar-Agar show syneresis at low concentration while sillicic acid shows it at high concentration.
2. **Imbibition or swelling of gel :** When gel is kept in a suitable liquid (water) it absorb large volume of liquid. The phenomenon is called imbibition or swelling of gel.
3. **Thixotropic :** Some gels when shaken to form a sol, on keeping changes into gel are termed as thixotropic gel and phenomenon is called thixotropy.
Ex: Gelatin and silica liquify on shaking changing into corresponding sol and the sol on keeping changes back into gel.

1. Which of the following is used to adsorb water ?
(A) Silica gel   (B) Calcium acetate   (C) Hair gel   (D) Cheese

2. The process of imbibing water when elastic gel are placed in water is called :
(A) imbibition   (B) synerisis   (C) coagulation   (D) thixotropy

3. Some types of gels like gelatin and silica liquify on shaking thereby changing into sols. The sols on standing change back into gels. This process is know as
(A) syneresis
(B) thixotropy
(C) double decompostion
(D) peptization

Comprehension # 2

The clouds consist of charged particles of water dispersed in air. Some of them are +vely charged, others are –vely charged. When +vely charged clouds come closer they cause lightening and thundering whereas when +ve and –ve charged colloids come closer they cause heavy rain by aggregation of minute particles. It is possible to cause artificial rain by throwing electrified sand or silver iodide from an aeroplane and thus coagulating the mist hanging in air.

Smoke screen is a cloud of smoke used to hide military, naval police etc. it consists of fine particles of TiO_2.

4. When excess of $AgNO_3$ is treated with KI solution, AgI forms
(A) +ve charged sol   (B) –ve charged sol   (C) neutral sol   (D) true solution

5. AgI helps in artificial rain because :
(A) it helps in ionisation of water
(B) it helps in dispersion process
(C) it helps in coagulation
(D) all of them

6. Smoke screens consist of
(A) fine particles of TiO_2 dispersed in air by aeroplanes
(B) fine particles of AgI dispersed in air by aeroplanes
(C) fine particles of Al_2O_3 dispersed in air by aeroplanes
(D) None of these

Comprehension # 3

Answer Q.7, Q.8 and Q.9 by appropriately matching the information given in the three columns of the following table.

	Column-1		Column-2		Column-3
(I)	Positively charged colloid	(i)	Can be coagulated by adding metal sulphide sol	(P)	During electrophoresis coagulation will take place at anode
(II)	Negatively charged colloid	(ii)	Can be coagulated by adding metal oxide sol	(Q)	During electro-osmosis level of dispersion medium will increase on anode side.
(III)	Can be prepared by Bredig's Arc method	(iii)	Coagulation value of $Na_2SO_4 > MgCl_2$ for this colloid	(R)	During Electro-phoresis coagulation will take place at cathode.
(IV)	Can be prepared by peptisation	(iv)	Coagulating power of $MgSO_4 > NaCl$ for this colloid.	(S)	During electro-osmosis level of dispersion medium will increase on cathode side.

7. Select the only incorrect option for AgI / I$^-$ sol.
(A) (II) (ii) (P)   (B) (IV) (iv) (P)   (C) (II) (iii) (S)   (D) (IV) (iii) (Q)

8. Select the only correct option Fe(OH)$_3$ sol.
(A) (I) (iii) (Q)   (B) (IV) (i) (Q)   (C) (I) (iii) (R)   (D) (IV) (iv) (S)

9. Select the only incorrect option for gold sol.
(A) (II) (ii) (P)   (B) (II) (iii) (S)   (C) (III) (iv) (S)   (D) (II) (iii) (Q)

Exercise-3

* **Marked Questions are having more than one correct option.**

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1. Rate of physisorption increases with   **[JEE 2003, 3/60]**
(A) decrease in temperature
(B) increase in temperature
(C) decrease in pressure
(D) decrease in surface area

2. Adsorption of gases on solid surface is generally exothermic because   **[JEE 2004, 3/84]**
(A) enthalpy is positive
(B) entropy decreases
(C) entropy increases
(D) free energy increases

3. Lyophilic sols are   **[JEE 2005, 3/84]**
(A) Irreversible sols
(B) They are prepared from inorganic compound
(C) Coagulated by adding electrolytes
(D) Self-stabilizing

4. Among the following, the surfactant that will form micelles in aqueous solution at the lowest molar concentration at ambient condition is :   **[JEE 2008, 3/163]**
(A) $CH_3(CH_2)_{15}N^+(CH_3)_3Br^-$
(B) $CH_3(CH_2)_{11}OSO_3^-Na^+$
(C) $CH_3(CH_2)_6COO^-Na^+$
(D) $CH_3(CH_2)_{11}N^+(CH_3)_3Br^-$

5. Among the electrolytes Na_2SO_4, $CaCl_2$, $Al_2(SO_4)_3$ and NH_4Cl, the most effective coagulating agent for Sb_2S_3 sol is :   **[JEE 2009, 3/160]**
(A) Na_2SO_4 (B) $CaCl_2$ (C) $Al_2(SO_4)_3$ (D) NH_4Cl

6. Silver (atomic weight = 108 gm mol^{-1}) has a density of 10.5 gm cm^{-3}. The number of silver atoms on a surface of area 10^{-12} m^2 can be expressed in scientific notation as $y \times 10^x$. The value of x is :
[JEE 2010, 3/163]

7.* The correct statement(s) pertiaining to the adsorption of a gas on a solid surface is (are)
[JEE 2011, 4/180]

(A) Adsorption is always exothermic
(B) Physisorption may transform into chemisorption at high temperature
(C) Physisorption increases with increasing temperature but chemisorption decreases with increasing temperature
(D) Chemisorption is more exothermic than physisorption, however it is very slow due to higher energy of activation.

8.* Choose the correct reason(s) for the stability of the **lyophobic** colloidal particles. **[JEE 2012, 4/168]**
(A) Preferential adsorption of ions on their surface from the solution.
(B) Preferential adsorption of solvent on their surface from the solution.
(C) Attraction between different particles having opposite charges on their surface.
(D) Potential difference between the fixed layer and the diffused layer of opposite charges around the colloidal particles.

9.* The given graph / data I, II, III and IV represent general trends observed for different physisorption and chemisorption processes under mild conditions of temperature and pressure. Which of the following choice (s) about I, II, III and IV is (are) correct.   **[JEE 2012, 4/168]**
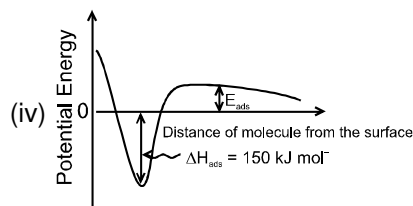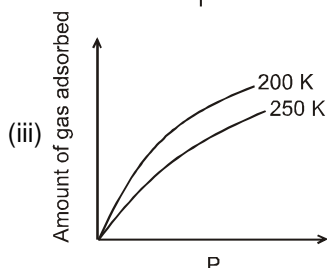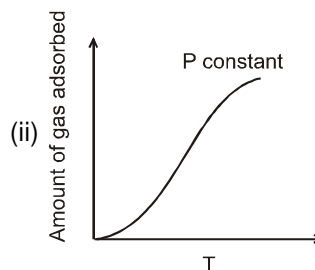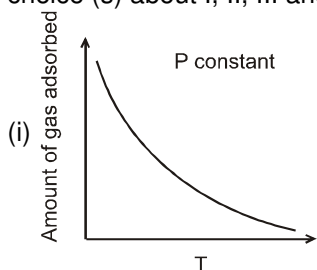
(A) I is physisorption and II is chemisorption   (B) I is physisorption and III is chemisorption
(C) IV is chemisorption and II is chemisorption   (D) IV is chemisorption and III is chemisorption

10. Methylene blue, from its aqueous solution, is adsorbed on activated charcoal at 25° C. For this process, the correct statement is   **[JEE(Advanced)-2013, 2/120]**
(A) The adsorption requires activation at 25°C.
(B) The adsorption is accompanied by a decreases in enthalpy.
(C) The adsorption increases with increase of temperature.
(D) The adsorption is irreversible.

11.* When O_2 is adsorbed on a metallic surface, electron transfer occurs from the metal to O_2. The **TRUE** statement(s) regarding this adsorption is(are)   **[JEE(Advanced)-2015, 4/168]**
(A) O_2 is physisorbed   (B) heat is released
(C) occupancy of π^*_{2p} of O_2 is increased   (D) bond length of O_2 is increased

12. The qualitative sketches I, II and III given below show the variation of surface tension with molar concentration of three different aqueous solution of KCl, CH_3OH and $CH_3(CH_2)_{11}OSO_3^-Na^+$ at room temperature. The correct assignment of the sketches is : **[JEE(Advanced)-2016, 3/124]**

(A) I : KCl   II : CH_3OH III : $CH_3(CH_2)_{11}OSO_3^-Na^+$
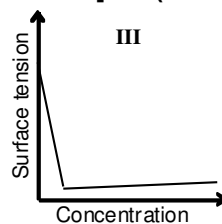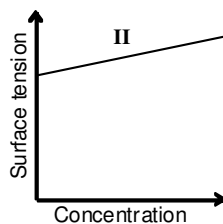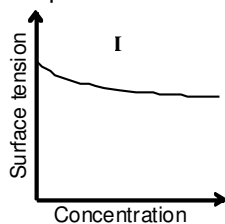
(B) I : $CH_3(CH_2)_{11}OSO_3^-Na^+$ II : CH_3OH III : KCl

(C) I : KCl   II : $CH_3(CH_2)_{11}OSO_3^-Na^+$ III : CH_3OH

(D) I : CH_3OH II : KCl   III : $CH_3(CH_2)_{11}OSO_3^-Na^+$

13.* The correct statement(s) about surface properties is(are)   **[JEE(Advanced)-2017, 4/122]**

(A) The critical temperatures of ethane and nitrogen are 563 K and 126 K, respectively. The adsorption of ethane will be more than that of nitrogen of same amount of activated charcoal at a given temperature.

(B) Cloud is an emulsion type of colloid in which liquid is dispersed phase and gas is dispersion medium.

(C) Adsorption is accompanied by decrease in enthalpy and decrease in entropy of the system.

(D) Brownian motion of colloidal particles does not depend on the size of the particles but depends on viscosity of the solution.

PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

JEE(MAIN) ONLINE PROBLEMS

1. Which one of the following characteristics is not correct for physical adsorption? **[AIEEE 2003, 3/225]**

(1) Adsorption on solids is reversible

(2) Adsorption increases with increase in temperature

(3) Adsorption is spontaneous

(4) Both enthalpy and entropy of adsorption are negative.

2. The disperse phase in colloidal iron (III) hydroxide and colloidal gold is positively and negatively charged, respectively. Which of the following statements is NOT correct ? **[AIEEE 2005, 3/225]**

(1) Coagulation in both sols can be brought about by electrophoresis

(2) Mixing the sols has no effect

(3) Sodium sulphate solution causes coagulation in both sols

(4) Magnesium chloride solution coagulates, the gold sol more readily than the iron (III) hydroxide sol.

3. The volume of collodial particle V_C as compared to the volume of a solute particle in a true solution V_S could be : **[AIEEE 2005, 3/225]**

(1) ~ 1   (2) ~ 10^{23} (3) ~ 10^{-3} (4) ~ 10^3

4. In langmuir's model of adsorption of a gas on a solid surface : **[AIEEE 2006, 3/165]**

(1) the rate of dissociation of adsorbed molecules from the surface does not depend on the surface covered

(2) the adsorption at a single site on the surface may involve multiple molecules at the same time

(3) the mass of gas striking a given area of surface is proportional to the pressure of the gas

(4) the mass of gas striking a given area of surface is independent of the pressure of the gas

5. Gold numbers of protective colloids A, B, C and D are 0.50, 0.01, 0.10 and 0.005, respectively. The correct order of their protective powers is **[AIEEE 2008, 3/105]**

(1) C < B < D < A   (2) A < C < B < D   (3) B < D < A < C   (4) D < A < C < B

6. Which of the following statements is incorrect regarding physiosorptions ? **[AIEEE 2009, 4/144]**

(1) More easily liquefiable gases are adsorbed readily.

(2) Under high pressure it results into multi molecular layer on adsorbent surface.

(3) Enthalpy of adsorption ($\Delta H_{adsorption}$) is low and positive.

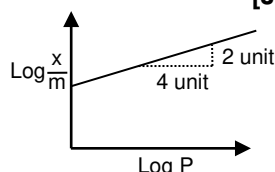(4) It occurs because of van der Waal's forces.

7. According to Freundlich adsorption isotherm which of the following is correct? **[AIEEE 2012, 4/120]**

(1) $\frac{x}{m} \propto p^0$ (2) $\frac{x}{m} \propto p^1$ (3) $\frac{x}{m} \propto p^{1/n}$

(4) All the above are correct for different ranges of pressure

8. The coagulating power of electrolytes having ions Na^+, Al^{3+} and Ba^{2+} for arsenic sulphide sol increases in the order : **[JEE(Main) 2013, 4/120]**
(1) $Al^{3+} < Ba^{2+} < Na^+$ (2) $Na^+ < Ba^{2+} < Al^{3+}$ (3) $Ba^{2+} < Na^+ < Al^{3+}$ (4) $Al^{3+} < Na^+ < Ba^{2+}$

9. 3 gram of activated charocoal was added to 50 mL of acetic acid solution (0.06N) in a flask. After an hour it was filtered and the strength of the fitrate was found to be 0.042 N. The amount of acetic acid adsorbed (per gram of charcoal) is : **[JEE(Main)-2015, 4/120]**
(1) 18 mg (2) 36 mg (3) 42 mg (4) 54 mg

10. For a linear plot of $\log(x/m)$ versus $\log p$ in a Freundlich adsorption isotherm, which of the following statements is correct? (k and n are constants) **[JEE(Main)-2016, 4/120]**
(1) 1/n appears as the intercept (2) Only 1/n appears as the slope.
(3) $\log(1/n)$ appears as the intercept. (4) Both k and 1/n appear in the slope term.

11. The Tyndall effect is observed only when following conditions are satisfied : **[JEE(Main)-2017, 4/120]**
(a) The diameter of the dispersed particles is much smaller than the wavelength of the light used.
(b) The diameter of the dispersed particles is not much smaller than the wavelength of the light used
(c) The refractive indices of the dispersed phase and dispersion medium are almost similar in magnitude.
(d) The refractive indices of the dispersed phase and dispersion medium differ greatly in magnitude.
(1) (b) and (d) (2) (a) and (c) (3) (b) and (c) (4) (a) and (d)

JEE(MAIN) ONLINE PROBLEMS

1. The following statements relate to the adsorption of gases on a solid surface. Identify the incorrect statement among them : **[JEE(Main) 2015 Online (10-04-15), 4/120]**
(1) On adsorption decrease in surface energy appears as heat
(2) Enthalpy of adsorption is negative
(3) On adsorption, the residual forces on the surface are increased
(4) Entropy of adsorption is negative

2. Under ambient conditions, which among the following surfactants will form micelles in aqueous solution at lowest molar concentration ? **[JEE(Main) 2015 Online (11-04-15), 4/120]**

(1) $CH_3-(CH_2)_8-COO^- Na^+$ (2) $CH_3(CH_2)_{11} \overset{\oplus}{N}(CH_3)_3Br^-$

(3) $CH_3-(CH_2)_{13}-OSO_3^- Na^+$ (4) $CH_3(CH_2)_{15} \overset{\oplus}{N}(CH_3)_3Br^-$

3. The most appropriate method of making egg-albumin sol is: **[JEE(Main) 2016 Online (09-04-16), 4/120]**
(1) Keep the egg in boiling water for 10 minutes. After removing the shell, transfer the yellow part of the content to 100 mL of 5% w/V saline solution and homogenize with a mechanical shaker.
(2) Break an egg carefully and transfer the transparent part of the content to 100 mL of 5% w/V saline solution and stir well.
(3) Keep the egg in boiling water for 10 minutes. After removing the shell, transfer the white part of the content to 100 mL of 5% w/V saline solution and homogenize with a mechanical shaker.
(4) Break an egg carefully and transfer only the yellow part of the content to 100 mL of 5% w/V saline solution and stir well.

4. A particular adsorption process has the following characteristics: (i) It arises due to vander Waals forces and (ii) it is reversible. Identify the correct statement that describes the above adsorption process: **[JEE(Main) 2016 Online (09-04-16), 4/120]**

(1) Enthalpy of adsorption is greater than 100 kJ mol^{-1}.
(2) Adsorption is monolayer.
(3) Adsorption increases with increase in temperature.
(4) Energy of activation is low.

5. Gold numbers of some colloids are :
Gelatin : 0.005 - 0.01; Gum Arabic : 0.15 - 0.25; Oleate : 0.04 - 1.0; Starch : 15 - 25.
Which among these is a better protective colloid ? **[JEE(Main) 2016 Online (10-04-16), 4/120]**
(1) Gelatin (2) Starch (3) Gum Arabic (4) Oleate

6. Among the following, **correct** statement is : **[JEE(Main) 2017 Online (08-04-17), 4/120]**
(1) One would expect charcoal to adsorb chlorine more than hydrogen sulphide
(2) Sols metal sulphides are lyophilic
(3) Hardy Schulze law states that bigger the size of the ions, the greater is its coagulating power.
(4) Brownian movement is more pronounced for smaller particles than for bigger-particles.

7. Adsorption of a gas on a surface follows Freundlich adsorption isotherm. Plot of log $\dfrac{x}{m}$ versus log p

gives a straight line with slope equal to 0.5, then : **[JEE(Main) 2017 Online (09-04-17), 4/120]**

($\dfrac{x}{m}$ is the mass of the gas adsorbed per gram of adsorbent)
(1) Adsorption is proportional to the pressure.
(2) Adsorption is proportional to the square root of pressure.
(3) Adsorption is proportional to the square of pressure.
(4) Adsorption is independent of pressure.

8. Which of the following statements about colloids is **False** ? **[JEE(Main) 2018 Online (15-04-18), 4/120]**
(1) When silver nitrate solution is added to potassium iodide solution a negatively charged colloidal solution is formed.
(2) Freezing point of colloidal solution is lower than true solution at same concentration of a solute.
(3) Colloidal particles can pass through ordinary filter paper.
(4) When excess of electrolyte is added to colloidal solution, colloidal particle will be precipitated.

9. If x gram of gas is adsorbed by m gram of adsorbent at pressure P, the plot of log $\dfrac{x}{m}$ versus log P is

linear. The slope of the plot is : (n and k are constants and n > 1)
[JEE(Main) 2018 Online (15-04-18), 4/120]

(1) 2 k (2) log k (3) n (4) $\dfrac{1}{n}$

10. Two compounds I and II are eluted by column chromatography (adsorption of I > II). Which one of the
following is a correct statement? **[JEE(Main) 2018 Online (15-04-18), 4/120]**
(1) I moves faster and has higher R_f value than II
(2) II moves faster and has higher R_f value than I
(3) I moves slower and has higher R_f value than II
(4) II moves slower and has higher R_f value than I

11. Which one of the following is not a property of physical adsorption ?
[JEE(Main) 2018 Online (16-04-18), 4/120]
(1) Higher the pressure, more the adsorption (2) Greater the surface area, more the adsorption
(3) Lower the temperature, more the adsorption (4) Unilayer adsorption occurs

12. Adsorption of a gas follows Freundlich adsorption isotherm. In the given plot, x is the mass of the gas

adsorbed on mass m of the adsorbent at pressure p. $\dfrac{x}{m}$ is proportional to :

[JEE(Main) 2019 Online (09-01-19), 4/120]

(1) p^2 (2) p (3) $p^{1/2}$ (4) $p^{1/4}$

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13. For coagulation of arsenious sulphide sol, which one of the following salt solution will be most effective?
[JEE(Main) 2019 Online (09-01-19), 4/120]

(1) Na_3PO_4 (2) $AlCl_3$ (3) $BaCl_2$ (4) $NaCl$

14. Which of the following is not an example of heterogeneous catalytic reaction ?
[JEE(Main) 2019 Online (10-01-19), 4/120]

(1) Ostwald's process   (2) Haber's process
(3) Combustion of coal   (4) Hydrogenation of vegetable oils

15. Haemoglobin and gold sol are examples of: **[JEE(Main) 2019 Online (10-01-19), 4/120]**
(1) negatively charged sols
(2) positively charged sols
(3) positively and negatively charged sols, respectively
(4) negatively and positively charged sols, respectively

16. An example of solid sol is: **[JEE(Main) 2019 Online (11-01-19), 4/120]**
(1) Butter   (2) Hair cream   (3) Paint   (4) Gem stones

17. Among the colloids cheese (C), milk (M) and smoke (S), the correct combination of the dispered phase and dispersion medium, respectively is :   **[JEE(Main) 2019 Online (11-01-19), 4/120]**
(1) C : liquid in solid; M : liquid in liquid; S : solid in gas
(2) C : solid in liquid; M : liquid in liquid; S : gas in solid
(3) C : solid in liquid; M : solid in liquid; S : solid in gas
(4) C : liquid in solid; M : liquid in solid; S : solid in gas

18. Given

Gas	H_2	CH_4	CO_2	SO_2
Critical Temperature / K	33	190	304	630

On the basis of data given above, predict which of the following gases shows least adsorption on a definite amount of charcoal ?   **[JEE(Main) 2019 Online (12-01-19), 4/120]**
(1) CH_4 (2) H_2 (3) CO_2 (4) SO_2

19. Among the following, the false statement is :   **[JEE(Main) 2019 Online (12-01-19), 4/120]**
(1) It is possible to cause artificial rain by throwing electrified sand carrying charge opposite to the one on clouds from an aeroplane.
(2) Lyophilic solution can be coagulated by adding an electrolyte
(3) Latex is a colloidal solution of rubber particles which are positively charged
(4) Tyndall effect can be used to distinguish between a colloidal solution and a true solution

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Answers

EXERCISE - 1

PART - I

A-1. Adsorption is accompanied by decrease of randomness, i.e. this factor opposes the process, i.e. ΔS is –ve. For the process to be spontaneous, ΔG must be –ve. Hence, according to eqn, $\Delta G = \Delta H - T\Delta S$, ΔG can be –ve only if ΔH is –ve.

A-2. **Difference between physical adsorption and chemical adsorption :**

Physical Adsorption	Chemical Adsorption
The forces between the adsorbate molecules and the adsorbent are weak van der Waal's forces.	The forces between the adsorbate molecules and the adsorbent are strong chemical forces.
Low heat of adsorption of the order of 20-40 kJ mol^{-1}	High heat of adsorption of the order 80-240 kJ mol^{-1}
Usually occurs at low temperature and decreases with increasing temperature.	It occurs at high temperature decreases with increasing temperature.
It is reversible.	It is irreversible.
The extent of adsorption depends upon the ease of liquefication of the gas.	There is no correlation between extent of adsorption and the ease of liquefication of gas.
It is less specific in nature, all gases are adsorbed on the surface of a solid to some extent adsorbent and adsorbate molecules.	It is highly specific in nature and occurs only when there is bond formation between extents.
It forms multimolecular layers.	It forms mono-molecular layer.

A-3. **(i) The nature of the gas (i.e. nature of the adsorbate).** The easily liquefiable gases such as HCl, NH_3, Cl_2 etc. are adsorbed more than the permanent gases such as H_2, N_2 and O_2. The ease with which a gas can be liquefied is primarily determined by its critical temperature. Higher the critical temperature (T_c) of a gas, the more easily it will be liquefied and, therefore, more readily it will be adsorbed on the solid.

Gas	SO_2	CH_4	H_2
T_C	330K	190 K	33 K

(ii) Nature of adsorbent. The extent of adsorption of a gas depends upon the nature of adsorbent. Activated charcoal (i.e. activated carbon), metal oxides (silica gel and aluminium oxide) and clay can adsorb gases which are easily liquified. Gases such as H_2, N_2 and O_2 are generally adsorbed on finely divided transition metals Ni and Co.

(iii) Activation of adsorbent.
(a) Metallic adsorbents are activated by mechanical rubbing or by subjecting it to some chemical reactions.
(b) To increase the adsorbing power of adsorbents, they are sub-divided into smaller pieces. As a result, the surface area is increased and therefore, the adsorbing power increases.
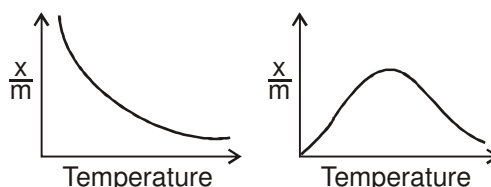
(iv) Effect of temperature.
Mostly the process of adsorption is exothermic and the reverse process or desorption is endothermic. If the above equilibrium is subjected to increase in temperature, then according to Le-Chaterlier's principle, with increase in temperature, the desorption will be favoured. Physical adsorption decreases continuously with increase in temperature whereas chemisorption increases initially, shows a maximum in the curve and then it decreases continuously.

The initial increase in chemisorption with increase in temperature is because of activation energy required.
This is why the chemical adsorption is also known as "**Activated adsorption".**
A graph between degree of adsorption (x/m) and temperature 't' at a constant pressure of adsorbate gas is known as **adsorption isobar.**

(v) Effect of pressure. The extent of adsorption of a gas per unit mass of adsorbent depends upon the pressure of the gas. The variation of extent of adsorption expressed as x/m (where x is the mole of adsorbate and m is the mass of the adsorbent) and the pressure is given as below. A graph between the amount of adsorption and gas pressure keeping the temperature constant is called an adsorption isotherm.

It is clear from the figure that extent of adsorption (x/m) increases with pressure and becomes maximum corresponding to pressure P_s called equilibrium pressure. Since adsorption is a reversible process, the

Figure-1

desorption also takes place simultaneously. At this pressure (P_s) the amount of gas adsorbed becomes equal to the amount of gas desorbed.
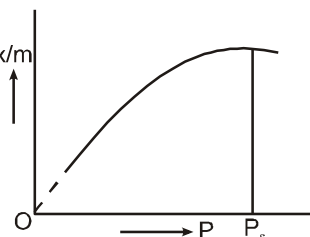
A-4. It represents the variation of the mass of the gas adsorbed per gram of the adsorbent with pressure at constant temperature.

A-5. It means increasing the adsorption power of an adsorbent and is done by increasing the surface area of the adsorbent by a suitable method.

A-6. NH_3 has higher critical temperature than that of CO_2, i.e. NH_3 is more easily liquefiable than CO_2 because, NH_3 has greater intermolecular forces of attraction and hence will be adsorbed more readily.

A-7. 1.2

A-8. 5×10^{-19} m^2

A-9. In heterogeneous catalysis, generally the reactants are gaseous where as catalyst is a solid. The reactant molecules are adsorbed on the surface of the catalyst. As a result, the concentration of the reactant molecules on the surface increases and hence the rate of reaction increases.

A-10. 0.02 g

A-11. $T_0 < 27^\circ C$

B-1. (i) Mfg. of NH_3 (Haber's process) – using iron as catalyst
(ii) Mfg. of H_2SO_4 – using platinised asbestos or V_2O_5 as catalyst.

B-2. (ii) → (i) → (v) → (iii) → (iv)

C-1. On the bases of physical state of D.P. and D.M. colloidal solution may be divided into eight system.

**Table : Type of Colloidal Systems**

| D P	D M	Type of colloid	Examples
Solid	Solid	Solid Sol	Some coloured glasses and gem stones
Solid	Liquid	Sol	Paints, cell fluids
Solid	Gas	Aerosol	Smoke, dust
Liquid	Solid	Gel	Cheese, butter, jellies
Liquid	Liquid	Emulsion	Milk, hair cream
Liquid	Gas	Liquid Aerosol	Fog, mist, cloud, insecticide sprays
Gas	Solid	Solid Sol	Pumice stone, foam rubber
Gas	Liquid	Foam	Froath, whipped cream, soap lather.

C-2. (a) Gel – a colloidal dispersion of a liquid in a soild, e.g., butter
(b) Liquid aerosol – a colloidal dispersion of a liquid in a gas, e.g., fog
(c) Hydrosol – a colloidal sol of a solid in water as the dispersion medium, e.g, starch sol or gold sol.

C-3. Associated colloids are formed by electrolytes so that they are dissociated into ions and these ions associate together to form ionic micelles whose size lies in the colloidal range, e.g. soaps.
Multimolecular colloids–formed by the aggregation of a large number of simple molecules.
Macromolecular colloids – due to large size of the molecules themselves.

C-4. Multimolecular – S_8 ; Macromolecular – starch

C-5. Sol of sulphur – oxidation method or by exchange of solvent.
Sol of platinum – Bredig's electro–disintegration method.

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D-1. **(a) Peptization:** The term has originated from the digestion of proteins by the enzyme pepsin. Peptization may be defined as (the process of converting a precipitate into colloidal sol by shaking it with dispersion medium in the presence of a small amount of electrolyte). The electrolyte used for this purpose is called peptizing agent. This method is applied, generally, to convert a freshly prepared precipitate into a colloidal sol. During peptization, the precipitate adsorbs one of the ions of the electrolyte on its surface. The ion adsorbed on the surface is common either with the anion or cation of the electrolyte. This causes the development of positive or negative charge on precipitates which ultimately break up into smaller particles having the dimensions of colloids.
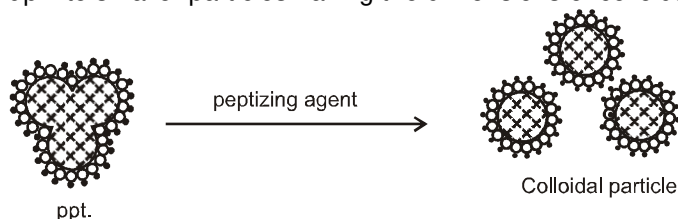
(b) Electrical Properties (Electrophoresis) : The particles of the colloids are electrically charged and carry positive or negative charge. The dispersion medium has an equal and opposite charge making the system neutral as a whole. Due to similar nature of the charge carried by the particles, they repel each other and do not combine to form bigger particles. That is why, a sol is stable and particles do not settle down. Arsenious sulphide, gold, silver and platinum particles in their respective colloidal sols are negatively charged while particles of ferric hydroxide, aluminium hydroxide are positively charged. The existence of the electric charge is shown by the phenomenon of electrophoresis. It involves the 'movement of colloidal particles either towards the cathode or anode, under the influence of the electric field'. The apparatus used for electrophoresis as shown in fig.
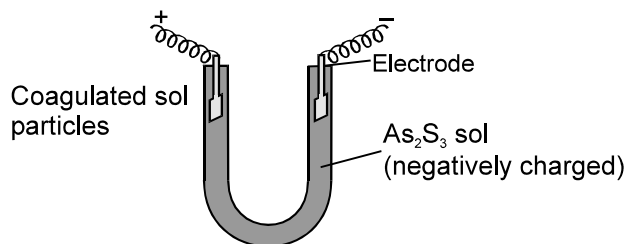
(Fig. : A set up for electrophoresis.)

The colloidal solution is placed in a U-tube fitted with platinum electrodes. On passing an electric current, the charged colloidal particles move towards the oppositely charged electrode. Thus, if arsenic sulphide sol is taken in the U-tube, in which negatively charge particle of arsenic sulphide move towards the anode.

*Earlier this process was called cataphoresis because most of the colloidal sols studied at that time were positively charged and moved towards cathode.

(c) Dialysis : It is a process of removing a dissolved substance from a colloidal solution by means diffusion through suitable membrane. Since particles in true solution (ions or smaller molecules) can pass through animal membrane or parchment paper or cellophane sheet but colloidal particle do not, the appratus used for this purpose is called Dialyser.

A bag of suitable membrane containing the colloidal solutions is suspended in a vessel through which fresh water continously flow. The molecules and ions (crystalloids) diffuse through membrane into the outer water & pure colloidal solution is left behind.

(d) Mechanical Properties :

Brownian movement: Robert Brown, a botanist, discovered in 1827 that pollen grains placed in water do not remain at rest but move about continuously and randomly. Later on, this phenomenon was observed in case of colloidal particles when they were seen under an ultramicroscope. The particles were seen to be in constant zig-zag motion as shown in fig. This zig-zag motion is called Brownian movement
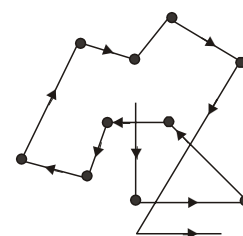
Figure
Brownian movement

D-2. At the time of settings, the sun is at the horizon. The light emitted by the sun 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.

D-3. Because colloidal solutions being bigger aggregate of a large number of molecule, the effective number of particles in colloidal solution is relative much smaller.

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E-1. According to Hardy – schulze rule, greater the charge on the oppositely charged ion of the electrolyte added, more effective it is in bringing about coagulation. Hence Na_3PO_4 (PO_4^{-3}) is most effective.

E-2. **Isoelectric point :** The H^+ concentration at which the colloidal particles have no charge is known as the isoelectric point. At this point stability of colloidal particles becomes very less & do not move under influence of electric field.

E-3. **Formation of deltas :** The river water contains colloidal particles of sand and clay which carry negative charge. The sea water contains +ve ions such as Na^+, Mg^{2+}, Ca^{2+}, etc. As the river water meets sea water, these ions discharge the sand or clay particle which are precipitated in the form of delta.

E-4. **Artificial rain :** Cloud consists of charged particle of water dispersed in air. Rain is caused by aggregation of these minute particles. Artificial rain can be done by throwing electrified sand of AgI from aeroplanes, colloidal H_2O particle present in cloud will get coagulated by these sand or AgI particles to form bigger water drops causing rain.

F-1. Alcohol, phenol.

F-2. (i) Sols are dispersions of solids in liquids while emulsions are dispersions of liquids in liquids.
(ii) Sols are quite stable wheres as emulsions are less stable.

F-3. The process of separation of the constituent liquids of an emulsion is called demulsification.

F-4. Changing of W/O emulsion to O/W emulsion and vise-versa is known as phase inversion.

PART - II

A-1.	(D)	**A-2.**	(B)	**A-3.**	(A)	**A-4.**	(C)	**A-5.**	(B)
A-6.	(A)	**A-7.**	(B)	**A-8.**	(A)	**B-1.**	(D)	**B-2.**	(C)
C-1.	(A)	**C-2.**	(C)	**D-1.**	(A)	**D-2.**	(B)	**D-3.**	(C)
E-1.	(C)	**E-2.**	(A)	**E-3.**	(C)	**E-4.**	(C)	**E-5.**	(D)
F-1.	(B)								

PART - III

1. (C) **2.** (A – p, q) ; (B–r) ; (C – q, t) ; (D – s) ; (E – u)

EXERCISE - 2

PART - I

1.	(D)	**2.**	(C)	**3.**	(D)	**4.**	(B)	**5.**	(A)
6.	(B)	**7.**	(D)	**8.**	(B)	**9.**	(A)	**10.**	(C)
11.	(C)	**12.**	(A)	**13.**	(B)	**14.**	(D)	**15.**	(A)
16.	(B)								

PART - II

1.	6	**2.**	56	**3.**	3 (i, ii, vi)	**4.**	560	**5.**	4
6.	8	**7.**	8						

PART - III

1.	(BCD)	**2.**	(ACD)	**3.**	(ABD)	**4.**	(AB)	**5.**	(AC)
6.	(AC)	**7.**	(CD)	**8.**	(AB)	**9.**	(BD)	**10.**	(BC)
11.	(BD)	**12.**	(AC)	**13.**	(ABC)	**14.**	(ABD)	**15.**	(AC)
16.	(ABD)	**17.**	(ABC)	**18.**	(AB)	**19.**	(CD)	**20.**	(BCD)

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PART - IV

1.	(A)	**2.**	(A)	**3.**	(B)	**4.**	(A)	**5.**	(C)
6.	(A)	**7.**	(D)	**8.**	(B)	**9.**	(D)		

EXERCISE - 3

PART - I

1.	(A)	**2.**	(B)	**3.**	(D)	**4.**	(A)	**5.**	(C)
6.	7	**7.***	(ABD)	**8.***	(AD)	**9.***	(AC)	**10.**	(B)
11.*	(BCD)	**12.**	(D)	**13.***	(AC)				

PART - II

JEE(MAIN) OFFLINE PROBLEMS

1.	(2)	**2.**	(2)	**3.**	(4)	**4.**	(3)	**5.**	(2)
6.	(3)	**7.**	(4)	**8.**	(2)	**9.**	(1)	**10.**	(2)
11.	(1)								

JEE(MAIN) ONLINE PROBLEMS

1.	(3)	**2.**	(4)	**3.**	(2)	**4.**	(4)	**5.**	(1)
6.	(4)	**7.**	(2)	**8.**	(2)	**9.**	(4)	**10.**	(2)
11.	(4)	**12.**	(3)	**13.**	(2)	**14.**	(3)	**15.**	(3)
16.	(4)	**17.**	(1)	**18.**	(2)	**19.**	(3)		

Additional Problems for Self Practice (APSP)

✍ Marked questions are recommended for Revision.

This Section is not meant for classroom discussion. It is being given to promote self-study and self testing amongst the Resonance students.

PART - I : PRACTICE TEST-1 (IIT-JEE (MAIN Pattern))

Max. Time : 1 Hr.   **Max. Marks : 120**

Important Instructions
1. The test is of **1 hour** duration.
2. The Test Booklet consists of **30** questions. The maximum marks are **120.**
3. Each question is allotted **4 (four)** marks for correct response.
4. Candidates will be awarded marks as stated above in Instructions No. 3 for correct response of each question. **¼ (one fourth)** marks will be deducted for indicating incorrect response of each question. No deduction from the total score will be made if no response is indicated for an item in the answer sheet.
5. There is only one correct response for each question. Filling up more than one response in any question will be treated as wrong response and marks for wrong response will be deducted accordingly as per instructions 4 above.

1. For adsorption of a gas on a solid, the plot of log (x/m) Vs log P is linear with a slope equal to :
    [n being a whole number]
    (1) K   (2) log K   (3) n   (4) 1/n

2. Surface tension of lyophilic sols is :
    (1) Lower than that of H_2O (2) More than that of H_2O
    (3) Equal to that of H_2O (4) None of the above

3. On passing light from collidal solution, the effect due to scattering of light is known as :
    (1) Electrophoresis   (2) Tyndall effect   (3) Electro osmosis   (4) Coagulation

4. Tyndall effect is shown by :
    (1) Colloid   (2) True Solution   (3) Suspension   (4) all of these

5. Milk is an example of :
    (1) True solution   (2) Gel   (3) Suspension   (4) Emulsion

6. Most effective ion to coagulate a negative sol is :
    (1) PO_4^{3-} (2) Al^{3+} (3) Ba^{2+} (4) K^+

7. Which of the following electrolytes will be most effective in the coagulation of gold sol :
    (1) $NaNO_3$ (2) $K_4[Fe(CN)_6]$ (3) Na_3PO_4 (4) $MgCl_2$

8.✍ The stability of lyophilic colloid is due to which of the following :
    (1) Charge on their particles   (2) Large size of their particles
    (3) Small size of their particles   (4) Solvation by dispersion medium

9.✍ A colloidal solution is subjected to an electrical field. The particles move towards anode. The coagulation of the same solution is studied using NaCl, $BaCl_2$ and $AlCl_3$ solutions. Their coagulating power should be
    (1) NaCl > $BaCl_2$ > $AlCl_3$ (2) $BaCl_2$ > $AlCl_3$ > NaCl
    (3) $AlCl_3$ > $BaCl_2$ > NaCl   (4) $BaCl_2$ > NaCl > $AlCl_3$

10. Which of the following is most effective in coagulating a ferric hydroxide sol :
    (1) KCl   (2) KNO_2 (3) K_2SO_4 (4) $K_3[Fe(CN)_6]$

11. Fog is an example of colloidal system of :
    (1) Liquid dispersed in gas   (2) Gas dispersed in gas
    (3) Solid dispersed in gas   (4) Solid dispersed in liquid

12. The charge on As_2S_3 sol is due to the adsorbed :
(1) H^+ (2) OH^- (3) O^{-2} (4) S^{-2}

13. The sky looks blue due to :
(1) Dispersion (2) Reflection (3) Transmission (4) Scattering

14. Tyndall effect will be mainly observed in :
(1) Lyophilic colloid (2) Lyophobic colloid (3) True solution (4) Vapour

15. The Brownian motion is due to :
(1) Temperature fluctuation within the liquid phase
(2) Attraction and repulsion between charge on the colloidal particles
(3) Impact of molecules of the dispersion medium on the colloidal particles
(4) All of these

16. In coagulating the colloidal solution of As_2S_3 which has the minimum coagulating value :
(1) NaCl (2) KCl (3) $BaCl_2$ (4) $AlCl_3$

17. Positive sol is :
(1) Gold (2) Gelatin (3) As_2S_3 (4) None

18. Which one is a lyophobic colloid :
(1) Gelatin (2) Starch (3) Sulphur (4) Gum arabic

19. Smoke is an example of :
(1) Gas dispersed in liquid (2) Gas dispersed in solid
(3) Solid dispersed in gas (4) Solid dispersed in solid

20. A colloidal solution of arsenious sulphide is most readily coagulated by the addition of a normal solution?
(1) NaCl (2) $CaCl_2$ (3) Na_3PO_4 (4) $Al_2(SO_4)_3$

21. A colloid always :
(1) Contains two phases (2) Is a true solution
(3) Contains three phases (4) Contains only water soluble particles

22. Which of the following ions has maximum flocculation value :
(1) $[Fe(CN)_6)]^{4-}$ (2) Cl^- (3) SO_4^{2-} (4) PO_4^{3-}

23. Which of the following gases, will be adsorbed maximum on a solid surface :
(1) CO_2 (2) O_2 (3) N_2 (4) H_2

24. Which of the following is a mismatch :
(1) Lyophilic colloids – reversible sols
(2) Associated colloids – micelles
(3) Tyndall effect – scattering of light by colloidal particle
(4) Electrophoresis – movement of dispersion medium under the influence of electric field

25. A negative catalyst will
(1) raise the energy of activation for a given reaction
(2) take away the internal energy of reactants and deactivate them
(3) catalyse the backward reaction more than the forward one, thereby shifting equilibrium backward.
(4) none of these

26. A liquid is found to scatter a beam of light but leaves no residue when passed through the filter paper. The liquid can be described as
(1) a suspension (2) Oil (3) a colloidal sol (4) a true solution

27. Which of the following kinds of catalysis can be explained by the adsorption theory?
(1) heterogeneous catalysis (2) enzyme catalysis
(3) homogeneous catalysis (4) acid base catalysis

28. Which of the following relations is (are) correct according to Freundlich ?
(i) x/m = constant
(ii) x/m = constant $\times$ $p^{1/n}$ (n > 1)
(iii) x/m = constant $\times$ p^n (n > 1)
(1) All are correct   (2) All are wrong   (3) (ii) is correct (4) (iii) is correct

29. The physical adsorption of gases on the solid surface is due to
(1) vander Waals forces   (2) covalent bonding
(3) hydrogen bonding   (4) All of these

30. Correct equation of Freundlich isotherm is

(1) $\log\left(\dfrac{x}{m}\right) = \log K + \dfrac{1}{n}\log C$ (2) $\log\left(\dfrac{x}{m}\right) = \log m + \dfrac{1}{m}\log C$

(3) $\log\left(\dfrac{x}{m}\right) = \log C + \dfrac{1}{K}\log C$ (4) $\log\left(\dfrac{x}{m}\right) = \log C + \dfrac{1}{n}\log K$

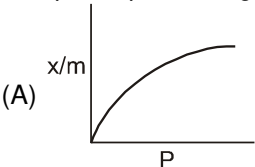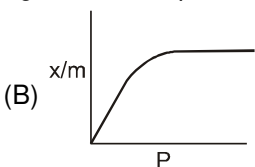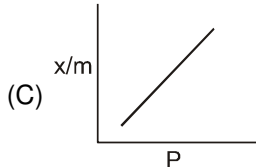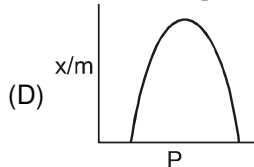# Practice Test-1 (IIT-JEE (Main Pattern))
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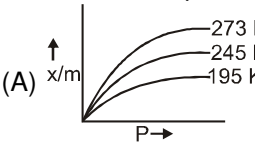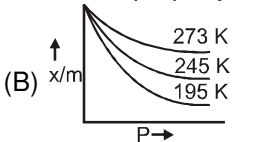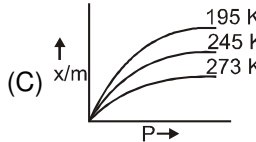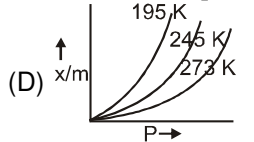
Que.	1	2	3	4	5	6	7	8	9	10
Ans.										
Que.	11	12	13	14	15	16	17	18	19	20
Ans.										
Que.	21	22	23	24	25	26	27	28	29	30
Ans.										

PART - II : NATIONAL STANDARD EXAMINATION IN CHEMISTRY (NSEC) STAGE-I

1. Smoke is a colloidal sol of   **[NSEC-2000]**
(A) gas dispersed in a solid   (B) solid dispersed in a gas
(C) solid dispersed in a liquid   (D) gas dispersed in a liquid

2. A catalyst :   **[NSEC-2001]**
(A) alters the reaction mechanism
(B) decreases the activation energy
(C) increases the average kinetic energy of reacting molecule
(D) increases the frequency of collisions of reacting species

3. The colloidal system in which the disperse phase and dispersion medium are both liquids is known as :
                                                [NSEC-2001]
(A) an emulsion   (B) an areosol   (C) gel   (D) a foam

4. Soaps essentially form a colloidal solution in water and remove the greasy matters by :   **[NSEC-2001]**
(A) adsorption   (B) emulsification   (C) coagulation   (D) absorption

5. Swimming for a long time in salt water makes the skin of one's finger tips wrinkled. Which one of the following properties is responsible for this observation ?   **[NSEC-2002]**
(A) osmosis   (B) dialysis   (C) electrodialysis   (D) coagulation.

6. Tyndal effect in a colloid is due to   **[NSEC-2002]**
(A) interference of light   (B) defraction of light
(C) reflection of light   (D) scattering of light.

7. Ferric chloride is used to stop bleeding in cuts, because **[NSEC-2002]**
(A) Fe^{3+} coagulates blood which is a positively charged sol
(B) Fe^{3+} coagulates blood which is a negatively charged sol
(C) Cl^- coagulates blood which is a positively charged sol
(D) Cl^- coagulates blood which is negatively charged sol

8. A catalyst is a substance which **[NSEC-2002]**
(A) accelerates the rate of reaction
(B) does not influence the rate of reaction
(C) changes the equilibrium position
(D) does not alter the energy of activation of the reaction

9. In nature, ammonia is synthesisd by nitrifying bacteria using enzymes while in industry it is manufactured from N_2 and H_2 using iron oxide catalyst at 550ºC. Under the same industrial conditions, enzymes cannot be used because **[NSEC-2003]**
(A) enzymes get deactivated at high temperature
(B) enzymes catalyze reactions only in living systems
(C) the reaction becomes vigorous and uncontrollable
(D) the enzymes use nitrates in place of N_2.

10. A catalyst increases the **[NSEC-2003]**
(A) rate of forward reaction only
(B) free energy change in the reaction
(C) rates of both forward and reverse reactions
(D) equilibrium constant of the reaction.

11. A soap solution in water removes greasy substances by **[NSEC-2004]**
(A) adsorption
(B) peptization
(C) coagulation
(D) emulsifiction.

12. Smoke is an example of **[NSEC-2005]**
(A) sol
(B) aerosol
(C) emulsion
(D) gel.

13. A catalyst speeds up a chemical reraction by **[NSEC-2008]**
(A) shifting the equilibrium
(B) increasing the activation energy
(C) initiating the reaction
(D) decreasing energy of activation

14. The plot representing Langmuir's adsorption isotherm is : **[NSEC-2009]**

15. Frendlich adsorption isotherms are properly represented as in **[NSEC-2010]**

16. A gold sol is prepared by : **[NSEC-2010]**
(A) dissolving gold in Aqua-regia and precipitation by dilution
(B) double decomposition of $AuCl_3$
(C) Bredy's arc method
(D) grinding in a colloidal mill

17. Effective electrolyte to cause the flocculation of a negatively charged arsenium sulphide colloid is: **[NSEC-2012]**
(A) NaCl
(B) $BaCl_2$
(C) $K_3Fe(CN)_6$
(D) $AlCl_3$

18. A catalyst is a substance that : **[NSEC-2013]**
(A) undergoes chemical change to accelerate the rate of the reaction
(B) decreases the energy of activation of the reaction
(C) increases the kinetic energy of the reaction
(D) lowers the potential energy of the products with respect to that of the reactants.

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19. Which of the following reaction parameters will change due to addition of a catalyst ? **[NSEC-2013]**
(A) Free energy 　　　　　　　　　　　(B) Only equilibrium constant
(C) Only rate constant 　　　　　　　　(D) Both equilibrium constant and rate constant

20. In electrophoresis, **[NSEC-2014]**
(A) the colloidal particles migrate in an applied electric field.
(B) the medium migrates in an applied electric field
(C) both colloidal particles and the medium migrate.
(D) neither the particles nor the medium migrate.

21. 100 mL of 0.3 M acetic acid is shaken with 0.8 g wood charcoal. The final concentration of acetic acid in the solution after adsorption is 0.125 M. The mass of "acetic acid adsorbed per gram of charcoal is:
[NSEC-2015]

(A) 1.05 g 　　　　　(B) 0.0131 g 　　　　　(C) 1.31 g 　　　　　(D) 0.131 g

22. The mass of argon adsorbed per unit mass of carbon surface is plotted against pressure. Which of the following plots is correct if x and m represent the masses of argon and carbon respectively ? (........ represents extrapolated data) **[NSEC-2016]**
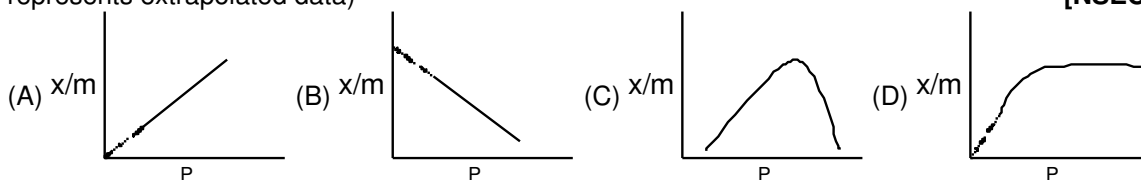
23. An adsorption isotherm equation proposed by Langmuir is of the form $V = \dfrac{V_0 b P O}{(1+bP)}$ where V is the volume of gas adsorbed at pressure P. For a given adsorbate/adsorbent system, V_0 and b are constants. The dependence of V on P can be depicted as **[NSEC-2018]**
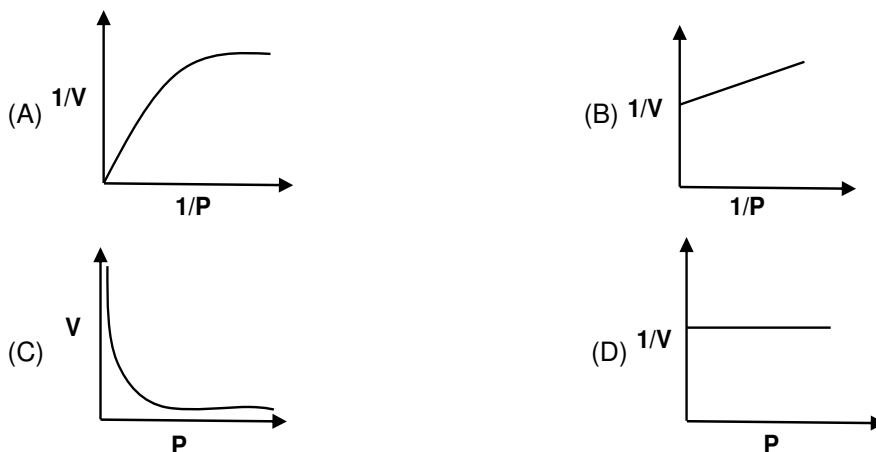
PART - III : HIGH LEVEL PROBLEMS (HLP)

SUBJECTIVE QUESTIONS

1. A 1 cm × 1 cm square paper coated with a suitable adsorbent on both sides. The paper is dipped in a aqueous solution of glucose of volume 20 mL and concentration 20 ppm. Final concentration glucose was dropped to 19 ppm due to adsorption. Find the number of glucose particles per unit area of the paper.

2. When 9.0 ml of arsenius sulphide sol and 1.0 ml of 1.0×10^{-4} M $BaCl_2$ are mixed, turbidity due to precipitation just appears after 2 hours. Find the coagulating value of the effective ion.

ONLY ONE OPTION CORRECT TYPE

3. Some type of gels like gelatin loose water slowly. The process is known as :
(A) Synerisis 　　　(B) Thixotropy 　　　(C) Peptisation 　　　(D) Imbibition

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4. Select correct statement (s) :
(A) hydrophilic colloid is a colloid in which there is a strong attraction between the dispersed phase and water
(B) hydrophobic colloid is a colloid in which there is a lack of attraction between the dispersed phase and water
(C) hydrophobic sols are often formed when a solid crystallises rapidly from a chemical reaction or a supersaturated solution
(D) all of the above

5. A reddish brown sol (containing Fe^{3+}) is obtained by:
(A) the addition of small amount of $FeCl_3$ solution to freshly prepared $Fe(OH)_3$ precipitate
(B) the addition of $Fe(OH)_3$ to freshly prepared $FeCl_3$ solution
(C) the addition of NH_4OH to $FeCl_3$ solution dropwise
(D) the addition of $NaOH$ to $FeCl_3$ solution dropwise

6. The stabilisation of a lyophobic colloid is due to :
(A) preferential adsorption of similiar charged particle on colloids surface.
(B) interaction between dispersed phase and dispersion medium
(C) the formation of a covalent bond between two phases.
(D) the viscosity of the medium.

7. Compared to common colloidal sols, micelles have :
(A) higher colligative properties   (B) lower colligative properties
(C) same colligative properties   (D) none of these

8. Graph between log x/m and log p is a straight line inclined at an angle of 45º. When pressure is 0.5 atm and ln k = 0.693, the amount of solute adsorbed per gram of adsorbent will be :
(A) 1   (B) 1.5   (C) 0.25   (D) 2.5

9. The coagulation of 200 mL of a positive colloid took place when 0.73 g HCl was added to it without changing the volume much. The flocculation value of HCl for the colloid is :
(A) 0.36   (B) 36.5   (C) 100   (D) 150

SINGLE AND DOUBLE VALUE INTEGER TYPE

10. 0.02 g of gelatin is required to protect 10 mL of gold sol from 10% NaCl, then find the gold number for gelatin. Report your answer by multiplying by 100.

ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

11. The **incorrect** statements are -
(A) For coagulation of As_2S_3 sol, +ve ions are effective.
(B) For coagulation of aluminium hydroxide sol Ba^{2+} ions are more effective than Na^+
(C) Cellulose solution is an example of multimolecular colloid system
(D) Colloidal sol of metals such as gold, silver etc are prepared by Bredig's arc method.

12. An example of extrinsic colloid (lyophobic colloids) is :
(A) As_2S_3 sol   (B) $Fe(OH)_3$ sol   (C) Egg albumin   (D) Au sol

13. Which of the following are the characteristic of chemisorption :
(A) Multilayer adsorption   (B) Exothermic nature
(C) Strong adsorption by adsorption sites   (D) Irreversible

14. If Cl_2 gas is enclosed in presence of powdered charcoal in a closed vessel, the pressure of the gas decreases. It is because
(A) the gas molecules are absorbed at the surface
(B) the gas molecules concentrate at the surface of the charcoal
(C) the gas molecules are adsorbed at the surface
(D) the gas molecules are desorbed by the surface

15. Which of the following colloidal solutions contain negatively charged colloidal particles?
(A) $Fe(OH)_3$ sol   (B) As_2S_3 sol   (C) Blood   (D) Gold sol

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16. Which of the following statements is correct for a lyophobic solution ?
(A) It can be easily solvated
(B) It carries charges
(C) The coagulation of this sol is irreversible in nature
(D) It is less stable in a solvent

17. Which one of the following statements is/are not correct ?
(A) Brownian movement is more pronounced for smaller particles than for bigger ones
(B) Sols of metal sulphides are lyophilic
(C) Schulze-Hardy law states, the bigger the size of the ion, the greater is its coagulating power
(D) One would expect charcoal to adsorb hydrogen gas more strongly than chlorine.

PART - IV : PRACTICE TEST-2 (IIT-JEE (ADVANCED Pattern))

Max. Time : 1 Hr.   **Max. Marks : 66**

Important Instructions
A. General :
1. The test is of 1 hour duration.
2. The Test Booklet consists of 22 questions. The maximum marks are 66.
B. Question Paper Format :
3. Each part consists of five sections.
4. Section-1 contains 7 multiple choice questions. Each question has four choices (A), (B), (C) and (D) out of which ONE is correct.
5. Section-2 contains 5 multiple choice questions. Each question has four choices (A), (B), (C) and (D) out of which ONE OR MORE THAN ONE are correct.
6. Section-3 contains 6 questions. The answer to each of the questions is a single-digit integer, ranging from 0 to 9 (both inclusive).
7. Section-4 contains 1 paragraphs each describing theory, experiment and data etc. 3 questions relate to paragraph. Each question pertaining to a partcular passage should have only one correct answer among the four given choices (A), (B), (C) and (D).
8. Section-5 contains 1 multiple choice questions. Question has two lists (list-1 : P, Q, R and S; List-2 : 1, 2, 3 and 4). The options for the correct match are provided as (A), (B), (C) and (D) out of which ONLY ONE is correct.
C. Marking Scheme :
9. For each question in Section-1, 4 and 5 you will be awarded 3 marks if you darken the bubble corresponding to the correct answer and zero mark if no bubble is darkened. In all other cases, minus one (– 1) mark will be awarded.
10. For each question in Section-2, you will be awarded 3 marks. If you darken all the bubble(s) corresponding to the correct answer(s) and zero mark. If no bubbles are darkened. No negative marks will be answered for incorrect answer in this section.
11. For each question in Section-3, you will be awarded 3 marks if you darken only the bubble corresponding to the correct answer and zero mark if no bubble is darkened. No negative marks will be awarded for incorrect answer in this section.

SECTION-1 : (Only One option correct Type)
This section contains 7 multiple choice questions. Each questions has four choices (A), (B), (C) and (D) out of which Only ONE option is correct.

1. An arsenious sulphide sol carries a negative charge. The maximum precipitating power of this sol is : possessed by :
(A) K_2SO_4 (B) $CaCl_2$ (C) Na_3PO_4 (D) $AlCl_3$

2. According to Hardy-Schulze rule, the coagulating power of cation follows the order :
(A) $Na^+ > Ba^{2+} > Al^{3+}$
(B) $Al^{3+} > Ba^{2+} > Na^+$
(C) $Ba^{2+} > Al^{3+} > Na^+$
(D) $Al^{3+} > Na^+ > Ba^{2+}$

3. Which of the following electrolytes is least effective in causing flocculation of ferric hydroxide sol :
(A) $K_4[Fe(CN)_6]$ (B) K_2CrO_4 (C) KBr (D) K_2SO_4

4. Lyophobic colloids are :
(A) Reversible colloids (B) Irreversible colloids (C) Protective colloids (D) Gum proteins

5. Which among the following statements is false ?
(A) Increase of pressure increases the amount of adsorption.
(B) Increase of temperature may decrease the amount of adsorption.
(C) The adsorption may be monolayered or multilayered.
(D) Particle size of the adsorbent will not affect the amount of adsorption.

6. (i) At 298 K the volume of NH_3 adsorbed by 1g of charcoal is higher than that of H_2 under similar conditions.
(ii) The movement of collodial particles towards the oppositely charged electrodes on passing electric current is known as Brownian movement.
(A) T, T   (B) T, F   (C) F, T   (D) F, F

7. Identify the correct statement regarding enzymes.
(A) Enzymes are specific biological catalysts that can normally function at very high tempt. (T $\approx$ 1000 K)
(B) Enzymes are normally heterogeneous catalysts that are very specific in action
(C) Enzymes are specific biological catalysts that can not be poisoned
(D) Enzymes are non-biological catalysts.

Section-2 : (One or More than one options correct Type)
This section contains 5 multiple choice questions. Each questions has four choices (A), (B), (C) and (D) out of which ONE or MORE THAN ONE are correct.

---

8. Which of the following statements is correct?
(A) The efficiency of a heterogeneous catalyst depends upon its surface area.
(B) Catalyst operates by providing alternate path for the reaction that involves a lower activation energy.
(C) Catalyst lowers the energy of activation of the forward direction without affecting the energy of activation of the backward direction.
(D) Catalyst does not affect the overall enthalpy change of the reaction.

9. Which of the following statements is (are) true?
(A) The concentration of a homogeneous catalyst may appear in the rate expression.
(B) A catalyst is always consumed in the reaction.
(C) A catalyst must always be in the same phase as the reactants.
(D) None of these

10. The correct statement(s) pertaining to the adsorption of a gas on a solid surface is (are)
(A) Adsorption is always exothermic
(B) Physisorption may transform into chemisorption at high temperature
(C) Physisorption increases with increasing temperature but chemisorption decreases with increasing temperature
(D) Chemisorption is more exothermic than physisorption, however it is very slow due to higher energy of activation.

11. The **incorrect** statements are -
(A) For coagulation of As_2S_3 sol, +ve ions are effective.
(B) For coagulation of aluminium hydroxide sol Ba^{2+} ions are more effective than Na^+
(C) Cellulose solution is an example of multimolecular colloid system
(D) Colloidal sol of metals such as gold, silver etc are prepared by Bredig's arc method.

12. Select the CORRECT statements :
(A) Langmuir adsorption isotherm is expected to be applicable at low gas pressure and moderately high temperature.
(B) The rate of an enzyme catalysed reaction depends upon enzyme concentration.
(C) A negative catalyst raises the activation energy barrier of a reaction and thus reduces its rate.
(D) In physisorption gases having higher critical temperature are adsorbed to a greater extent than those with lower critical temperature.

Section-3 : (One Integer Value Correct Type.)
This section contains 6 questions. Each question, when worked out will result in one integer from 0 to 9 (both inclusive)

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13. On addition of one ml solution of 10% NaCl to 10 ml gold sol in the presence of 0.0250 g of starch the coagulation is just prevented. Starch has the following gold number :

14. At 2 atm pressure the value of $\dfrac{x}{m}$ will be : (log 2 = 0.3010)

15. 1 L of 0.6 M acetic acid is shaken with 2 g activated carbon. Activated carbon absorbs some acetic acid on its surface only. This process is called adsorption. The final concentration of the solution after adsorption is 0.5 M. What is the amount of acetic acid adsorbed per gram of carbon.

16. A detergent ($C_{12}H_{25}SO_4Na$) solution becomes a colloidal solution at a concentration of 10^{-3} mol/lit. On an average 10^{13} colloidal particles are present in 1 mm^3 what is average number of $C_{12}H_{25}SO_4Na$ in one colloidal particle ?

17. For the coagulation of 200 mL of As_2S_3 solution, 10 mL of 1 M NaCl is required. What is the coagulating value of NaCl.

18. A solution of palmitic acid (Molar mass = 256) in Benzene contain 5.12 g of acid per litre of solution. When this solution is dropped on a water surface, the Benzene evaporates and acid forms a monolayer film of solid type. If 500 cm^2 are is to be covered by a monolayer, then find X, where X = $\dfrac{V}{100}$, when V is volume required of solution. The area covered by 1 molecule = 0.2 nm^2.
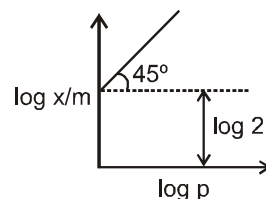
SECTION-4 : Comprehension Type (Only One options correct)
This section contains 1 paragraphs, each describing theory, experiments, data etc. 3 questions relate to the paragraph. Each question has only one correct answer among the four given options (A), (B), (C) and (D).

Paragraph for Questions 19 to 21
Read the following passage carefully and answer the questions.
The Colloidal particles are electrically charged as is indictated by their migration towards cathode or anode under the applied electric field. In a particular colloidal system, all particles carry either positive charge or negative charge.
The electric charge on colloidal particles originate in several ways. According to preferential adsorption theory, the freshly obtained precipitate particles adsorb ions from the dispersion medium, which are common to their lattice and acquire the charge of adsorbed ions. For example, freshly obtained $Fe(OH)_3$ precipitated is dispersed, by a little $FeCl_3$, into colloidal solution owing to the adsorptions of Fe^{3+} ions in preference. Thus sol particles will be positively charged.
In some cases the colloidal particles are aggregates of cations or anions having amphiphilic character. When the ions possess hydrophobic part (hydrocarbon end) as well as hydrophilic part (polar end group), they undergo association in aqueous solution to form particles having colloidal size. The formation of such particles, called micelles plays a very important role in the solubilization of water insoluble substances, (hydrocarbon, oils, fats, grease etc.). In micelles, the polar end groups are directed towards water and the hydrocarbon ends into the centre.
The charge on sol particles of proteins depends on the pH. At low pH, the basic group of protein molecule is ionized (protonated) and at higher pH (alkaline medium), the acidic group in ionized. At Isoelectric pH, characteristic to the protein, both basic and acidic groups are equally ionized.
The stability of colloidal solution is attributed largely to the electric charge of the dispersed particles. This charge causes them to be coagulated or precipitated. On addition of small amount of electrolytes, the ions carrying opposite charge are adsorbed by sol particles resulting in the neutralization of their charge.When the sol particles either with no charge or reduced charge, come closer due to Brownian movement, they aggregate to form bigger particles resulting in their separation from the dispersion medium. This is what is called coagulation or precipitation of the colloidal solution. The coagulating power of the effective ion, which depend on its charge, is expressed in terms of its coagulating value, defined as its minimum concentration (m mol/L) needed to precipitate a given sol.

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19. How would you obtain a sol of AgI, the particles of which migrate toward cathode under the electric field?

(A) By adding little excess of KI to $AgNO_3$ solution

(B) By adding little excess of $AgNO_3$ to KI solution

(C) By mixing equal volumes of 0.010 M $AgNO_3$ and 0.010 M KI

(D) None of these

20. 100 ml each of two sols of AgI, one obtained by adding $AgNO_3$ to slight excess of KI and another obtained by adding KI to slight excess of $AgNO_3$, are mixed together. Then

(A) The two sols will stabilize each other   (B) The sol particles will acquire more electric charge

(C) The sols will coagulate each other mutually   (D) A true solution will be obtained

21. Under the influence of an electric field, the particles in a sol migrate towards cathode. The coagulation of the same sol is studied using NaCl, Na_2SO_4 and Na_3PO_4 solutions. Their coagulating values will be in the order

(A) $NaCl > Na_2SO_4 > Na_3PO_4$ (B) $Na_2SO_4 > Na_3PO_4 > NaCl$

(C) $Na_3PO_4 > Na_2SO_4 > NaCl$ (D) $Na_2SO_4 > NaCl > Na_3PO_4$

SECTION-5 : Matching List Type (Only One options correct)
This section contains 1 questions, each having two matching lists. Choices for the correct combination of elements from List-I and List-II are given as options (A), (B), (C) and (D) out of which one is correct.

22. Match list I with list II and select the correct answer :

	List I		List II
P	Coagulation	1.	Scattering of light
Q	Dialysis	2.	Formation of colloidal solution from precipitates.
R	Peptization	3.	Purification of colloids
S	Tyndall effect	4.	Accmulation of collidal sols

Code:

	P	Q	R	S		P	Q	R	S
(A)	3	4	1	2	(B)	1	2	4	3
(C)	3	3	2	1	(D)	2	3	1	4

Practice Test-2 ((IIT-JEE (ADVANCED Pattern))
OBJECTIVE RESPONSE SHEET (ORS)

Que.	1	2	3	4	5	6	7	8	9	10
Ans.										
Que.	11	12	13	14	15	16	17	18	19	20
Ans.										
Que.	21	22								
Ans.										

APSP Answers

PART - I

1.	(4)	2.	(1)	3.	(2)	4.	(1)	5.	(4)
6.	(2)	7.	(4)	8.	(4)	9.	(3)	10.	(4)
11.	(1)	12.	(4)	13.	(4)	14.	(2)	15.	(3)
16.	(4)	17.	(2)	18.	(3)	19.	(3)	20.	(4)
21.	(1)	22.	(2)	23.	(1)	24.	(4)	25.	(2)
26.	(3)	27.	(1)	28.	(3)	29.	(1)	30.	(1)

PART - II

1.	(B)	2.	(B)	3.	(A)	4.	(B)	5.	(A)
6.	(D)	7.	(B)	8.	(A)	9.	(A)	10.	(C)
11.	(D)	12.	(B)	13.	(D)	14.	(B)	15.	(C)
16.	(C)	17.	(D)	18.	(B)	19.	(C)	20.	(A)
21.	(C)	22.	(D)	23.	(B)				

PART - III

1.	3.33×10^{16} cm^{-2}			2.	Ba^{2+}, 10 m mol/L			3.	(A)
4.	(D)	5.	(A)	6.	(A)	7.	(B)	8.	(A)
9.	(C)	10.	20	11.	(BC)	12.	(ABD)	13.	(BCD)
14.	(BC)	15.	(BCD)	16.	(BCD)	17.	(BCD)		

PART - IV

1.	(D)	2.	(B)	3.	(C)	4.	(B)	5.	(D)
6.	(B)	7.	(B)	8.	(ABD)	9.	(A)	10.	(ABD)
11.	(BC)	12.	(ABD)	13.	25	14.	4	15.	03
16.	60	17.	50	18.	2	19.	(B)	20.	(C)
21.	(A)	22.	(C)						

APSP Solutions

PART - I

1. $\dfrac{x}{m} = KP^{1/n},$ $\qquad \log \dfrac{x}{m} = \log K + \dfrac{1}{n} \log P$

2. That's why lyophilic colloid has affinity for water.

3. Scattering of light by colloidal particles is known as Tyndall effect.

4. Tyndall effect is shown by colloidal solution.

5. In milk, liquid fat particles are dispersed in water.

6. Higher the charge on coagulating ion, higher the coagulating power.

7. Gold sol is – ve sol, so coagulating ion is cation.

8. Lyophilic colloid is solvated by dispersion medium and becomes more stable.

9. Coagulating power $\propto$ charge on coagulating ion.

10. Effectiveness of coagulation by electrolyte $\propto$ charge on coagulating ion.

11. Fog is an example of liquid dispersed in gas.

12. As_2S_3 colloidal sol is obtained when As_2O_3 is saturated with H_2S :

$\qquad As_2O_3 + 3H_2S \rightarrow As_2S_3 + 3H_2O.$

As_2S_3 adsorbs S^{2-} ions (common between H_2S and As_2S_3 and thus is negatively charged).

$\qquad As_2S_3 + H_2S \rightarrow As_2S_3 \qquad\qquad S^{2-} : 2H^+.$

13. Light is scattered by colloidal particles present in environment so sky looks blue.

14. Colloidal particle shows Tyndall effect because of it's larger size.

15. Brownian motion is due to impact of molecules of the dispersion medium on the colloidal particles.

16. As_2S_3 is negatively charged sol so more positively charged ion will have minimum coagulating value.

17. Gelatin is positive sol.

18. Sulphur is a lyophobic colloid.

19. Smoke is an example of solid dispersed in gas.

20. Arsenious sulphide is negatively charged sol so more the charge on cation of electrolyte, more the efficiency of electrolyte for coagulation.

21. Colloid is heterogeneous, biphasic solution.

22. Smaller the charge on coagulating ion, higher the flocculation value.

23. Easily liquefiable gases like CO_2 are adsorbed to a greater extent than gases like O_2, N_2 and H_2

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24. Electrophoresis means movement of colloidal particles under the influence of electric field.

25. Negative catalyst provides a path of higher activation energy

26. These are the properties of colloidal solution.

27. Adsorption theory is given for heterogeneous catalyst. Example : adsorption of gas on solid surface.

28. According to Freundlich adsorption isotherm, $\dfrac{x}{m} \propto kp^{1/n}$ (n > 1).

29. Physical adsorption is due to vander waals forces.

30. According to Freundlich isotherm : $\dfrac{x}{m} = Kp^{1/n}$ or $\log \dfrac{x}{m} = \log K + \dfrac{1}{n}\log P$ (For solution, P = C).

PART - III

1. Mass of glucose adsorbed = $(20 - 19) \times \dfrac{20}{10^6}$ = 2×10^{-5} g.

Moles of glucose adsorbed = $\dfrac{2 \times 10^{-5}}{180}$ = $\dfrac{10^{-6}}{9}$.

Number of glucose molecules = $\dfrac{10^{-6}}{9} \times 6 \times 10^{23}$ = $\dfrac{20}{3} \times 10^{16}$

Number of glucose molecules per unit area = $\dfrac{1}{2} \times \dfrac{20}{3} \times 10^{16}$ = 3.33×10^{16} cm^{-2}.

2. Conc. of Ba^{2+} = $\dfrac{10^{-4}}{10 \times 10^{-3}}$ M = 10^{-2} M = 10 mmole/L.

3. Loss of water from gel is known as synerisis.

4. All are facts to remember.

5. Reddish brown sol is prepared by adding $FeCl_3$ in $Fe(OH)_3$ precipitate.

6. Similar charged colloidal particles will repel each other so colloidal system will not be suspended.

7. Micelles have large molar mass so less colligative property.

8. $\log \dfrac{x}{M} = \log k + \dfrac{1}{n} \log P$

$\dfrac{1}{n} = \tan 45°$ $\qquad\qquad$ ln k = 0.69

n = 1 $\qquad\qquad\qquad$ k = 2

$\dfrac{x}{m} = 2 \times (0.5)^1$

x = 1

9. 200 mL of the sol require = 0.73 g HCl

$$= \frac{0.73}{36.5} \text{ mol} = 0.02 \text{ mol} = 20 \text{ m mol}.$$

So, flocculation value of HCl = $\frac{20 \text{ mmole}}{0.2 \text{ lit}}$ = 100

10. Gold number is minimum amount of protective colloid which can protect 10 mL standard gold sol from coagulation when 1 mL of 10% NaCl is added.

11. (B) Aluminium hydroxide is a +ve sol, so – ve ions are effective in coagulation.
(C) Cellulose solution is an example of macromolecular colloid.

12. Egg albumin is lyophlic colloid.

13. Monolayer is formed during chemisorption.

14. This is because of absorption.

15. $Fe(OH)_3$ is postive sol, remaining all three are negative sol.

16. Lyophobic colloid are solvent hating.

17. Small particles has more random behaviour.

PART - IV

1. –ve charged sol is coagulated by cation of electrolyte. More the charge on cation, higher the precipitating power.

2. More the charge on cation, higher the coagulating power.

3. Ferric hydroxide sol is + vely charged sol.

4. Lyophobic colloids are irreversible colloids.

5. Particle size of the adsorbent affects the amount of adsorption.

6. (i) NH_3 is easily liquifiable, so ordered more than H_2.
(ii) This phenomenon is known as electrophoresis, not Brownian movement.

7. Enzymes are highly specific heterogeneous catalyst.

8. Efficiency of a heterogeneous catalyst increases with its surface area.
Catalyst provides a path of lower activation energy but enthalpy of reaction is not affected.

9. Catalyst may appear in rate expression. But it is not consumed in the reaction.

10. (A) ΔH = –ve for adsorption
(B) fact
(D) chemical bonds are stronger than vander waal's forces so chemical adsorption is more exothermic.

11. (B) Aluminium hydroxide is a +ve sol, so – ve ions are effective in coagulation.
(C) Cellulose solution is an example of macromolecular colloid.

12. A negative catalyst does not raises the activation energy barrier of a reaction; it actually functions to remove the active intermediate from the reaction and thus, it retards the rate of a reaction.

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13. Gold number is minimum amount of protective colloid which can protect 10 ml standard gold sol from coagulation when 1 ml of 10% NaCl is added.

15. Mass of acetic acid adsorbed = $(0.6 - 0.5) \times 1 \times 60 = 6$ g

Mass of acetic acid adsorbed per gram of carbon = $\dfrac{6}{2} = 3$ g

16. 1 litre colloidal solution contains = $10^{-3} \times N_A$ molecule of $C_{12}H_{25}SO_4Na$.

1 mm^3 colloidal solution contains = $\dfrac{10^{-3} \times N_A \times 1}{10^6} = 6 \times 10^{14}$ molecule of $C_{12}H_{25}SO_4Na$.

10^{13} colloidal particles = 6×10^{14} molecule of $C_{12}H_{25}SO_4Na$.

1 colloidal particle = $\dfrac{6 \times 10^{14}}{10^{13}}$ molecule of $C_{12}H_{25}SO_4Na$ = 60 molecules.

17. 10 ml of 1 M NaCl contains NaCl = $10 \times 1 = 10$ milli mole

200 ml of As_2S_3 required NaCl for the coagulation = 10 milli mole

$\therefore$ 1000 ml of As_2S_3 required NaCl for the coagulation = $10 \times 1000 / 200 = 50$ milli mole

18. Let V litre of palmitic acid is required.

Number of molecules = $\dfrac{5.12\ V}{256} \times 6.023 \times 10^{23} = 1.2 \times 10^{22}$ V

Area covered = $(1.2 \times 10^{22}\ V)(0.2 \times 10^{-14}\ cm^2) = 2.4 \times 10^7\ V\ cm^2$

$2.4 \times 10^7\ V\ cm^2 = 500\ cm^2$

$V = 0.02\ cm^3 = \dfrac{2}{100}\ cm^3$

$X = 2$

19. We want to prepare sol of AgI having positively charged particles, so a little excess of Ag^+ should be added to KI.

20. The sols will neutralise each other so will coagulate each other because of opposite charge.

21. Greater the charge on negative ions of salt used (since sol is positively charged) smaller will be its coagulating value.

22. P. Coagulation is known as accomulation of collidal sols.
Q. Dialysis is purification of colloids.
R. Peptization is formation of colloidal solution from precipitates.
S. Tyndall effect is scattering of light by colloidal particle.