1. Adsorption

The surface of the solid has a tendency to attract the molecules of a gas or a liquid when they come in its contact. Since energy is released on account of attraction, the solid acquires a more stable state. These molecules attracted by the finely divided solid, remain on the surface only and do not penetrate into the bulk of the solid. Thus, there is a high concentration of these species of gas or liquid on the surface and they are said to be adsorbed on the surface. Hence, adsorption may be defined as:

The phenomenon of higher concentration of the molecular species (gases or liquids) on the surface of the solid than in the bulk.

Adsorbent and adsorbate: The solid substance on the surface of which adsorption occurs is known as adsorbent while the molecular species that get adsorbed on the solid surface due to intermolecular attractions are called **adsorbate**. For example, activated charcoal which is finely divided has a tendency to adsorb a number of gases like ammonia, phosgene etc. Here charcoal acts as an adsorbent while gas molecules act as adsorbate. In a similar manner, animal charcoal is used for decolourising a number of organic substances in the form of their solution. The discharge of the colour is due to fact that the coloured component (generally an organic dye) gets adsorbed on the surface of the adsorbent i.e. animal charcoal.

Explanation of Adsorption: As discussed above, the adsorption is a surface phenomenon. The atoms in a solid are held together by certain binding forces which are main van der Waal's forces or may be even chemical forces. The unutilized or unbalanced forces present on the surface (indicated by dotted lines) make it quite active. Moreover, when a solid substance shown in figure 1 (a) is broken into two or more pieces, new surfaces get formed shown in figure 1 (b) i.e., the number of the unbalanced forces becomes more. In other words, the number of active centres or free valencies becomes more by taking the adsorbent in the finely powdered form.



Due to the unbalanced forces, the atoms or molecules on the surface have a tendency to attract and retain the molecules of the gases or liquids when they come in contact with the surface. The results into higher concentration of any particular species at the surface than in the bulk and this leads to adsorption. The adsorption which are commonly used are activated charcoal, animal charcoal, silica gel and a number of finely divided metals such as Cu, Ni, Pd, etc. Activated charcoal is a powerful adsorbent since it is a microscopic crystalline variety of graphite having a very large surface area.

2. Desorption

Adsorption is of reversible nature i.e., the species which get adsorbed on the surface of the adsorbent have a tendency to come out of the surface. The reverse phenomenon is called desorption. Though the desorption takes place of its own, it can be accelerated by increasing the temperature. The energy absorbed weakens the forces binding the molecules of the adsorbent and the adsorbate. As a result, the latter gets released from the surface. The desorption is very common in gases which are adsorbed on the surface of finely divided metals as a result of weak van der Waal's forces of attraction. They can be easily overcome and lead to desorption.

3. Absorption

Absorption is another important phenomenon which is noticed in our daily life. *When* the molecules of a substance are uniformly distributed throughout the body of other substance, it is known as adsorption. For example, when ammonia gas is passed through water, the molecules of ammonia get uniformly distributed in water and we say that ammonia has been absorbed by water.

Different between Adsorption and Absorption

On the basis of the above discussion, it appears that adsorption is quite different from absorption. Whereas adsorption is linked only with the surface of one substance which takes up the particles of the other substance, absorption occurs in the bulk of the substance which absorbs. In order to make a proper distinction between the two, let us place a silica gel and anhydrous calcium chloride on contact with water vapours taken in two separate containers. When silica gel is placed in an environment of water vapours, it simply adsorbs these water vapours. As shown in figure 2(a), the water vapours are present in a high concentration at the surface of silica gel whereas the interior of the gel has no water vapours. On the other hand, when anhydrous calcium



Figure 2: (a) Higher concentration of water vapours at the surface of silica gel (Phenomenon of a adsorption)

Figure 2: (b) Uniform distribution of water vapours throughout the body of calcium chloride (Phenomenon of absorption)

chloride is placed in water vapours, it absorbs these. The water vapours uniformly get distributed throughout the body of anhydrous calcium chloride as shown in figure 2(b). Thus, silica gel absorbs water vapours while anhydrous calcium chloride absorbs moisture. It is quite obvious that the concentration of the water vapours is mainly on the surface of the gel while these vapours have penetrated into the bulk of the anhydrous calcium chloride. Now, as the adsorption is linked with the surface only, the extent of adsorption depends upon the availability of space on the surface. Therefore, it is expected to be quite fast to start with while its rate must decrease with the passage of time. On the other hand, the absorption must proceed at a uniform speed since it is no way connected with the surface of the substance which absorbs. The main points distinction between the two phenomenon are listed in a tabular form.

	Absorption	Adsorption
1.	It is phenomenon as a result of which the species of one substance get distributed uniformly throughout the body of the other substance.	It is the phenomenon as a result of which the species of one substance get concentrated mainly at the surface of the other substance which adsorbs these.
2.	The concentration of the same throughout the material.	The concentration on the surface of the adsorbent is different from that in the bulk.
3.	It is a bulk phenomenon since it occurs throughout the bulk of the material.	It is only a surface phenomenon since it occurs only at the surface.
4.	Absorption proceeds at uniform rate.	Adsorption is rapid in the beginning and its rate slowly decreases with the non-availability of the surface.

4. Sorption

Some cases are known in which both adsorption and absorption occur together. This means that a particular substance gets distributed throughout the bulk of the other substance but at the same time, its concentration on the surface also increases and is more than in the bulk. However, it is very difficult to make a clear distinction between the two. This is known as *sorption*. Certain dyes get adsorbed as well as absorbed on the fibres resulting in sorption.

Thermodynamical Feasibility of Adsorption: We have studied that the phenomenon adsorption arises because of attraction between he particles or molecules of adsorbent and adsorbate. Therefore, it is exothermic in nature and is accompanied by release in energy known as enthalpy of adsorption (heat of adsorption). It may be defined as: *the change in enthalpy taking place for the adsorption of one mole of*

the adsorbate on the surface of the adsorbent.

The adsorption is also likely to influence the randomness. (T Δ S) factor. The randomness of the adsorbed species on the surface of the adsorbent is likely to decrease i.e., T Δ S is negative. Let us study the feasibility of the phenomenon in the light of Gib's Helmholtz equation. Since Δ H favours while T Δ S opposes the phenomenon of adsorption, the magnitude of the former must be more. This is feasible only at low temperature and this is what we actually notice. We shall discuss the effect of temperature on the rate of adsorption at a later stage.

 $\Delta H = \Delta H - T\Delta S_{(-ve)}$

5. Physical and Chemical Adsorption

Adsorption as discussed arises because of the attraction between the particles of the adsorbate and adsorbent. Depending upon the nature of the forces, it has been classified into physical and chemical adsorption.

Physical adsorption: When the particles of the adsorbate are held to the surface

of the adsorbent by physical forces such as van der Waal's forces, it is called physical adsorption. This is called physisorption or even van der Waal's adsorption. Since the attractive forces are weak, they can be easily overcome either by increasing the temperature or decreasing the pressure. Therefore, the physisorption can be easily reversed or decreased by either raising temperature or by reducing the pressure of the gas. The enthalpy of adsorption in case of physical adsorption is quite low. It is varies between 20 to 40 kJ mol⁻¹.

Chemical adsorption: When the molecules of the adsorbate and adsorbent are held together by stronger forces similar to the chemical bonds, the adsorption is known as chemical adsorption or Chemisorption. This leads to formation of some sort of compound on the surface of the adsorbent. These are known as surface compounds. This is further confirmed by the fact that the when oxygen is adsorbed on the surface of metal like tungsten or activated charcoal, the molecules which are released from the surface are not of oxygen but those of tungsten oxide in case of metal and of carbon monoxide or carbon dioxide in case of charcoal. Moreover, the enthalpy of adsorption unlike physical adsorption is also quite high (nearly 400 kJ mol⁻¹) which is almost of the same magnitude that we come across in chemical reactions. However, it is mono layer in nature which means that only the atoms of the molecules present on the surface of the adsorbent are involved in the bond formation. Physical adsorption, on the other hand is multilayer in nature because more than one layer of the adsorbent may be involved in van der Waal's forces of attraction. Another major difference between the two types of adsorption is that whereas the physical adsorption can be easily reversed (i.e. desorption is very easy), it is not so in case of chemical adsorption since bonds are to break and certain energy is needed for the same.

	Property	Physisorption	Chemisorption
1.	Nature of forces	Weak van der Waal's forces	Strong chemical forces present
2.	Heat of adsorption	Low; of the order of 20-40kJ/ mol.	High; of the order of 400kJ/mol
3.	Temperature	Usually occurs at low temperature	Occurs at high temperature
4.	Reversibility	Reversible	Irreversible
5.	Specificity	It is not specific in nature, i.e., all gases are adsorbed on the surface of a solid to the same extent.	It is highly specific in nature and occurs only when there is bond formation between adsorbent and adsorbate molecules.
6.	Nature of molecular layers	Forms multi-molecular layers	Forms mono-molecular layer
7.	Extent of adsorption	The extent of adsorption is directly related with the case of liquefaction of the gas.	There is no correlation between extent of adsorptiona nd the ease of liquefaction of the gas.
8.	Activation energy	It does not involve appreciable activation energy. In most cases, the activation energy required is almost nil.	It generally requires appreciable activation energy since a chemical reaction is to take place.
9.	State of adsorbate	Same state as in the bulk.	State of adsorbate molecules may be quite different from that in the bulk.

6. Factors Influencing Adsorption of Gases by Solids

Gases are adsorbed on the surface of either finely divided metals such as Ni, Pt, Fe, Pd etc. or porous solids such activated charcoal or as activated charcoal, animal charcoal, silica gel, alumina etc. The extent of adsorption depends upon a number of factors which are briefly discussed.

1. **Nature of gas or adsorbate:** Since physical adsorption is non specific in nature, every gas will get adsorbed on the surface of any solid to a lesser or greater extent. The only criteria for the extent of adsorption is the magnitude of the attractive forces which exist between the particles of the adsorbent and adsorbate. For example, under given conditions of temperature and pressure, the easily liquefiable gases like NH₃, HCl and CO₂ are adsorbed tog greater extent than the gases like H₂, O₂ and N₂ which are liquefied with difficulty. The former being heteroatomic in nature, have a greater magnitude of the attractive forces as compared to the latter. In general, the ease of the liquefaction of gases can be compared in terms of their critical temperatures. The critical temperature of a gas may be defined as:

the minimum temperature above which a gas cannot be liquefied lower large its pressure may be

Thus greater the value of critical temperature easier will be the ease of liquefaction of the gas and more will be the extent of its adsorption on a particular solid. The critical temperatures of different gases along the extent of their adsorption in cc in one gram of the activate charcoal (adsorbent) are listed.

Gas	H_2	N ₂	СО	CH_4	CO ₂	HC1	NH ₃	SO ₂
Critical temperature (K)	33	126	134	190	304	324	406	430
Amount adsorbed (in cc)	4.7	8.0	9.3	16.2	48	72	18	380
—— Extent of adsorption increases ——>								

This does not apply to chemisorption since adsorption can occur only when specific bonds Note: are formed between the molecules of adsorbate and adsorbent. Thus, chemisorption is of selective nature.

- 2. **Nature of adsorbent:** The nature of adsorbent which is normally a solid sis linked with its surface area. Animal charcoal, silica gel and alumina are regarded as good adsorbents because of their porous nature and large surface area. Metals acting as adsorbent are also taken in finely divided form so that large surface area may be available for adsorption of the gases.
- 3. Activation of the adsorbent: Activation of adsorbent implies increasing its adsorbing power. This is done by increase the surface area and also the number of pores or vacant sites (also called activate centres) per unit area. This can be carried in a number of ways.
 - (i) Activation of the adsorbent is carried out by mechanical rubbing or by subjecting it to some chemical reaction.
 - Some adsorbents are activated by strong heating in contact with superheated (ii) steam. For example, charcoal which is commonly employed in adsorption of gases, is activated by subjecting it to the action of superheated steam. This will remove the molecules of gases like CH_4 , C_2H_6 (hydrocarbons) that are occupying these pores.
 - To increase the adsorbing power, the adsorbent is sub-divided into small fine (iii) pieces. By doing so, the surface area increases and so is the adsorbing power.
- Effect of Pressure: In order to study the effect of pressure on the adsorption of a 4. gas on the surface of a solid, we must bear in mind that adsorption is a reversible process i.e., desorption is also taking place simultaneously. In case, the adsorbate and

adsorbent are enclosed in a closed container, a stage is reached when the amount of gas adsorbed becomes equal to the amount of gas desorbed. This stage is reached when the amount of gas adsorbed becomes equal to the amount of gas desorbed. This stage is called equilibrium state i.e. the surface of the adsorbent gets saturated with the adsorbed gas and no more adsorption occurs. The extent of the adsorption is generally expressed as x/m where m is the mass of the adsorbent and x is the mass of the adsorbate when equilibrium has been attained. If we plot a graph between x/m and the pressure p of the gas at a constant temperature, the curve is called adsorption isotherm.

A simple type of adsorption isotherm (i.e. the relation between the pressure of the gas (adsorbate) and the amount (x/m) of it adsorbed on the surface of adsorbent is shown in figure 3.



At the equilibrium pressure, p_s , x/m reaches its maximum value i.e., no more adsorption takes place even if the pressure is further increased. This rate is also called saturation state in adsorption and the corresponding pressure (p_s) is regarded as *saturation pressure*. Such isotherms are considered when the adsorbate simply forms a unimolecular layer on the surface of adsorbent.

On the basis of experimental studies, **Freundlich** gave a relation between the amount of the gas adsorbed (x) per unit mass of the adsorbment (m) and the pressure (p). This is known as **Freundlich's adsorption isotherm** because the graph has been plotted at constant temperature.

(i) Form the adsorption isotherm (Figure 3), it is clear that at low pressure, the graph is almost straight. This means that x/m is directly proportional to the pressure. This may be expressed as

$$\frac{1}{x} \propto p^1$$
 or $\frac{x}{m} = K_{p^1}$

Where K is constant.

(ii) **At high pressure:** The value of x/m becomes almost constant, i.e., it does not change with the change in pressure. The relation may be expressed as:

$$\frac{x}{m} = \text{constant} \quad \text{or} \qquad \frac{x}{m} \propto p^0 \qquad (\because p^0 - 1)$$
$$\frac{x}{m} = K_{p^0}$$

or

(iii) **At intermediate range of pressure**, x/m, will depend upon the power of pressure which lies between 0 to 1 i.e., fraction power of pressure. This may be expressed as

$$\frac{1}{m} \propto p^{1/n} \qquad \text{or} \qquad \frac{x}{m} = K_{p^{1/n}}$$

Where n is a constant (whole number) which depends upon the nature of adsorbate and adsorbent.

The constants K and n can be determined as follows: Taking logarithsm on both sides of equation, we get

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

 $f_{\text{go}} = \frac{100}{100}$ Intercept = log K $O \quad \log p \rightarrow Figure 4:$ Liner graph between log x/m and log p.

Thus, if we plot a graph between log (x/m) and long p, a straight line will be obtained. Thus slope of the line (figure 4) is equal to 1/n and the intercept on long (x/m) axis will correspond to log k.

7. Langmuir Adsorption Isotherm

This was studied by Langmuir in 1916. The main features of the adsorption theory are as follows:

- (i) All adsorption sites on the surface of the adsorbent are equivalent and the ability of a particle to bind itself to a particular site is quite independent of the presence of other sites whether occupied or not.
- (ii) The layer of the adsorbed gas is only one molecule thick i.e., it is unimolecular in nature. Since this type of adsorption is noticed only in case of chemisorption. Langmuir adsorption isotherm is applied only to chemisorption.
- (iii) Adsorption process represents two opposing tendencies i.e., condensation (or adsorption) of the gas molecules on the surface of the solid and evaporation (or desorption) of these molecules back to the gaseous state.
- (iv) The rate of condensation of a gas is proportional to the uncovered surface of the adsorbent while that of evaporation to its covered surface.

To start with, the entire surface of the solid (adsorbent) is uncovered and the rate of condensation is very high while that of evaporation is negligible. With the passage of time, more and more of the surface becomes covered. As a result, the rate of condensation decreases while that of evaporation increases till the two are equal.

Derivation of Express ion for Langmuir Adsorption Isotherm: Let 1 square of the surface solid be exposed to a gas maintained at a pressure P. Let at any instant of the time, the fraction of the surface covered by the adsorbate molecules be θ sq. cm. Therefore, the uncovered surface of the adsorbent will be $(1 - \theta)$ sq. cm.

The rate of condensation $\propto (1 - \theta) = k_1 (1 - \theta)P$

The rate of evaporation $\propto \theta = k_2 \theta$

At the adsorption equilibrium,

Rate of condensation = Rate of evaporation

$$k_1(1 - \theta)p = k_2\theta$$
 or $k_1P - k_1P = k_2\theta$



$$\therefore \qquad \theta(k_2 + k_1 P) = k_1 P \text{ or } \theta \frac{k_1 P}{(k_2 + k_1 P)}$$

Dividing by k_2 ; $\theta = \frac{(k_2 / K_2 P)}{(1 + k_2 / k_2 O)} = \frac{bP}{1 + bP}$ (here $b = k_1 / k_2$ = constant)

Now, θ is proportion to x/m i.e. the mass of the gas adsorbed per unit mass of the adsorbent (solid).

$$\therefore \qquad x / m \propto \theta \propto \frac{bP}{1 + bP} = \frac{k_3 bP}{1 + bP} = \frac{aP}{1 + bP}$$

Here, is a constant and is equal to k₂b

 $x/m = \frac{aP}{1+bp}$ (Langmuir Adsorption Isotherm) Thus,

Validity of the Langmuir Adsorption Isotherm



Since a and b are constant, a graph between $\frac{P}{x/m}$ and P must be straight line. The slope is equal to b/a and intercept on Y-axis is equal to 1/a.

8. Effect of temperature (Adsorption Isobar)

When a gas is not involved in the formation of any compound with the surface of the adsorbent, it represents adsorption. The curves between x/m (amount of the gas adsorbed per unit mass of adsorbent) and the temperature at constant pressure for the two types of adsorption are as follows:



From the curves, it is evident that the extent of adsorption decreases with rise in temperature in case of physical adsorption or physisorption. This is quite expected also because adsorption is of exothermic nature. Therefore, the reverse process i.e., desorption is endothermic in nature. As the temperature is increased, the process desorption i.e., reverse process is favoured. In other words, the extent of adsorption of the gas on the surface of the solid decreases with rise in temperature.

 $Gasa + Solid \square \square \square Gas absorbed;$ $\Delta H=-ve$

The similar trend is expected in chemisorption also but here the adsorption is initially shown to increase with the rise in temperature and then follows the same trend. This may be attributed to the fact that the energy supplied by the initial rise in temperature provides the molecules of the adsorbate the desired activation energy so that proper bonds could be formed with the particles of the adsorbent. When all the species of the adsorbate have been properly oriented, a further rise in temperature will decrease the extent of adsorption as in case of physical adsorption.

9. Adsorption from Solution

Apart from adsorption of the gases, solids have also the capacity to adsorb substances present in solutions. For example, if we place a piece of charcoal in a litmus solution taken in a test tube and shake, the solution becomes colourless. It is because of adsorption of the litmus which is in fact a dye, by the charcoal. Similarly, animal charcoal decolourses impure sugar solution by adsorbing colouring dye.

The actual mechanism of adsorption from the solution is not definite. However, it is believed that it continues till a unimolecular layer is built up on the surface of the adsorbent. The Freundlich adsorption isotherm as well as Langmuir adsorption isotherm are applicable to the adsorption from the solutions in the same way as from the gases. The effect of temperature is also similar. However, equilibrium concentration (C) is used in place of equilibrium pressure and the mathematical expressions for the two types of isotherms are:

 $\frac{x}{m} = kC1/n$ (Freundlich Adsorption Isotherm) $\frac{x}{m} = \frac{aC}{1+bC}$ (Langmuir Adsorption Isotherm)

Completing Adsorption: When more than one type of the adsorbate species are in contact with a particular adsorbent, there is a competition between their molecules or particles to be adsorbed on the solid surface. This depends upon their nature. However, the one which can form stronger bonds is adsorbed more in preference to the other. This is known as competing adsorption and it also happens in the reverse process also i.e. desorption. In this case, the species which is weakly adsorbed as dislodged first from the solid surface. It may be noted that the adsorption chromatography is based upon the principle adsorption.

10. Applications of Adsorption

The phenomenon of adsorption finds extensive applications in industry in laboratory and also in various chemical processes. A few important applications are listed below:

- 1. **Removal of colouring matter:** Many substances such as sugar, juice and vegetable oils are coloured due to the presence of impurities. They can be decolorized by placing in contact with adsorbents like activated charcoal or fuller's earth. Similarly, most of the organic compounds that are synthesized in the laboratory are coloured. They can also be decolorised with the help of animal charcoal.
- 2. In gas masks: Activated charcoal is generally used in gas masks to adsorb poisonous and toxic gases from air. These masks are used by the miners since there is atmosphere of CO and other such gases prevailing in the coal mines.
- 3. In dyeing of cloth: Mordants such as alums are used in dying of cloth. They adsorb the dye particles which, otherwise, do not stick to the cloth.

or

- 4. **In dehumidizers:** Silica gel is commonly employed to adsorb humidity or moisture from air. This is necessary for the storage of delicate instruments which might otherwise be damaged by contact with most air.
- 5. **Heterogeneous catalysis:** The use of the metal catalysts such as Fe, Ni, Pd, etc., in the manufacturing processes such as Contact process, Haber process and the hydrogenation oils, is based upon the phenomenon of adsorption.
- 6. In ion-exchange resins: The organic polymer containing groups like -COOH, $-SO_3H$, $-NH_2$ etc., possess the property of selective adsorption of ions from solutions. These are quite useful in the softening of water and also in the separation of the elements of the Lanthanide series (also called rare earths).
- 7. **In Chromatography:** The different chromatographic techniques such as adsorption, paper or column chromatography which are used for the purification and the separation of the substances available in small amounts, are based upon the theory of selective adsorption.
- 8. In qualitative analysis: Certain qualitative tests such as the lake test for the confirmation of AI^{3+} ions are based upon adsorption, i.e., $al(OH)_3$ has the capacity to adsorb the colour of the blue litmus from the solution.
- 9. **In adsorption indicators:** In many titrations involving precipitating reactions, dyes such as eosin and flourescein are used as adsorption indicators. This is based upon the fact that these are more adsorbed by the precipitates than by the solution.

11. The Colloidal State

Thomas Grahma in 1862 coined the term colloids (Greek *Kollo* – glue, *iods* – like) to distinguish some amorphous glue-like substances from crystalloids which crystallize easily. He distinguished these two substances on the basis of their diffusion through parchment membrane.

- 1. Crystalloids: The one having faster rate of diffusion.
- 2. Colloids: The one having slower rate of diffusion.

However, this classification has now historical importance and was rejected because some substances diffuse rapidly in water but slowly in alcohol medium (e.g. NaCl), whereas some substances diffuse slowly in water but rapidly in alcohol medium (.e.g soaps). Therefore, a new term *colloidal state* was preferred.

It is therefore convenient to examine the colloidal state and not the colloids as such. Though Graham's concept of colloids is not fully valid, the term colloids has, however, been retained.

12. Characteristics of Colloids

- 1. It is a particular state and not a class of compounds.
- 2. It is the state in which rate of diffusion through parchment membrane is slow.
- 3. It is heterogeneous state, i.e., number of phases ≥ 2 , i.e, each particle is contained within its own boundaries which separate it form dispersion medium.
- 4. Thus a colloidal state must have at least two phases. The one phase dispersed in other is known as dispersed phase (D.P.) or internal phase whereas the other in which dispersions are made is known as dispersion medium (D.M.) or external phase.
- 5. It is an intermediate state in between true solution state and suspension state, i.e., particle size of colloidal state (of dispersed phase) lies in between true solution state and suspension state.

True solution	Colloidal state	Suspension
Solution + Solvent	D.P. + D.M.	Precipitate + medium
Size: Solute $< 1 \times 10^{-7}$ cm	$DP = 10^{-5} \text{ to } 10^{-7} \text{ cm}$	Precipitate = 0.2×10^{-4} cm

- 6. Particles in a colloidal state are not detectable even under microscope; however, their images can be noticed in ultra microscope.
- 7. Colloidal particles do not settle down under the force of gravity even in keeping for long.
- 8. Colloidal particles always carry charge, +ve or -ve on dispersed phase particles.

13. Distinction in true solutions, colloids and suspensions

A colloidal solution differs from true solutions and coarse suspensions due to the size of solute particles. Usually the size of the solute in true solution is of the order of atomic/molecular size 10^{-7} cm) whereas in coarse dispersion or suspension the particle size exceeds 10^{-4} cm. the colloidal size lies between the two extremes of true solutions and coarse dispersions. In table are shown some distinctions. Though a clear cut boundary on the basis of particle size is not established, colloidal particles are often considered in the range $10^{-5} - 10^{-7}$ cm. This range is not microscope or an electron microscope. However, emulsions, which are also considered in the category of colloids and often have particle size towards longer side of the colloidal range, $\sim 10^{-4}$ cm are visible under the ordinary microscope.



Figure 7: The colloidal dispersions

Particle s shown in solid circles are those of continuous medium (i.e. molecules of the order of angstrom i.e. 10^{-8} cm)

Solute particles (molecules) in true solution of the size of the continuous medium colloidal particles range $(10^{-5}10^{-7})$ whereas coarse suspension have even bigger sized particles.

Alyophobic colloid is always heterogeneous. It consists of atleast two phases immiscible with each other. Thus a colloidal dispersion made by two different immiscible substances contains one phase in the form of dispersed particle called dispersed phase which remain present in a continuous medium of the other substance called dispersion medium. Some general differences in true solution, colloidal solution and coarse suspension are given in table.

Table	2:	Distinguishing	features	in	suspension,	colloids	and	true
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Property	Suspension	Colloid	Solution
Particle size	$> 10^{-5}$ cm or 10^{3} Å or 100 mµ	10^{-7} to 10^{-5} cm or 10Å to 10^{3} Å or 1 mµ to 100 mµ	$<10^{-7}$ cm or 10Å or 1 mµ
Visibility	Visible with naked eye	Images are visible under ultra microscope	Not visible with any of the optical means
Separation			
a) with filter paper	Possible	Not possible	Not possible
b) with membranes	Possible	Possible	Not possible
Diffusion	Does not diffuse	Diffuses very slowly	Diffuses readily
Setting or sedimentation	Settles under influence of gravity	Settle under centrifuge	Does not settle
Nature	Heterogeneous	Heterogeneous	Heterogeneous
Appearance	Opaque	Turbid	Clear

Classification of Colloidal State

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- 1. **Classification based on the nature of dispersion medium:** If dispersion medium is
 - air then aerosol water then hydrosol or aquosol
 - benzene then benzosol alcohol then alcosol
- 2. **Classification based on the nature of charge** If dispersed phase particles carry +ve charge; it is +ve sol If dispersed phase particles carry -ve charge; it is -ve sol
- 3. Classification based on the physical state of dispersed phase and dispersion medium: Considering the three physical states of aggregation of all matter as solids (S), Liquid (L) and Gas (G), eight different categories exists taking two immiscible substances as dispersed phase and dispersion medium as described in table. Table 3: Some examples of different class of Lyophobic Colloidal Systems

Internal phase or dispersed phase	External phase or dispersion medium	Colloidal name	Example
0.111	Solid	Solid Solution	Alloys, ruby glass, Gems or Precious stones, Marbles, Optical and vision glasses.
Solia	Liquid	Sol	Muddy water, gold sol, paints, cell fluids
	Gas	Aerosols	Smoke, particulate clouds, dust
	Solid	Gel	Alloys, ruby glass, Gems or Precious stones, Marbles, Optical and vision glasses.
Liquid	Liquid	Emulsion	Muddy water, gold sol, paints, cell fluids
	Gas	Aerosols	Smoke, particulate clouds, dust
	Solid	Solid form	Purnice stone, polystyrene foam, foamed rubber.
Gas	Liquid	Foam or froth	Froth, soap suds, whipped cream
	Gas	Homogenous system	Do not exits as colloids

4. **Classification based on affinity of dispersed phase for dispersion medium:** The substance that remains present as the dispersed phase does not have any affinity towards the solvent (dispersion medium) and these colloids are thus called Lyophobic colloids. A lyophobic colloid thus needs some special methods of preparation. This can be done in two ways. In the first case, the substance that forms the dispersed phase, is finely divided (dispersion method) or is condensed by forming aggregates of atoms/molecules (condensation method). These two methods of preparation of lyophobic colloids has been dealt later in this chapter along with their characteristic features.

14. Lyophilic and Lyophobic Colloids

Apart from lyophobic colloids, some substances, when simply, placed in the dispersion medium, dissolve and form colloidal solutions. The two substances are not immiscible with each other as in case of lyophobic colloids. Such colloids solutions are called Lyophilic colllid due to the affinity of the solute with the solvent. How then the colloidal properties develop in such systems? As has been made clear that colloidal solutions are typical in that they contain particles in the range 10^{-5} to 10^{-7} cm.

Lyphilic Colloids

1. **Association Colloids:** Soap and detergent when dissolved in water show the aggregation and form colloidal particles called micelles.



2. **Macromolecular Colloids:** Large polymer molecular when dissolved in a liquid molecularly dissolve. Very high molecular mass of polymer gives colloidal dimension to its molecule.



When a polymer (a high molecular weight substance) is placed in a solvent, it dissolves at molecular level but because of high molecular mass (1000 times or even more for example, compared to low molecular weight materials), the polymer molecule itself becomes of the size comparable to the colloidal range. Such lyophilic colloids, which are molecular solutions of polymers are called macromolecular colloids. Apart from this class of lyophilic colloids, the solution of soaps and detergents in water from lyophilic colloidal dispersions. When placed in water, a soap or detergent dissolves at molecular level and forms true solutions. However, if the concentration of soap is high, hundred of molecules of soap aggregate together by physical forces and form a colloidal entity called Micelle. The formation and properties of micelles will be dealt later in this unit. Soaps and detergents for their aggregation behaviour that leads to colloidal solutions are also known as Association colloids. Thus colloidal solutions of soap and detergents and those of high mol mass polymeric materials (e.g., starch, gelatin, gums) in water are collectively known as hydrophilic solutions. These are shown in figure.

No special method is employed in making of a lyophilic dispersion (simple dissolution is enough). For example, gelatin, agar-agar, starch etc. when mixed with hot water get converted into sols. In principle any molecular solution of a high polymer in any solvent can be called as a sol. Lyophilic sols (of association colloids) can be made by simply dissolving soaps and detergents in above certain concentration. These solutions are thermodynamically stable and cannot be coagulated (to create dispersed phase material from dispersion medium i.e., precipitation or breaking up of solid).

In table, the two types of sols are distinguished from one another.

Property	Lyophilic Sols	Lyophobic Sols
Nature	Dispersed phase has more affinity for dispersion medium	Dispersed phase has less affinity for dispersion medium.
Preparation	Need no special methods for preparation. Adding of the material in solvent gives the sols. For example adding starch in water gives starch sol	Simple mixing does not produce sols. Special methods (dispersion or condensation) are necessary.
Concentration	Sols have higher concentration of dispersed phase.	Sols have lower concentration of dispersed phase.
Stability	Thermodynamically more stable systems	Thermodynamically less stable systems. Coagulate with time.
Solvation	Dispersed phase particles are highly solvated	Dispersed phase particles are not solvated.
Viscosity	Viscosity of sols are often higher than the viscosity of dispersion medium.	Almost same as that of dispersion medium.
Surface tension	Surface tensions of sols are much lesser than the surface tensions of dispersion medium	Almost same as that of dispersion medium.
Reversibility	Reversible with temperature.	Irreversible.
Charge	The charge on dispersed phase particles depends upon pH of medium.	Independent of pH of medium.
Tyndall effect	Less scattering of light.	More scattering of light.
Coagulation by electrolytes	Very high concentration of salt is required for phase separation.	A small amount of salt is required for their coagulation.

Lyophilic and Lyophobic Sols

The lyophobic sols consist the colloidal particles in the form of aggregates of small molecules or atoms (gold, sol, sulphur sol, As_2S_3) sol etc. are some examples) which are held together by van der Waals forces. These are thus also called as multimolecular colloids.

The surface area of colloidal particles in a colloidal solution is very large. This can be nicely illustrated considering one cube of 1 cm dimension. Its total surface area will be 6 cm². Now if this cube is cut into several cubes of 1 mm length, the total number of cubes will be 1000 with each cube of total surface area = 6 mm² = 0.06 cm². For 1000 cubes this area will be 0.06×1000 cm² = 60 cm². Further subdivision say to cubes of 1 µm size will give a surface area of 6000 cm² and to 1 mm size will give a surface area as high as 6×10^7 cm². It is due to the large surface area of colloidal size particle, that adsorption on to the particle is of great importance. It fact, colloid chemistry and surface chemistry are highly interrelated fields.

15. Preparation of Colloids

The two different techniques that can be employed to obtain a lyophobic sol are condensation methods and dispersion methods. In condensation method, as the name suggests, the atoms and molecules of the substance condense (aggregate) leading to the particles of colloidal dimension. The condensation can be brought about by both physical and chemical means.

The Physical methods are illustrated below:

- (i) **By exchange of solvent:** A true solution of a solute in a solvent when mixed with another liquid (which is miscible with the solvent but does not dissolve solute in it) then a colloidal system is produced. For example, sulphur is molecularly dissolved in alcohol; an addition of excess amount of water to this solution produces colloidal solution of sulphur in water.
- By excessive cooling: Cooling sometimes produces colloidal dispersions. An example of the method is to produce colloidal solution of ice in organic solvents like ether, chloroform etc., by freezing a mixture of solvent and water. Using Chemical Methods, a sol can be prepared by hydrolysis, reduction, oxidation, double decomposition etc.
- (i) **By hydrolysis:** Addition of drop by drop of an aqueous solution of FeCl₃ on boiling hydrolysis of Fe(OH)₃ solution.

 $FeCl_3 + 3H_2O \longrightarrow Fe(OH)_3 + 3HCl$

(ii) **By reduction:** gold sol can be prepared on reducing a solution of gold (III) chloride with formaldehyde an d tannic sol.

$$2AuCl_3 + 3HCHO + 3H_2O \longrightarrow 2Au + 3HCOOH + 6HCl$$

Gold sol can be prepared by reducing $AuCl_{3(aq)}$ by hydrazine or $SnCl_2$.

$$4\text{AuCl}_3 + 3\text{NH}_2\text{NH}_2 \longrightarrow 4\text{Au} + 3\text{N}_2 + 12\text{HCl}$$

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

(iii) **Oxidation:** Sulphur sols are obtained when H_2S gas is bubbled through the solution of an oxidisng agent like Br_2 , HNO_3 , Mn^{2+} etc. where H_2S is oxidized to elemental sulphur.

$$H_{2}S + Br_{2} \longrightarrow 2HBr + S_{sol}$$
$$H_{2}S + 2HNO_{3} \longrightarrow 2H_{2}O + 2NO_{2} + S$$

Therefore during 2^{nd} group analysis of mixture, by passing H₂S in cold solution of mixture sometimes (if it contains an oxidant) leads to the formation of white, grey turbidity of sulphur sols instead of precipitates of 2^{nd} group sulphides.

A colloidal solution of sulphur can also be obtained by adding dil. HCl to sodium thiosulphate.

 $Na_2S_2O_3 + 2HCl \longrightarrow 2NaCl + SO_2 + H_2O + S_{col}$

(iv) **Double Decomposition:** This method is often used to prepare various colloidal solutions. Sulphide sols are often obtained by this method. For example, on passage of H_2S through cold aqueous solutions of $AsCl_3$, $CdCl_2$, $Hg(CN)_2$, their sulphide sols are formed.

$$2AsCl_{3} + 3H_{2}S \longrightarrow As_{2}S_{3} + 6HCl$$

$$CdCl_{2} + H_{2}S \longrightarrow CdS + 2HCl$$

$$Hg(CN)_{2} + H_{2}S \longrightarrow HgS + 2HCN$$

Also, drop wise addition of FeCl_3 solution to solution of sodium ferrocyanide gives Prussian blue sol.

$$4FeCl_3 + 3Na_4[Fe(CN)_6] \longrightarrow Fe_4[Fe(CN)_4] + 12NaCl$$

Silver chloride sols, Barium sulphate sols are formed by allowingthe following reactants to react in cold, dilute conditions.

$$AgNO_{3} + NaCl \longrightarrow AgCl + NaNO_{3}$$

BaCl₂ + H₂SO₄ \longrightarrow BaSO₄ + 2HCl

The dispersion methods employed for make lyopho bic sols involve the following techniques.

(i) By Grinding: The coarse particles of dispersed phase in presence of dispersion medium are grinded into smaller colloidal size particles in grinding machines such as mixie or colloidal mill (figure). These fine particles can then be stabilized by an stabilizer, for example, gum, tannin etc.



(ii) By Grinding Method: This is a simple method (Figure) for preparing metal sols (e.g., gold sol) and involves an electric are between the two metal rods partly dipped into the water as dispersion medium. The high electric tears the particles from rod (or wires) which are of colloidal size and remain dispersed in dispersion medium.



The heat generated during the process is removed by putting system under ice cold water. Little amount of KOH in water prevents growth of sol particles and stabilizes the dispersion. Purple of Cassuis (Au sol in water) sol is obtained by this method.

(iii) **Peptization**

- 1. The phenomenon of converting fresh precipitate into colloidal state by the action of solute or solvent is known as peptization. The solute or solvent used are known as peptizing agent.
- 2. For example
 - a) Freshly precipitated $Fe(OH)_3$ turns into in colloidal state by the action of $FeCl_3$.



Peptization – A method for the preparation of a sol

- b) Freshly precipitated stannic acid can be peptized by $NH_{3(1)}$ or HCl_{aa} .
- c) Freshly precipitated HgS, CdS and NiS can be peptized by H₂S.
- d) Peptization of albumin in water of nitrocellulose in acetone or ethyl alcohol to form collodion.
- 3. The process of peptization thus involves the adsorption of suitable ions (supplied by the electrolyte added particularly a common ion) and electrically charged particles then split from the precipitate as colloidal particles. A coarse suspension of silver chloride on shaking with electrolytes produces AgCl sol. Shaking of AgCl suspension with AgNO₃ solution produces positively charged AgCl sol due to adsorption of Ag⁺ ions whereas shaking of AgCl suspension with HCl produces negatively charged AgCl sol due to adsorption of Cl⁻ ions.

16. Purification of Sols

Sols so obtained are contaminated with two types of impurities and need purification.

- (a) **Insoluble impurities:** These are removed by simple filtration of impure sols. Impurities are retained on filter paper and sols are filtered.
- (b) **Soluble Impurities:** The soluble impurities either of molecular nature or of ionic nature in colloidal solutions need special methods for their removal from sols. Following techniques are used for this purpose.

Dialysis: The separation of soluble impurities from a colloidal solution on the basis of their different rates of diffusion through parchment membrane is known as dialysis. This can be done by using a bag made of a semipermeable bag. It has small pores which allows the small molecular / ionic species to pass through but not the colloidal particles which are larger in sizxe as compared to the membrane pores. Thus, a colloidal solution is filtered in the bag (figure a) which is tied on the mouth and suspended in the liquid (the dispersion medium). Slow diffusion of molecules/ions from colloidal solution to the outer medium purifies the sol.





Figure: (b)

In case of ionic nature of impurities, dialysis can be speeded up by taking an advantage of electricity and the process is known as electrodialysis (figure b).

17. Properties of Colloids

Due to their small size, these colloidal solutions remain stable over a long period of time as they do not settle down under earth's gravity (sedimentation rate is very slow). At the same time most lyophobic colloids are stable due to the surface charge or a layer of a protective material on to the surface of colloidal particles. This surface modification does not allow the isolated particles to come close to each other, colloid and form bigger particles. However, as the systems are associated with large surface area and consequently large surface free energy, these systems have to break one day. Thus, lyophobic colloids are thermodynamically unstable systems.

Large surface area provides a tremendous adsorption capacity to the colloidal particles. This property is utilized, for example, to remove poisonous gases by use of colloidal charcoal in gas masks and removal of effluents like dyes etc. from waste water. Following are some characteristic properties of colloidal solutions.

1. **Physical Properties**

- Heterogeneity: Sols are heterogeneous in nature. (a)
- Diffusibility: Sol particles have slow rate of diffusion through parchment (b) membrane.
- Filtrability: sol particles can pass through ordinary filter papers. (c)
- (d) Non settling nature: Sol particles do not settle down due to gravity.
- Viscosity and surface tension: Viscosity and surface tensions of sols are (e) almost similar to those of pure solvent in case of lyophobic colloids. In lyophilic colloidal solutions, viscosity is higher than the solvent and surface tension being lower than the solvent used as dispersed medium for sols.

Visibility and Size of the Particles (f)

- (i) It is not possible even by the help of a most powerful microscope to see colloidal particles because clear image formation of a particle smaller in size than the wavelength of light used is not possible. However, zones, of scattered light can be seen by a microscope and some times with naked eye also.
- The upper limit of colloidal particle size has been obtained as the lower (ii) limit of microscopic visibility. It is not possible to see any particle whose diameter is less than half of the wavelength of visible light, i.e., $(1/2) \times$ 4000Å i.e. 2000Å since sol particles are invisible even under microscope and thus their upper limit is 2000Å or 2×10^{-5} cm or 0.2 μ or 200m μ . The lower limit has been taken to be 10Å since particles lesser in size than10Å are assumed to be true solution particles. Thus size of sol particles likes in between 10Å to 2000Å.

- (g) **Surface area and adsorption:** The surface area of the particles in colloidal state is appreciably larger than compared with an equal mass of the matter in coarse grained size. It is due to the larger surface area, sol particles shown high tendency for adsorption. The property has got application in medicinal chemistry where drugs are sold in from of sols.
- 2. **Colligative Properties:** Like true solutions, colloidal solutions also exhibit colligative properties such as osmotic pressure, elevation in boiling point, depression in freezing point, lowering in vapour pressure. Since colligative properties of a solution depends upon the number of particles present in solution as well as on their weight. Since in colloidal state, there exists aggregates of thousands of molecules of high molecular weight and thus number of particles being relatively lower than true solutions and therefore the colligative properties are lesser than those observed for true solutions containing the same amount.
- 3. **Optical Properties: Tyndal effect:** All colloidal solutions are capable of scattering light or iopalescence.

When a beam of converging rays falls in colloidal solution, scattering of light by sol particles in all the directions, gives rise to a bright glowing cone when looked at it sideways. This is known as Tyndall effect.



Figure: Light scattering by colloid dispersions (Tyndal effect)

The solu particles absorb light, become self luminous and then scatter light in all possible directions.

The scattering of light depends upon the

- (i) **Wavelength of light used:** Scattering $\propto (1/\lambda^4)$; That is why scattering of blue light is maximum.
- (ii) **Size of particles:** Larger size is dispersed phase particles show more scattering. That is why lyophobic sols shown more scattering.
- (iii) Difference in refractive indices of dispersed phase and dispersion medium, (i.e. $\Delta(\mu_p \sim \mu_m)$: Larger is $\Delta\mu$, more is scattering.

Some examples of Tyndal effect are:

- (i) Blue colour of sky and sea water.
- (ii) Visibility of tails of comets.
- (iii) Twinkling to stars.
- (iv) Visibility of sharp ray of sunlight entering through a slit in dark room.
- (v) Visibility of projector path and circus light.

True solutions do not show Tyndall effect because the size of molecules or ions here is too small to cause scattering.

4. **Mechanial Properties: Brownian motion:** English Botanish Robert Brown noticed the *irregular or chaotic motion* of (pollen grains) *particles suspended in water*. This was later on named as Brownian motion. Later on Zsigmondy, after the discovery of ultrmicroscope (based on Tyndal effect) noticed the similar irregular motion

of the images of sol particles (figure) and concluded that colloidal particles move much more vigorously than small microscope particles



Figure: Brownian movement the zig-sag motion of a colloidal particle.

Following are the important characteristic conclusion regarding Brownian motion of particles.

- (i) Brownian motion is observed upto a particle size of 0.5 microns.
- (ii) The smaller the particle, the more rapid is the movement.
- (iii) The movement is independent of λ of light used and time of illumination.
- (iv) The movement does not change with time and exist till last.
- (v) The movement depends upon temperature; the intensively of the movement increases with increasing temperature.
- (vi) The movement is due to the bombardment of solvent of the movement increases with increasing temperature.

Applications of Brownian motion are

- (i) It offers an explanation for the stability of colloidal solutions.
- (ii) It offers an experimental set up to determine Avogadro's number.
- (iii) It offers an explanation for kinetic theory of matter.
- 5. **Electrical Properties: Electrophoresis:** Colloidal particles move towards the oppositely charged electrode when an external electrical field is applied. This phenomenon is called electrophoriesis. A set up demonstrating electrophoresis consists of U-tube filled with colloidal solution and attached with electrodes as shown in figure. On applying direct current (dc), colloidal particles move and coagulate.





Charge on sol particles is a fundamental factor for their existence. Generally dispersed particles with less charge coagulate. It is the charge on sol particles which keeps them apart and prevent them from coming closer to each other to coagulate. The charge may be +ve or -ve. For example, Metal hydroxide sols are -ve sol, smoke is -vely charged.

18. The stability and instability of colloids and coagulation

The stability of a colloidal dispersion means it to remain in unaltered condition over a certain period of lime. The instability means the breaking down of a colloidal dispersion into two phases.

- (i) Spontaneous breaking up of a colloidal solution, i.e., the separation of dispersed phase from dispersion medium or destabilization of sol is known as ageing.
- (ii) Destabilization of sols may also be made by artificial means and the phenomenon is known as coagulation.

The stability of a colloidal dispersion is usually achieved by using finer particles, inducing charge on the particles or by using the dispersion of high viscosity. Stable lyophobic dispersions can also be made by the coating of some polymers like starch, gelatin, gum etc. (These substances are called protective colloids and their efficiency to stabilize a lyophobic dispersion is measured in terms of gold number).

Conversely, the instability or the coagulation of sol can be achieved by adding a substance (called coagulant) which will remove the protective layer or will neutralize the charge from the surface of colloidal particles.

Following are some general methods used for coagulation of sols.

(a) General methods:

- 1. By heating: Coagulation of butter
- 2. By cooling: Coagulation of milk, fat floats over
- 3. By exposure to light 4. By mechanical agitation
- 5. By persistent dialysis
- (b) **Cataphoresis:** Sol particles during migration under cataphoresis towards opposite electrodes get adhered and lose their charge.
- (c) **Mutual coagulation:** A deep red +ve sol of Fe(OH), on mixing with bright yellow -ve sol of As_2S_3 shows mutual coagulation of both leading to a colouress solution with precipitate settled down due to neutrlalization of charges by each other. The coagulation of sols by electrolytes has been dealt in terms of Hardy-Schulze rule.

According to this rule:

- 1. One of the ions furnished by an electrolyte, carrying charge opposite to that of sol particles is responsible for coagulation of sols and is known as effective ion or counter ion.
- 2. The greater is the valency of the counter-ions, the greater will be its coagulating power. For example, in coagulating, a negatively charged sol (e.g., As_2S_3 sol) the order of efficiency of coagulating ions will be $Th^{4+} > Fe^{3+} > Ca^{2+} > Na^+$. Similarly, for a positively charged sol say Fe(OH)₃ sol, the order will be $[Fe(CN)_6]^{4-} > [Fe(CN)_6]^{3-} > SO_4^{2-} > Cl^-$.
- 3. More is the coagulating power, lesser is coagulation or flocculation value (i.e., the minimum amount of electrolyte required to coagulate a definite amount of (sol).

Usually, the flocculating value of these ions are quantitatively described as $\frac{1}{(z)^6}$ where x is the valency of the coagulating ion. For example, for mono-, di-, tri- and tetra-valent ions, the ratio in the flocculation value will be

$$\frac{1}{(1)^6} : \frac{1}{(2)^6} : \frac{1}{(3)^6} : \frac{1}{(4)^6} \quad \text{or} \quad 100 : 1.56 : 0.137 : 0.025$$

Thus if 100g of a monovalent ion is required to coagulate a sol, only 0.025g of a tetravalent ion will be necessary. Most natural colloids e.g. blood, milk, aerosol etc., bear negative charge and to our common experience alum (Al^{3+}) is used to remove the suspended impurities to clarify was or to stop bleeding by clotting (or coagulating) blood.

For	negatively charg	ed sols	For positively charged sols			
Electrolyte	Positive ion	Coagulation value	Electrolyte	Negative ion	Coagulation value	
FeCl ₃	Fe ³⁺	0.136	KCl	Cl ⁻	103	
CaCl ₂	Ca^{2+}	0.649	KNO3	NO_3^-	131	
BaCl ₂	Ba^{2+}	0.691	K_2SO_4	SO_4^-	0.22	
KC1	\mathbf{K}^+	49.5	K ₂ CrO ₄	$\operatorname{CrO}_4^{2-}$	0.33	
NaCl	Na ⁺	51.0	$K_4[Fe(CN)_6]$	[Fe(CN)6]4-	0.06	

Coagulation values of cations and anions are reported in table.

Addition of electrolyte to sol particles, neutralizes their charge and thus electrokinetic potential approaches to zero. At this point sol particles do not carry charge and are either coagulated or just to coagulate; however, they become inert towards cataphoresis. This condition is known as isoelectric point, i.e., the $H^{=}$ ion concentration at which the colloidal particles do not carry charge and process minimum stability.

- Following are some applications of coagulation:
- (a) Coagulation of latex (sol) gives rubber.
- (b) Removal of carbon from smoke (-ve of carbon in air) is down on the basis of charge neutralization using Cottrell's precipitators.
- (c) Sewage water disposal is done by using coagulation technique. Dirt, dust particles suspended in water are coagulated by adding salts or polymers.
- (d) Alum (a very good coagulating agent) is used to purify impure water having clay particles suspended in it.
- (e) River water contaminated with various sol particles in it, on meeting with ocean shows their coagulation by salts present sea water and forms delta.

19. Protection of Colloids

- (i) Lyophobic sols are less stable than lyophilic sols. However, their stability may be increased on addition of lyophilic sols. This phenomenon of stabilizing lyophobic sols by the addition of lyophilic colloids is known as protection. The lyophilic colloids used for this purpose are known as protective colloids.
- (ii) The protective colloids form a thin layer around the dispersed phase of lyophobic colloids and thus prevent them from coming close to each other and stabilize them.
- (iii) The protective character of various lyophilic substances is expressed in terms of gold number.
- (iv) Gold number of lyophilic is defined as the minimum amount of lyophilic colloid in milligrams which prevents the coagulation of 10 ml gold sol by 1 ml of 10% NaCl solution.
- (v) More is the gold number, lesser is the protective power of lyophilic colloid.

Substance	Gold Number
Gelatin	0.005 - 0.01
Haemoglobin	0.03 - 0.07
Gum Arabic	0.15 - 0.25
Sodium oleate	0.04 - 1
Starch	15 - 25

- (vi) Gelatin, protein, gums and other macromolecules etc. are popoular protective agents.
- (vii) A hydrophilic substance does not protect all hydrophobic colloids and protecting power varies for different lyophobic sols. Therefore, another term Congo robin number was

introduced to express protective power of lyophilics. Congo robin number is defined as the amount of protective colloid in milligrams which prevents colour change in 100 ml of 0.01% Congo robin dye solution to which 0.16 equivalent of KCL are added.

- viii) It has been found that protective action of hydrophilics is altogether different for gold and Congo robin sols.
 Lyophilic colloids on the other hand are stable dispersions. In principle, these would not coagulate but the dispersed phase can be precipitated from the dispersion medium by the addition of large quantities of salts ('salting out' action of electrolytes) or by adding a liquid which is miscible with water (dispersion medium). Both these methods work by decreasing the interaction of dispersed phase with dispersion medium.
- (i) Addition of electrolyte: Salting out effect: When a large amount of an electrolyte is added to a lyophilic sol, coagulation takes place. The excess electrolyte removes solvent layers because of salvation of the added electrolyte and thus makes available less solvent for salvation of colloidal particles. This leads to unstability and ultimate coagulation of particles.
- (ii) **Addition of a liquid in which solvent is solute:** When alcohol or acetone is added to an aqueous hydrophilic sol, water being miscible with alcohol results in the removal of solvent layers and hence precipitation of sol.

20. Emulsions

Emulsions are colloidal dispersion of one liquid into another liquid (the two liquids should beimmiscible). Normally one of the two liquids is water.

Emulsions are broadly classified into two types:

- i) Oil-in water (or o/W)
- ii) Water-in-oil (or w/o)

An oil-in-water emulsion consists of droplets of oil dispersed in water. In a water-inoil emulsions water is present as dispersed phase with oil as the dispersion (or continuous) medium. Which type of emulsion will form on mixing oil and water along with an emulsifying agent will depend on the composition of the oil and water (usually the liquid with higher percentage becomes dispersion medium), nature of emulsifying agent (usually water soluble substance stabilize o/w emulsion whereas oil soluble substance favours the formation of w/o emulsions). The two types of emulsions are shown in figure. Also a comparison of o/w and w/o emulsion is shown in table.



Figure: Use of emulsions e.g. soap and detergent form emulsions

Preparation of Emulsions: The process of making in emulsion is known as emulsification. Emulsions are obtained by vigorously mixing both the immiscible liquids. However, this gives an unstable emulsion. The dispersed drops at once come together and form separate layers. To stabilizes an emulsion, the addition of a small quantity of a third substance known as emulsifying agent or emulsifier is essential. Soaps and detergents and polymers are most frequently used as emulsifiers. They coat the dispersed droplets of an emulsion and check them from coming together.

Characteristics	Water-in-oil emulsion	Oil-in-water emulsion
Dispersed phase	Water	Oil
Dispersion medium	Oil	Water
Appearance	Oily, opaque and translucent (permits light to pass through but diffusing it so that objects on the other side are not clearly visible.	Watery, opaque and translucent.
Electrical conductivity	Very low	Appreciable
Viscosity	More than water	Little more than water.
Dilution test	More oil added is soluble but not water.	More water added is soluble but no oil.
Spreading test	Spreads easily on oil surface	Spreads easily on water surface.
Dye-test with oil soluble dye e.g., methylene blue. Examples	Dye is soluble giving a bright colour. Butter, cold creams, benzene water, aniline-water etc.	Dye is practically insoluble, coloured droplets are seen. Milk, cream, face creams.

Comparison of the properties of two types of emulsions

Emulsions are prepared by vigorous shaking of the relevant liquids or by subjecting a coarse mixture to ultrasonic vibrations. Emulsions, like other colloidal systems are unstable and are stabilized by the addition of a third component known as emulsifying agent or emulgents or emulsifiers. In the absence of an emulsifying agent, the dispersed droplets coalesce together and the two liquids are separated into separate layers. Commonly used emulsifiers a surfactants, polymers and metal oxides and hydroxides in finely divided states. The function of an emulsifying agent is simply to absorb onto the oil-water interface and impart stability.

21. Identification of Emulsion Type

Two common and routinely used methods for quickly identifying the emulsion type are:

- (i) Dilution test: An oil-in-water emulsion (where water is continuous phase) can be diluted by water. On adding water to water-in-oil emulsion, will form a separate layer. For example, milk which is an oil-in-water emulsion can be diluted by water but butter which is water-in-oil emulsion cannot be diluted by water.
- (ii) **Dye test:** A water soluble dye will give uniform coloured background when added to oil-in-water emulsion. Similarly, an oil soluble in dye will give colour background on adding to water-in-oil emulsion.

Emulsions exhibit all those properties as shown by lyophobic sols. These are also thermodynamically unstable and can be coagulated by adding electrolytes. The only difference in the properties of sols and emulsions can be of the particle size. Emulsions are usually in the larger limit of colloidal range $(10^{-5} - 10^{-7} \text{ cm})$ and are often of the size of the order of a micro (=10⁻⁴ cm). The large size of emulsion droplets make emulsions opaque or translucent.

Emulsions have found wide applications in day to day life in cosmetics (e.g., creams, hand lotions, cleansing milk are all emulsions), pharmaceuticals (e.g., ointments),

agricultural, textile surface by soaps and detergents principally involves emulsification. Digestion of fats in the intestine is aided by bile salts which act as emulsifying agent to form fat in water emulsions.

Emulsions are not always desirable. Sometimes unwanted stable emulsions are formed by nature that need to be broken, the breaking of an emulsion is called demulsification. For example, the crude petroleum obtained by digging wells in oil fields is always associated with some water which is in the form of water-in-oil emulsion. The crude oil is to be freed from water before sending it to the refineries for fractionation. Here demulsification plays an important role. An emulsion can be demulsified by physical methods like freezing, boiling or centrifugation. For example, centrifugation provides milk cream and remaining skimmed milk contains very little amount of fat. The chemical methods involve the use of substance (demulsifiers) which destroy the emulsifying agent from the oil-water interface which is responsible for the stability. Demulsification means the breaking of an emulsion into aqueous and nonaqueous phases.

22. Association Colloids

These colloids are better known as surface active agents (or surfactants). They do show surface activity, i.e., the property to lower the surface tension of liquids or the tendency to increase surface area.

A surface active substance has in its molecule distinct hydrophobic and hydrophilic part. When dissolved in water, their aqueous solution contains isolated molecules or ions (if the surface active agent is an electrolyte like a soap which is RCOO⁻ Na⁺) upto a certain concentration. However, above a certain concentration these molecules or dissociated ions aggregate by themselves such that the nonpolar tails (hydrophobic part) of the surface active agent does not have any interaction with water. Such a thermodynamically favourable situation results in the formation of particles of colloidal dimensions, usually spherical in shape and are termed as Micelles (figure). Micelles are the aggregates consisting of several tens or few hundreds of molecules or ions of a surface active substance when it is dissolved in a solvent usually water. The soap concentration at which the micelles first appear is called is called the critical micellar concentration (CMC) and the number of molecules that constitute one micelle is called aggregation number.



Figure: The miscelles

The formation of micelles is a result of the hydrophobic interaction which allows the aggregation of nonpolar (hydrophobic) tails of the surfactant. In this way the polar head groups only remain in contact with water.

For example, a soap sodium laurate ($C_{11}H_{23}COO^-Na^+$) or detergents, like sodium lauryl sulphate ($C_{12}H_{25}SO_4^-Na^+$) or sodium salt of linear alkyl benzene sulphonate (LABS) will dissolve in water and will form ions, say laurate ion and sodium ion from sodium laurate. Above about 100 mM sodium laurate concentration, the micelles with an aggregation number of about 100 will form. These spherical aggregates formed from several laurate

ions are of colloidal size and will provide the soap solutions all the properties of colloids like light scattering, electrophoresis, viscosity etc.

Micelles have the core usually made of a non-polar portion of the soap. Thus these are capable of solubilizing substances otherwise insoluble in water. For example, fat soluble vitamins like A,E, E, K and stored drugs can be made soluble in aqueous solutions of micelles.

23. Applications of Colloids

Colloidal dispersions play a very significant role is natural processes in our daily life and in industries. Some of the important applications of colloids are in:

- ✤ Food: Most of our food preparations are colloidal in nature. Milk, butter and cream are example of emulsions, Jam, jellies, ice-creams, salad dressing, bread etc., are all examples of food colloids.
- Medicines: Most drugs (insoluble in water) are administered as colloidal dispersions namely suspensions, emulsions. In the colloidal form the drug is easily absorbed by body tissues and is therefore more effective. Most skin ointments are emulsions.
- Detergency: Soaps and detergents by themselves are lyophilic colloids and therefore the entire detergent industry involves colloids.
- ✤ Water treatment: Suspended/colloidal particles of undesirable muddy mass need be removed before making it fir for drinking. The water cleansing process involves the coagulation of the suspended material by alum or high mol mass polyelectrolytes in water treatment plants.
- Precipitation of Smokes: Cottrell smoke precipitater is a device installed in the chimney of an industrial plant emitting gaseous waste as colloidal system (serosols) with unburnt solid particles as dispersed phase. The precipitator has (Figure) two metal discs charged to a very high potential. Such a device neutralizes the charged suspended unburnt solid matter which precipitates down to the bottom of the chimney which then emits out only gaseous mixture.



Figure: The Cottrell smoke precipitator

Formation of the Delta: as the mouth of the river is an example of coagulation. Rivers carrying muddy water as suspension when come near sea, the high salinity (salt content) of the sea cause suspension to coagulate forming delta. Artificial rain can be made by coagulating the water containing clouds in the sky.

One can endlessly quote the application where the stability or instability of colloidal dispersions is desired.

Rubber Plating: The negatively charged rubber particles from the latex are deposited on wares and handles of different tools. Ruber gloves are formed by rubber plating on suitable templates.

- In nontechnology: nanosized materials are prepared for use as catalyst by using reverse micelles.
- In metallurgy: The metal sulphide ores are concentrated by froth-floatation process which involves the treatment of the pulverized ore in emulsion of pine oil.
- In road construction: Asphalt in water emulsion is used for building roads without the necessity of melting the asphat.

Daily Practice Problems - 01

- 1. Physical adsorption is appreciable at
 - (A) Higher temperature
 - (C) At room temperature
- 2. The rate of chemisorption
 - (A) Decreases with increase of pressure
 - (B) is independent of pressure
 - (C) is maximum at one atmospheric pressure
 - (D) increases with increase of pressur
- 3. Sorption is the term used when
 - (A) adsorption takes place (B) absorption takes place
 - (C) both takes place (D) desorption takes place
- 4. Which of the following is not a characteristic of chemisorption?
 - (A) Adsorption is irreversible
 - (B) ΔH is of the order of 400 KJ
 - (C) Adsorption is specific
 - (D) Adsorption increases with increase of surface area
- 5. Which is not correct regarding the adsorption of a gas on surface of solid?
 - (A) On increasing temperature adsorption increases continuously
 - (B) Enthalpy and entropy change is negative
 - (C) Adsorption is more for some specific substance
 - (D) Reversible

6. Which one of the following characteristics is not correct for physical adsorption?

- (A) Adsorption on solid is reversible
- (B) Adsorption increase with increase in temperature
- (C) Absorption is spontaneous
- (D) Both enthalpy and entropy of adsorption are negative
- 7. The heats of adsorption in physisorption lie in the range (KJ/mol)
 - (A) 40 400 (B) 40 100 (C) 20 40 (D) 1 10
- 8. In physical adsorption, the forces associated are
 - (A) Ionic (B) Covalent (C) Vander Waals (D) H-bonding
- 9. How many Layers are adsorbed in chemical adsorption?
 - (A) 1 (B) 2 (C) 3 (D) 4
- 10. The amount of gas adsorbed on charcoal increases with
 - (A) Temperature and pressure
 - (B) Temperature and decreases with pressure
 - (C) Pressure and decreases with temperature
 - (D) None

- (B) Lower temperature
- (D) 100°C



2. Zeolites

1.

- (A) Are microporous aluminosilicates
- **(B)** Have general formula $Mx/n [(AlO_2)(SiO_2)_4].mH_2O$
- (C) Have pore sizes between 260 pm to 740 pm
- (D) All
- 3. Which characteristic of adsorption is wrong?
 - Physical adsorption in general decreases with temperature (A)
 - **(B)** Physical adsorption in general increases with temperature
 - (C) Physical adsorption is a reversible process
 - (D) Adsorption is limited mainly to the surface only
- The volumes of gases H₂, CH₄, CO₂ and NH₃ adsorbed by 1 g of charcoal at 288K 4. are in the order
 - $\begin{array}{ll} (B) & CH_4 > CO_2 > NH_3 > H_2 \\ (D) & NH_3 > CO_2 > CH_4 > H_2 \end{array}$ (A) $H_2 > CH_4 > CO_2 > NH_3$
 - $\tilde{CO}_{2} > NH_{2} > H_{2} > CH_{4}$ (C)

5. The slope of the straight line graph between log x/m and log P for the adsorption of a gas on solid is

(B) (C) (D) (A) k log k 1/n n

6. According to Langmuir adsorption isotherm, the amount of gas adsorbed at very high pressure

- Reaches a constant limiting value (A)
- **(B)** Goes on increasing with pressure
- (C) Goes on decreasing with pressure
- (D) increases first and decreases later with pressure
- 7. Which among the following statement is false?
 - increase of pressure increase the amount of adsorption (A)
 - (B) increase of temperature may decrease the amount of adsorption
 - (C) the adsorption may be monolayered or multilayered
 - Particle size of the adsorbent will not affect the amount of adsorption (D)
- 8. Graph between $\log(x/m)$ and $\log P$ is a straight line at an angle 45° with intercept on y-axis, 0.3010. Calculate amount of the gas absorbed in gram per gram of the adsorbent when pressure is 0.2 atm. 0.2 (D)

(A) 0.4 **(B)** 0.6 (C) 0.8

Daily Practice Problems - 03

- 1. Butter is a colloid formed when
 - Fat is dispersed in fat (A)
 - Water is dispersed in fat (C)
- 2. Lyophobic colloids are

- **(B)** Fat is dispersed in water
- (D) Suspension of casein in water
- (A) Reversible **(B)** Irreversible
- (D) Water loving Solvent loving (C)

3.	Sulphu	ur sol contains									
	(A)	Discrete sulphur atoms (Discre	te sulphi	ır molec	cules	
	(C)	Water disperse	d in soli	d sulphi	ır	(D)	Large	aggregat	es of su	lphur m	olecules
4.	When	freshly precipitat	ted Fe(C)H), is t	poiled wi	th water	in the	presence	e of few	drops o	f dil. HCl,
	a hydr	ated ferric oxide	sol is o	btained.	The met	thod is t	ermed a	as			
	(A)	Electro dispers	sion	(B)	Peptiza	tion	(C)	Ultra f	iltration	(D) Di	alysis
5.	Greate	r the valency, the	e higher	is the co	cagulating	g power	of ion.	This rul	e was in	ntroduced	l by
	(A)	Hardy-Schulze	e	(B)	Grahar	n	(C) K	ossel and	d Lewis	(D) Fa	araday
6.	All co	lloidal solution sł	IOW								
	(A)	Very high osm	otic pres	ssure		(B)	High	osmotic	pressure		
	(C)	Low osmotic	pressure			(D)	No os	motic p	ressure		
7.	An ex	amples of micelle	e is								
	(A)	As_2O_3 solution	l			(B)	Ruby	glass		_	
0	(C)	Na_2CO_3 soluti	on			(D)	Sodiu	m steara	te conce	entrated a	solution
8.	Which	is not shown by	/ sols?	T 11	1		D				1.
0	(A)	Adsorption	.(B)	Tyndal	l effect	(C)	Param	agnetism	1	(D) Fl	occulation
9.	Which	of the following	is an er	nulsifier?		(\mathbf{C})	01				C1
10	(A) Missil	Soap	(B)	water		(C)	Oil			(D) Na	aCI
10.		es are	taa			(D)		atad aall	aida		
	(\mathbf{A})	adsorbed surf				(D) Id	associ	tion	olus		
11	(C) Substa	nces whose solu	tions car	n readily	diffuse	(D) Ith	animal	membra	nes are	called	
11.	(A)	Colloids	(B)	Crysta	lloids	(C)	Electr	olvtes	(D)	Non-e	lectrolytes
12	The si	ze of the colloid:	al particle	res is in 1	hetween	(0)	Licen	orytes	(D)		leettorytes
121	(A)	$10^{-7} - 10^{-9}$ cm				(B)	10-9 -	- 10 ⁻¹¹ ct	n.		
	(C)	$10^{-5} - 10^{-7}$ cm	1			(D)	10-2 -	10 ⁻³ cm	1		
13.	Peptiz	ation is a process	s of								
	(A)	Precipitating th	ne colloi	dal parti	cles						
	(B)	Purifying the c	olloidal s	sol							
	(C)	Dispersing the	precipita	te in to	colloidal	l sol					
	(D)	Movement of	colloida	l particle	es toward	ds the o	pposite	charged	electroc	les	
14.	Colloi	ds are purified by	У								
	(A)	Brownian moti	ion	(B)	Precipi	tation	(C)	Dialysi	S	(D)	Filtration
15.	When	excess of electro	olyte is a	idded to	a colloio	d it?					
	(A)	Coagulates				(B)	Gets of	liluted			
	(C)	Dissolved				(D) Do	pes not	change			

Daily Practice Problems - 04

- 1. Bleeding is stopped by application of ferric chloride. This is because
 - (A) the blood starts flowing in opposite direction
 - (B) the ferric chloride seats the blood vessel
 - (C) the blood reacts and forms a solid which seals the blood vessel
 - (D) the blood is coagulated and thus, the blood vessel is sealed
- 2. Gold number is a measure of
 - (A) the amount of gold present in the colloidal solution
 - (B) the amount of gold required to break the colloid
 - (C) the amount of gold required to protect the colloid
 - (D) the protective power of the lyophilic colloid

3.	On ad	dition of one n	nl soluti	on of 10% NaC	Cl to 10	ml. gold sol ir	n presen	ice of 0.0025 g of	
	starch,	the coagulation	is just p	revented. The g	old num	ber of starch is			
	(A)	25	(B)	2.5	(C)	0.25	(D)	0.025	
4.	Which	of the following	; has mir	nimum flocculatio	on value	?			
	(A)	Pb^{2+}	(B)	Pb^{4+}	(C)	Sr^{2^+}	(D)	Na ⁺	
5.	The cl	harge of As_2S_3 so	ol is due	e to the absorbed	1				
	(A)	H^{+}	(B)	OH⁻	(C)	O^{2-}	(D)	\mathbf{S}^{2-}	
6.	To coa	igulate gelatin so	l, which	of the following	; is most	effective?			
	(A)	NaCl	(B)	Na ₃ PO ₄	(C)	AlCl ₃	(D)	Alcohol	
7.	Brown	ian motion shov	vn by co	olloidal particle i	s its	property.			
	(A)	Optical	(B)	Electrical	(C)	Kinetic	(D)	Chemical	
8.	A coll	oidal solution of	Fe(OH)	, in water is					
	(A)	A hydrophilic	colloid		(B) A	hydrophobic col	loid		
	(C)	An emulsion			(D)	A solid sol			
9.	A fres colloid	hly prepared Fe al particle is due	(OH) ₃ p e to pref	recipitate is pept ferential absorption	tized by on of	adding FeCl ₃ so	olution.	The charge on the	
	(A)	Cl⁻ ions	(B)	Fe ⁺⁺⁺ ions	(C)	OH⁻ ions	(D)	None	
10.	Hardy	-schulze rule sta	te that						
	(A)	Non-electrolyte	es have	better coagulatin	g action	on colloids that	n electro	olytes	
	(B)	Sols are coagu	lated by	effective ions w	whose ch	arge is opposite	to that	of sol and the ions	
	of high	higher charge are much more effective than the ions of lower charge.							
	(C)	Charge of the ions has no effect on the coagulation of a sol							
11	(D) T. ·)) Sols are coagulated only by those ions whose charges is similar to that of the sol							
11.	Tannin	g of leather is	.4 1	.1					
	(A) (D)	Coloring of lea	ather by	chemicais					
	(D)	Drying process	s lo mak	e une leauner na	iu motivo				
	(\mathbf{C})	Coognitative he	amer 10	of the leather by	ractive				
12	(D) Which	is correct states	noening	of the leather by		वि			
12.	(Λ)	Milk is an emi	ulsion of	fat in water	(\mathbf{B})	Mille in emulsi	on of pr	otein in water	
	(Γ)	Milk is stabiliz	red by m	rotein	(D)	Milk is stabilise	ed by fa	t	
13	(C) The c	agulating nowe	r of an	effective ion ca	rrving tl	ne charge oppos	ite to th	ne sol particles has	
15.	been i	llustrated by		checuve ion ca	irying u	ie enarge oppos		le soi particles has	
	(A)	Brownian mov	vement		(B)	Gold no			
	(C)	Tyndall effect			(D)	Schulze hardy	rule		
14.	Deterg	ent action of syn	nthetic d	etergents is due					
	(A)	Interfacial area	l		(B)	High molecula	weight		
	(C)	Ionisation			(D)	Emulsifying pr	operties		
15.	Which	of the following	g is mos	t effective in cau	sing the	coagulation of fe	erric hyd	roxide sol?	
	(A)	KCl	(B)	KNO ₃	(C)	K ₂ SO ₄	(D)K ₃	Fe(CN) ₆	

L

Solved Example Subjective

- **Problem 1.** Gelatin is generally added to ice creams.
- **Solution:** Ice cream is an emulsion of milk or cream in water (oil in water). Gelatin is added in the preparation of ice cream to act as emulsifier i.e., it helps in the formation of a stable emulsion.
- **Problem 2:** The addition of ferric hydroxide solution to arseneous sulphide solution results in the precipitation of both.
- **Solution:** This is possible only in case equimolar solutions (solutions with same number of moles) are mixed. Since the ferric hydroxide sol carries positive charge and arsenic oxide sol is negatively charged on mixing they will get their charge neutralized and will be coagulated.
- **Problem 3:** Lyophilic solar are called reversible colloids.
- **Solution:** Lyophilic sols are generally known as reversible colloids. In fact, if th dispersed phase is removed completely the colloidsl solution can be formed again by mixing the dispersed phase (residue) left in a fresh sample of dispersion medium. for example, if a colloidal sol of starch in water is dried completely, it can be reformed by mixing the residue with fresh water.
- **Problem 4:** Artificial rain can be caused by spraying charged dust particles over colloids.
- **Solution:** Clouds represent the colloidal solutions of water drops in air (liquid in gas type). These drops are expected to carry some charge (positive or negative). In order to neutralize the charge on these, charged dust particles carrying opposite charge are sprayed over a certain layer of cloud. These will neutralize the charge on water droplets resulting in their coagulation. The bigger water drops can no longer be retained by the atmosphere and will result in the artificial rain.
- **Problem 5:** Ferric hydroxide sol is more readily coagulated by Na_3PO_4 in c o m p a r i s o n to KCl.
- **Solution:** Ferric hydroxide sol is positively charged and to cause its coagulation, ions carrying negative charge are needed. Since PO_4^{3-} ions have higher negative charge than Cl⁻ ions therefore, Na₃PO₄ coagulates the ferric hydroxide sol most efficiently.
- **Problem 6:** Delta is generally formed when river meets the ocean.
- **Solution:** River water is generally muddy and carries along with colloidal dust particles which are charged in nature. Sea water contains a large number of electrolytes. When the river comes in contact with the sea water, the colloidal particles get their charge neutralized by the oppositely charged ions present in sea water and are coagulated. This ultimately results a hard solid mass known as delta.
- **Problem 7:** The layer of fat in the pans used for preparing soaps can be removed by adding boiling washing soda solution. How will you account for it?

Solution: Washing soda (Na₂CO₃) gets hydrolysed to form NaOH as follows:

 $Na_2CO_3 + H_2O \xrightarrow{(boil)} 2NaOH + H_2O + CO_2$

NaOH reacts with fat which is a triglyceride to form soap and glycerol by saponification reaction. The soap thus formed helps in cleaning the pan.

Problem 8: SnO₂ forms a positively charged colloidal sol in the acidic medium and negatively charged sol in the basic medium. Explain.

Solution: SnO_2 is of amphoteric in nature which means that it can react with both acis and bases. With an acid such as HCl, if forms $SnCl_4$. The Sn^{4+} ions are adsorbed on the surface of SnO_2 to give a positively charged colloidal sol.

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

$$SnO_2 + Sn^{4+} \longrightarrow [SnO_2]Sn^{4+}$$

Positively charged

Similarly with base like NaOH, if forms sodium stannate (Na_2SnO_3) . The stannate ions get adsorbed on the surface of SnO_2 to give negatively charged colloidal sol.

 $SnO_2 + 2NaOH \longrightarrow Na_2SnO_3$

$$SnO_2 + SnO_3^{2-} \longrightarrow [SnO_2]SnO_3^{2-}$$

negatively charged

Problem 9: In fine weather, we normally see red colour of setting sun. Can you co-relate this with the colloids?

- **Solution:** We all know that dust particles are present in the atmosphere. When light emitted by the setting sun passes through the blanket of dust, the blue part of the light is scattered away from our eyes and at the same time the red colour is seen. Thus, the setting sun has red colour.
- **Problem 10:** Which out of the following solutions having the same concentration will be most effective in causing the coagulation of the arsenic sulphide sol which is yellowing colour: KCl, MgCl, AlCl, or Na₂PO₄?
- **Solution:** Arsenic sulphide (As_2S_3) sol has a negative charge on it. To cause it coagulation or precipitation the active ions must be positively charged. According to hardy-Schulze rule, greater the magnitude of the positive charge on the ion more will be its coagulating power. Thus, AlCl₃ containing Al³⁺ ions will be the most effective in causing the coagulation of the sol.
- **Problem 11:** The coagulation values of the electrolytes $AlCl_3$ and NaCl for As_2S_3 sol are 0.093 and 52 respectively. How many times $AlCl_3$ has greater coagulating power than NaCl?
- **Solution:** It may be noted that the coagulating powers of the electrolytes are inversely proportional to their coagulating values. Thus,

 $\frac{\text{Coagulatign power of AlCl}_3}{\text{Coagulating power of NaCl}} = \frac{52}{0.093} = 559$

Thus, coagulating power of AlCl₃ is 559 times more than that of NaCl.

Problem 12: Draw a flow diagram for the separation and recovery in almost quantitative yield of a mixture of the water – insoluble compounds PhCHO, PhNMe, PhCl, p-MeC, H₂OH and PhCOOH.



Problem 13: A mixture of p-amino benzoic acid and p-hydroxy benzoic acid is taken in diethyl ether. How will you separate them (in not more than three steps)? Write the reagents and all the required conditions to separate them. Given confirmatory test for the presence of each functional group.



Separate the two layers using separating funnel.

Step 2: Basification of aqueous layer with NaOH.

Test for -NH_2 group: When compound containing $-NH_2$ group is heated with CHCl₃ and KOH, a very pungent smell of isocyanide is obtained.

 $RNH_2 + CHCl_3 + 3KOH \longrightarrow RNC + 3KClk + 3H_2O$

Test for –COOH group: The compound containing –COOH group gives brisk effervescence on treatment with NaHCO₃ solution due to evolution of CO_2 .

Test for –OH group: A blue or green coloration obtained when the compound is treated with neutral FeCl₃ solution.

Solved Example Objective

Problem 1: The Brownian movement of colloidal particles is because of

- (a) Convection currents in the fluid
- (b) Unequal bombardments by the molecules of the dispersion medium on colloidal particles.
- (c) Setting of dispersed phase under gravity
- (d) Thermal gradient in the medium
- **Solution:** (a) Unequal bombardments of solvent particles on colloidal particles cause zig-zag motion.
- **Problem 2:** The process of converting precipitate into collidal solution on adding an electrolyte is called:
 - (a) Peptisation (b) Dialysis
 - (c) Electro-osmosis (d) Eelectrophoresis
- **Solution:** (a) The conversion of a fresh ppt. into colloidal state by addition of small amount of a suitable electrolyte is called peptization e.g.



i.e., ions are adsorbed on particles to give colloidal size.

- **Problem 3:** The stabilization of the dispersed phase in a lyophobic sol is due to (a) The viscosity of the medium
 - (b) The surface tension of the medium
 - (c) Liking for the medium
 - (d) The formation of an electrical layer between the two phases
- **Solution:** (d) Due to preferential adsorption of similar ions, an electrical double layer formed on the surface of colloidal particles e.g., arsenius sulphide solution.



- **Problem** 4: When FeCl₃ solution is added to NaOH a negatively charged sol is obtained. It is due to the
 - (a) Presence of basic group
 - (b) Preferential adsorption of OH⁻ ions
 - (c) Self dissociation
 - (d) Electron capture by sol particles

Solution: (b) $FeCl_2 + 3NaOH \longrightarrow Fe(OH)_3 + 3NaCl$

NaOH \longrightarrow Na⁺ + OH⁻ OH⁻ ions having similarity with Fe(OH)₃ will be adsorbed on the surface of Fe(OH)₃ to form an electrical double layer.

$$Fe(OH)_{3} \begin{vmatrix} OH^{-} \\ OH^{-} \\ OH^{-} \\ OH^{-} \end{vmatrix} \begin{vmatrix} Na^{+} \\ Na^{+} \\ Na^{+} \end{vmatrix}$$

Problem 5: 1 mol of $[AgI]I^-$ can be coagulated by

(a) 1 mol of
$$Pb(NO_3)_2$$

(b) $\frac{1}{2}$ mol of $Pb(NO_3)_2$
(c) $\frac{2}{3}$ mol of $Pb(NO_3)_2$
(d) None of these

Solution: (b)
$$Pb(NO_3)_2 + 2[Ag[I^- \longrightarrow PbI_2 \downarrow + AgI \downarrow 2[Ag]I^- \equiv Pb(NO_3)_2$$

 $\therefore [Ag]I^- \equiv \frac{1}{2}Pb(NO_3)_2$

Problem 6:For adsorption, the thermodynamic requirement is that:

(a) ΔH must be negative	(b) ΔS must be negative
(c) ΔG must be negative	(d) ΔH , ΔS and ΔG must be negative

Solution: (d) On the basis of equation, ΔG = ΔH - TΔS can be negative if ΔH has sufficiently high negative value as -TΔS is positive. Thus, in adsorption which is a spontaneous process.
ΔS is negative
ΔH is sufficiently negative and as a result ΔG is also negative

Problem 7: Graph between $\log \frac{x}{m}$ and $\log P$ is a straight line inclined at an angle θ - 45°. When pressure of 0.5 atm and log k = 0.699, the amount of solute adsorbed per g of adsorbent will be (a) 1 g/g adsorbent (b) 1.5 g/g adsorbent (c) 2.5 g/g adsorbent (d) 0.25 g/g adsorbent

Solution: (c) $\frac{x}{m} = k \cdot P^{1/n}$ since log k = 0.699, hence k = 5 hence k = 5 slope = $\frac{1}{5}$ = tan 45° = 1 thus, $\frac{x}{m} = 5 \times 0.5 = 2.5$ g/g adsorbent

- **Problem 8:** Which of the following reactions leads to the formation of a substance in colloidal state?
 - (a) $2HNO_3 + 3H_2S \longrightarrow 3S + 3H_2O + 2NO$
 - (b) $SnCl_2 + HgCl_2 \longrightarrow SnCl_4 + Hg$
 - (c) $2Mg + CO_2 \longrightarrow 2MgO + C$
 - (d) $Cu + CuCl_2 \xrightarrow{HCl} Cu_2Cl_2$
- **Solution:** (a) Due to oxidation of H₂S by HNO₃ colloidal particles of sulphur (S₈) are formed. In other cases, particles of colloidal size are not formed.
- **Problem** 9:A white precipitate of Sn(OH)₄ is peptized with dil. HCl. The sol particle will carry:
 - (a) Positive charge
 - (b) Negative charge
 - (c) Sometimes positive and sometimes negative charge
 - (d) No charge
- **Solution:** (a) $Zn(OH)_4 + 4HC1 \longrightarrow SnCl_4 + 4H_2O$ [Zn(OH)_]Sn⁴⁺ : 4Cl⁻ (Positive charge)

Problem 10: At 400K energy of activation of a reaction is decreased by 0.8 kcal in presence of catalyst. Hence rate will be

- (a) Increased by 2.71 times (b) Increased by 1.18 times
- (c) Decreased by 2.72 times (d) Increased by 6.26 times
- **Solution:** (a) K_1 (no catalyst) = $Ae^{-E_a/RT}$ K_2 (catalyst) = $Ae^{-E_a-0.8/RT}$ $\frac{K_2}{K_1} = e^{0.8/RT} = e^{0.8/0.002 \times 400}$ 2.72



The colloidal sol of As₂S₃ prefers to adsorb 1. (C) S^{2-} (A) NO_3^{-} (B) K^+ (D) H⁺ 2. Fe3+ ions coagulate blood. This shows blood contains colloidal particles bearing (A) Negative charge (B) Positive charge (C) No charge (D) Either positive or negative charge The gold numbers of A, B, C and D are 0.04, 0.002, 10 and 25, respectively. The protective powers 3. of A, B, C and D are in the order $(A) \quad A > B > C > D$ $(B) \quad B > A > C > D$ (C) D > C > B > A(D) C > A > B > D4. The movement of dispersion medium in an electric field when the dispersed particles are prevented from moving is called (A) Cataphoresis (B) Electrophoresis (C) Electro-osmosis (D) Brownian movement 5. The potential difference between the fixed charged layer and the diffused layer having opposite charge is called (A) Colloidal potential (B) Zeta potential (C) Electrostatic potential (D) None of these 6. Colloidal particles carry charge. This can be shown by (A) Tyndall effect (B) Cataphoresis (C) Brownian movement (D) Dialysis 7. Which metal sol cannot be prepared by Bredig's are method? (A) K (B) Cu (C) Au (D) Pt On adding AgNO₃ solution into KI solution, a negatively charged colloidal sol is obtained when they 8. are in (A) $100 \text{ ml of } 0.1 \text{ MAgNO}_3 + 100 \text{ ml of } 0.1 \text{ M KI}$ (B) $100 \text{ ml of } 0.1 \text{ MAgNO}_3 + 50 \text{ ml of } 0.2 \text{ M KI}$ (C) $100 \text{ ml of } 0.1 \text{ MAgNO}_3 + 50 \text{ ml of } 0.1 \text{ MKI}$ (D) $100 \text{ ml of } 0.1 \text{ MAgNO}_3 + 100 \text{ ml of } 0.15 \text{ M KI}$ 9. Micelles have (A) higher colligative properties compared of common colloidal sols (B) lower colligative properties (C) same colligative properties (D) low molar mass 10. Which of the following ion has minimum flocculation value? (B) SO_4^{-2} (A) Cl⁻ (C) PO_4^{3-} (D) $[Fe(CN)_{6}]^{4-}$ If 1000 mg of lyophilic sol prevent the coagulation of 1L lyophobic sol, then protection number is 11. (A) 10 mg (B) 1 mg (C) 25 mg (D) None 12. Which of the following substance give a positively charges sol? (A) Gold (B) Arsenious sulphide (C) Starch (D) Ferric hydroxide 13. 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 (A) A suspension (B) Oil (C) A colloidal sol (D) True solution Which is lyophobic in nature? 14. (B) Phosphorus (C) Starch (D) Agar-Agar (A) Gelatin

15.	Gelatin is mostly used in making ice creams in ord	ler to							
	(A) Prevent making of colloid								
	(B) Stabilise the colloid and prevent crystallisation	on							
	(C) Stabilise the mixture								
	(D) Enrich the aroma								
16.	When some special substances like protein part	ticles, blood corpuscles,	, etc., are separated by a						
	permeable membrane. The process is called								
	(A) Dialysis (B) Diffusion	(C) Exosmosis	(D) Endosmosis						
17.	At critical micelle concentration (CMC) the surface	tant molecules							
	(A) Decomposes	(B) Becomes comp	letely soluble						
	(C) Associates	(D) Dissociates							
18.	According to Hardy-Schulze law the order of coa	gulation power of cation	s will be						
	(A) $Na^+ > Ba^{+2} > Al^{+3}$	(B) $Al^{+3} > Ba^{+2} > N$	Ia^+						
	(C) $Ba^{+2} > Al^{+3} > Na^{+3}$	(D) $Al^{+3} > Na^{+} > Ba^{+3}$	a^{+2}						
19.	Which one of the following method is commonly	used for destruction of co	lloid?						
	(A) Dialysis	(B) Condensation							
	(C) Filtration by animal membrane	(D) By adding elect	rolyte						
20.	Position of non polar and polar part in micelles		5						
20.	(A) Polar at outer surface but non polar at inner surface								
	(B) Polar at inner surface but non polar at outer	surface							
	(C) Distributed over all the surface	(D) Are present in t	he surface only						
21.	Milk is a colloidal		5						
	(A) Liquid is dispersed in a liquid	(B) Solid is disperse	ed in a liquid						
	(C) Gas is dispersed in a liquid	(D) Sugar is dispers	ed in a liquid						
22.	Surface tension of lyophilic sol is		1						
	(A) lower than that of H ₂ O	(B) more than that	ofH_O						
	(C) equal than that of H_{a}^{2}	(D) none of these	2						
23.	Sulphur sol contains								
	(A) Discrete sulphur atoms	(B) Discrete sulphur molecules							
	(C) Water dispersed in solid sulphur	(D) Large aggregate	es of sulphur molecules						
24.	Which forms a colloidal solution in water?		1						
	(A) NaCl (B) Glucose	(C) Starch	(D) Barium nitrate						
25.	Flocculation value is expressed in terms of								
	(A) Millimole per litre	(B) Mol per litre							
	(C) Gram per litre	(D) Mol per millilitre	2						
26.	Which one of the following substances is not used	for preparing lyophilic s	ols?						
	(A) Metal sulphide (B) Gum	(C) Gelatin	(D) Starch						
27.	The simplest way to check whether a system is co	lloidal is by							
	(A) Tyndall effect	(B) Brownian move	ment						
	(C) Electro dialvsis	(D) Finding out part	icle size						
28.	Tyndall effect in colloidal solution is due to								
-	(A) absorption of light	(B) scattering of light	nt						
	(C) reflection of light	(D) presence of elec	trically charged particles						
29.	Which one of the following colloidal solutions is p	ositive sol?							
	(A) Blood	(B) Clay soil							
	(C) Smoke	(D) Gelatin in strongly acidic solution							
30.	I vophilic sols are more stable than lyophobic sols	because	5-5						
	(A) The colloidal particles have positive charge	(B) The colloidal par	rticles have no charge						
	(C) The colloidal particles are solvated	()F-	8-						
	(D) These are strong electrostatic repulsions betw	veen the negatively charge	ed colloidal particles						
		0 ,8	L						

EX	ERCISE 2	
1. 2.	The size of particles in suspension, true so (a) Suspension > Colloidal > True Solution (c) Suspension > Colloidal = True Solution Out of the following which reaction gives	lution and colloidal solution varies in the order on (b) True Solution > Suspension > Collidal on (d) None of the above s a colloidal solution?
	(a) $Cu + HgCl_2 \rightarrow CuCl_2 + Hg$	(b) $2HNO_3 + 3H_2S \rightarrow 3S + 4H_2O + 2NO$
	(c) $2Mg + CO_2 \longrightarrow 2MgO + C$	(d) $Cu + CuCl_2 \longrightarrow Cu_2Cl_2$ (in presence of excess of HCl)
3.	Colloidal solution of silver is prepared by (a) Colloidal mill (c) Bredig's method	y (b) Double decomposition method (d) Peptization
4.	Which is a natural colloid?	
5.	(a) Sodium chloride(b) UreaWhich of the following is a homogeneous(a) Muddy water	(c) Starch (d) Barium nitrate s system? (b) Brea
	(c) Concrete	(d) A solution of sugar in water
6.	Emulsifiers are generally	
	(a) Soap	(b) Synthetic detergents
7	(c) Lyophilic solutions	(d) all of the above
/.	medium is termed as	id as dispersed phase in a solid as dispersion
	(a) Aerosol (b) Gel	(c) Emuslion (d) Foam
8.	Gels on standing exude small amounts of	liquid. This phenomena is known as
0	(a) efflorescence (b) synersis	(c) thixotropy (d) adsorption
9.	Substances whose solutions can readily d	(b) Crystalloids
	(c) Electrolytes	(d) Non electrolytes
10.	When dispersed phase is liquid and disperies called	rsion medium is gas then the colloidal system
	(a) Smoke (b) Clouds	(c) Jellies (d) Emulsions
11.	The extra stability of lyophilic colloids is	due to
	(a) Charge on their particles	d
	(b) A layer of medium of dispersion on t	neir particles
	(d) The large size of their particles	
12.	Lyophilic solutions are more stable than l	yophbic solutions because
	(a) The colloidal particles have positive c	harge
	(b) The colloidal particles have negative of	charge
	(c) The colloidal particles are solvated	na hattaan tha naartiyala ahaanad aallaidal
	(d) The are strong electrostatic repulsion particles.	ns between the negatively charged colloidal
13.	Which of the following is not a property	of hydrophilic solutions?
	(a) High concentration of dispersed phase	e can be easily attained
	(b) Coagulation is reversible	The second se
	(c) viscosity and surface tension are nea (d) The charge of the particle depends on	rly same as that of water the pH value of medium; it may be positive
	negative, or even zero	the pri value of medium, it may be positive,
12.	 (c) The smaller size of their particles (d) The large size of their particles (d) The large size of their particles Lyophilic solutions are more stable than 1 (a) The colloidal particles have positive c (b) The colloidal particles have negative c (c) The colloidal particles are solvated (d) The are strong electrostatic repulsion particles. Which of the following is not a property (a) High concentration of dispersed phase (b) Coagulation is reversible (c) Viscosity and surface tension are nea (d) The charge of the particle depends on negative, or even zero 	yophbic solutions because harge charge ns between the negatively charged colloida of hydrophilic solutions? e can be easily attained rly same as that of water the pH value of medium; it may be positive

14.	Flocculation value is	expressed in terms	of	
	(a) millimole L ⁻¹		(b) mole L^{-1}	
	(c) gram L ⁻¹		(d) mole ml ⁻¹	
15.	When a colloidal sol	lution is observed ur	nder an ultramicrosco	pe, we can see
	(a) Light scattered by	y colloiodal particles	(b) Size of the partie	cle
	(c) Shape of the par	ticle	(d) Relative size	
16.	The colour of the co	ollidal particles of go	old by different metho	ods differ because of
	(a) variable valency of	of gold	(b) different concent	ration of gold particles
	(c) different type of i	impurities	(d) different diameter	rs of colloidal particles
17.	On adding few drops	of dil. HCl to fresh	ly precipitated ferric l	vdroxide, a red coloured
	colloidal solution is	obtained. This pheno	menon is known as	
	(a) Peptization	1	(b) Dialvsis	
	(c) Protective action		(d) Dissolution	
18.	The ability of an ior	to bring about coas	gulation of a given co	olloid depends upon
	(a) Its size	8 8	(b) The magnitude o	f its charge only
	(c) The sign of its c	harge alone	(d) Both magnitude	and sign of its charge
19.	A negatively charged	suspension of clav in	water will need for r	precipitation the minimum
	amount of		· · · · · · · · · · · · · · · · · · ·	<u>-</u>
	(a) Aluminium chlorid	le	(b) Potassium sulpha	te
	(c) Sodium hydroxide	2	(d) Hydrochloric acid	1
20.	The coagulation pow	ver of an electrolyte	for As S, decreases	in the order
	(a) $N_{a^+} \wedge 1^{3+} P_{a^{2+}}$	5	(b) $C_{1-}^{2-} C_{2-}^{2-} D_{2-}^{3-}$	-
	(a) Na [*] , Al ^{**} , Ba ^{**}		$(0) CI, SO_4, PO_4$	
	(c) Al ³⁺ , Ba ²⁺ , Na ⁺		(d) PO_4^{3-} , $SO_4^{2-}Cl^{-}$	
21.	Which of the followi solutions are mixed?	ng pairs of ions wou	ld be expected to for	m precipitate when dilute
	(a) Na ⁺ , SO ₃ ²⁻		(b) NH_4^+ , CO_3^{2-}	
	(c) Na ⁺ , S ²⁻		(d) Fe^{3+} , PO_4^{3-}	
22.	Silver iodide is used	for producing artific	cial rain because AgI	
	(a) is easy to spray	at high attitudes	(b) is easy to synthe	esize
	(c) has crystal structu	are similar to ice	(d) is insoluble in w	ater
23.	Which of the follow	ing electrolytes is le	east effective in causi	ng flocculation of ferric
	hydroxide solution?			
	(a) $K_3[Fe(CN)_6]$		(b) $K_2 CrO_4$	
	(c) KBr		(d) $\tilde{K_2SO_4}$	
24.	Separation of colloid	al particles from tho	se of molecular dime	nsion is known as
	(a) Electrolysis		(b) Electrophoresis	
	(c) Electrodialysis		(d) None of the abo	ove
25.	The blue colour of y	water in the sea is o	due to	
	(a) Refraction of the	blue light by the im	purities in sea water	
	(b) Reflection of blu	e sky by sea water		
	(c) Scattering of blue	e light by water mole	ecules	
	(d) Absorption of oth	her colours except th	ne blue colour by wa	ter molecules
26.	100 mL of 0.6 M ac	cetic acid is shaken	with 2 g activated ca	rbon. The final cone, of
	the solution after ad	lsorption is 0.5 M.	What is the amount	of acetic acid adsorbed
	per gram of carbon	?		
	(a) 0.6 g	(b) 0.3 g	(c) 1.2 g	(d) None of these

- 27. A detergent $(C_{12}H_{25}SO_4^-Na^+)$ solution becomes a colloidal sol at a concentration of 10^- ³ M. On an average 10^{13} colloidal particles are present in 1 mm³. What is the average number of ions are contain in one colloidal particle (micelle) ? [Given N_A = 6 × 10²³] (a) 6 × 10⁷ (b) 10 (c) 60 (d) None of these 28. One graph of activates earlier has a surface area of 1000 m⁻² Considering complete
- 28. One gram of activates carbon has a surface area of 1000 m⁻². Considering complete coverage as well as monomolecular adsorption, how much ammonia at STP would be

adsprbed on the surface of $\frac{44}{7}$ g carbon if radius of a ammonia molecules is 10⁻⁸ cm.

 $[N_A = 6 \times 10^{23}]$ (a) 7.46 L

- (b) 0.33 L (c) 44.8 L (d) 23.5 L
- 29. At STP the volume of nitrogen gas required to cover a sample of silica gel, assuming Langmuir monolayer adsorption, is found to be $1.30 \text{ cm}^3\text{g}^{-1}$ of the gel. The area occupied by a nitrogen molecule is 0.16 nm^2 . What is the surface area per gram of silica gel ? [GivenN_A = 6×10^{23}]

(a) $5.568 \text{ m}^2 \text{ g}^{-1}$ (b) $3.48 \text{ m}^2 \text{ g}^{-1}$ (c) $1.6 \text{ m}^2 \text{ g}^{-1}$ (d) None of these

30. A sample of 16 g charcoal was brought into contact with a CH_4 gas contained in a vessel of 1 litre at 27°C. The pressure of gas was found to fall from 760 to 608 torr. The density of charcoal sample is 1.6g/cm³. What is the volume of the CH_4 gas adsorbed per gram of the adsorbent at 608 torr and 27°C?

(a) 125 mL/g (b) 16.25 mL/g (c) 26 mL/g (d) None of these

EXERCISE 🖁

BRAINSTORMING OBJECTIVES

[SINGLE	CORRECT1
L	

1.	When freshly precipitated Fe(OH), is boiled with	water in the presence of few drops of dil. HCl, a						
	hydrated ferric oxide sol is obtained. The method	is termed as						
	(1) Electro dispersion (2) Peptization	(3) Ultra filtration (4) Dialysis						
2.	An examples of micelle is							
	(1) As_2O_3 solution	(2) Ruby glass						
	(3) Na_2CO_3 solution	(4) Sodium stearate concentrated solution						
3.	Fe^{3+} ions coagulate blood. This shows blood conta	ains colloidal particles bearing						
	(1) Negative charge	(2) Positive charge						
	(3) No charge	(4) Either positive or negative charge						
4.	The potential difference between the fixed charged is called	layer and the diffused layer having opposite charge						
	(1) Colloidal potential	(2) Zeta potential						
	(3) Electrostatic potential	(4) None of these						
5.	On adding AgNO ₃ solution into KI solution, a nega	tively charged colloidal sol is obtained when they						
	are in							
	(1) $100 \text{ ml of } 0.1 \text{ M AgNO}_3 + 100 \text{ ml of } 0.1 \text{ M}$ (2) $100 \text{ ml of } 0.1 \text{ M AgNO}_3 + 50 \text{ ml of } 0.2 \text{ M}^2$							
	(2) $100 \text{ m} \text{ of } 0.1 \text{ M AgNO}_3 + 50 \text{ m} \text{ of } 0.2 \text{ M}$ (3) $100 \text{ m} \text{ of } 0.1 \text{ M AgNO} + 50 \text{ m} \text{ of } 0.1 \text{ M}$	KI KI						
	(4) $100 \text{ ml of } 0.1 \text{ MAgNO}_3 + 50 \text{ ml of } 0.1 \text{ M}$	M KI						
6.	Lyophilic sols are more stable than lyophobic sols	because						
	(1) The colloidal particles have positive charge	(2) The colloidal particles have no charge						
	(3) The colloidal particles are solvated							
	(4) These are strong electrostatic repulsions betwee	en the negatively charged colloidal particles						
7.	Gold number is a measure of							
	(1) the amount of gold present in the colloidal so	lution						
	 (2) the amount of gold required to break the colloid (3) the amount of gold required to protect the colloid 							
	(4) the protective power of the lyophilic colloid	noid						
8	On addition of one ml solution of 10% NaCl to 10	ml gold sol in presence of 0 0025 g of starch the						
0.	coagulation is just prevented. The gold number of	starch is						
	(1) 25 (2) 2.5	(3) 0.25 (4) 0.025						
9.	Which of the following has minimum flocculation v	alue?						
	(1) Pb^{2+} (2) Pb^{4+}	(3) Sr^{2+} (4) Na^+						
10.	Which of the following sols is negatively charged?							
	(1)Arsenius sulphide	(2) Aluminium hydroxide						
	(3) Ferric hydroxide	(4) Silver iodide in $AgNO_3$ solutoni						
E M								



MULTIPLE CHOICE ANSWER TYPE

- 1. Select the correct statement (s) :
 - (a) Physical adsorption is multilayer, non-directional
 - (b) Chemical adsorption highly specific in nature
 - (c) Physical adsorption is due to free valence of atoms
 - (d) Chemical adsorption is due to stronger interaction or bond formation
- 2. Select the correct statement(s):
 - (a) Adsorption is a non-spontaneous process
 - (b) Surface energy decreases during the process of adsorption
 - (c) Adsorption takes place with decrease of entropy
 - (d) In general adsorption is exothermic process
- 3. Select the correct statement (s):
 - (a) Physisorption is favoured by low temperature
 - (b) Chemisorption is favoured by very high temperature because the process is endothermic
 - (c) Chemisorption increases with increase in temperature owing to high activation energy
 - (d) Oxygen adsorbed by charcoal can be desorbed by lowering pressure and temperature
- 4. If adsorption of a gas on a solid is limited to monolayer formation, then which of the following statements are true ?
 - (a) At low pressures, $\frac{x}{m}$ varies proportionately with p
 - (b) At moderate pressures, $\frac{x}{m}$ varies less than proportionately with p
 - (c) At high pressures, $\frac{x}{m}$ becomes independent of p
 - (d) At high pressures, $\frac{x}{m}$ varies more than proportionately with p
- 5. Which of the following aie multimolecular colloids?
- (a) Sulphur sol (b) Starch (c) Gold sol (d) Soap solution
- 6. Which of the following is not lyophilic ?
- (a) Gelatin sol (b) Silver sol (c) Sulphur sol (d) As_2S_3 sol
- 7. Which of the following is/are correct for lyophilic sols?
 - (a) Its surface tension is lower than that of water
 - (b) Its viscosity is higher than that of water
 - (c) Its surface tension is higher than that of water
 - (d) Its viscosity is equal to that of water
- 8. Select the correct statement (s):
 - (a) Benzene is dispersed phase in benzosols
 - (b) Lyophobic sols are irreversible and not so stable
 - (c) Lyophobic sol can be produce by double decomposition
 - (d) When a solution of sulphur in alcohol is added in excess of water a sol of alcohol is formed
- 9. When negatively charged colloid like As_2S_3 sol is added to positively charged $Fe(OH)_3$ sol in stoichiometric amounts ?
 - (a) Both the sols are precipitated simultaneously (b) This process is called

mutual coagulation

(c) They becomes positively charged colloid (d) They become negatively charged colloid

- 10. Colloidal gold can be prepared by:
 - (a) Bredig's arc method (b) reduction of AuCl₃
 - (c) hydrolysis (d) peptization
- 11. The coagulation of sol particles may be brought about by :
 - (a) heating (b) dialysis
 - (c) adding electrolyte (d) adding oppositely charged sol
- 12. Select the correct statement(s) :

(a) A solution is prepared by addition of excess of $AgNO_3$ solution in KI solution. The charge likely to develop on colloidal particle is positive

- (b) The effects of pressure on physical adsorption is high if temperature is low
- (c) Ultracentrifugation process is used for preparation of lyophobic colloids
- (d) Gold number is the index for extent of gold plating done
- 13. Colloidal solution can be purified by:
 - (a) dialysis (b) electrodialysis (c) electrophoresis (d) ultrafiltration
- 14. Coagulation of colloids can be achieved by:
 - (a) centrifugation (b) adding electrolyte (c) change in pH (d) adding water
- 15. Which are the properties of sols ?
 - (a) Adsorption (b) Tyndall effect
 - (c) Flocculation (d) Depression of freezing point
- 16. In the aqueous solution of soaps above CMC :
 - (a) the cations associate to form the aggregates
 - (b) the anions associate to form the clusters of colloidal dimension
 - (c) the polar ends of the ions forming the clusters are directed towards water
 - (d) the non-polar (hydrocarbon) ends are directed towards water
- 17. Amongst the following which is/are correct statement about the metal sulphide sols ?
 - (a) The sol particles are positively charged due to preferential adsorption of metal ions
 - (b) The sol particles are negatively charged due to preferential adsorption of sulphide ions

(c) The cations of added electrolytes are effective in causing the coagulation of the sol

(d) The sol is unstabilized due to both the electric charge and hydration of the particles

- 18. Emulsion can be destroyed by:
 - (a) the addition of an emulsifier (b) electrophoresis with a high potential
 - (c) freezing (d) all of these
- 19. Which of the following statement is/are correct for electrophoresis?

(a) Colloids are uncharged particles and do not migrate towards the electrodes when electric field is applied

(b) In electrophoresis, solution migrates either to the anode or to the cathode depending on the positively or negatively charged solution

- (c) Electrophoresis is useful for finding the charge on a sol
- (d) All of these
- 20. Select the false statement (s):

- (a) Brownian motion and Tyndall effect are shown by true solutions
- (b) Sorption process is combinations of adsorption and adsorption process
- (c) Hardy-Schulze law is related with coagulation of a sol
- (d) Higher is the gold number greater will be the protective power of a lyophilic colloid

LINKED COMPREHENSION TYPE

Passage-I

There are certain substances which behave as normal, strong electrolytes at low concentration but at hihger concentration they behave as colloidal solutions due to the formation of aggregated particles. Such colloidal are called associated colloids and the aggregated particles are called micelles. Soaps and detergents are the examples of associated colloids. The formation of micelles takes place above certain concentration called critical micellization concentration (CMC) and a characteristic temperature.

- 21. What type of molecules form micelles? (1) Non-polar molecules (2) Polar molecules (3) Surfactant molecules (4) Salt of weak acid and weak base Micelles are formed only. 22. (1) below the CMC and the Kraft temperature (2) above the CMC and below the Kraft temperature (3) Above the CMC and above the Kraft temperature (4) below the CMC and above the Kraft temperature 23. Above CMC, the surfactant molecules undergo: (4) all of these
 - (1) dissociation (2) peptization (3) micelle formation

REASONING TYPE

The question given below consist of two statements each printed as 'Assertion' (A) and 'Reason' (R). While answering these questions you are required to choose any one of the following four responses :

- (a) If both (A) and (R) are true and (R) is the correct explanation of (A).
- (b) If both (A) and (R) are true but (R) is not the correct explanation of (A)
- (c) If (A) is correct but (R) is incorrect.
- (d) If (A) and (R) are both incorrect.
- 24. Assertion: Lyophilic colloids are called as reversible sols.

Reason: Lyophilic sols are liquid loving.

25. Assertion: Addition of AgNO₃(aq.) to KI (aq.) gives negative sol whereas addition of KI (aq) to AgNO₂ gives positive sol of AgI. Reason: The sol particles adsorb the common ions present in solution and acquire their

charge.

- Assertion: Sol particles show Tyndall effect. 26.
 - **Reason:** The scattering is directly proportional to size of sol particle.
- 27. Assertion : In chemi-sorption, adsorption keeps on increasing with temperature **Reason**: Heat keeps on providing more and more activation energy.
- **Assertion :** For adsorption ΔG , ΔS and ΔH all have negative values. 28. **Reason**: Adsorption is spontaneous process accompanied by decreases in randomness.

- 29. Assertion : Physical adsorption of molecules on the surface requires activation energy. Reason : Because the bonds of adsorbed molecules are broken.
- **30.** Assertion: Colloidal silver iodide is prepared by adding silver nitrate in slight excess to potassium iodide solution. When subjected to an electric field, the colloidal particles migrate to the anode

Reason : Colloidal particles absorb ions and thus become electrically charged.

31. Assertion: The micelle formed by sodium stearate in water has -COO⁻ groups at the surface.

Reason : Surface tension of water is reduced by the addition of stearate.

- **32.** Assertion: Fe^{3+} can be used for coagulation of As_2S_3 sol.
- **Reason :** Fe^{3+} reacts with As_2S_3 to give Fe_2S_3 .
- **33.** Assertion: Gold sol is hydrophobic and multimolecular. **Reason :** Gold sol is prepared by Bredig's arc method.
- **34. Assertion:** The reaction of oxalic acid with acidified KMnO4 is first slow and then proceed with faster speed.

Reason : Acidified KMnO₄ is a strong oxidising agent.

35. Assertion: Alcohols are dehydrated to hydrocarbons in presence of acidic zeolite. **Reason :** Zeolites are porous catalyst.

MATRIX MATCH TYPE

MATCH THE COLUMN MAY HAVE MORE THAN ONE MATCH

Column — I

- (A) Rain cloud
- (B) Smoke
- (C) Butter
- (D) Soap sud
- 37. Match the following Columns

Column – I

- (A) Coagulation
- (B) Peptization
- (C) Tyndall effect
- (D) Dialysis
- 38. Match the following Columns Column – I

Column - II

(Q) Cellulose

Water

(Colloidal solution) (A) Colloidion

(Disperesed phase) (P) Water

(R) Fat

- (B) Fog
 - b) Pog
- (C) Butter(D) Milk
- (S)
- 39. Match the following Columns

Column – I

- (A) Cottrell precipitation
- (B) Electrophoresis
- (C) Hemidialysis

Column – II

- (P) Gel
- (Q) Foam
- (R) Aerosol
- (S) Gas as dispersion medium

Column – II

- (P) Scattering of light
- (Q) Purification of colloidal solution
- (R) Addition of electrolyte
- (S) Precipitation of colloidal solution

Column – III

(Dispersion medium)

- (U) Ethanol
- (V) Oil
- (W) Air
- (X) Water

Column – II

- (P) Purification of blood
- (Q) Precipitation of colloidal particles by addition of electrolytes
- (R) Removal of pollutants from industrial

(D) Coagulation particles

Ni

AlCl₂

Zeolite

Co/Al₂O₂

Match the column–I with column–II Column–I (Catalyst)

40.

(A)

(B)

(C)

(D)

waste gases

(S) Movement of charged colloidal

towards oppositely charge electrode

Column-II (Process)

- (p) Cracking of hydrocarbons
- (q) Fischer-Tropsch process
- (r) Hydrogenation of oil
- (s) Friedel- Crafts reaction

INTEGER TYPE

- 41. 10% sites of catalyst bed have absorbed by H_2 . On heating H_2 gas is evolved from sites and collected at 0.03 atm and 300 K in a small vessel of 2.46 cm³. No. of sites available is 6.0×10^{15} per cm² and surface area is 1000 cm². Find out the no. of surface sites occupied per molecule of H_2 . (Given $N_A = 6 \times 10^{23}$) [3]
- 42. The Volume of nitrogen gas (measured at STP) required to cover a sample of silica gel with a mano-molecular layer is 129 cm³ gm⁻¹ of gel. Calculate the surface area per gram of the gel if each nitrogen molecule occupies 2.6×10^{-21} m². [9]
- **43.** A graph between x/m and the pressure P of the gas at a constant temperature is called adsorption isotherm. Where x is the no. of moles of the adsorbate and m is the mass of the adsorbent. Adsorption isotherms of different shapes have been experimentally observed. According to Frundlich adsorption isotherm.

$$\mathbf{x}/\mathbf{m} = \mathbf{k}\mathbf{P}^{1/\mathbf{n}}$$

where k and n are constant parameters depending upon the nature of the solid and gas.



- Graph between $log\left(\frac{x}{m}\right)$ and logP is a straight line at angle [4]
- 44. Gold number of haemoglobin is 0.03. Hence, 100 ml of gold solution will require haeomoglobin is found to be $x \times 10^{y}$ mg so that gold is not coagulated by 10 ml of 10 % NaCl solution. Find the value of x [3]
- 1. [AgI] I⁻ colloidal sol can be coagulated by the addition of a suitable cation. 1 mol of [AgI] I⁻ requires mol of A_{gNO_3} , $Pb(NO_3)_2$ and $Fe(NO_3)_3$ as

(a) 1, 1, 1 (b) 1, 2, 3 (c) 1,
$$\frac{1}{2}, \frac{1}{3}$$
 (d) 6, 3, 2

The minimum quantity of sodium chloride which is necessary to precipitate 10 litres of sol in two hours is 0.585 gm. The flocculation value of sodium chloride is

 (a) 0.585
 (b) 0.0585
 (c) 0.1
 (d) One

45° with intercept OA as shown. Hence, $\left(\frac{x}{m}\right)$ at a pressure of



AIEEE FLASH BACK

Questions asked in AIEEE

- 1 Adding alum to turbid water, impurties are removed due to (2002)
 - (1) Coagulation (2) Brownian movement (3) Electrophoresis (4) Tyndall effect
- 2. Which one of the following characteristics is not correct for physical adsorption ?
 - (1) Both enthalpy and entropy of adsorption are negative
 - (2) Adsorption on solids is reversible
 - (3) Adsorption increases with increase in temperature
 - (4) Adsorption is spontaneous
- **3.** 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 ?
 - (1) Mixing of the sols has no effect
 - (2) Coagulation in both the sols can be brought about by electrophoresis
 - (3) Magnesium chloride solution coagulates the gold sol more readily than the iron (III) hydroxide sol

(2003)

(2006)

- (4) Sodium sulphate solution causes coagulation in both the sols (2005)
- 4. The volume of a colloidal particle, V_c, as compared to the volume of a solute particle in a true solution, V_s could be

(1)
$$V_c / V_s \square 10^{-3}$$
 (2) $V_c / V_s = 10^3$ (3) $V_c / V_s = 1$ (4) $V_c / V_s = 10^{23}$ (2005)

- 5. In Langmuir's model of adsorption of a gas on a solid surface
 - (1) the mass of gas striking a given area of surface is independent of the pressure of the gas
 - (2) the rate of dissociation of adsorbed molecules from the surface does not depend on the surface covered
 - (3) the adsorption at a single site on the surface may involve multiple molecules at the same time
 - (4) the mass of gas striking a given area of surface is proportional to the pressure of the gas
- 6. 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 (2008)

(1) $B \le D \le A \le C$ (2) $D \le A \le C \le B$ (3) $C \le B \le D \le A$ (4) $A \le C \le B \le D$

- 7. Which of the following statements is incorrect regarding physisorptions ? (2009)
 - (1) Under high pressure, it results into multimolecular layer on adsorbent surface
 - (2) Enthalpy of adsorption $(\Delta_{ads}H)$ is low and positive
 - (3) It occurs because of vander Waals forces
 - (4) More easily liquefiable gases are adsorbed readily

Questions asked in IIT-JEE

8. 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 - (2009)

(1) Na_2SO_4 (2) $CaCl_2$ (3) $Al_2(SO_4)_3$ (4) NH_4Cl

- The correct statement(s) pertaining to the adsorption of a gas on a solid surfacce is (are) (2011)
 - (1) adsorption is always exothermic.

9.

- (2) Physisorption may transform into chemisorption at high temperature.
- (3) Physisorption increases with increasing temperature but chemisorption dereases with increasing temperature.
- (4) Chemisorption is more exothermic than physisorption, however it is very slow due to higher energy of activation.



IIT - JEE FLASH BACK

1.	Rate of physiorption increases with		[2003S]
	(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:	[2004S]
	(A) enthalpy is positive	(B) entropy decreases	
	(C) entropy increases	(D) free energy increases	
3.	Lyophilic sols are		[2005S]
	(A) Irreversible sols	(B) They are prepared from inorganic compour	nd
	(C) Coagulated by adding electrolytes	(D) Self-stabilizing	

- 4. Choose the correct reason(s) for the stability of the lyophobic colloidal particles. [2012]
 - (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.

Sol: (ACD)

 The given graphs/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? [2012]



(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.
Sol: (AC)

ANSWER SHEET											
			aily	Prac	ctice	Pro	blen	ns - 0)1		
1. 7.	D C	2. 8.	D C	3. 9.	C A	4. 10.	B C	5. 15.	A A	6.	В
			aily	Prac	ctice	Pro	blen	ns - 0	2		
1. 7.	C C	2. 8.	D A	3.	В	4.	D	5.	D	6.	A
			aily	Prac	tice	Pro	blen	ns - 0	3		
1. 7. 13.	C D C	2. 8. 14.	B D C	3. 9.	D A	4. 10.	B B	5. 11.	A B	6. 12.	C C
			aily	Prac	tice	Pro	blen	ns - 0	4		
1. 7. 13.	D C D	2. 8. 14.	D B D	3. 9. 15.	B B D	4. 10.	A B	5. 11.	D D	6. 12.	C A
					Exe	rcise	- 01				
1. 7. 13. 19. 25.	C A C D A	2. 8. 14 20. 26.	A D B A A	3. 9. 15. 21. 27.	B B A A	4 10. 16. 22. 28.	C D A A B	5. 11. 17. 23. 29.	B A C B D	6. 12. 18. 24. 30.	B D B C C
					Exe	rcise	- 02	2			
1. 7. 13. 19. 25.	a b c a c	2. 8. 14. 20. 26.	b b a c b	3. 9. 15. 21. 27.	c b a d c	4. 10. 16. 22. 28.	d b d c a	5. 11. 17. 23. 29.	d b a c a	6. 12. 18. 24. 30.	d c d c b
				E	kerci	se -	03				
1. 7.	2 4	2. 8.	4 2	3. 9.	1 1	4. 10.	2 1	5.	4	6.	3

				Ex	kerci	se -	04					
1. b,	d	2.b,c,	d	3.a,c	3.a,c		4. a,b,c		5. a,c		6.b,c,d	
7. a,	b	8. b,c	;	9. a, e	d	10.a,	b	11. c	,d	12. a,b		
13. a	ı,b,d	14. a,	b,c	15. a.	b,c,d	16.b,	16.b,c		17.b.c		18.b,c	
19.c		20.a, o	d	21.	3	22.	3	23.	3	24.	В	
25.	А	26.	А	27.	D	28.	А	29.	D	30.	4	
31.	1	32.	3	33.	2	34.	2	35.	2			
36.	$A \rightarrow P$,	$S; B \rightarrow$	R, S ;	$C \rightarrow P;$	$D \rightarrow Q$							
37.	$A \rightarrow R$, S ; B \rightarrow	• R ; C	$\rightarrow P ; D$	$\rightarrow Q$							
38.	A – Q -	– U ; B –	P - W	; C – P	– V ; D	-R-X						
39.	$A \rightarrow R$, S ; B \rightarrow	• S ; C ·	$\rightarrow P ; D$	$\rightarrow Q$							
40.	A-r-]	B-s, C-q	, D-p									
	Exercise - 05											

1.	1	2.	4	3.	4	4.	3	5.	2	6.	2
7.	3	8.	3	9.	1,2,4						

Exercise - 06

1. A 2. B 3. D 4. acd 5. ac