**Syllabus**

**Colloidal State** - Definition of colloids, classification of colloids.

Solids in liquid (sols): Properties - kinetic, optical and electrical, stability of colloids, protective action, Hardy- Schulze law, gold number.

Liquids in Liquid (emulsions): Types of emulsions, preparation, emulsifier,

Liquids in solid (gels)- classification, preparation and properties, inhibition, general applications of colloids.

***Colloids***

Colloids (also known as colloidal solutions or colloidal systems) are mixtures in which microscopically dispersed insoluble particles of one substance are suspended in another substance. The size of the suspended particles in a colloid can range from 1 to 1000 nanometres (10-9 metres). For a mixture to be classified as a colloid, its suspended particles must not settle (in the manner that the particles of suspensions settle at the bottom of the container if left undisturbed). Colloidal solutions are known to exhibit the Tyndall Effect, which is a phenomenon in which beams of light incident on colloids are scattered due to the interactions between the light and the colloidal particles.

The IUPAC definition of the colloidal state can be written as follows: “*The colloidal state is the state of subdivision in which molecules or polymolecular particles having at least one dimension in the range of 1 nanometre and 1 micrometre, are dispersed in some medium*.” Colloids usually feature substances that are evenly dispersed in another. In such mixtures, the substance that is dispersed is referred to as the **dispersed phase** whereas the substance through which it is dispersed is called the **continuous phase**.

**Table of Contents**

• Colloids Meaning and Definition

• Classification of Colloids

• Preparation of Colloid Solutions

• Purification of Colloids

• Examples of Colloids

• Application of Colloids

**Colloids Meaning and Definition**

 In simple terms, we can define colloids as a mixture where one of the substances is split into very minute particles which are dispersed throughout a second substance. The minute particles are known as colloidal particles. Alternatively, we can also say that colloids are basically solutions in which solute particle size ranges from 1nm – 1000 nm.

**Classification of Colloids**

Colloids are classified into many types.

* Classification Based on Physical State
* Classification Based on Dispersion Medium
* Classification Based on Interaction Forces
* Classification Based on Properties/size of Sol Particle
* **Multimolecular colloids**
* **Macromolecular colloids**
* **Associated colloids**

**Classification Based on Physical State**

A most common method of classifying colloids is based on the phase of the dispersed substance and what phase it is dispersed in. The types of colloids includes sol, emulsion, foam, and aerosol.

Table: Classification of Colloids

| **Dispersed Phase** | **Dispersion Medium** | **Type of Colloid** | **Example** |
| --- | --- | --- | --- |
| Solid | Solid | Solid sol | Ruby glass |
| Solid | Liquid | Sol | Paints, cell fluids |
| Solid | Gas | Aerosol | Smoke |
| Liquid | Solid | Solid emulsion/gel | Pearl, cheese, butter, jelly |
| Liquid | Liquid | Emulsion | Milk, oil in water |
| Liquid | Gas | Liquid Aerosol | Fog, mist, cloud |
| Gas | Solid | Solid foam | Lava, pumice, foam rubber |
| Gas | Liquid | Foam | Soap suds, whipped cream |

**(a) Solid Solution**

In this both dispersed phase and the dispersion medium are solid. Eg: gemstones, ruby glass

**(b) Sol:** In this solid articles are dispersed in the solid dispersion medium. Paints

**(c) Aerosol**

These colloids consist of air as the dispersion medium. Examples:Cloud- This contains air as dispersion medium and water drops as the dispersed phase, Dust- This contains air is dispersion medium and dent particle as the dispersed phase, Smoke- this contains carbon particles in the air.

**(d) Gels**

These contain solid dispersion medium and liquid dispersed phase. Example-Cheese, butter.

**(e) Emulsion**

These are liquid-liquid solutions in which the dispersed phase is liquid and liquid dispersed medium. Emulsion mainly consists of two aspects.

Oil in water type (O/W): Oil is dispersed phase and water is dispersion medium. Eg- Milk

Water in oil type (W/O): Water is the dispersed phase and oil/fat is dispersion medium. Example- Vanishing cream

Sols and gels are reversible and interconvertible. This is known as thixotropy.

**Classification Based on Dispersion Medium**

On the basis of dispersion medium sol are classified as;

**(a) Hydrosol:**

When the dispersion medium is water, the collodial system is often referred to as a hydrocolloid. The particles in the dispersed phase can take place in different phases depending on how much water is available. For example, Jello powder mixed in with water creates a hydrocolloid. A common use of hydrocolloids is in the creation of medical dressings. In these colloids water act as a dispersion medium. Example-Starch

**(b) Alcosol:** In this type, alcohol acts as a dispersion medium.

**(c) Acrosol:** These contain a dispersed phase particle in the air. Example**:** Smoke

**Classification Based on Interaction Forces**

On the basis of interaction forces between the dispersion medium and dispersed phase-

**Lyophobic Sols: [Emulsoid]** These are less stable sols. A weak interaction is present between the dispersed phase and the dispersion medium. Eg.-Metallic sols like Ag, gold etc. Following are the characteristics of lyophobic sols.

**a) Surface Tension:** It is same as that of the medium.

**b) Viscosity:** It is the same as that of the medium.

**c) Irreversible:** These are irreversible colloids when once dispersion medium is evaporated and again when the solvent is added no new sol is formed.

**d) Stability:** There is weak interaction between the dispersed phase and dispersion medium hence lyophobic sols are unstable.

**e) Visibility:** Particle can be detected using ultramicroscope.

**f) Migration:** Particle migrates either colloid an anode depending upon the charge of sol particle.

**g) Action of electrolyte:** When the electrolyte is added to sol, coagulation takes place.

**h) Hydration:** No hydration of sol takes place.

**Lyophilic Sols**

These are stable strong sols. A strong interaction is present between the dispersed phase and the dispersion medium. Example:gum, gelatin, starch. Following are the characteristics of lyophilic sols.

**a) Surface tension:** Lower than that of the medium.

**b) Viscosity:** Higher than medium.

**c) Reversibility:** These are reversible sols. When dispersion medium is evaporated and the solvent is added again the same type of sol is formed.

**d) Stability:** More stable due to strong interaction between the dispersed phase and the dispersion medium.

**e) Visibility:** The particles are visible under an electron microscope.

**f) Addition of electrolyte:** Small amount of electrolyte is required for the formation of sol.

**g) Hydration:** Extensive hydration takes place.

**Classification Based on Type of Particles of Dispersed Phase**

Depending upon how different substances forming colloidal solution acquire the size of particles in this range, colloidal solutions may be classified into the following three categories. Classification of sols on the basis of properties is given as-

**Multi Molecular Colloids**

A solution occurs atoms or smaller molecules of substance (having a diameter less than 1nm) aggregate together to form particles of colloidal dimensions. The particles thus formed are called multimolecular colloids.

In these sols, the dispersed phase consists of aggregates of atoms or molecules with a molecular size less than 1 atm. For example sols of gold atoms and sulphur (Sf) molecules. In these colloids, the particles are held together by physical forces called Van der Waals forces. Metallic sols are usually multimolecular sols prepared by Bredig’s are melted. These are usually lyophobic unstable, and separation is early possible.

**Macromolecular Colloids**

These are substances having big size molecular called macromolecular which on demolition form size in the colloidal ran such substance are called macromolecular colloids. Thus macromolecule forming the dispersed phase are generally polymers having very high molecular masses.

Naturally occurring macromolecular are starch, cellulose proteins, enzyme gelatin etc. Artificial macromolecular and synthetic polymers such as nylon, polyester, plastics, polishers etc. They have usually lyophobic sols.

**Associated Colloids (Micelles)**:

Certain colloids behave as strong electrolytes at lower concentrations but exhibit colloidal properties at higher concentrations. At a particular concentration, the molecules of dispersed phase align in such a way as to form micellar structures. This particular concentration is known as critical micellar concentration. The colloids that form micelles are known as associated colloids.

**Preparation of Colloid Solutions**

Stable colloids are also known as lyophilic sols; in these strong forces of interaction exist between the dispersed phase and the dispersion medium. These are prepared by the two following suitable methods-

 (I) Condensation Method and

 (II) Dispersion Method.

**Condensation Method**

In this method, small solute particles are condensed to form a dispersed phase particle.

**1. Chemical methods:**

**a) By oxidation:**

Colloidal sulphur can be obtained by passing oxygen gas through a solution of hydrogen sulphides. In this method any oxidising agent like HNO3, H3Br2 can also be used.

2H2S + O2 → 2H2O + 2S (Sulphur sol)

**b) By double decomposition:**

A solution of arsenic sulphide is obtained in this method. In this process hydrogen sulphide is passed through Arsenious oxide cold solution in water.

AS2O3 + 3H2S → AS2S3 + 3H2O Arsenic sulphide (sol)

**c) By reduction:**

A number of metals such as gold, silver, and platinum are obtained in a colloidal state by reacting the aqueous solution of these salts with suitable reducing agents such as formaldehyde, phenylhydrazine, hydrogen peroxide, stannous chloride etc.

2AuCl3 + 3SnCl2 → 3SnCl4 + 2Au (gold sol)

2AuCl3 + 3HCHO + 3H2O → 2Au + 3HCOOH + 6HCl

The gold sol prepared in the reduction of gold chloride solution has a purple colour and is called purple of Cassius.

**d) By hydrolysis:**

Many salt solutions are rapidly hydrolysed by boiling a dilute solution of their salts. For example, ferric hydroxide and aluminium hydroxide sols are obtained by boiling solutions of the corresponding chloride.

FeCl3 + 3H2O → Fe(OH)3 + 3HCl colloidal sol

Silicic acid sol is obtained by the hydrolysis by sodium silicate.

**f) By excessive cooling:**

A colloidal sol of ice is obtained in this process. Ice is taken in an organic solvent like chloroform ether. Sol of ice is obtained by freezing a solution of water in the solvent. The molecules of water are no longer in the solution separately combine to form particles of colloidal size.

**h) By exchange of solvent:**

In this process, colloidal sol of certain substances such as sulphur, phosphorus which are soluble in alcohol but insoluble in water can be prepared by pouring their alcoholic solution into water. For enough alcoholic solution of sulphur on pouring into water gives a milky colloidal solution of sulphur.

**i) By change of physical state:**

Sols of substance like mercury and sulphur are prepared by passing the vapour through cold water containing a suitable stabilizer such as ammonium salt or citrate.

**Dispersion Methods**

In these methods, large particles of a substance (suspension) are broken into smaller particles. The following methods are employed.

**a) Mechanical dispersion**

In this method, the substance is first grounded to coarse particles. It is then mixed with dispersion medium to get a suspension. The suspension is then grinded in a colloidal mill.



It consists of two metallic dyes nearly touching each other and rotating in the opposite direction at a very high speed 7000 revolution per minute. The space between the dyes of the mill is so adjusted that coarse suspension to great shearing force giving rise to particles of colloidal size. Colloidal solution of black ink, paints varnishes dyes are obtained by this method.

**b) Bredig’s Arc Method or by Electrical Dispersion**

This method is used to prepare sols of platinum, silver copper or gold. The metal whose sol is to be prepared is made as two-electrode which immersed in a dispersion medium such as water etc.



The dispersion medium is kept cool by ice. An electric arc is placed between the electrodes. The tremendous heat generated by and give colloidal solute. Electrolytes are used for this process for stabilization and cooling.

**c) Peptization**

The process of converting a freshly prepared precipitate into a colloidal solution is known as peptization. In this method as the electrolyte in smaller amounts is added which is known as peptization agent or peptizing agent. Cause of peptization is the adsorption of the ions of the electrolyte by the particles of the precipitate. Important peptizing agent are sugar gem gelatin and electrolyte.

Examples

1. Freshly prepared ferric hydroxide can be converted into the colloidal state by shaking it with water contains Fe3+ or OH– ions i.e. FeCl3 or NH4OH respectively.

Fe(OH)3 + FeCl3 → (Fe(OH)1 Fe)+3 + 3Cl– precipitate electrolyte

2. A stable sol of stannic oxide is obtained by adding a small amount of dilute HCl to stannic oxide precipitate similarly a colloidal solution of Al(OH)3 and AgCl are obtained by treating the corresponding freshly prepared with a very dilute solution of HCl and AgNO3 or KCl respectively.

**Purification of Colloids**

Colloids contain ionic impurities and other categories of impure substances that decrease the quality of colloids used in various applications. Following are the methods to purify the colloids.

**1) Dialysis**

Method of separation of ionic substances from the colloidal solution by means of effusion through a suitable membrane is dialysis. The principle is that sol particle cannot pass through parchment paper or semipermeable membrane due to the impurity slowly diffused out of the base leaving pure colloid.

**Precautions:**

The distilled water in the container where a bag is immersed should be changed frequently to prevent the accumulation of crystalloids otherwise there is a possible change of diffusing back of impurities into the bag.



**2) Electro Dialysis**

Dialysis is a slow process and takes so much time for the removal of impurities. The process is improvised by an applied electrical force. This is known as electrodialysis. In this method two electrical plates are inserted into the distilled water and are connected to the terminals of source, long moves to the opposite electric plate with greater speed and the sol is purified.



**3) Ultrafiltration**

Normal filter papers cannot be used to filter the impurities of colloid since due to the large size of pores, impurities along with sol particle will be filtered off. The pore size is reduced by impregnating the papers in collodion solution which is 4 – s. Calculate nitrate solution in alcohol – ether mixture and dried with acetaldehyde. This is known as ultrafiltration and such papers are known as ultrafilter papers.

**Examples of Colloids**

**1) Blood:** A respiration pigment which has albumin protein in water. Pigment part contains albumin that acts as the dispersed phase and the dispersion medium is water. It is a hydrosol.

**2) Cloud:** It contains air which is the dispersion medium and droplets of water as a dispersed phase. These are aerosol.

**3) Gold sol:** It is a metallic sol in which gold particles are dispersed in the water.

**Application of Colloids**

Colloids are widely useful in industries, medical and domestic applications.

1. **As food items:** Syrup, Halwa, Soup belongs to a colloidal type of system.
2. **Medicine:** Colloidal silver in the name of Argyrols, it acts as antiseptic for eye infection.
3. **In Purification of air by Cottrell precipitator:** This process involves coagulation of solution particle. Dust or smoke is passed through the inlet of an electrified chamber which has a central electrical plate which is provided with opposite charge of a dent a smoke particle when dust passes the particles are coagulated and pure air is passed through another outlet.
4. **Tanning of leather:** Animal skins are very soft, when these are immersed in the solution of tannin which has the opposite charge of animal skin, particles are coagulated and the skin becomes hard this is known as tanning of leather.
5. **Formation of delta:** It involves coagulation of clay particles of the river with an electrolyte of seawater.

# ****Properties of Colloids****

# General Physical Properties of Colloidal Solutions

# Optical Properties of Colloids (Tyndall Effect)

# Mechanical Properties (Brownian Movement)

#  Cause of Brownian Movement

# Electrical Properties of Colloidal Solutions

#  Origin of Charge on Colloidal Particles

#  Electrophoresis

#  Electro-Osmosis

# Coagulation or Flocculation

# Protective Colloids and Gold Number

## ****General Physical Properties of Colloidal Solutions****

Following are the important physical properties of colloidal solutions:

* **Heterogeneity:** Colloidal solutions are heterogeneous in nature. These consist of two phases-dispersed phase and dispersion medium.
* **Visibility of dispersed particles:** Although colloidal solutions are heterogeneous in nature, yet the dispersed particles present in them are not visible to the naked eye and they appear homogenous. This is because colloidal particles are too small to be visible to the naked eye.
* **Filterability:** Due to very small size, the colloidal particles pass through an ordinary filter paper. However, they can be retained by animal membranes, cellophane membrane and ultrafilters.
* **Stability:**Lyophilic sols in general and lyophobic sols in the absence of substantial concentrations of electrolytes are quite stable and the dispersed particles present in them do not settle down even on keeping. However, on standing for a long time, a few colloidal particles of comparatively larger size may get sedimented slowly.
* **Colour:** The colour of a colloidal solution depends upon the size of colloidal particles present in it. Larger particles absorb the light of longer wavelength and therefore transmit light of shorter wavelength. For example, a silver so having particles of size 150nm appears violet, whereas that having particles of size 60nm appears orange yellow.

## ****Optical Properties of Colloids (Tyndall Effect)****

* When an intense converging beam of light is passed through a colloidal solution kept in dark, the path of the beam gets illuminated with a bluish light. This phenomenon is called Tyndall effect and the illuminated path is known as **Tyndall cone**.
The phenomenon was first observed by Tyndall in 1869.
* The Tyndall effect is due to the scattering of light by colloidal particles. Since the dimensions of colloidal particles are comparable to the wavelength of ultraviolet and visible radiations, they scatter these and get illuminated.



* Tyndall observed that the zone of scattered light is much larger than the particle itself. This is why colloidal particles look like bright spots when viewed with a microscope at right angles to the beam of light as shown in figure. Thus, Tyndall effect may be defined as the scattering of light by colloidal particles present in a colloidal solution.
* Tyndall effect is not exhibited by true solutions. This is because the particles (ions or molecules) present in a true solution are too small to scatter light. Thus,
* Tyndall effect can be used to distinguish a colloidal solution from a true solution. The phenomenon has also been used to devise an instrument known as ultra microscope. The instrument is used for the detection of the particles of colloidal dimensions. Tyndall effect also establishes the fact that colloidal systems are heterogeneous in nature.

## Brownian Movement

## ****Mechanical Properties (Brownian Movement)****

Colloidal particles present in a colloidal solution exhibit a very important property called Brownian movement. When a colloidal solution is viewed under an ultra microscope, the colloidal particles are seen continuously moving in a zigzag path. The property was discovered by a botanist Robert Brown in 1827, when he observed that pollen grains suspended in water exhibit random zigzag motion. After the name of the discoverer, the property was named as Brownian movement. It may be defined as follows.
The continuous zigzag movement of the colloidal particles in the dispersion medium in a colloidal solution is called Brownian movement.

### ****Cause of Brownian Movement****

Brownian movement is due to the unequal bombardments of the moving molecules of dispersion medium on colloidal particles. The moving molecules of the dispersion medium continuously attack on colloidal particles from all sides and impart momentum to them.

Since the chances of their collisions are unequal, the net driving force on a colloidal particle forces it to move a particular direction. As the particle moves in that direction, other molecules of the medium again collide with it and the particle changes its direction. The process continues. This results in a random zigzag movement of the colloidal particle.

The Brownian movement decreases with an increase in the size of colloidal particle. This is why suspensions do not exhibit this type of movement. Brownian movement plays an important role in imparting stability to a sol. This is because Brownian movement opposes the gravitational forces acting on colloidal particles and prevents them from getting settled down.

## ****Electrical Properties of Colloidal Solutions****

Some important electrical properties of colloidal solutions are as follows:

**Presence of electrical charge on colloidal particles and stability of sols**

One of the most important properties of colloidal solutions is that colloidal particles posses a definite type of electrical charge. In a particular colloidal solution, all the colloidal particles carry the same type of charge, while the dispersion medium has an equal but opposite charge. Thus, the charge on colloidal particles is balanced by that of the dispersion medium and the colloidal solution as a whole is electrically neutral. For example, in a ferric hydroxide sol, the colloidal ferric hydroxide particles are positively charged, while the dispersion medium carries an equal and opposite negative charge.

The stability of a colloidal solution is mainly due to the presence a particular type of charge on all the colloidal present in it. Due to the presence of similar and equal charges, the colloidal particles repel one another and are thus unable to combine together to form larger particles. This keeps them dispersed in the medium and the colloidal remains stable. This is why sol particles do not settle down even on standing for a long time.

Based on the nature of charge, the colloidal sols may be classified as positively charged and negatively charged sols. Some common examples of these sols are given below.



* **Positively** **charged sols:**Metallic hydroxide sols e.g., Fe(OH)**3**, Al(OH)**3**, Cr(OH)**3**, etc., TiO**2** sol, haemoglobin, sols of basic dyes such as methylene blue etc.
* **Negatively charged sols:**Metal sols e.g., Au, Ag, Cu, Pt etc. sols, metal sulphide sols e.g., As**2**S**3**, CdS etc. sols; starch sol, sols of acid dyes such as Congo red etc.

## ****Origin of Charge on Colloidal Particles****

There are several views regarding the origin of charge on colloidal particles. According to these views, colloidal particles acquire charge due to the following reasons.

* **Due to dissociation of the adsorbed molecular electrolytes:** Colloidal particles have a strong tendency to adsorb reactant or product molecules. The molecules thus adsorbed on the surface of colloidal particles may undergo dissociation/ionization and may impart charge to them.
For example, during the preparation of sulphide sols (e.g., As**2**S**3** sol), H**2**S molecules get adsorbed on colloidal particles. H**2**S molecules thus adsorbed undergo ionization and release H**+**ions into the medium. Consequently, colloidal particles are left with negative charge.
* **Due to the dissociation of molecules forming colloidal aggregates:** The molecules responsible for the formation of aggregates of colloidal dimensions may themselves undergo dissociation/ionisation resulting in the development of charge on the colloidal particles formed by their aggregation.
For example, the soap molecules (RCOONa) dissociate to give RCOO**-** and Na**+** ions. RCOO**-** ions aggregate together to form micelles which carry negative charge as explained earlier.
* **Due to preferential adsorption of ions from solutions:** The colloidal particles have a tendency to preferentially adsorb a particular type of ions from the solution. A colloidal particle usually adsorbs those ions which are in excess and are common to its own lattice.
This preferential adsorption of a particular type of ions imparts a particular type of charge to colloidal particles.
For example, when a ferric hydroxide sol is prepared by the hydrolysis of ferric chloride in warm water, the colloidal particles of Fe(OH)**3** formed have a tendency to adsorb preferentially the Fe**3+** ions present in the solution. This is because Fe**3+** ions are common to the lattice of Fe(OH)**3** particle. The Fe**3+**ions thus adsorbed impart positive charge to the colloidal particles present in the sol.

|  |
| --- |
| **Fe(OH)3     +           Fe3+        →          Fe(OH)3    :      Fe3+ (colloidal            (ions common         preferential adsorption of Fe3+ ions particle)          to the lattice of           (colloidal particle acquires                         colloidal particle)                positive charge)** |

* Similarly, during the preparation of AgCl sol using excess of KCl solution, the Cl**–** ions are preferentially adsorbed and the colloidal particles acquire negative charge. However, if an excess of AgNO**3** is used, Ag**+** ions get preferentially adsorbed and the colloidal particles acquire positive charge.

|  |
| --- |
| **AgCI          +        CI-                 →                        AgCI : CI-****(colloidal)        (Chloride ions present              Preferential adsorption of CI- ions particle)           in excess in the solution)       (Collodial particle acquires negative charge) AgCI          +                  Ag+                →                 AgCI : Ag+ (colloidal)             (Silver ions present in          Preferential adsorption of Ag+ions particle)              excess in the solution)     (Collodial particle acquires positive charge)** |

### ****Electrophoresis****

Due to the presence of a particular type of electrical charge, the colloidal particles present in a colloidal dispersion move towards a particular electrode under the influence of an electric field.
The direction of movement of the colloidal particles is decided by the nature of charge present on them. If the colloidal particles carry positive charge, they move towards cathode when subjected to an electric field and vice versa. The phenomenon is called electrophoresis and may be defined as the movement of colloidal particles towards a particular electrode under the influence of an electric field.



The phenomenon of electrophoresis clearly indicates that the colloidal particles carry a particular type of charge. The property can be used to find the nature of charge carried by colloidal particles in a colloidal dispersion.Electrophoresis is an important phenomenon and finds several applications in industry.

### ****Electro-Osmosis****

* When the movement of colloidal particles under the influence of the applied electric field is checked with the help of a suitable membrane (semi permeable membrane), the dispersion medium moves in a direction opposite to the direction in which the colloidal particles would have otherwise moved. This phenomenon is called electro-osmosis and may be defined as the  movement of dispersion medium under the influence of an electric field in the situation when the movement of colloidal particles is prevented with the help of a suitable membrane.
* The colloidal solution is placed between two partitions made by semi permeable membranes.
* The outer compartments consisting of platinum electrodes and side tubes are filled with water.
* On passing electric current, water level begins to rise in one of the side tubs and falls in the other.
* The phenomenon can be explained as follows :
We have already seen that the colloidal particles and dispersion medium carry charges which are equal but opposite in nature. Under the influence of an electric field, both have a tendency to move towards the oppositely charged electrodes. Semi permeable membranes do not allow the passage of colloidal particles. However, dispersion medium can pass through them. Therefore during electro-osmosis, colloidal particles are checked and it is the dispersion medium that moves towards the oppositely charged electrode.



###

### ****Coagulation or Flocculation****coagulation of positively charged colloids

* The stability of a sol is due to the charge present on the colloidal particles. Due to similar charges, colloidal particles repel one another and are unable to combine together to form larger particles. However, if the charge on colloidal particles is destroyed, they are free to come nearer and grow in size.
* When the particles become sufficiently large, they get precipitated. This phenomenon is termed as coagulation or flocculation.
* The coagulation of colloidal solution can be achieved by the addition of an electrolyte.
* It is to be noted that a small amount of electrolyte is necessary for the stability of a sol because the ions of the electrolyte get adsorbed on colloidal particles and impart them some charge. However, when an electrolyte is added in substantial amount the positively charged ions of the electrolyte neutralize the charge on colloidal particles and compel the sol to get coagulated.
* Coagulation may be defined as t**he phenomenon involving the precipitation of a colloidal solution on addition of an electrolyte.**
* **Hardy-Schulze rule:**The coagulation capacity of an electrolyte depends upon the valence of ion responsible for causing coagulation. As we have seen above, the ion responsible for causing coagulation is the one which carries charge opposite to that present on colloidal particles. For example, a positively charged sol gets coagulated by the negatively charged ions of the added electrolyte. From a study of the coagulation behavior of various electrolytes towards a particular sol, Hardy and Schulze suggested a general rule known as Hardy-Schulze rule.
The rule can be stated as **the greater is the valence of the oppositely charged ion of the electrolyte added to a colloidal solution, the faster is the coagulation of the colloidal solution.**
* Thus, higher the charge on oppositely charged ion greater is its coagulating power. For example, the coagulation power of different cations for coagulating a negatively charged sol of As**2**S**3** follows the order.
Al**3+** > Ba**2+** > Na**+**
* Similarly, for the coagulation of a positively charged sol such as Fe(OH)**3**, the coagulating power of different anions follows the order.
[Fe(CN)6]**4-**   >   PO**43-**  >  SO**42-** >   Cl**-**
* **Flocculation value:** The coagulating power of an electrolyte is usually expressed in terms of its flocculation value which may be defined as the minimum concentration (in millimoles per litre) of an electrolyte required to cause the coagulation of a sol.
* The flocculation values (in millimoles per litre) for the coagulation of negatively charged As**2**S**3** sol and positively charged Fe(OH)**3** sol are given in the Table below.

|  |  |
| --- | --- |
| **For Negatively charged As2S3 Sol** | **For Positively charged Fe(OH)3 Sol** |
| **Electrolyte** | **Flocculating ion** | **Flocculation value (millimoles/litre)** | **Electrolyte** | **Flocculating ion** | **Flocculation value (millimoles/litre)** |
| **NaCl** | **Na+** | **52** | **KBr** | **Br-** | **138** |
| **KCl** | **K+** | **50** | **HCl** | **Cl-** | **132** |
| **HCl** | **H+** | **30** | **KNO3** | **NO-3** | **132** |
| **MgCl2** | **Mg2+** | **0.72** | **K2CrO4** | **CrO42-** | **0.315** |
| **BaCl2** | **Ba2+** | **0.69** | **K2SO4** | **SO42-** | **0.210** |
| **ZnCl2** | **Zn2+** | **0.68** | **K2C2O4** | **C2O42-** | **0.238** |
| **AlCl3** | **Al3+** | **0.093** | **K3[Fe(CN)6]** | **Fe(CN)6]3-** | **0.096** |

It is to be noted that a smaller flocculation value indicates the greater coagulating power of the electrolyte. Thus.


Some other methods for causing coagulation: The most commonly used method for causing coagulation in a colloidal solution is the addition of an electrolyte as described above. However, the coagulation of colloidal solution can also be achieved by any of the following methods.

* **By electrophoresis:**In electrophoresis, the charged colloidal particles migrate to the oppositely charged electrode and get discharged. This results in the coagulation of the colloidal solution.
* **By mixing two oppositely sols:** When two sols carrying opposite charges are mixed together in suitable proportions, the colloidal particles of one sol neutralize the charge present on the particles of the other sol and both get coagulated.
* **By persistent dialysis:** We have already seen that a small amount of electrolyte is essential to make a sol stable. When a sol is subjected to persistent dialysis, the traces of electrolyte also pass out through the membrane. In the absence of electrolyte, sol becomes unstable and gets coagulated.??

|  |
| --- |
| **Example** |
| **Question:**For the coagulation of 100 mL of arsenious sulphide sol, 5 ml of 1 M NaCl is required. What is the flocculation value of NaCl?**Solution:**5 mL of 1 M NaCl  contains NaCl = (1/1000) x 5 moles = 5 millimolesThus, 100 mL of As2S3 sol  require NaCl for complete coagulation = 5 millimolesso, 1 L, i.e., 1000 mL of the sol require NaCl for complete coagulation = 50 millimolesso, by definition, flocculation value of NaCl = 50. |

## ****Protective Colloids and Gold Number****

* Lyophobic sols such as those of metals (e.g. Au, Ag, Pt etc.) are not very stable in the sense that they get easily coagulated (precipitated) in the presence of an electrolyte. This poses a big problem in their storage and usage. Contrary to this, lyophilic sols are much more stable and do not get coagulated easily under similar conditions.
* It has been observed that in the presence of certain lyophilic colloids such as gum Arabic, gelatin, starch etc. the hydrophobic sols acquire greater stability towards coagulation, i.e. they get protected and do not get coagulated easily when an electrolyte is added.
* The process of protecting a lyophobic sol from being coagulated (precipitated) on addition of an electrolyte by the use of a lyophilic colloids is called protection and the lyophilic colloid used for purpose is called a protective colloid.
For example, the addition of gelatin (a lyophilic colloid) to a gold sol (lyophobic sol) protects the latter from being coagulated on addition of sodium chloride solution.
* 
* The exact mechanism of protection is not very clearly understood. However, it is believed that the lyophilic colloid particles get adsorbed on the surface of the colloid particles present in the lyophobic sol. The adsorbed lyophilic particles thus form an envelope around the lyophobic sol particles and protect them from the action of electrolytes.
* **Gold Number:** The protective power a lyophilic colloid is usually expressed in terms of a number called gold number introduced by Zsigmondy (1901).. **The gold number of a protective colloid is its minimum amount in milligrams which is just sufficient to prevent the coagulation of 10 ml of a gold sol on the addition of 1 mL of 10% sodium chloride solution.**
* It is to be noted that the smaller the value of gold number, the greater is the protective power of the protective colloid. The gold numbers of a few protective colloids are given in the Table below.

|  |  |
| --- | --- |
| **Protective (Lyophilic) Colloid** | **Gold Number** |
| **Gelatin** | **0.005-0.01** |
| **Casein** | **0.01-0.02** |
| **Hemoglobin** | **0.03-0.07** |
| **Egg albumin** | **0.08-0.10** |
| **Gum Arabic** | **0.10-0.15** |
| **Dextrin** | **6-20** |
| **Starch** | **20.2**5 |



**Question 1:** Which of the following alternatives represents the correct order of coagulation power of ions?

a.  Na**+**>Al**3+** > Ba**2+**

b.  Ba**2+** > Al**3+** >  Na**+**

c.  Ba**2+** > Na**+** >Al**3+**

d. Al**3+** > Ba**2+** > Na**+**

**Question 2:** When an intense converging beam of light is passed through a colloidal solution kept in dark, the path of the beam gets illuminated with a bluish light. This phenomenon is called

a. Tyndrall effect

b. Coagulation of colloids

c. Peptization

d. Dispersion of light

**Question 3:** Which of the following alternatives  does not form a positively charged sol ?

a. Fe(OH)**3**

b. Al(OH)**3**

c. TiO**2**

d. Cd

**Question 4:** The minimum amount of any colloid in milligrams which is just sufficient to prevent the coagulation of 10 ml of a gold sol on the addition of 1 mL of 10% sodium chloride solution is called its

a. gold number

b. coagulation value

c. flocculation value

d. osmotic potential