A Study on Surface Chemistry Colloidal Solutions

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ABSTRACT

A colloid is a mixture in which one substance is suspended in another by microscopically dispersed insoluble particles. Because of its unique structure, colloid has a wide range of physical and chemical properties. Let us delve deeper into the physical, chemical, optical, and electrical properties of colloidal solutions. Colloids exhibit a phenomenon known as the Tyndall effect, which Tyndall observed in 1869. When we shine a bright converging beam of light through a dark colloidal solution, the path of the beam is illuminated with a bluish light. The scattering of light by colloidal particles is known as the Tyndall effect, and the illuminated path is known as the Tyndall cone. The dispersed colloidal particles scatter the light that falls on them, producing emissions similar to ultraviolet and visible radiations. These scattered radiations are lit up. A Study on Surface Chemistry Colloidal Solutions will be discussed in this paper.

Keywords*: Surface Chemistry, Colloidal Solutions, Physical, Chemical, Optical, Electrical Properties, Chemical Properties, Electrolyte, Dialysis, Electro-Dialysis, Ultra-Filtration.*

Introduction

The particle size of a homogeneous or true solution is less than 10-7 cm, whereas the particle size of a heterogeneous solution is greater than 10-4 cm. Colloidal State of Matter is the intermediate state between these two.

Surface chemistry is the branch of chemistry that studies the type of surface and the species that exist on it. This anomaly is investigated using adsorption and colloidal state, which are very useful in understanding the chemical and physical properties of the substance. Substance properties differ at the surface and in the bulk because molecules in the bulk are attracted symmetrically in all directions with zero net force, whereas molecules at the surface familiarise attraction unequally. In this unit, we will investigate a surface phenomenon. [1]

Colloidal Solution:

When colloidal solutions are prepared, they typically contain an excess of electrolytes as well as some other soluble impurities. Purification of colloidal solution refers to the process of reducing the number of impurities to a bare minimum.

Dialysis: It is the removal of a dissolved substance from a colloidal solution via diffusion through a suitable membrane.

Electro-dialysis: Dialysis is a time-consuming procedure. If the dissolved substance in the impure colloidal solution is only an electrolyte, it can be accelerated by applying an electric field. The procedure is then known as electro-dialysis.

Ultra-filtration: The process of separating colloidal particles from the solvent and soluble solutes present in the colloidal solution using specially prepared filters that are impermeable to all substances except the colloidal particles is known as ultrafiltration. Because the pores in ordinary filter paper are too large, colloidal particles can pass through. To stop the flow of colloidal particles, the pores of filter paper can be reduced in size by impregnating with a collodion solution.

Properties of Colloidal Solution:

A colloid is a mixture of different substances. A colloid's particles are too small to be seen individually with the naked eye. Colloids are large enough to scatter a light beam passing through them and reveal their path. A colloid is quite stable because it does not settle down when left undisturbed.

They cannot be separated from the mixture through the filtration process. However, a specific separation technique known as centrifugation (perform activity 2.5) can be used to separate the colloidal particles.

Brownian movement refers to the continuous zigzag motion of particles. This motion is independent of the nature of the colloid but is affected by particle size and solution viscosity. Coagulation is the process of precipitating a colloid by adding a small amount of electrolyte. [2]

Review of Literature:

Kim (2010) conducted column experiments to investigate the efforts of the solution chemistry sequence on clay release from sands with different grain sizes, revealing that increasing pH and decreasing ionic strength have only a minor effect on clay release. Clay release was significantly increased when monovalent sodium ions on the clay and sand surfaces were exchanged for multivalent cations. [3]

According to the colloid filtration theory (CFT), increasing the interstitial flow rate reduces the number of collisions between passive colloid particles and collectors, which does not favour colloidal retention and increases the number of movable colloids (Walshe et al., 2010). [4]

This is because as the flow rate increases, the contact time between the colloid and the quartz sand particles decreases, decreasing the possibility of colloid adsorption on the surface of the quartz sand particles, which promotes colloidal migration. Another reason is that increasing the flow velocity generates more hydraulic shear force, which causes colloids to gain propulsion and migrate to the water along the liquid phase's trajectory, resulting in more colloids at the outflow end (Chowdhury et al., 2011). [5]

Furthermore, many researchers have worked hard to understand the migration and retention of clay colloids in partially saturated porous media. Zevi et al. (2005) used pore scale visualisation technologies to directly observe and characterise colloid transport behaviours in partially saturated quartz. [6]

Objectives:

- The adsorption concept of Surface Chemistry is based on the fact that the surface of a solid has a tendency to attract and retain the molecules of the phase with which it comes into contact.
- These molecules remain only at the surface and do not penetrate deeper into the bulk.
- Adsorption refers to the accumulation of molecular species at the surface rather than in the bulk of a solid or liquid.

Research Methodology:

This study's overall design was exploratory. Physical chemistry includes the study of colloids and surfaces. Colloids are distinguished by their numerous intriguing properties, such as kinetic or optical properties, as well as by observing their stability over time. Colloidal systems are made up of small particles that are dispersed in a medium. Because these particles have such small dimensions, a large surface or interfacial area is created. Because of the large interface associated with colloids, colloid and surface chemistry are frequently studied together. Colloids and interfaces are present and important in a wide range of products and processes, including food, milk, and pharmaceuticals, as well as cleaning agents, paints, and glues. Colloids are classified based on the phase of the dispersed phase and the dispersion medium, as well as their stability. Thermodynamically, colloidal dispersions are unstable, whereas association colloids and polymer/protein solutions are stable. [7]

Result and Discussion:

Classification of Colloids: -

1. Lyophobic Sol:

If water is used as the medium, it is also known as hydrophobic sol. It is the suspension of a hydrophobic (water repellent) substance in water that contains non-polar groups. This includes the dispersion of oil, fats, metal oxide, hydroxide, sulphide, and other substances in water. These sols are quite unstable and must be stabilised with a small amount of electrolyte (stabiliser).

2. Lyophilic Sol:

If water is used as the medium, it is also known as hydrophilic sol. It is the suspension of polar groups in water of a hydrophilic (water-loving) substance. Substances such as gum, albumin, gelatine, and so on. These sols are very stable, requiring no stabiliser.

3. Preparation of Colloids

Lyophilic sols can be made simply by warming the solid in a liquid dispersion medium. For example, gum with water. Lyophobic sols, on the other hand, must be prepared using specific techniques. These methods are classified into two types:

A. Condensation or Aggregation Methods.
B. Dispersion Methods.

A. Condensation or Aggregation Methods:

These methods involve chemical reactions or solvent changes in which the atoms or molecules of the dispersed phase appear first and aggregate to form colloidal particles. The conditions (temperature, pressure, etc.) used allow the formation of sol particles while preventing the particles from becoming too large and forming precipitate.

The following are the key chemical methods for producing lyophobic sols:

a. Double Decomposition:

A slow stream of hydrogen sulphide gas is passed through a cold solution of arsenious oxide (AS_2O_3) to produce an Arsenic Sulphide (AS_2S_3) sol. This is repeated until the yellow colour of sol reaches its peak intensity.

$AS_2O_3 + 3\ H_2S$-------->AS_2S_3 (Yellow Sol) + $3H_2O$

Silver halide sols are formed by mixing equal parts dilute solutions of silver salts and alkali halides. This method involves combining dilute solutions of sodium silicate and HCl to produce silica gel sol. [8]

b. Oxidation:

Colloidal sulphur sols can be made by passing hydrogen sulphide through a solution of sulphur dioxide in water or through a solution of an oxidising agent (bromine water, nitric acid).

$SO_2 + 2H_2S$-------->$3S + 2H_2O$

H_2S + (O)-------->S + H_2O

c. Reduction:

A colloidal solution of a metal, such as silver, gold, or platinum, can be made by reducing their salt solutions with appropriate reducing agents, such as stannous chloride, formaldehyde, hydrazine, tannic acid, and so on.

$2AuCl_3 + 3SnCl_2$--------> 2Au (Gold sol.) + 3 $SnCl_4$

or $AuCl_3$ + Tannic acid-------->Au (Sol.)

d. Hydrolysis:

The method is used to make hydroxides and oxides of weakly electropositive metals such as Fe, Al, and Sn. By adding a few drops of 30% ferric chloride solution to a large volume of almost boiling water and stirring with a glass rod, a red sol of ferric hydroxide is obtained. $FeCl_3 + 3H_2O = Fe(OH)_3$ (Red Sol.) + 3HCl.

The following physical methods are important for preparing lyophobic sols:

e. By Exchange of Solvent:

A colloidal solution is formed when a true solution is mixed with an excess of another solvent in which the solute is insoluble but the solvent is soluble. For example, when a sulphur solution in alcohol (ethanol) is added to an excess of water, a colloidal sulphur solution is formed due to a decrease in solubility. [9]

f. By Excessive Cooling:

By freezing a solution of water in the solvent, a colloidal solution of ice in an organic solvent such as $CHCl_3$ or ether can be obtained. Water molecules that can no longer be held in solution separately combine to form colloidal particles.

g. Dispersion Methods:

In the presence of a dispersion medium, large particles of the substances are broken down into colloidal particles. Because the formed sols are highly unstable. They are stabilised by the addition of an appropriate stabiliser. The following are some of the methods used for dispersion:

h. Mechanical Dispersion:

In this method, coarse particles and dispersion medium are ground into a colloidal state in a colloidal mill, ball mill, or ultrasonic disintegrator. The colloidal mill receives solid particles from the dispersion medium. The mill is made up of two steel plates that are nearly touching and rotating at high speeds (7000 rev/min). This method produces sol colloidal graphite (lubricant) and printing inks by shredding solid particles to colloidal size and dispersing them in liquid. A mercury sol was recently prepared by dissolving a layer of mercury into sol particles in water using an ultrasonic vibrator.

i. Bredig's Arc Method:

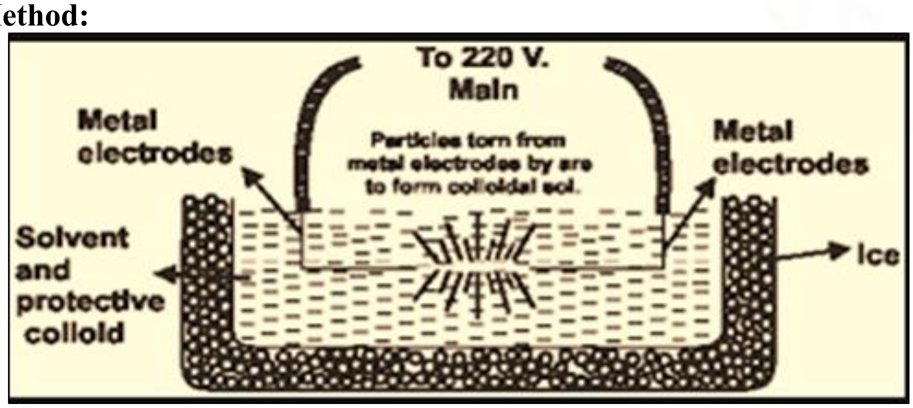

Figure 1: Bredig's Arc Method

This procedure includes both dispersion and aggregation. This method can be used to create colloidal solutions of metals such as gold, silver, and platinum. An electric arc is struck between electrodes of metal immersed in the dispersion medium in this method. The intense heat produced vapourises some of the metal, which then condenses to form colloidal particles.

j. Peptization:

Peptisation is the process of converting a precipitate into colloidal form by shaking it in the presence of a small amount of electrolyte in a dispersion medium. Peptizing Agent is the name given to the electrolyte used for this purpose. This method is commonly used to convert fresh precipitate into colloidal solution because such precipitates are simply clusters of colloidal particles held together by weak forces. [10]

Colloidal State

Certain solutes, such as starch, glue, and gelatin, could not pass through the parchment membrane, whereas ordinary solutes, such as sodium chloride, urea, and sugar, could. Thus, colloid is not a substance, but rather a state of a substance that varies with molecular size.

Three Types of Solutions:

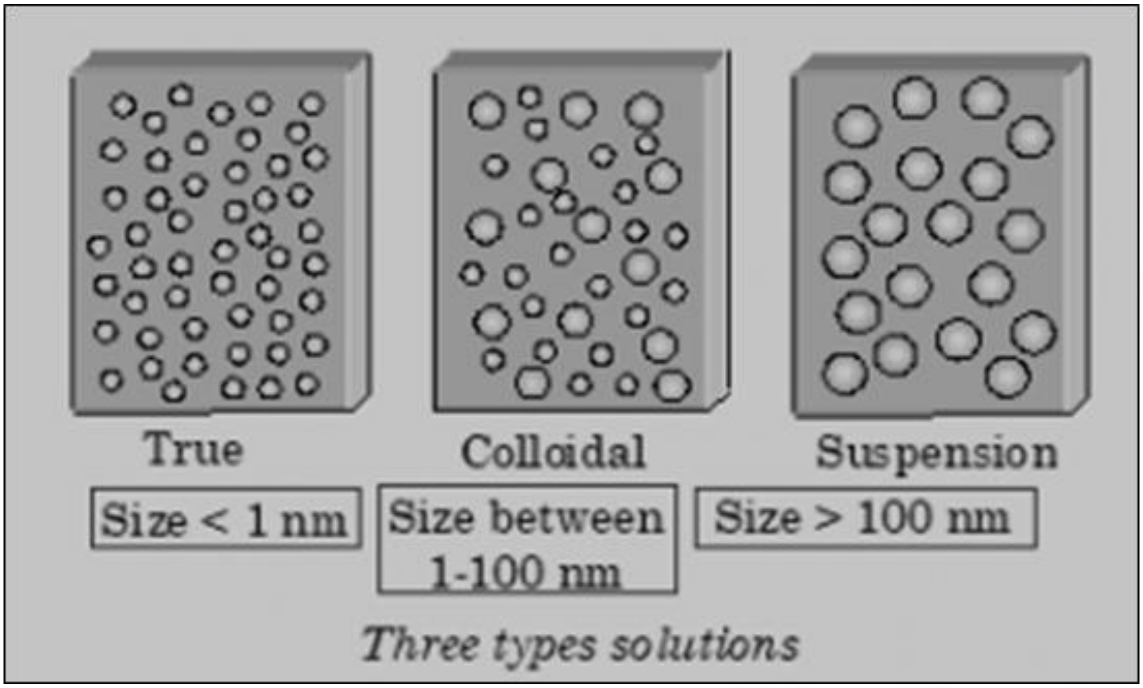

Figure 2: Types of Solution

A **true solution** is one that is homogeneous and contains small solute particles (molecules or ions) dispersed throughout a solvent.

Suspension is a heterogeneous mixture of insoluble small particles. The particle size exceeds 1000 nm.

Colloidal solution is a heterogeneous solution containing particles of varying sizes.

Colloids and their Classification:

Dispersed Phase:

It is a minor component that functions similarly to a solute in a solution.

Dispersion Medium:

It is a component that is commonly present in excess and functions similarly to a solvent in a solution.

Table 1: Colloids Classification [11]

Property	True solution	Colloidal Solution	Suspension
Size of Particles	Less than 10^{-9} m	Between range of 10^{-9} – 10^{-6} m	More than 10^{-6} m
Nature	Homogeneous	homogeneous but is heterogeneous.	Homogeneous
Visibility	The solute particles are invisible to naked eye and also under the microscope.	The solute particles are invisible to naked eye but can be viewed under powerful microscope	The solute particles are visible to naked eye.
Stability	The solute particles do not settle down and are stable.	The solute particles do not settle down and are stable. (On centrifugation the particles can settle)	The solute particles settle down and are unstable.
Filtration	The solute particles can pass through filter paper and no residue is seen on filter paper.	The solute particles passes through filter paper and no residue is left. (But the particles cannot pass through parchment membrane)	The solute particles can not pass through filter paper and residue is collected on filter paper.
Transparency	Transparent	Translucent	Opaque

Table 2: Types of Colloidal Dispersion [12]

Type name	Dispersed phase	Dispersion medium	Examples
Foam	Gas	Liquid	Whipped cream, shaving cream, soda-water
Solid foam	Gas	Solid	Froth cork, pumice stone, foam rubber
Aerosol	Liquid	Gas	Fog, mist, clouds.
Emulsion	Liquid	Liquid	Milk, hair cream.
Solid emulsion (gel)	Liquid	Solid	Butter, cheese.
Smoke	Solid	Gas	Dust, soot in air.
Sol	Solid	Liquid	Paint, ink, colloidal gold.
Solid sol	Solid	Solid	Ruby glass (gold dispersed in glass), alloys.

A colloidal dispersion of one gas in another is not possible since the two gases would give a homogeneous molecular mixture. The various types of colloidal systems are listed below in table 2. [13]

Conclusion:

The purpose of these experiments is to use standard spectroscopic techniques to investigate the surface chemistry of colloidal transition metals in organic solvents in order to establish a relationship between metallic clusters and molecular clusters and to determine the changes in chemical and physical properties that occur as cluster size increases from the molecular scale to the bulk. In general, the relationships are quite complex, necessitating sophisticated models and lengthy computations. However, understanding the structure-property relationships can significantly improve the tailored preparation and processing of colloidal suspensions. Although the book has reviewed current knowledge and methods, the final chapter also addresses the need to improve both.

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