Natural and Physical Sciences in Everyday Life
B.Sc FYUGP 2nd Sem
Paper: MDC-2
Paper Code: MDC0200103
Dr. Kangkana Deka

Unit : 2

Solutions and Colloids

A solution is a homogeneous mixture of two or more components in which the particle size is smaller than 1 nm. The term solution is commonly applied to the liquid state of matter, but solutions of gases and solids are possible. Common examples of solutions are sugar in water and salt in water solutions, soda water, etc. In a solution, all the components appear as a single phase. There is particle homogeneity i.e. particles are evenly distributed.

Colloids 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 nanometers. 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.

Classification of Colloids
The colloids are classified based on the following:
1. Based on their Physical State
Aerosol (air as the dispersion medium), Gels (solid dispersion medium) and Emulsion (liquid-liquid solutions in which the dispersed phase is liquid)

2. Based on their Dispersion Medium
Hydrosol (water acts as a dispersion medium), Alcosol (alcohol acts as a dispersion medium and Acrosol (contains a dispersed phase particle in the air).

3. Based on Interaction Forces
The types of colloidal solutions based on the interaction between the forces of the dispersion medium and dispersed phase are discussed below:

- **Lyophilic Colloids**
  The colloidal systems in which the colloidal particles interact to an appreciable extent with the dispersion medium are referred to as the lyophilic colloids. The term lyophilic means solvent loving. Owing to their affinity for the dispersion medium, such materials form colloidal sols.
- **Lyophobic Colloids**

Lyophobic colloids are composed of substances which have very little attraction, if existing, for the dispersion medium. These are the lyophobic (solvent-hating) colloids and, predictably, their properties differ from those of the lyophilic colloids. This is primarily due to the absence of a solvent sheath around the particle.

- **Association Colloids**
  Association or amphiphilic colloids are the third type of colloidal systems. In these types of colloids, certain molecules or ions, termed amphiphiles or surface-active agents, are characterized by having two distinct regions of opposing solution affinities within the same molecule or ion. They have one polar region which is attracted towards a polar solvent and within the same molecule; they have a no-polar region which is attracted towards the non-polar solvent.

Plastics

Any synthetic or semi-synthetic polymers are plastics. Plastics used for industrial work come from petrochemicals and refers to its ability to deform without breaking. The polymer used in making plastics are usually a combination of additives, colorants, plasticizers, stabilizers, fillers, and reinforcements. These additives affect the chemical composition, properties, and mechanical properties of plastic.

Plastics are mostly carbon-based atoms. Silicones are an exception since they based on the silicon atom. The carbon atom can link to other atoms with up to four chemical bonds.

The two types of plastics are Thermoplastics and thermosetting polymers.

1. **Thermoplastic**: Plastics that can be deformed easily upon heating and can be bent easily. Linear polymers and a combination of linear and cross-linked polymers come under thermoplastics. Examples are polypropylene (PP), polyethylene (PE), polyvinyl chloride (PVC) and polystyrene (PS).
2. **Thermosetting**: Plastics that cannot be softened again by heating once they are moulded. Heavily cross-linked polymers come under this category. Example: Bakelite, melamine, etc. Bakelite is used for making electrical switches whereas melamine is used for floor tiles.

Uses of Plastic

- Plastics are highly durable, lightweight and, most significantly, can be moulded into any form or shape. These properties are a few reasons for the use of plastics. Plastics are extremely versatile materials that can be useful for a wide range of applications. Below given are some applications.
- The potential to be moulded makes plastic ideal packaging material. Plastics in packaging help keep food healthy and fresh.

- As durable and lightweight, plastics have helped in the field of electronics. From computers and cell phones to TV and refrigerator, nearly all the appliances around us use plastic.
- Plastics help in making safety gears such as helmets, goggles, etc.
- Plastics are also useful in the construction sector because of their low maintenance and high durability.

Cement

Cement generally refers to a very fine powdery substance chiefly made up of limestone (calcium), sand or clay (silicon), bauxite (aluminum), and iron ore, and may include shells, chalk, marl, shale, clay, blast furnace slag, slate.

Cement is chiefly of two kinds based on the way it is set and hardened: hydraulic cement, which hardens due to the addition of water, and non-hydraulic cement, which is hardened by carbonation with the carbon present in the air, so it cannot be used underwater.
Non-hydraulic cement is produced through the following steps (lime cycle):

1. Calcination: Lime is produced from limestone at over 825°C for about 10 hours. ($CaCO_3 \rightarrow CaO + CO_2$)
2. Slaking: Calcium oxide is mixed with water to make slaked lime. ($CaO + H_2O \rightarrow Ca(OH)_2$)
3. Setting: Water is completely evaporated.
4. The cement is exposed to dry air, and it hardens after time-consuming reactions. ($Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$)

On the other hand, hydraulic cement is mainly made up of silicates and oxides:

1. Belite ($2CaO{\cdot}SiO_2$);
2. Alite ($3CaO{\cdot}SiO_2$);
3. Tricalcium aluminate/ Celite ($3CaO{\cdot}Al_2O_3$)
4. Brownmillerite ($4CaO{\cdot}Al_2O3{\cdot}Fe_2O_3$)

The most commonly used cement nowadays is hydraulic cement (i.e. hardens when water is added) known as Portland cement or Portland cement blends. These are usually the basic ingredient in making concrete, which is a construction material used as a load-bearing element. Portland cement is suitable for wet climates and can be used underwater.

Glass

Glass can be defined as a rigid super cooled liquid having no definite melting point and a high viscosity that prevents crystallization. It is an inorganic solid and non-crystalline material that is transparent in appearance. Using archaeological evidence, we can trace the usage of glass in the stone age period too. Some of the weapons and tools were made of naturally occurring volcanic glass. Silica is the main component of glass. There four types of glasses, they are:

- Annealed Glass
- Heat Strengthened Glass
- Toughened Glass
- Laminated Glass

Soap and Detergent

Chemical compounds used as cleaning agents like soaps and detergents are made up of a variety of different components. Various fatty acid combinations are dissolved in water to form a soapy sodium or potassium salt. Because the term “detergent” refers to a cleaning agent and is unaffected by the hardness of the water, detergents are much preferable to cleaning solutions.

Soap is the sodium or potassium salt of long-chain carboxylic acids (fatty acids). Detergents are sodium salts of long-chain benzene sulphonic acids. Hard soaps are sodium salts of fatty acids, while soft soaps are potassium salts of fatty acids. The soap contains many non-ionic hydrocarbons and an ionic $COO^- Na^+$ group. Soaps are surfactants (compounds that reduce the surface tension between a liquid and another substance) and therefore help in the emulsification of oils in water.

Soaps are generally prepared via the saponification of fats and oils.

The carboxylate end of the soap molecule is hydrophilic whereas the hydrocarbon tail is hydrophobic.

Pollutants and Contaminants

Pollutants are substances or materials which impact the environment and its creatures thereby hampering the quality of life. These include elements, molecules, and particles that contribute to pollution; when exposed to these materials, life can be harmed, and the effects on humans and plants are well known. They can be caused by human activity, such as trash, or by natural processes, such as volcanic ash. Pollutants have a negative impact on the quality of water and air and land.

The Pollutants come in a variety of the forms and including:

- Nitrogen oxides (NOx)
- Sulfur oxides (SOx)
- Particulate matter (PM)
- Ground level ozone (O_3)
- Volatile organic compounds (VOCs)
- Mercury (Hg)
- Peroxyacyl nitrates (PANs)

Types of Pollutants:

- **Water pollutants:** The runoff from industries, agricultural fields, and even urban areas contribute largely to water pollution. For instance, the industrial waste consists of toxic contaminants which hamper the quality of water. Moreover, these pollutants also cause the growth of algae which results in choking of the aquatic plants. Other than that, it also brings down the levels of oxygen which is the basis for the survival of the species found underwater. In addition, raw sewage is a major pollutant of water.
- **Soil Pollutants:** Soil also has a lot of pollutants which makes it very tough for the soil to remain fertile. The main source of soil pollution comes from Industries. Moreover, there is no proper disposal of the toxic chemicals, so they end up in the soil. Some common examples of soil contaminants are asbestos, lead, pesticide, and herbicide overdose and more.
- **Air Pollutants:** One of the major air contaminants of air is burning fossil fuels. This happens due to factory emissions and the use of automobiles. When one burns fossil fuels, smog gets formed as well as a thick layer containing particulate matter which encloses large zones in it. Air is polluted by harmful or excessive quantities of substances such as smoke and harmful gases from industries, CFCs and oxides produced by automobiles, the combustion of solid wastes. Air pollution contributes majorly to the respiratory problems which are lung cancer, bronchitis, asthma, and other lung diseases.

Heavy Metal Poisoning

Heavy metal is a metal or a metalloid element whose density is larger than 4 g/cm3. It is characterized by its thermal and electrical conductivity, high toxicity, ductility, and luster. The term "heavy metal" has been traditionally used in environmental and scientific literature to refer to certain elements, typically transition metals, metalloids, and some non-metals, that are associated with contamination and potential toxicity. Alongside these harmful elements, heavy metals such as: iron, zinc, copper, and manganese are vital for various physiological functions in living organisms, in small quantities. Although excessive exposure to these essential metals can be harmful, they serve crucial roles in cellular processes and enzyme activities.

The most common heavy metals are:

- Mercury (Hg)
- Lead (Pb)
- Chromium (Cr)
- Cadmium (Cd)
- Arsenic (As)
- Copper (Cu)

Heavy metal poisoning occurs when microscopic molecules of metals accumulate within your body after exposure. Heavy metals attach to your cells and prevent them from performing their functions, which causes symptoms that could be life threatening without treatment.
Several metals can be toxic to your body. The most common toxic metals are:

- **Lead:** Contaminated water from lead pipes, batteries, paint, gasoline, construction materials.
- **Mercury:** Liquid in thermometers, lightbulbs, batteries, seafood, topical antiseptics.
- **Arsenic:** Topical creams, herbicides, insecticides, pesticides, fungicides, paints, enamels, glass, contaminated water, seafood, algae.
- **Cadmium:** Cigarette smoke, metal plating, batteries.
- **Thallium:** Rodenticides, pesticides, fireworks.

Some complications that may arise from overexposure:

- **Lead Poisoning** Overexposure can lead to high blood pressure and damage to your reproductive organs.
- **Mercury Poisoning** It's possible to experience lung damage, brain damage, vision problems, skin changes, and gastrointestinal problems.
- **Arsenic Poisoning** Overexposure can cause neurological problems, gastrointestinal issues, cancer, and low blood pressure.
- **Cadmium Poisoning** You may experience decreased lung and kidney function.

Poisonous Gases

- **Carbon Monoxide:** Carbon Monoxide is colourless, tasteless and lighter than air with a garlicky odour. It is a highly poisonous gas that is absorbed into the lungs and combines with haemoglobin of the RBC in the blood and forms a stable compound carboxyhaemoglobin. The affinity of haemoglobin for Carbon Monoxide has 200-300 times greater for haemoglobin than that of oxygen. It reduces oxygen content of blood and then of tissues. Apart from its role as an environmental contaminant, Carbon Monoxide is responsible for a significant number of deaths encountered in forensic practice.
- **Carbon Dioxide:** Carbon Dioxide is colourless, odourless, non-flammable gas which is heavier than air. In its solid form (dry ice) it is whitish in colour and acts as a corrosive. The carbon dioxide intoxication usually results from the physiological disturbances. The gas may disperse slowly if ventilation is poor. It is used as Fire extinguisher, in Carbonation of soft drinks, as Shielding gas during welding processes, in Synthesis of urea, dry ice, and other organic synthesis. Carbon Dioxide poisoning is generally Accidental in nature like worker working in deep well, dampen pit, overcrowding in ill-ventilated room etc.
- **Methyl Isocyanate:** Methyl Isocyanate (MIC) is one of a group of Isocyanates, the others being toluene diisocyanate (TDI) and diphenylmethane di-isocyanate (MDI). Methyl Isocyanate is a colourless liquid with pungent sweetish odour below 27°C but it becomes gas at 39°C. It is a highly volatile and inflammable in nature. It is an extremely reactive chemical and needs to be stored carefully. Its contact with water results in an exothermic reaction. Methyl isocyanate is produced by heating metal cyanates or by heating N, N-diphenyl-N'- methylurea. Methyl Isocyanate is generally used in the manufacture of carbamate pesticide and polyurethane articles like plastics, urethane foam, adhesives, etc. Methyl Isocyanate causes carbamylation at biochemical level Methyl Isocyanate is a powerful respiratory irritant. Even brief exposure at high concentrations may cause severe injury, burns, or even death.
- **Hydrogen Sulphide:** Hydrogen sulphide is in general referred as Sewer Gas and a well-known neurotoxic leading to olfactory nerve paralysis and loss of consciousness at a relatively low dose. Hydrogen sulphide is a colourless, toxic and flammable gas. It is responsible for the foul odour of rotten eggs and pretentiousness. It is formed during decomposition of organic substances containing sulphur. Hydrogen Sulphide readily diffuses through the tissues. The toxicity of Hydrogen sulphide is similar with that of hydrogen cyanide. It forms a complex bond with iron in the mitochondrial cytochrome enzymes, thereby blocking oxygen from binding and stopping cellular respiration.
- **Phosgene:** Phosgene is a colourless gas, heavier than air, with an odour of freshly-cut hay. At high concentrations, the gas has an odour described as suffocating, strong, stifling, or pungent. At low temperature or when compressed, phosgene condenses to a colourless to light yellow, non-combustible, highly toxic, fuming/volatile liquid that produces poisonous vapour and sinks in water. Phosgene is hydrolysed in the body to hydrochloric acid which produces a systemic inflammatory response. It also stimulates the synthesis of

lipoxygenase-derived leukotrienes causing pulmonary oedema. Further, phosgene increases pulmonary vascular permeability, leading to increased fluid accumulation in the interstitial and alveolar compartments.

- **Hydrgen Cyanide:** Salts of cyanide releases hydrogen cyanide in stomach due to action of hydrochloric acid and then absorbed as cyanide ion (CN-).Cyanide occurs as a gas or liquid or solid. In its gaseous state it is referred to as Hydrogen Cyanide (HCN). Hydrogen cyanide is a colourless flammable gas with a faint bitter almond odour. Hydrogen cyanide is occasionally used for fumigation (ships, greenhouses), deaths can occur from negligence. Industrial and laboratory mishaps involving this chemical are also not infrequent. Cyanogen and cyanogen halides (cyanogen bromide, cyanogen chloride, and cyanogen iodide) release hydrogen cyanide and have been used as military chemical warfare agents. During the First World War, HCN was used as a war gas but was quickly replaced by other more effective war gases such as Mustard Gas.
- **Chlorine:** Chlorine is a greenish-yellow gas with a pungent odour. Chlorine is not found free in nature due to its reactivity with other chemicals. Instead, it is found as sodium chloride in landlocked lakes, as rock salt in underground deposits, in brines, and in natural deposits of Sylvite and Carnallite. Chlorine is an extremely active oxidising agent and causes rapid and extensive destruction of organic tissue. It combines with tissue water to produce HCl, producing injury and reactive oxygen species. Swimming pool chlorinator tablets or pellets may result in chlorine gas exposure.