Module 1: "Introduction to Colloid"

Lecture 2: ""

The Lecture Contains:

- Intraction between Particles
- Types of Common Colloids
- Are Alloys Colloids?
- Importance of Colloids
- Surfactants
- Detergency
- Scope of the Field
- Industrial Concerns

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Interactions between particles

The interaction between particles is due to the interaction of the molecules in one particle with those in the other particles (Fig. 1.5). Although an interaction between two individual molecules becomes negligible after a small distance (say about 5 Angstrom), the interaction between two particles containing many molecules is significant upto much larger distances. There are many different types of interactions between molecules.

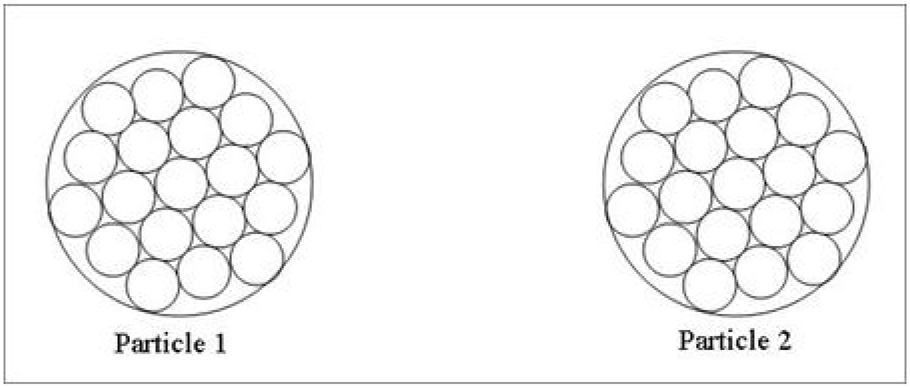

Figure 1.5. Particles are made up of many molecules which interact with each other

Some of the significant types of interactions between molecules are-

1. Van Der Waals force
2. Electrostatic double layer force
3. Acid-Base interactions (For this interaction, conjugate polarity is required amongst neighboring molecules)

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These forces between two molecules can be expressed in a generalized relation

$$F = -\nabla\Phi \qquad (1.1)$$

where Φ is the total interaction energy (or potential) function obtained by summing up all pair-wise interactions between the molecules, and F is the generalized force.

If F is a negative quantity, it means that the force is attractive in nature, and vice versa. Therefore, having an insight into molecular level interactions paves the way to understand the macroscopic properties of such a system.

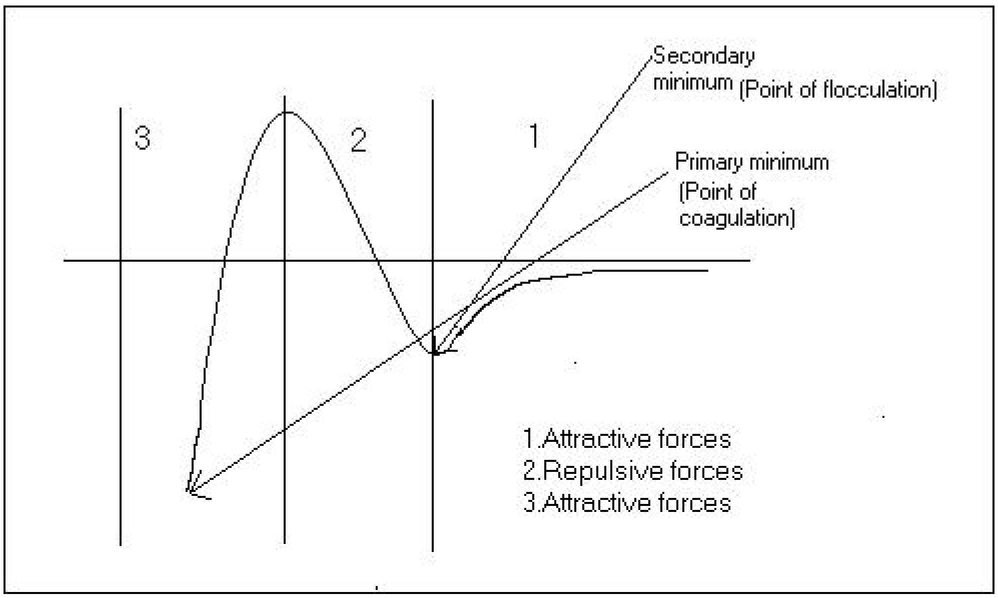

Figure 1.6. An example of an energy function

Consider an example of an energy function (Fig. 1.6). Three regions can be observed here. In region 1, the slope of the potential function is positive which makes F negative. Thus, this is the region where the forces are attractive in nature. The dispersion in such a state would not be stable because the particles would tend to come close to each other. Similarly, in region 2, F is positive which makes the forces repulsive.

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We start with the particles placed far apart and bring them closer till we reach the secondary minimum. When particles come together in a secondary minimum, it is called flocculation. Then we further decrease the distance to reach the primary minimum and this is termed as coagulation.

Consider another example (Fig. 1.7). Here the forces are always attractive, even up to the primary minimum. So this dispersion would not be thermodynamically stable until it reaches the primary minimum . But still it could be kinetically stable because viscous resistance could resist the coagulation and it could take a very long time to reach the primary minimum. If F_d is the drag force on a particle and F_i is the interaction force, then for such a (kinetically stable) system,

$$F_i + F_d = 0 \qquad (1.2)$$

Even though forces between two atoms or molecules are very weak and persist to short distances, summing up of these forces on the volume of colloidal particles can generate enough muscle to manifest even macroscopic behavior.

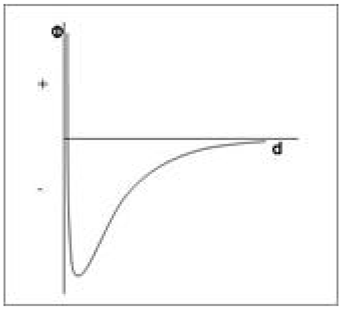

Figure 1.7. Another example of an energy function

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Types of common colloids

Continuous phase	Dispersed phase	General name	Example
Gas	Liquid	Aerosol	Fog, mist, fine sprays
Gas	Solid	Aerosol	Smoke
Liquid	Gas	Foam[1]	Soap foam
Liquid	Liquid	Emulsions, micro-emulsions[2]	Cream
Liquid	Solid	Sols	Paint
Solid	Gas	Solid foam	Polyurethane
Solid	Liquid	Gel[3]	Bitumen
Solid	Solid	Composite material[4]	Composites, ceramics

[1] In a foam (soap foam, for example), the dispersed particles may not be small. But still it falls in the category of colloids because it is interfacial phenomena that are important in such a case.

[2] Micro-emulsion is a dispersion in which the dispersed particles have the size of the order of a micron.

[3] Liquid particles trapped in solid matrix.

[4] To obtain an even distribution is a point of concern in composite materials.

Are alloys colloids?

Alloys are solid solutions (i.e. homogenous) of two or more metals. The homogeneity implies that such solutions are not a part of colloidal phenomenon. A colloid should necessarily have two discernible phases, but in alloys the metals are indistinguishable from each other.

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Importance of colloids

Using the knowledge of colloidal phenomena, we can create materials having some desired properties. For example,

- Composites, where we can tailor the properties appropriate for a particular purpose.
- Pastes for micro-electronic components having a suitable thermal conductivity.
- Structural materials for aircrafts and automobiles, which make them tough as well as lightweight.
- Coatings for contact lens or a graft giving it the right surface properties. Here, one is concerned with the bio-compatibility which is a property of the surface and not the bulk because the lipids or proteins would see only the surface of the lens/graft.
- Nano-composites where the dispersed particles are of the size less than one nm.

But we cannot simply blend one kind of particles with another kind to make a composite. There are involved procedures for doing this, which require an understanding of colloid physics and chemistry. For example, consider a composite. When it is loaded, a failure is more likely to get initiated at an interface. The interface might tear leaving behind a blister. So, we have to go the colloidal scale to determine the strength of a composite.
Apart from the above applications, colloidal phenomenon also has immense importance in the field of surfactants and detergency.

Surfactants

Foam, emulsions and micro-emulsions cannot be prepared without the use of surfactants.

A surfactant molecule (Fig. 1.8) has a hydrophilic head and a hydrophobic tail. The head could have a charge and accordingly the molecule would be called anionic, cationic or a neutral surfactant. Many surfactant molecules may come together to form structures known as micelles. These could take various shapes (Fig. 1.9) like spherical, cylindrical and bilayered micelles.

Figure 8: Structure of a surfactant molecule

[1] water loving , and hence soluble in water-like substances.

[2] water hating, and hence soluble in oil-like substances.

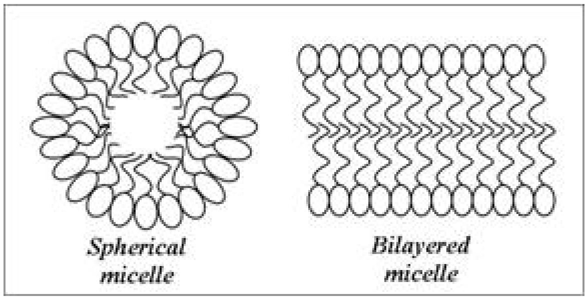

Figure 1.9. Micelles

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Detergency

Two important applications of detergency are:

1. Cleaning of fabrics
2. Cleaning of wafers

These applications rest on the concept of interfacial tension. Addition of surfactant molecules helps in altering the interfacial tension between two surfaces. The surfactant molecules minimize the total energy of a system by favorably changing their orientation .For example, air-water interfacial tension can be reduced to 10 dynes/cm from a value of 72 dynes/cm by use of suitable surfactants.

Scope of the field

Colloid and interface science is an interdisciplinary and a multidisciplinary science. For example, consider MEMS and NEMS. Micro-Electro-Mechanical Systems (MEMS) is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through micro-fabrication technology. These micromechanical components are fabricated using compatible "micromachining" processes that selectively etch away parts of the silicon wafer or add new structural layers to form the mechanical and electromechanical devices. This way of fabrication is also known as the top-down approach.

Nano-Electro-Mechanical Systems (NEMS) means machines, sensors, computers and electronics that are on the nano-scale. Here, a top-down approach can not be followed. Instead a bottom-up approach is used. In a bottom-up approach, one starts from the basic building units, molecules, and make larger objects by arranging those units in an order. Today, great importance is being attached to this approach to science, and in coming years it is expected to have a tremendous impact on our society

Within the domain of chemical engineering, colloids have been found to be of great use in applications in many areas like catalysis, chromatography and tertiary oil recovery.

Colloids are also equally important in other fields like nano-biology. For example, scientists have been working on targeted drug delivery where they intend to use the specificity of nano-molecules in treating diseases like cancer.

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Industrial concerns

1. Preparation of colloids

The main concern is to make stable dispersions so that the product has an acceptable shelf-life.

2. Use of colloids

Colloids, as we have seen, have varied uses. To name a few, they find use in photographic films, catalysis, membrane separation, chromatographic separation, detergency and flotation.

3. Handling of colloids.

Colloids are viscous fluids and therefore they behave as non-Newtonian fluids. We need to understand rheology (the science of the deformation and flow of matter) when dealing with issues like transportation and storage.

4. Destruction of colloids.

In some situations (like sewage disposal etc.), knowledge of methods of efficiently destroying colloids is also required.

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