



Interfacial Phenomena



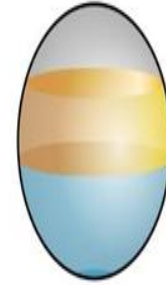
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Physical Pharmacy- 2nd course

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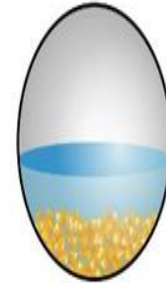


- When phases exist together, the **boundary between two of them** is known as an **interface**.
- The **properties of the molecules forming the interface** are often sufficiently **different from those in the bulk of each phase** that they are referred to as forming an **interfacial phase**.
- Several types of interface can exist, depending on whether the two adjacent phases are in the solid, liquid, or gaseous state as shown in the following table.
- For convenience, these various combinations are divided into two groups, namely, **liquid interfaces and solid interfaces**.



Liquid/Liquid

- The liquid/liquid interface—including classic oil/water products—is found in separation, purification, catalysis, extraction and other processes.



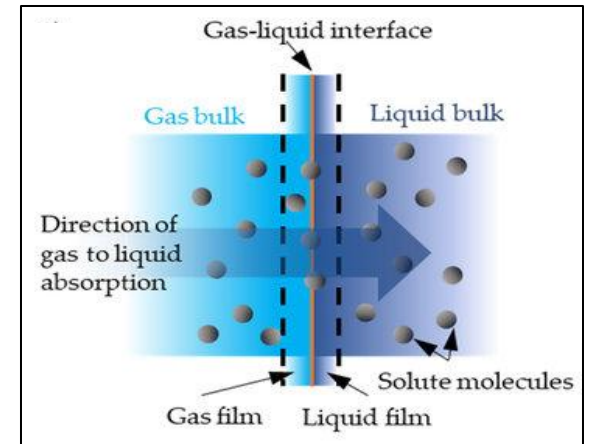
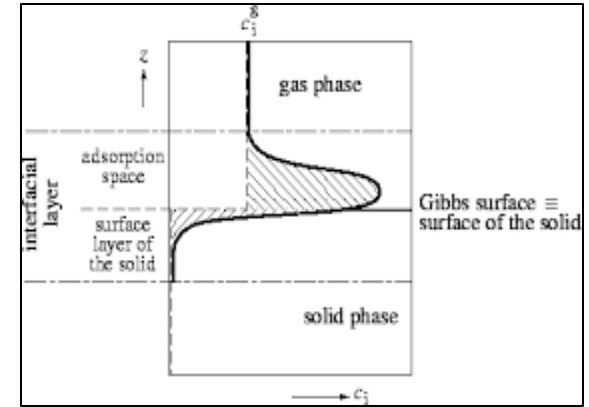
Liquid/Solids

- These interfaces are common in Water and Wastewater Treatment, Pulp and Paper, Mining and Quarrying, and Chemical Processing.

- **Liquid interfaces** involve the association of a **liquid phase with a gaseous or another liquid phase.**
- **Solid interfaces** will deal with systems containing **solid–gas and solid–liquid interfaces. Solid–solid interfaces** have practical significance in **pharmacy** (e.g., the **adhesion between granules, the preparation of layered tablets, and the flow of particles**)
- The term **surface** is used when **referring to either a gas–solid or a gas–liquid interface.**

Ex: 1- tabletop surface forms a gas–solid interface with the atmosphere above it.

2- The surface of a rain drop constitutes a gas–liquid interface.



Phase	Interfacial Tension	Types and Examples of Interfaces
Gas–Gas	—	No interface possible
Gas–liquid	γ_{LV}	Liquid surface, body of water exposed to atmosphere
Gas–solid	γ_{SV}	Solid surface, tabletop
Liquid–liquid	γ_{LL}	Liquid–liquid interface, emulsion
Liquid–solid	γ_{LS}	Liquid–solid interface, suspension
Solid–solid	γ_{SS}	Solid–solid interface, powder particles in contact

Liquid Interfaces

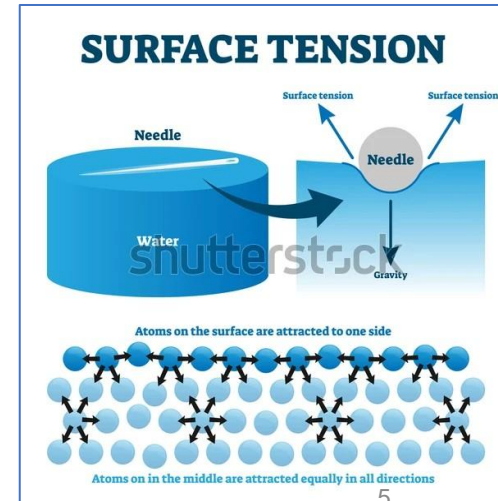
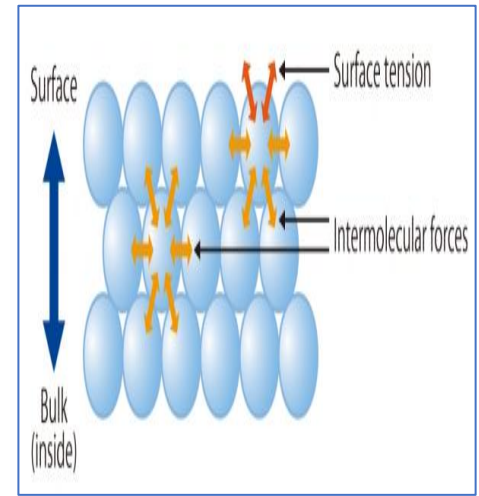
Surface and Interfacial Tensions

Surface tension: It is a property of the surface of the liquid that causes it to behave as an elastic sheet. It is **caused by the attraction between molecules of the liquid** by various intermolecular forces. In the liquid state, the **cohesive forces between adjacent molecules** are well developed.

➤ **Molecules in the bulk liquid** are surrounded in all directions by other molecules for which they have an **equal attraction (Intermolecular forces)**.

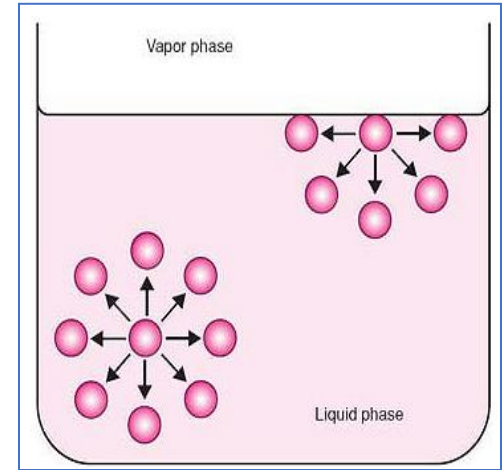
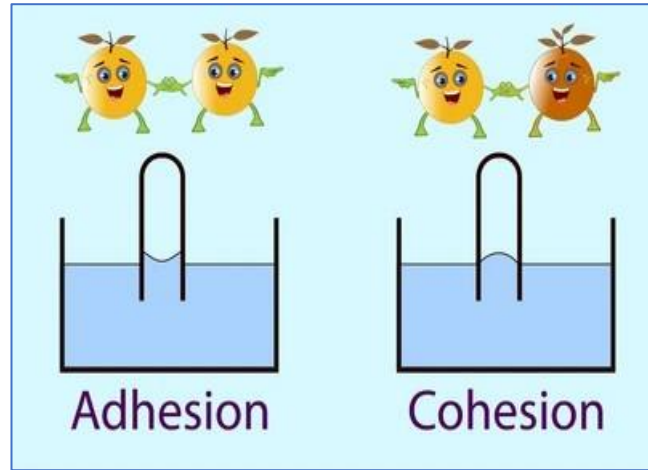
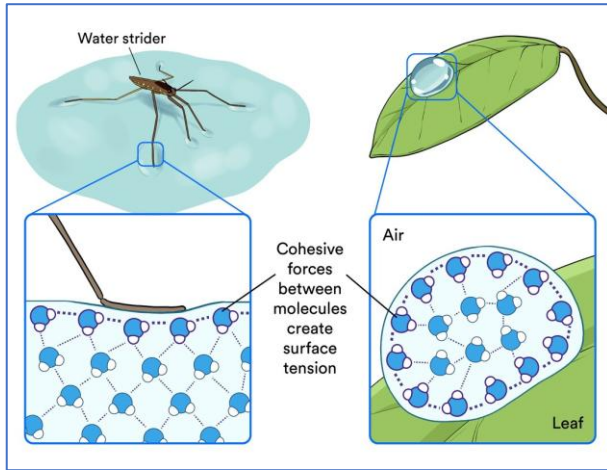
➤ **Molecules at the surface** (i.e., at liquid–air interface) can only develop:
A- **Attractive cohesive forces** with other **liquid molecules that are situated below and adjacent to them**.

B- **Adhesive forces of attraction** with the **molecules constituting the other phase involved in the interface**, although, in the case of the **liquid–gas interface, this adhesive force of attraction is small**.



Note:

1. The net effect is that the molecules at the surface of the liquid experience an inward force toward the bulk, as shown in the Figure. Such a force pulls the molecules of the interface together and, as a result, contracts the surface, resulting in a **surface tension**.



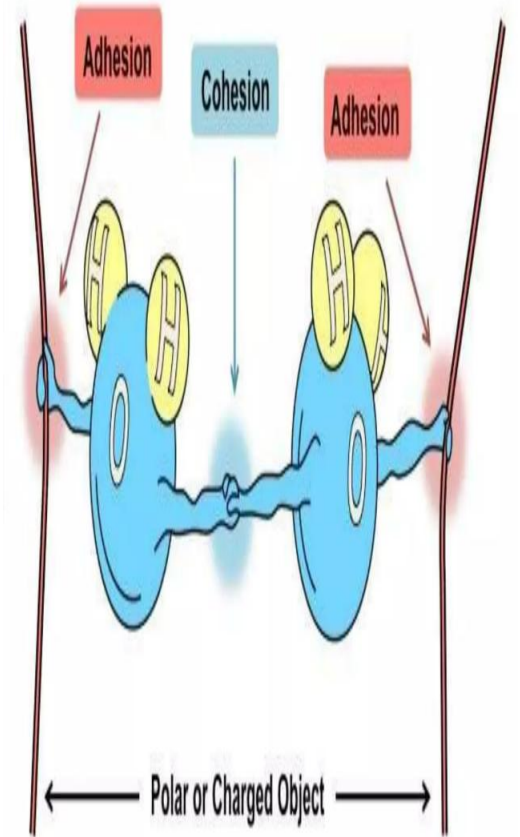
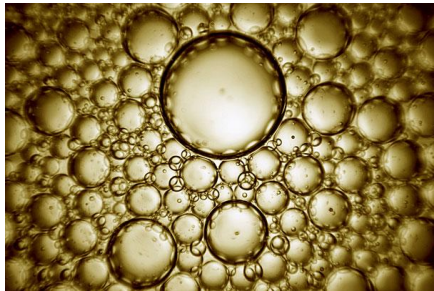
2. Unequal attractive forces acting on molecules at the surface of a liquid as compared with molecular forces in the bulk of the liquid.

Interfacial tension

- **Is the force per unit length** existing **at the interface** between two immiscible liquid phases and, like surface tension, has the units of **dynes/cm**.
- Ordinarily, **interfacial tensions are less than surface tensions** because the adhesive forces between two liquid phases forming an interface are greater than when a liquid and a gas phase exist together. That's mean:

Adhesive forces between two liquids more than cohesive forces with the liquids.

Note: If two liquids are completely miscible, no interfacial tension exists between them.



Some representative surface and interfacial tensions are listed in the following table

Substance	Surface Tension (dynes/cm)	Substance	Interfacial Tension (dynes/cm)
Mercury	476	Mercury	375
Water	72.8	Water	-----
Glycerin	63.4	Glycerin	Zero (miscible liquids)
Oleic acid (Carboxylic acid)	32.5	Oleic acid	15.6
Benzene	28.9	Benzene	35.0
Chloroform	27.1	Chloroform	32.8
Olive oil (Oleic acid is the chief constituent)	35.8	Olive oil	22.9
Octanol (alcohol)	26.5	Octanol	8.5

- Values for surface tension reflects the nature of intermolecular forces present.

➤ Large values for mercury (metallic bonds) and water (H-bond) and the lower values for benzene and chloroform (London dispersion forces).

- Values of interfacial tensions reflects the differences in chemical structure of the two phases involved

➤ The greater the tendency to interact, the less interfacial tension (means no interface as in water).

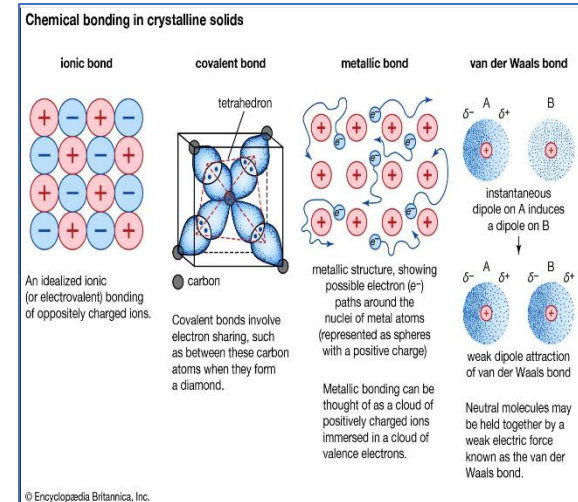


In each case the presence of chemical groups capable of hydrogen bonding with water markedly decrease interfacial tension.

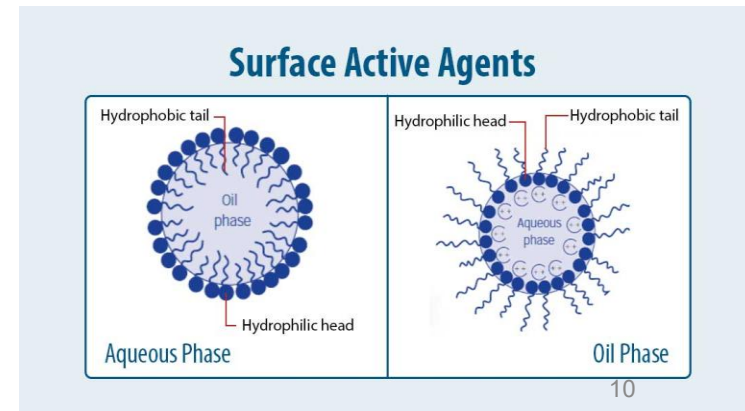
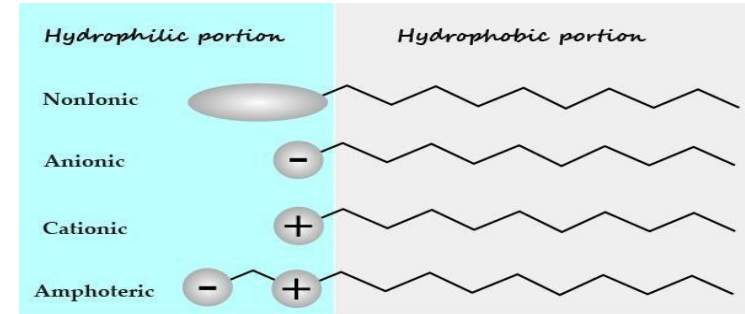
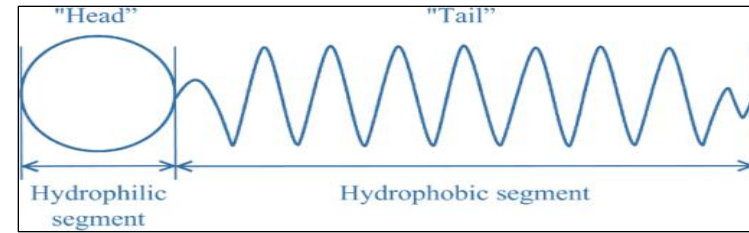
The weak intermolecular force which results when unevenly distributed electrons create a temporary dipole



London dispersion force



- Interfacial tension causes immiscible liquids to resist mixing (due to formation of interface between liquids).
- Oil and water do not mix because of interfacial tension. To dispense one in the other, it is necessary to introduce another kind of molecule that has **affinity for both oil and water** like an **amphiphile molecule**. This type of molecule is called **surface active agent (S.A.A) or Surfactant**. These molecules when placed at the interface of oil and water will decrease the interfacial tension, allowing oil and water to mix.
- **Both Surface and interfacial tensions decrease** by:
 - Increasing temperature, due to increase in the kinetic energy of the molecules.
 - Addition of S.A.A



Surface free energy

Each molecule near the surface of liquid possesses a certain excess of potential energy as compared to the molecules in the bulk of the liquid.



The **higher the surface of the liquid**, the more molecules have this excessive potential energy.

Therefore, if the **surface of the liquid increases** (e.g., when water is broken into a fine spray), the **energy of the liquid also increases**. Because this energy is proportional to the size of the free surface, it is called a surface free energy.

Surface free energy: defined as the work that must be done to increase the surface by unit area. As a result of such an expansion, more molecules must be brought from the bulk to the interface. The more work that has to be expended to achieve this, the **greater is the surface free energy**.

The liquid takes form with minimal free surface and with minimal surface energy. For example, **liquid droplets** tend to assume a **spherical shape** because a sphere has the **smallest surface area per unit volume**.

Measurement of Surface and Interfacial Tensions

Among the several methods that exist for obtaining surface and interfacial tensions, only the **capillary rise** and the **DuNoüy ring methods**.

The choice of a particular method often depends on:

1. Whether surface or interfacial tension is to be determined
2. Accuracy and convenience desired
3. Sample size
4. Whether the effect of time on surface tension is to be studied

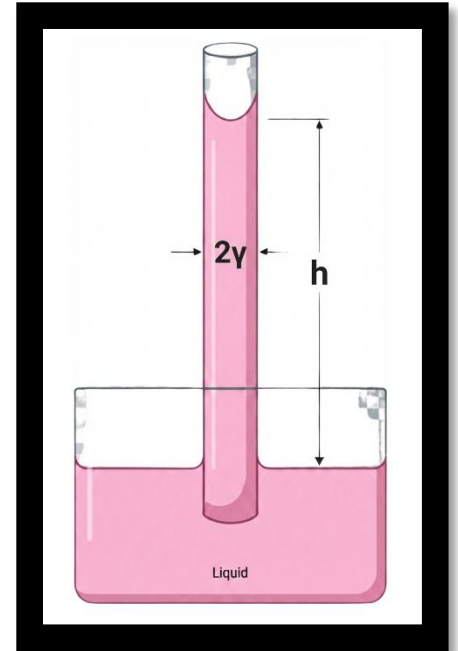
Capillary Rise Method

When a capillary tube is placed in a liquid contained in a beaker, the liquid generally rises up in the tube to a certain distance.



Because the **force of adhesion** between the liquid molecules and the capillary wall is **greater than** the **cohesion** between the liquid molecules, the **liquid is said to wet**

The capillary wall, spreading over it and rising in the tube (spreading is discussed in some detail later).



By measuring this **rise in a capillary**, it is possible **to determine the surface tension of the liquid**.

It is **not possible**, however, to obtain **interfacial tensions** using the capillary rise method.

Consider a capillary tube immersed in a liquid that wets its surface, as seen in Figure before. **Because of the surface tension, the liquid continues to rise in the tube, but because of the weight of the liquid, the upward movement is just balanced by the downward force of gravity**

$$\gamma = \frac{1}{2} r h \rho g$$

where r is the inside radius of the tube, h is the height of the liquid inside the tube,

ρ is the density of the liquid, g is the acceleration due to the gravity

Example: A sample of chloroform rose to a height of 3.67 cm at 20°C in a capillary tube having an inside radius of 0.01 cm. What is the surface tension of chloroform at this temperature? The density of chloroform is 1.476 g/cm³. We write

$$\gamma = \frac{1}{2} r h \rho g$$

$$\gamma = \frac{1}{2} \times 0.01 \text{ cm} \times 3.67 \text{ cm} \times 1.476 \text{ g/cm}^3 \times 981 \text{ cm/sec}^2$$

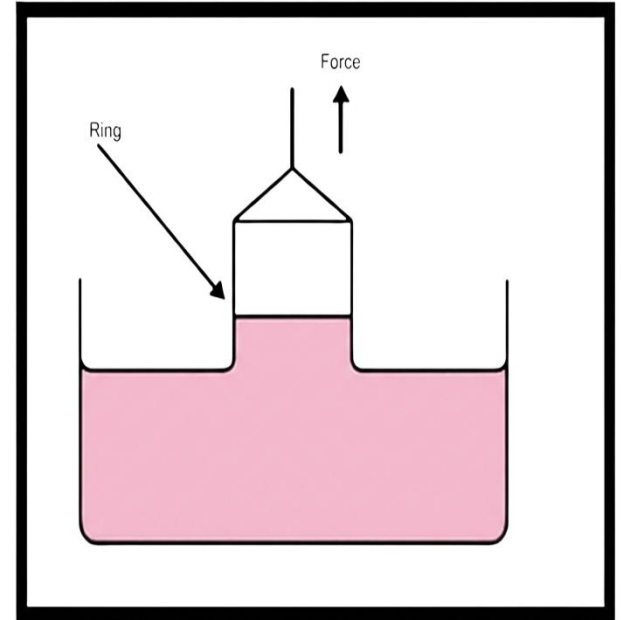
$$\gamma = 26.6 \text{ g/sec}^2 = 26.6 \text{ dynes/cm}$$

DuNoüy Ring Method

The DuNoüy tensiometer is widely used for measuring surface and interfacial tensions.

Mechanism: the principle of the instrument depends on the fact that the force necessary to detach a platinum–iridium ring immersed at the surface or interface is proportional to the surface or interfacial tension.

The **force** required to **detach the ring** in this manner is **provided by a torsion wire** and is **recorded in dynes** on a calibrated dial.



Spreading Coefficient (S)

Lotions, creams, sunscreens, and many cosmetics must be spread on the skin to exert their effect.

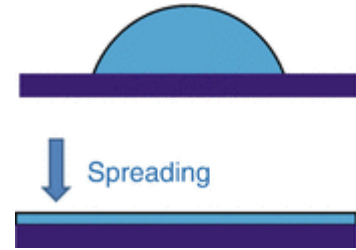
When a liquid spreads over the surface of a substrate, it covers all or a part of the surface. (Substrate can be a solid or another liquid that is immiscible with the spreading liquid).

➤ When a drop of oil is added on the surface of water, 3 things may happen:

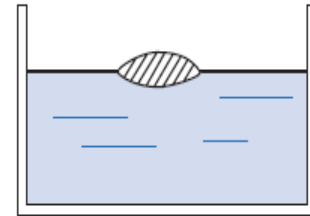
A. The drop may spread as a **thin film** on the surface of water.

B. It may form a **liquid lens** if the oil cannot spread on the surface of water.

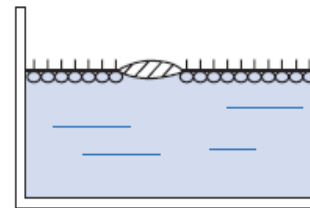
C. The drop may spread as a **monolayer film with areas that are identified as lenses**.



A



B



C

Spreading depends on the surface tension of the liquids involved and on the interfacial tension between them, that is mean spreading depends on the force of cohesion and adhesion.

For example : oleic acid is placed on the surface of water, it will spread as a film if the force of adhesion between the oleic acid molecules and the water molecules is greater than the cohesive forces between the oleic acid molecules themselves.

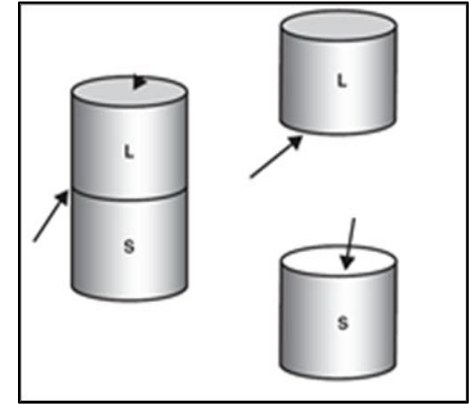
➤ Since spreading is dependent on the forces of adhesion and cohesion

That is mean it depend on:

1- **work of adhesion:** energy required to break adhesive bond between oil and water (is the energy required to break the attraction between the unlike molecules or to separate two immiscible liquids that form an interface).

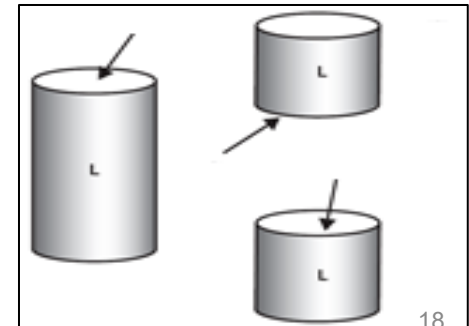
2- **work of cohesion:** energy required to break cohesive bond between oil molecules.

Work of Adhesion



L: is the spreading liquid
S: is the substrate

Work of Cohesion



Work of adhesion: is equal to the newly created surface tensions, γ_L and γ_S , minus the interfacial tension, γ_{LS} , that has been destroyed in the process. The work of adhesion is thus:

$$W_a = \gamma_L + \gamma_S - \gamma_{LS}$$

Work of cohesion: is the work required to separate **the molecules of the spreading liquid** so that it can flow over the substrate:

$$W_c = 2 \gamma_L$$

For spreading to occur the work of adhesion should be greater than the work of cohesion

W_a - W_c = S (S is known as spreading coefficient)

OR

S = W_a - W_c

$$= (\gamma_L + \gamma_S - \gamma_{LS}) - 2\gamma_L$$

$$= \gamma_L + \gamma_S - \gamma_{LS} - 2\gamma_L$$

$$= \gamma_S - \gamma_{LS} - \gamma_L$$

$$\mathbf{S = \gamma_S - (\gamma_L + \gamma_{LS})}$$

S = +ve value the liquid spread as a film

S = -ve value the liquid form **globules or floating lens** and fail to spread over the liquid

Example : Which liquid is spread over the other?

$$\gamma_{\text{Hexane}} = 18 \text{ dyne/cm}$$

$$\gamma_{\text{water}} = 72.8 \text{ dyne/cm}$$

$$\gamma_{\text{Hexane/water}} = 50.8$$

If we want to spread hexane over water

$$S = \gamma_S - (\gamma_L + \gamma_{LS})$$

$$S = 72.8 - (18 + 50.8)$$

$$S = 4.0 \text{ dyne/cm}$$

If we want to spread water over hexane

$$S = \gamma_S - (\gamma_L + \gamma_{LS})$$

$$S = 18 - (72.8 + 50.8)$$

$$S = -105.6 \text{ dyne/cm}$$

- Therefore, the fact that both liquids are the same, the **high surface tension of water prevent its spreading over hexane**, while hexane with low surface tension and low cohesive forces can spread over water.

Home Work

If you know that

$$\gamma_{\text{water}} = 72.8 \text{ dyne/cm} \quad \gamma_{\text{oleic acid}} = 32.5 \text{ dyne/cm} \quad \gamma_{\text{water/oleic acid}} = 15.6 \text{ dyne/cm}$$

Which liquid can spread over the other ? Explain

Note: Sometimes **spreading** will occur only **initially**, and **later** the spreading liquid will be converted, and a **lens will form**.



- The **conversion of the liquid to a lens** occurs because the two **substances** in contact with each other become **mutually saturated** and their respective **surface tensions become different from the initial surface tensions** (when the liquids were pure).
- If we use a **prime (')** to denote the values following equilibration (**saturation**) (i.e., final rather than initial values), then the new surface tensions are γ_S' and γ_L' . When mutual saturation has taken place, the **spreading coefficient may be reduced or may even become negative**.

Example 16-7: If the surface tension of water γ_S is 72.8 dynes/cm at 20°C, the surface tension of benzene, γ_L , is 28.9 dynes/cm, and the interfacial tension between benzene and water, γ_{LS} , is 35.0 dynes/cm, what is the initial spreading coefficient? Following equilibration, γ_S' is 62.2 dynes/cm and γ_L' is 28.8 dynes/cm. What is the final spreading coefficient?

$$S = \gamma_S - (\gamma_L + \gamma_{LS})$$

$$S = 72.8 - (28.9 + 35)$$

$$S = 8.9 \text{ dyne/cm}$$

After equilibrium

$$S' = \gamma_S' - (\gamma_L' + \gamma_{LS})$$

$$S' = 62.2 - (28.8 + 35)$$

$$= -1.6 \text{ dyne/cm}$$

Therefore, when **benzene is added to water**: 1- Observe an initial rapid spreading of benzene on the surface of the water

2- Later benzene and water become mutually saturated with each other, the benzene retracts and forms a lens.

• In the case of **organic liquids spread on water**, it is found that although the initial spreading coefficient may be positive or negative, the **final spreading coefficient always has a negative value**.

It is **important to consider the types of molecular structures that lead to high spreading coefficient**.

Initial Spreading Coefficient, S, at 20°C

Ethyl alcohol	50.4
Propionic acid	45.8
Ethyl ether	45.5
Acetic acid	45.2
Acetone	42.4
Undecylenic acid	32 (25°C)
Oleic acid	24.6
Chloroform	13
Benzene	8.9
Hexane	3.4
Octane	0.22
Ethylene dibromide	-3.19
Liquid petrolatum	-13.4

Notes: 1. A material spreads over water because it contains polar groups such as COOH or OH (Ex: Propionic acid and ethyl alcohol).

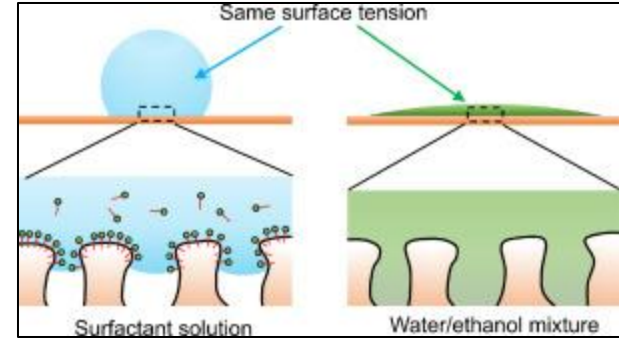
2. Increase in carbon chain of acid → decrease polar–nonpolar ratio and the spreading coefficient (S) on water decreases.



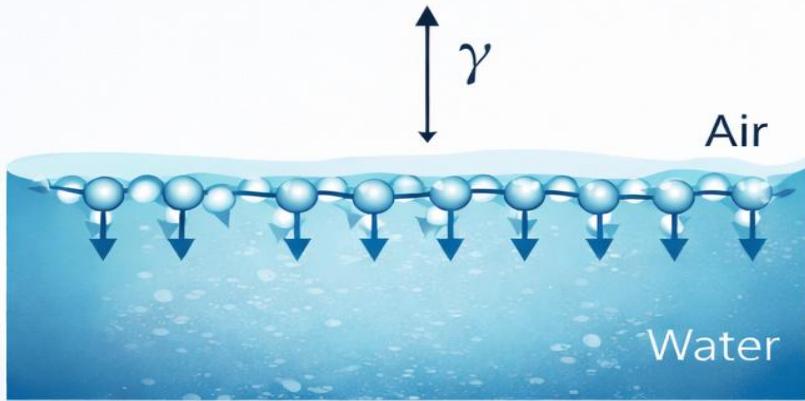
Many nonpolar substances, such as liquid petrolatum ($S = -13.4$), fail to spread on water.

3. While Benzene spreads on water not because it is polar but because the cohesive forces between its molecules are much weaker than the adhesion for water.

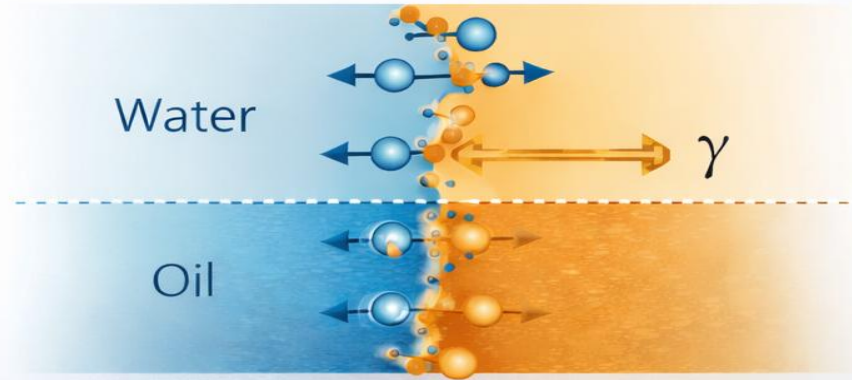
4. Surface active agents (SAA) increase (S) because they interfere with cohesive forces.



Thank You for Your Attention!



Surface Tension



Interfacial Tension

Adsorption at Liquid Interfaces

Adsorption is a **spontaneous phenomenon**, adsorption it can **occurs at the surface or interfaces of liquid with other liquids (positive adsorption)**.

It is the **amphiphilic nature of surface-active agents** that causes them to be absorbed at interfaces, whether these are **liquid-gas or liquid-liquid interfaces**.

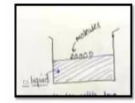
For the **amphiphile** to be **concentrated at the interface**, it must be **balanced with the proper amount of polar and nonpolar groups**.

- If the **molecule is too hydrophilic**, it **remains within the body of the aqueous phase** and exerts no effect at the interface.
- If it is **too lipophilic**; it **dissolves completely in the oil-phase** and little appears at the interface

On the other hand, **negative adsorption** is related to **materials** that are **found in the bulk of liquid**.

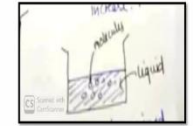
• Positive adsorption

- ✓ Molecule deposit on the surface of liquid.
- ✓ Surface free energy and surface tension decreased.



• Negative adsorption

- ✓ Molecule does not deposit on surface it mix with the liquid.
- ✓ Surface free energy and surface tension increased.



- ✓ Molecule settle down on surface.

- ✓ Molecule mixed with liquid.

NEGATIVE ADSORPTION	POSITIVE ADSORPTION
Molecules partitioned in favour of bulk	Molecules partitioned in favour of surface/interface
Increase in the surface tension	Decrease in the surface tension

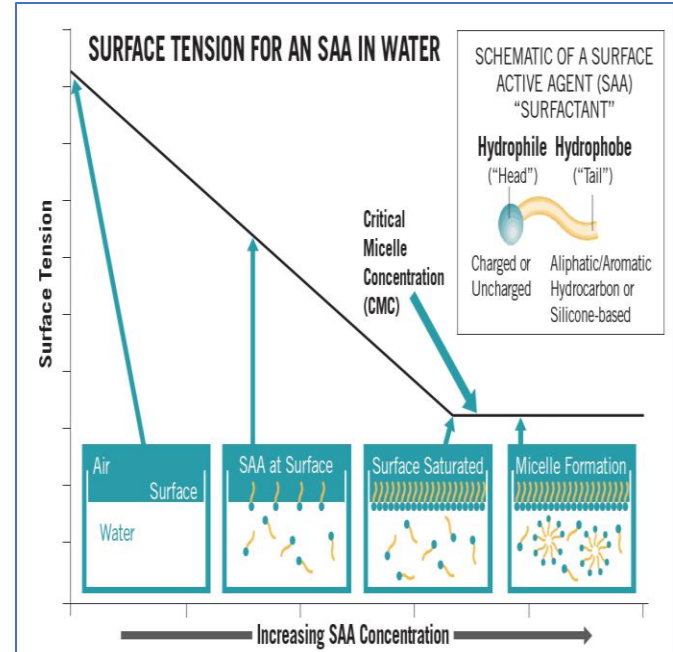


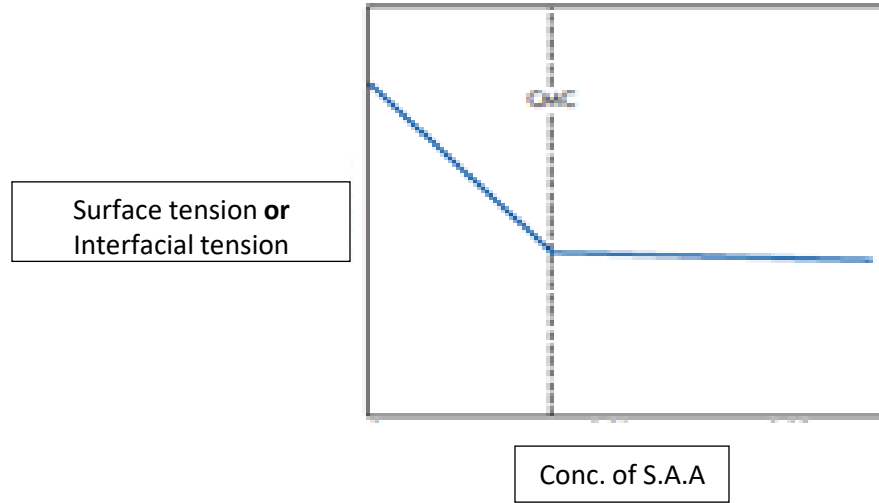
Effect of surface-active agents on surface and interfacial tension of water

The **SAA reduce surface tension** because:

- 1- surfactant molecules **adsorb at the water surface**,
- 2- surfactant molecules **replace some of the water molecules in the surface**
- 3- **forces of attraction between surfactant and water molecules are less than those between two water molecules** (interfere with hydrogen of water), hence the **contraction force is reduced**.

The surface tension decreases with increasing concentrations of the SAA; however, **after a certain concentration of the SAA, the surface tension stops decreasing and reaches a plateau.** This concentration is called **critical micelle concentration (CMC)**.





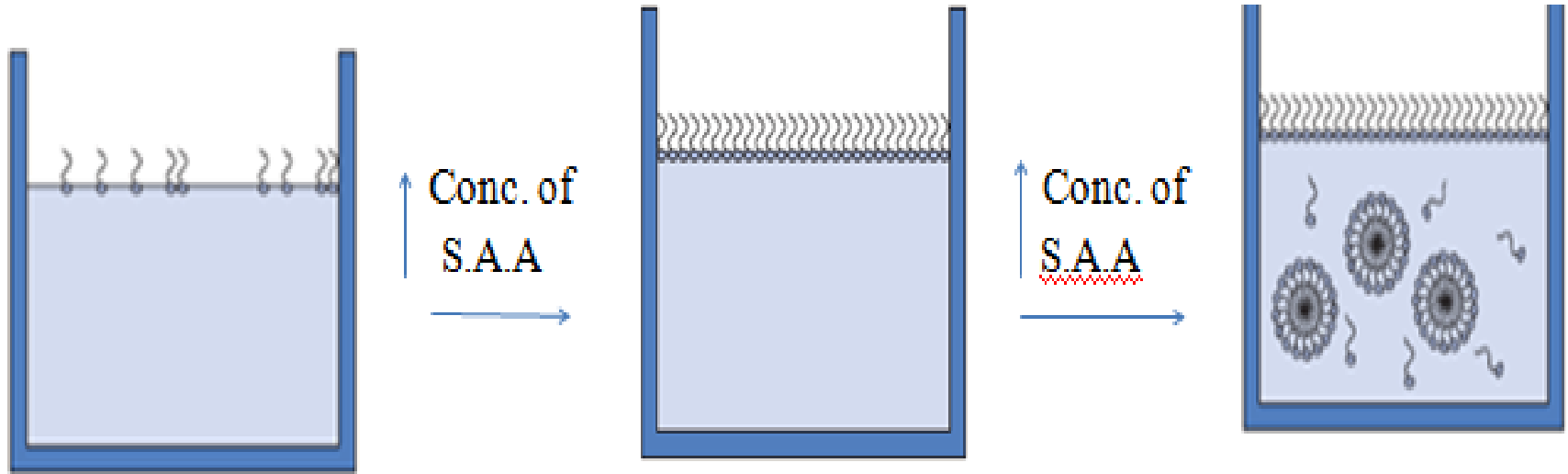
(**Note:** materials that concentrated in the bulk of liquid increase the surface tension of a liquid and they are called **surface inactive agents** like (e.g., inorganic electrolytes such as NaCl and sugar)

Mechanism:

- 1- NaCl or sugar dissolve
- 2- Formation of charges (repulsion at the surface)
- 3- More force pull water molecules to the bulk
- 4- Increase contraction and reduce surface area.

Why surface tension stops decreasing and reaches a plateau?

This is because **at this concentration the surface is saturated with surface active molecules** and any **increase in their concentration will cause them to form micelles in the bulk**



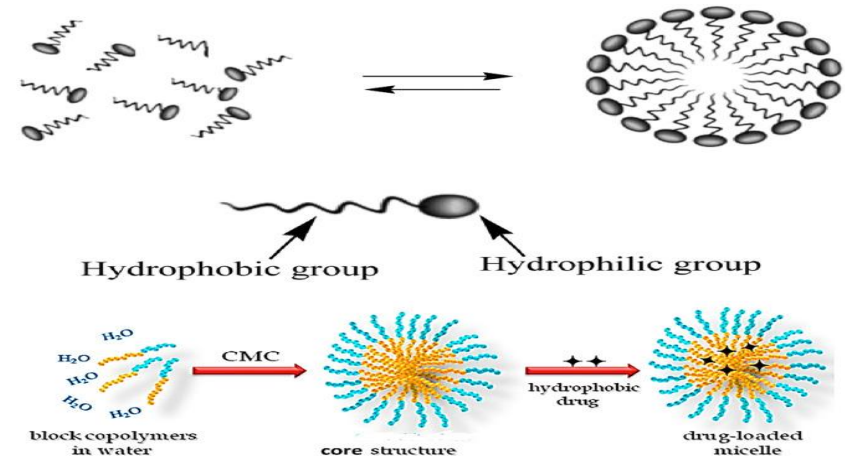
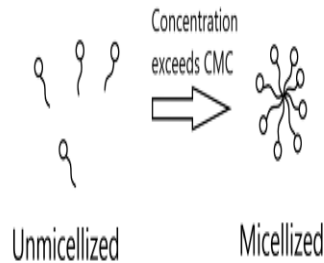
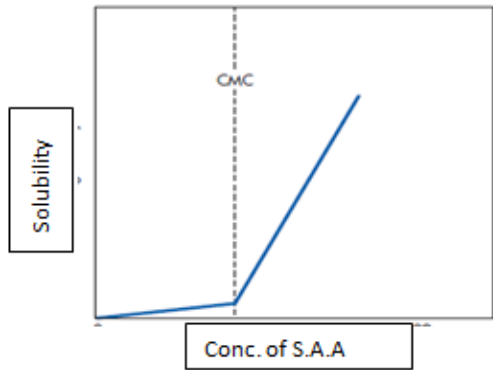
As more surface active agent is added to water, the surface of the water is covered by molecules of the surface active agent, and then micelles start forming

Why micells are formed?

To protect their hydrophobic groups from the aqueous environment

Effect of surfactant on solubility of slightly soluble substance

The ability of the solution to solubilize a drug, **increase sharply when the concentration of the SAA increases beyond the CMC concentration since the nonpolar molecules in aqueous systems would be located in the hydrocarbon core of the micelle.**



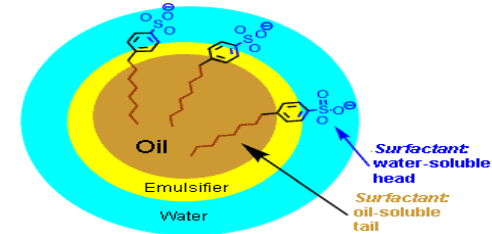
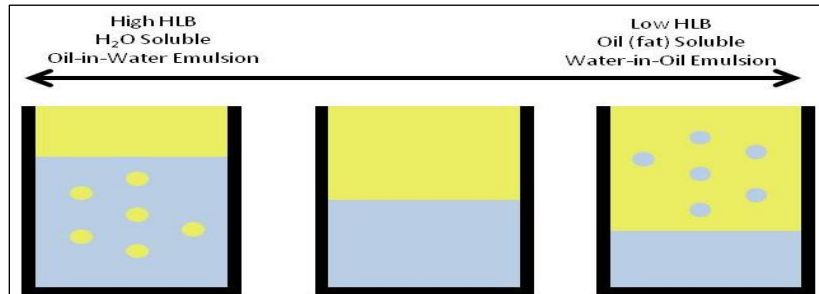
Hydrophile-Lipophile Balance

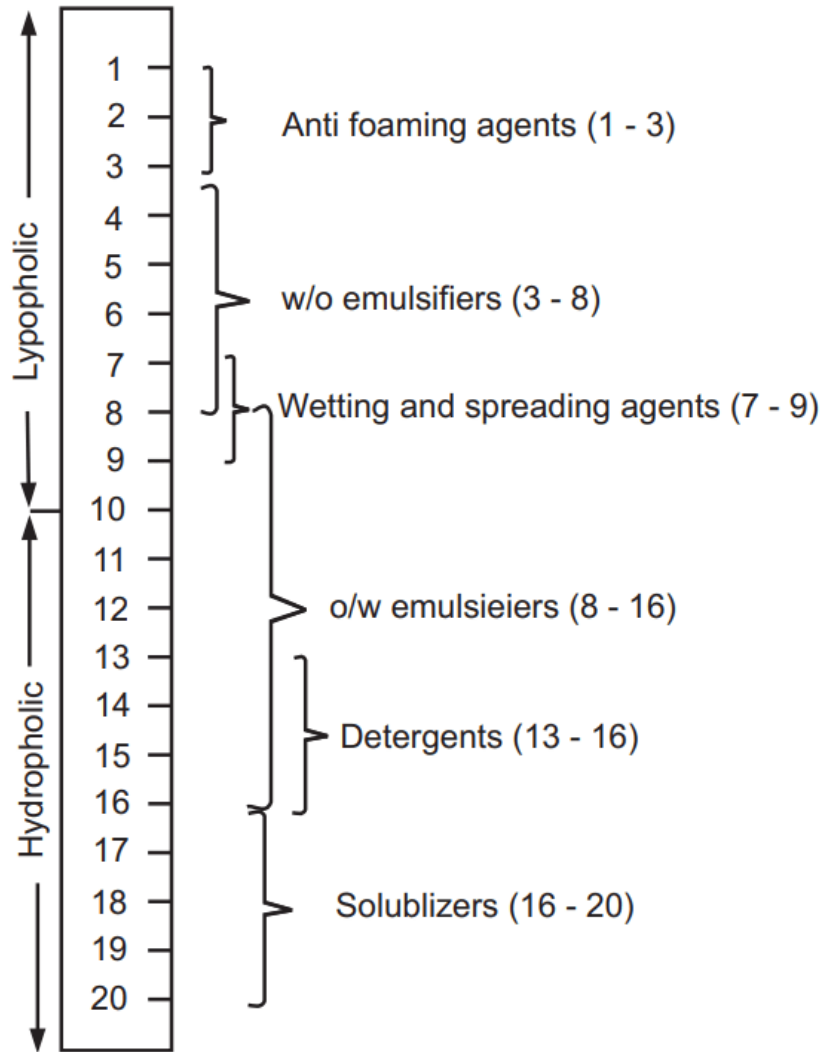
The hydrophile–lipophile balance (HLB) number is a measure of the balance between hydrophobic and hydrophilic portions of a surfactant.

The HLB of a surfactant is expressed using an arbitrary scale which ranges from 0 to 20

At the higher end of the scale, the surfactants are hydrophilic and act as solubilizing agents, detergents and oil-in-water emulsifiers.

Oil-soluble surfactants have low HLB and act as water-in-oil emulsifiers.





A scale showing surfactant function based on hydrophilic–lipophilic balance (HLB) values.

Key: O/W = oil in water, w/o= water in oil

Adsorption at solid interfaces

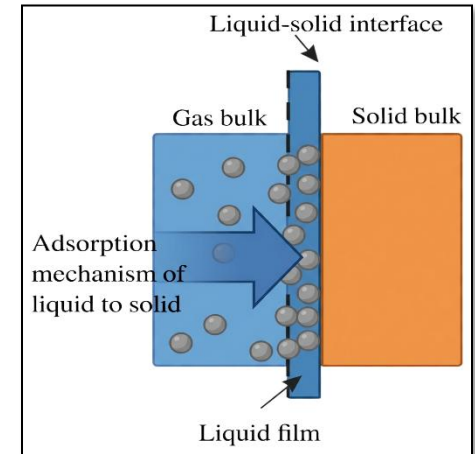
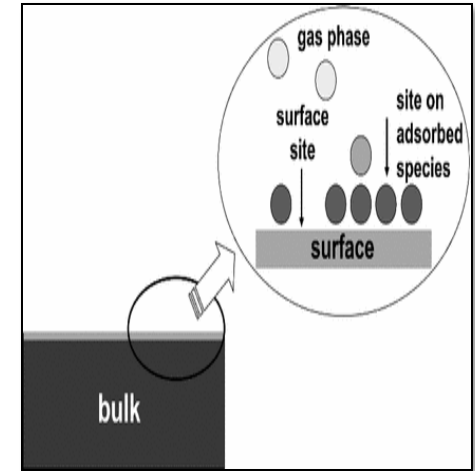
Adsorption of material at solid interfaces can take place from either an adjacent liquid or gas phase.

Solid-Gas: The study of adsorption of gases arises in such diverse applications as the removal of objectionable odors from rooms and food, and the operation of gas masks.

Solid-liquid: The principles of adsorption are used in decolorizing solutions, adsorption chromatography, detergency, and wetting.

Note:

1. Adsorption of materials from a gas or a liquid onto a solid surface is similar to that discussed for liquid surfaces. Thus, adsorption of this type can be considered as an attempt to reduce the surface free energy of the solid.
2. The surface tensions of solids are invariably more difficult to obtain than those of liquids.
3. solid interface is immobile in comparison to the turbulent liquid interface.



The Solid–Gas Interface

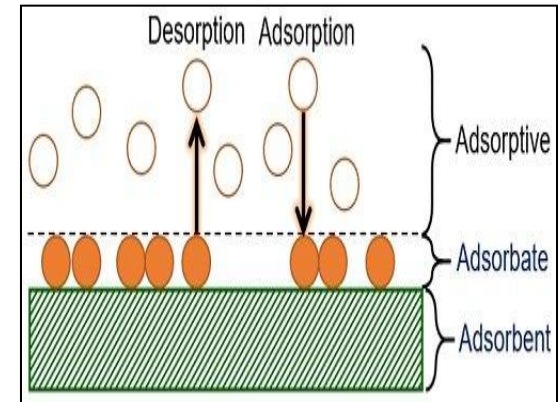
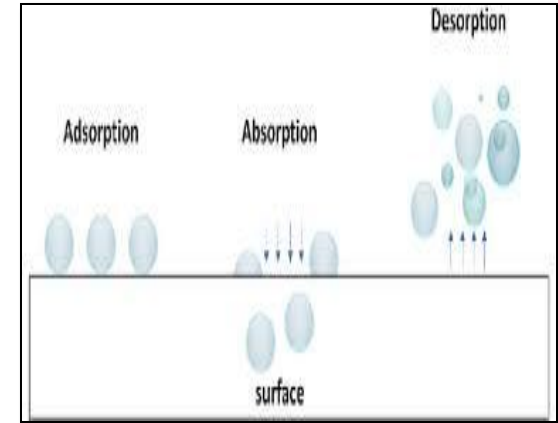
The degree of adsorption of a gas by a solid depends on:

- 1- **Chemical nature of the adsorbent** (the material used to adsorb the gas) and the **adsorbate** (the substance being adsorbed)
- 2- **Surface area of the adsorbent**
- 3- **Temperature**
- 4- **Partial pressure of the adsorbed gas.**

The types of adsorption are generally recognized as:

A. Physical adsorption or van der Waals adsorption, associated with van der Waals forces, is **reversible**, the removal of the adsorbate from the adsorbent being known as **desorption**. A **physically adsorbed gas can be desorbed from a solid by increasing the temperature and reducing the pressure.**

B. Chemical adsorption or Chemisorption, in which the adsorbate is attached to the adsorbent by primary **chemical bonds**, is **irreversible unless the bonds are broken.**



The Solid–Liquid Interface

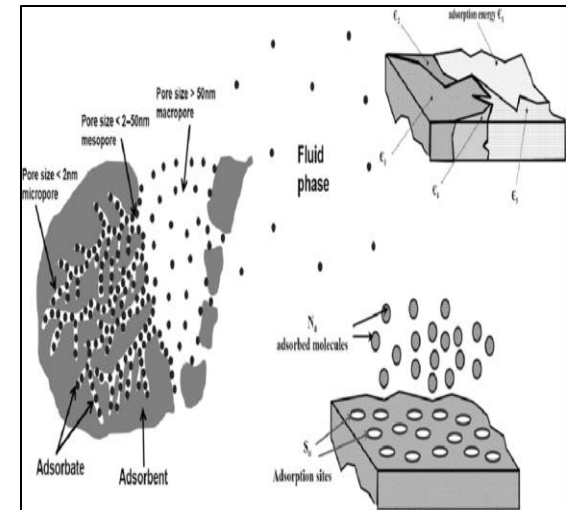
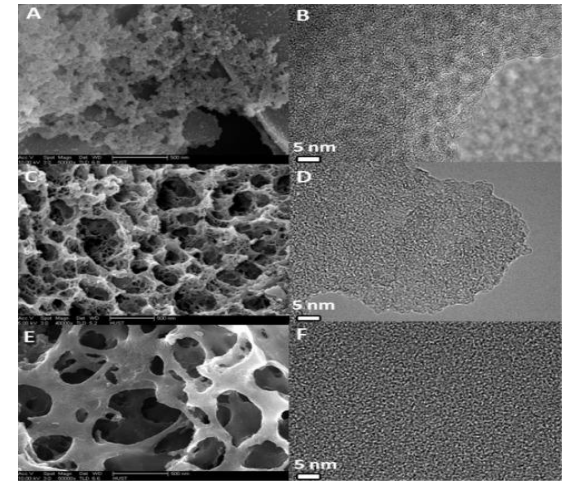
Drugs such as **dyes, alkaloids, fatty acids, and even inorganic acids and bases** can be adsorbed from solution onto solids such as **charcoal and alumina**.

The adsorption of solute molecules from solution can be treated in a manner analogous to the adsorption of molecules at the solid–gas interface.

An example of a **substance that can adsorb enormous amounts of gases or liquids is activated charcoal, the residue from destructive distillation of various organic materials, treated to increase its adsorptive power.**

• **To adsorb more adsorbate**, an adsorbent of a given mass should have the greatest possible surface area. This might be achieved **by the use of porous or milled adsorbents**.

Ex: Activated **charcoal** is made from material **burnt in a superheated high-oxygen atmosphere, creating small holes in the range of 100 to 800 °A in diameter** throughout the grain of the charcoal. This effectively increases the charcoal's surface area so that the surface area of 1 g of charcoal is approximately 1000 m².



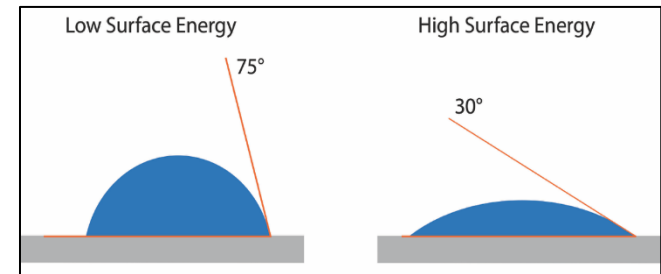
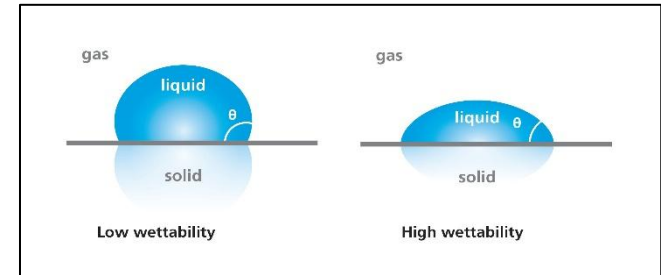
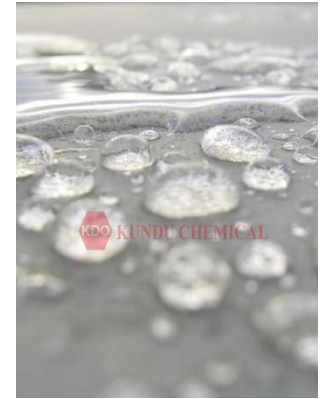
Wetting phenomena and wetting agents

Wettability: is the property that indicates the affinity between solid and fluid phase.

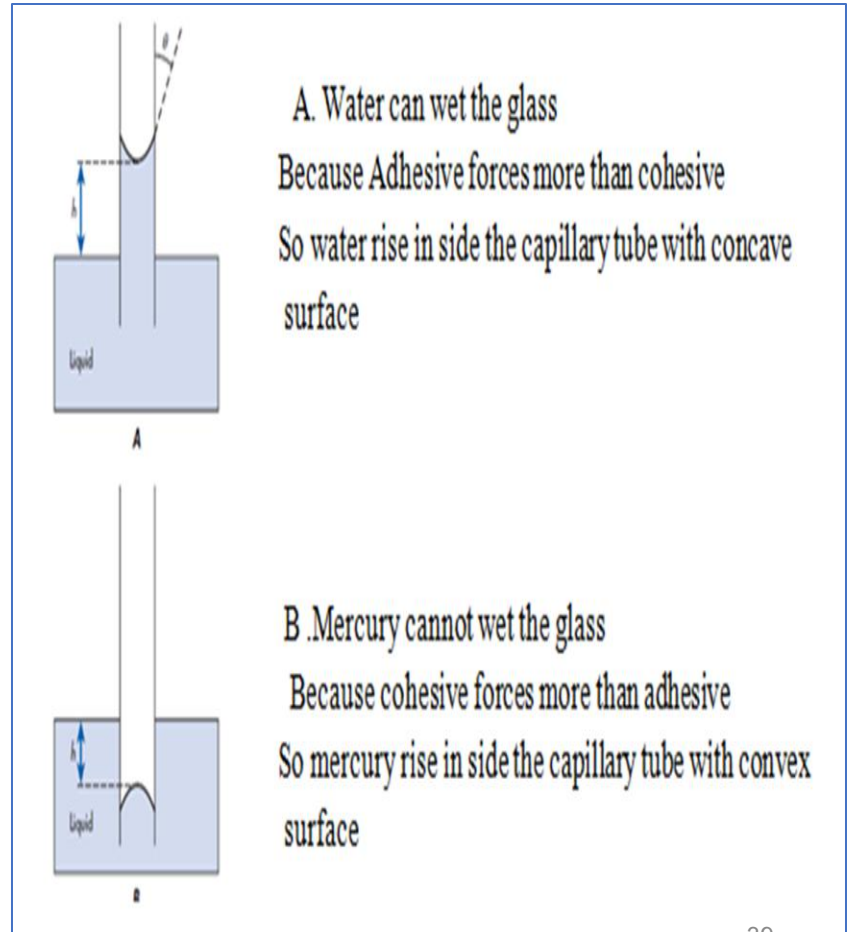
Ex: Talc or charcoal sprinkled on the surface of water; they will float even though their densities are higher than that of water.

Mechanism: 1- For wetting of solid to occur, the liquid must displace air and spread over the surface of the solid, otherwise, we say that the solid is NOT wetted

2- When a liquid comes into contact with the solid, the behavior of the liquid will depend on the balance between the forces of attraction of molecules in the liquid (cohesion) and the forces of attraction between the liquid and the solid phases (adhesion).



- For **water and glass**, attractive forces between the solid and liquid molecules are greater than the forces between molecules of liquid themselves, and so the liquid can wet the surface of the glass.
- In the case of **mercury and glass**, attractive forces between molecules of mercury and glass are much smaller than the forces of attraction between molecules of mercury themselves. As a result, mercury will come together as a single spherical drop.



Many pharmaceutical preparations require dispersion of solid in liquids

Example: The preparation of **suspension** requires that the fine solid particles **immersed** and then **dispersed** in a liquid vehicle, this means the solid particles must be **wetted** to be dispersed in a liquid.

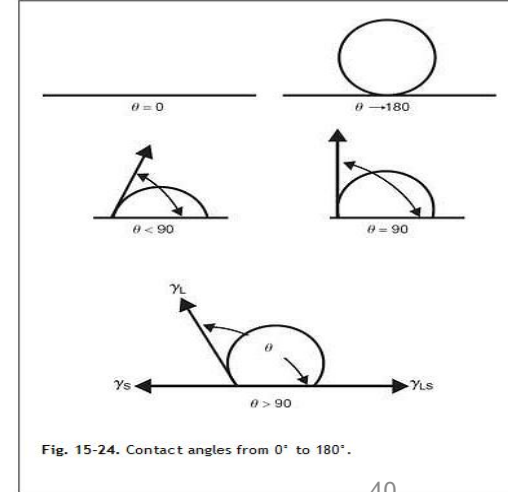
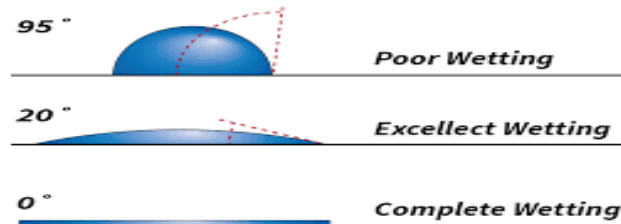
The parameter that reflects the degree of wetting is known as contact angle

Contact angle (Θ):- which is the angle between a liquid droplet and surface over which it spread it range from 0 - 180°.

$\Theta = \text{zero}$ means **complete wetting** (glass and water)

$\Theta = 180^\circ$ means **no wetting** (water and greasy surface)

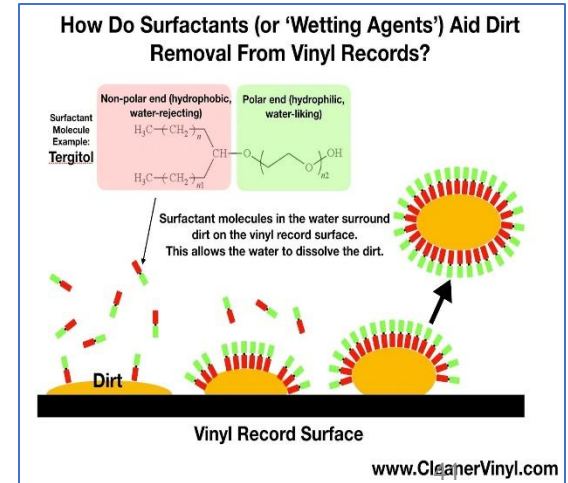
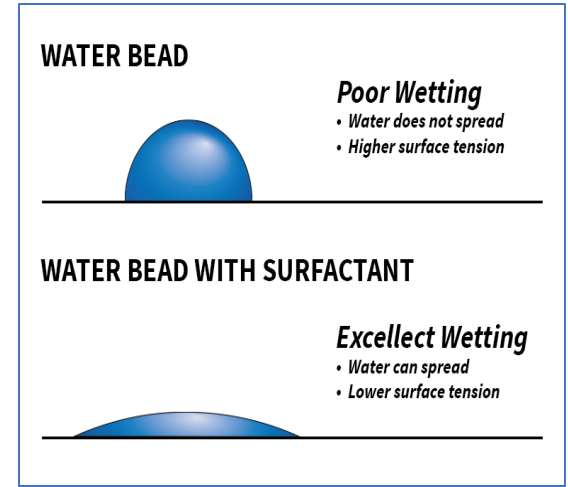
The contact angle with any value between these limits (partial wetting)



- **Hydrophilic material have small contact angle with water** while **hydrophobic material have large contact angle**
- To increase wetting, the contact angle should be decreased this is done by adding **surfactant** which is called **wetting agent**
- **A wetting agent** is a **surfactant** that, when **dissolved in water**, **lowers the contact angle**, **aids in displacing an air phase at the surface**, and **replaces it with a liquid phase**.

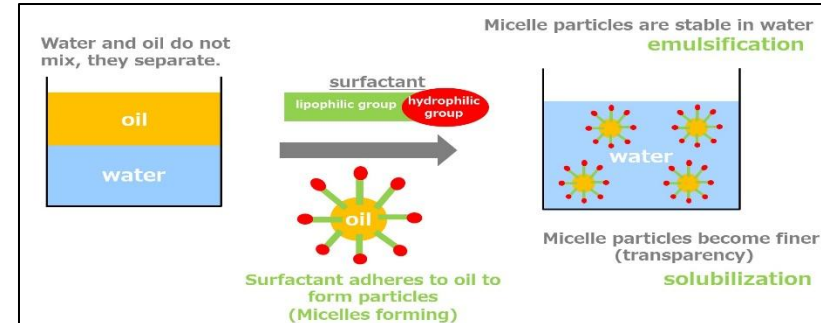
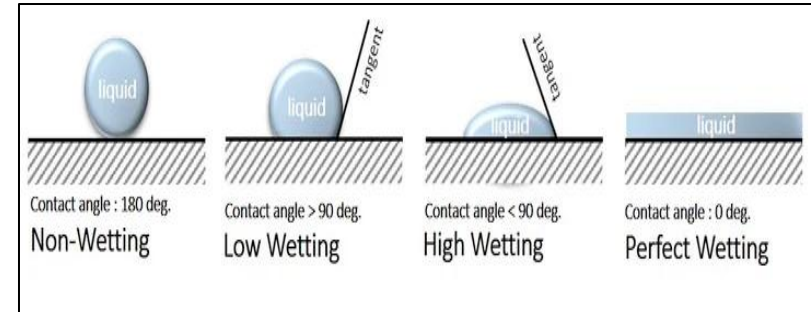
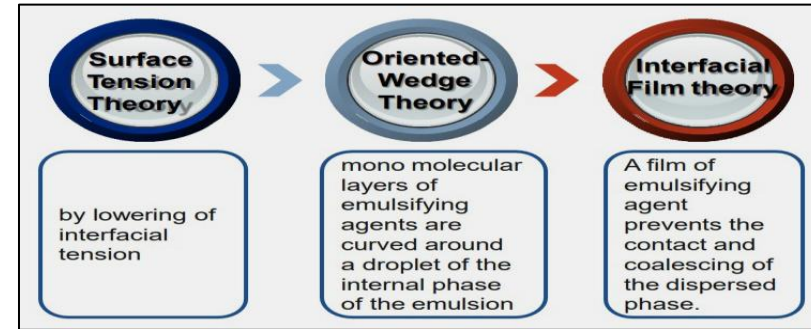
Examples of the application of wetting to pharmacy and medicine:

- 1- The displacement of air from the surface of sulfur, charcoal, and other powders for the purpose of dispersing these **drugs in liquid vehicles**.
- 2- The displacement of dirt by the use of detergents in the **washing of wounds**; and the application of medicinal lotions and sprays to the surface of the skin and mucous membranes.



Application of S.A.A

- 1- As **emulsifying agents** by decrease Interfacial tension.
- 2- **Wetting agents** by decreasing the contact angle; wetting is the first step for dispersing a solid in a liquid vehicle.
- 3- **Detergents** which are surfactants that are used for removal of dirt.
- 4- **Solubilizing agents** by formation of micelles.



5- A **surfactant** may affect the activity of a drug [increase or decrease]

The presence of a **low concentration of surfactant will potentiate the activity of anthelmintic drug.**

Mechanism: reduction in interfacial tension between the liquid phase and the cell wall of the organism.



As a result, the **adsorption and spreading of the drug over the surface** of the organism is facilitated.



Side effect: if **concentration of SAA present exceeds that required amount**

Form micelles  **the rate of penetration of the anthelmintic decreases nearly to zero.**

(This is because the **drug is now partitioned between the micelles and the aqueous phase**, resulting in a **reduction in the effective concentration** or may itself exert drug action).

Surfactant Effect on Drug Activity

A surfactant may affect the activity of a drug [increase or decrease]

✓ Potentiation
Low Concentration → Increased Activity

Mechanism: Reduction in Interfacial Tension Between the Liquid Phase and the Cell Wall of the Organism

Facilitates Adsorption & Spreading of the Anthelmintic Drug over the Organism's

Drug is partitioned between micelles and aqueous phase, resulting in a reduction in the effective concentration

Inhibition
High Concentration → Decreased Activity

Side Effect: If concentration of Surfactant (SAA) Exceeds Required Amount

Forms Micelles

Rate of Penetration Nearly Zero; May Exert Drug Action

*Drug is partitioned between micelles and aqueous phase, resulting in a reduction in effective concentration

The infographic includes a 'RATE OF PENETRATION' gauge with a needle pointing towards 'LOW' and a warning sign icon.

6- A surfactant may exert a drug action

Quaternary ammonium compounds are examples of SAA that in themselves possess antibacterial activity.

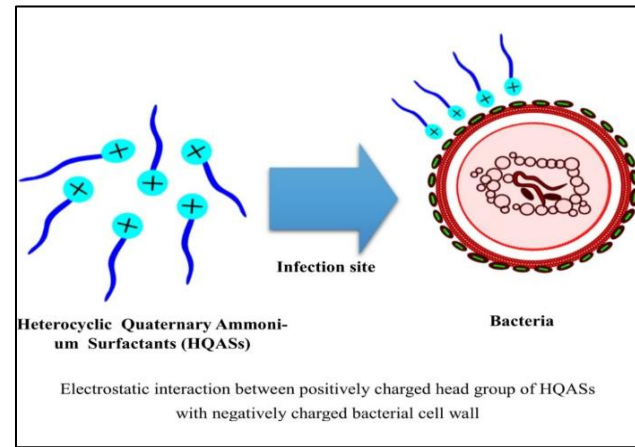
This may depend in part on interfacial phenomena, but other factors are also important.

Mechanism: The agents are adsorbed on the cell surface and supposedly bring about destruction by increasing the permeability or “leakiness” of the lipid cell membrane.



Death occurs through a loss of essential materials from the cell.

Both gram-negative and gram-positive organisms are susceptible to the action of the cationic quaternary compounds (Disruption and destabilization)



Foam and antifoaming agents

Any solutions containing surface-active materials produce stable foams when mixed intimately with air.

A **foam** is a relatively stable structure consisting of **air pockets enclosed within thin films of liquid**, the gas-in-liquid dispersion being stabilized by a foaming agent.

The **foam dissipates** as the liquid drains away from the area surrounding the air globules, and the **film finally collapses.**

Antifoaming agents: agents used to break the foam such as **alcohol, ether, castor oil, and some surfactants.**

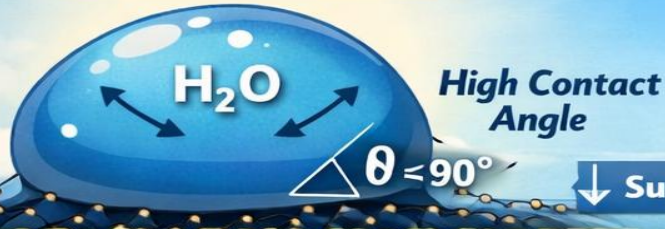
Foams are sometimes useful in pharmacy (e.g., **antimicrobial formulations**) but are usually a **nuisance and are prevented or destroyed when possible.** The undesirable foaming of solubilized liquid preparations poses a problem in formulation.



Thank You!

The Effect of Surface-Active Agents

Before Surfactant



Solid Surface

Air (Solid-Gas Interface)

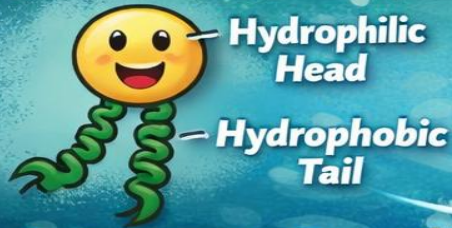
↓ Surface Tension

After Surfactant



Solid Surface

Air (Solid-Gas Interface)



Surfactant to the Rescue!

Reducing Surface Tension!

Enhancing Wetting!

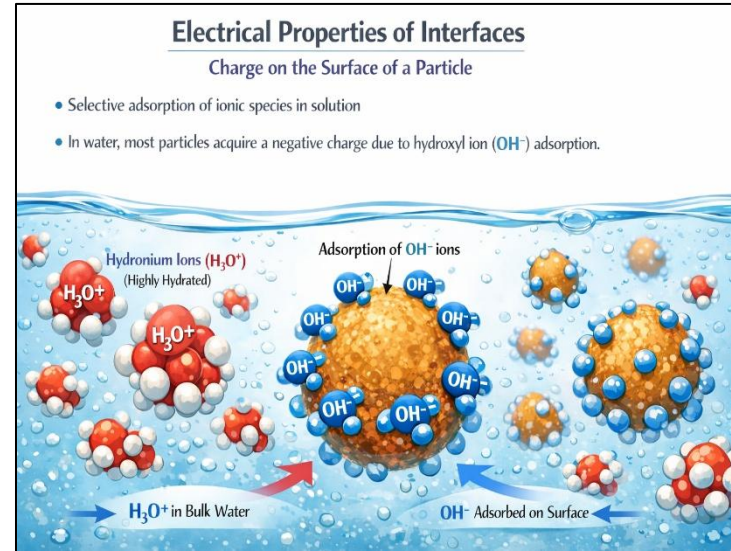
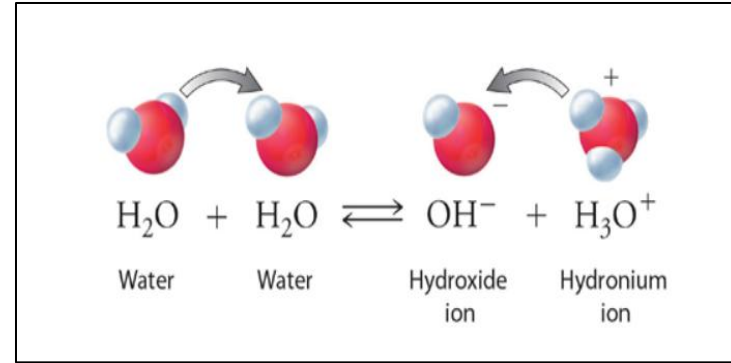
Electrical Properties of interfaces

Electric Properties - charge on the surface of a particle

Particles dispersed in liquid media may become charged mainly in one of two ways:

The first: involves the **selective adsorption of a particular ionic species present in solution**. This may be an **ion added to the solution**, or, in the case of pure water, it may be the **hydronium or hydroxyl ion**.

Most particles dispersed in water acquire a negative charge due to preferential adsorption of the hydroxyl ion because the hydronium ion is more hydrated than hydroxyl ion, so they have greater tendency to be in the bulk of aqueous medium, whereas the less hydrated hydroxyl ion have greater tendency to be adsorbed at the surface of particle.



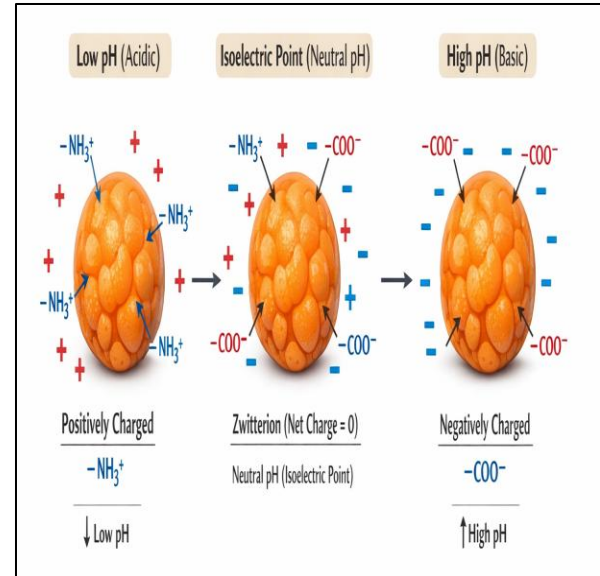
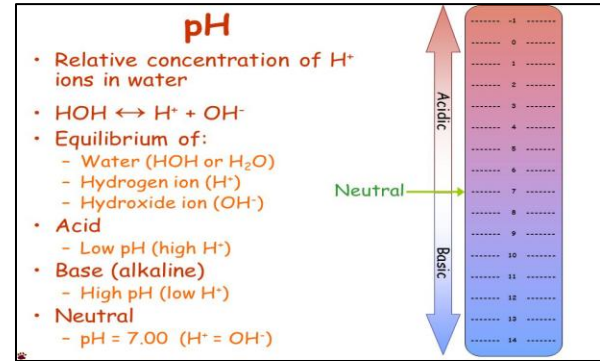
Second: charges on particles arise from ionization of groups that may be situated at the surface of the particle. In these cases, the charge is a function of pH and pKa.

Example: amino acid and protein (have COOH and NH₂) groups on their structure.

At low pH, the protein will have +ve charge due to ionization of -NH₂ groups to -NH₃⁺

At high pH, the protein will have -ve charge due to ionization of -COOH groups to -COO⁻

At certain pH (specific for each protein), the total no. of +ve charge equal to the total no. of -ve charge and the net charge will be zero (This pH is termed as isoelectric point of protein, and the protein exists as Zwitter ion).



The Electric Double Layer

Consider a solid surface in contact with a polar solution containing ions, **Ex: an aqueous solution of an electrolyte.**

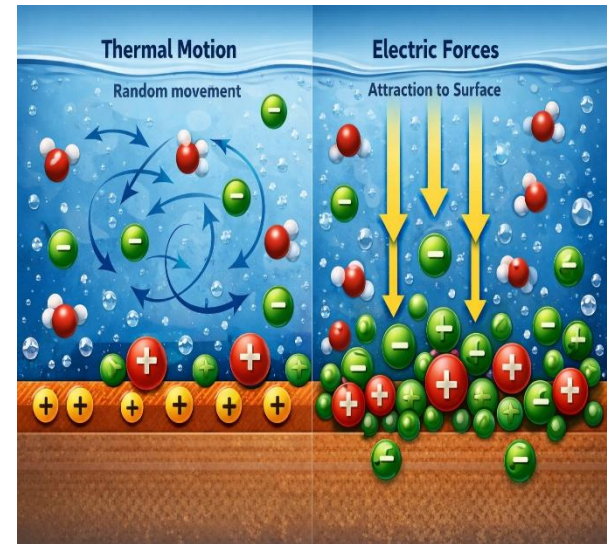
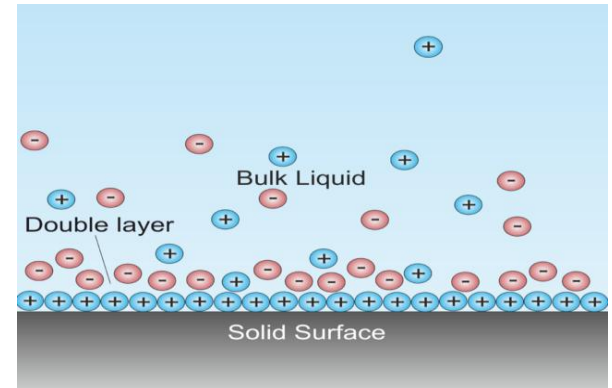
Furthermore, let us suppose that **some of the cations are adsorbed onto the surface, giving it a positive charge.** Remaining in solution are the rest of the cations plus the total number of anions added.

These anions are attracted to the positively charged surface by electric forces that also serve to repel the approach of any further cations once the initial adsorption is complete.

Type of motion:

1- Electric forces

2- **Thermal motion** (produce an equal distribution of all the ions in solution).



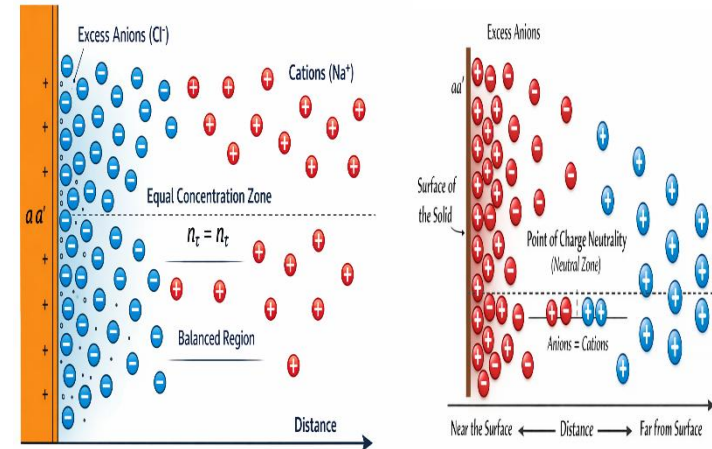
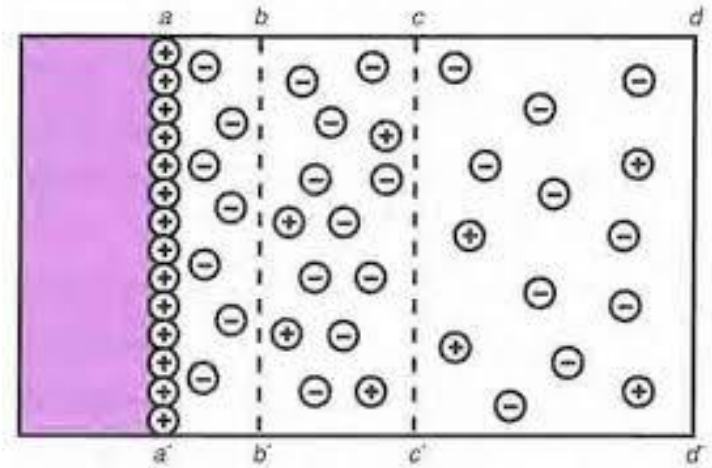
- In **equilibrium situation** set up:
 - **excess anions approach the surface**
 - **remainders distributed in decreasing amounts away from the charged surface.**

• **Electric neutrality condition:**

At a particular distance from the surface, the concentrations of anions and cations are equal.

Note: It is important to remember that the system as a whole is electrically neutral, even though there are regions of unequal distribution of anions and cations.

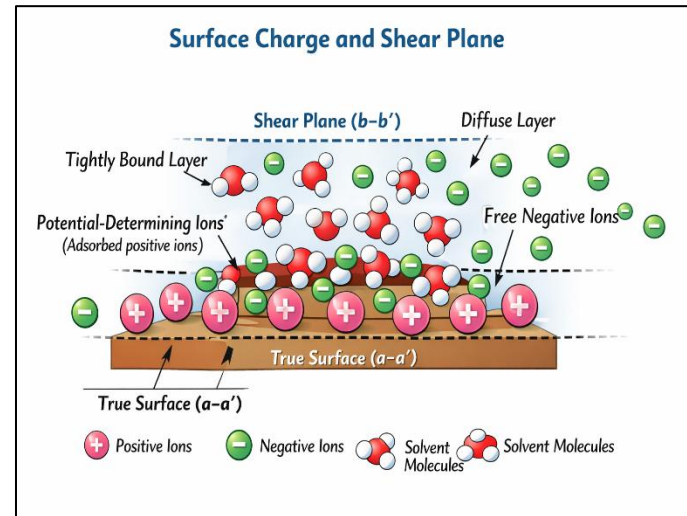
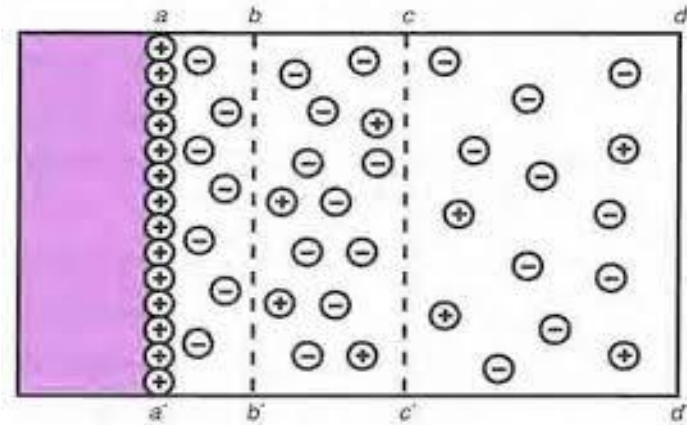
- Such a situation is shown in the Figure 1, where **aa'** is the surface of the solid.



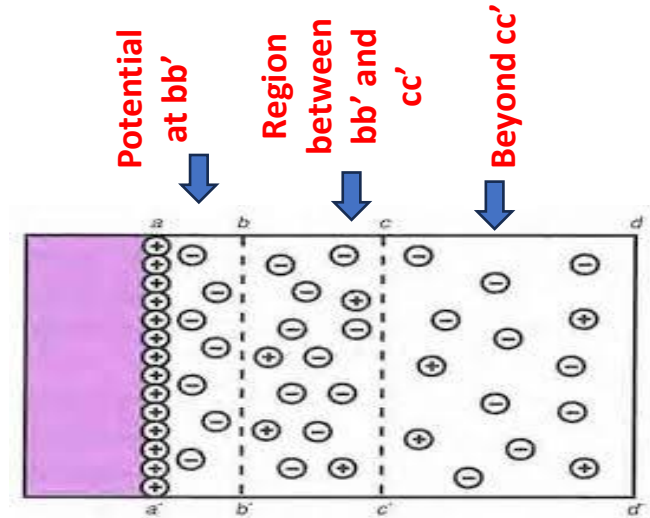
• The adsorbed ions that give the surface its positive charge are referred to as the **potential-determining ions**.

• Immediately adjacent to this surface layer is a region of tightly bound solvent molecules, together with some negative ions, also tightly bound to the surface. The limit of this region is given by the line bb' in the Figure 1. These ions, having a charge opposite to that of the potential-determining ions, are known as counterions or gegenions.

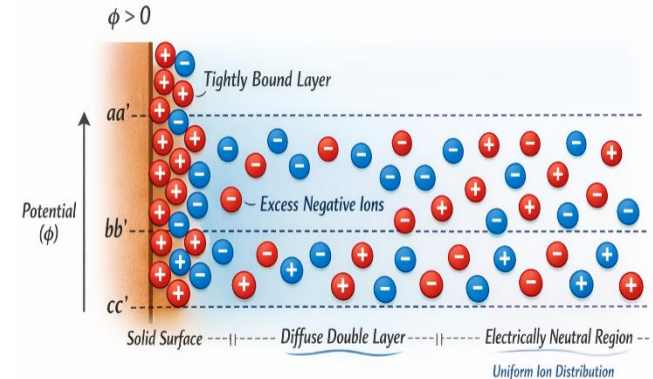
• The degree of attraction of the solvent molecules and counterions is such that if the surface is moved relative to the liquid, the shear plane is bb' rather than aa', the true surface.



- **The potential at bb'** is still positive because, there are fewer anions in the tightly bound layer than cations adsorbed onto the surface of the solid.
- **In the region bounded by the lines bb' and cc'** , there is an excess of negative ions.
- **Beyond cc'** , the distribution of ions is uniform and electric neutrality is obtained.



Thus, the electric distribution at the interface is equivalent to a double layer of charge, the first layer (extending from aa' to bb') tightly bound and a second layer (from bb' to cc') that is more diffuse, the so-called diffuse double layer therefore extends from aa' to cc' .



Two situations (New cases) other than that represented by the figure are possible:

(a) If the counterions in the tightly bound layer equal the positive charge (high +ve) on the solid surface, then electric neutrality occurs at the plane bb' rather than cc' .

(b) Should the total charge of the counterions in the region $aa'-bb'$ exceed the charge due to the potential-determining ions (high +ve), then the net charge at bb' will be negative rather than less positive (high -ve), as shown in the figure 2.



This means for electric neutrality to be obtained at cc' , an excess of positive ions (high +ve) must be present in the region $bb'-cc'$.

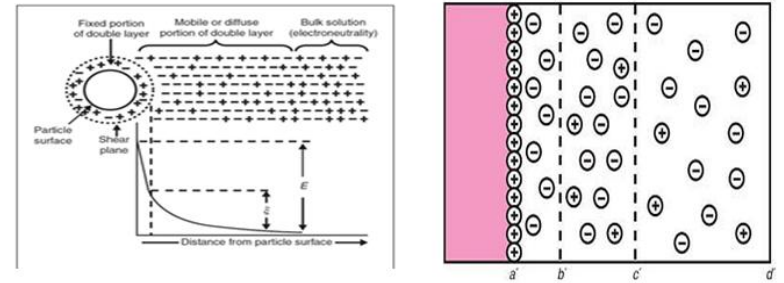
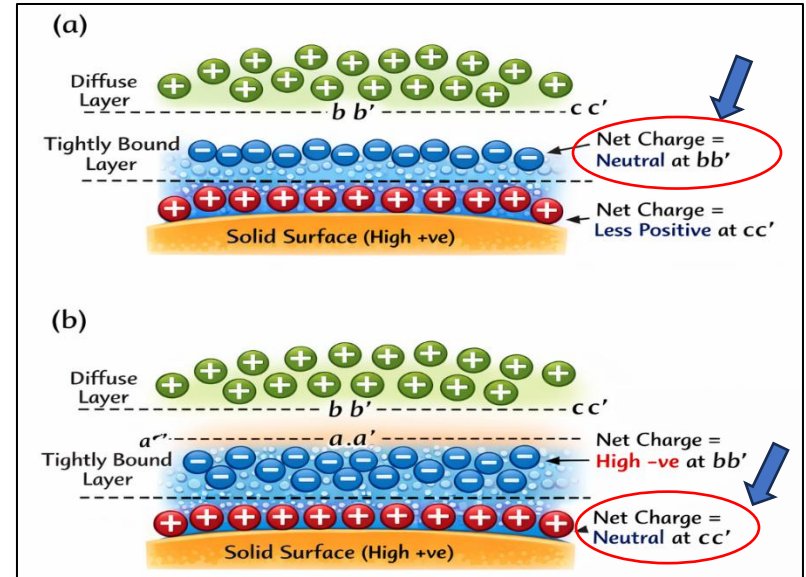


Fig.1. the electric double layer at the surface of separation between two phases, showing distribution of ions. The system as a whole is electrically neutral.



- **Note: (Reverse cases)** The student should appreciate that if the **potential-determining ion is negative**, the arguments just given still apply, although now **positive ions will be present in the tightly bound layer**.

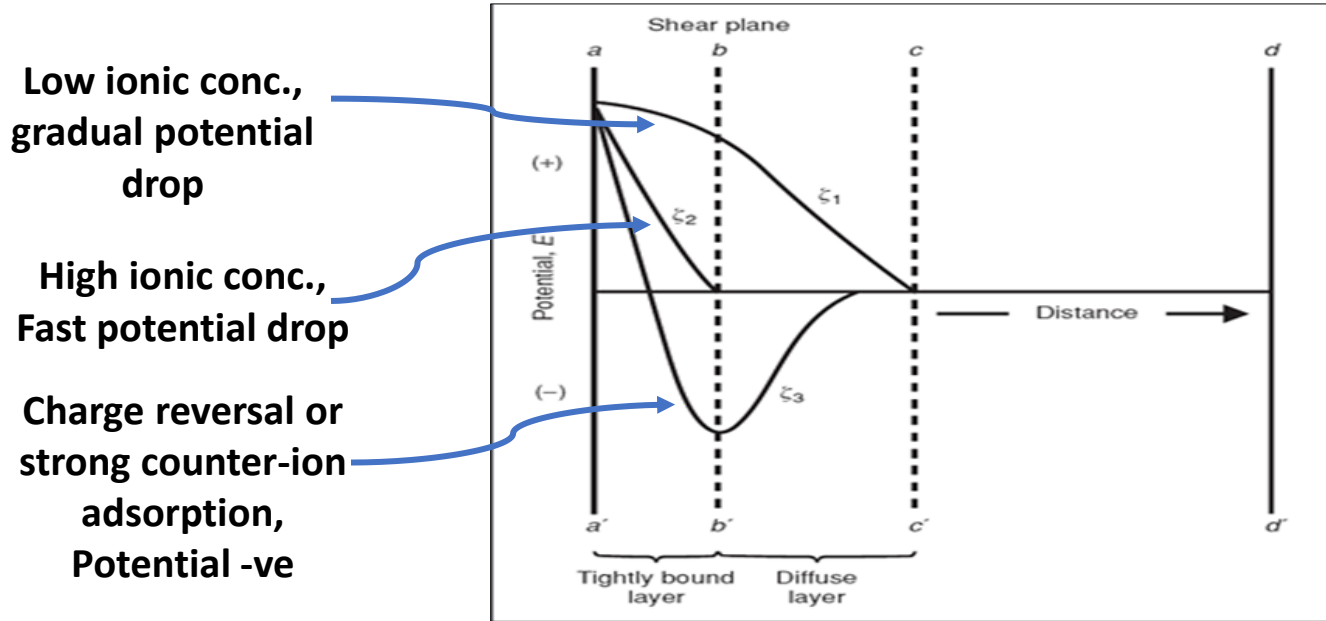


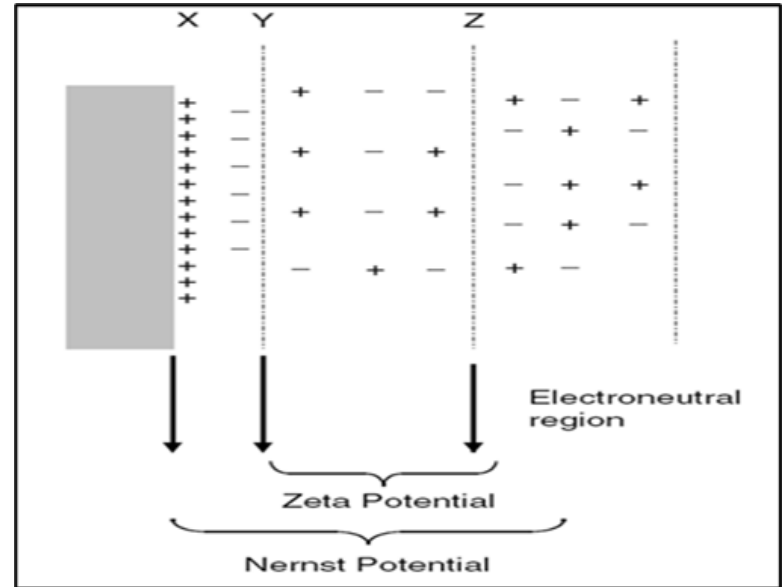
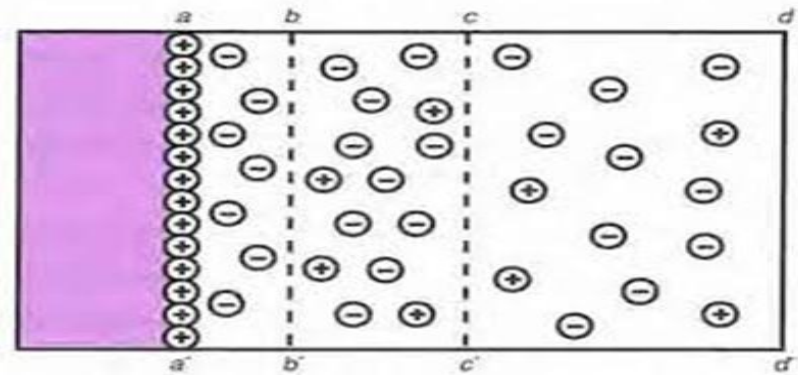
Fig. 2. **Electrokinetic potential, E , at solid–liquid boundaries.** Curves are shown for three cases characteristic of the ions or molecules in the liquid phase. Note that although E is the same in all three cases, the zeta potentials are **positive (ζ_1)**, **zero (ζ_2)**, and **negative (ζ_3)**.⁵⁴

Nernst and Zeta Potentials

The changes in potential with distance from the surface for the various situations discussed in the previous section can be represented as shown in Figure 2.

The potential at the solid surface aa' due to the potential-determining ion is the electrothermodynamic (Nernst) potential, E :

(Defined as the difference in potential between the actual surface and the electroneutral region of the solution). ($aa'-cc'$).

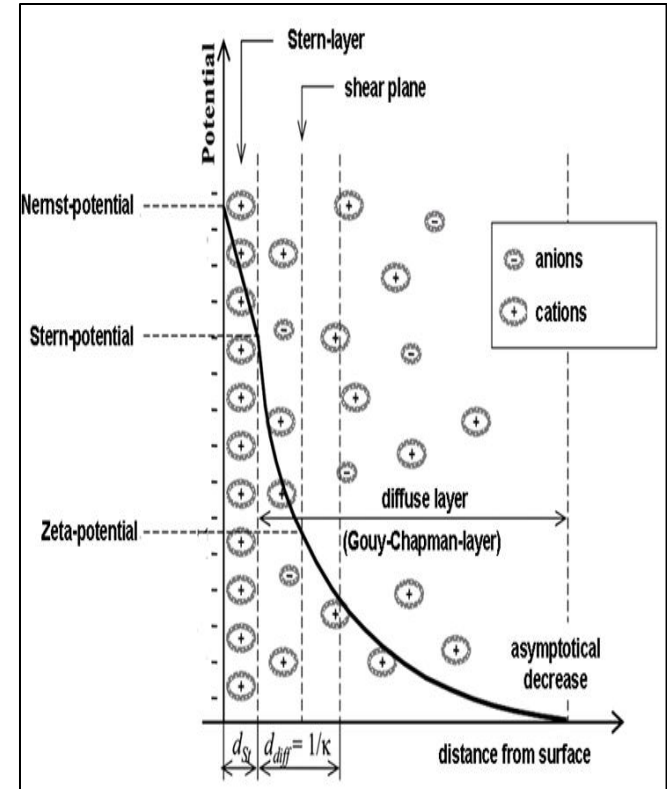


- The potential located at the shear plane bb' is known as the electrokinetic, or zeta, potential, **The zeta potential, ζ**

(Defined as the difference in potential between the surface of the tightly bound layer (shear plane) and the electroneutral region of the solution). ($bb'-cc'$).

Note: As shown in Figure 2, the potential initially drops off rapidly, followed by a more gradual decrease as the distance from the surface increases.

(This is because the counterions close to the surface act as a screen that reduces the electrostatic attraction between the charged surface and those counterions further away from the surface).



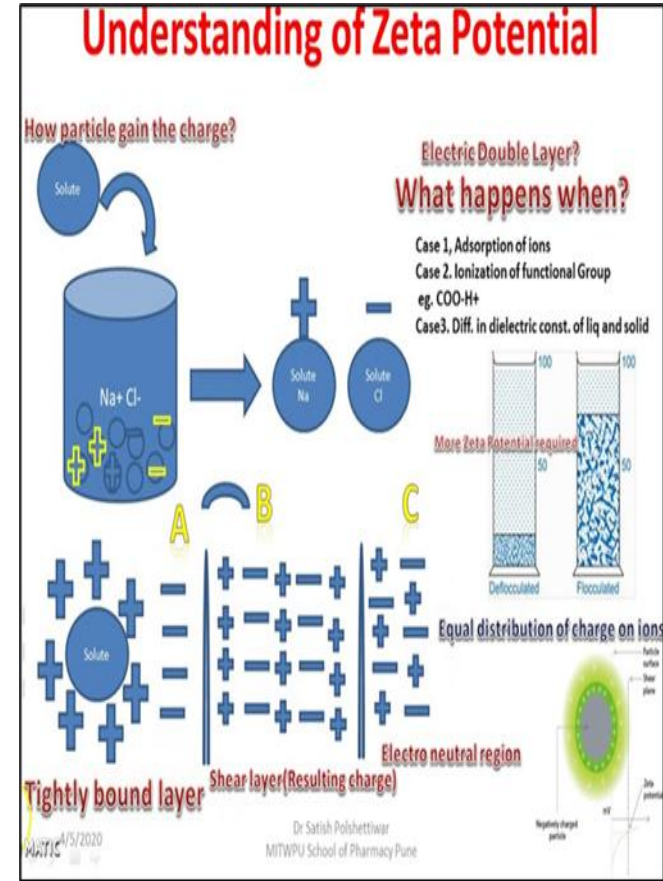
•The **zeta potential** has practical application in the stability of systems containing dispersed particles

Because this potential, rather than the Nernst potential, it governs the degree of repulsion between adjacent, similarly charged, dispersed particles.

EX: In (NaCl or KCl reaches zero Zeta potential) means if the zeta potential is reduced below a certain value (which depends on the particular system being used)



The **attractive forces exceed the repulsive forces**, and the particles come together. This phenomenon is known as **flocculation**



Effect of Electrolytes

First case: As the concentration of electrolyte present in the system is increased (High ion strength)

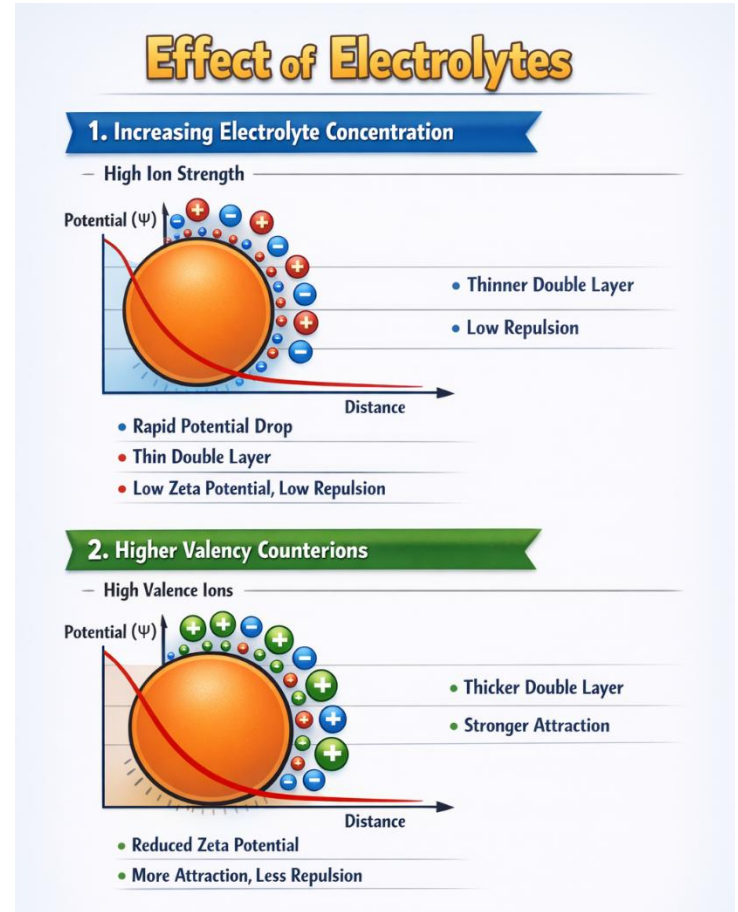


The potential falls off more rapidly with distance and the thickness of the double layer decreased (low repulsion, low Zeta potential).

Second case: When the valency of the counterion is increased while the total concentration of electrolyte is held constant.



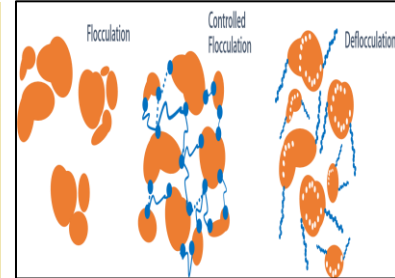
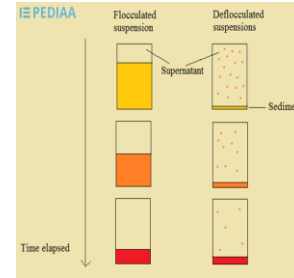
The overall effect causes a reduction in zeta potential (more attraction than repulsion).



Application of Zeta potential

1- Interfacial Properties of Suspended Particles

- The particles in a **liquid suspension** tend to **flocculate**, that is, to form light, fluffy conglomerates that are held together by weak van der Waals forces.
- Under certain conditions, the particles may adhere by stronger forces to form what are termed **aggregates or cake**
- When the **repulsion energy (zeta potential)** is high, the **collision of the particles is opposed**. The system remains **deflocculated (dispersed or suspended)**.
- When sedimentation is complete, the particles form a close-packed arrangement with the smaller particles filling the voids between the larger ones.



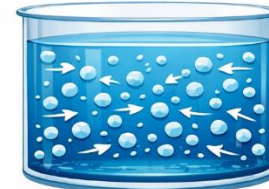
Light, Fluffy Clumps

Flocculation (Weak Van der Waals Forces)



Dense, Hard Cake

Aggregation / Caking (Strong Attraction)



Repulsion Barrier

Deflocculated Suspension (High Zeta Potential)

Particles Remain Dispersed



Compact Packing

Sedimented Cake (After Settling)

Small Particles Fill the Voids

Those particles lowest in the sediment are gradually pressed together by the weight of the ones above and they will adhere together by strong forces to form **aggregates or cake**.

To resuspend and redispense these particles, it is again necessary to overcome these forces. Because this is not easily achieved by agitation, the particles tend to remain strongly attracted to each other and form a hard **cake**.

Flocculated particles are weakly bonded, settle rapidly, do not form a cake, and are easily resuspended.

Note: a very high +ve or -ve zeta potential is not preferred in preparation of suspension, but its value should be controlled within certain limit as shown in the figure below, and this is done by adding a flocculating agents.

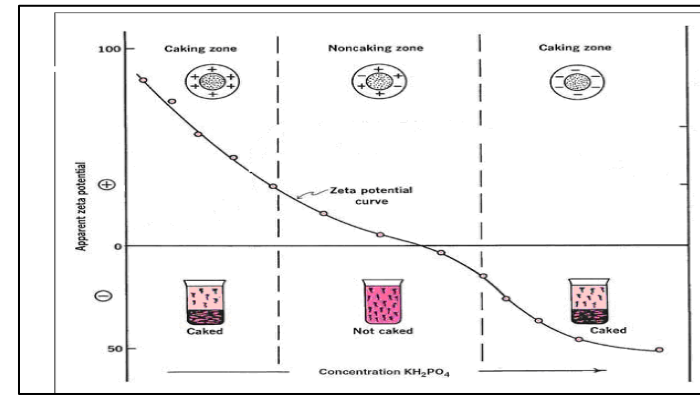
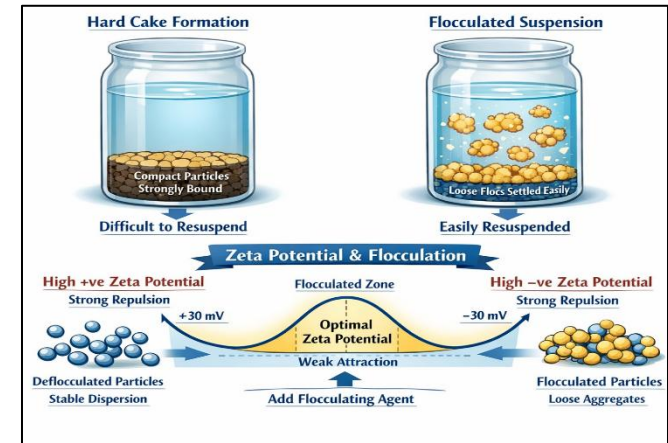


Fig. 3. Caking diagram, showing the flocculation of suspension by means of the flocculating agent monobasic potassium phosphate



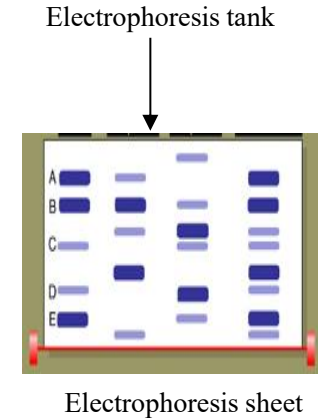
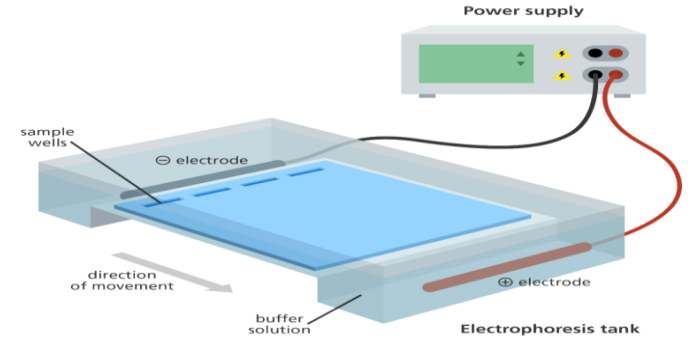
2- Electrokinetic Phenomena

The movement of a charged surface with respect to an adjacent liquid phase. The most important application of this phenomena is electrophoresis.

3- Electrophoresis:

Involves the movement of a charged particle through a liquid under the influence of an applied potential difference.

- An electrophoresis cell fitted with two electrodes contains the dispersion.
- When a potential is applied across the electrodes, the particles migrate to the oppositely charged electrode.
- From knowledge of the direction and rate of migration, the sign and magnitude of zeta potential can be determined.
- It is mainly used for separation of plasma protein.





THANK YOU

