

**FACULTY OF PHARMACEUTICAL SCIENCES,  
RAMAUNIVERSITY, KANPUR**



**B.PHARM 3<sup>rd</sup> SEM  
PHYSICAL PHARMACEUTICS-I  
BP302T**

**MR. PEEYUSH**  
Assistant professor  
Rama university, kanpur

**INTERFACIAL PHENOMENA**

**OVERVIEW**

**Liquid interfaces**

- Surface tension
- Interfacial tension
- Surface free energy
- Measurement of tensions  
Spreading coefficient

**Surface active agents**

- Classification
- Reduction of surface tension
- Micellisation
- Adsorption
- HLB system
- Wetting

## LEARNING OBJECTIVES

1. Differentiate among different types of interfaces and describe relevant examples in the pharmaceutical sciences.
2. Understand the terms surface tension and interfacial tension and their application in pharmaceutical sciences.
3. Appreciate the different methods of surface and interface tension measurements and calculations.
4. Define surface free energy and spreading coefficient.
5. Understand the mechanisms of adsorption on liquid and solid interfaces.
6. Classify surface-active agents and appreciate their applications in pharmacy.
7. Differentiate between different types of monolayers and recognize basic methods for their characterization

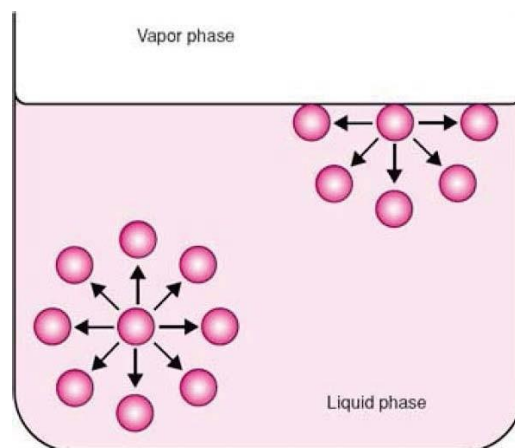
### Liquid interfaces

Interface is the boundary between two phases.

Surface is a term used to describe either a gas-solid or a gas-liquid interface.

Interfacial phase is a term used to describe molecules forming the interface between two phases which have different properties from molecules in the bulk of each phase.

### Surface Tension



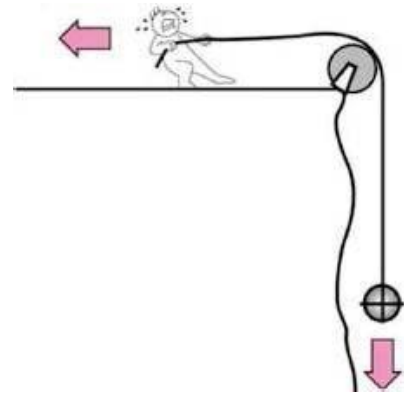
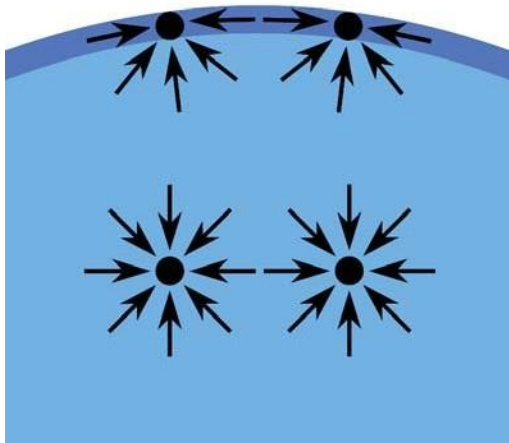
Molecules in the bulk liquid are surrounded in all directions by other molecules for which they have an equal attraction (only cohesive forces).

Molecules at the surface can only develop cohesive forces with other molecules that are below and adjacent to them; and can develop adhesive forces with molecules of the other phase.

This imbalance in the molecular attraction will lead to an inward force toward the bulk that pulls the molecules of the interface together and contracts the surface, resulting in a **surface tension**.

Surface tension is the force per unit length that must be applied parallel to the surface to counterbalance the net inward pull.

It has the units of dynes/cm or N/m.



## Interfacial tension

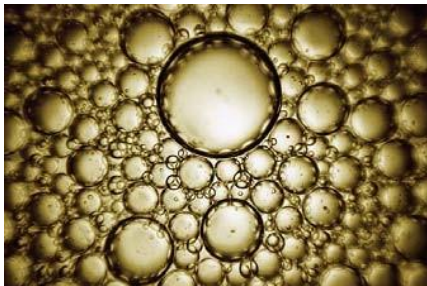
Interfacial tension is the force per unit length existing at the interface between two immiscible phases (units are dynes/cm or N/m).

The term **interfacial tension** is used for the force between:

Two liquids =  $\gamma_{LL}$

Two solids =  $\gamma_{SS}$

Liquid-solid =  $\gamma_{LS}$



The term **surface tension** is reserved for the tensions:

Liquid-vapor =  $\gamma_{LV}$  (written simply as  $\gamma_L$ ).

Solid-vapor =  $\gamma_{SV}$  (written simply as  $\gamma_S$ ).

Interfacial tensions are weaker than surface tensions because the adhesive forces between two liquid phases forming an interface are greater than that between liquid and gas phases.



## Surface free energy

The surface layer of a liquid possesses additional energy as compared to the bulk liquid.

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*:

$$W = \gamma \Delta A$$

W: surface free energy (ergs)

$\gamma$ : surface tension (dynes/cm)

$\Delta A$ : increase in area ( $\text{cm}^2$ ).

**Therefore, surface tension can also be defined as the surface free energy per unit area of liquid surface.**

Each molecule of the liquid has a tendency to move inside the liquid from the surface; therefore, when the surface is increased, the liquid takes the form with minimal surface and as a result, minimal surface energy:

# Sphere!



## Measurement of Tensions

### Capillary Rise Method

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

By measuring this rise in the capillary, it is possible to determine the surface tension of the liquid using the formula:

$$y = \frac{1}{2} r M p g$$

y: surface

tension r:

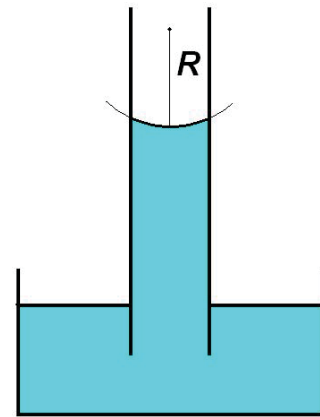
radius of

capillary

M: height

p: density of the liquid

g: acceleration of gravity



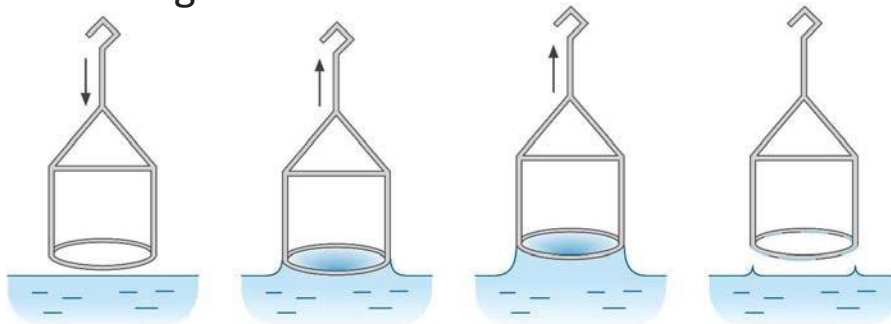
**This method cannot be used to obtain interfacial tensions.**

### The DuNoüy Ring Method

The force necessary to detach a platinum–iridium ring immersed at the surface or interface is proportional to the surface or interfacial tension. The surface tension is given by the formula:

$$y = \frac{\text{Dial reading in dynes}}{2 \times \text{Ring circumference} \times \text{Correction factor}}$$

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



# Surface Active Agents

Classification

Reduction of Surface Tension Micellisation

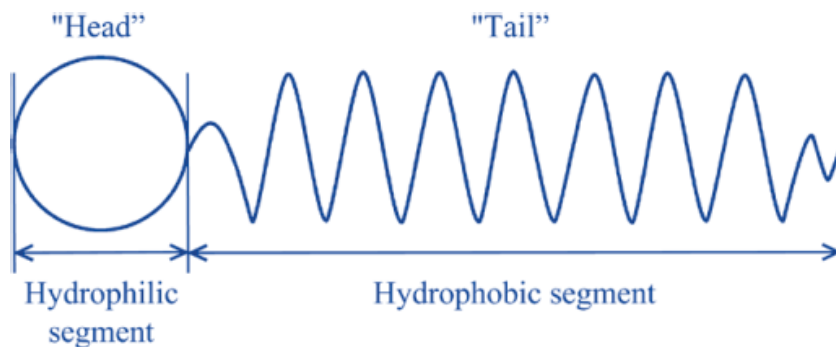
Adsorption

HLB system

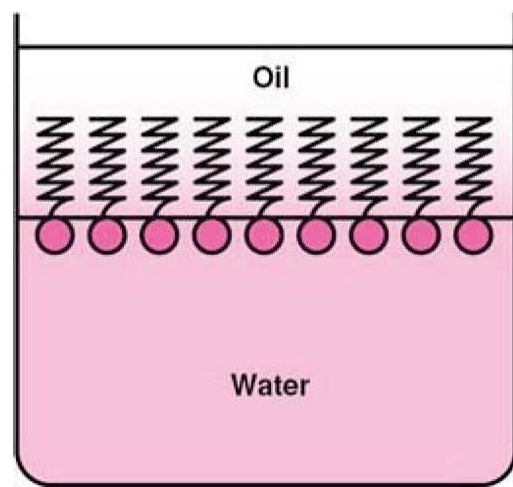
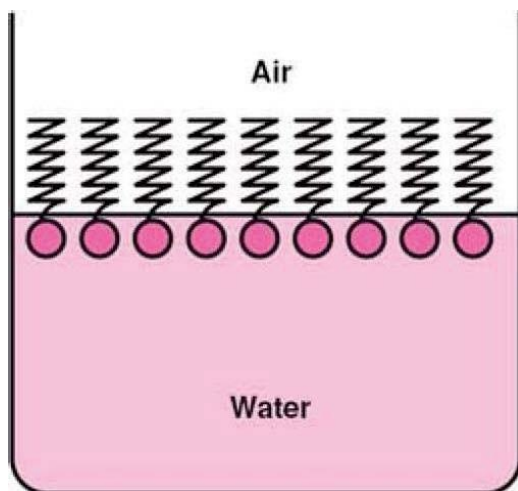
Wetting

Molecules and ions that are adsorbed at interfaces are termed *surface-active agents* or *surfactants*.

Surfactants have two distinct regions in their chemical structure, one of which is water-loving (*hydrophilic*) and the other of which is lipid-loving (*lipophilic*). These molecules are referred to as *amphiphile*.



When such molecule is placed in an air-water or oil-water system, the polar groups are oriented toward the water, and the nonpolar groups are oriented toward the air or oil.



### Non-ionic surfactants

Have low toxicity and high stability and compatibility, e.g. Sorbitan esters (spans) and Polysorbates (tweens).

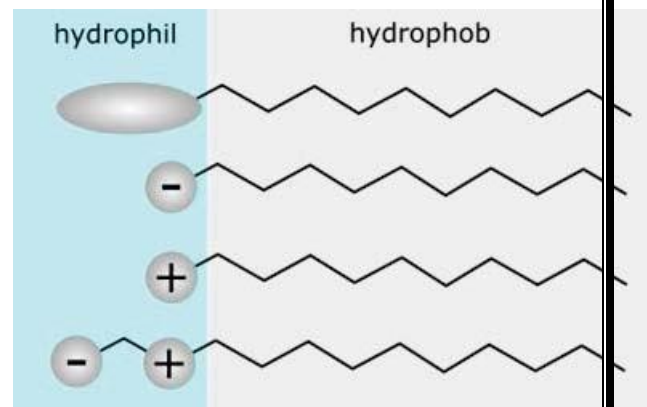
### Anionic surfactants

Have bacteriostatic action  
e.g. Sodium Lauryl Sulphate

### Cationic surfactants

Have bactericidal activity  
e.g. benzalkonium chloride

### Ampholytic Surfactants



## Reduction of Surface Tension

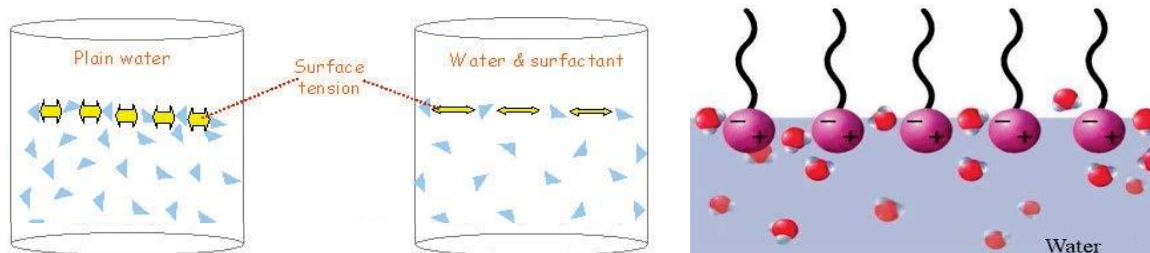
### Principle

When surfactants are dissolved in water they can reduce surface tension by replacing some of the water molecules in the surface so that the forces of attraction between surfactant and water molecules are less than those between water molecules themselves, hence the contraction force is reduced.

### Effect of Structure on Surface Activity

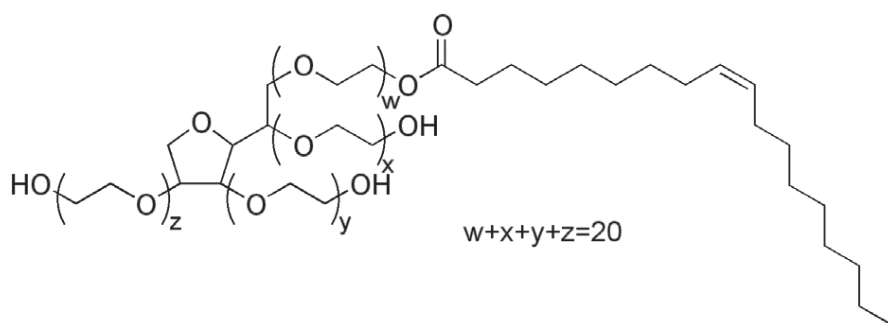
The surface activity (surface tension reduction) of a particular surfactant depends on the balance between its hydrophilic and hydrophobic properties.

An increase in the length of the hydrocarbon chain (hydrophobic) of a surfactant increases the surface activity.



An increase in the length of the hydrocarbon chain (hydrophobic) of a surfactant increases the surface activity.

An increase in the length of the ethylene oxide chain (hydrophilic) of a non-ionic surfactant results in a decrease of surface activity





# MICELLISATION

## Definition

Micelles are formed when the concentration of a surfactant reaches a given concentration called *critical micelle concentration (CMC)* in which the surface is saturated with surfactant molecules.

When the concentration of the surfactant is increased above the CMC, the number of micelles increases but the free surfactant concentration and surface tension stays constant at the CMC value

Micelles are dynamic structures and are continually formed and broken down in solution (they are not solid spheres).

The main reason for micelle formation is to obtain a minimum free energy state.

In a micelle, polar or ionic heads form an outer shell in contact with water, while non polar tails are sequestered in the interior to avoid water.

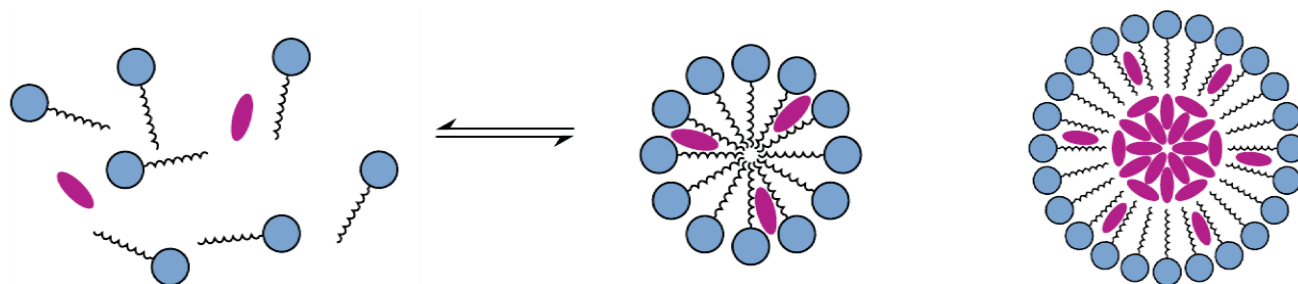


## Solubilization

Solubilization is the process where water-insoluble substances are brought into solution by incorporation into micelle.

Solubilization does not occur until the micelles are formed (i.e. above CMC)

The amount of substance solubilized increases as the number of micelles increases.



## Factors Affecting Micellisation

### Structure of the surfactant

Increase in length of the hydrocarbon chain results in a decrease in CMC and an increase in micellar size.

An increase in the ethylene oxide chain length of a non-ionic surfactant makes the molecule more hydrophilic and the CMC increases.

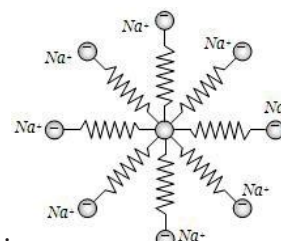
### Type of counterion

Micellar size increases for a cationic surfactant as the counterion is changed according to the series  $\text{Cl}^- < \text{Br}^- < \text{I}^-$ , and for a particular anionic surfactant according to  $\text{Na}^+ < \text{K}^+ < \text{Cs}^+$ .

### Addition of electrolytes

Electrolyte addition to solutions of ionic surfactants decreases the CMC and increases the micellar size.

This is because the electrolyte reduces the forces of repulsion between the charged head groups at the micelle surface, allowing the micelle to grow.

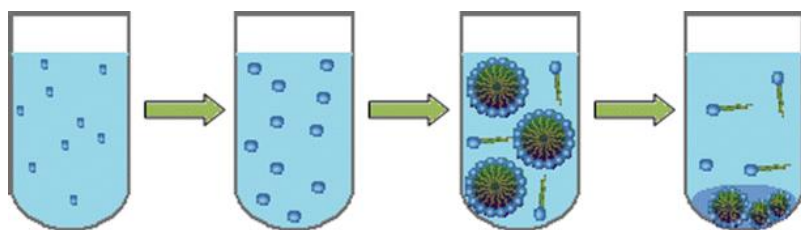


### Effect of temperature

For non-ionic surfactants, increasing temperature increases micellar size and increases CMC.

The effect of temperature stops at a characteristic temperature called the *cloud point* where

the solution become turbid due to the separation of the solution into two phases.

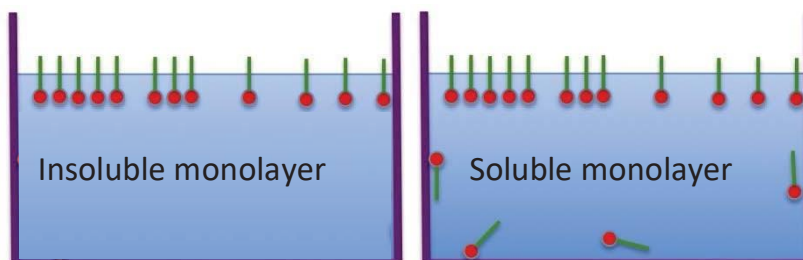


Temperature has a comparatively small effect on the micellar properties of ionic surfactants.

### **Insoluble Monolayers**

Insoluble amphiphilic compounds (e.g. surfactants with very long hydrocarbon chains) can also form films on water surfaces when they are dissolved in a volatile solvent and carefully injected onto the surface.

They differ from soluble amphiphilic compounds in that all the molecules injected on to the surface stay at the surface, and do not continually move back and forward between the surface and the bulk of the solution in equilibrium.



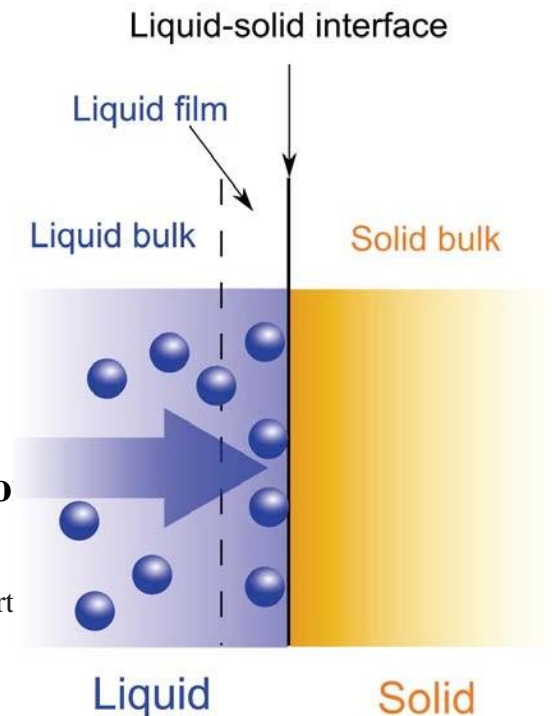
# ADSORPTION

## Types of Adsorption

Adsorption is the adhesion of atoms, ions, or molecules from a gas, liquid, or dissolved solid to a interface.

There are two general types of adsorption:

1. Physical adsorption, in which the adsorbate is bound to the surface through the weak van der Waals forces.
2. Chemical adsorption or chemisorption, which involves the stronger valence forces.



## Factors Affecting Adsorption

### Solubility of the adsorbate

The extent of adsorption of a solute is inversely proportional to the extent of its solubility.

### pH

For simple molecules adsorption increases as the ionization of the drug is suppressed, reaching a maximum when the drug is completely unionized.

### Nature of the adsorbent

The extent of adsorption is proportional to the surface area of the adsorbent. Thus, the more finely divided or the more porous the solid, the greater its adsorption capacity.

### Temperature

Since adsorption is generally an exothermic process, an increase in temperature normally leads to a decrease in the amount adsorbed.

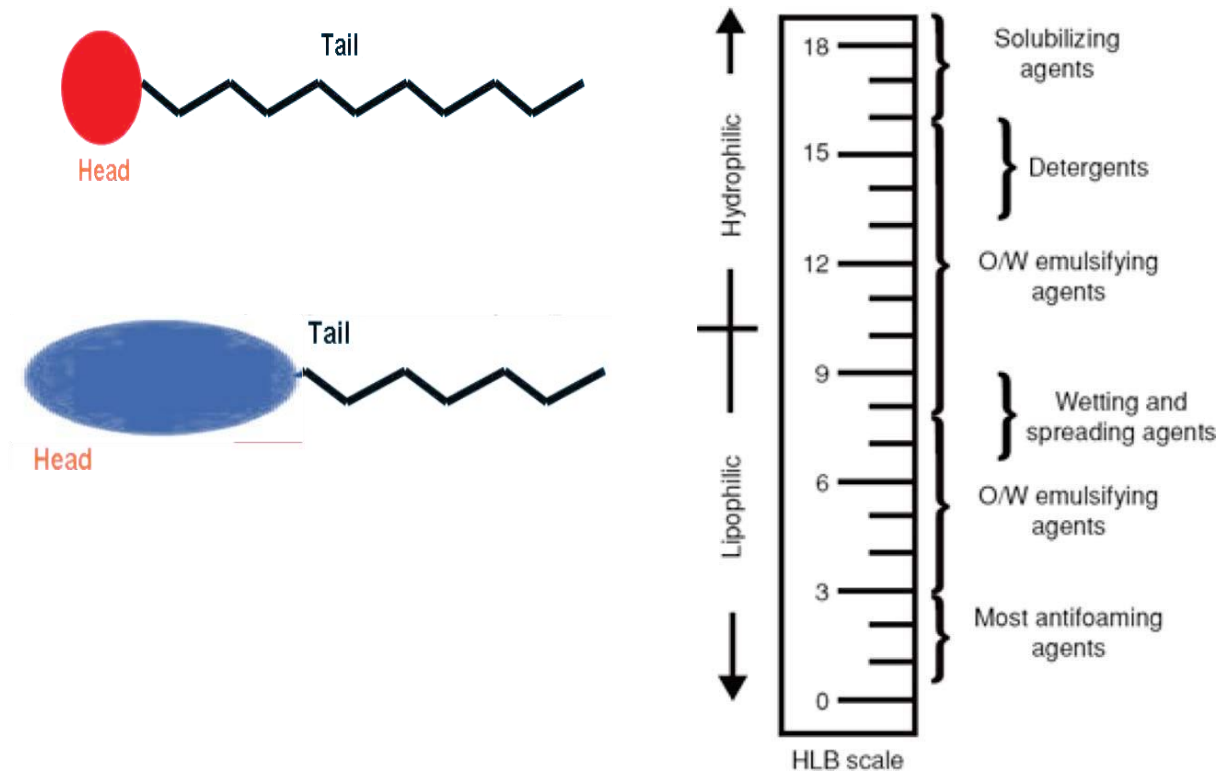
## Pharmaceutical Applications

1. **Adsorption of poisons/toxins:** Activated charcoal are used in adsorbing the toxins and reducing the effects of poisoning by the oral route.
2. **Separation:** HPLC and TLC techniques rely on the principle of adsorption.
3. **Taste masking:** Drugs such as diazepam may be adsorbed onto solid substrates to minimize taste problems.
4. **Adsorption in drug formulation:**
  1. Suspensions are stabilized by adsorption of surfactants and polymers on the dispersed solid.
  2. Adsorption of surfactants onto poorly soluble solids increase their dissolution rate by increased wetting.

# HLB system

## Definition

The **hydrophile-lipophile balance (HLB)** system is an arbitrary scale for expressing the hydrophilic and lipophilic characteristics of an emulsifying agent.



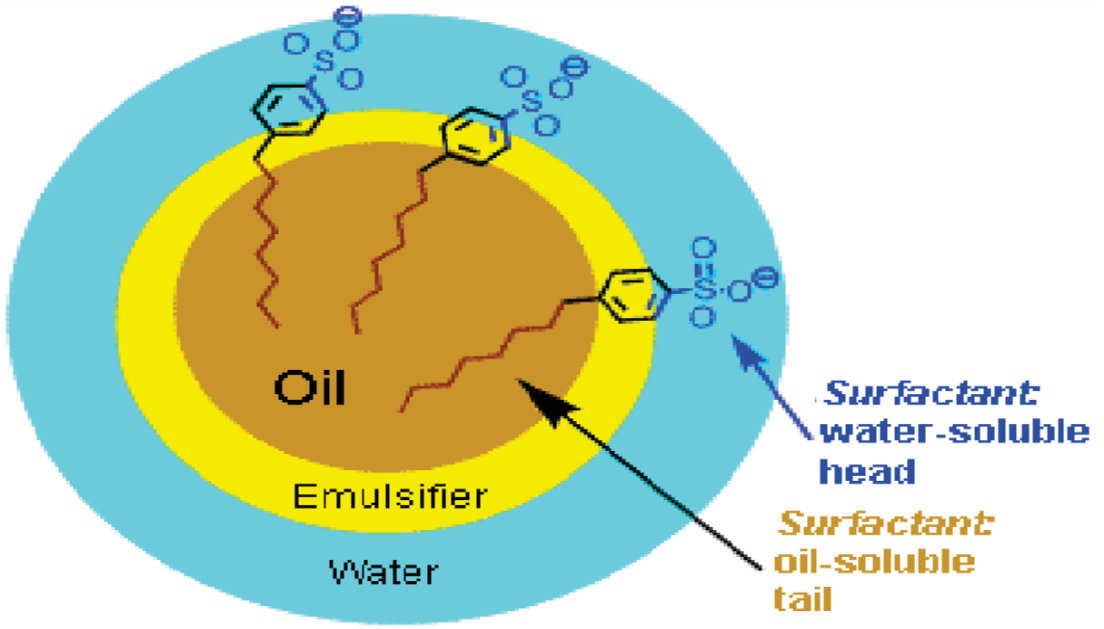
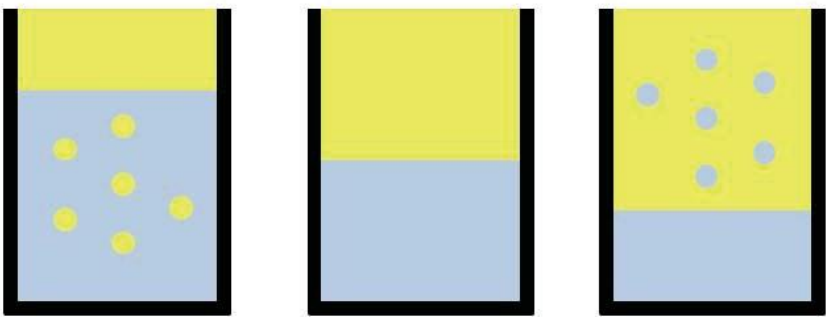
## Definition

Agents with HLB value of 1-8 are lipophilic and suitable for preparation of w/o emulsion, and those with HLB value of 8- 18 are hydrophilic and good for o/w emulsion.

The oil phase of an o/w emulsion requires a specific HLB, called the **required hydrophile-lipophile balance (RHLB)**.

High HLB  
H<sub>2</sub>O Soluble  
Oil-in-Water Emulsion

Low HLB  
Oil (fat) Soluble  
Water-in-Oil Emulsion



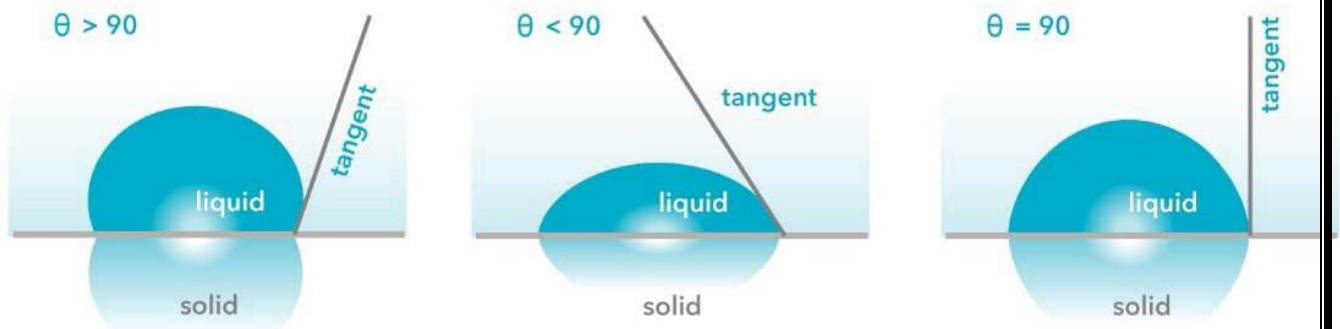
### Example

Ingredient	Amount	RHLB (O/W)
1. Beeswax	15 g	9
2. Lanolin	10 g	12
3. Paraffin wax	20 g	10
4. Cetyl alcohol	5 g	15
5. Emulsifiers (Tween 80 + Span 80)	5 ml	
6. Preservative	As required	
7. Color	0.2 g	
8. Water, purified	q.s. 100 ml	

### Wetting Agents

A wetting agent is a surfactant that lowers the contact angle by displacing an air phase at the surface, and replacing it with a liquid phase.

The contact angle is the angle between a liquid droplet and the surface over which it spreads.





## Applications

Application of wetting to pharmacy and medicine include:

1. The displacement of air from the surface of pharmaceutical powders in order to disperse them in liquid vehicles.
2. The displacement of air from the matrix of cotton pads and bandages so that medicinal solutions can be absorbed for application to various body areas.
3. The displacement of air from the surface of the skin and mucous membranes when medicinal lotions and sprays are applied.

## References

1. Attwood, D. & Florence, A. T. 2008. *Physical pharmacy*, London. Chicago, Pharmaceutical Press.
2. Sinko, P.J. M. A. N. 2006. *Martin's physical pharmacy and pharmaceutical sciences: physical chemical and biopharmaceutical principles in the pharmaceutical sciences*, Philadelphia, Lippincott Williams & Wilkins.
3. Hamid Alghurabi Assistant Lecturer in Pharmaceutics; Physical Pharmacy; University of Kerbala.