Surface and Interfacial Phenomena

Liquid interfaces

1. Surface & Interfacial tension

1.1. Definition of Surface tension:

One of the most important phenomenon in nature:

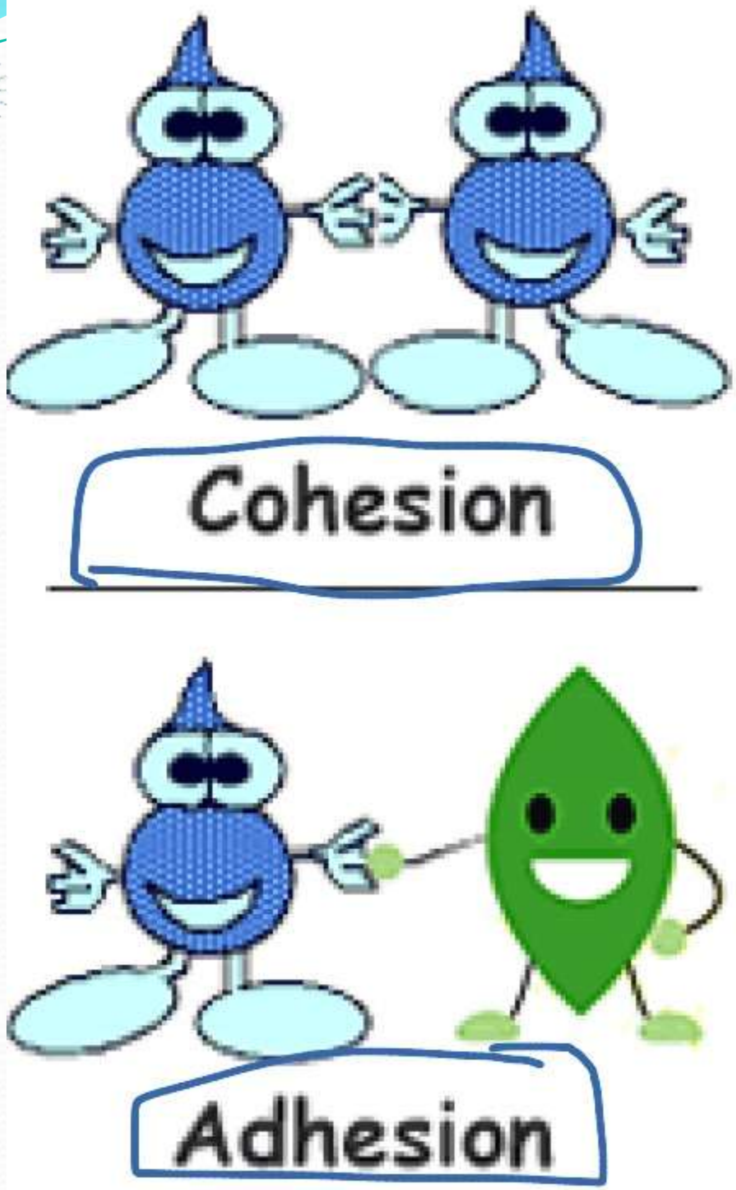
- It is a property of the surface of a liquid that causes it to behave as an elastic sheet.

- It allows insects to walk on water.
- It allows small objects, such as needles to float on the surface of water.
- It is involved in formation of water droplets on various surfaces or raindrops.

The term Surface tension is typically used when the liquid surface is in contact with gas (air).

2

Cohesion and Adhesion forces



Water sticking to water.

water is sticking other substances

- **To keep the equilibrium, an equal force must be applied to oppose the inward tension in the surface.**

- **Thus *SURFACE TENSION* [γ] is the force per unit length that must be applied parallel to the surface so as to counterbalance the net inward pull and has the unit of dyne/cm**

- ***INTERFACIAL TENSION* is the force per unit length existing at the interface between two immiscible liquid phases and has the unit of dyne/cm.**

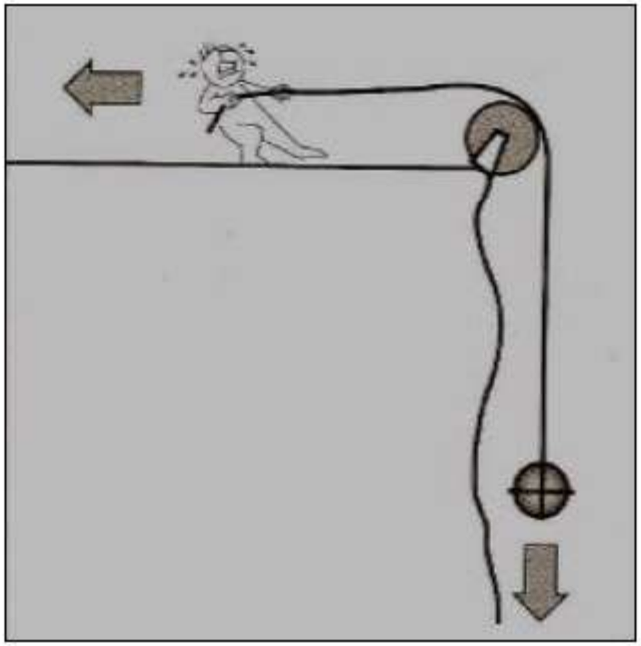
- **Invariably, interfacial tensions *are less than* surface tensions because an adhesive forces, between the two liquid phases forming the interface are greater than when a liquid and a gas phase exist together.**

- **If two liquids are completely miscible, no interfacial tension exists between them.**

- **Greater surface tension reflects higher intermolecular force of attraction, thus, increase in hydrogen bonds or molecular weight cause increase in ST.**

Surface tension is “the force per unit length that must be applied ‘parallel’ to the surface so as to counterbalance the net inward pull”.

Units of this force: dyne/cm (or N/m), the force in dynes required to break a film of length 1 cm.



Visualization of surface tension as a person lifting a rock up the side of a cliff by pulling the rope in a horizontal direction

- Surface tension of various liquids

Liquid	Surface tension at 20°C (in dynes/cm)
Mercury	476
Water	72.8
Oleic acid	32.5
Benzene	28.9
Ethyl alcohol	22.3

Measurement of Surface and Inter-facial Tensions

Methods for measuring surface and interfacial tension

1- Capillary rise method

2- Ring (Du Nouy) tensiometer

3- Drop weight method (Stalagmometer)

The choice of the method for measuring surface and interfacial tension depends on:

- **Whether surface or interfacial tension is to be determined.**
- **The accuracy desired**
- **The size of sample.**

Capillary Rise Method

The Principle

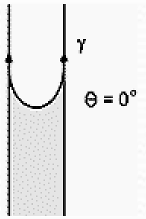
- **When a capillary tube is placed in a liquid, it rises up the tube a certain distance. By measuring this rise, it is possible to determine the surface tension of the liquid.**
- ***Cohesive force*** **is the force existing between like mole-cules in the surface of a liquid**
- ***Adhesive force*** **is the force existing between unlike molecules, such as that between a liquid and the wall of a glass capillary tube**
- ***When the force of Adhesion is greater than the cohesion, the liquid is said to*** ***wet the capillary wall, spreading over it***, ***and rising in the tube.***

For surface tension only

- If a capillary tube of inside radius =r immersed in a liquid that wets its surface, the liquid continues to rise in the tube due to the surface tension, until the upward movement is just balanced by the downward force of gravity due to the weight of the liquid

- ***The upward component of the force*** resulting from the surface tension of the liquid at any point on the circumference is given *by:*

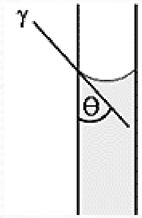
$$a = \gamma \cos \theta$$



Cont. angle water and glass

Thus the total upward force around the inside circumference of the tube is

$$a = 2 \pi r \gamma \cos \theta$$

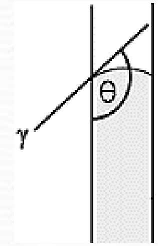


Where

θ = ***the contact angle between the surface of the liquid and the capillary wall***

$2 \pi r$ = the inside circumference of the capillary.

For water the angle θ is insignificant, i.e. the liquid wets the capillary wall so that $\cos \theta$ = unity



Cont. angle Mercury and glass

The downward force of gravity

(mass x acceleration) is given by

$$\pi r^2 h (p - p^o) g + w$$

Where:

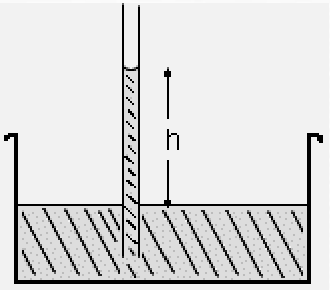
πr^2 = the cross-sectional area

h = the height of the liquid column to the lowest point of the meniscus

$(p - p o)$ = the difference in the density of the liquid p and its vapor po

g = the acceleration of gravity

w = the weight of the upper part of the meniscus.



At Maximum height, the opposing forces are in equilibrium

$$2 \pi r \gamma \cos \theta = \pi r^2 h (p - p o) g + w$$

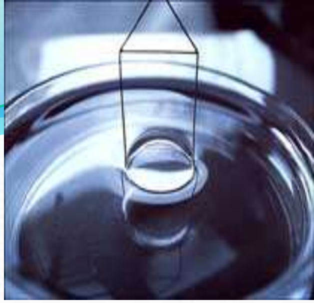
$p o$, θ and w can usually be disregarded

Hence the surface tension can be calculated.

$$2 \pi r \gamma = \pi r^2 h p g$$

$$\gamma = 1/2 \, r h p g$$

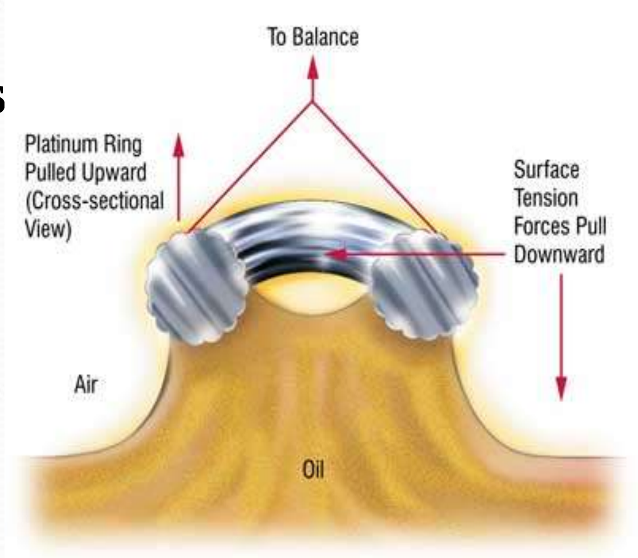
Ring (Du Nouy) Tensiometer



- For measuring surface and interfacial tensions.

The principle

- 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 of detachment is recorded in dynes on a calibrated dial
- The surface tension is given by:



$$\gamma = F / 2\pi (R_1 + R_2)$$

Where:

F = the detachment force

R_1 and R_2 = the inner and outer radii of the ring.

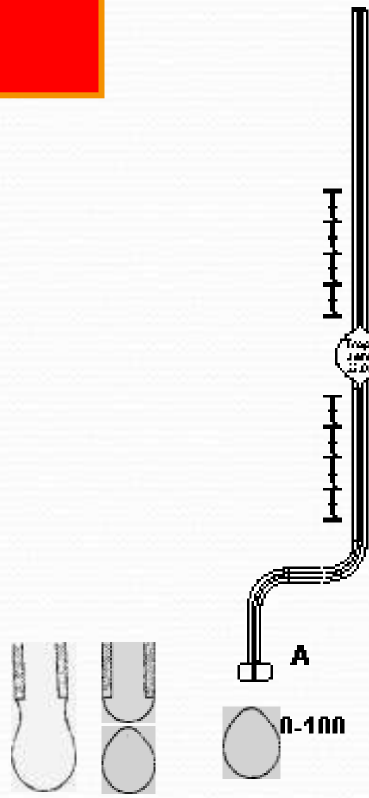
Drop Weight and drop volume method

If the volume or weight of a drop as it is detached from a tip of known radius is determined, *the surface and interfacial tension* can be calculated from

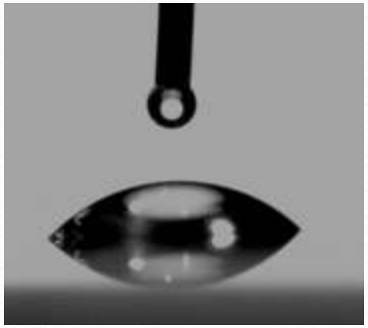
$$\gamma = \frac{\Phi\, mg}{2\pi r} = \frac{\Phi\, V pg}{2\pi r}$$

Where m = the mass of the drop
V = the volume of the drop
p = the density of the liquid
r = the radius of the tip
***g* = the acceleration due to gravity**
Φ = a correction factor

- ***The correction factor is required as not all the drop leaves the tip on detachment***
- ***The tip must be wetted by the liquid so as the drop doesn't climb the outside of the tube.***



Contact Angle (ϴ)



- The **contact angle** is the angle at which a liquid/vapor interface meets the solid surface.
- The contact angle is specific for any given system and is determined by the interactions across the three interfaces.

Contact Angle (ϴ)

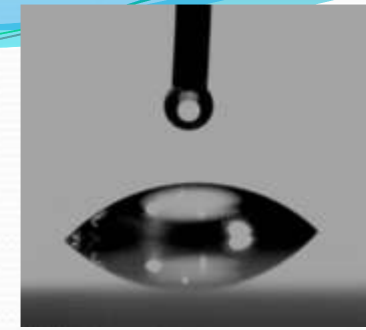


Figure 10 - The contact angle of a liquid with a solid is used as wettability index. For $\alpha < 90°$ the liquid wet the wall (eg: water on glass), for $\alpha > 90°$ the liquid does not wet the wall (eg: mercury on glass). If $\alpha = 0°$ the liquid perfectly wet the wall.

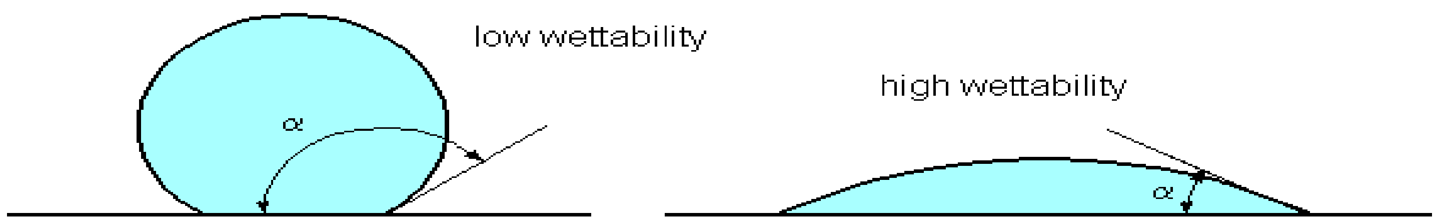
According to the nature of the liquid and the solid, a drop of liquid placed on a solid surface will adhere to it or no. which is the wettability between liquids and solids.

When the forces of adhesion are greater than the forces of cohesion, the liquid tends to wet the surface and vice versa. Place a drop of a liquid on a smooth surface of a solid. According to the wettability, the drop will make a certain angle of contact with the solid.

A contact angle is lower than 90°, the solid is called wettable

A contact angle is wider than 90°, the solid is named non-wettable.

A contact angle equal to zero indicates complete wettability.



[redacted] The contact angle of a liquid with a solid is used as wettability index. For $\alpha < 90^\circ$ the liquid wet the wall (eg: water on glass), for $\alpha > 90^\circ$ the liquid does not wet the wall (eg: mercury on glass). If $\alpha = 0^\circ$ the liquid perfectly wet the wall.