The Heat

Heat in physics and chemistry is a form of energy, accompanied by the movement of atoms, molecules, or any particle that enters into the composition of matter. All bodies consist of atoms or molecules in a state of constant motion, and the energy of these atoms is called internal energy, and it is proportional to the body's thermal energy.

Thermal energy can be converted from one form to another, and thus thermal energy can be obtained by:

* Chemical energy through chemical reactions such as combustion.

* Nuclear energy through nuclear reactions such as nuclear fusion in the sun.

* Electric power through electric heaters.

* Electromagnetic energy through electromagnetic radiation, such as in electromagnetic stoves or microwaves.

Temperature

When studying heat, its quantities, methods of transmission, and its effect on bodies, we need the basic quantity known as temperature, since the temperature of a body is a measure of the amount of thermal energy that the body stores, that is, it is an indicator of the extent of the movement of its atoms, and it determines whether the body will acquire more heat energy. Or will it lose part of it when it touches another object? To determine the temperature of an object, we use the thermometer.

Thermometer

A thermometer is an instrument for measuring the temperature in the human body or room temperature. It contains a scale numbered in certain ways, so the temperature can be expressed in degrees.

There are different types of them, and most of them work by measuring the change in the volume of a liquid such as mercury with temperature. Or the electrical resistance changes with temperature. Or the expansion of a gas by increasing its temperature.

A thermometer works through a change in one of the physical properties with a change in temperature, such as:

1- The property of the expansion of bodies with increasing temperature. The mercury thermometer
2- The property of changing the pressure of the gas thermometer.
3- The thermocouple's electromotive force change property.

The most important types of thermometers are:

liquid thermometer

A common type of thermometer measures temperature by expanding a liquid in a tiny glass tube (capillary tube). A glass bulb contains a liquid that is usually mercury or colored alcohol. They are liquids that respond to temperature change - mercury is used for high temperatures and alcohol for low temperatures.

Example of a liquid thermometer:

Medical thermometer: It is used to measure body temperature, and therefore its temperature range is relatively low and its gradations are medium to give an accurate reading. Its components: In the medical thermometer, there is a ladder that usually ends at a temperature of 43 degrees Celsius (C), and there are tenths of a degree in the ladder. In the medical thermometer, there is a narrow column of mercury because it is porous and is magnified by a triangular glass leg. Also, in a medical thermometer, there is a constriction in the first glass tube, the expanding mercury expands, rushes, and bypasses it. A capillary tube surrounds the narrow column containing mercury. Medical thermometer features:

Mercury moves a visible distance with each change in temperature.

When the mercury cools and contracts, it can only fall back into the bulb by shaking (allowing time for reading). The walls of the glass bulb are so thin that the mercury heats up quickly.

Maximum and minimum thermometers:

Liquid thermometers record the maximum or minimum temperature that is reached in a specified period of time. It has a vitreous mineral index that the meniscu pushes up or pulls down on the fluid. The pointer remains at the maximum or minimum position it reaches during the time the thermometer is left on. It is reset with a magnet.

Other types of thermometers

electric thermometer:

It measures the temperature from the resistance change that occurs as a result in the wire. Other devices under the wings of an aircraft, for example, are used to measure the resistance change in thermal rectifiers.

It is necessary to find a scale or scale that expresses the temperature regardless of the change in the physical property, and these scales include the Celsius scale, the Fahrenheit scale, and the absolute scale.

Celsius Scale

Celsius relied on the presence of two points in which the temperature does not change with the supply of water with heat, which are the melting point of ice and the boiling point of water at one atmospheric pressure.

And divided between these two degrees into 100 sections and named each section degrees Celsius or Celsius C. Celsius C (degrees Celsius), which is the main measure adopted in our daily lives in most countries of the world.

Fahrenheit scale

Fahrenheit relied on the same principle of Celsius gradation, ie on the point of water turning into a gaseous or solid state, but considered the melting point to be 32 F instead of zero and the boiling point of water to be 212 instead of 100. Fahrenheit is the standard adopted in the United States of America.

Absolute scale (Kelvin)

Kelvin was based on the temperature of the triple point (a point where ice, water and steam exist together and considered its value 273.16 degrees absolute or Kelvin. Kelvin, which is the scale adopted by the SI global system, is a widely used measure in scientific fields. It must be used if you want to calculate ratios of temperature.

The following table shows the conversion formulas from one step to another:

The transfer	Formula	Example
From percent to absolute	$T_K = T_C + 273$	$21\ ^{O}C = 294\ K$
From absolute to percent	$T_C = T_K - 273$	$313\ K = 40\ ^{O}C$
From Fahrenheit to Celsius	$T_C = 5/9 \times (T_F - 32)$	$86\ ^{O}F = 30\ ^{O}C$
Celsius to Fahrenheit	$T_F = 9/5 \times (T_C + 32)$	$50\ ^{O}C = 122\ ^{O}F$

The following table shows a comparison of the three different grades:

	^{O}F	^{O}C	^{O}K
boiling point of water	212	100	373
human body temperature	98.6	37	310
freezing point of water	32	0	273
absolute zero	-460	-273	0

Examples

Example (1) :

Find the value of the temperature at which Celsius and Fahrenheit are the same?

Solution:

We assume that the temperature is T, and by substituting it in the relationship:

$T_C = 5/9\ (T_F - 32)$

$9F = 5F - 160$

$4F = -160 \quad F = -160 / 4 = -40$

$-40\ ^{O}C = -40\ ^{O}F$

Example (2)

Convert 77 degrees Fahrenheit to its corresponding absolute scale ?

solution

There is no relationship between the Fahrenheit scale and the absolute scale, so we convert first to the Celsius scale and from it we convert to the absolute scale

$T_C = 5/9 (T_F - 32)$

$T_C = 5/9 (77 - 32) = 25 \, ^OC$

$T_K = T_C + 273$

$T_K = 25 + 273$

$T_K = 298 \, ^ok$

Zeroth Law of Thermodynamics

* Two objects in contact tend to be at the same temperature *

The zeroth law of thermodynamics states that if two bodies are in thermal equilibrium with a third body, then the two bodies are in equilibrium with each other.

When two bodies of different temperatures come into contact, the thermal energy is transferred from the hot body to the cold body by collision of atoms or molecules of the hot, fast-moving body with the lower-energy cold body atoms or molecules, which increases their speed.

This transition continues until equilibrium is reached, at which point the temperature of the two bodies is equal.

Just as water flows from top to bottom only, heat (thermal energy) is transferred only from a body with a higher temperature to another with a lower temperature. The greater the temperature difference between the two bodies, the faster the heat transfer between them.

It is very important to realize that the temperature and the amount of heat are two completely different things and not one thing. The temperature of the body is an indication of its energy level, while the amount of heat is the heat energy transferred from one body to another.

Amount of heat

It is the amount of heat energy gained or lost by a body and it is proportional to the mass of the body **m**, the temperature difference **T2 - T1,** and the proportionality constant **C**. It is called the specific heat of the substance. Whereas;

$$Q = mc\,(T_2 - T_1)$$

** The amount of heat gained by the body is measured in calories.

**Thermal energy is measured in joules

**The scientist James Joule came and did mechanical work on the body and found that it turns into

heat gained by the body and reached a relationship between joules and calories and agreed that

4.186 joules = 1 calorie

The amount of heat depends on-:

1- Change in temperature: The greater the difference between the temperatures, the more necessary large amount of heat .
2- Mass: the greater the mass, the greater the amount of heat needed to heat it .
3- Type of material: Each material has a physical property that affects the amount of heat required to heat up . A certain mass of it, to reach a certain temperature and this property was called heat The quality of the material .

The specific heat of a substance is defined as the amount of heat needed to raise the temperature of one gram of the substance by one degree Celsius, and its unit of measure is the calorie /g. ^{O}C

A calorie is defined as the amount of heat needed to raise the temperature of one gram of water one degree Celsius from 14.5 to 15.5

The heat capacity S of a body is defined as the amount of heat required to raise the body temperature by one degree Celsius. The unit of measurement is calories / ^{O}C.

Heat capacity is a property of the body, while specific heat is a property of matter.

- When two bodies of different temperatures come into contact, heat energy is transferred from the hot body to the cold body until it reaches the state of equilibrium. Then the temperature of the two bodies will be equal and:

The amount of heat lost = the amount of heat gained

Methods of heat energy transfer

Heat cannot be transmitted between two bodies or between two points in one body unless the temperatures between them are different. Heat energy is transmitted from one body or from one place to another in three ways: conduction, convection and radiation.

conduction heat transfer

Thermal energy is transmitted by conduction and that is through the transfer of heat through solid bodies from the hottest part to the least hot part, and through this the body temperatures are equal and its transmission stops.

For example, when one end of a copper rod is placed in a flame, the other end heats up rapidly.

What is the explanation for that?

Heat transfer by pregnancy

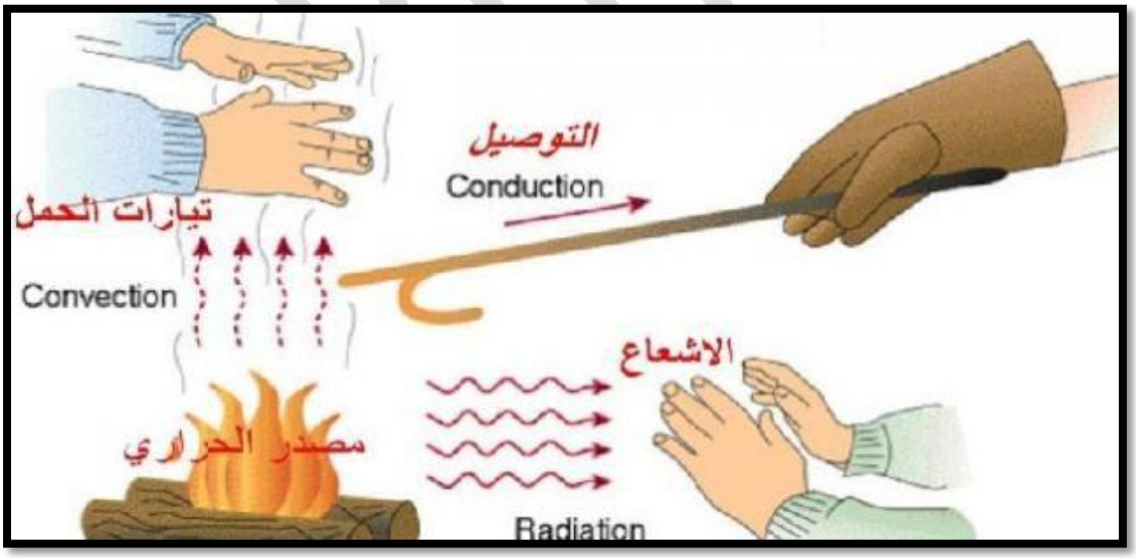
When heat is transferred to the part near the heat source in liquid or gaseous bodies, the density decreases, as the liquid or gaseous bodies decrease in density when their temperature increases, which makes those bodies rise to the top and parts of them decrease to the bottom. The process of exchanging objects again.

If a gas or liquid is heated, it expands, and its density decreases and rises, and the colder gas or liquid decreases to occupy its place, thus creating a convective current. The convection current continues until all the gas or liquid reaches the same temperature.

Heat transfer by radiation

In this method, heat is transferred from a hot place to a cold place without the medium having any role. It can also happen in a vacuum, unlike conduction and pregnancy.

Thermal energy is transmitted in the form of electromagnetic waves located in the infrared region. Hot objects radiate an amount of infrared rays greater than the amount radiated by cold objects. Energy is transmitted from the sun to the Earth through space by radiation.



Linear Expansion

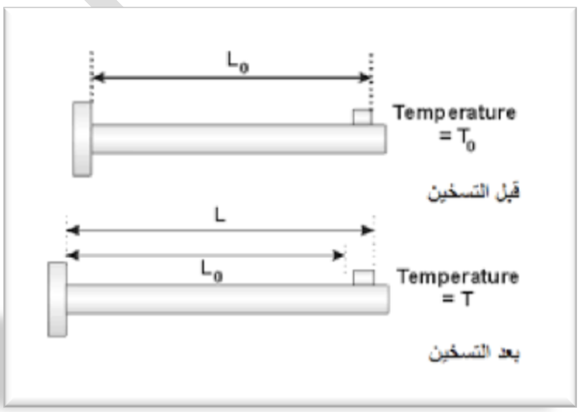
It is known that most bodies, with the exception of limited cases, expand with heat and contract with cold. This can be explained by the fact that when a quantity of heat is transferred to the body, the movement of its atoms or molecules increases, and as a result of the increase in the movement of atoms or molecules, it occupies more space and therefore the body expands and the opposite occurs when the body loses a quantity of heat as Atoms or molecules move more slowly and therefore occupy less space, and then the body shrinks.

If we have a rod of length $\mathbf{L_O}$ at a temperature $\mathbf{T_O}$ and with an increase in temperature of $\Delta\mathbf{T}$, an increase in length of $\Delta\mathbf{L}$ occurs.

$\Delta\mathbf{L}$ is directly proportional to $\mathbf{L_O}$, Δ **T** and the proportionality constant $\boldsymbol{\alpha}$ is called the coefficient of longitudinal expansion of the rod material

$$\Delta L = \alpha\, LO\, \Delta T$$

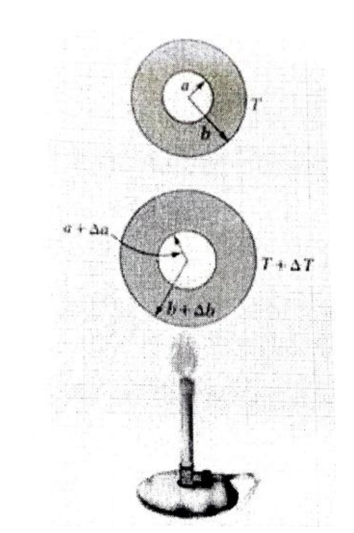
The coefficient of linear expansion α is defined as the increase in the length of a rod of a substance of unit length at its temperature by one degree Celsius. The unit of the coefficient of linear expansion is $^{\mathrm{O}}\mathbf{C}^{-1}$. The value of the coefficient of linear expansion depends on the type of material used. And its value is not completely fixed .



Example (3)

At a temperature of 25 ^{O}C, it was found that the diameter of a solid sphere is 4 cm and the inner diameter of an iron ring is 3.97 cm. Calculate the temperature to which the iron ring must be heated until the ball can pass through it, knowing that the coefficient of longitudinal expansion of the iron is $^{O}C^{-1}$ 11 x 10^{-6}.

Solution :



Suppose the required temperature is T_2, then it is

Ball diameter = ring diameter

a = 3.97 cm ,, a + Δa = 4 cm ------ Δa= 0.03 cm

Using the relationship:

$\Delta L = \alpha L_O \Delta T$

$\Delta T = \Delta L / L_O \alpha$

$\Delta T = \Delta a / L_O \alpha$

$\Delta T = 0.03 / (3.97 \times 0.000011) = 687\ ^{o}C$

$T^2 = 687 + 25 = 712\ ^{O}C$

Example (4)

Find the change in the length of a copper rod of length 0.8 m if its temperature changes from 15 ^{O}C to 35 ^{O}C, given that the value of the linear expansion of copper is equal to 17 X 10^{-6} C^{-1} ?

Solution-:

$L_O = 0.8$ m

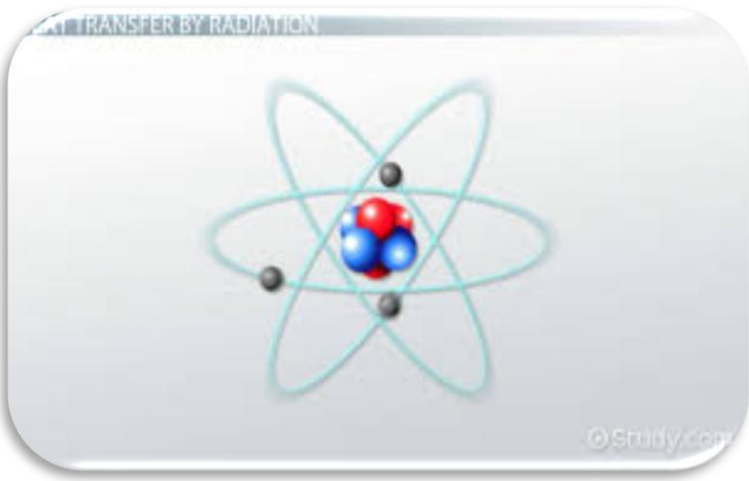
$\Delta T = 35 - 15 = 20\ ^{o}C$

$\alpha = 17 \times 10^{-6}\ {}^{O}C^{-1}$

$\Delta L = L - L_O = \alpha\, L_O\, \Delta T$

$\Delta L = 17 \text{ X } 10^{-6}\ {}^{O}C^{-1} \times 0.8 \text{ m} \times 20\ {}^{o}C$

$\Delta L = 272 \times 10^{-6} \text{ m} = 0.272 \text{ mm}$



The kinetic theory of gases

Gas is made up of distant particles that move randomly freely because of the small forces of attraction and repulsion between them, as well as because of the lack of the earth's gravitational force for the gaseous particles when compared with their kinetic energy.

The molecules of a gas confined in a closed space move at a very fast speed according to straight paths between each successive collision of collisions between the molecules of the same gas or between the molecules of the gas and the walls of the container in which it is located.

Collisions between gaseous molecules result in chemical transformations, while collisions between gaseous molecules and the vessel walls produce forces that continuously affect the vessel walls. in unit volume and time and to the great speed with which these particles move.

The volume of a gas changes when its temperature and the pressure applied to it change. Since ordinary gases vary in their properties, this leads us to assume a typical state, which is the ideal (complete) state of the gases,

The Ideal Gas

It is a gas whose molecules are infinitely small, completely flexible, and there is no friction between them because they do not affect each other with any forces. Therefore, its total energy is kinetic energy only. An ideal gas does not exist in reality.

The Real Gas

It is a gas whose molecules are small and far from each other, and under normal conditions of pressure and temperature, the properties of a real gas approach those of an ideal gas, and its total energy is the sum of its kinetic and potential energy.

Gass Laws

Experiments that were carried out on many gases showed that there are four variables:

Temperature (T), pressure (P), volume (V), amount of gas expressed in moles (n) .

The equations that express the relationship between these four variables are known as gas laws.

When a quantity of gas is heated at a constant volume, its pressure will increase linearly with temperature.

The relationship between pressure and temperature in this case is a linear relationship and as shown in Figure (1) which shows that the extension of the straight line will intersect the temperature axis at (-273)

When the volume of the gas is fixed, then

$P \alpha T$

$P = const.\ T$ ----------(1)

But when the same amount of gas is heated under constant pressure, its volume will change linearly similar to the previous change, and we will get a linear relationship between gas volume and temperature .

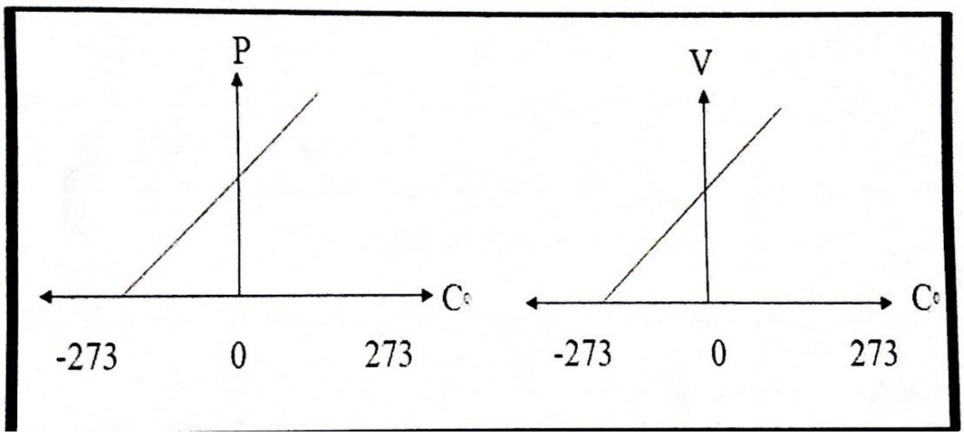


Figure (1) The left shows the relationship between pressure and temperature, and the right shows the relationship between volume and temperature .

It shows that the contraction of a gas under constant pressure will be accompanied by a decrease in temperature

V α T

V = const. T ----------(2)

When the pressure applied to the gas is constant

Relationships (1) and (2) can be reformulated into a single relationship

PV = const. T -----------(3)

It was found experimentally that the value of the constant is **nR**

number of moles = n

The general constant for gases, R, has a value of

R = 8.314 J/g. mole

After compensation, we get:

$$PV = nRT$$

This equation is called the ideal gas equation, or the constant R is called the general constant of gases, and the value of the units of this constant depends on the units of pressure, temperature, volume, and quantity of gas.

Note: The temperature in an ideal gas equation must always be expressed in absolute heat. The amount of gas n is usually expressed in moles.

whereas

The number of moles = the weight of the gas in grams divided by its molecular weight .

The ideal gas law includes secondary laws:

Boyle's Law:

If the pressure on a balloon is reduced, the balloon will expand, and this explains why the balloon used in meteorology is stretched during ascent through the air, in contrast when the gas volume is compressed, the gas pressure increases.

The British scientist Robert Boyle was the first to verify the relationship between pressure and volume and created the law which states that:

"**The volume of a given amount of gas held at a constant temperature is inversely proportional to pressure "**

PV = constant when the temperature is constant

Charles' Law:

Balloons containing hot air rise up because the air expands upon heating, so the warm air in the balloon is less dense than the cold air in the balloon at the same pressure and this difference in density is what makes the balloon rise up, and on the contrary, the balloon deflates when cooling occurs for gas.

It was the French scientist who created the relationship between the volume and temperature of a gas, as he discovered that :

"The volume of a certain amount of gas at a constant pressure increases linearly with temperature ".

V / T = constant at constant pressure

Avocado's Law:

The volume of the gas is not only affected by pressure and temperature, but it is also affected by the amount of gas. When gas is added to a balloon, it expands.

Equal volumes of different gases at the same conditions of pressure and temperature contain the same number of molecules.

For example, experiments proved that 22.37L of any gas at 0°C and 1 atmosphere contains 6.023 x 1023 gas molecules.

Thus, Avocado's law states that:

" The volume of any gas kept at constant pressure and temperature is directly proportional to the number of moles of that gas "

$$V = \text{constant} \times n$$

Standard conditions for a gas are temperature = 0 degrees Celsius, and pressure = 1.013 par (atmospheric pressure).

Some important relationships

When the volume of a certain amount of gas changes with a change in pressure with constant temperature

$$P_1 V_1 = P_2 V_2$$

But if the temperature is also variable, then:

$$P_1 V_1 / T_1 = P_2 V_2 / T_2$$

Kinetic theory of gases

The aforementioned gas laws apply to the simple structure of gases at normal pressures and temperatures, and the kinetic theory of gases has been developed to explain the behavior of gases and the various laws that apply to gases.

The kinetic theory of gases depends on the main assumptions that can be summarized in the following points:

1- Gases are composed of infinitesimally small particles (point mass), meaning that they have mass but do not have volume.
2- Neglecting the forces acting between gas molecules, except for the moment of collision.
3- The movement of particles is random and continuous and in straight lines between collisions.
4- Gas molecules are fully elastic, and the collision between molecules is elastic.
5- The temperature of a gas is a measure of the average kinetic energy possessed by its molecules as a result of their motions.

Interpretation of gas laws according to the kinetic theory of gases

Temperature: The velocity of gas molecules increases with increasing temperature. The temperature can be defined based on the kinetic theory of gases as being proportional to the average kinetic energy of the molecules, as:

$$\mathbf{ke = 3/2\ k_B T \ \ldots\ldots\ldots\ldots\ldots\ ke = 1/2\ mv^2}$$

T = temperature in Kelvin.

ke = kinetic energy.

k_B = Boltzmann's constant represents the product of dividing the general constant for gases by Avocado's number and its value is 1.380 x 10-23.

v = the average velocity of the particles.

Boyle's Law

Boyle's law can be easily explained when applying the assumptions of the kinetic theory of gases. The pressure of the gas depends on the number of times that the gas particles hit the surface of the vessel that contains it per second. Explains the inverse proportion of pressure with volume, and this is what came from Boyle's law, which means that the pressure increases when the volume decreases when the temperature remains constant, meaning that:

$$P\,v = \text{constant}$$

Charles' Law

The hypotheses of the kinetic theory of gases state that an increase in temperature leads to an increase in the rate of kinetic energy of the gas particles. The volume of gas This explains Charles' law, which states that the volume of a specific mass of gas is directly proportional to the temperature when the pressure is constant, meaning that:

$$V = \text{constant} \times T$$

Avocado's Law

When the number of gas particles increases in a closed vessel, the number of collisions per unit time with the wall of the vessel containing these particles will increase if we assume that the pressure remains constant. This means that the number of collisions per unit time remains constant, in this case the volume must increase with the increase in the number of gas particles in the closed container.

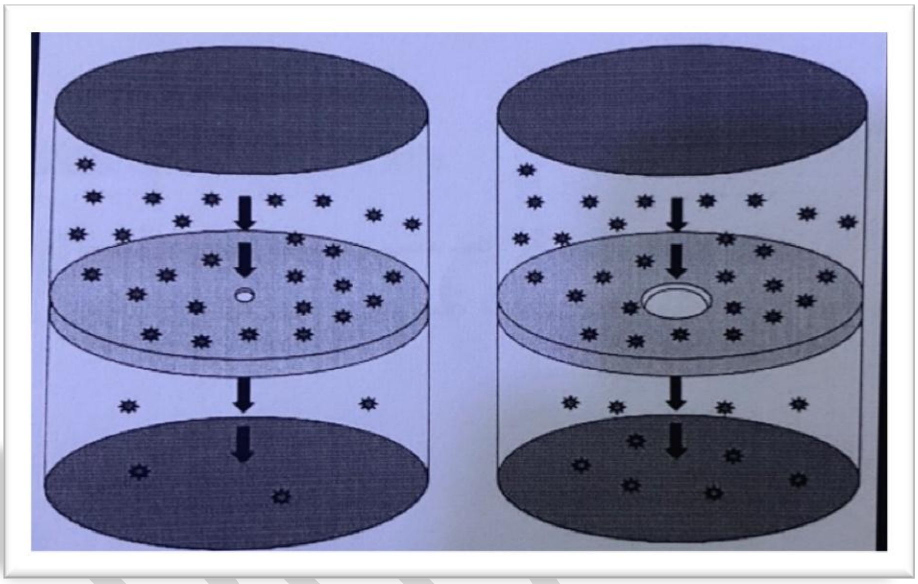
The conclusion is what came from Avocado’s law about the **proportionality of the volume of gas directly with the number of moles of gas when the temperature and pressure of the gas are constant**, meaning that:

$$V / n = \text{constant}$$

Flow and spread

The ability of a gas to spontaneously mix with diffusion through an entire other gas is a process known as diffusion.

As for the flow, it is the process that enables a gas under pressure to move in one chamber in a container to another by passing through a very small opening as shown in the figure (the picture on the left represents the flow, while the picture on the right represents the diffusion).



Graham's law of diffusion states that the rate of diffusion of a gas is inversely proportional to the square root of the gas's density. It is known that the density of a gas is proportional to the molecular weight of the gas, so Graham's law for checking can take the following formula:

(The velocity of the gas flow is inversely proportional to the square root of the molecular weight of the gas) .

The law of flow and diffusion can be explained by the kinetic theory of gases, as the molecules are in a constant state of collision, and these collisions lead to the diffusion of gases through the medium and their flow through small holes.

Examples of applications of gas laws

Example (1)

If the pressure of the gas inside an insecticide canister equals 152 kilopascals at 25 m and assuming that this gas follows the ideal gas equation. Calculate the pressure of the gas inside the canister if it is heated to 450 m؟

P1 / T1 = P2 / T2

P2 = P1 x T2 / T1

P2 = 152 kPa x 723 K / 298 K = 369 kPa

Example (2) If the volume of a balloon filled with gas is 6 liters at sea level and allowed to rise to the highest height until the pressure was 45.6 kilopascals, then if you know that the temperature of the gas decreased from 22 m to -21. Calculate the volume of the balloon at this pressure؟

T1 = 22 + 273 = 295 K

T2 = -21 + 273 = 252 K

From the general law of gases

P1V1 / T1 = P2 V2 / T2

V2 = V1 x p1 T2 / P2 T1

V2 = V1 x P1/P2 x T2 / T1

Example (3) A sample of an ideal gas, if its volume is 5 liters at a pressure of 15 atm, then calculate the volume of this gas if its pressure becomes 3 atm, considering the temperature is constant.

Solution / This problem can be solved by Boyle's law directly as follows

P1V1=P2V2

V2 = P1 V1 / P2 = 15 x5 / 3 = 25 L

Example (4) A cylinder with a moving piston contains 540 cm3 of oxygen gas under a pressure of 63.3 kpa. If the piston moves until it becomes the same volume of masses. 325cm3 Calculate the final pressure inside the cylinder.

The solution/

P1V1=P2V2

P2 = P1 V1 / V2 = 63.3 x 540 / 325 = 105.17 kpa

Example (5) The volume of a certain amount of gas is 2.24 L at a pressure of 1 atm and a temperature of 0 ºC. What is the volume of the same quantity at the same pressure and at room temperature 25 °C ؟

V1 /T1 = V2 /T2

V2 = V1 x T2 / T1

V2 = 2.24 x 298 / 273 = 2.44 L

Fluid properties

Liquids

The liquid state of matter is distinguished from the solid and gaseous state by having a fixed volume and a variable shape, as it takes the shape of the container in which it is placed, and the bonding forces between the atoms and molecules of the liquid are much less than they are in the solid state.

Density

Mass density is defined as the mass of a unit volume. The density of a substance with mass (m) and volume (v) is defined by the equation:

$$\mathbf{P = m / v}$$

The SI unit of mass density is (kg / m^3) or (g / cm^3).

The mass density of water at $4^{O}C$ is 310 kg/m^3 or 1 g/cm^3 .

The density of mercury at room temperature is 13.6×10^3 kg /m^3 or 13.6 g/cm^3 .

The density of a substance changes with its temperature. The reason for this is that the particles of the material vibrate with greater distances when the temperature of the material increases, so the rate of distance between the particles will increase, that is, the mass of the material will occupy a larger volume, which leads to a change in density with a change in temperature. In general, the density of materials decreases with increasing temperature (except for some exceptions in which the density increases with increasing temperature within a certain range of temperatures, and a well-known example is water whose density increases when the temperature rises from 0°C to 4°C).

Table (1) shows the density of some known liquids.

Table (2) also shows the dependence of water density on temperature.

Table (1) Density of some known liquids

Subject	**g/cm^3 mass density**
water	**0.998**
benzene	**0.879**
Mercury	**13.6**
sea water	**1.025**

Table (2) Density of the substance and temperature

Subject	**g/cm^3 mass density**
water at $0^{O}C$	**0.9998**
Water at $4^{O}C$	**1.000**
water at $20^{o}C$	**0.9983**
water at 100OC	**0.9584**
Sea water at $15^{o}C$	**1.035**

The density of the material depends on two main factors, namely:

1- The mass of atoms or particles.

2- The distance between atoms and molecules.

An example is iron and aluminum, as we find that the ratio of the density of iron 7.9 g/cm^3 cm to the density of aluminum 2.7 g/cm^3 is (2.9), while we find that the ratio of the atomic number of iron (56) to the atomic number of aluminum (27) is slightly more than (2) .

If the distance between the same atoms of the two materials, the ratio of the density of iron to aluminum will be double,

This indicates that the iron atoms are more closely related than the aluminum atoms.

Specific Gravity

Due to the possibility of an error in measuring the volume of the material, a new concept was resorted to, which is the specific weight (SG) or **Relative density**: a property closely related to density, and it is known as the ratio between the density of a substance and the density of water at 4°C

$SG= p /^{p}H_2O$

Since the specific weight is a dimensionless ratio, it has the same value in all unit systems.

Example 1: What volume does a 300g quantity of mercury occupy? mercury density =13600Kg/m³

The solution:

$P= m /v$

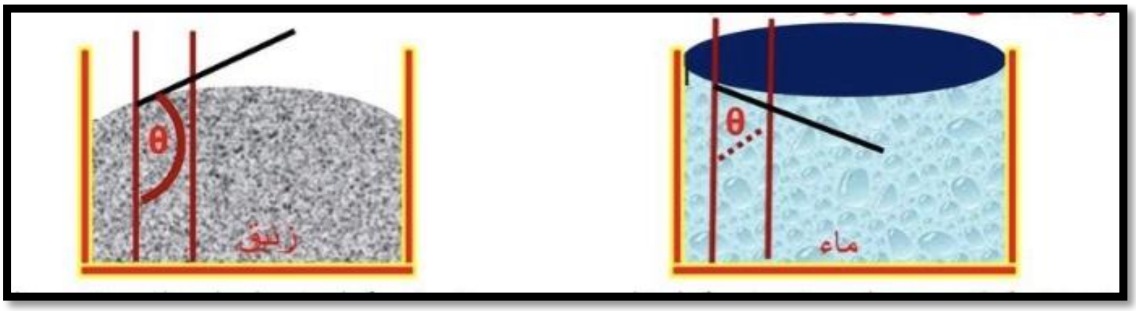
$V = m /p = 300x10^{3}$ kg / 13600 kg / m^{3}

$V= 2.2x10^{-5}$ m³

Contact Angle:

When placing a capillary tube in a container of water, we notice that the water rises in the capillary tube and the shape of the water surface is concave as shown in the following figure. This is due to the result that the force of adhesion between the water and the tube is greater than the force of cohesion. The angle between the tangent to the liquid surface and the tube wall is known as the contact angle and is acute in the case of water. In the case of mercury, the shape of the mercury surface is convex and the contact angle is obtuse, as shown in the figure.

Note: The contact angle is sharp if the adhesive forces are greater than the cohesive forces. While it is obtuse if the villages of adhesion are less than the forces of cohesion .



The contact angle depends on:

1- The nature of the liquid
2- The nature of the solid surface in contact with the liquid
3- The nature of the medium above the surface of the liquid

For example, the contact angle between mercury and glass in the case of air above the mercury differs from the contact angle between mercury and glass if the medium surrounding the mercury is water.

The contact angle is given by the following relationship:

$$\Theta = \cos^{-1} [-\Upsilon_s / \Upsilon_L]$$

where Υ_s is the surface tension between the surface of the liquid and the medium surrounding the liquid while Υ_L is the surface tension between the surface of the liquid and the surface of the solid.

Fluid Properties

- **Compression**: Liquids resist compression and their volume changes in a small amount under very high pressures.
- **Volume**: Liquids have a fixed volume. 15 cm3 of water remains 15 cm3 regardless of the change in the shape of the container in which it is placed.
- **Shape**: It has no fixed shape.
- **Diffusion**: the liquids spread among each other if they are miscible, so if you drop a drop of ink in a glass of water, you will initially see a clear separating line between the water and the ink, but then

the ink gradually spreads and all the boundaries between it and the water disappear.

- **Evaporation**: liquids evaporate if they are placed in an open container: despite the presence of attractive forces between their molecules, surface molecules with high energy and not strongly attracted to the rest of the molecules escape and turn into a gaseous state.
- **Brownian motion**: While the scientist Robert Brown in 1827 was examining microscopically some pollen grains that he had placed on a slide with drops of water, he was surprised that the grains were moving in a continuous random movement, and Brown could not explain what he saw. Scientists have found an explanation for these movements. The particles of the liquid move in a random and continuous movement, carrying with them these minutes in which they swim.
- **So the movement** is the movement of the particles of the liquid in the original, and we helped us to see it by the presence of these small suspended particles. Scientists have called this random movement of the liquid particles the name of the Brownian movement in relation to the scientist Brown who was the first to notice it.
- **Brownian motion** is not limited to liquids, as it is present in gases, and its evidence is the movement of dust grains and other things that are suspended in the air.
-

Forces of cohesion and adhesion

Between the molecules of a homogeneous substance are forces called intermolecular forces of attraction (**cohesive forces**) that hold the molecules of this substance together،

The value of these forces in liquids is less than in solid bodies, and this explains the change in the shape of the liquid with the change in the container in which it is located.

In addition to these forces, there are forces that affect the molecules of the liquid and the molecules of other media that it touches, whether the state of those media is solid, liquid or gaseous. These forces are called (**adhesive forces**).

Cohesive forces:

are the forces that result from the attraction of particles of the same (similar) substance to each other as in the bonds of atoms and Van der Waals forces (Van der Waals force), which are the forces of mutual effects between the electrically neutral particles of the same substance with each other It results from the attraction of the nuclei of atoms in a particular molecule with valence electrons in a neighboring molecule), which resists the scattering of the material and makes the material coherent with each other as it is almost non-existent in gases, medium in liquids and large in solids, as in the cohesion of iron particles in iron rod.

Adhesion forces:

are the forces that make two or more materials stick together, as they result from the adhesion of particles of different materials by mechanical or static forces and are non-existent in gases, relatively high in liquids and few in solid materials, as in the adhesion of clay to glass.

Pressure

Pressure is defined as the perpendicular force acting on a unit area

P = F / A

Pressure unit, newton's per square meter (N /m^2) Pascal (Pa).

mmHg ------- P = pgh

p = 13500kg/m^3

Atmospheric pressure is measured with a barometer

bar = 10^5 Pa

1 at m = 1.013 x 10^5 Pa = 760 mmHg = 760 tor

Example

a- A person weighing 500 Newton's is standing on the ice of a frozen pond so that his feet are attached to an area of ice. What is the pressure applied to the ice?

b- If you know that the ice will collapse at a pressure of 16000 Pa, how much weight would a person need to make the ice break down, given the same area of contact as before?

Sol.

P = F/A = 500 / 0.05 = 10000 Pa = 10 k Pa

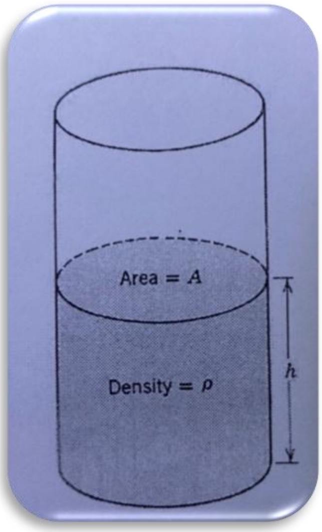
F = P A = 16000 x 0.05 = 800 N

Static fluid pressure

The pressure of static fluids was described through Pascal's principle, where the scientist focused on the study of fluids, which led him to discover the law of pressure for static fluids, which states that fluids in a closed container transfer pressure on them from one side to the rest equally Pascal's physical law also helped in the manufacture of many devices, including air compressors, vacuum pumps, hydraulic jacks, heavy car lifts, and compressors. The pressure in fluids is caused by the weight of the fluid, which is in all directions and perpendicular to the object in which it is immersed, and to the walls of the container in which it is placed as well.

The pressure varies according to the depth,

for example, as shown in the figure- :



The pressure on the bottom is

F= w = mg

m = pV =p A h

F = p Ah g

P = F/A = phg

The relationship shows an increase in pressure with an increase in depth and with an increase in the density of the liquid .

where **V** = volume of the liquid column

p = density of liquid

And if we want to calculate the total pressure affecting the bottom area A, we add the atmospheric pressure (because the vessel is open) to the pressure of the liquid column.

$\mathbf{P_t = P_a + P}$

$\mathbf{P_t = P_a + p\ g\ h}$

It is known that atmospheric pressure under standard conditions $\mathbf{P_a}$ **= 1.013 x 105 Pa** and this represents the pressure of a column of mercury with a height of 76 cm

Example /

Find the pressure of a column of mercury with a height of 76 cm, knowing that the density of mercury is

P = hdg

$= 0.76 \text{ m} \times 13600 \text{ kg / m}^3 \times 9.8 \text{ m/s}^2$

$= 1.01 \times 10^5 \text{ Pa} = 1 \text{ atm}$

Example /

What is the total pressure at the bottom of a 2m deep swimming pool that is completely filled with water ?

$P_t = P_a + hdg$

$= 1.013 \times 10^5 + 2 \times 1000 \times 9.8$

$= 1.013 \times 10^5 + 19600$

$= 120900$ p

Surface tension

Surface tension is the effect that causes the surface layer of a liquid to behave like a flexible sheet. This effect that allows insects to walk on water, and small metal objects such as needles, or pieces of tin foil from floating on water, is also the cause of capillary action. A frontal tension is the name for the same effect when it occurs between two liquids.

Who among us has not asked himself why a drop of water remains hanging in the tap for some time? And why do liquids tend to make their surfaces spherical? Also, weren't some insects able to walk on the surface of the water? , And how can we make a dry steel needle able to float on the surface of the water if placed carefully؟

The cause of these phenomena is the surface phenomenon of liquids known as surface tension.

Surface tension (tensile) in everyday life:

The phenomenon of surface tension provides an explanation for many common phenomena in our lives. For example, droplets of liquids take almost spherical shapes due to the phenomenon of surface tension, because the sphere is the geometric shape with the least surface area. The variation in the strength of the cohesive forces of the liquid molecules and the adhesion forces with the material surrounding the liquid explains to us why a certain liquid wets some materials while it does not wet others. For example, water does not spread on nylon surfaces or surfaces covered with wax, because the forces of cohesion of water molecules with each other are greater than the forces of water adhesion to the waxed surface, and therefore water drops collect on that surface in the form of drops that can easily fall without wetting the surface. These observations were used in the manufacture of raincoats and umbrellas.

The phenomenon of surface tension provides an explanation for the possibility of making soap bubbles in a way that cannot be done using pure water alone, because pure water has strong surface tension forces, but by adding surfactants (such as soap) to it, transferring those villages by more than ten times, thus it becomes possible Making bubbles with large surfaces with a small mass of liquid

Adding soap to water makes it an excellent cleaner by reducing its surface tension and thus making it able to wet and surround dirt to facilitate its removal. Making tiny drops of oil inside a quantity of water or vice versa, while if soap was not present, the two liquids would not mix, because the surface tension forces of each of the two liquids are greater than the cohesion forces one with the other, all of these things show the critical importance of the phenomenon of surface tension.

Another observation that explains the phenomenon of surface tension is the formation of some liquids of a convex surface or a sloping surface when placed in a tubular container. This is due to the difference in the strength of the surface tension and the strength of the adhesion of the liquid molecules to the surrounding vessel .

Molecular theory and surface tension

Cause of surface tension (tensile) :

Surface tension is caused by the attraction between the molecules of a liquid by the change in the intermolecular forces. In most liquids, every molecule inside the liquid is affected by equal attractive forces from all directions by the surrounding liquid molecules, and therefore the forces acting on it are balanced, meaning that the sum of these forces is zero.

At the surface of the liquid, the particles are pulled by the other particles inside the liquid. Why?

Because the forces acting on this molecule become unbalanced, and the reason for this is that a molecule from the upper hemisphere is located above the surface of the liquid, so the number of attractive molecules in it is less than those in the lower hemisphere, and there is a net force of attraction to the inside of the liquid.

The closer the molecule gets to the surface of the liquid, the more the state of disequilibrium increases until it reaches its value .

Great when the molecule is on the surface of the liquid. Therefore, the molecules on the surface of the liquid are subjected to great attractive forces in the direction of the inside of the liquid. These forces make the surface of the liquid tend to contract to get smaller in space. These forces cause tension forces on the surface of the liquid, which are known as surface tension forces Υ.

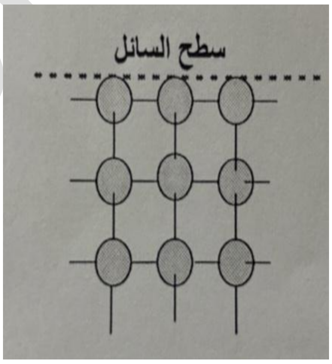
From the above it can be concluded that to increase the surface of the liquid, work must be done in order to push some molecules from inside the liquid to its surface, and this work will be done against the attractive forces that attract these particles to the inside of the liquid, i.e. against the forces of surface tension. Therefore, any of the molecules on the surface have an additional potential energy in addition to that of the molecule submerged under the surface. (The energy of the molecules on the surface of the liquid is greater than the energy of the molecules inside the liquid) .

The work done to increase the surface area of a liquid by the unit area when the temperature is constant is defined by the surface tension coefficient of this liquid ϒ . It is clear from the definition that its units are joules / square meter. There is another definition of the surface tension coefficient as the force acting perpendicular to unit lengths of liquid.

ϒ=F/L

The importance of tension or surface tension

They are surface forces that make the liquid droplets take a spherical shape, which means that the surface of the liquid has more energy than the rest of the liquid parts, which is used to reduce its surface area.



Tension or surface tension plays an important role in biological systems

- Gas exchange through the alveoli wall in the lung.
- Some insects, such as mosquitoes, walk on the surface of the water.

Capillarity

It is the phenomenon of the liquid rising - opposite the direction of gravity - in a thin tube due to forces between the surface of the tube and the liquid, and the surface of the liquid takes a concave shape.

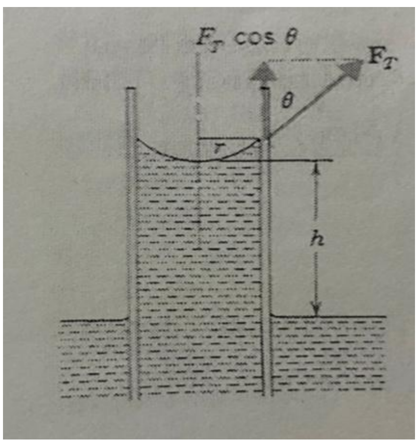
The rise of liquid in a narrow-section tube is one of the most prevalent phenomena of the surface of the liquid. This phenomenon is called capillary property, because it is observed in fine-sectioned tubes. There are many phenomena in nature that explain the action of the capillary property. It is deposited on its surface after its evaporation.

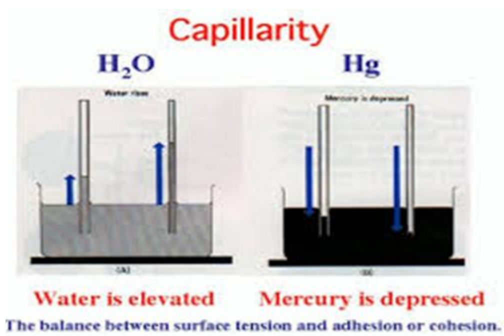
The liquid molecule close to the wall of the tube is affected by three forces, which are the force of cohesion with the liquid molecules (**force cohesive**) and the force of adhesive with the particles of the wall (**force adhesive**) and a third force that is usually neglected because it is weaker than the previous two forces, which is the force of adhesion with air particles. If the force of adhesion is greater than the force of cohesion, the liquid wets the tube and climbs it up and its surface becomes concave like water. If the opposite is the case, the liquid does not wet the tube, and its level in the tube is lower than its level in the container, and its surface is convex like mercury with glass.

Where :-

$\mathbf{F_{\Upsilon} = \Upsilon \cos\theta \, 2\pi R}$ ------ $\mathbf{F_g = mg = V\, p\, g = \pi R^2 h\, p\, g}$

$\mathbf{F_{\Upsilon} = F_g}$ --------- $\mathbf{h = 2\,\Upsilon \cos\theta / \; p\, g\, h}$ ------- $\mathbf{h \;\alpha\; 1/R}$



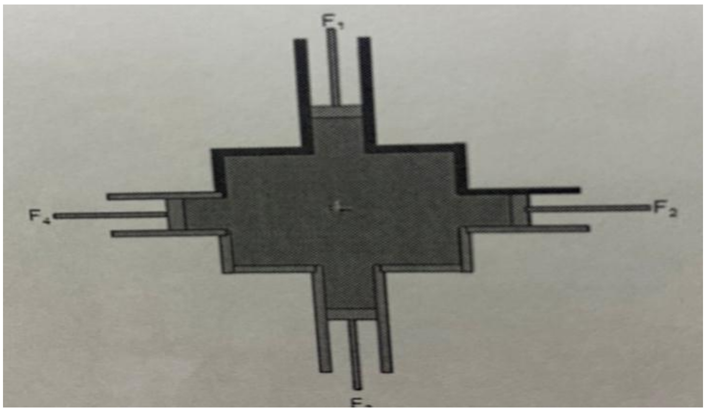


Pascal's Base

The pressure applied to a liquid confined in a closed container is transmitted to all parts of the liquid evenly.

This fact can be proven experimentally if we take a closed container containing a number of pistons filled with water as in the figure. in the same places.

F1 = F2 = F3 = F4



Applying Pascal's Base

Given that the pressure is equal at all points of equal depth, any increase in pressure must be transmitted to any point in the liquid equally, which is called Pascal's law, which states:

"External pressure applied to a liquid within a closed vessel is transmitted without any decrease to all points of the liquid and to the walls of the closed vessel ".

As an application on Pascal base we have the hydraulic jack shown in the figure where

P1 = P2

F1 / A1 = F2 / A2

$\Delta P = F1 / A1$ ………….(1)

This increase in pressure will be transmitted to piston 2, where

$\Delta P = F2 / A2$ ………….(2)

$F1 / A1 = F2 / A2$ ………(3)

$F2 = A2\ F1 / A1$ ………..(4)

The force F2 is equal to the force F1 multiplied by the coefficient (A2 / A1), meaning that the amount of gain in the force is determined by the ratio (A2 / A1). The more A2 is greater than A1, the greater the pressure can be obtained. Therefore, such a piston will be able to lift more weight or apply more pressure using a small force.

Archimedes Principle

Archimedes' principle states, "If a body is completely or partially immersed in a liquid, it loses its weight by an amount equal to the weight of the fluid displaced by the body".

The weight loss is caused by the upward force of the fluid pushing the body up, which is called the buoyant force. It is known that the fluid pressure at face C is greater than the pressure at face B, because face C is located at a greater depth than face B, and it is known that the pressure increases With increasing height h, as for face D and face E, the pressure on them is equal in amount and different in direction, so it can be said that the sum of pressure on them is zero.

If the pressure at C is P_1 and the cross-sectional area C is A, then the force is given by

$$\mathbf{F_1 = P_1\, A = pgh_1A}$$

where p is the density of the liquid. As for the force at face B, it is

$$\mathbf{F_2 = P_2\, A = pgh_2A}$$

So the net force is the difference between the two forces:

$$\mathbf{\Delta F = F_1 - F_2 = pgh_1A - pgh_2A = (h_1 - h_2)\, pgA}$$

But the volume of an object V equals its cross-sectional area A and the height which is this difference in the depth of face C and face B

$$\mathbf{V = (\, h_1 - h_2\,)\, A}$$

$$\mathbf{\Delta F = Vpg}$$

Since mass is equal to volume times density

$$\mathbf{m = pV}$$

$$\mathbf{\Delta F = mg}$$

So the buoyant force is equal to the weight of the displaced fluid and this agrees with Archimedes' rule. Archimedes' rule applies to all floating and submerged bodies, whatever their shape. The following important points should be noted about this important rule:

1- Archimedes' rule applies to all floating and partially or completely submerged bodies, regardless of their shape.
2- Archimedes' rule enables us only to find the value of the buoyant force, and it does not enable us to find the value of the sum of the forces acting on the body.

Based on this point, the body will sink if its weight is greater than the buoyant force, while the body will float if its weight is less than the upward force of the liquid.