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Chemistry

State of Matter

What is Chemistry?

Chemistry is the branch of science which deals with the study of composition, properties and transformation of matter.

Chemistry may be sub-divided into the following major branches.

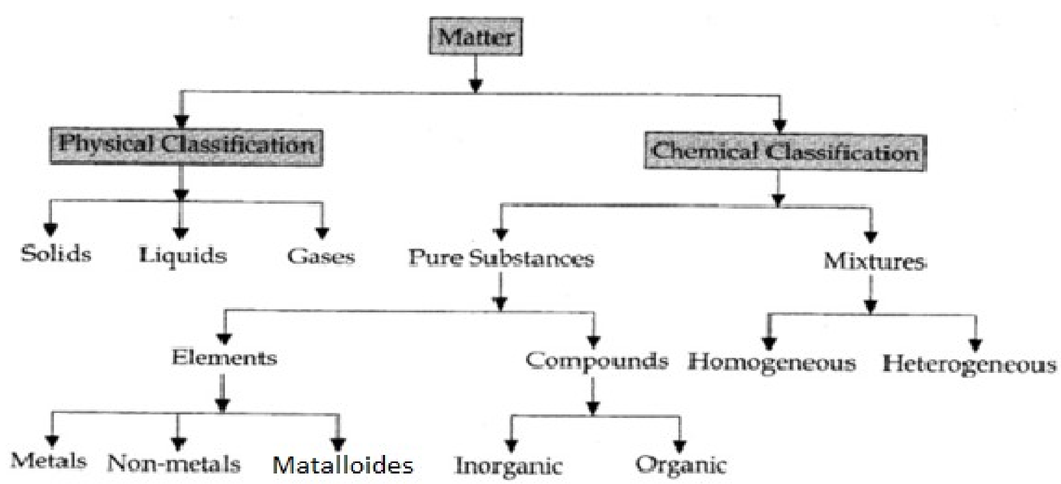
- Physical chemistry
- Organic chemistry
- Inorganic chemistry
- Biochemistry
- Nuclear chemistry
- Analytical chemistry
- Industrial chemistry

Matter

Matter is anything which occupies space, possesses mass and can be judged one or more our five senses.

Example: Marble, Common salt, Water, Benzene, Oxygen, Nitrogen etc.

Classification of matter



Physical classification

This classification of matter on the basis of state is called physical classification or state classification. They are solid, liquid and gases.

The solid

The solid possess definite shape and volume. In solid state the molecules constituting the solid are closely packed and there is very little space between them. The molecules in the solid are tightly held by the strong force of attraction. So solid has definite shape and volume.

The liquid

The liquid have definite volume but not definite shape. In liquid state, the molecules are closely packed but not tightly held like in solid molecules but slide one over the other easily in liquid state. So, liquid has definite volume but not definite shape.

The gas

The gas has neither definite shape nor volume. In gaseous state, the molecules are very far apart and free to move in all direction. In gaseous state the intermolecular forces of attraction are very week. So, gas has neither definite volume nor definite shape.

Solid	***Liquid***	***Gas***
1. Have strong intermolecular force.	Weak intermolecular force.	Very weak intermolecular force.
2. Very less intermolecular space.	Large intermolecular space.	Very large intermolecular space.
3. Have definite shape and volume.	Do not have definite shape but have definite volume.	No definite shape and volume.
4. Have high density.	Density is low.	Very low density.
5. Solids cannot be compressed.	Liquids can be compressed.	Gases can be highly compressed.

Plasma

- Plasma is a fourth state of matter.
- It is an electrically charged particle gas.
- They are affected by electrical and magnetic fields.
- Most of the matter in the sun and other stars exists in a plasma state.

Heating and cooling effect of matter

$$\text{Solid} \underset{\text{Cool}}{\overset{\text{heat}}{\rightleftharpoons}} \text{Liquid} \underset{\text{Cool}}{\overset{\text{heat}}{\rightleftharpoons}} \text{Gas}$$

Classification of properties of matter

The properties of the matter can be observed in mainly two ways viz. macroscopic properties and microscopic properties.

Macroscopic properties

The properties of matter which can be observed with the help of our sense organs are called macroscopic properties. Example: Pressure, temperature and volume etc.

Microscopic Properties

The properties of matter which can be observed based on atomic and molecular Theory are called microscopic properties.

The Gaseous state

The physical behaviors of the gases are the function of temperature, pressure, volume, number of mole etc. The kinetic molecular theory can explain the gaseous behavior well.

Physical characteristics of the gases

- Gases do not possess definite shape and volume.
- Gases undergo diffusion.
- Gases expand on heating and compress on cooling.
- Gases exert pressure on the wall of the vessel.
- Gasses are colorless.

Exception: F_2 and $Cl_2 \longrightarrow$ Greenish yellow

$Br_2 \longrightarrow$ Reddish Brown

$I_2 \longrightarrow$ Voilet color

$NO_2 \longrightarrow$ Reddish brown color

Q.)*Why gases do not settle down at the bottom of the vessel*?

Gaseous do not settle down at the bottom of the vessel because they have negligible intermolecular forces of attraction between the particles of gas so they all are free to move separately in all the direction and hence making negligible volume and also, they are very less dense.

Measurable properties of gases

The measurable properties of gases can be described below such as:

i) Mass and amount

The mass of the gaseous substance is expressed in milligram (mg), gram (gm), kilogram (kg). Similarly, the amount of gas is expressed in terms of moles.

No. of moles (n) = $\frac{mass\ of\ the\ gas(m)}{Molecular\ mass\ of\ the\ gas(M)}$

Mass of gas is expressed in g and molecular mass in amu.

ii) Volume

The volume of gas can be expressed in liter, milliliter (ml) or cubic centimeter (cm^3). The SI unit of volume is cubic meter (m^3)

$1m^3 = 10^3dm^3 = 10^6cm^3$

$1lit. = 1dm^3,\ 1dm^3 = 10^3cm^3$

$1ml = 1\ cm^3$ or cc

The volume of certain mass of gas is the function of temp., pressure and amount.

V = f (Temp., pressure, amount)

iii) Pressure

Pressure is force per unit area and can be measured in different unit like atm, cmHg, mmHg, torr, pascal etc. The SI unit of the pressure is pascal (p_a), which is defined as the pressure exerted when one Newton force acts upon an area equals to $1m^2$. So, the unit of pressure is Nm^{-2}

$1P_a = 1Nm^{-2}$

$1\ atm = 1.01325 \times 10^5\ p_a = 101.325\ kp_a$

1 atm = 760 mmHg = 76 cmHg = 760 torr

Atmospheric pressure is expressed by the following relation

P = hdg

Where,

h = height of mercury column in the barometer.

d = density of mercury

g = acceleration due to gravity

At standard state, 0^0c temp and 1 atm pressure

$g = 981cm/s^2$ and density of Hg = $13.5\ gcm^{-3}$

iv) Temperature

Temperature is measured in most cases in Celcius scale (^0c) but in the studies of gaseous behavior it can be expressed in absolute or kelvin scale (k). These two scales are inter related by

Temp. in kelvin scale = Temp. in Celcius scale + 273

$T = (t^0c + 273)k$

If temperature of 0^0C or 273k and pressure 1 atm. are called standard temperature and pressure or Normal temperature and pressure

At NTP, 1 atm = 760mmHg

0^0C Temperature = 273k Temp.

Gas Law

The inter relationship between Volume, Pressure, Temperature, Molecular Mass, Density etc. can be studied with certain generalization called gas laws. The important gas laws are

1) Boyle's law
2) Charle's law
3) Avogadro's law
4) Dalton's law of partial pressure
5) Graham's law of diffusion

Boyle's law

In 1662 A.D. (Anno Domini), Robert Boyle's studied the mathematical relationship between the volume of a certain mass of gas and pressure at constant temperature.

Statement

The volume of a certain mass of a gas is inversely proportional to its pressure at constant temperature.

Mathematically,

$$V \propto 1/p \qquad \text{at constant T}$$

$$V = k. 1 / p$$

$$PV = K$$

Where P and V be the pressure and volume of a certain mass of gas and k is constant

$$PV = \text{Constant}$$

Suppose, P_1 and V_1 be the initial pressure and volume of a certain mass of gas at constant temperature. The pressure is changed to P_2 then volume of corresponding gas to V_2.

According to Boyle's law

P_1V_1 = constant

and P_2V_2 = Constant

Then,

$$P_1V_1 = P_2V_2$$

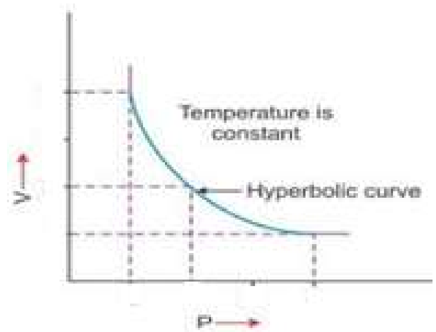
This equation is general form of Boyle's law

Graphical representation of Boyle's law

The Boyle's law relationship can be shown graphically as plots of,

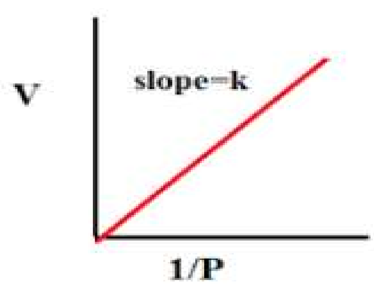
1. Volume – pressure graph

When the volume of a certain mass of gas is plotted against pressure at constant temperature, a hyperbolic curve is obtained. This curve is known as P-V isotherm.



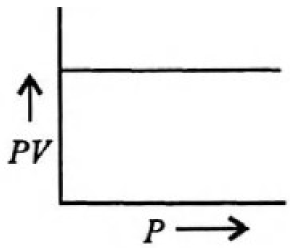
2. Volume – (1 / pressure) graph

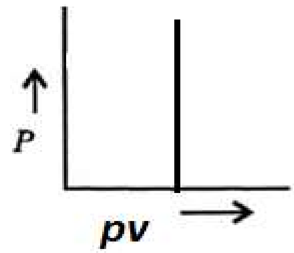
When the volume of a certain mass of gas is plotted against reciprocal of pressure at constant temperature, a straight line is obtained which is passes through the origin.



3. Pressure x Volume – pressure graph

When the product of pressure – volume (PV) for a certain mass of gas is plotted against pressure at constant temperature a Straight line is obtained which is parallel to pressure axis.





Explanation of Boyle's law from kinetic theory of gases

According to kinetic molecular theory of gases, the pressure exerted by gas is due to collision of gas molecules on the wall of the vessel. Thus, the pressure exerted by the gas depends upon ***number of collisions per unit time*** and ***Force by which gas molecules strike on the wall.***

At constant temperature, when the volume of gas is doubled, the second factor **(*force by which the gas molecule strike on the wall*)** remains almost same but first factor **(*number of collisions per unit time*)** is reduced to half. As a result, the pressure exerted by gas is also reduced to half. Thus, when volume of gas is reduced to half, the number of collisions per unit time becomes doubled and hence pressure is doubled. This means pressure and volume are inverse relation at constant temperature.

Applications of Boyle's law

- The balloon is partially filled by gas on the ground state but as it rises into the upper atmosphere the gas expands due to the decrease in atmospheric pressure of surrounding's the balloon, there by filling the balloon completely. This effect is an agreement with Boyle's law.
- At higher altitude as the pressure decreases, the air becomes less dense. As a result, the less oxygen is available for breathing. This cause altitude sickness. To avoid this sickness, the mountain climbers always carry oxygen cylinder for proper breathing.

Question: Show that $P_1/d_1 = P_2/d_2$

Charle's Law

In 1787 A.D., Charle's studied the mathematical relationship between the volume of a given mass of gas and temperature at constant pressure.

Statement

At constant pressure, the volume of a given mass of gas increases or decreases by 1/273 rd of its volume at 0^0C for every 1^0C rises or fall in temperature

If V_0 be the volume of a given mass of gas at pressure P and 0^0C temperature

If pressure be kept constant and gas be heated then

At 0^0C, Volume of gas = V_0

At 1^0C, Volume of gas = $V_0 + \frac{1}{273} V_0$

$= (1+\frac{1}{273}) V_0$

At 5^0C, Volume of gas = $V_0 + \frac{5}{273} V_0$

$= (1 + \frac{5}{273}) V_0$

At t^0C, Volume of gas = $V_0 + \frac{t}{273} V_0$

$= (1 + \frac{t}{273}) V_0$

Similarly, if the gas be cooled at constant pressure

At -1^0C, Volume of gas = $(1 - \frac{1}{273}) V_0$

At -5^0C, Volume of gas = $(1 - \frac{5}{273}) V_0$

At $-t^0C$, Volume of gas = $(1 - \frac{t}{273}) V_0$

At -273^0C, Volume of gas = $(1-\frac{273}{273}) V_0$

$= 0$

Thus, at -273^0C, the volume of gas becomes equal to zero theoretically. In fact, all the gases become liquid or solid before this temperature is reached. This lowest hypothetical temperature -273^0C (to be exact -273.15^0C) is called absolute zero. This is the lowest temperature that is theoretically possible. At this temperature, the gas molecules have no kinetic energy, no velocity and occupy no volume theoretically.

A temperature scale with its zero volume at -273^0C and each degree being equal to that on celcius scale has been built which is known as absolute or kelvin scale temp. To convert celcius temperature into absolute scale, add 273 to celcius temperature. If t^0C be the celcius scale temperature the corresponding temp. in kelvin scale(T) is

$$T = (t + 273)\ k$$

Alternate statement of Charle's law

If V_0, V_1 and V_2 be the volume of a certain mass of the gas at 0^0C, $t_1{}^0C$, and $t_2{}^0C$ temperature at constant pressure

Then, $V_1 = V_0 + (t_1/273) \times V_0$

$= (1 + t_1 / 273) \times V_0$

$= [(273 + t_1)/273] \times V_o$

$V_2 = [(273 + t_2)/273] \times V_0$

Now, $V_1 / V_2 = [(273 + t_1) / 273] \times V_0 / [(273 + t_1) / 273] \times V_0$

$V_1 / V_2 = (273 + t_1) / (273 + t_2)$

$V_1 / V_2 = T_1 / T_2$ {Where T_1 and T_2 be the temperature in absolute or kelvin scale}

Therefore, $V \propto T$ {at constant pressure}

This equation affords us to give an alternate statement of Charle's law which may be stated that

At constant pressure the volume of a certain mass of a gas is directly proportional to temperature in Kelvin or absolute scale.

Mathmetically,

$V \propto T$ At constant P

$V = K T$

$\frac{V}{T} = K$

If V_1 and V_2 be the volume of a certain mass of a gas at temperature T_1 and T_2

If pressure be kept constant

$V_1 / T_1 = k$ & $V_2 / T_2 = k$

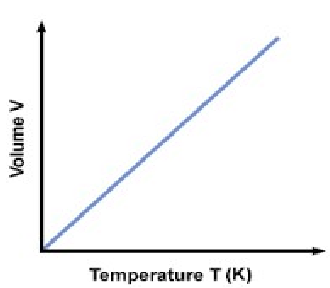
From both equations,

$V_1 / T_1 = V_2 / T_2$

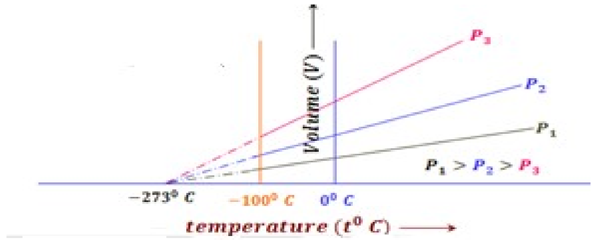
This is the mathematical equation of the charle's law.

Graphical Expression of Charle's Law

When volume (V) of a certain mass of gas is plotted against Kelvin scale temperature (T) at constant pressure, then it gives a straight line passing through origin, which verifies the charle's law.



1) When volume of a given mass of gas is plotted against the temperature in celcius scale, a st. line is obtained which verifies Charle's law.



It should be noted that on extrapolation the curve meets at the temperature axis at -273^{0}C.Where the volume of gas becomes theoretically equal to zero. Similar curves will be obtained if the volume against temperature is plotted at another constant pressures, the three straight lines represents the plots of volume of the same mass of gas against temperature at different pressure. Note that all three curves meet at -273^{0}C, volume of a gas becomes zero.

Applications of Charles law

1) The gas expands on heating and contracts on cooling.
2) A flying hot air balloon.
3) Shrinking of a car tire in the winter season.
4) Blasting of balloons on hot days..

Explanation of Charles law from kinetic theory of gases

According to kinetic theory of gases, when temperature of a gas is increased, the kinetic energy of gas molecules is also increased. Due to increases kinetic energy of the gas molecules, the molecules of gas strike on the wall more frequently and more vigorously. If the volume of a gas remains constant, increase in temperature leads to increase in pressure. However, to keep the pressure constant the gas must be expanded so, the number of Collision per unit time remains constant. This means when the temperature is increased the volume of gas must be increased to keep the pressure constant. This is the statement of Charles law.

Question

Using $V_1 / T_1 = V_2 / T_2$, to prove that $d_1T_1 = d_2T_2$