Avogadro's law

In 1811, Amedeo Avogadro's studied the mathematical relationship between volume and number of gas molecules and deduced a law which is called Avogadro's law.

Statement

Under similar condition of temperature and pressure, Equal volumes of all gases contain the same number of molecules.

It also implies that under similar condition of temperature and pressure, Equal volumes of all gases contain the same number of mole.

$V \propto n$ at constant T and P

$n \propto V$

Where, V is the volume of given mass of gas and n is the number of mole of gas.

For two gaseous systems having n_1 and n_2 number of moles with their corresponding volume V_1 and V_2 respectively

$n_1 \propto V_1$.......... (1)

$n_2 \propto V_2$.......... (2)

From equation (1) and (2) we get,

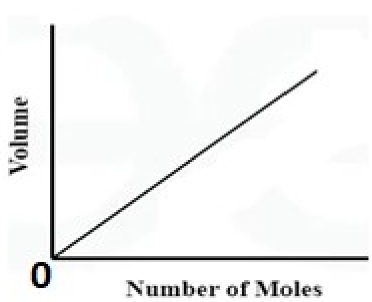
$n_1/n_2 = V_1/V_2$

If $V_1 = V_2$, $n_1 = n_2$

Therefore, at constant temperature and pressure, equal volume of all gases contains equal number of mole. This is Avogadro's law.

Graphical explanation of Avogadro's law

When volume (V) of gas is plotted against number of moles of gas at constant pressure and temperature, then it gives a straight line passing through origin, which verifies the Avogadro's law.



Applications of Avogadro's law

1. Explanation of Gay-Lussac's law.
2. Determination of atomicity of gases.
3. Determination of molecular formula of a gaseous compound.
4. Establishment of relationship between the relative vapor density of a gas and its relative molecular mass.
5. Establishment of relationship between gram molecular weight and volume of the gas at STP.

Combined gas equation:

According to Boyle's law

$V \propto 1/P$ at constant T

According to Charles law

$V \propto T$ at constant P

Combining both the laws

$$V \propto \frac{T}{P}$$

$$V = k.\frac{T}{P}$$

$PV/T = K$ Where K is constant

Suppose P_1, V_1 and T_1 be the initial P_2, V_2 and T_2 be the final pressure, volume and temperature of a given mass of gas.

$P_1V_1/T_1 = K$ & $P_2V_2/T_2 = K$

From both the equation

$$P_1V_1/T_1 = P_2V_2/T_2$$

This equation is called ***combined gas equation***.

Question:

Starting from $P_1V_1/T_1 = P_2V_2/T_2$, to prove that $P_1/d_1T_1 = P_2/d_2T_2$

Ideal gas equation

According to Boyle's law $V \propto 1/P$ at constant T

According to Charles law $V \propto T$ at constant P

Combining both the laws: $V \propto T / P$

$$or,\ V = k\ (T/P)$$

$$PV = KT$$

Where K is constant and its value depend upon the mass of a gas taken. If one gram of any gas is taken, then K is shown as a specific gas constant its value differ from one gas to another gas. If one mole of gas is taken then instead of k, the symbol R is used and its value is the same for all gases. Hence R is called ***universal gas constant*.**

For one mole of gas

$$PV = RT$$

If n mol of gas is taken then above equation becomes as

$$PV = nRT$$

The value of universal gas constant "R"

From ideal gas equation,

$$PV = nRT$$

$$R = PV / nT$$

$$R = \frac{Pressure\ .\ Volume}{Mole\ .\ Temperature}$$

$$= \frac{\frac{Force}{Area}\ .\ Volume}{Mole\ .\ Temperature}$$

$$= \frac{\frac{Force}{(Length)2}\ .\ Length3}{Mole\ .\ Temperature}$$

$$= \frac{Force\ .\ Length}{Mole\ .\ Kelvin}$$

$$R = Energy.\ K^{-1}.mole^{-1}$$

Hence, R has the dimension of energy (work done) per Kelvin per mole.

1) Value of R in lit. atmosphere

$$PV = nRT$$

$$R = PV / nT$$

1 mole of any gas at NTP occupies 22.4 lit.

$$=\frac{1\ atm.\ \ 22.4 lit.}{1\ mole\ .\ 273\ K}$$

= 0.0821 Lit. atm. K^{-1}. Mol^{-1}

2) ***In CGS system***, *pressure is expressed in dynes per sq. cm and volume in cubic centimeter.*

From ideal gas equation

PV = nRT

R = PV / nT

$$=\frac{(hd\ \ )\ x\ V}{n\ x\ T}$$

$$=\frac{(76\ cm\ x\ 13.596\ g\ cm{-}3\ x\ 980.6 cm\ S{-}2).(22.4x1000\ cm3)}{1Mole\ x\ 273K}$$

$$=\frac{(1013250\ dynes\ .cm{-}2).(22.4x1000\ cm3)}{1Mole\ x\ 273}$$

= 8.314 x 10^7 (dynes . cm). k^{-1}. $Mole^{-1}$

= 8.314x 10^7 ergs. k^{-1}. $Mole^{-1}$

3) ***In SI unit***, pressure is expressed in Newton per square meter (Pascal) and volume in meter cube (m^3).

From n mole of an ideal gas

PV = nRT

$$R = \frac{P\ .\ V}{nT}$$

$$= \frac{(hdg)\ .\ V}{nT}$$

$$=\frac{(0.76m\ x\ 13.596\ x1000\ \ kg\ m{-}3\ x\ 9.8\ ms{-}2).\ \ (22.4\ lit.)}{1\ mole\ .\ \ 273\ k}$$

$$=\frac{(101325\ Newtons\ .\ \ m{-}2).\ \ (22.4\ x\ 10{-}3\ m3)}{1\ mole\ .\ \ 273\ k}$$

= 8.314 (Newton . m). k^{-1}. $Mole^{-1}$

= 8.314 Jouies. k^{-1}. $Mole^{-1}$

4) ***The value of R in calories***

4.183 Joules = 1 Calories

1 joule $= \frac{1}{4.183}$ Calories

$$8.314 \text{ joules} = \frac{1}{4.183} \times 8.314 \text{ Calories}$$

$$= 1.987 \text{ Calories}$$

$$R = 1.987 \text{ Calories } K^{-1}. \text{ Mole}^{-1}$$

Significances of R

- **R is the work done by the gas per mole per Kelvin.**
- It's Proportionality between energy and temperature.
- The value of R was deduced from studies of mechanical properties of gases .