

STATES OF MATTER

GASES

PRESSURE: RESULT OF MOLECULAR COLLISIONS ON THE WALLS OF THE CONTAINER

The pressure exerted by a gas depends **on the number of gas particles** in a given volume—the fewer the gas particles, the lower the force per unit area and the lower the pressure.

Since the number of gas particles in a given volume generally decreases with increasing altitude, pressure decreases with increasing altitude.

1 atm
760 torr
760 mm Hg
76 cm Hg
101.325 kPa

PROPERTIES

- Indefinite volume and shape
- Compressible → particles with high KE and free to move

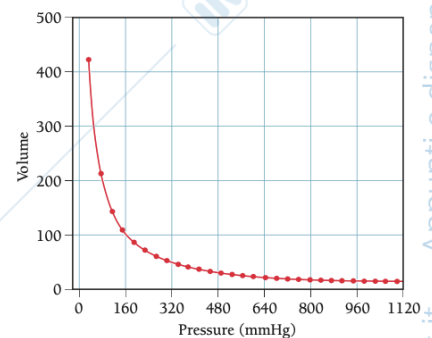
SIMPLE GAS LAWS

Simple: two of the four basic properties were held **constant** in order to elucidate the relationship between the other two.

BOYLE'S LAW – ISOTHERMAL

At constant temperature (T), the volume (V) of a fixed mass of a gas is inversely proportional to the pressure (P), which may be expressed as

$$V \propto \frac{1}{P} \quad \text{or} \quad P_1 V_1 = P_2 V_2$$



CHARLES'S LAW – ISOBARIC

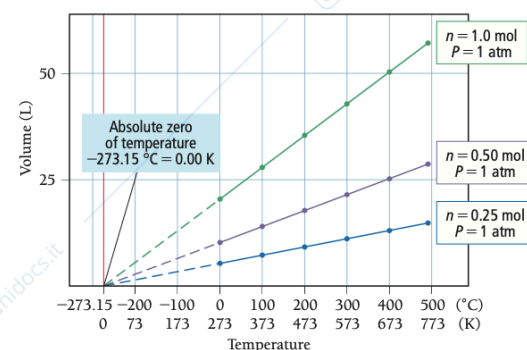
At constant pressure the volume of a fixed mass of any gas is directly proportional to the absolute temperature, which may be expressed as

$$V \propto T \quad \text{or} \quad \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Any quantity of any gas would have zero volume if it could be cooled to -273°C .

BUT no real gas can be cooled to -273°C because it would liquefy before that temperature is reached.

$-273^\circ\text{C} = \text{ABSOLUTE ZERO, } 0 \text{ K}$



GAY-LUSSAC'S LAW**ISOCORE LAW**

$$P \propto T \quad \text{or} \quad P = kT,$$

At V constant $\rightarrow T$ and P directly proportional

LAW OF COMBINING VOLUMES:

When measured at the same temperature and pressure, the ratios of the volumes of reacting gases are small whole numbers.

AVOGADRO'S LAW

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

DALTON'S LAW – PARTIAL PRESSURES

$$P_{\text{total}} = P_a + P_b + P_c + \dots$$

$$P_a = \chi_a P_{\text{total}}$$

HENRY'S LAW – DISSOLUTION OF A GAS INTO A LIQUID

A gas, that exerts a pressure on the surface of a liquid, passes into the solution until it has reached inside the liquid the same pressure exerted on it.

$$c = k_x P$$

\rightarrow The concentration of the gas dissolved in **proportional** to the partial pressure

$\rightarrow k$: constant for each liquid

DISSOLUTION OF A GAS INTO A LIQUID \rightarrow EXOTHERMIC PROCESS

The solubility of a gas increases as the temperature decreases.

The solubility of a gas depends on the polarity, the dimensions and the chemical properties.

Decompression sickness: nitrogen dissolved in the blood at high pressure forms of air bubbles as pressure decreases.

IDEAL GAS LAW

$$PV = nRT$$

$$R = 0.08206 \frac{\text{L} \cdot \text{atm}}{\text{mol} \cdot \text{K}}$$

KMT – KINETIC MOLECULAR THEORY

Simplest model to explain the behavior of gases.

Gases are treated as **IDEAL GASES**.

1) Particles do have mass, but **NEGLIGIBLE VOLUME**.

Under normal pressures the distance between atoms or molecules in a gas is very large compared to the size of the atoms or molecules themselves.

2) Particles have **NO ATTRACTION FORCES** → they are highly separated

3) Particles move in straight lines

4) Collisions **PERFECTLY ELASTIC** → *no loss of energy* and no deformation of particles

5) The **AVERAGE KINETIC ENERGY** for particles is the same for all gases at the same temperature, and its value is directly proportional to the Kelvin temperature. ($E = 3/2 k_b \times T$)
But the higher the temperature, the faster the overall motion and the greater the average kinetic energy.

DIFFUSION: process of gas particles that spread homogeneously into another substance in response to a concentration gradient. DEPEND ON CONCENTRATION.

EFFUSION: process of gas particles that escape through a small hole from a high-pressure region to a low-pressure one or to the vacuum where the number of collisions is minimum.

DEPEND ON PRESSURE.

RATE OF EFFUSION OF A GAS IS INVERSELY PROPORTIONAL TO THE SQUARE ROOT OF THE MOLAR MASS OF THE GAS.

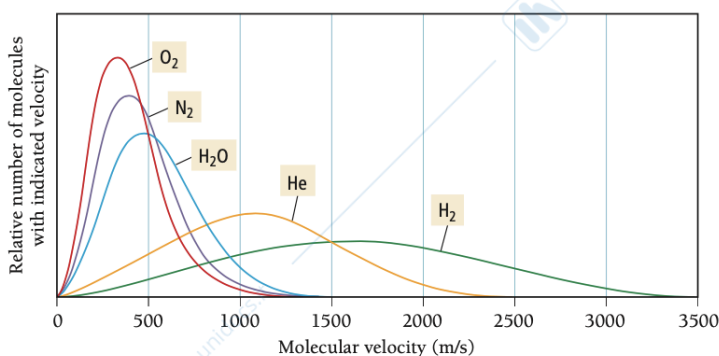
GRAHAM'S LAW OF EFFUSION: ratio of effusion rates of two different gases.

$$\frac{\text{rate}_A}{\text{rate}_B} = \sqrt{\frac{\mathcal{M}_B}{\mathcal{M}_A}}$$

MAXWELL-BOLTZMANN EQUATION

MOLECULAR SPEED DISTRIBUTION

Variation of Velocity Distribution with Molar Mass



Used to determine how many molecules are moving at certain velocities.

DIFFERENT CURVES BUT SAME AREA UNDER THE CURVE = SAME AVERAGE VELOCITY

T constant

REAL GASES

Particles do have volume → **EFFECT OF FINITE VOLUME**

At low pressure, the molar volume of argon is nearly identical to that of an ideal gas.

At high pressure, the **VOLUME OF THE PARTICLES BECOMES RELEVANT** because they occupy a significant portion of the total gas volume → *b* – covolume

$$V_{\text{REAL GAS}} > V_{\text{IDEAL GAS}}$$

Ideal behavior

$$V = \frac{nRT}{P}$$

Corrected for volume of gas particles

$$V = \frac{nRT}{P} + nb$$

Particles do interact → **EFFECT OF INTERMOLECULAR FORCES**

At low pressure and high temperature, the molecules are far apart and have high kinetic energies, so the weak attraction between them does not affect the collision much.

At lower temperatures, the collisions occur with less kinetic energy, and weak attractions can affect the collisions.

DECREASE IN THE NUMBER OF COLLISIONS WITH THE SURFACES OF THE CONTAINER AND A CORRESPONDING **DECREASE IN THE PRESSURE** COMPARED TO THAT OF AN IDEAL GAS.

$$P_{\text{REAL GAS}} < P_{\text{IDEAL GAS}}$$

Ideal behavior

$$P = \frac{nRT}{V}$$

Corrected for intermolecular forces

$$P = \frac{nRT}{V} - a\left(\frac{n}{V}\right)^2$$

VAN DER WAALS EQUATION

$$\left[P + a\left(\frac{n}{V}\right)^2\right] \times [V - nb] = nRT$$

Correction for
intermolecular forces

Correction for
particle volume