Kinetic Theory of Gases and Equipartition Theorem

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Results of Kinetic Theory

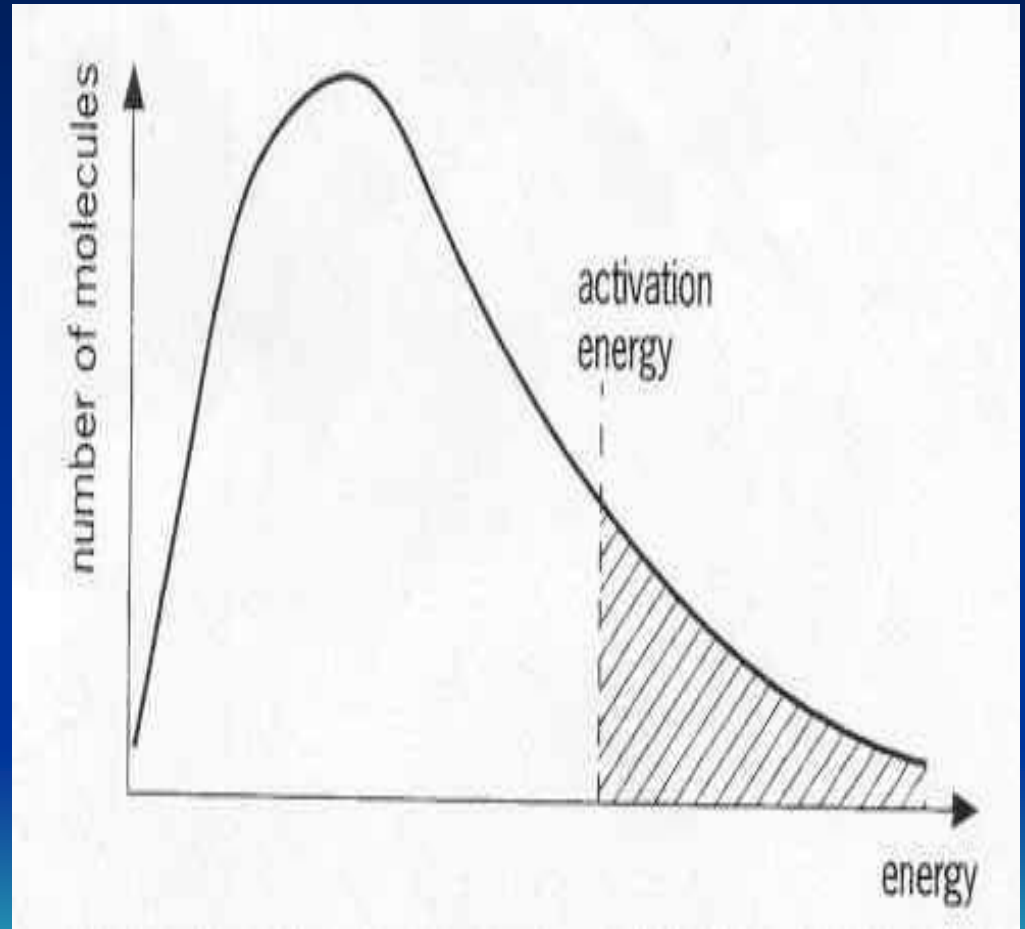- KE of individual particles is related to the temperature of the gas:

$$\tfrac{1}{2}\, mv^2 = \tfrac{3}{2}\, kT$$

Where v is the average velocity.

Boltzmann Distribution

- Demonstrated that there is a wide range of speeds that varies with temperature.

Equipartition of Energy

The Kinetic Theory result tells us that the average translational KE is proportional to the temperature.

Types of allowed motion are referred to as Degrees of Freedom (DOF)

Linear motion in three directions (x,y,z) is three DOF.

Equipartition of Energy

- Each degree of translational freedom takes ½ kT.

$$KE_x + KE_y + KE_z = ½ \, kT + ½ \, kT + ½ \, kT$$
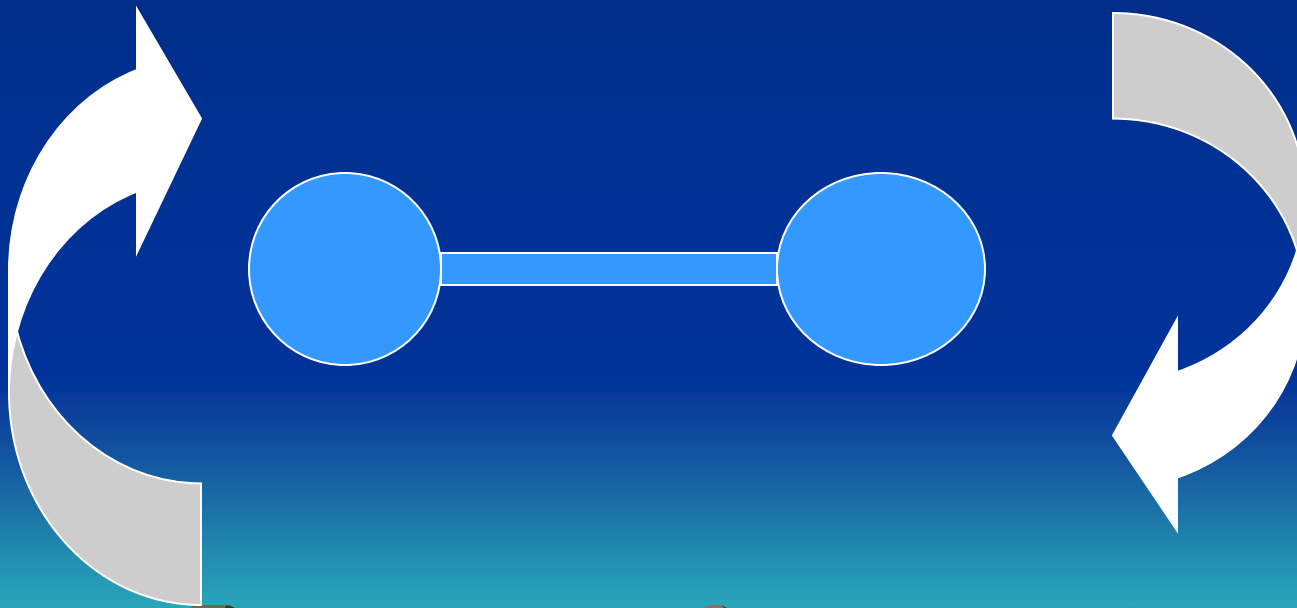
$$KE_{total} = 3/2 \, kT$$

This is true for single point masses that possess no structure.

Equipartition of Energy

For molecules, i.e. multi-atom particles, there are added degrees of freedom.

Equipartition of Energy

- Each new DOF requires ½ kT of energy.

Each new DOF contributes ½ kT to the total internal energy of the gas. This is the **Equipartition Theorem.**

Internal Energy, U

- The internal energy of a gas is the sum of all the kinetic and potential energies.

U = KE + PE.

For an ideal gas we allow no PE of interaction, so U is comprised solely of the various type of kinetic energies, i.e. translational, rotational and vibrational.

Internal Energy of Di-Atom

- Three translational DOF + 2 rotational DOF = 5 DOF.

Each DOF contributes ½ kt, so the internal energy of a diatomic gas is,

$$U = 5/2 \ NkT,$$

For a gas of N molecules.