KINETIC MOLECULAR THEORY (KMT)

Theory used to explain gas laws. KMT assumptions are:
- Gases consist of molecules in constant, random motion.
- P arises from collisions with container walls.
- No attractive or repulsive forces between molecules. Collisions elastic.
- Volume of molecules is negligible.

Because we assume molecules are in motion, they have a kinetic energy.

KE = _____________

At the same T,

As T goes up, KE also _____________ — and so does speed.

KE = \frac{\sqrt{3RT}}{M}

where \( u \) is the speed and \( M \) is the molar mass.
- speed INCREASES with T
- speed DECREASES with M

At the same T, all gases have the same average KE.

As T goes up, KE also increases — and so does speed.

Distribution of Gas Molecule Speeds

Molecules of a given gas have a range of speeds.
Velocity of Gas Molecules

Average velocity decreases with increasing mass.

GAS DIFFUSION AND EFFUSION

- **Diffusion** is the gradual mixing of molecules of different gases.
- **Effusion** is the movement of molecules through a small hole into an empty container.

Molecules effuse through holes in a rubber balloon, for example, at a rate (= moles/time) that is
- proportional to T
- inversely proportional to M.
Therefore, He effuses more rapidly than O₂ at same T.

GAS DIFFUSION AND EFFUSION

Graham’s law governs effusion and diffusion of gas molecules.

\[
\text{Rate for } A = \sqrt{\frac{M \text{ of } B}{M \text{ of } A}}
\]

Rate of effusion is inversely proportional to its molar mass.

Gas Diffusion

Relation of mass to rate of diffusion

- HCl and NH₃ diffuse from opposite ends of tube.
- Gases meet to form NH₄Cl
- HCl heavier than NH₃
- Therefore, NH₄Cl forms closer to HCl end of tube.

Using KMT to Understand Gas Laws

Recall that KMT assumptions are
- Gases consist of molecules in constant, random motion.
- P arises from collisions with container walls.
- No attractive or repulsive forces between molecules. Collisions elastic.
- Volume of molecules is negligible.
Avogadro’s Hypothesis and Kinetic Molecular Theory

P proportional to n

Gas Pressure, Temperature, and Kinetic Molecular Theory

P proportional to T

Boyle’s Law and Kinetic Molecular Theory

P proportional to 1/V

Deviations from Ideal Gas Law

- Real molecules have volume.
- There are intermolecular forces.
- Otherwise a gas could not become a liquid.

Fig. 12.20

Deviations from Ideal Gas Law

Account for volume of molecules and intermolecular forces with VAN DER WAAL’S EQUATION.

\[ P_{\text{van der Waals}} = \frac{nRT}{V} - \frac{n^2a}{V^2} - \frac{nb}{V} \]

J. van der Waals, 1837-1923, Professor of Physics, Amsterdam, Nobel Prize 1910.

Deviations from Ideal Gas Law

\[ P_{\text{ideal}} = \frac{nRT}{V} \]

Measured P

Cl₂ gas has \( a = 6.49 \), \( b = 0.0562 \)

For 8.0 mol Cl₂ in a 4.0 L tank at 27 °C.

\( P \) (ideal) = \( \frac{nRT}{V} = 49.3 \text{ atm} \)

\( P \) (van der Waals) = 29.5 atm