Kinetic Molecular Theory

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Chem 102B
Volume of 1 mole of an ideal gas?

• What is the molar volume of an ideal gas at STP? (How much volume does 1 mole of gas occupy?)

What is STP? 0°C and 1 atm  \( T = K = 0°C + 273.15 \)

\[
PV = nRT \quad V = \frac{nRT}{P} = \frac{(1.000 \text{ mol})(0.08206 \text{ L\cdot atm/mol\cdot K})(273.15\text{ K})}{1.000 \text{ atm}}
\]

\[V = 22.42 \text{ L} = 22.42 \text{ L/mol ideal gas}\]
Application of Dalton’s Partial Pressures Law.

- \( P_{\text{Total}} = P_1 + P_2 + P_3 + \ldots \ldots \)
- Commonly we collect gases over water during an experiment.
- \( P_{\text{Total}} = P_{\text{gas}} + P_{\text{water vapor}} \)
Kinetic Molecular Theory (KMT)

Attempts to explain why gases behave the way they do.

1) Gases are mostly empty space; the volume of particles is negligible.

2) Gas particles are in constant random motion.

3) Gas particles neither attract nor repel each other.

4) Pressure is due to collisions of gas particles with container walls.

5) The average kinetic energy of a gas sample is proportional to the Kelvin Temperature.

\[ KE = \frac{3}{2} RT \quad \text{where} \quad R = 8.3145 \text{ J/mol} \cdot \text{K} \]
Are gases mostly empty space?

- Ratio of the volume of $N_2$ (g) to $N_2$ (l) is 640 : 1
- $N_2$ molecules are 9 times farther apart in the gas.
Random Motion of Gas Particles
**Boyle’s Law**

\[ \frac{V_1}{T_1} = \frac{V_2}{T_2} \]

Volume is decreased

\[ P_1 V_1 = P_2 V_2 \]

**Charles’s Law**

Temperature is increased
Avogardo’s Law

\[ \frac{n_1}{V_1} = \frac{n_2}{V_2} \]
Velocity of gas molecules

- Gas molecules are constantly colliding
- Transfer of energies
- Maxwell-Boltzman distribution of velocities
- \( KE_{\text{avg}} = \frac{3}{2} \, RT \)
- \( KE_{\text{avg}} = \frac{1}{2} \, mv^2 \)
Temperature Effects on Velocity

- Average velocity of $\text{N}_2$ molecules at different temps.
- Peak velocity becomes greater.
- Range of velocities also increases.
Kinetic Energy

Note: KE = \( \frac{1}{2} mv^2 \)
where \( m \) = mass and \( v \) = velocity

KE = \( \frac{3}{2} RT \) but KE = \( \frac{1}{2} mv^2 \)
So \( \frac{3}{2} RT = KE = \frac{1}{2} mv^2 \)

\( v_{avg} = (\frac{3RT}{M})^{1/2} \)
where \( M \) = molar mass of gas
Average velocity and mass

• Consider two gases at the same temperature, which has the higher average velocity?
• The lighter the gas molecule, the faster the average velocity.
• To check this, let’s calculate the average velocity of He and Ar gas at 25°C.