12: Temperature and Kinetic Theory of Gases

Key Physics Terms

- **Kinetic Molecular Theory (KMT):** An attempt to explain the behavior of matter, in terms of molecular forces, the energy the molecules posses and their motion.
- **Kelvin (K):** Temperature scale used in gas calculations. Has an absolute zero, so often referred to as absolute scale. °C + 273 = K
- **Pressure:** Force per unit area, in gases the force of gas molecules colliding with surfaces.
- **Atmospheric pressure:** Pressure due to the layers of air in the atmosphere.
- **Temperature:** State which is proportional to average kinetic energy of particles in an object.
- **Standard Temperature and pressure:** 1 atm (or anything it's equal to) and 0°C (273 K).
- **Ideal Gas:** Theoretical gas, for which all assumptions of the kinetic molecular theory are true (see below).
- **Mole:** The amount of material that contains the same number of atoms or molecules as there are in 12 grams of Carbon 12.
- **Molecular Mass:** Relative measure of mass, where 1 u is equal to the mass of $1/12^{th}$ of that of a carbon 12 atom. $1\ u = 1.6605 \times 10^{-27}$ kg.
- **Avogadro's number:** The number of molecules in one mole of any pure substance.
- **Density:** Mass per unit volume of matter.
- **Mean Free Path:** Average distance a molecule travels between collisions.
- **Average Translational Kinetic Energy:** Average kinetic energy (energy due to motion) of each molecule.
- **Root-Mean-Square Speed:** A measure of average speed of a molecule in a gas.
- **Maxwell's Probability Distribution:** Probability function that indicates the probability that a particle in a gas will be moving at a certain speed.
- **Real Gas:** All gases that exist, unlike an ideal gas the molecules have significant volume and experience attractive and repulsive forces.
- **Molar Volume of a gas:** 1 mole of any gas at STP = 22.4 Liters
- **Diffusion:** Rate at which a gas travels through a container.
- **Effusion:** Rate at which a gas escapes through a tiny hole.

Variables Used and Their Units

- P = Pressure, Pa
  1 atm = 101,300 Pa = 101.3 kPa = 760 mm Hg = 14.7 psi
- V = Volume, m^3
- T = Temperature, °C or K
- n = number of moles
- N = number of molecules
- R = Universal Gas constant, 8.314 J/(mol•K)
- N_A = Avogadro's Number, 6.02×10^{23} molecules/mole
- m = mass, kg
- MM = molar mass, kg/mol
- k = Boltzmann's constant, $R/N_A = 1.38 \times 10^{-23}$ J/K
- KE = kinetic energy, J
- v_{rms} = Root mean square speed, m/s

Kinetic Molecular Theory

Assumptions of the KMT

- Gases are made of atoms or molecules
- Gas particles are in constant, rapid, and random motion
- Temperature is proportional to the average kinetic energy
- Gas particles are not attracted nor repelled from each other
- All gas particle collisions are perfectly elastic (they leave with the same energy they collided with)
- The volume of gas particles is small compared to the space between them so it is insignificant.

Key Formula

- **Combined gas law:** $\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$
- **Avogadro's Law:** P, T constant, $\frac{V_1}{n_1} = \frac{V_2}{n_2}$
- **Boyle's Law:** n, T constant, $P_1V_1 = P_2V_2$
- **Charles' Law:** n, P constant, $\frac{V_1}{T_1} = \frac{V_2}{T_2}$
- **Gay-Lussac's Law:** n, V constant, $\frac{P_1}{T_1} = \frac{P_2}{T_2}$
- **Molar mass:** $MM = \frac{m}{n}$
- **Density :** $D = \frac{m}{V}$
- **Ideal gas law:** PV=nRT
- **Ideal Gas Law with Molar Mass:** $PV = \frac{m}{MM}RT$
- **Ideal Gas Law with Density:** $P = D\frac{RT}{MM}$
- **Average translational KE per mole for ideal gas:**
  $KE_{Ave} = \frac{3}{2}RT$
- **Average Translational KE per molecule for ideal gas:**
  $KE_{Ave} = \frac{3}{2}kT = \frac{3}{2}\frac{R}{N_A}T$
- **Root mean square speed:** $v_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{MM}}$
- **Mean free path of a gas molecule:** $\lambda = \frac{1}{\sqrt{2}\pi d^2 N/V}$

  d is the diameter of the gas molecule
- **Pressure in ideal gas :** $P = \frac{n\,MM\,v_{rms}^2}{3V}$
- **Van der Waal's Real Gas Law:** $\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$

  a and b are constants whose value is gas dependent

Strategy for Ideal Gas Problems.

1. Identify quantities by their units
2. Write known and unknown quantities symbolically
3. Choose equation based upon list of quantities
   Plug quantities into equation and solve.

Remember:
Number of molecules and pressure: Directly proportional
Pressure and volume: Inversely proportional
Pressure and temperature: Directly proportional

Pressure Inside and Outside

- Atmospheric pressure decreases as altitude increases.
- A soft container, or one with a moveable piston, expands or contracts to allow internal pressure to equal external pressure.
  - Expansion lowers internal pressure
  - Contraction raises internal pressure
- Rigid container cannot expand or contract—they will explode or implode.

How to Use This Cheat Sheet: This is the key information for this topic. Try to read through it carefully twice then write it out on a blank sheet of paper. Review it again before the exams.