Gases and Their Properties

Starting Point: *Kinetic-Molecular Theory of Gases*:

1. Large separation b/w individual molecules
2. Gas molecules are in continual, random, rapid motion
3. The average kinetic energy of gas molecules is proportional to temperature.
   - KE = $\frac{1}{2}mv^2$ (for a particle of given velocity)
   - BUT, there is a distribution of velocities for a gas
   - SO it is easiest to talk about <u>average</u> KE.
   - If KE $\propto$ T that must mean that ________
4. Gas molecules collide with one another (and other things) without energy loss..

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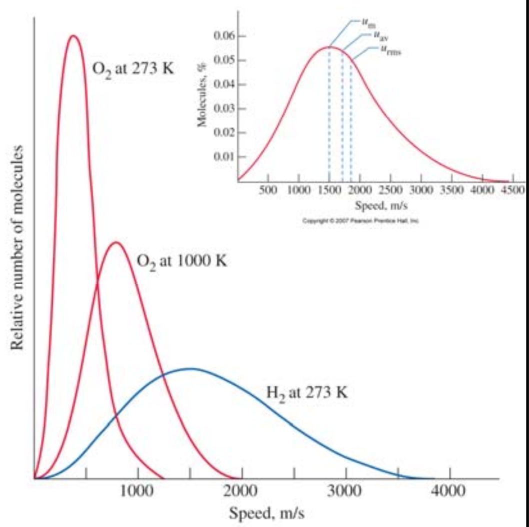
Gas Velocities

- Pressure is a result of collisions with walls.
- Depends on:
  – Kinetic Energy ($mv^2/2$)
  – Frequency of collisions (speed and # of molecules)
  – Momentum (mv)
- Observed pressure is result of these factors for molecules at a variety of speeds (v)
  – v_m, v_{av}, v_{rms}



How does the Kinetic Theory manifest itself?

Pressure:

- Arises from collisions of gas with walls of the container
- Units: wide variety
  - mm Hg (Torr), atm, Pascal, bar
  - be able to do conversions!

Gas Laws: (experimentally determined)

- Relationships based on a fixed mass of gas.
- Boyle's Law: $P \propto 1/V$
- Charles' Law: $V \propto T$
- Avogadro's Law: $V \propto$ number of moles of gas (n)

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VERY IMPORTANT RELATIONSHIP #1: Combined Gas Law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

- **Example**. You have a 22 L cylinder of helium at a pressure of 150 atm and at 31^{o}C. How many balloons can you fill, each with a volume of 5.0 L on a day when the atmospheric pressure is 755 mm Hg and the temp is 22^{o}C?

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VERY IMPORTANT RELATIONSHIP #2: Ideal Gas Law

$V \propto 1/P$
$V \propto T$
$V \propto n$

$\rightarrow \quad V \propto \frac{nT}{P}$

- R = 0.08206 L atm/mol K (value depends on units)
- Standard Temperature and Pressure: 1 atm and 0°C

- **Example:** If a balloon is filled with 1300 mol of H_2 at a pressure of 750 Torr and a temperature of 23°C, what is the balloon's volume?

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Gas Laws and Stoichiometry

Don't forget that reactions occur on a per <u>mole</u> basis

- If you can convert to moles and remember stoichiometry, you are home free!

Example: Oxygen reacts with aqueous hydrazene to produce water and gaseous nitrogen. If a solution contains 180 g of N_2H_4, what is the maximum volume of O_2 that will react if the oxygen is measured at a pressure of 750 mm Hg and at a temperature of 21°C?

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Gas Mixtures

Daltons Law of Partial Pressures:

$P_{total} = P_1 + P_2 + P_3 + \ldots$

– P_{total}:

– P_A:

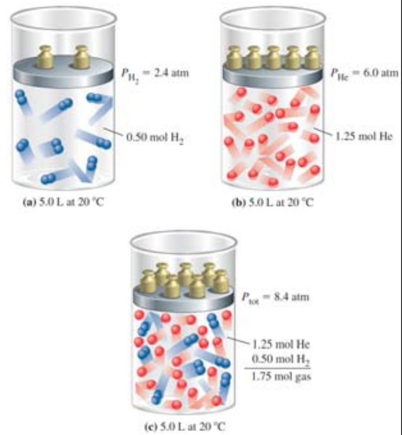
- Substitute $P_A = n_A RT/V$ to get:

  $P_{total} = n_{total}(RT/V)$

Mole Fraction (not just for gases)

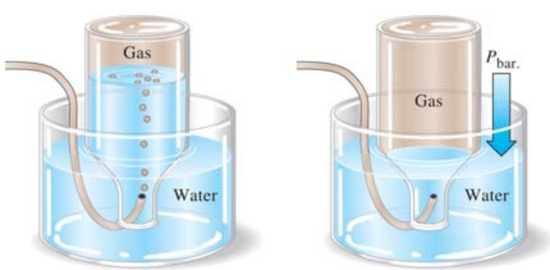
$$X_A = \frac{n_A}{n_{total}}$$

– Using mole fraction: $P_A = X_A P_{total}$



Collecting Gas over Water

- Common method for trapping gas produced in a process



Vapor Pressure of Water at Various Temperatures

Temperature (°C)	Vapor Pressure (mmHg)
15.0	12.79
17.0	14.53
19.0	16.48
21.0	18.65
23.0	21.07
25.0	23.76
30.0	31.82
50.0	92.51

- Resulting gas also contains some water vapor
  – Amount depends on temperature
  – $P_{total} = P_{H2O} + P_{gas}$

Gas Mixtures

Example: A mixture of 15.0g $C_2HBrClF_3$ gas and 23.5 g oxygen is placed in a 5.00L tank at 25.0^{o}C. What is the total pressure of the gas in the tank? What are the partial pressures of each gas?

Example: An 89.3 mL sample of O_2 is collected over water at 21.0^{o}C at a barometric pressure of 756 mm Hg. What is the partial pressure of O_2 in the sample collected? How many grams of O_2 are present in the sample?

READ Section 6.8: Diffusion, Effusion

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Deviations from Ideal Gas Character;

Or: When the Kinetic Molecular Theory Fails;

Or: What to do When Your Gas is Non-ideal!

- Ideal gas law works best at low pressures (< 1 atm) and moderate to high temperatures (~room temperature).

- Remember key assumptions of KM-Theory:
  1. No energy is lost in collisions
  2. Large distance between gas molecules
  3. Assume no <u>attractive interaction</u> b/w gas molecules

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Characterizing Real Gases

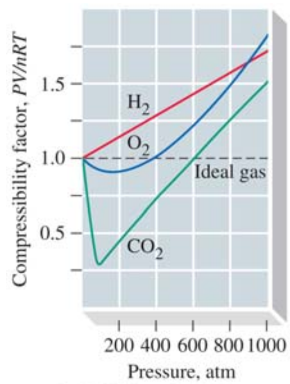
- At low T and high P, these assumptions are less good! Need correction for Ideal Gas Law:

- **<u>Van der Waals Equation:</u>**

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

  – Where a and b are constants that are specific for a given gas. As a and b get smaller, the gas is more "ideal"

Gas	**a** (atm L^2/mol^2)	**b** (L/mol)
He	0.034	0.0237
H_2O	2.25	0.0428



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