Topic 3 - Ideal Gases and the Ideal Gas Law

An ideal gas is a hypothetical gas that obeys all the gas laws
- Always a gas (no matter what the temperature or pressure)

Real gases behave like ideal gases when
- Pressure is low
- Temperature is high
- Like at STP or SATP

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Differences b/w real and ideal gases are noticeable when P is near 1000kPa and T is near the condensation point of the gas

Difference b/w real and ideal gases is due to the presence of intermolecular forces

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ideal gases - ignoring I.M. forces

Table 1 Comparison of Ideal and Real Gases

KMT assumption for ideal gases	Interpretation for real gases
Gas molecules are very far apart compared to their size. In other words, the molecules' size is negligible.	For high pressures, the molecules are forced much closer together and their size becomes significant. In other words, the empty space available is less than the size of the container.
Gas molecules are in constant, random, straight-line motion because no forces exist between them.	As the temperature decreases, the molecules slow down. At some point, the intermolecular attractions may cause the molecules to stick together and the gas becomes a liquid.
Gas molecules undergo perfectly elastic collisions in which no energy is lost and collisions (and rebounds) occur very quickly (**Figure 1(a)**).	Molecules of a real gas are more like "soft" spheres (**Figure 1(b)**). Shape change during collision and rebound makes this process occur a little more slowly. This means that the pressure of the gas is actually a little less than ideal.

The Ideal Gas Law

Formula:

$$PV = nRT$$

P = pressure (in kPa)
V = volume (in L)
n = number of moles (mol)
R = universal gas constant (kPa*L / mol*K) $8.31 \frac{kPa \cdot L}{mol \cdot K}$
T = temp (in K)

Example:
Predict the volume occupied by 0.39mol of hydrogen gas at 22°C and 125kPa

P = 125 kPa
V = ?
n = 0.39 mol
R = $8.31 \frac{kPa \cdot L}{mol \cdot K}$
T = 295 K

$PV = nRT$

$(125\ kPa)(V) = (0.39\ mol)(8.31 \frac{kPa \cdot L}{mol \cdot K})(295\ K)$

$V = 7.648...\ L$

$= 7.6\ L$

Example:
What mass of argon gas should be put into an evacuated 0.88L tube to produce a pressure of 90kPa at 30°C?

P = 90 kPa
V = 0.88 L
n = ?
R = $8.31 \frac{kPa \cdot L}{mol \cdot K}$
T = 303 K

$PV = nRT$

$(90\ kPa)(0.88\ L) = n\ (8.31 \frac{kPa \cdot L}{mol \cdot K})(303\ K)$

$n = 0.0314...\ mol$

$m = nM$

$= (0.0314...\ mol)(39.95\ g/mol)$

$= 1.256...\ g$

$= 1.3\ g$

Practice Sheet 7

H_2

1. A common use of the ideal gas law is to predict volumes or masses of gases under specified conditions of temperature and pressure. For example, predict the volume occupied by 0.78 g of hydrogen at 22 °C and 125 kPa.

$PV = nRT$

$(125\ kPa)(V) = (0.386...)(8.31\ \frac{kPa \cdot L}{mol \cdot K})(295\ K)$

$V = 7.5727...\ L = \boxed{7.6\ L}$

$n = \frac{m}{M} = \frac{0.78\ g}{2.02\ g/mol} = 0.386...\ mol$

2. Determine the pressure in a 50 L compressed air cylinder containing 30 mol of air at a temperature of 40 °C.

$1.6 \times 10^3\ kPa$

3. Predict the chemical amount of methane gas present in a sample that has a volume of 500 mL at 35.0 °C and 210 kPa.

$PV = nRT$

$(210\ kPa)(0.500\ L) = n\ (8.31\ \frac{kPa \cdot L}{mol \cdot K})(308.0\ K)$

$n = 0.0410\ mol$

4. What volume does 50 kg of oxygen gas occupy at a pressure of 150 kPa and a temperature of 125 °C?

34 kL or 3.4×10^4 L

5. When an air bag is activated in a collision, sodium azide rapidly decomposes to produce nitrogen gas. Chemical engineers carefully choose the quantity of sodium azide to produce the required chemical amount of nitrogen gas. Use the ideal gas law to predict the chemical amount of nitrogen gas required to fill a 60 L air bag at a pressure of 233 kPa and a temperature of 25 °C.

$PV = nRT$

$(233\ kPa)(60\ L) = (n)(8.31\ \frac{kPa \cdot L}{mol \cdot K})(298\ K)$

$n = 5.645...\ mol = \boxed{5.6\ mol}$

6. At what temperature does 10.5 g of ammonia gas exert a pressure of 85.0 kPa in a 30.0 L container?

498 K

7. A 1.49 g sample of a pure gas occupies a volume of 981 mL at 42.0 °C and 117 kPa.

(a) Determine the molar mass of the compound.

$PV = nRT$

$(117\,kPa)(0.981\,L) = n\left(8.31\,\frac{kPa \cdot L}{mol \cdot K}\right)(315\,K)$

$n = 0.04384...\,mol$

$m = nM$

$M = \frac{m}{n}$

$M = 33.98\,g/mol$

(b) If the chemical formula is known to be XH3, identify the element "X."

$XH_3 = 33.98\,g/mol$

?

$-\,3.03$

$30.95\,g/mol = X$ = Phosphorous

8. The density of a gas is the mass per unit volume of the gas in units of, for example, grams per litre. By finding the mass of one litre (assume 1.00 L) of gas, you can then calculate the density of the gas. Knowledge of the densities of gases compared with the density of air (at 1.2 g/L) can save your life.

(a) What is the density of carbon monoxide gas at 20 °C and 98 kPa in a home?

(b) Using your answer to (a), where should a carbon monoxide detector be located, close to the floor or close to the ceiling?

(c) What is the density of propane, $C_3H_8(g)$, at 22 °C and 96.7 kPa?

(d) If the density of air at 20 °C is 1.2 g/L, what happens to propane gas that may leak from a propane cylinder in a basement or from the tank of an automobile in an underground parkade? Why is this a problem?