CHEM 101A – TOPIC C
GAS LAWS AND THE KINETIC THEORY

WHAT YOU SHOULD BE ABLE TO DO WHEN YOU HAVE FINISHED THIS TOPIC:

1) Use classical gas laws to relate changes in pressure, volume, temperature, and number of moles to one another.
2) Use vapor pressure information and the classical gas laws to describe the behavior of a gas when it is collected over water.
3) Solve stoichiometry problems involving gases, using the ideal gas law.
4) Have sufficient understanding of basic kinetic theory to be able to:
    a) Solve problems involving kinetic energy, temperature, molar mass, and particle velocity for an ideal gas.
    b) Use effusion rates to determine the molar mass of a gas.
    c) Answer qualitative questions about the Boltzmann distribution of kinetic energies and velocities, and their relationships to temperature and molar mass.
5) Describe the factors that differentiate real gas behavior from the ideal gas model, and use the van der Waals equation to model real gas behavior.

READING ASSIGNMENT:

Sections 5.1 through 5.7 and section 5.10. Omit "the quantitative kinetic molecular model" on pages 157-161 (6^{th} edition) or 156-160 (5^{th} edition).

RELEVANT PROBLEMS:

(6^{th} edition): Chapter 5, problems 21, 27, 29, 33, 41, 43, 45, 49, 61, 65, 73, 75, 77, 81, 83, 87, 103, 107, 111 and 135

(5^{th} edition): Chapter 5, problems 21, 27, 29, 33, 39, 41, 43, 45, 55, 59, 63, 65, 67, 71, 73, 79, 95, 99, 103, and 131.

THE REQUIRED HOMEWORK ASSIGNMENT STARTS ON THE NEXT PAGE OF THIS HANDOUT

CHEM 101A **TOPIC C PROBLEM ASSIGNMENT**

1) You have a 455 mL sample of oxygen at 18ºC and a pressure of 739 torr.

a) If you lower the temperature to –61ºC without changing the volume, what pressure will the oxygen exert?

b) If you then increase the volume to 623 mL while keeping the temperature at –61ºC, what pressure will the oxygen exert?

c) If you now increase the temperature to 83ºC while keeping the pressure constant, what will the volume of the oxygen be?

d) What is the mass of the oxygen?

2) A compound contains 88.8% carbon and 11.2% hydrogen. At 150ºC and 565 torr, this compound is a gas with a density of 2.32 g/L. Determine the molecular formula of this compound.

3) Calculate the approximate mass of the air in room S-201 (one of our Chem 101A labs), given the following information:

width of room = 8.9 m length of room = 7.5 m height of room = 4.6 m

temperature = 20ºC air pressure = 1 atm

Typical molar composition of air in San Francisco: 77.0% N_2, 20.7% O_2, 1.4% H_2O, 0.9% Ar

4) Acidic solutions of $CrCl_2$ can remove oxygen from the atmosphere via the following reaction:

$$4\ CrCl_2(aq) + 4\ HCl(aq) + O_2(g) \rightarrow 4\ CrCl_3(aq) + 2\ H_2O(l)$$

50.0 mL of a 0.123 M solution of $CrCl_2$ is placed into a container that holds 500.0 mL of air at a temperature of 18ºC. The partial pressure of the oxygen in the container is 156 torr. Once the reaction is complete, what will be the partial pressure of oxygen in the container? (Assume that the temperature is constant and HCl is present in excess.)

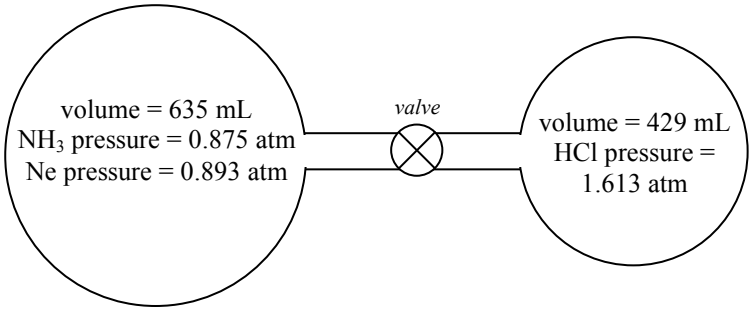
5) The apparatus below contains ammonia, neon, and hydrogen chloride gases at a temperature of 27ºC. The valve in the center is opened and the ammonia reacts with the hydrogen chloride:

$$NH_3(g) + HCl(g) \rightarrow NH_4Cl(s)$$

Neon does not react.

a) What mass of ammonium chloride will be formed?

b) What will be the total pressure in the apparatus after the reaction is complete, assuming the temperature remains constant?



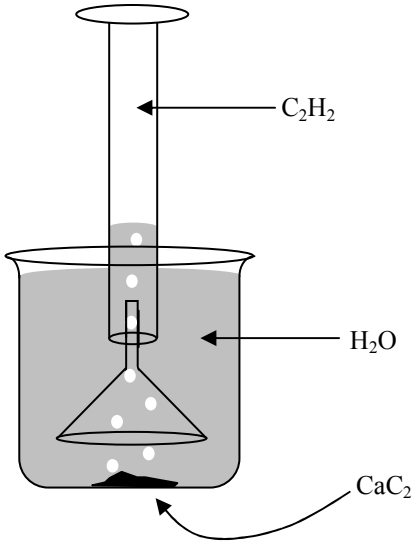
6) Calcium carbide (CaC_2) reacts with water to form gaseous acetylene (C_2H_2) according to the following equation:

$$CaC_2(s) + 2\ H_2O(l) \rightarrow C_2H_2(g) + Ca(OH)_2(s)$$

A sample of calcium carbide is placed into a container of water and the acetylene is collected over water as shown below. The acetylene occupies 261 mL at a pressure of 751 torr and a temperature of 22.5ºC. The vapor pressure of water at 22.5ºC is 20.5 torr.

a) How many moles of acetylene were formed?

b) What was the mass of the calcium carbide sample?



7) Calculate the kinetic energy of the following:

a) A roller coaster car that weighs 625.0 kg and is moving at 18.0 m/s.

b) A molecule of CO_2 that is moving at 419 m/s.

c) A molecule of N_2 that is moving at 511 m/s.

d) Express your answers to parts b and c in kJ/mole.

8) A mole of He atoms has a kinetic energy of 3.86 kJ/mole. Calculate the velocity of a He atom.

9) Which is larger, the average speed of a nitrogen molecule at 20ºC or the speed of sound? Sound travels at 768 miles per hour at 20ºC.

10) Explain each of the following observations, using the kinetic theory of gases.

a) The pressure that a gas exerts increases if you reduce the size of the container.

b) The pressure that a gas exerts decreases if you reduce the temperature.

c) Reactions that involve gases speed up if you raise the temperature.

11) For each of the following pairs of quantities, tell which one is larger and explain your answer. If they are equal, say so and explain how you can tell. ("KE" means kinetic energy)

a) The rms velocity of nitrogen at 25ºC or the rms velocity of oxygen at 75ºC.

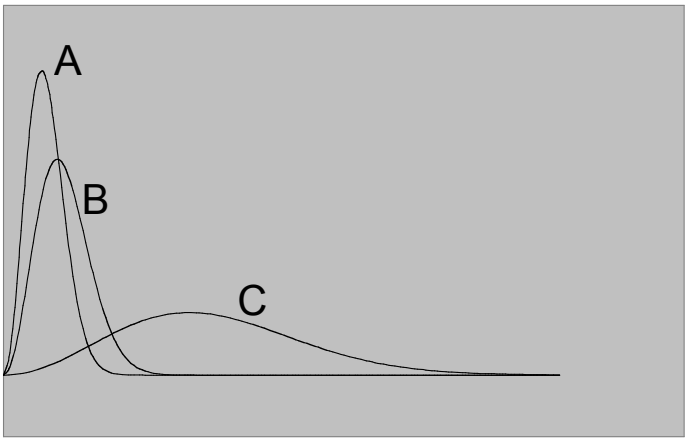
b) The most probable KE for argon at 25ºC or the most probable KE for neon at 25ºC.

c) The average velocity of hydrogen or the average velocity of helium at the same temperature.

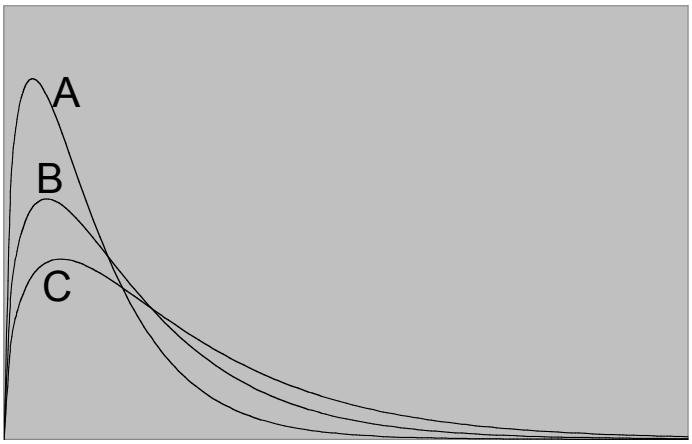
d) The fraction of CH_4 molecules with velocities greater than 500 m/sec, or the fraction of NH_3 molecules with velocities greater than 500 m/sec at the same temperature.

e) The fraction of He atoms with kinetic energies between 100 and 200 J/mol, or the fraction of Ne atoms with kinetic energies between 100 and 200 J/mol, if both gases are at 100ºC.

12) The graph below shows the relationship between velocity (x coordinate) and fraction of molecules (y coordinate) for three gas samples: neon at 0ºC, carbon dioxide at 25ºC, and hydrogen at 50ºC. Match each curve (A, B and C) with the correct gas sample, and explain your reasoning.



13) The graph below shows the relationship between kinetic energy (x coordinate) and fraction of molecules (y coordinate) for three gas samples: hydrogen at 50 K, oxygen at 100 K, and neon at 150 K. Match each curve (A, B and C) with the correct gas sample, and explain your reasoning.



14) Nickel can combine with carbon monoxide to form a compound that has the chemical formula $Ni(CO)_n$, where *n* is a whole number. This compound is a gas at 75ºC. In an effusion experiment at 75ºC, 12.1 mL of this compound escapes through the pinhole in 10.0 minutes. Under the same conditions, 11.9 mL of carbon dioxide effuses in 5.0 minutes. Using this information, determine the chemical formula of the unknown compound.

15) An engineer is designing a reactor that will be filled with oxygen under high pressure. The volume of the reactor is 253 L, the maximum temperature inside the reactor will be 250ºC, and the pressure inside the reactor must not exceed 150 atm. The engineer uses the ideal gas law to calculate the maximum number of moles of oxygen that can be put into the reactor without exceeding 150 atm.

a) What number of moles does the engineer calculate using the ideal gas law?

b) Now use the van der Waals equation to calculate a more accurate value for the pressure inside the reactor at 250ºC, using the number of moles you obtained in part a. Will the reactor be at risk of failure, based on your answer?