Chem E-1a
Friday Review Problems
Chapter 5: Gases

1. Gaseous acetylene, C_2H_2, will react with hydrogen gas under appropriate conditions to form ethane gas, C_2H_6. A 2.00 L reaction vessel is filled with 3.00 atm of hydrogen and 1.00 atm of acetylene at 25°C and the reaction is allowed to proceed to completion. After the reaction is complete the temperature in the vessel is returned to 25°C.

   a) Write a complete balanced equation for this reaction. (Note: acetylene and ethane are both gases under these conditions.)

$$C_2H_2(g) + 2H_2(g) \longrightarrow C_2H_6(g)$$

   b) Calculate the mass of ethane that is formed.

LIMITING REAGENT PROBLEM $\Longrightarrow$ LET'S USE A RICE TABLE!

ATM: $\frac{1.00}{1} = 1$ $\qquad \frac{3.00}{2} = 1.5$ $\qquad$ SMALLEST SO $x = 1$

	$C_2H_2(g)$ +	$2H_2(g)$ $\longrightarrow$	$C_2H_6(g)$
R:	$C_2H_2(g)$	$2H_2(g)$	$C_2H_6(g)$
I:	1.00	3.00	0
C:	$-x$	$-2x$	$+x$
E:	$1-x$	$3-2x$	x
	$=1-1=0$	$=3-2(1) = 1$	$=1$

FIND MOL C_2H_6:

$$PV = nRT$$

$$n_{C_2H_6} = \frac{P_{C_2H_6}V}{RT} = \frac{(1\text{ ATM})(2.00\text{ L})}{(0.0821\ \frac{\text{L·ATM}}{\text{MOL·K}})(298\text{ K})}$$

$$n_{C_2H_6} = 0.0817\text{ MOL}$$

CHOOSE UNITS FOR RICE TABLE:

- # OF MOLES IS ALWAYS ACCEPTABLE
- PARTIAL PRESSURES IN ATM IS OK IF:
  - IT IS AN ALL-GAS-PHASE REACTION (OR YOU DON'T CARE ABOUT QUANTITIES OF LIQUIDS OR SOLIDS)
  - V AND T MUST BE THE SAME IN THE "I" AND "E" ROWS

$$0.0817\text{ MOL } C_2H_6 \times \frac{30\text{ g } C_2H_6}{1\text{ MOL}} = \boxed{2.451\text{ g } C_2H_6}$$

1. (cont.)

c) Calculate the total pressure inside the vessel after the reaction is complete.

$$P_T = P_{C_2H_2} + P_{H_2} + P_{C_2H_6}$$

$$= 0 + 1\text{ ATM} + 1\text{ ATM} = \boxed{2\text{ ATM} = P_{TOTAL}}$$

d) Calculate the mole fraction of ethane in the resulting mixture.

$$X_{C_2H_6} = \frac{n_{C_2H_6}}{n_{TOTAL}} = \frac{P_{C_2H_6}}{P_{TOTAL}} = \frac{1\text{ ATM}}{2\text{ ATM}} = \boxed{0.5 = X_{C_2H_6}}$$

e) Inert argon gas is pumped into the vessel until the total pressure is 5.00 atm. Calculate the number of moles of argon gas that were added.

BEFORE ARGON ADDED: 2 ATM TOTAL PRESSURE

AFTER ARGON ADDED: 5 ATM TOTAL PRESSURE

$$P_{Ar} = 3\text{ ATM}$$

$$n_{Ar} = \frac{P_{Ar}V}{RT} = \frac{(3\text{ ATM})(2.00\text{ L})}{\left(0.0821\frac{\text{L}\cdot\text{ATM}}{\text{MOL}\cdot\text{K}}\right)(298\text{ K})} = \boxed{0.245\text{ MOL ARGON}}$$

f) Calculate the rms speed of the ethane molecules at 25°C.

$$u_{RMS} = \sqrt{\frac{3RT}{\mathcal{M}}} = \sqrt{\frac{3(8.314\text{ J/MOL K})(298\text{ K})}{(0.030\text{ kg/MOL})}} = \boxed{498\text{ m/s}}$$

MOLAR MASS IN kg

g) Calculate the average kinetic energy per mole and per molecule of the ethane molecules at 25°C.

$$KE = \frac{3}{2}RT = \frac{3}{2}(8.314\text{ J/MOL}\cdot\text{K})(298\text{ K}) = \boxed{3716\text{ J/MOL}}$$

$$\frac{3716\text{ J}}{\text{MOL}} \times \frac{1\text{ MOL}}{6.02\times10^{23}\text{ MOLECULES}} = \boxed{6.17\times10^{-21}\text{ J/MOLECULE}}$$

2. Solid calcium chlorate, $Ca(ClO_3)_2$, will decompose upon heating, releasing oxygen gas and leaving behind solid $CaCl_2$. 2.00 grams of calcium chlorate are completely decomposed, and the oxygen gas is collected over water at a temperature of 25°C and a pressure of 756 torr. (Note: The vapor pressure of water at 25°C is 23.8 torr.)

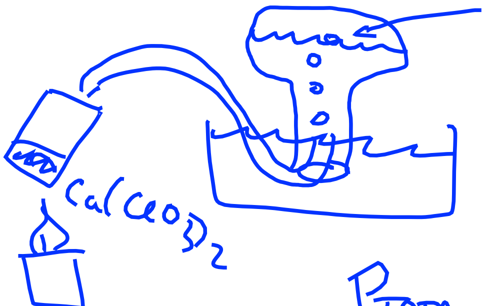
TOTAL PRESSURE

a) Write a complete balanced equation for the decomposition of $Ca(ClO_3)_2$.

$$Ca(ClO_3)_2(s) \longrightarrow 3O_2(g) + CaCl_2(s)$$

b) Calculate the volume of oxygen that was collected.

COLLECTING GAS OVER WATER:



$O_2(g)$ AND $H_2O(g)$

$P_{H_2O(g)}$ = VAPOR PRESSURE OF WATER AT THIS TEMP. = 23.8 TORR @ 25°C

$$P_{TOTAL} = P_{O_2} + P_{H_2O}$$

$$756 \text{ TORR} = P_{O_2} + 23.8 \text{ TORR}$$

$$P_{O_2} = 732.2 \text{ TORR}$$

FIND n_{O_2}

$$2.00 \text{ g } Ca(ClO_3)_2 \times \frac{1 \text{ MOL } Ca(ClO_3)_2}{207 \text{ g } Ca(ClO_3)_2} \times \frac{3 \text{ MOL } O_2}{1 \text{ MOL } Ca(ClO_3)_2} = 0.0290 \text{ MOL } O_2$$

$$V = \frac{n_{O_2}RT}{P_{O_2}} = \frac{(0.0290 \text{ MOL})(0.0821)(298 \text{ K})}{\left(732.2 \text{ TORR} \times \frac{1 \text{ ATM}}{760 \text{ TORR}}\right)} = \boxed{0.737 \text{ L}}$$

c) What mass of water vapor is mixed with the oxygen gas?

$$n_{H_2O(g)} = \frac{P_{H_2O(g)}V}{RT} = \frac{\left(23.8 \text{ TORR} \times \frac{1 \text{ ATM}}{760 \text{ TORR}}\right)(0.737 \text{ L})}{(0.0821)(298 \text{ K})}$$

$$n_{H_2O(g)} = 9.43 \times 10^{-4} \text{ MOL} \Longrightarrow \boxed{0.0170 \text{ g } H_2O(g)}$$

3. Sulfur dioxide gas can react with oxygen gas under appropriate conditions to form sulfur trioxide gas. A 1.00 L reaction vessel is charged with 2.00 atm of sulfur dioxide and 2.00 atm of oxygen at a temperature of 1000 K. Sulfur trioxide is formed, but the reaction **does not** go to completion. The final total pressure in the vessel is 3.32 atm.

a) Write a complete balanced equation for this gas-phase reaction.

$$SO_2(g) + \frac{1}{2}O_2(g) \longrightarrow SO_3(g)$$

b) Calculate the partial pressure of each gas in the resulting mixture.

ATM

R:	$SO_2(g)$ +	$\frac{1}{2}O_2(g)$ $\longrightarrow$	$SO_3(g)$
I	2.00	2.00	0
C	$-x$	$-\frac{1}{2}x$	$+x$
E	$2-x$	$2-\frac{1}{2}x$	x

FINAL

$$P_{TOTAL} = 3.32 \text{ ATM} = P_{SO_2} + P_{O_2} + P_{SO_3}$$

$$3.32 = (2-x) + (2-\tfrac{1}{2}x) + (x)$$

$$3.32 = 4 - \tfrac{1}{2}x$$

$$x = 1.36$$

PLUG BACK IN

$$P_{SO_2} = 2 - x = 2 - 1.36 = 0.64 \text{ ATM}$$

$$P_{O_2} = 2 - \tfrac{1}{2}x = 2 - \tfrac{1}{2}(1.36) = 1.32 \text{ ATM}$$

$$P_{SO_3} = x = 1.36 \text{ ATM}$$