CH 101 - Practice problems – 4/02/2013

Gases, pressure and gas laws.

1. Answer the following multiple choice questions, basing your reasoning on the equation PV=nRT.

   a. If the absolute temperature of a gas is increased by a factor of two and the volume is increased by a factor of two, the pressure of the gas will:
      - increase by a factor of 4
      - increase by a factor of 2
      - [✓ stay the same]
      - decrease by a factor of 2
      - decrease by a factor of 4

   b. If the absolute temperature of a gas is increased by a factor of two and the volume is reduced by a factor of two, the pressure of the gas will:
      - [✓ increase by a factor of 4]
      - increase by a factor of 2
      - stay the same
      - decrease by a factor of 2
      - decrease by a factor of 4

   c. If the absolute temperature of a gas is doubled and the volume stays the same, the pressure of the gas will:
      - increase by a factor of 4
      - [✓ increase by a factor of 2]
      - stay the same
      - decrease by a factor of 2
      - decrease by a factor of 4

2. A sealed, rigid container holds pure argon at 3000.0 torr and 300.0 °C. What will the pressure be if the container is cooled to 30.0 °C? (6 pts.)

$T_1 = 300.0\,^{\circ}C = 573.2\ K \qquad T_2 = 30.0\,^{\circ}C = 303.2\ K$

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \Rightarrow P_2 = \frac{P_1 T_2}{T_1} = \frac{3000.0\ \text{torr} \cdot 303.2\ K}{573.2\ K} = 1587\ \text{torr}$$

3. What is the density of krypton gas at STP? (6 pts.)

$$d = \frac{MM \cdot P}{RT} = \frac{83,80 \frac{g}{mol} \cdot 1 \text{ atm}}{0,082 \frac{L \cdot atm}{mol \cdot K} \cdot 273,15 \text{ K}} = 3,719 \frac{g}{L}$$

4. Hydrogen gas is collected over water in a eudiometer by reacting iron with excess hydrochloric acid. (Iron(III) chloride is also produced in this reaction.) After the reaction stops, the water level inside the eudiometer is even with the water level outside, and the volume reads 54.6 ml. The lab conditions are 723.2 torr and 32.0 °C. What was the mass of iron that was used? (12 pts.)

$$2Fe + 6HCl \longrightarrow 2FeCl_3 + 3H_2$$

From V, P, T we can calculate how many moles of H_2 were produced.

$$n = \frac{PV}{RT} = \frac{723.2 \text{ torr} \cdot 0,0546 \text{ L}}{62.36 \frac{L \cdot torr}{K \cdot mol} \cdot 305,15 \text{ K}} = 2,075 \text{ mol}$$

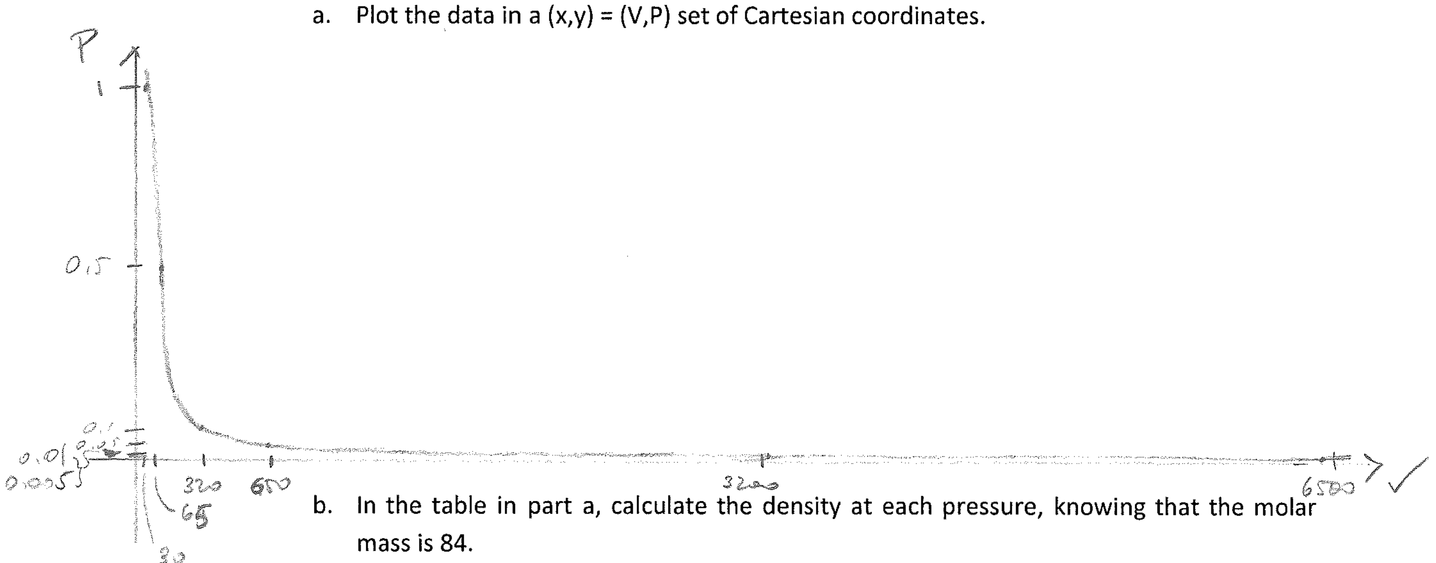
From the stoichiometry of the reaction:

$$n_{Fe} = \frac{2}{3} n_{H_2} = 1,383 \text{ mol} \qquad m_{Fe} = n_{Fe} \cdot MM_{Fe} = 77,26 \text{ g}$$

5. 1.32 mmol of an ideal gas are expanded at the constant temperature of 298K.
   a. Calculate the Volume the gas will occupy at the pressures provided in the table below.

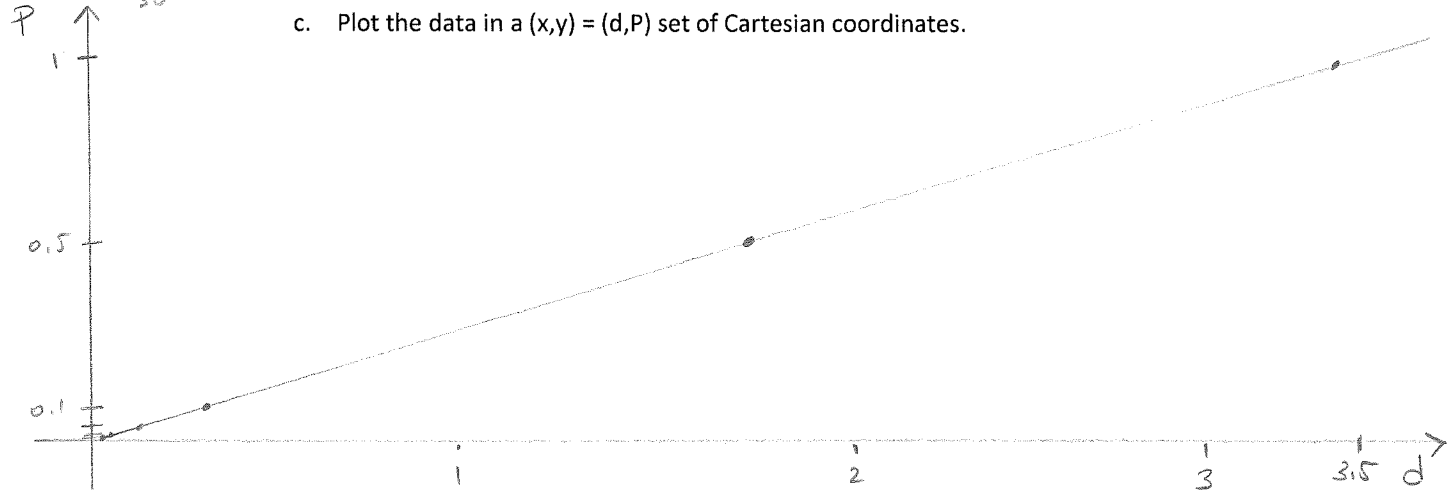
Pressure (atm)	Volume (L)	density (g/L)
1	32,25	3.44
0.5	64,50	1,72
0.1	322,5	0.344
0.05	645.0	0.172
0.01	3225.0	0.0344
0.005	6450.0	0.0172

a. Plot the data in a (x,y) = (V,P) set of Cartesian coordinates.



b. In the table in part a, calculate the density at each pressure, knowing that the molar mass is 84.

c. Plot the data in a (x,y) = (d,P) set of Cartesian coordinates.



6. A gas has the following elemental composition: C = 82.7%; H = 17.3% in mass. At stp (room temperature, 0°C, and pressure, 760 mmHg), it's density is 2.496 Kg/m^3. Assuming that this gas behave~~s~~ ideally, what's it's molecular formula?

In 100 g : C 82.7g → 6.89 mol

H 17.3g → 17.3 mol

Ratio = $C_1H_{2.5}$ => Empirical formula = C_2H_5 → Molecular formula = C_4H_{10}

$$MM = d\frac{RT}{P} = 2.496\frac{g}{L} \cdot \frac{0.082\frac{L \cdot atm}{K \cdot mol} \cdot 273.16\ K}{1\ atm} \approx 56\frac{g}{mol}$$

7. Partial pressure and stoichiometry of reactions:

- 5g of Urea (d= 1.32 g/mL) is burned at 320°C in a sealed cubic container (l = 1m) according to the following reaction:

$$CH_4ON_{2\,(s)} + O_{2\,(g)} \rightarrow CO_{2\,(g)} + NO_{2\,(g)} + H_2O_{\,(g)}$$

At the beginning of the reaction, only a strictly stoichiometric amount of oxygen is present. Calculate how does the total pressure (in atm) change inside the box.

See next page.

8. A sealed container holds 10.0 g of nitrogen gas and 40.0 g of helium gas at 60.0 °C. The total pressure in the container is 650.0 torr.

a. What is the partial pressure of the nitrogen gas in the container?

$n_{N_2} = \frac{10.0}{28} = 0.357 \text{ mol}$ $\quad \chi_{N_2} = \frac{0.357}{10.357} = 0.034$

$n_{He} = \frac{40.0}{4} = 10.0 \text{ mol}$ $\quad P_{N_2} = \chi_{N_2} \cdot P_{TOT} = = 0.034 \cdot 650.0 = 22.4 \text{ torr}$

b. What is the partial pressure of helium gas in the container?

$\chi_{He} = 1 - 0.034 = 0.966$ $\quad P_{He} = \chi_{He} \cdot P_{TOT} = 628 \text{ torr}$

Volume of the container $V = l^3 = (1\,dm)^3 = 1\,dm^3$

space free in the container @ the beginning : $V - V_{urea} =$

$$V_{urea} = \frac{m}{d} = \frac{5\,g}{1.32\,g/mL} = 3.8\,mL \sim 4\,mL$$

$$V_{space} = V_{container} - V_{urea} = 1.000\,L - 0.004\,L = 0.996\,L$$

@ the beginning the pressure is $= P_{O_2}$

$$P_{O_2} = \frac{n_{O_2}RT}{V} = \frac{\frac{7}{2} n_{UREA}\, RT}{V} = \frac{7}{2} \cdot \frac{5g}{60\,\frac{g}{mol}} \cdot \frac{0.082\,\frac{L \cdot atm}{K \cdot mol} \cdot (320 + 273)K}{0.996\,L}$$

$$= 14.2\ atm$$

@ the end the pressure is $= P_{CO_2} + P_{NO_2} + P_{H_2O}$

Note: Now the volume is 1 L as there is no solid left to occupy space

$$P_{CO_2} = \frac{n_{UREA}\, RT}{V} = 4.06\ atm$$

$$P_{NO_2} = \frac{2 n_{UREA}\, RT}{V} = 8.12\ atm$$

$$P_{H_2O} = \frac{2 n_{UREA}\, RT}{V} = 8.12\ atm$$

$$P_{TOT} = 20.3\ atm$$

the change in P is :

$$\Delta P = P_{END} - P_{BEGINNING} = 20.3 - 14.2 = \boxed{7.1\ atm}$$

CH 101 - Practice problems – 4/09/2013

Kinetic theory of gases, real gases.

1. Calculate the kinetic energy of 1 mol of Helium atoms, contained in a cubic container (l = 5cm) at 2.5atm of pressure.

Since $KE = \frac{1}{2}mv^2 \Rightarrow mv^2 = 2KE$; thus, we can substitute mv^2 in the equation $P = \frac{nN_A mv^2}{3V} = \frac{nN_A 2KE}{3V}$ and then solve for KE.

$$KE = \frac{3PV}{2nN_A} = \frac{3 \cdot 101325 \frac{Pa}{atm} \cdot 0.125\ L \cdot 2.5\ atm}{2 \cdot 1\ mol \cdot 6.022\times10^{23}} = 7.9 \times 10^{-20}\ J$$

2. What atoms would have the same kinetic energy at a pressure of 10atm?

Since $N_A \cdot m = MM$, we can write $P = \frac{n MM v^2}{3V}$

If P increases 4x, MM needs to increase 4x as well.

$MM_{He} = 4 \frac{g}{mol} \Rightarrow 4 \times 4 = 16$ which are O atoms.
(or CH_4, methane molecules)

3. After each collision, the change in momentum of a single particle is equal to:

☐ mv/2

☐ mv

[✓ 2mv]

4. Ammonia, NH_3, a real gas has the following Van der Waals parameters: a = 4.169 L^2 x atm / mol^2; b = 3.71×10^{-2} L/mol. At -241 °C, which is a very low temperature, the compression factor Z will be:

☐ > 1

☐ = 1

[✓ < 1]

It means that it lost 23%

5. A red balloon was filled with He gas, while a black one instead was filled with an unknown gas. Both balloons were forgotten in a closet (STAP conditions). When they were found, a week later, the red balloon was inflated for only 77% of its original volume, while the black one had lost only 7% of its initial volume. What gas was contained in the black balloon?

$Rate_{RED} = \frac{23}{7} Rate_{BLACK}$; Graham's law says that $Rate \propto \frac{1}{\sqrt{MM}}$

Thus: $\frac{1}{\sqrt{MM_{Red}}} = \frac{23}{7} \cdot \frac{1}{\sqrt{MM_{BLACK}}}$; $MM_{Red} = MM_{He} = 4 \frac{g}{mol} \Rightarrow MM_{BLACK} \cong 44 \frac{g}{mol} \Rightarrow \boxed{CO_2}$

6. Sodium reacts violently with water (excess) to release hydrogen gas which immediately burns, reacting with the atmospheric oxygen (excess) to form water vapor according to the following reactions:

$$2\,Na_{(s)} + 2\,H_2O_{(l)} \rightarrow 2\,NaOH_{(s)} + H_{2\,(g)}$$

$$2\,H_{2\,(g)} + O_{2\,(g)} \rightarrow 2\,H_2O_{(g)}$$

a. If 1g of sodium is reacted with water, how many grams of water vapor will be released?

$$1\,g_{Na} \cdot \frac{1\ mol_{Na}}{23\ g_{Na}} \cdot \frac{1\ mol_{H_2O}}{2\ mol_{Na}} \cdot \frac{18\ g_{H_2O}}{1\ mol_{H_2O}} = \boxed{0.39\ g_{H_2O}}$$

Density of H_2O vapor @ 100°C $= 0.804 \frac{g}{L} \Rightarrow V_{H_2O} = 0.485\ L$

b. Assuming that the steam produced is at 100 °C, calculate the compression factor Z for the vapor released during this reaction.

$$Z = \frac{V}{V - nb} - \frac{an}{RTV} =$$

$$= \boxed{\frac{0.485}{0.485 - (0.022 \cdot 0.0305)}} - \boxed{\frac{0.022 \cdot 5.464}{0.082 \cdot 373 \cdot 0.485}} = \boxed{0.993}\ (< 1)$$

c. Are attractive contributions more or less strong than repulsive contributions between the molecules of water vapor? Justify your answer.

$Z < 1 \Rightarrow$
- Attractive contributions are stronger than repulsive contributions.
- the "a" van der Walls parameter makes the attraction related term of the equation prevail over the "b" parameter driven term of the equation.

CH 101 - Practice problems – 4/16/2013

Intermolecular forces, introduction to thermodynamics.

PART I: Intermolecular forces in liquids and solids.

1. Most substances have a higher density at the solid state than at the liquid state. This is not true for water which occupies instead less space in the liquid state than as a solid.

   - ● The molecules in the liquid are less organized than in the solid, hence they occupy less space
   - ○ The molecules of the solid move slower than the molecules in the liquid
   - ○ The liquid is in equilibrium with the gas, so the water molecules at the interface are not actually part of the liquid
   - ○ The heat capacity of liquid water is much higher than that of solid ice

Justify your answer.

Molecules in ice are organized in a perfect web of six-member rings via H-bonds; this takes more space than the molecules in the liquid.

2. Rank the following intermolecular forces in order of strength (1 stronger, 4 weaker):

3 Dipole-Dipole

1 Ion-Ion

4 Induced dipole- Induced dipole

2 Hydrogen Bond

3. Reasoning about intermolecular forces, rank the following molecules in order of solubility in water (1 – most soluble, 4 – least soluble). Hint: the more intermolecular forces you can form between the solvent and the solute, the more soluble the solute will be.

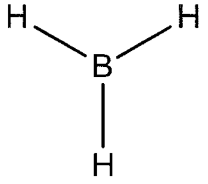
4 NiO_2

2 $NaCl$

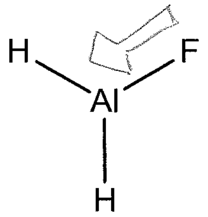
3 $Ba(OH)_2$

1 CH_3OH

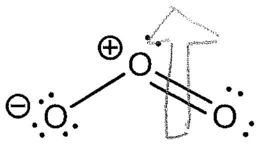
4. For each of the following molecules, list all the intermolecular forces that are present:



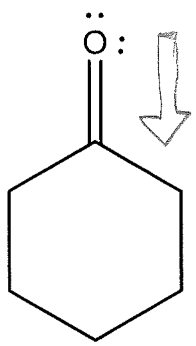
London forces



London forces
Dipole - Dipole



London forces
Dipole - Dipole



London forces
Dipole - Dipole

: N≡N :

London forces