Name (in ink):_______________________

Student Number (in ink):_______________________

Fall 2011 SC/CHEM 1000 C - Quiz #1

October 4, 2011

Calculators are permitted. Answer all questions in the space provided on this paper; **additional paper for rough work is not permitted.**

All final answers must be written in ink!

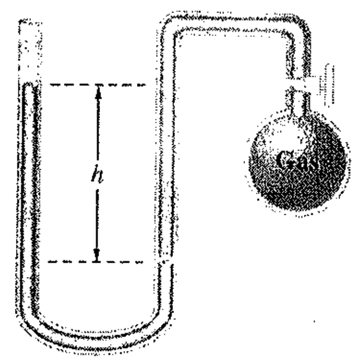
Important Note: The last page of this quiz is a reference page that may be removed if you wish. You will need information from this sheet to answer some of the questions.

Time Allowed: 50 minutes

Total Marks = 30

Marks

5 1. An experiment is set up, as shown to the right, in which a gas is confined in a bulb which is connected to a manometer with one end open to the atmosphere. The liquid in the manometer is water and the atmospheric pressure is 1.08 atm. If the difference in the heights of the water in the manometer is 11.7 inches, what is the pressure of the gas in the bulb? Your answer MUST be expressed in Torr. (**Note:** All measurements were made at 25°C.)



$\Delta P = (ghd)_{H_2O} = (ghd)_{Hg}$

$(hd)_{H_2O} = (hd)_{Hg}$

$\therefore h_{Hg} = 11.7 \text{ inches} \times 0.99707 \text{ g/mL} / 13.5340 \text{ g/mL}$

$= 0.862 \text{ inches} \times 2.54 \text{ cm/in}$

$= 2.19 \text{ cm} \times 10 \text{ mm/cm}$

$= 21.9 \text{ mm Hg}$

$P_{gas} = P_{atm} + \Delta P$

$= 1.08 \text{ atm} \times 760 \text{ mmHg/atm} + 21.9 \text{ mm Hg}$

$= 820.8 \text{ mm Hg} + 21.9 \text{ mm Hg}$

$= 843 \text{ mm Hg}$ or $\underline{843 \text{ Torr}}$

Marks

5 2. A balloon filled with helium has a volume of 1.35 L at 0.997 atm and 22.6°C. The balloon is released and rises to an altitude of 4.77 km where the temperature is -20.2°C and the atmospheric pressure is 427 Pa. What is the volume of the balloon at this altitude in litres? (Assume that the balloon does not leak nor does it burst.)

$$PV = nRT$$

"no leaks" ∴ n is constant

$$\frac{PV}{T} = nR = \text{constant}$$

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

$$V_2 = P_1V_1T_2 / P_2T_1$$

$$= \frac{(0.997\,atm)(1.35\,L)(252.95\,K)}{(427\,Pa \times 1\,atm/1.013\times10^5\,Pa)(295.75\,K)}$$

$$= \underline{\underline{273\,L}}$$

2 3. A large collection of helium atoms has an average speed of 1310 m/s. What is the temperature of this gas? Your answer MUST be expressed in °C.

$$u_{av} = \sqrt{8RT/\pi M}$$

$$T = \pi M (u_{av})^2 / 8R$$

$$= \pi(4.0026\times10^{-3})(1310)^2/(8\times8.314472)\,K$$

$$= 324\,K \text{ or } \underline{\underline{51^\circ C}}$$

Marks

7 4. A mixture of 39.5 g of ammonia, NH_3, and 27.2 g of molecular oxygen react according to the following equation:

$$4\,NH_3(g) + 3\,O_2(g) \rightarrow 2\,N_2(g) + 6\,H_2O(g)$$

The initial temperature of the reagents is 21.0°C and the reaction occurs in a rigid container with a volume of 27.5 L. What is the pressure in this container when the reaction reaches completion if the final temperature is also 21.0°C?

$n_{NH_3} = 39.5\,g / 17.0304\,g\,mol^{-1} = 2.319\,mol$

$n_{O_2} = 27.2\,g / 31.9988\,g\,mol^{-1} = 0.8500\,mol$

$\Rightarrow$ must determine limiting reagent

$\frac{3}{4} n_{NH_3} = 1.739\,mol > n_{O_2}$

$\therefore$ O_2 is limiting reagent (i.e. all O_2 is consumed)

$\Rightarrow$ after reaction is complete

$n_{NH_3} = 2.319 - \frac{4}{3}(0.8500) = 1.186\,mol$

$n_{N_2} = \frac{2}{3}(0.8500) = 0.567\,mol$

$n_{H_2O} = 2(0.8500) = 1.700\,mol$

$n_{Total} = 3.453\,mol$

$PV = nRT$

$P = nRT/V$

$$= \frac{(3.453\,mol)(0.0820574\,L\,atm\,mol^{-1}K^{-1})(294.15\,K)}{27.5\,L}$$

$= \underline{\underline{3.03\,atm}}$

Marks

7 5. A sample of oxygen gas is confined in a container at a pressure of 745 Torr and a temperature of 22°C. Given that the average speed of the oxygen molecules is 442 m/s, what would be the rate of effusion of this oxygen gas if it could escape into a vacuum through a hole in the container that had a radius of 5.2×10^{-5} m?

$$\text{rate of effusion} = Z_w \cdot A$$
$$= \left(\tfrac{1}{4}\tfrac{N}{V}u_{av}\right)(\pi r^2)$$

recall $PV = nRT = NkT$

$$\frac{N}{V} = \frac{P}{kT}$$

∴ rate of effusion

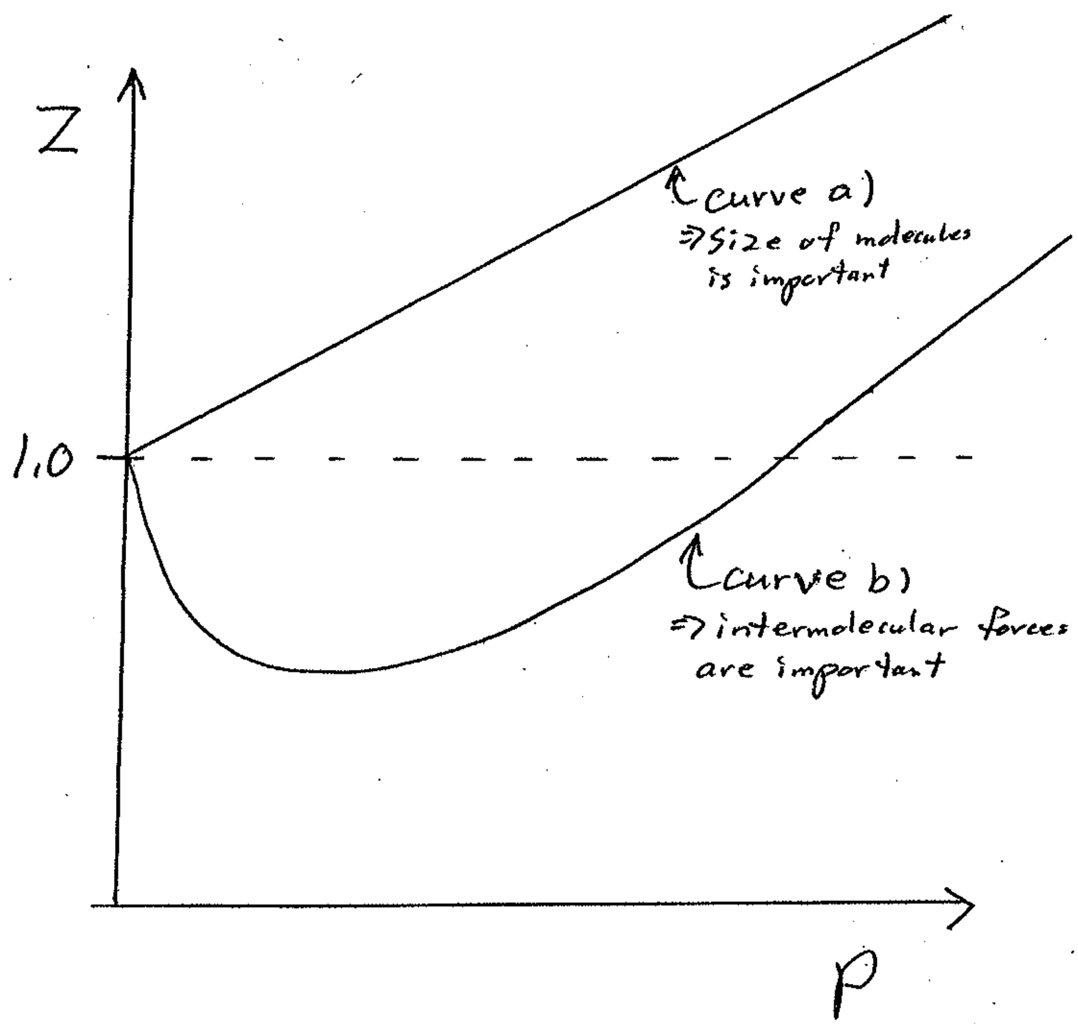
$$= \tfrac{1}{4}\left(\frac{P}{kT}\right)u_{av}(\pi r^2)$$
$$= \tfrac{1}{4}\left(\frac{745\ \text{Torr} \times 1.013\times10^{5}\ \text{Pa}/760\ \text{Torr}}{1.38066\times10^{-23}\ \text{J/K} \times 295.15\ \text{K}}\right)(442\ \text{m/s})(\pi \times (5.2\times10^{-5}\ \text{m})^2)$$
$$= \tfrac{1}{4}(2.437\times10^{25})(442)(8.49\times10^{-9})\ s^{-1}$$
$$= \underline{\underline{2.3\times10^{19}\ s^{-1}}}$$

Marks

4 6. The van der Waals equation may be expressed as

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

a) Sketch a graph of the compressibility factor versus pressure for a gas for which the non-ideal behaviour is primarily due to the size of the gas molecules.
b) On the same diagram, sketch the graph for a gas for which the non-ideal behaviour is primarily due to intermolecular forces.
Clearly label the identity of each curve on the graph.



Reference Page for CHEM 1000C Quiz 1

Constants:

$R = 8.314472\ JK^{-1}mol^{-1} = 0.0820574\ L\ atm\ K^{-1}\ mol^{-1}$
$k = 1.38066 \times 10^{-23}\ J\ K^{-1}$
$g = 9.80665\ m\ s^{-2}$
$1.00\ atm = 1.013 \times 10^{5}\ Pa = 760\ Torr\ (mm\ Hg)$
$1\ mL = 1\ cm^{3}$
$N_A = 6.02214199 \times 10^{23}\ mol^{-1}$
0°C = 273.15 K
$\pi = 3.14159$

density of water = 0.99707 g/mL @ 25°C
density of mercury = 13.5340 g/mL @25°C
1 inch = 2.54 cm

Equations:

$$u_m = \sqrt{\frac{2RT}{M}} \quad u_{av} = \sqrt{\frac{8RT}{\pi M}} \quad u_{rms} = \sqrt{\frac{3RT}{M}} \qquad Z = \frac{PV}{nRT}$$

$$Z_w = \frac{1}{4}\frac{N}{V}u_{av} \qquad Z_A = \sqrt{2}\pi d^2 u_{av}\frac{N}{V}$$

$$Z_{AA} = \frac{1}{\sqrt{2}}\pi d^2 u_{av}\left(\frac{N}{V}\right)^2 \qquad \lambda = \frac{1}{\sqrt{2}\pi d^2}\frac{V}{N}$$

volume of a sphere = $4/3\pi r^3$
circumference of a sphere = $2\pi r$
surface area of a sphere = $4\pi r^2$
diameter of sphere = 2r

area of a circle = πr^2
circumference of a circle = $2\pi r$
diameter of circle = 2r

Atomic Weights (g/mol):

H 1.0079 He 4.0026 O 15.9994 N 14.0067 Hg 200.59