Name (**in ink**) ANSWER KEY

Student Number (**in ink**) ____________

Fall 2011 SC/CHEM 1000 A - Quiz #1

October 6, 2011

Calculators are permitted.
Answer all questions on this paper; **additional paper for rough work is not permitted. You may carry out your work in pencil if you wish, but please write your final answer in ink.**

Time Allowed: 50 minutes **Total Marks = 30**

1. **(8 pts)** A balloon is filled with He(*g*) to a volume of 18.3 L and the pressure inside the balloon was measure to be 1280 torr at 26.0°C, and given to your 9 year old son, who immediately started complaining that it was "losing gas". After 20.0 minutes, the balloon shrunk to 17.8 L, but the pressure remained the same. Obviously there is a hole somewhere in the balloon, but it's too small to see. Your son demands that you estimate the diameter of the hole … and so do I. Please estimate the diameter of the hole in the balloon. I'll break the problem up into parts to make it easier.

A. **(2 pt)** Calculate the number of moles of He(*g*) initially in the balloon (before any leaked out).

$$n = \frac{PV}{RT} = \frac{(1.684\ atm)(18.3\ L)}{(0.08206\ L\ atm\ K^{-1} mol^{-1})(299.15\ K)} = 1.255\ mol$$

B. **(2 pts)** Calculate the collision frequency per unit area of the gas on the inside surface of the balloon at initial conditions (before any gas leaked out).

$$Z_w = \frac{N}{4V}\left(\frac{8RT}{\pi M}\right)^{1/2}$$

$N = (6.022 \times 10^{23}\ \text{atoms mol}^{-1})(1.255\ \text{mol}) = 7.560 \times 10^{23}\ \text{atoms}$

$V = 18.3\ \text{L} \cdot \frac{1\ \text{m}^3}{1000\ \text{L}} = 1.83 \times 10^{-2}\ \text{m}^3$

$$Z_W = \frac{7.560 \times 10^{23}\ \text{atoms}}{4(1.83 \times 10^{-2}\ \text{m}^3)} \left[\frac{8(8.314\ \text{kg m}^2\text{s}^{-2}\text{K}^{-1}\text{mol}^{-1})(299.15\ \text{K})}{\pi(4.003 \times 10^{-3}\ \text{kg mol}^{-1})} \right]^{1/2}$$

$Z_W = 1.299 \times 10^{28}\ \text{atoms s}^{-1}\text{m}^{-2}$

C. **(2 pt)** Calculate the number of moles of gas that leaked out

$$n_2 = \frac{PV_2}{RT} = \frac{(1.684\ \text{atm})(17.8\ \text{L})}{(0.08206\ \text{L atm K}^{-1}\text{mol}^{-1})(299.15\ \text{K})} = 1.221\ \text{mol}$$

$\Delta n = n - n_2 = 1.255\ \text{mol} - 1.221\ \text{mol} = 3.400 \times 10^{-2}\ \text{mol}$

D. **(2 pts)** Using your answers for parts B and C, estimate the diameter of the hole

$\Delta N = (6.022 \times 10^{23}\ \text{atoms mol}^{-1})(3.400 \times 10^{-2}\ \text{mol}) = 2.047 \times 10^{22}\ \text{atoms}$

$$(2.047 \times 10^{22}\ \text{atoms})\left(\frac{\text{m}^2\text{s}}{1.299 \times 10^{28}\ \text{atoms}}\right) = 1.576 \times 10^{-6}\ \text{m}^2\text{s}$$

$$\frac{1.576 \times 10^{-6}\ \text{m}^2\text{s}}{1200\ \text{s}} = 1.313 \times 10^{-9}\ \text{m}^2$$

$A = \pi r^2$

$r = \left(\frac{A}{\pi}\right)^{1/2} = 2.044 \times 10^{-5}\ \text{m}$

$d = 4.09 \times 10^{-5}\ \text{m} = 0.0409\ \text{mm} = 40.9\ \mu\text{m}$

2. **(6 pts)** Consider the following reaction,

$$3\ H_2(g) + CHCl_3(l) \rightarrow CH_4(g) + 3\ HCl(g)$$

This reaction is conducted in a sealed 1.80 L flask containing 4.02 g $CHCl_3$ and 2.20 atm H_2 at 25°C. Calculate the total pressure in the flask after the reaction is complete.

$$3H_2(g) + CHCl_3(l) \longrightarrow CH_4(g) + 3HCl(g)$$

2.20 atm   4.02 g

	$3H_2(g)$	$CHCl_3(l)$	$CH_4(g)$	$3HCl(g)$
I;	0.1619 mol	0.03367 mol	0	0
F;	0.0609 mol	0	0.03367 mol	0.1010 mol

$$n_{H_2} = \frac{PV}{RT} = 0.1619 \text{ mol}$$

$$n_{CHCl_3} = \frac{4.02\text{ g}}{119.4\text{ g mol}^{-1}} = 0.03367 \text{ mol} \quad (\times 3 = 0.1010$$

$\therefore$ $CHCl_3$ is limiting)

$$\sum n_{gas} = 0.0609 \text{ mol} + 0.03367 \text{ mol} + 0.1010 \text{ mol} = 0.1956 \text{ mol}$$

$$P = \frac{nRT}{V} = \frac{(0.1956\text{ mol})(0.08206\text{ L atm K}^{-1}\text{mol}^{-1})(298.15\text{ K})}{1.80\text{ L}}$$

$$P = 2.66 \text{ atm}$$

3. **(6 pts)** 215 g (4.89 mol) of dry ice, $CO_2(s)$, is placed in a 1.98 L vessel containing 1.00 atm air, and the vessel was sealed tightly. After all the dry ice evaporated into $CO_2(g)$, the total pressure in the vessel was measured to be 45.8 atm at 25°C.

A. **(1 pt)** What is the partial pressure of $CO_2(g)$ in the vessel (yes, this is easy)?

$$P_{CO_2} = 45.8 \text{ atm} - 1.00 \text{ atm} = 44.8 \text{ atm}$$

B. **(2 pts)** Use the Ideal Gas Law to calculate the $CO_2(g)$ pressure in the vessel.

$$P_{IDEAL} = \frac{n_{CO_2}RT}{V} = \frac{(4.89 \text{ mol})(0.08206 \text{ L atm K}^{-1}\text{mol}^{-1})(298.15 \text{ K})}{1.98 \text{ L}}$$

$$P_{IDEAL} = 60.4 \text{ atm}$$

C. **(3. pts)** Use the van der Waals equation to calculate the $CO_2(g)$ pressure in the vessel, given the following constants for $CO_2(g)$: $a = 3.59 \text{ L}^2 \text{ atm mol}^{-2}$, and $b = 0.0427 \text{ L mol}^{-1}$.

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

$$\left[P + \frac{(3.59 \text{ L}^2 \text{ atm mol}^{-2})(4.89 \text{ mol})^2}{(1.98 \text{ L})^2}\right]\left[1.98 \text{ L} - (4.89 \text{ mol})(0.0427 \text{ L mol}^{-1})\right]$$

$$= (4.89 \text{ mol})(0.08206 \text{ L atm K}^{-1} \text{ mol}^{-1})(298.15 \text{ K})$$

$$(P + 21.90 \text{ atm})(1.771 \text{ L}) = 119.6 \text{ L atm}$$

$$P = 45.6 \text{ atm}$$

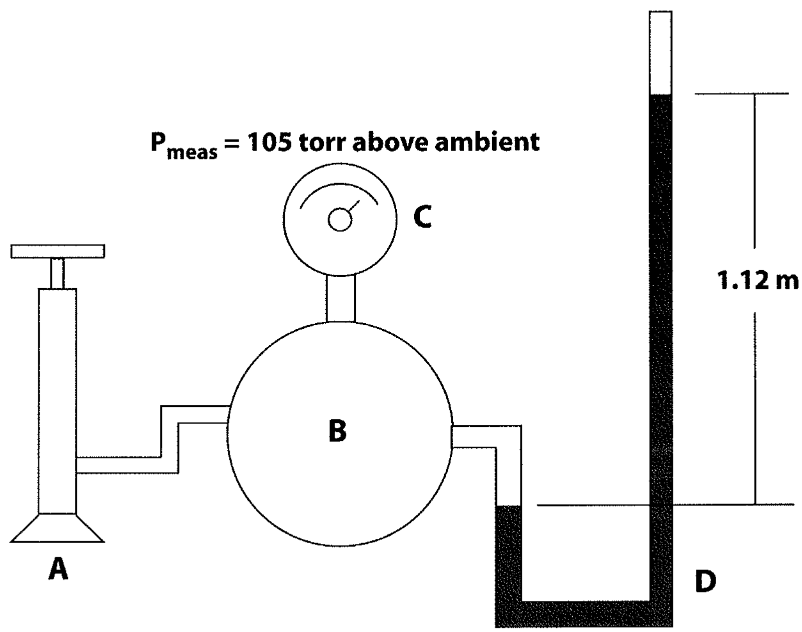
4. **(4 pts)** The RMS average speed of a N_2 molecule in N_2 gas at room temperature is 515 m s^{-1}. At what temperature is the RMS average speed of the N_2 molecules equal to 120 km hr^{-1}, the typical speed of a car on the 407?

$$(120\ km\ h^{-1})\left(\frac{h}{3600 s}\right)\left(\frac{1000 m}{km}\right) = 33.33\ m s^{-1}$$

$$\overline{u}_{RMS} = \left(\frac{3RT}{M}\right)^{1/2}$$

$$T = \frac{\overline{u_{RMS}}^2 M}{3R} = \frac{(33.33\ m s^{-1})^2 (28.02 \times 10^{-3}\ kg\ mol^{-1})}{3(8.314\ J K^{-1} mol^{-1})} = 1.2 K$$

5. **(6 pts)** Your 9 year old son was in the kitchen on day, and became curious about the density of honey. In the kitchen he had no way of measuring weight or volume. So he decided to measure the density of honey by rigging up the following contraption using a bicycle tire pump (**A**), a vessel of unknown volume (**B**), a tire pressure gauge (**C**), and a U-shaped glass tube he found in the backyard (**D**). He put the honey in the glass tube, which is open at one end and connected to the vessel at the other, then pressurized the system with a few pushes on the tire pump. The pressure gauge read that the pressure in the system was 105 torr above ambient. Using a tape measure, he measured the height indicated in the diagram to be 1.12 m. From these data he was able to calculate the density of honey. Please do the same.



$\Delta P = 105 \text{ torr} = 105 \text{ mm Hg}$

$$\frac{h_{HON}}{h_{Hg}} = \frac{\rho_{Hg}}{\rho_{HON}}$$

$$\rho_{HON} = \frac{\rho_{Hg} h_{Hg}}{h_{HON}} = \frac{(13.6 \text{ g mL}^{-1})(105 \text{ mm})}{1120 \text{ mm}} = 1.28 \text{ g mL}^{-1}$$