LAST NAME: ______________________________

FIRST NAME: ______________________________

Student Number: ______________________________

CHM 1311 B
Midterm #1
Fall 2014

Please keep your work covered at all times and keep your eyes on your own paper! Cheating or any appearance of cheating will result in an F in the course and possible expulsion from the university.

There are 9 pages in this test. A periodic table and data sheets are provided at the end. You may rip these pages off of the exam and use them to cover your work during the test. Any scratch work should be done on the back of these pages.

Please show all work to receive partial credit.

You have 75 minutes to complete the test.

A

Question	**Points Possible**	**Points Earned**
1	**12**	
2	**5**	
3	**9**	
4	**10**	
5	**9**	
TOTAL	**45**	

#1. (12 points) Short Answer Questions

a) Give the molecular formula for potassium carbonate:

K_2CO_3

b) What is the common name of $FeBr_3$?

ferric bromide

c) What is the name of the acid that is derived from F^-?

hydrofluoric acid

d) If a glass bottle is filled with air at 25^{o}C, and then put in the fridge, the partial pressure of N_2 in the air will:

[✓ A) decrease] B) increase C) stay the same

e) Circle the term(s) in the van der Waals equation that account for repulsive interactions between real gas molecules.

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

f) Complete the table:

Chemical symbol	Number of protons	Number of neutrons	Number of electrons	Mass number
$^{207}_{82}Pb^{2+}$	82	125	80	207

g) What is the molality of a solution containing 0.368 mol of HCl in 543 g of water?

0.678 mol/kg

h) Calculate the volume of 0.500 mol/L sulphuric acid that must be added to water to prepare 500 mL of 0.250 mol/L solution.

250 mL

i) How many gas molecules are in a standard molar volume?

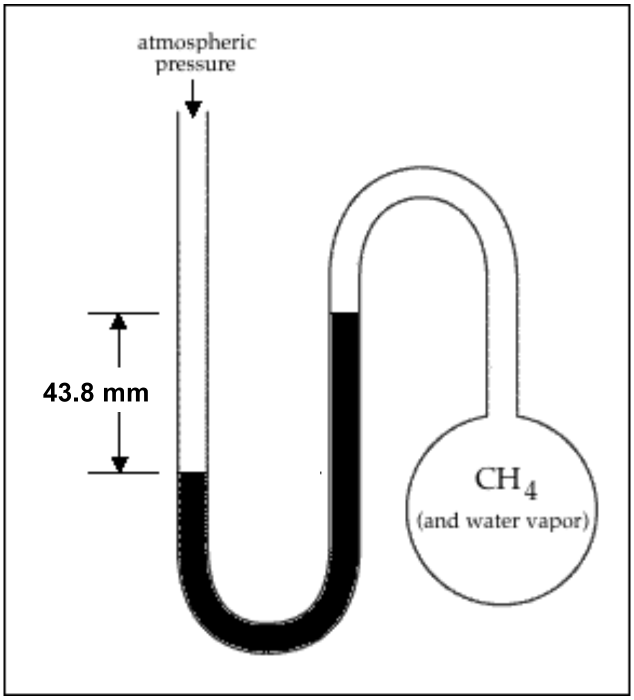
$6.022\text{x}10^{23}$ molecules

j) How many μL of a liquid would fit into a rectangle that is 3.0 cm long, 1.0 m wide and 5.6 μm high?

$(3.0\text{ cm})(10\text{ mm/cm})(1.0\text{ m})(10^3\text{ mm/m})(5.6\ \mu\text{m})(10^{-6}\text{ m}/\mu\text{m})(10^3\text{ mm/m}) = 168\ \mu\text{L}$

Question 2.

a) What is the pressure of the gas mixture in the mercury manometer shown? (1 mark)



$$\begin{aligned} p_{gas} &= p_{atm} - \Delta h \\ &= 760 \text{ mmHg} - 43.8 \text{ mmHg} \\ &= 716 \text{ mmHg} \end{aligned}$$

b) Suppose the temperature of the gas mixture is brought well below the freezing point of water. What will happen to the difference in the mercury level on the two sides of the U-tube? Briefly explain your answer. (1 mark)

Δh will increase (the level on the right will go up, the level on the left will go down). The pressure of the gas mixture will decrease since the water will come out of the gas under these cold conditions. This will allow the pressure from the atmosphere to push the mercury column further down the U-tube.

c) At its boiling point, the density of liquid methane is 422 g/L and the density of the gas is 2.16 g/L. What volume of liquid methane would be produced if the 2.58 L of methane gas in the bulb was liquefied? (3 marks)

$d = \frac{m}{V}$ **and hence** $m = dV$ **. Since the mass of the methane will not change after the phase transition, we can say:**

$$m = d_{liquid}V_{liquid} = d_{gas}V_{gas}$$

$$\begin{aligned} V_{liquid} &= \frac{d_{gas}V_{gas}}{d_{liquid}} \\ &= \frac{(2.16 \text{ g/L})(2.58 \text{ L})}{(422 \text{ g/L})} = 13.2 \text{ mL} \end{aligned}$$

Question 3.

When gaseous F_2 and solid I_2 are heated to high temperatures, the I_2 sublimes and gaseous iodine heptafluoride forms. Suppose 46.7 kPa of F_2 and 9.85 mmol of solid I_2 are put into a 2.50 L container at 250 K, and the container is heated to 550 K.

a) **Which reagent is in excess? (You must show the calculations required to identify the excess reagent.) (5 marks)**

$7\ F_2\ (g) + I_2\ (g) \rightarrow 2\ IF_7(g)$ (1 mark)

$n_{I2} = 9.85 \times 10^{-3}$ mol

Number of moles of product from I_2: $n_{IF_7} = n_{I_2} \dfrac{2 \text{ mol IF}_7}{1 \text{ mol I}_2} = 0.0197 \text{ mol}$ **(1 mark)**

Number of moles of product formed by F_2:

$$n_{IF_7} = n_{F_2} \frac{2 \text{ mol IF}_7}{7 \text{ mol IF}_2}$$

(1 mark)

$$n_{F_2} = \frac{pV}{RT} = \frac{(46.7 \text{ kPa})(2.50 \text{ L})}{(8.314 \text{ kPa L K}^{-1} \text{ mol}^{-1})(250 \text{ K})} = 0.05617 \text{ mol}$$

(1 mark)

$$n_{IF_7} = (0.05617 \text{ mol}) \frac{2 \text{ mol IF}_7}{7 \text{ mol IF}_2} = 0.0160 \text{ mol}$$

(1 mark)

Since F_2 forms less product, it is the limiting reagent.

b) **What is the <u>total</u> final pressure of the mixture at 550 K? (4 marks)**

$p_T = p_{I_2} + p_{F_2} + p_{IF_7}$ **(1 mark)**

Since the fluorine is limiting, it is used up and $p_{F_2} = 0$

We calculated the amount of IF_7 that would be produced in part a: $n_{IF_7} = 0.0160 \text{ mol}$

For I_2, we need to use the initial amount, subtract the amount that reacted to find the excess:

$$n_{I_2} = n_{initial} - n_{reacted} = n_{initial} - n_{F_2} \times \frac{1 \text{ mol I}_2}{7 \text{ mol F}_2}$$

$$= 0.00985 \text{ mol} - 0.05617 \text{ mol} \times \frac{1 \text{ mol I}_2}{7 \text{ mol F}_2} = 0.00183 \text{ mol}$$

(1 mark)

The total number of moles can be put into ideal gas law:

$$n = \frac{(n_{I_2} + n_{IF_7})RT}{V} = \frac{(0.0160 + 0.00183) \text{ mol}(8.314 \text{ kPa L K}^{-1} \text{ mol}^{-1})(550 \text{ K})}{2.50 \text{ L}} = 32.6 \text{ kPa}$$

(2 marks)

Question 4.

A sample of an unknown gas effuses in 13.0 min. An equal volume of H_2 in the same apparatus under the same conditions effuses in 2.42 min. Combustion analysis shows that the unknown gas is a hydrocarbon, producing 68 g of CO_2 and 34.8 g of H_2O in the reaction.

a) What is the molar mass of the unknown gas? (3 marks)

$$\frac{\text{Rate H}_2}{\text{Rate } x} = \sqrt{\frac{M_x}{M_{\text{H}_2}}}$$

(1 mark)

$$\frac{\text{Rate H}_2}{\text{Rate } x} = \frac{\frac{V}{t_{\text{H}_2}}}{\frac{V}{t_x}} = \frac{t_x}{t_{\text{H}_2}}$$

(1 mark)

Solve for the unknown: $$M_x = M_{\text{H}_2}\left(\frac{t_x}{t_{\text{H}_2}}\right)^2 = (2.016 \text{ g/mol})\left(\frac{13.0 \text{ min}}{2.42 \text{ min}}\right)^2 = 58.2 \text{ g/mol}$$

(1 mark)

b) What is the molecular formula of this gas? (5 marks)

$$n_\text{C} = \frac{m_{\text{CO}_2}}{M_{\text{CO}_2}} = \frac{68 \text{ g}}{44.01 \text{ g/mol}} = 1.55 \text{ mol}$$

(1 mark)

$$n_\text{H} = \frac{m_{\text{H}_2\text{O}}}{M_{\text{H}_2\text{O}}} \times \frac{2 \text{ mol H}}{1 \text{ mol H}_2} = \frac{34.8 \text{ g}}{18.02 \text{ g/mol}} \times \frac{2 \text{ mol H}}{1 \text{ mol H}_2} = 3.86 \text{ mol}$$

(1 mark)

Empirical formula is: $\text{C}_{\frac{1.55}{1.55}}\text{H}_{\frac{3.86}{1.55}} = \text{C}_1\text{H}_{2.5}$ **- multiply through by 2 to get whole numbers: C_2H_5 (1)**

Whole number multiple: $$\frac{M_x}{M_{\text{C}_2\text{H}_5}} = \frac{58.2 \text{ g/mol}}{29.06} = 2$$

(1 mark)

Therefore molecular formula is: $\text{C}_{2\times2}\text{H}_{5\times2} = \text{C}_4\text{H}_{10}$

(1 mark)

c) Suppose the oxygen supply got cut off during the combustion reaction so that only 39 g of CO_2 was produced. How much H_2O would be produced in that reaction? (2 marks)

$$\%\text{ Yield} = \frac{\textit{Actual}}{\textit{Theoretical}} = \frac{39 \text{ g}}{68 \text{ g}} \times 100\% = 57.3\%$$

(1 mark)

$$\textit{Actual} = \%\text{ Yield} \times \textit{Theoretical} = 0.573 \times 34.8 \text{ g} = 20 \text{ g}$$

(1 mark)

#4. For the following reaction in aqueous solution:

$$HPO_3^{2-}\,(aq) + PH_3\,(g) \rightarrow P_4\,(s)$$

+1 +3 -2 -3 +1 0

a) **Write the oxidation numbers below each element in the reaction above (3 marks)**

b) **Based on your answer in a), what is being reduced in this reaction? (1 mark)**

HPO_3^{2-}

c) **Balance this equation in acidic solution (5 marks).**

$$20\,H^+ + 4\,HPO_3^{2-} + 12\,e\text{-} \longrightarrow P_4 + 12\,H_2O$$

$$\underline{\quad 4\,PH_3 \longrightarrow P_4 + 12\,H^+ + 12\,e\text{-} \quad .}$$

$$20\,H^+ + 4\,HPO_3^{2-} + 4\,PH_3 \longrightarrow 2P_4 + 12\,H_2O + 12\,H^+$$

Cancel out species that appear on both sides:

$$8\,H^+ + 4\,HPO_3^{2-} + 4\,PH_3 \longrightarrow 2P_4 + 12\,H_2O$$

Divide by 2:

$$4\,H^+ + 2\,HPO_3^{2-} + 2\,PH_3 \longrightarrow P_4 + 6\,H_2O$$

(~0.5 marks for each correct balancing step, e.g. 0.5 each for balancing P in one half reaction, balance O in one half reaction, balance H in one half reaction, balance charge etc…)

Final balanced chemical equation:

$$4\,H^+\,(aq) + 2\,HPO_3^{2-}\,(aq) + 2\,PH_3\,(g) \longrightarrow P_4\,(s) + 6\,H_2O\,(l)$$

Constants and Conversion Factors

1 mmHg = 1 torr   760 mmHg = 1 atm   1 atm = 101.325 kPa   1 atm = 1.013125 bar
1 cm^3 = 1 mL   1 dm^3 = 1000 mL = 1 L   1 mm^3 = 1 μL   1 m^3 = 1000 L
1 mol = 1000 mmol   1 cm = 10 mm   1 m = 10^6 μm = 10^3 mm

Avogadro's Number	N	$6.022\text{x}10^{23}\ \text{mol}^{-1}$
Atomic mass unit	u	$1.66054\text{x}10^{-27}\ \text{kg}$
Gas constant	R	$8.31451\ \text{J}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
	R	$8.31451\ \text{kPa}\cdot\text{L}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
	R	$0.08206\ \text{atm}\cdot\text{L}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
	R	$8.31451\ \text{m}^3\ \text{Pa}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$
	R	$0.0831451\ \text{bar L}\cdot\text{K}^{-1}\cdot\text{mol}^{-1}$

Equations

$$T\left(\text{in K}\right)=T\left(\text{in }^{\text{o}}\text{C}\right)+273.15\text{ K}$$

$$n=\frac{m}{M}$$

$$\%\text{ Yield}=\frac{\text{actual yield}}{\text{theoretical yield}}$$

$$c\left(\text{mol / L}\right)=\frac{n}{V}$$

$$c_1V_1=c_2V_2$$

$$pV=nRT$$

$$\frac{p_1V_1}{T_1}=\frac{p_2V_2}{T_2}$$

$$p_T = p_1+p_2+p_3+\ldots$$

$$p_A=X_A\times p_T$$

$$X_A=\frac{n_A}{n_T}$$

$$d=\frac{m}{V}=\frac{p\cdot M}{RT}$$

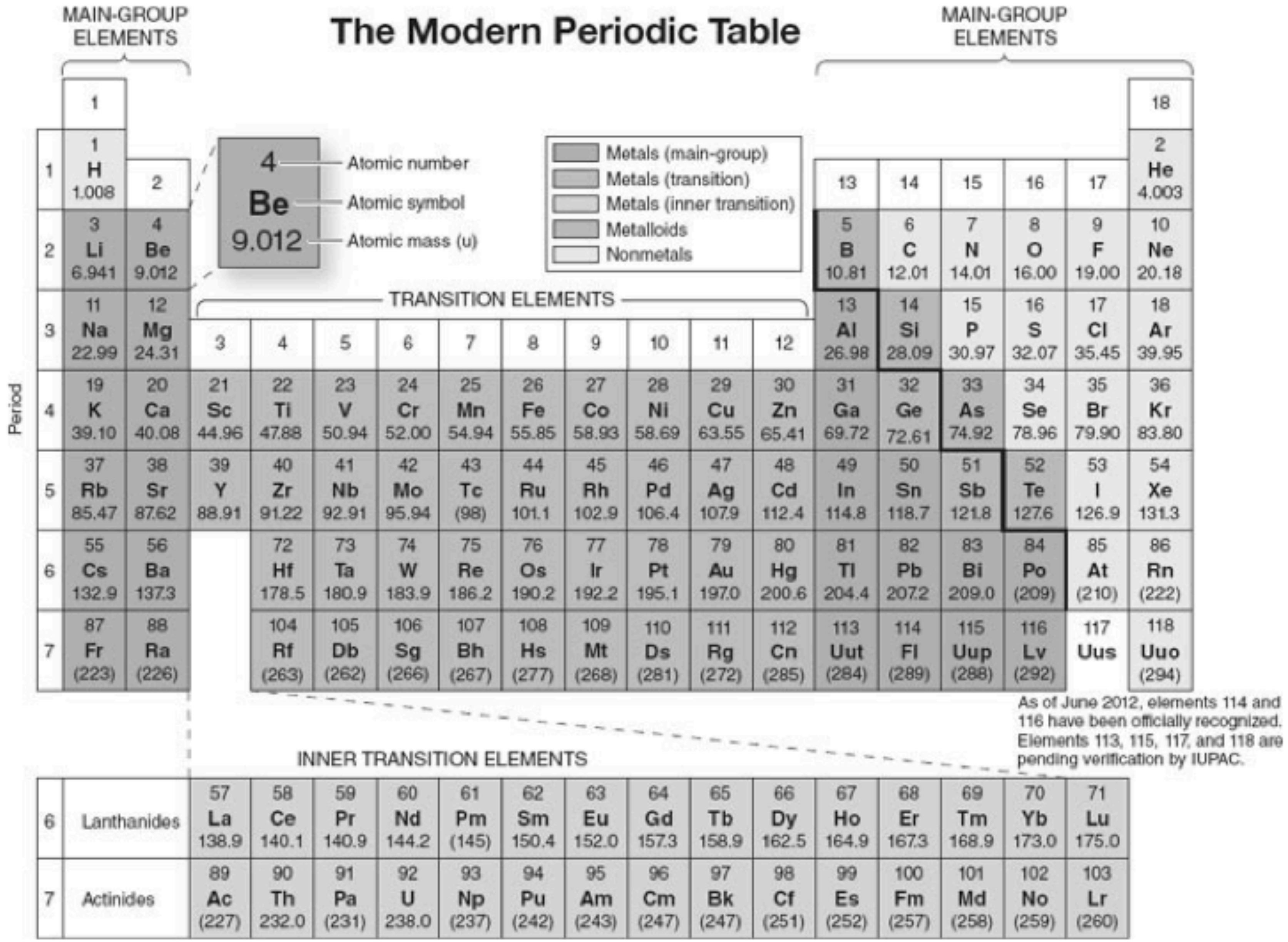
$$E_K=\frac{1}{2}m\text{v}^2$$

$$u_{rms}=\sqrt{\frac{3RT}{M}}$$

$$\frac{Rate\ A}{Rate\ B}=\sqrt{\frac{M_B}{M_A}}$$

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

The Modern Periodic Table



Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 H 1.008																	2 He 4.003
2	3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
3	11 Na 22.99	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95
4	19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.88	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.41	31 Ga 69.72	32 Ge 72.61	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
5	37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc (98)	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3
6	55 Cs 132.9	56 Ba 137.3		72 Hf 178.5	73 Ta 180.9	74 W 183.9	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po (209)	85 At (210)	86 Rn (222)
7	87 Fr (223)	88 Ra (226)		104 Rf (263)	105 Db (262)	106 Sg (266)	107 Bh (267)	108 Hs (277)	109 Mt (268)	110 Ds (281)	111 Rg (272)	112 Cn (285)	113 Uut (284)	114 Fl (289)	115 Uup (288)	116 Lv (292)	117 Uus	118 Uuo (294)

As of June 2012, elements 114 and 116 have been officially recognized. Elements 113, 115, 117, and 118 are pending verification by IUPAC.

INNER TRANSITION ELEMENTS

6	Lanthanides	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm (145)	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0	71 Lu 175.0
7	Actinides	89 Ac (227)	90 Th 232.0	91 Pa (231)	92 U 238.0	93 Np (237)	94 Pu (242)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)