Chem 120
Exam 2, Ch 4-6
100 Points

Name________________________________
October 16, 2008

Please follow the instructions for each section of the exam. Show your work on all mathematical problems. Provide answers with the correct units and significant figures. Be concise in your answers to discussion questions.

Part 0: Warmup. 4 points each

1. For a fixed amount of gas at a fixed pressure, changing the temperature from 100^oC to 200K causes the gas volume to:

   a. double
   b. increase
   c. decrease
   d. stay the same

   Answer _____C_______

2. Under what conditions is Cl_2 most likely to behave like an ideal gas?

   a. 100^oC and 10.0 atm
   b. 0^oC and 0.50 atm
   c. 200^oC and 0.50 atm
   d. 400^oC and 10.0 atm

   Answer _____C_______

3. To precipitate Zn^{2+} from a solution of $Zn(NO_3)_2$, add

   a. NH_4Cl
   b. $MgBr_2$
   c. K_2CO_3
   d. $(NH_4)_2SO_4$

   Answer _____C_______

4. In the half reaction in which NpO_2^+ is converted to Np^{4+}, the number of electrons appearing in the half reaction is

   a. 1
   b. 2
   c. 3
   d. 4

   Answer _____A_______

5. In the reaction of 2 mol CCl_4 with an excess of HF, 1.70 mol CCl_2F_2 is obtained.

$$CCl_4 + 2\ HF \rightarrow CCl_2F_2 + 2\ HCl$$

   a. The theoretical yield is 1.70 mol CCl_2F_2.
   b. The theoretical yield is 1.00 mol CCl_2F_2.
   c. The theoretical yield depends on how large an excess of HF was used.
   d. The percent yield is 85%.

   Answer _____D_______

Part I: Complete all of problems 6-10

6. Complete the chart below: (12 points)

Species	Name	Oxidation States			Water Soluble? (Y/N)
$Ca(ClO_4)_2$	calcium perchlorate	Ca =+2	Cl = +7	O = -2	Y
$Zn_3(PO_4)_2$	zinc (II) phosphate	Zn =+2	O = -2	P = +5	N

7. Ammonia can be generated by heating together the solids NH_4Cl and $Ca(OH)_2$ to produce NH_3, water, and $CaCl_2$. If a mixture containing 33.0 g each of ammonium chloride and calcium hydroxide is heated, how many grams of ammonia will form? (10 points)

$$2\ NH_4Cl + Ca(OH)_2 \rightarrow 2\ NH_3 + 2\ H_2O + CaCl_2$$

$$33.0\ \cancel{g\ NH_4Cl} \times \frac{1\ \cancel{mol\ NH_4Cl}}{53.4912\ \cancel{g}} \times \frac{2\ \cancel{mol\ NH_3}}{2\ \cancel{mol\ NH_4Cl}} \times \frac{17.0356\ g\ NH_3}{1\ \cancel{mol\ NH_3}} = 10.51\ g\ NH_3$$

$$33.0\ \cancel{g\ Ca(OH)_2} \times \frac{1\ \cancel{mol\ Ca(OH)_2}}{74.093\ \cancel{g}} \times \frac{2\ \cancel{mol\ NH_3}}{1\ \cancel{mol\ Ca(OH)_2}} \times \frac{17.0356\ g\ NH_3}{1\ \cancel{mol\ NH_3}} = 15.17\ g\ NH_3$$

Since the ammonium chloride produces less, it must be the limiting reagent, so 10.5 g NH_3 will be formed.

8. Write the (1) *overall reaction* and (2) *net ionic equation* for the following reactions. Indicate the state of all reactants and products. (10 points)

   a. Aqueous potassium sulfate with aqueous calcium chloride.

      (1) Overall reaction:

      $$K_2SO_4\ (aq) + CaCl_2\ (aq) \rightarrow CaSO_4\ (s) + 2\ KCl\ (aq)$$

      (2) Net ionic equation:

      $$Ca^{2+}\ (aq) + SO_4^{2-}\ (aq) \rightarrow CaSO_4\ (s)$$

   b. Aqueous sodium carbonate with aqueous silver nitrate.

      (1) Overall reaction:

      $$Na_2CO_3\ (aq) + 2\ AgNO_3(aq) \rightarrow Ag_2CO_3\ (s) + 2\ NaNO_3\ (aq)$$

      (2) Net ionic equation:

      $$2\ Ag^{+}\ (aq) + CO_3^{2-}\ (aq) \rightarrow Ag_2CO_3\ (s)$$

9. Calculate the volume of hydrogen gas, measured at 26°C and 751 torr required to react with 28.5 L of carbon monoxide, measured at 0°C and 760 torr in the reaction below. (10 points)

$$3\ CO\ (g) + 7\ H_2\ (g) \rightarrow C_3H_8\ (g) + 3\ H_2O\ (l)$$

$$n_{CO} = \frac{PV}{RT} = \frac{(1\ \cancel{atm})(28.5\ \cancel{L})}{(0.08206\ \cancel{L\ atm}/mol\ \cancel{K})(273\cancel{K})} = 1.272\ mol\ CO$$

$$1.272\ \cancel{mol\ CO} \times \frac{7\ mol\ H_2}{3\ \cancel{mol\ CO}} = 2.969\ mol\ H_2$$

$$P_{H2} = 751\ torr \times \frac{1\ atm}{760\ torr} = 0.9882\ atm$$

$$V = \frac{nRT}{p} = \frac{(2.969\ \cancel{mol})(0.08206\ L\ \cancel{atm/mol\ K})(299\cancel{K})}{(0.9882\ \cancel{atm})} = 73.7\ L = \mathbf{74\ L}$$

10. Redox reactions:

a. Balance the following reaction in acidic solution. (10 points)

$$UO^{2+} + NO_3^- \rightarrow UO_2^{2+} + NO(g)$$

Oxidation	$3(UO^{2+} + H_2O$	$\rightarrow$	$UO_2^{2+} + 2H^+ + 2e^-)$
Reduction	$2(NO_3^- + 4H^+ + 3e^-$	$\rightarrow$	$NO + 2H_2O)$
Overall	$3UO^{2+} + 3H_2O + 2NO_3^- + 8H^+ + 6e^-$	$\rightarrow$	$3UO_2^{2+} + 6H^+ + 6e^- + 2NO + 4H_2O$
Final	$\mathbf{3UO^{2+} + 2NO_3^- + 2H^+}$	$\rightarrow$	$\mathbf{3UO_2^{2+} + 2NO + H_2O}$

b. Permanganate ion can oxidize cyanide ion in acidic solution by the reaction below.

$$2\ MnO_4^- + 3\ CN^- + 2\ H^+ \rightarrow 2\ MnO_2 + 3\ OCN^- + H_2O$$

Write the corresponding balanced reaction that would occur in basic solution. (2 points)

$$2\ MnO_4^- + 3\ CN^- + 2\ H^+ \mathbf{+ 2\ OH^-} \rightarrow 2\ MnO_2 + 3\ OCN^- + H_2O \mathbf{+ 2\ OH^-}$$

Since $H^+ + OH^- = H_2O$:

$$2\ MnO_4^- + 3\ CN^- + \mathbf{2\ H_2O} \rightarrow 2\ MnO_2 + 3\ OCN^- + H_2O + 2\ OH^-$$

After cancelling waters:

$$\mathbf{2\ MnO_4^- + 3\ CN^- + H_2O \rightarrow 2\ MnO_2 + 3\ OCN^- + 2\ OH^-}$$

Part II. Answer two (2) of problems 11-14. Clearly mark the problem you do not want graded. 12 points each.

11. You are following a laboratory procedure to prepare a dilute chloride solution to use as a standard in an absorbance measurement. You prepare the standard by dissolving 1.45 g $MgCl_2$ in 100.0 mL of solution, which you label solution A. After mixing, you pipet 3.00 mL of solution A to a 50.0 mL volumetric flask, and dilute to the mark to prepare solution B. Finally, you pipet 2.00 mL of solution B into a 25 mL volumetric flask and dilute to the mark to prepare solution C. What is the molarity of *chloride ions* in solution C? Assume $MgCl_2$ is a strong electrolyte.

$$MgCl_2\,(aq) \rightarrow Mg^{2+}\,(aq) + 2\,Cl^-\,(aq)$$

$$1.45\ \cancel{g\ MgCl_2} \times \frac{1\ \cancel{mol\ MgCl_2}}{94.2104\ \cancel{g}} \times \frac{2\ mol\ Cl^-}{1\ \cancel{mol\ MgCl_2}} \times \frac{1}{0.100\ L} = \frac{0.3078\ mol\ Cl^-}{L} = [A]$$

$$M_1V_1 = M_2V_2$$

For solution B:

$$M_B = \frac{M_AV_A}{V_B} = \frac{(0.3078\ M)(3.00\ \cancel{mL})}{50.00\ \cancel{mL}} = 0.01847\ M = [B]$$

For solution C:

$$M_C = \frac{M_BV_B}{V_C} = \frac{(0.01847\ M)(2.00\ \cancel{mL})}{25.00\ \cancel{mL}} = 0.001478\ M = [C]$$

So, the molarity of chloride ions in solution C is **0.001478 M**

12. Dichlorodifluoromethane, once widely used as a refrigerant, can be prepared by the balanced reactions shown. How many moles of Cl_2 must be consumed to produce 2.25 kg CCl_2F_2? What volume would this Cl_2 gas occupy at STP? Assume all the CCl_4 produced in the first reaction is consumed in the second.

$$CH_4 + 2\,Cl_2 \rightarrow CCl_4 + 4\,HCl$$

$$CCl_4 + 2\,HF \rightarrow CCl_2F_2 + 2\,HCl$$

How many moles of Cl_2 gas is needed?

$$2.25\ \cancel{kg\ CCl_2CF_2} \times \frac{1\ \cancel{mol\ CCl_2CF_2}}{120.913\ \cancel{g}} \times \frac{10^3\ \cancel{g}}{1\ \cancel{kg}} \times \frac{1\ \cancel{mol\ CCl_4}}{1\ \cancel{mol\ CCl_2CF_2}} \times \frac{2\ mol\ Cl_2}{1\ \cancel{mol\ CCl_4}} = 37.22\ mol\ Cl_2$$

What volume will this gas occupy at STP?

$$V = \frac{nRT}{p} = \frac{(37.22\ \cancel{mol})(0.08206\ L\ \cancel{atm/mol\ K})(273\cancel{K})}{(1\ \cancel{atm})} = 833.7\ L = \mathbf{834\ L}$$

13. A NaOH solution cannot be made up to an exact concentration simply by weighing out the required mass of solid NaOH, because the NaOH is not pure. Also, water vapor condenses on the solid as it is weighed. To determine the concentration of such soutions, they must be standardized by titration. For this purpose, a 25.00 mL sample of NaOH solution requires 33.61 mL of 0.1086 M HCl. What is the molarity of the NaOH? Include a balanced reaction in your solution.

$$NaOH + HCl \rightarrow NaCl + H_2O$$

$$33.61\ \cancel{mL\ HCl} \times \frac{0.1086\ \cancel{mol\ HCl}}{1\ \cancel{L\ HCl}} \times \frac{1\ mol\ NaOH}{1\ \cancel{mol\ HCl}} \times \frac{1}{25.00\ \cancel{mL}} = \mathbf{0.146\ M\ NaOH}$$

14. A 2.89 g aluminum ore sample is reacted with excess HCl in the reaction below, and the liberated H_2 is collected over water at 25°C at a barometric pressure of 744 mm Hg. If 322 mL of hydrogen is collected, what is the percent aluminum (by mass) in the ore sample?

$$2\ Al(s) + 6\ HCl\ (aq) \rightarrow 2\ AlCl_3(aq) + 3\ H_2(g)$$

$P_T = P_{H2} + P_{H2O}$ so that 744 mm Hg = P_{H2} + 23.76 mm Hg and P_{H2} = 720.24 mm Hg

$$P_{H2} = 720.24\ mm\ Hg \times \frac{1\ atm}{760\ mm\ Hg} = 0.9476\ atm$$

$$n_{H2} = \frac{PV}{RT} = \frac{(0.9476\ \cancel{atm})(0.322\ \cancel{L})}{(0.08206\ \cancel{L\ atm}/mol\ \cancel{K})(298\cancel{K})} = 0.01248\ mol\ H_2$$

$$0.01248\ \cancel{mol\ H_2} \times \frac{2\ \cancel{mol\ Al}}{3\ \cancel{mol\ H_2}} \times \frac{26.9815\ g\ Al}{1\ \cancel{mol\ Al}} = 0.2245\ g\ Al$$

$$\frac{0.2245\ g\ Al}{2.89\ g\ sample} \times 100\% = \mathbf{7.77\%\ Aluminum}$$

Possibly Useful Information

R = 0.08206 L atm mol^{-1} K^{-1}	STP = 1 atm, 0^oC
1 atmosphere = 760 Torr	$\left(P + a\left(\frac{n}{V}\right)^2\right)(V - bn) = nRT$
$P_{total} = n_{total}RT/V$	$P_A = X_aP_{total}$
$N_a = 6.02214 \times 10^{23}\ mol^{-1}$	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Molar Masses	
Compound	**Molar Mass (g/mol)**
$AlCl_3$	133.3396
C_3H_8	44.097
$Ca(OH)_2$	74.093
$CaCl_2$	110.983
CCl_2F_2	120.913
CCl_4	153.822
CH_4	16.043
Cl_2	70.9504
CO	28.010
H_2	2.01588
H_2O	18.0153
HCl	36.4606
HF	20.00634
$MgCl_2$	94.2104
NaOH	39.9971
NH_3	17.0356
NH_4Cl	53.4912

Vapor Pressure of Water at Various Temperatures

Temperature (°C)	Vapor Pressure (mmHg)
15.0	12.79
17.0	14.53
19.0	16.48
21.0	18.65
23.0	21.07
25.0	23.76
30.0	31.82
50.0	92.51

TABLE 5.1 Solubility Guidelines for Common Ionic Solids

Follow the lower-numbered guideline when two guidelines are in conflict. This leads to the correct prediction in most cases.

1. Salts of group 1 cations (with some exceptions for Li^+) and the NH_4^+ cation are soluble.
2. Nitrates, acetates, and perchlorates are soluble.
3. Salts of silver, lead, and mercury(I) are insoluble.
4. Chlorides, bromides, and iodides are soluble.
5. Carbonates, phosphates, sulfides, oxides, and hydroxides are insoluble (sulfides of group 2 cations and hydroxides of Ca^{2+}, Sr^{2+}, and Ba^{2+} are slightly soluble).
6. Sulfates are soluble except for those of calcium, strontium, and barium.

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8 8B	9 8B	10 8B	11 1B	12 2B	13 3A	14 4A	15 5A	16 6A	17 7A	18 8A
1 **H** 1.00794																	2 **He** 4.00260
3 **Li** 6.941	4 **Be** 9.01218											5 **B** 10.811	6 **C** 12.011	7 **N** 14.0067	8 **O** 15.9994	9 **F** 18.9984	10 **Ne** 20.1797
11 **Na** 22.9898	12 **Mg** 24.3050											13 **Al** 26.9815	14 **Si** 28.0855	15 **P** 30.9738	16 **S** 32.066	17 **Cl** 35.4527	18 **Ar** 39.948
19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.9559	22 **Ti** 47.88	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.9381	26 **Fe** 55.847	27 **Co** 58.9332	28 **Ni** 58.693	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.9216	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.9059	40 **Zr** 91.224	41 **Nb** 92.9064	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.906	46 **Pd** 106.42	47 **Ag** 107.868	48 **Cd** 112.411	49 **In** 114.818	50 **Sn** 118.710	51 **Sb** 121.757	52 **Te** 127.60	53 **I** 126.904	54 **Xe** 131.29
55 **Cs** 132.905	56 **Ba** 137.327	57 ***La** 138.906	72 **Hf** 178.49	73 **Ta** 180.948	74 **W** 183.84	75 **Re** 186.207	76 **Os** 190.23	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.967	80 **Hg** 200.59	81 **Tl** 204.383	82 **Pb** 207.2	83 **Bi** 208.980	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** 226.025	89 **†Ac** 227.028	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (266)	107 **Bh** (264)	108 **Hs** (277)	109 **Mt** (268)	110 **Ds** (271)	111 **Rg** (272)							

*Lanthanide series	58 **Ce** 140.115	59 **Pr** 140.908	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.965	64 **Gd** 157.25	65 **Tb** 158.925	66 **Dy** 162.50	67 **Ho** 164.930	68 **Er** 167.26	69 **Tm** 168.934	70 **Yb** 173.04	71 **Lu** 174.967
†Actinide series	90 **Th** 232.038	91 **Pa** 231.036	92 **U** 238.029	93 **Np** 237.048	94 **Pu** (244)	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** (262)