FORM A

Chem 130
Exam 1, Ch 5-6
100 Points

Name________________________________
October 21, 2011

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. Point vales are in parentheses by each problem.

Part 0: Warmup. 4 points each

1. Choose the INCORRECT statement:
   a. Most molecular compounds are either non-electrolytes or weak electrolytes.
   b. Most ionic compounds are strong electrolytes.
   c. Net ionic equations include only the actual participants in the reaction.
   d. An acid produces hydride ions in solution.

   Answer _____d_______

2. If someone were to light a cigar at one end of a closed room, persons on the other end of the room might soon perceive an odor due to gaseous emissions from the cigar. Such a phenomenon is an example of:
   a. ideality
   b. diffusion
   c. dissolution
   d. effusion

   Answer ______b______

Part I: Complete all of problems 3-8

3. Compare the following using a maximum of three sentences for each pair of terms.
   a. **strong electrolyte** versus **weak electrolyte**. (5)

   Strong electrolytes are ionic compounds that dissociate completely into their component ions in solution. In a solution of a weak electrolyte, not all of the electrolyte compound dissociates.

   b. **ideal gas** versus **non-ideal (or real) gas**: (5)

   Ideal gases do not interact with one another, are small in volume compared to the total volume the gas occupies, and undergo elastic collisions. Real gases do undergo interactions, inelastic collisions, and have finite volume.

4. It is possible to use precipitation reactions to separate ions in solution by removing target ions as insoluble salts. Propose an approach to separate Fe^{2+} from Ba^{2+} using precipitation reactions. Include balanced reactions (indicating states of products and reactants). (10)

   One possibility is to take advantage of the fact that barium forms an insoluble salt with sulfate, but iron does not. Therefore, if a solution containing sulfate ion is added to a solution containing Fe^{2+} and Ba^{2+}, we would expect the formation of insoluble barium sulfate, as shown below:

$$Fe^{2+}(aq) + Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow Fe^{2+}(aq) + BaSO_4\,(s)$$

or

$$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4\,(s)$$

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5. Answer the following based on the reaction: $SO_3^{2-} + MnO_4^- \rightarrow SO_4^{2-} + Mn^{2+}$

   a. What is the oxidation state of manganese in the permanganate ion?____+7_______ (2)

   b. What is the oxidation state of sulfur in the sulfite ion? ____+4_______ (2)

   c. Balance the reaction in acidic aqueous solution. (8)

First balance the half reactions:

Oxidation: $5(SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e^-)$

Reduction: $2(MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O)$

Now add half reactions together, ensuring that electrons will cancel.

$$5SO_3^{2-} + 5H_2O + 2MnO_4^- + 16H^+ + 10e^- \rightarrow 5SO_4^{2-} + 10H^+ + 10e^- + 2Mn^{2+} + 8H_2O$$

Finally, cancel redundant terms to get the final balanced reaction.

$$\mathbf{5SO_3^{2-} + 2MnO_4^- + 6H^+ \rightarrow 5SO_4^{2-} + 2Mn^{2+} + 3H_2O}$$

6. A 1.27 g sample of an oxide of nitrogen, believed to be either NO or N_2O, occupies a volume of 1.07 L at 25°C and 737 mm Hg. Which oxide is it? (10)

If we can determine the molar mass, we can identify the oxide. How many moles is 1.27g? Use the ideal gas law: n = PV/RT

$$P = 737 \text{ mm Hg} \times \frac{1 \text{ atm}}{760 \text{ mm Hg}} = 0.969_7 \text{ atm}$$

So,

$$n = \frac{0.969_7 \text{ atm} \times 1.07 \text{ L}}{0.08206 \text{ L atm/mol K} \times 298 \text{ K}} = 0.0424_3 \text{ moles}$$

And,

$$\text{molar mass} = \frac{1.27 \text{ g}}{0.0424_3 \text{ moles}} = 29.9_3 \text{ g mol}^{-1}$$

Looking at our two oxides, NO has a molar mass of 29.9_9 g mol^{-1} and N_2O has a molar mass of 44.0_1 g mol^{-1}. Therefore, the oxide must be NO.

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7. A 0.755 gram sample of solid magnesium hydroxide is added to 125 mL of a 0.444 M solution of nitric acid. Will the resulting solution be acidic, basic, or neutral? Justify your answer. (10)

The neutralization reaction below will occur:

$$Mg(OH)_2 + 2\ HNO_3 \rightarrow Mg(NO_3)_2 + 2H_2O$$

One approach is to calculate how much nitric acid will be required to neutralize all of the magnesium hydroxide.

$$0.755\ g\ Mg(OH)_2 \times \frac{1\ mol\ Mg(OH)_2}{58.320\ g} \times \frac{2\ mol\ HNO_3}{1\ mol\ Mg(OH)_2} \times \frac{1\ L\ HNO_3}{0.444\ mol\ HNO_3} = 0.0583\ L$$

So, we would need 58.3 mL nitric acid to consume all of the magnesium hydroxide. Since we have 125 mL, there is an excess of nitric acid, meaning there will be nitric acid left after the reaction is complete, causing the resulting solution to be **acidic**.

8. How does the kinetic-molecular theory of gases help explain why a helium-filled balloon shrinks if it is taken outside on a cold winter day? (10)

As the temperature decreases, the velocity of gas particles decreases as well. This leased to a decrease in both the frequency and intensity of collisions of gas particles with the walls of the balloon. Since it is these collisions that result in pressure, this leads to a decrease in pressure as well. As the pressure decreases, so does the volume of the balloon.

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Part II. Answer <u>two (2)</u> of problems 9-12. Clearly mark the problems you do not want graded. 15 points each.

9. Write balanced overall reactions and net ionic equations for each of the following: Indicate the state (*s, l, g, aq*) of each of the reactants and products.

   a. Aqueous sulfuric acid is mixed with aqueous sodium bicarbonate

   Balanced Reaction: (5)

$$H_2SO_4(aq) + 2NaHCO_3(aq) \rightarrow Na_2SO_4(aq) + 2H_2O(l) + 2CO_2(g)$$

   Net Ionic Equation: (2)

$$H^+(aq) + HCO_3^-(aq) \rightarrow H_2O(l) + CO_2(g)$$

   b. Aqueous lead (II) nitrate is mixed with aqueous lithium hydroxide

   Balanced Reaction: (5)

$$Pb(NO_3)_2(aq) + 2LiOH(aq) \rightarrow 2LiNO_3(aq) + Pb(OH)_2(s)$$

   Net Ionic Equation: (2)

$$Pb^{2+}(aq) + 2OH^-(aq) \rightarrow Pb(OH)_2(s)$$

10. Sodium dithionite, $Na_2S_2O_4$, is an important reducing agent. One interesting use is in the purification of wastewater by the reduction of chromate ion with $S_2O_4^{2-}$ in basic solution to form insoluble chromium (III) hydroxide, with sulfite ion produced as another product.

   a. Write the balanced reaction for the process occurring in basic solution. (10)

   Unbalanced Reaction:

$$CrO_4^{2-} + S_2O_4^{2-} \rightarrow Cr(OH)_3 + SO_3^{2-}$$

   Half Reactions:

$$2(CrO_4^{2-} + 5H^+ + 3e^- \rightarrow Cr(OH)_3 + H_2O)$$
$$3(S_2O_4^{2-} + 2H_2O \rightarrow 2SO_3^{2-} + 4H^+ + 2e^-)$$

   Overall reaction in acid:

$$2CrO_4^{2-} + 10H^+ + 6e^- + 3S_2O_4^{2-} + 6H_2O \rightarrow 2Cr(OH)_3 + 2H_2O + 6SO_3^{2-} + 12H^+ + 6e^-$$
$$2CrO_4^{2-} + 3S_2O_4^{2-} + 4H_2O \rightarrow 2Cr(OH)_3 + 6SO_3^{2-} + 2H^+$$

   Overall reaction in base:

$$\mathbf{2OH^-} + 2CrO_4^{2-} + 3S_2O_4^{2-} + 4H_2O \rightarrow 2Cr(OH)_3 + 6SO_3^{2-} + 2H^+ + \mathbf{2OH^-}$$

$$\mathbf{2CrO_4^{2-} + 3S_2O_4^{2-} + 2H_2O + 2OH^- \rightarrow 2Cr(OH)_3 + 6SO_3^{2-}}$$

   b. What mass of $Na_2S_2O_4$ is consumed in a reaction with 100.0 L of wastewater having $[CrO_4^{2-}] = 0.0148$ M? (5)

$$100.0\text{ L} \times \frac{0.0148\text{ mol } CrO_4^{2-}}{1\text{L}} \times \frac{3\text{ mol } S_2O_4^{2-}}{2\text{ mol } CrO_4^{2-}} \times \frac{1\text{ mol } Na_2S_2O_4}{1\text{ mol } S_2O_4^{2-}} = 2.22\text{ mol } Na_2S_2O_4$$

$$2.22\text{ mol } Na_2S_2O_4 \times \frac{174.109\text{ g } Na_2S_2O_4}{\text{mol } Na_2S_2O_4} = 386.52\text{ g} = \mathbf{387\text{ g } Na_2S_2O_4}$$

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11. Birmabright is a metal alloy consisting of aluminum, magnesium, and manganese. A 0.273 g sample of Birmabright is dissolved in an excess of hydrochloric acid, producing hydrogen gas as shown in the balanced reaction below. If 355 mL of hydrogen is collected over water at a temperature of 25°C and pressure of 755 mm Hg, what is the mass percent of aluminum in Birmabright?

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

Since the gas was collected over water, $P_{total} = P_{H2} + P_{H2O}$. The vapor pressure of water at 25°C is 23.75 mm Hg. Therefore, P_{H2} = (755-23.76)mm Hg = 731 mm Hg.

Now we can find the number of moles of H_2 produced (n = PV/RT)

$$P = 731\ \cancel{mm\ Hg} \times \frac{1\ atm}{760\ \cancel{mm\ Hg}} = 0.961_8\ atm$$

So,

$$n = \frac{0.961_8\ \cancel{atm} \times 0.355\ \cancel{L}}{0.08206\ \cancel{L}\ \cancel{atm}/mol\ \cancel{K} \times 298\ \cancel{K}} = 0.0139_6\ moles\ H_2$$

So, the mass of aluminum consumed must have been:

$$0.0139_6\ moles\ H_2 \times \frac{2\ mol\ Al}{3\ mol\ H_2} \times \frac{26.9815\ g\ Al}{1\ mol\ Al} = 0.251_1\ g\ Al$$

And the percent aluminum must be:

$$\frac{0.251_1\ g\ Al}{0.273\ g\ sample} \times 100\% = \mathbf{92.0\%\ Aluminum}$$

12. Nitroglycerine ($C_3H_5N_3O_9$, molar mass = 227.088 g/mol) is a contact explosive that rapidly decomposes via the reaction below and releases a large quantity of heat and gas. Assume 10.0 grams of nitroglycerine decomposes in a 2.0 L soda bottle and instantaneously generates a temperature of 5230K.

$$4\ C_3H_5N_3O_9(\ell) \rightarrow 12\ CO_2(g) + 10\ H_2O(g) + 6\ N_2(g) + O_2(g)$$

a. What will the pressure be inside the bottle once the reaction is complete? (5)

First find the total number of moles of gas produced:

$$10.0g\ C_3H_5N_3O_9 \times \frac{1\ mol\ C_3H_5N_3O_9}{227.088\ g} \times \frac{29\ mol\ gas}{4\ mol\ C_3H_5N_3O_9} = 0.319_3\ mol\ gas$$

Now find the pressure

$$P = \frac{nRT}{V} = \frac{(0.319_3\ \cancel{mol})(0.08206\ \cancel{L}\ atm/\cancel{mol}\ \cancel{K})(5230K)}{2.0\cancel{L}} = 68.5_1\ atm = \mathbf{69\ atm}$$

b. What is the partial pressure of carbon dioxide when the reaction is complete? (5)

$$P_{CO2} = \frac{n_{CO2}\ (P_{total})}{n_{total}} = \frac{12\ mol\ CO_2}{29\ mol\ total} \times 69\ atm = 28.5_5\ atm = \mathbf{29\ atm}$$

c. What volume would the gas mixture produced occupy at STP? (5)

Use the combined gas law to find:

$$V_2 = \frac{P_1V_1T_2}{P_2T_1} = \frac{(69\ \cancel{atm})(2.0\ L)(273\ \cancel{K})}{(1\ \cancel{atm})(5230\ \cancel{K})} = \mathbf{7.2\ L}$$

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Possibly Useful Information

$R = 0.08206\ L\ atm\ mol^{-1}\ K^{-1}$	STP = 1 atm, 0^oC $K = 273.15 + {}^oC$
1 atmosphere = 760 Torr = 760 mm Hg	$\left(P + \frac{n^2a}{V^2}\right)(V - bn) = nRT$
$P_{total} = n_{total}RT/V$	$P_A = X_A P_{total}$
$N_a = 6.02214 \times 10^{23}\ mol^{-1}$	$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Molar Masses	
Compound	**Molar Mass (g/mol)**
aluminum chloride	133.340
carbon dioxide	44.010
chromium (III) hydroxide	103.018
hydrochloric acid	36.461
hydrogen gas	2.016
magnesium hydroxide	58.320
nitric acid	63.013
nitrogen gas	28.0135
nitrogen monoxide	30.006
nitroglycerine	227.088
oxygen gas	31.999
sodium carbonate	105.989
sodium dithionite	174.109
sodium nitrite	68.995
water	18.015

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 5.3 Some Common Gas-Forming Reactions

Ion	Reaction
HSO_3^-	$HSO_3^- + H^+ \longrightarrow SO_2(g) + H_2O(l)$
SO_3^{2-}	$SO_3^{2-} + 2\,H^+ \longrightarrow SO_2(g) + H_2O(l)$
HCO_3^-	$HCO_3^- + H^+ \longrightarrow CO_2(g) + H_2O(l)$
CO_3^{2-}	$CO_3^{2-} + 2\,H^+ \longrightarrow CO_2(g) + H_2O(l)$
S^{2-}	$S^{2-} + 2\,H^+ \longrightarrow H_2S(g)$
NH_4^+	$NH_4^+ + OH^- \longrightarrow NH_3(g) + H_2O(l)$

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)