**Chem 130**
**Exam 2, Ch 4-6**
**100 Points**

**Name**________________________________
**October 12, 2016**

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. Under what conditions is $Cl_2$ likely to behave most like an ideal gas?
   a. 100°C and 10.0 atm
   b. 0°C and 0.50 atm
   c. 200°C and 0.50 atm
   d. 400°C and 10.0 atm

   Answer ____C_______

2. 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_______

**Part I: Complete all of problems 3-8**

3. The terms **strong electrolyte** and **weak electrolyte** are used in multiple contexts. Discuss how these terms are used in each of the contexts below. Use a maximum of three sentences per context. (8 points)

   a. When describing a compound:

   When describing a compound, the term *electrolyte* refers to the compound's tendency to dissociate into ions when dissolved in solution. A strong electrolyte tends to dissociate completely in solution, while only a fraction of all the weak electrolyte units dissociate.

   b. When describing a solution:

   When describing a solution, the term *electrolyte* refers to the solution's ability to conduct electricity. A strongly electyroytic solution conducts electricity well because it contains a high concentration of ions, while a weakly electrolytic solution is a poor conductor because of a low concentration of ions.

4. Complete the following table. (12 points)

| Species | Name | Oxidation States | | | Water Soluble? (Y/N) |
|---|---|---|---|---|---|
| $Co(ClO_4)_3$ | cobalt (III) perchlorate | Co =+3 | Cl = +7 | O = -2 | Yes |
| $Zn_3(PO_4)_2$ | zinc (II) phosphate | Zn =+2 | O = -2 | P = +5 | No |

5. Write balanced overall reactions and net ionic equations for each of the following: Indicate the state (s, $\ell$, g, aq) of each of the reactants and products. (12 points)

   a. Aqueous sulfuric acid is mixed with aqueous ammonium hydroxide

   Balanced Reaction: (4)

   $$H_2SO_4(aq) + 2NH_4OH(aq) \rightarrow (NH_4)_2SO_4(aq) + 2H_2O(\ell)$$

   Net Ionic Equation: (2)

   $$H^+(aq) + OH^-(aq) \rightarrow H_2O(\ell)$$

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

   Balanced Reaction: (4)

   $$Pb(NO_3)_2(aq) + Li_2S(aq) \rightarrow PbS(s) + 2LiNO_3(aq)$$

   Net Ionic Equation: (2)

   $$Pb^{2+}(aq) + S^{2-}(aq) \rightarrow PbS(s)$$

6. 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 points)

   You should discuss how the kinetic energy of a gas depends on temperature. As T decreases, KE decreases. As KE drops, the average velocity of a gas decreases, resulting in fewer collisions with the walls of the container (and the collisions have less force). Fewer collisions mean lower pressure inside the balloon than outside the balloon. Since the balloon is elastic, the larger pressure outside the balloon, causes it to shrink.

7. A 7.55 g sample of barium hydroxide is added to 125 mL of a 0.762 M nitric acid solution. After any reaction is complete, with the solution still be acidic? (10 points)

Start with a balanced reaction:

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

You must do a limiting reagent calculation, here's one approach:
How many mL of $HNO_3$ do we need to use all the $Ba(OH)_2$?

$$7.55\ \cancel{g\ Ba(OH)_2} \times \frac{1\ \cancel{mol\ Ba(OH)_2}}{171.34\ \cancel{g}} \times \frac{2\ \cancel{mol\ HNO_3}}{1\ \cancel{mol\ Ba(OH)_2}} \times \frac{1000\ mL}{0.762\ \cancel{mol\ HNO_3}} = 115.7\ mL\ HNO_3 \text{needed}$$

Since we have much more $HNO_3$ than we need to consume all the $Ba(OH)_2$, $Ba(OH)_2$ will be the limiting reagent. Therefore, there will be $HNO_3$remaining after the reaction is complete, so the solution will still be acidic.

**Answer**_____yes______________________

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

How many moles of gas do we have?

$$P = \frac{737\ mm\ Hg}{} \times \frac{1\ atm}{760\ mm\ Hg} = 0.970\ atm$$

$$n = \frac{PV}{RT} = \frac{(0.970\ \cancel{atml})(1.07\cancel{L})}{(0.0821\ \cancel{L\ atm}/mol\ \cancel{K})(298\ \cancel{K})} = 0.0424\ mol\ gas$$

So, we have 0.0424 mol gas with a mass of 1.27 g, giving a molar mass of:

$$\frac{1.27\ g}{0.0424\ mol} = 29.9_5\ g/mol$$

The molar mass of NO = 30.0 g/mol and the molar mass of $N_2O$ = 44.0 g/mol. Therefore, the gas must be NO.

(note there are many other ways to go about this, all of which involve determining the number of moles of the gas in question)

**Answer**________NO____________________

**Part II. Answer three (3) of problems 9-12. Clearly mark the problem you do not want graded. 12 points each.**

9. You can dissolve an aluminum soft drink can in an aqueous base such as potassium hydroxide.

$$2\ Al\ (s) + 2\ KOH\ (aq) + 6\ H_2O\ (\ell) \rightarrow 2\ KAl(OH)_4\ (aq) + 3\ H_2\ (g)$$

a. If you place 2.05 g of aluminum in a beaker with 125 mL of 1.25 M KOH, will any aluminum remain? Justify your answer with a calculation, no calculation, no credit. (8 points)

You must do a limiting reagent calculation. There are several ways to approach the problem.

**One approach:**

How many mL of KOH do we need to use all the aluminum?

$$2.05\ \text{g Al} \times \frac{1\ \text{mol Al}}{26.9815\ \text{g}} \times \frac{2\ \text{mol KOH}}{2\ \text{mol Al}} \times \frac{1000\ \text{mL}}{1.25\ \text{mol KOH}} = 60.8\ \text{mL KOH needed}$$

Since we have much more KOH than we need, aluminum will be the limiting reagent. Therefore, there will be no aluminum remaining after the reaction is complete

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**An alternative approach:**

How many mol $H_2$ would be produced assuming each reactant is the limiting reagent?

$$2.05\ \text{g Al} \times \frac{1\ \text{mol Al}}{26.9815\ \text{g}} \times \frac{3\ \text{mol}\ H_2}{2\ \text{mol Al}} = 0.114\ \text{mol}\ H_2\ \text{if Al is limiting reactant}$$

$$0.125\ \text{L sol'n} \times \frac{1.25\ \text{mol KOH}}{\text{L sol'n}} \times \frac{3\ \text{mol}\ H_2}{2\ \text{mol KOH}} = 0.234\ \text{mol}\ H_2\ \text{if KOH is limiting reactant}$$

Since Al produces less $H_2$, Al must be the limiting reagent and will be completely consumed in the reaction.

b. After the reaction is complete, what is the concentration of $KAl(OH)_4$ in moles per liter? You may assume a final solution volume of 125 mL. (4 points)

$$2.05\ \text{g Al} \times \frac{1\ \text{mol Al}}{26.9815\ \text{g}} \times \frac{2\ \text{mol}\ KAl(OH)_4}{2\ \text{mol Al}} \times \frac{1}{0.125\ \text{L}} = \mathbf{0.608\ M\ KAl(OH)_4}$$

**Answer**________**0.608 M $KAl(OH)_4$** _____

10. At elevated temperatures, solid sodium chlorate ($NaClO_3$, molar mass 106.44 g/mol) decomposes to produce sodium chloride and oxygen gas. In an experiment, a 0.8765 g sample of impure sodium chlorate was heated until the production of oxygen ceased. The $O_2$ gas was collected over water. The collected gas occupied a volume of 57.2 mL at 23.0°C and 734 mm Hg. Calculate the mass percentage of sodium chlorate in the original sample. Assume that none of the impurities produce $O_2$.

$$2NaClO_3 \rightarrow 2NaCl + 3O_2$$

$$P_{total} = P_{O2} + P_{H2O}$$

From the table of vapor pressures, the partial pressure of water at 23.0°C is 21.07 mm Hg. So:

$$734 \text{ mm Hg} = P_{O2} + 21.07 \text{ mm Hg}$$
$$P_{O2} = 713 \text{ mm Hg}$$

Converting to atmospheres:

$$P = \frac{713 \text{ mm Hg}}{} \times \frac{1 \text{ atm}}{760 \text{ mm Hg}} = 0.938 \text{ atm}$$

$$n = \frac{PV}{RT} = \frac{(0.938 \cancel{\text{atm}})(0.0572\cancel{\text{L}})}{(0.0821 \cancel{\text{L atm}}/\text{mol } \cancel{\text{K}})(296 \cancel{\text{K}})} = 0.00221 \text{ mol } O_2$$

Therefore, how many grams of $NaClO_3$ must have decomposed?

$$0.00221 \cancel{\text{mol } O_2} \times \frac{2 \cancel{\text{mol } NaClO_3}}{3 \cancel{\text{mol } O_2}} \times \frac{106.44 \text{ g } NaClO_3}{1 \cancel{\text{mol } NaClO_3}} = 0.157 \text{ g } NaClO_3$$

And the percent $NaClO_3$ is:

$$\frac{0.157 \text{ g } NaClO_3}{0.8765 \text{ g sample}} \times 100\% = \mathbf{17.9\ \%\ NaClO_3}$$

**Answer_______17.9 % $NaClO_3$___________**

11. Redox reactions:

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

$$BrO_3^-(aq) + H_2O_2(aq) \rightarrow Br_2(\ell) + O_2(g)$$

| | | | |
|---|---|---|---|
| Oxidation | $5(H_2O_2$ | $\rightarrow$ | $O_2 + 2H^+ + 2e^-)$ |
| Reduction | $2BrO_3^- + 12H^+ + 10e^-$ | $\rightarrow$ | $Br_2 + 6H_2O$ |
| Overall | $5H_2O_2 + 2BrO_3^- + 12H^+ + 10e^-$ | $\rightarrow$ | $5O_2 + 10H^+ + 10e^- + Br_2 + 6H_2O$ |
| **Final** | $\mathbf{5H_2O_2 + 2BrO_3^- + 2H^+}$ | $\rightarrow$ | $\mathbf{5O_2 + Br_2 + 6H_2O}$ |

b. Permanganate ion can oxidize cyanide ion in acidic solution by the reaction below. Write the corresponding balanced reaction that would occur in basic solution. (2 points)

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

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

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:

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

12. Answer the following questions related to the combustion of ethanol. Assume the ideal gas law applies.

$$2\ CH_3CH_2OH(\ell) + 6\ O_2(g) \rightarrow 4\ CO_2(g) + 6\ H_2O(g)$$

a. If 5.00 g of ethanol (molar mass 46.07 g/mol) is burned in a 2.00 L container filled with oxygen at 2.08 atm and 100°C, will be the final pressure in the container? (8 points)

When the reaction is done, we will have a mixture of gases and $P_{Total} = nRT/V$.

We need to do a limiting reagent calculation. How many moles of $H_2O$ do we make if ethanol is the L.R.?

$$5.00\ \text{g ethanol} \times \frac{1\ \text{mol ethanol}}{46.07\ \text{g}} \times \frac{6\ \text{mol } H_2O}{2\ \text{mol ethanol}} = 0.3256\ \text{mol } H_2O$$

What if $O_2$ is the L.R.?

$$N_{O2} = \frac{PV}{RT} = \frac{(2.08\ \text{atm})(2.00\ \text{L})}{(0.0821\ \text{Latm/molK})(373\text{K})} = 0.1359\ \text{mol } O_2$$

$$0.1359\ \text{mol } O_2 \times \frac{6\ \text{mol } H_2O}{6\ \text{mol } O_2} = 0.135_9\ \text{mol } H_2O$$

Therefore $O_2$ must be the L.R. and 0.136 mol of water will be formed, as well as some $CO_2$, but all the $O_2$ is consumed. How much $CO_2$ is made?

$$0.1359\ \text{mol } H_2O \times \frac{4\ \text{mol } CO_2}{6\ \text{mol } H_2O} = 0.0906\ \text{mol gas}$$

So, we have a total of 0.1359 + 0.0906 = 0.2265 mol gas and our pressure is:

$$p = \frac{nRT}{V} = \frac{(0.2265\ \text{mol})(0.0821\ \text{L atm/mol K})(373\ \text{K})}{2.0\text{L}} = \mathbf{3.47\ atm}$$

**Answer**__________**3.47 atm** __________

b. What volume would the gas produced by this reaction occupy at STP? (4 points)

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

$$V_2 = \frac{P_1T_2V_1}{P_2T_1} = \frac{(3.47\ \text{atm})(273\ \text{K})(2.00\ \text{L})}{(1\ \text{atm})(373\ \text{K})} = \mathbf{5.08\ L}$$

**Answer**__________**5.08 L**__________

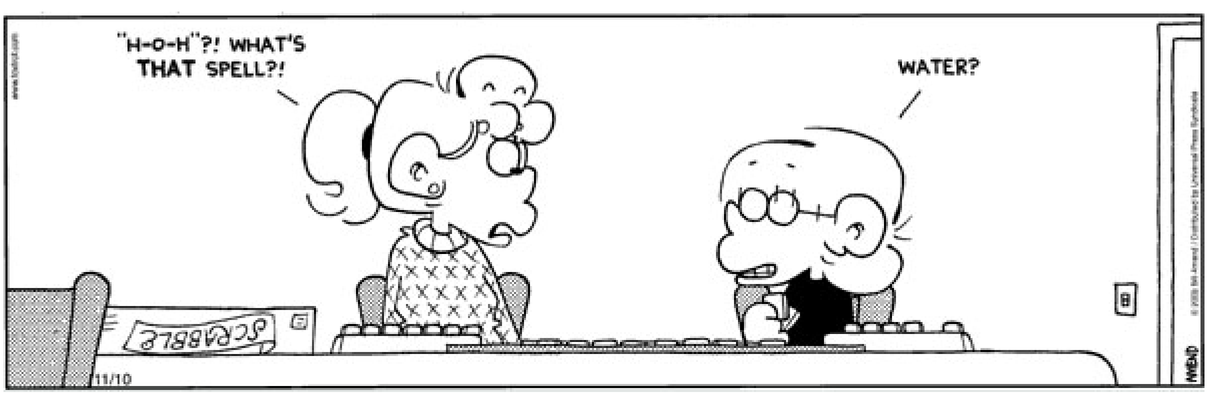
## Possibly Useful Information

| | |
|---|---|
| $R = 0.08206\ \text{L atm mol}^{-1}\ \text{K}^{-1}$ | $K = {}^{o}C + 273.15$ |
| 1 atmosphere = 760 Torr = 760 mm Hg | $\left(P + a\left(\frac{n}{V}\right)^2\right)(V - bn) = nRT$ |
| $P_{total}V = n_{total}RT$ | $P_A = X_a P_{total}$ |
| $N_a = 6.02214 \times 10^{23}\ \text{mol}^{-1}$ | $\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$ |
| $\%\ \text{by mass} = \frac{\text{g component}}{100\ \text{g sample}}$ | d = m/v |

**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 |





To save some calculation time, you may round all atomic masses to two (2) decimal points.

| 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) |