Chem 130
Exam 2
100 Points

Name_______________________________
October 11, 2017

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 I: Complete all of problems 1-9

1. Choose the INCORRECT statement: (4)
   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. Answer__d___
   d. An acid produces hydride ions in solution.

2. For a fixed number of moles of gas at a fixed pressure, changing the temperature from 100°C to 200K causes the gas volume to: (4)
   a. double
   b. increase
   c. decrease
   d. stay the same

   Answer __c___

3. Which of the following is NOT a key assumption of the kinetic-molecular theory of gases? (4)
   a. There is a large separation between gas particles.
   b. Gas particles are in continual, rapid motion.
   c. All gas particles at a given temperature have the same velocity. Answer __c___
   d. Gas particles undergo elastic collisions.

4. Suppose I am holding a balloon partially filled with air. If I squeeze the balloon in my hands, I feel resistance as I try to make the balloon smaller. Use the kinetic-molecular theory of gases to *briefly* explain this observation. (6)

   As the volume of the balloon decreases, there is an increase in the frequency of collisions of gas particles with the walls of the balloon. This increased number of collisions results in greater pressure in the balloon.

5. It is possible to use precipitation reactions to separate ions in solution by removing target ions as insoluble salts. Show how to separate Fe^{2+} from Ba^{2+} using precipitation reactions to cause one ion to precipitate, but allow the other to remain in solution. Include balanced reactions (indicating states of products and reactants). (6)
   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

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

6. 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.

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

7. In order for your car battery to function properly, the sulfuric acid in the battery must be between 4.8 and 5.3 M H_2SO_4. A 5.00 mL sample of acid from a battery requires 49.74 mL of 0.935 M NaOH to be completely neutralized in a titration. Does the concentration of this battery acid fall within the desired range? Justify your answer with a calculation. (10)

$2\ NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2\ H_2O$

$$49.74\ \cancel{mL\ NaOH} \times \frac{0.935\ \cancel{mol\ NaOH}}{1\ \cancel{L\ NaOH}} \times \frac{1\ mol\ H_2SO_4}{2\ \cancel{mol\ NaOH}} \times \frac{1}{5.00\ \cancel{mL}} = \mathbf{4.65\ M\ H_2SO_4}$$

No, the concentration of acid is outside the desired range.

Answer______No______________

8. Common 2.0 liter plastic soda (or pop, depending on where you are from) bottles are rated to hold pressures of 175 psi before bursting (1 atm =14.7 psi). If you put 56.8 grams of solid carbon dioxide (dry ice, molar mass 44.01 g/mol) in a 2 L bottle and allow the dry ice to convert to gas at room temperature (25.0 ^{o}C), will the bottle burst? Justify your answer with a calculation. (10)

To find the total pressure, we need the number of moles of gas:

$$56.8\ \cancel{g\ CO_2} \times \frac{1\ mol\ CO_2}{44.010\ \cancel{g\ CO_2}} = 1.291\ mol\ CO_2$$

T = 25.0+273.15 = 298.15K

$$P = \frac{nRT}{V} = \frac{(1.291\ mol)(0.08206\ L\ atm/mol\ K)(298.15\ K)}{(2.0\ L)} = \mathbf{15.8\ atm}$$

$$15.8\ \cancel{atm} \times \frac{14.7\ psi}{1\ \cancel{atm}} = 232\ ps1$$

Since this exceeds 175 psi, we would expect the bottle to burst.

Answer______yes_____________

9. Ammonia can be generated by heating together the solids $Ca(OH)_2$ and NH_4Cl. $CaCl_2$ and water are also formed. How many grams of NH_3 will form if 33.0 grams each of NH_4Cl and $Ca(OH)_2$ are heated? (molar masses (g/mol): NH_4Cl = 53.4912, NH_3 = 17.03056, $Ca(OH)_2$ = 74.093, $CaCl_2$ = 110.983, water = 18.0153) (10)

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

If NH_4Cl is the limiting reactant, how many grams of ammonium could be produced?

$$33.0\ \cancel{g\ NH_4Cl} \times \frac{1\ \cancel{mol\ NH_4Cl}}{53.4912\ \cancel{g\ NH_4Cl}} \times \frac{2\ \cancel{mol\ NH_3}}{2\ \cancel{mol\ NH_4Cl}} \times \frac{17.03056\ \cancel{g\ NH_3}}{1\ \cancel{mol\ NH_3}} = \mathbf{10.51\ g\ NH_3}$$

If $Ca(OH)_2$ is the limiting reactant, how many grams of ammonium could be produced?

$$33.0\ \cancel{g\ Ca(OH)_2} \times \frac{1\ \cancel{mol\ Ca(OH)_2}}{74.093\ \cancel{g\ Ca(OH)_2}} \times \frac{2\ \cancel{mol\ NH_3}}{1\ \cancel{mol\ Ca(OH)_2}} \times \frac{17.03056\ \cancel{g\ NH_3}}{1\ \cancel{mol\ NH_3}} = \mathbf{15.17\ g\ NH_3}$$

Therefore, ammonium chloride must be the limiting reagent, and a maximum of 10.5 grams of ammonia could be produced.

Answer________10.5 g NH_3______

Part II. Answer <u>three (3)</u> of problems 10-13. Clearly mark the problems you do not want graded. 12 points each.

10. 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 potassium hydroxide is mixed with aqueous iron (II) nitrate

Balanced Reaction: (4)

$$2KOH\ (aq) + Fe(NO)_2\ (aq) \rightarrow 2KNO_3(aq) + Fe(OH)_2(s)$$

Net Ionic Equation: (2)

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

b. Aqueous ammonium phosphate is mixed with aqueous magnesium chloride

Balanced Reaction: (4)

$$2(NH_4)_3PO_4(aq) + 3MgCl_2(aq) \rightarrow Mg_3(PO_4)_2(s) + 6NH_4Cl\ (aq)$$

Net Ionic Equation: (2)

$$3Mg^{2+}(aq) + 2PO_4^{3-}(aq) \rightarrow Mg_3(PO_4)_2(s)$$

11. In a combustion reaction, 5.00 g of ethanol (C_2H_6O).is allowed to react in a 2.00 L container filled with oxygen gas at a pressure of 2.08 atm and a temperature of 100°C, producing water and carbon dioxide. If 1.53 g water forms, what is the percent yield for the reaction? (molar masses (g/mol): C_2H_6O = 46.068 , O_2 = 31.998, CO_2 = 44.010 , water = 18.0153)

$$C_2H_6O + 3\ O_2 \rightarrow 3\ H_2O + 2\ CO_2$$

If ethanol is limiting reactant:

$$5.00\ \cancel{g\ C_2H_6O} \times \frac{1\ \cancel{mol\ C_2H_6O}}{46.0684\ \cancel{g\ C_2H_6O}} \times \frac{3\ \cancel{mol\ H_2O}}{1\ \cancel{mol\ C_2H_6O}} \times \frac{18.0153\ g\ H_2O}{1\ \cancel{mol\ H_2O}} = 5.86_6\ g\ H_2O$$

If oxygen is limiting reactant:

$$n = \frac{PV}{RT} = \frac{(2.08\ atm)(2.00\ L)}{(0.08206\ L\ atm/mol\ K)(373\ K)} = 0.135\ mol\ O_2$$

$$0.135\ mol\ O_2 \times \frac{3\ \cancel{mol\ H_2O}}{3\ \cancel{mol\ O_2}} \times \frac{18.0153\ g\ H_2O}{1\ \cancel{mol\ H_2O}} = 2.44_8\ g\ H_2O$$

Therefore, oxygen is the limiting reactant and the theoretical yield is 2.44_8 g H_2O

$$\%\ yield = \frac{1.53\ g\ water}{2.44_8 g\ water} \times 100\% = \mathbf{62.5\ \%\ yield}$$

Answer____62.5 % yield_______

12. Sodium dithionite, $Na_2S_2O_4$ (molar mass 174.109 g/mol), is an important reducing agent. One interesting use is in the purification of wastewater by the reduction of chromate ion (CrO_4^{2-}) 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)

c. $$100.0\ L \times \frac{0.0166\ mol\ CrO_4^{2-}}{1L} \times \frac{3\ mol\ S_2O_4^{2-}}{2\ mol\ CrO_4^{2-}} \times \frac{1\ mol\ Na_2S_2O_4}{1\ mol\ S_2O_4^{2-}} = 2.49\ mol\ Na_2S_2O_4$$

$$2.49\ mol\ Na_2S_2O_4 \times \frac{174.109\ g\ Na_2S_2O_4}{mol\ Na_2S_2O_4} = 433.53\ g = 434\ \mathbf{g\ Na_2S_2O_4}$$

Answer_______434 **g $Na_2S_2O_4$**_______

13. You dissolve 2.83 g of a copper-containing mixture in water in a 100.0 mL volumetric flask and dilute it to the mark to prepare solution A. You then pipet 5.00 mL of solution A into a 25.00 mL volumetric flask and dilute it to the mark to make solution B. Finally, you pipet 1.00 mL of solution B into a 25.00 mL flask and dilute it to the mark to make solution C. You then determine the copper concentration in solution C to be 6.62×10^{-4}M. What is the percent copper by mass in your original solid mixture?

For solution B:

$$M_B = \frac{M_C V_C}{V_B} = \frac{(6.62 \times 10^{-4} M)(25.00\ \cancel{mL})}{1.00\ \cancel{mL}} = 0.01655\ M = [B]$$

For solution A:

$$M_A = \frac{M_B V_B}{V_A} = \frac{(0.01655\ M)(25.00\ \cancel{mL})}{5.00\ \cancel{mL}} = 0.08275\ M = [A]$$

So, the molarity of copper in solution A is 0.08275 M, how many grams of copper must be in the solution?

$$0.1000\ \cancel{L\ sol'n} \times \frac{0.08275\ \cancel{mol\ Cu}}{1\ \cancel{L\ sol'n}} \times \frac{63.546\ g\ Cu}{1\ \cancel{mol\ Cu}} = 0.5258\ g\ Cu$$

So, the percent copper is:

$$\frac{0.5258\ g\ Cu}{2.83\ g\ mixture} \times 100\% = \mathbf{18.6\ \%\ copper}$$

Answer____18.6 % copper_____

Possibly Useful Information

$R = 0.08206 \text{ L atm mol}^{-1} \text{ K}^{-1}$	$K = 273.15 + {}^{o}C$
1 atmosphere = 760 Torr = 760 mm Hg	$N_a = 6.02214 \times 10^{23} \text{ mol}^{-1}$
PV =nRT	$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$

1 1A	2 2A	3 3B	4 4B	5 5B	6 6B	7 7B	8	9 8B	10	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)