Chem 130
Exam 2, Ch 4-6
100 Points

Name______________________________
July 7, 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. For a fixed amount of gas at a fixed pressure, changing the temperature from 100°C to 200K causes the gas volume to:
   a. double
   b. increase
   c. decrease
   d. stay the same

   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. Complete the chart below: (12 points)

Species	Name	Oxidation States			Water Soluble? (Y/N)
$Al_2(SO_4)_3$	aluminum sulfate	Al = +3	S =+6	O =-2	Y
$Zn_3(PO_4)_2$	zinc (II) phosphate	Zn =+2	O = -2	P = +5	N

4. 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 ammonium carbonate with aqueous silver nitrate.
   (1) Overall reaction:

   $$(NH_4)_2CO_3\ (aq) + 2\ AgNO_3(aq) \rightarrow Ag_2CO_3\ (s) + 2\ NH_4NO_3\ (aq)$$

   (2) Net ionic equation:

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

5. 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)

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

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

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

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

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

$$\mathbf{UO^{2+} + NO_3^- \rightarrow UO_2^{2+} + NO}$$

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	$\mathbf{3UO^{2+} + 2NO_3^- + 2H^+}$	$\rightarrow$	$\mathbf{3UO_2^{2+} + 2NO + H_2O}$

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? (10 points)

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

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

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

8. 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 pressure of 744 mm Hg. If 322 mL of hydrogen is collected, what is the percent aluminum (by mass) in the sample? (10 points)

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

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

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

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

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

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

Part II. Answer three (3) of problems 9-12. Clearly mark the problem you do not want graded. 10 points each.

9. 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?

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

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

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

10. The ideal gas law works best under a very limited set of conditions. What are these conditions? What assumptions of the ideal gas law fail as you deviate from these conditions?

    Two key assumptions of the ideal gas law are that there is a large space between particles and that particles do not interact with one another when they collide (they have elastic collisions).

    These two assumptions work best under low pressure and high temperature conditions. Low pressure corresponds to large space between particles and, therefore, infrequent collisions. At high temperatures, particles have higher velocities and kinetic energies. Therefore, any energy lost in collisions is minimal compared to the particle's total kinetic energy.

11. A student puts 50.0 grams each of dry ice (solid carbon dioxide) and liquid nitrogen into a 500.0 mL soda bottle and quickly closes the lid. After a short time, all of the CO_2 and N_2 have been converted into gas and allowed to reach a temperature of 27.2°C.

a. What is the total pressure in the container? (7 points)

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

$$50.0\ \cancel{g\ CO_2} \times \frac{1\ mol\ CO_2}{44.010\ \cancel{g\ CO_2}} = 1.136\ mol\ CO_2$$

$$50.0\ \cancel{g\ N_2} \times \frac{1\ mol\ N_2}{28.0134\ \cancel{g\ N_2}} = 1.785\ mol\ N_2$$

So, the total moles of gas is: 1.136 + 1.785 = 2.921 moles

T = 27.2+273.15 = 300.35K

$$P = \frac{nRT}{V} = \frac{(2.921\ mol)(0.08206\ L\ atm/mol\ K)(300.35\ K)}{(0.500\ L)} = \mathbf{144\ atm}$$

b. What is the partial pressure of CO_2 in the container? (3 points)

$$P_{CO2} = \frac{n_{CO2}RT}{V} = \frac{(1.136\ mol)(0.08206\ L\ atm/mol\ K)(300.35\ K)}{0.500\ L)} = \mathbf{56.0\ atm}$$

Another approach is to use $P_{CO2} = X_{CO2}P_{Total}$ = (1.136/2.921) x 144 atm = **56.0 atm**

12. 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:

$$\frac{0.5258\ g\ Cu}{2.86\ g\ mixture} \times 100\% = \mathbf{18.4\ \%\ copper}$$

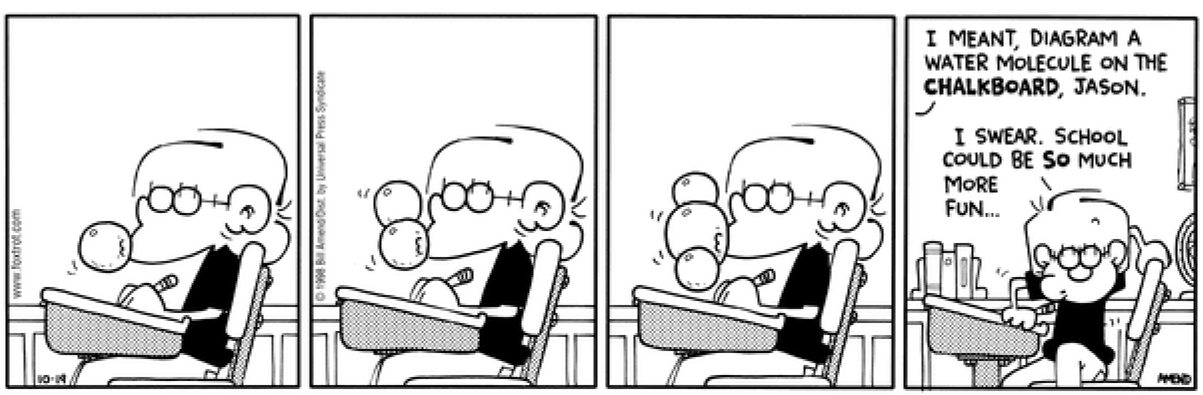
Possibly Useful Information

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

Molar Masses	
Compound	**Molar Mass (g/mol)**
$AlCl_3$	133.3396
C_2H_6O	46.0684
$Ca(OH)_2$	74.093
$CaCl_2$	110.983
CO_2	44.010
H_2	2.01588
H_2O	18.0153
HCl	36.4606
H_2SO_4	98.079
NaOH	39.9971
NH_3	17.0356
NH_4Cl	53.4912
N_2	28.0134
O_2	31.9988

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



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)