Chem 130
Exam 1, Ch 4-6.7
100 Points

Name__________________________________
October 12, 2018

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. Any values in curly brackets { } are molar masses in grams per mole.

Part 0: Warmup. 4 points each

1. In order to prepare 0.0500 M HCl from a 1.00 M HCl solution, you should pipet ____ mL of the 1.00 M solution into a 200.0 mL volumetric flask and dilute to the mark.
   a. 1.00
   b. 2.00
   c. 5.00
   d. 10.00

   Answer _____d______

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______

3. A bottle contains 1.0 mol hydrogen gas, 2.0 mol helium gas, 1.0 mol neon gas and 1.0 mol of solid metallic gold. If the total pressure in the bottle is 2.0 atm, what is the partial pressure of helium in the bottle?
   a. 0.20 atm
   b. 0.25 atm
   c. 0.50 atm
   d. 1.0 atm

   Answer _____d______

Part I: Complete all of problems 4-9

4. Complete the following table. (10 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. Ammonia, NH_3, may react with oxygen to form nitrogen gas and water {18.02}. If 3.65 g of NH_3 {17.03} reacts with 5.48 g O_2 {32.00} and produces 0.850 L of N_2 {28.01}, at 295 K and 1.00 atm, what is the percent yield for the reaction? (10 points)

$$4\ NH_3 + 3\ O_2 \rightarrow 2\ N_2 + 6\ H_2O$$

Theoretical yield:

$$3.65\text{ g }NH_3 \times \frac{1\text{ mol }NH_3}{17.03\text{ g }NH_3} \times \frac{2\text{ mol }N_2}{4\text{ mol }NH_3} = 0.1076\text{ mol }N_2$$

$$5.48\text{ g }O_2 \times \frac{1\text{ mol }O_2}{32.00\text{ g }O_2} \times \frac{2\text{ mol }N_2}{3\text{ mol }O_2} = 0.1142\text{ mol }N_2$$

So our theoretical yield is 0.1076 mol N_2. What is the actual yield?

$$\text{mol }N_2 = \frac{PV}{RT} = \frac{(1.00\text{ atm})(0.850\text{ L})}{(0.08206\text{ L atm/mol K})(295\text{ K})} = 0.03511\text{ mol }N_2$$

Percent yield is:

$$\%\text{ yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\% = \frac{0.03511\text{ mol}}{0.1076\text{ mol}} \times 100\% = 32.6\ \%$$

Answer__________32.6%___________

6. How does the kinetic-molecular theory (KMT) of gases help explain why a helium-filled balloon shrinks if it is taken outside on a cold winter day? Use the components of the KMT in your explanation. No calculations are necessary(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. Suppose we have a solution of lead nitrate, $Pb(NO_3)_2(aq)$ {331.21}. A solution of NaCl(aq) {58.44} is added slowly to cause the formation of $PbCl_2(s)$ {278.11} until no further precipitation occurs. The precipitate is collected, dried, and weighed. A total of 10.62 g of $PbCl_2(s)$ is obtained from 200.0 mL of the original solution. Calculate the molarity of the $Pb(NO_3)_2(aq)$ solution. (10 points)

$$Pb(NO_3)_2\ (aq) + 2\ NaCl\ (aq) \rightarrow PbCl_2\ (s) + 2\ NaNO_3\ (aq)$$

$$10.62\ \text{~~g PbCl}_2\text{~~} \times \frac{1\ \text{~~mol PbCl}_2\text{~~}}{278.11\ \text{~~g PbCl}_2\text{~~}} \times \frac{1\ \text{mol } Pb(NO_3)_2}{1\ \text{~~mol PbCl}_2\text{~~}} = 0.03819\ \text{mol } Pb(NO_3)_2$$

$$\frac{0.03819\ \text{mol } Pb(NO_3)_2}{0.2000\ \text{L solution}} = \mathbf{0.1909\ M\ Pb(NO_3)_2}$$

Answer_____0.1909 M $Pb(NO_3)_2$_____

8. A solution is prepared by diluting 71.0 mL of a 1.30 M $CaCl_2$ solution to a total volume of 268 mL. A 134-mL portion of that solution is diluted by adding 155 mL of water. What is the chloride ion concentration in the final solution? Assume the volumes are additive. (10 points)

Two dilutions to account for, as well as the dissociation of calcium chloride:

$$CaCl_2(aq) \rightarrow Ca^{2+}(aq) + 2Cl^-(aq)$$

$$M_C V_C = M_D V_D$$

$M_D = M_C V_C/V_D = (1.30M\ CaCl_2)(71.0\ mL/268\ mL) = 0.3444\ M\ CaCl_2$ after the first dilution.

$$M_C V_C = M_D V_D$$

$$M_D = M_C V_C/V_D = (0.3444\ M)(134\ mL)/(289\ mL) = 0.1597\ M\ CaCl_2$$

Accounting for dissociation:

$$\frac{0.\ 0.1091\ \text{mol } CaCl_2}{1\ \text{L solution}} \times \frac{2\ \text{mol } Cl^-}{1\ \text{mol } CaCl_2} = \frac{0.319_3\ \text{mol } Cl^-}{1\ \text{L solution}} = \mathbf{0.319\ M\ Cl^-}$$

Answer_______0.319 M Cl^-______

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. (10 points)

a. Aqueous sulfuric acid is mixed with aqueous ammonium hydroxide

Balanced Reaction:

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

Net Ionic Equation:

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

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

Balanced Reaction:

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

Net Ionic Equation:

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

Part II. Answer three (3) of problems 10-13. Clearly mark the problem you do not want graded. 10 points each.

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

$$\underset{\{26.98\}}{2\ \text{Al (s)}} + \underset{\{56.11\}}{2\ \text{KOH (aq)}} + \underset{\{18.02\}}{6\ H_2O\ (l)} \rightarrow \underset{\{134.11\}}{2\ \text{KAl(OH)}_4\ \text{(aq)}} + \underset{\{2.02\}}{3\ H_2\ \text{(g)}}$$

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. (6 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?

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

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 $KAl(OH)_4$ would be produced assuming each reactant is the limiting reagent?

$$2.05\ \cancel{\text{g Al}} \times \frac{1\ \cancel{\text{mol Al}}}{26.9815\ \cancel{\text{g}}} \times \frac{2\ \text{mol KAl(OH)}_4}{2\ \cancel{\text{mol Al}}} = 0.0760\ \text{mol if Al is limiting reactant}$$

$$0.125\ \cancel{\text{L sol'n}} \times \frac{1.25\ \cancel{\text{mol KOH}}}{\cancel{\text{L sol'n}}} \times \frac{2\ \text{mol KAl(OH)}_4}{2\ \cancel{\text{mol KOH}}} = 0.156\ \text{mol if KOH is limiting reactant}$$

Since Al produces less $KAl(OH)_4$, 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)

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

Answer_______0.608 M $KAl(OH)_4$ ______

11. Consider the reaction of zinc metal with hydrochloric acid, as shown below. In an experiment, 2.04 grams of zinc is introduced into 25.0 mL of 2.00 M HCl. The gas that is evolved is collected over water. When the reaction is complete, 0.200 L of gas has been collected at 21ºC. What is the pressure in the container when the reaction is complete?

$$Zn(s) + 2HCl(aq) \rightarrow ZnCl_2(aq) + H_2(g)$$

$$2.04 \text{ g Zn} \times \frac{1 \text{ mol Zn}}{65.39 \text{ g Zn}} \times \frac{1 \text{ mol } H_2}{1 \text{ mol Zn}} = 0.03120 \text{ mol } H_2$$

$$0.0250 \text{ L HCl} \times \frac{2.00 \text{ mol HCl}}{1 \text{ L HCl}} \times \frac{1 \text{ mol } H_2}{2 \text{ mol HCl}} = 0.0250 \text{ mol } H_2$$

So, HCl is the limiting reactant and 0.0250 mol H_2 is formed. What pressure does this gas exert at our experimental conditions?

$$P_{H2} = \frac{nRT}{V} = \frac{(0.0250 \text{ mol } H_2)(0.08206 \text{ L atm/mol K})(294 \text{ K})}{0.200 \text{ L}} = \mathbf{3.02 \text{ atm } H_2}$$

Since this gas is collected over water, we also must account for the vapor pressure of water at 21ºC:

$$P_{H2O} \quad 18.65 \text{ mm Hg} = 18.65 \text{ mm Hg} \times \frac{1 \text{ atm}}{760 \text{ mmHg}} = \mathbf{0.025 \text{ atm } H_2O}$$

So, the total pressure is $P_{H2} + P_{H2O} = 3.02 + 0.024 =$ **3.04 atm**

Answer________3.04 atm ___________

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

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

a. If 1.00 g of ethanol {46.07} is burned in a 2.00 L container filled with oxygen {32.00}at 2.08 atm and 80ºC, how many moles of carbon dioxide {44.01} are produced? (4 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 CO_2 do we make if ethanol is the L.R.?

$$1.00\ \cancel{\text{g ethanol}} \times \frac{1\ \cancel{\text{mol ethanol}}}{46.07\ \cancel{\text{g}}} \times \frac{4\ \text{mol } CO_2}{2\ \cancel{\text{mol ethanol}}} = 0.0434_1\ \text{mol } CO_2$$

What if O_2 is the L.R.?

$$N_{O2} = \frac{PV}{RT} = \frac{(2.08\ \cancel{\text{atm}})(2.00\ \cancel{\text{L}})}{(0.0821\ \cancel{\text{Latm}}/\text{mol}\cancel{\text{K}})(353\cancel{\text{K}})} = 0.1359\ \text{mol } O_2$$

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

Therefore ethanol must be the L.R. and 0.0434_1 mol of CO_2 will be formed.

Answer________0.0434 mol CO_2_________

b. What will be the final pressure in the container? You may ignore the contribution of water vapor. (4 points)

Since O_2 is in excess, some will remain at the end of the reaction. How much?

$$0.0434_1\ \text{mol } CO_2 \times \frac{6\ \text{mol } O_2}{4\ \cancel{\text{mol}}\ CO_2} = 0.0651_2\ \text{mol } O_2 \text{ is consumed}$$

Therefore, $0.1359 - 0.0651_2 = 0.0708$ mol O_2 remains

So, we have a total of 0.0708 mol O_2 + 0.0434 mol CO_2 = 0.1142 mol gas and our pressure is:

$$p = \frac{nRT}{V} = \frac{(0.1142\ \cancel{\text{mol}})(0.0821\ \cancel{\text{L}}\text{-atm}/\cancel{\text{mol}}\ \cancel{\text{K}})(353\ \cancel{\text{K}})}{2.00\cancel{\text{L}}} = \mathbf{1.65\ atm}$$

Answer_________1.65 atm ____________

c. What volume would the gas occupy at STP? Use "old STP" of 0ºC and 1 atm. (2 points)

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

$$V_2 = \frac{P_1T_2V_1}{P_2T_1} = \frac{(1.65\ \text{atm})(273\ \text{K})(2.00\ \text{L})}{(1\ \text{atm})(353\ \text{K})} = \mathbf{2.56\ L}$$

Answer__________2.56 L _____________

13. Redox reactions:

a. Balance the following reaction in acidic solution. (8 points)

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

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:

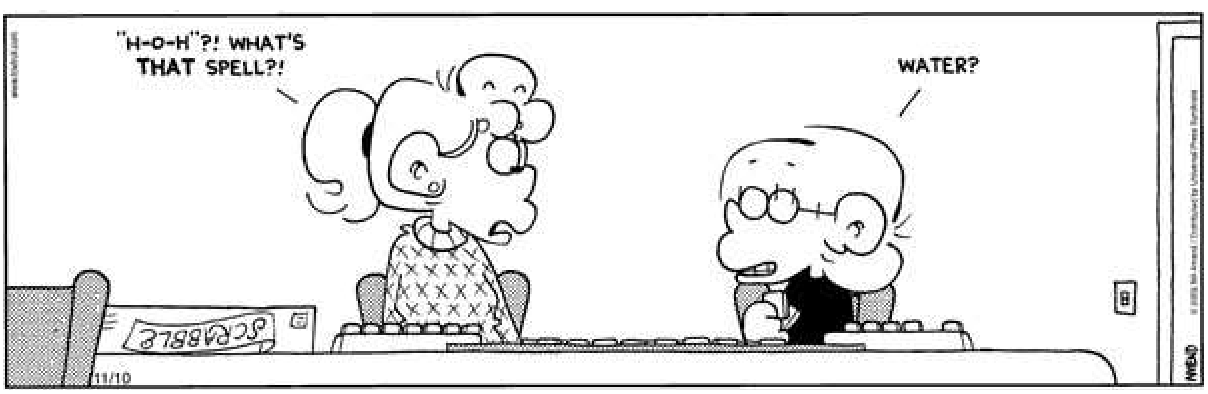
$$\mathbf{2\ MnO_4^- + 3\ CN^- + H_2O \rightarrow 2\ MnO_2 + 3\ OCN^- + 2\ OH^-}$$

Possibly Useful Information

$R = 0.08206$ L atm mol^{-1} K^{-1}	K = ºC + 273.15
1 atmosphere = 760 Torr = 760 mm Hg	Look both ways before crossing the street!
$P_{total}V = n_{total}RT$	$P_A = X_a P_{total}$
$N_a = 6.02214 \times 10^{23}$ mol^{-1}	$\frac{P_1V_1}{n_1T_1} = \frac{P_2V_2}{n_2T_2}$
% by mass = $\frac{\text{g component}}{\text{100 g sample}}$	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	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)