Chem 130
Exam 1, Ch 1-4
100 Points

Name________________________________
September 21, 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. Which of the following aspects of Dalton's atomic theory remains unchanged in our current understanding:
   a. Atoms are indivisible.
   b. All atoms of a particular element are identical.
   c. Compounds are the result of a combination of two or more different kinds of atoms in fixed ratios.
   d. None of the above.

   Answer ____**c**_______

2. A reaction mixture contains 1.0 mol $CaCN_2$ and 1.0 mol H_2O. The maximum number of moles NH_3 produced in the reaction below is

$$CaCN_2(s) + 3H_2O(l) \rightarrow CaCO_3(s) + 2NH_3(g)$$

   a. 3.0
   b. 2.0
   c. Between 1.0 and 2.0
   d. Less than 1.0

   Answer ____**d**_______

Part I: Complete all of problems 3-10

3. Identify four elements that exist naturally as diatomic molecules. (4 points)

   hydrogen, nitrogen, oxygen, fluorine, chlorine, bromine, iodine (any 4 will do)

4. Gallium is solid at 20°C. There are 1.16 x 10^{21} atoms in 134 mg of gallium at this temperature. Above 30°C, gallium melts (it melts in your hand!). How many atoms are there in 134 mg of gallium at 40°C? Briefly justify your answer. (4 points)

   Since all that has occurred is a phase change, the number of atoms will not change, therefore there are 1.16 x 10^{21} atoms!

5. Does calcium tend to form anions or cations? What is the charge on the ion? Briefly justify your answer. (4 points)

   Since calcium is a Group 2A element, it will form cations with +2 charge because losing two electrons allows it to reach a noble gas electron configuration. Were it to become an anion, it would need to gain 6 electrons, which is much less favorable energetically.

6. Complete the following table. (12 points)

Symbol	$^{79}Se^{2-}$	$^{133}Cs^{+}$	^{112}Cd
# of protons	34	**55**	48
# of neutrons	45	**78**	64
# of electrons	**36**	**54**	48
Charge	-2	**+1**	**0**
Name	**selenide-79**	**cesium-133 ion**	**cadmium-112**

7. Name the following compounds or provide the correct formula for the given names. (16 points)

a. $Mo(NO_3)_4$ **molybdenum (IV) nitrate**

b. B_2Br_4 **diboron tetrabromide**

c. $Sr(OH)_2$ **strontium hydroxide**

d. $(NH_4)_2S$ **ammonium sulfide**

e. xenon hexafluoride **XeF_6**

f. magnesium perchlorate **$Mg(ClO_4)_2$**

g. chromium (VI) cyanide **$Cr(CN)_6$**

h. sulfuric acid **H_2SO_4**

8. The atomic mass of gold (Au) is 196.97 amu and all gold atoms in a naturally occurring sample of gold have this mass. The atomic mass of silver (Ag) is 107.87 amu, but no silver atoms in a naturally occurring sample of silver have this mass. Explain this observation. (8 points)

Since all gold atoms have the same mass, this implies that there is only a single gold isotope (^{197}Au), since the atomic mass is the weighted average of the masses and abundances of all of the isotopes. Note that we don't say gold has *no isotopes*. Since no silver atom has a mass that corresponds to its atomic mass, there must be more than one isotope of silver. We can't say how many with the information that we are given. The best that we can say is that there are at least two silver isotopes and that the weighted average of their masses and abundances must be 107.87 amu

9. Write balanced reactions, specifying the state for all reactants and products. (8 points)

   a. Solid barium hydroxide octahydrate reacts with solid ammonium chloride to produce aqueous barium chloride, aqueous ammonium hydroxide and liquid water.

   $Ba(OH)_2 \bullet 8H_2O(s) + 2NH_4Cl(s) \rightarrow BaCl_2(aq) + 2NH_4OH(aq) + 8H_2O(\ell)$

   b. Aqueous potassium sulfide reacts with aqueous iron (III) nitrate to produce aqueous potassium nitrate and solid iron (III) sulfide.

   $3K_2S(aq) + 2Fe(NO_3)_3(aq) \rightarrow 6KNO_3(aq) + Fe_2S_3(s)$

10. A brand new penny is 19.05 mm in diameter and 1.52 mm thick and is 97.5% zinc and 2.5% copper by mass. Assuming the penny has the same density as zinc (7.13 g/cm^3), how many copper atoms are in a new penny? You may assume the penny is a cylinder with a volume of $\pi r^2 h$, where π = 3.14159, r is the radius and h is the thickness.(8 points)

First find the volume of the penny:

$$d = 2r = 19.05\text{ mm} = 1.905\text{ cm, so the radius is } 1.905\text{ cm}/2 = 0.9525\text{ cm}$$

$$V = \pi r^2 h = 3.14159\text{x}(0.9525\text{ cm})^2\text{x}0.152\text{ cm} = 0.4332\text{ cm}^3$$

Now that we know the volume, we use the density to find the mass:

$$0.4332\text{ cm}^3 \times \frac{7.13\text{ g penny}}{1\ \cancel{\text{cm}^3}} = 3.089\text{ g penny}$$

But, only 2.5 % of this mass is copper:

$$3.089\ \cancel{\text{g penny}} \times \frac{2.5\ \cancel{\text{g Cu}}}{100\ \cancel{\text{g penny}}} \times \frac{1\ \cancel{\text{mol Cu}}}{63.456\ \cancel{\text{g Cu}}} \times \frac{6.022\text{x}10^{23}\text{ atoms Cu}}{1\ \cancel{\text{mol Cu}}} = 7.3\text{x}10^{20}\text{ atoms Cu}$$

Answer_______7.3x10^{20} atoms Cu______

Part II. Answer three (3) of problems 11-14. Clearly mark the problem you do not want graded. 10 points each.

11. Nitrogen gas can be prepared by passing gaseous ammonia (NH_3) over solid copper (II) oxide at high temperatures. The other products of the reaction are solid copper and water vapor. In a certain experiment, a reaction mixture containing 18.1 g ammonia and 90.4 g copper oxide produces 6.63 g nitrogen gas. What is the percent yield for the reaction?

$$2NH_3 + 3CuO \rightarrow N_2 + 3Cu + 3H_2O$$

We need to find the limiting reactant and theoretical yield:

$$18.1\ \text{g NH}_3 \times \frac{1\ \text{mol NH}_3}{17.03\ \text{g NH}_3} \times \frac{1\ \text{mol N}_2}{2\ \text{mol NH}_3} \times \frac{28.01\ \text{g N}_2}{1\ \text{mol N}_2} = 14.86\ \text{g N}_2$$

$$90.4\ \text{g CuO} \times \frac{1\ \text{mol CuO}}{79.55\ \text{g CuO}} \times \frac{1\ \text{mol N}_2}{3\ \text{mol CuO}} \times \frac{28.01\ \text{g N}_2}{1\ \text{mol N}_2} = 10.61\ \text{g N}_2$$

Therefore CuO is the limiting reactant and the theoretical yield is 10.61 g N_2.

$$\%\ \text{yield} = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\% = \frac{6.63\ \text{g N}_2}{10.61\ \text{g N}_2} \times 100\% = 62.5\ \%\ \text{yield}$$

Answer_______62.5 % yield______

12. The Ostwald process, used for the commercial production of nitric acid, involves the three steps below. How many kilograms of ammonia (NH_3) are required to produce 1.00 kilograms of nitric acid if the percent yield for the entire process is 73.2%?

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$
$$2NO(g) + O_2(g) \rightarrow 2NO_2(g)$$
$$3NO_2(g) + H_2O(\ell) \rightarrow 2HNO_3(aq) + NO(g)$$

If 1.00 kg is only 73.2 % yield, we first need to figure out the theoretical yield for the reaction:

$$73.2\% = \frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$$

Therefore

$$73.2\% = \frac{1.00\ \text{kg}}{\text{theoretical yield}} \times 100\%$$ And the theoretical yield is 1.36_6 kg

$$1.36_6\ \text{kg HNO}_3 \times \frac{10^3\ \text{g}}{1\ \text{kg}} \times \frac{1\ \text{mol HNO}_3}{63.01\ \text{g HNO}_3} = 21.681\ \text{mol HNO}_3$$

$$21.681\ \text{mol HNO}_3 \times \frac{3\ \text{mol NO}_2}{2\ \text{mol HNO}_3} \times \frac{2\ \text{mol NO}}{2\ \text{mol NO}_2} \times \frac{4\ \text{mol NH}_3}{4\ \text{mol NO}} = 32.522\ \text{mol NH}_3$$

$$32.522\ \text{mol NH}_3 \times \frac{17.031\ \text{g NH}_3}{1\ \text{mol NH}_3} \times \frac{1\ \text{kg}}{10^3\ \text{g}} = 0.5539\ \text{kg NH}_3 = \mathbf{0.554\ kg\ NH_3}$$

Answer_______0.554 kg NH_3______

13. Isobutylene contains only carbon and hydrogen and is an important industrial chemical used in the production of a variety of products, ranging from antioxidants to polymers. Combustion of 1.00 grams of isobutylene results in the production of 3.14 grams of carbon dioxide and 1.28 grams of water. If the molar mass of isobutylene is 56.106 g/mol, what is its molecular formula?

$$3.14\ \cancel{g\ CO_2} \times \frac{1\ \cancel{mol\ CO_2}}{44.01\ \cancel{g\ CO_2}} \times \frac{1\ mol\ C}{1\ \cancel{mol\ CO_2}} = 0.07134\ mol\ C$$

$$1.28\ \cancel{g\ H_2O} \times \frac{1\ \cancel{mol\ H_2O}}{18.01\ \cancel{g\ H_2O}} \times \frac{2\ mol\ H}{1\ \cancel{mol\ H_2O}} = 0.1422\ mol\ H$$

So, a start at the empirical formula is $C_{0.07134}H_{0.1422}$. Since these are not whole number subscripts, we divide by the smallest one to produce C_1H_2 or CH_2 as the empirical formula. If this were also the molecular formula, the formula mass (14.03 g/mol) would match the molar mass, but it does not. Relating the molar mass to the formula mass tells us how many empirical formula "units" are in the molecular formula:

$$\frac{56.106\ g/mol}{14.03\ g/mol} = 3.999$$

This implies that our molecular formula contains four times as many atoms of each element as the empirical formula. **Therefore the molecular formula is C_4H_8**

Answer_______ C_4H_8_________

14. A compound that contains only potassium, chromium and oxygen was analyzed. If was found that the compound contained 26.58% potassium and 35.45% chromium by mass. What is the formula for this compound?

Given the percent composition, in 100 grams of the compound, there would be 26.58 g K, 35.45 g Cr and 100-(26.58+35.45) = 37.97 g O. We need a ratio of moles to determine the formula.

$$26.58\ \cancel{g\ K} \times \frac{1\ \cancel{mol\ K}}{39.10\ \cancel{g\ K}} = 0.6798\ mol\ K$$

$$35.45\ \cancel{g\ Cr} \times \frac{1\ \cancel{mol\ Cr}}{51.99_6\ \cancel{g\ K}} = 0.6818\ mol\ Cr$$

$$37.97\ \cancel{g\ O} \times \frac{1\ \cancel{mol\ O}}{15.99_9\ \cancel{g\ O}} = 2.373\ mol\ O$$

So, a first shot at a formula is $K_{0.6798}Cr_{0.6818}O_{2.373}$. Dividing by the smallest subscript, the formula becomes $KCrO_{3.49}$. We now double each subscript to produce whole number values, making the formula **$K_2Cr_2O_7$**.

Answer_______ $K_2Cr_2O_7$_________

Possibly Useful Information

% by mass $= \frac{\text{g component}}{\text{100 g sample}}$	$d = m/v$	$N_A = 6.022 \times 10^{23}$

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)