Chem 130 **Name**________________________________
Exam 1 **September 20, 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.

Part 0: Warmup. 4 points each

1. When 10.0 g zinc and 8.0 g sulfur are allowed to react, all of the zinc is consumed and 15.0 g zinc sulfide is produced. The mass of unreacted sulfur remaining is:
   a. 2.0 g
   b. 3.0 g
   c. 5.0 g — Answer _____b_______
   d. Impossible to predict from this information alone.

2. Which of the following have roughly the same mass:
   a. a proton and an electron
   b. an electron and a neutron
   c. a neutron and a proton — Answer _____c_______
   d. a proton and a bowling ball

3. Thallium has two stable isotopes, ^{203}Tl and ^{205}Tl. Given that the atomic mass of thallium is 204.383 amu, which isotope must have the larger natural abundance?
   a. ^{203}Tl
   b. ^{205}Tl
   c. Both have the same natural abundance. — Answer _____b_______
   d. Not enough information to make this determination.

Part I: Complete all of problems 4-10

4. Define the following using a maximum of two sentences for each definition. (4 points)
   a. accuracy: The proximity of a data point to the "true value"

   b. precision: The reproducibility of a measurement or set of data.

5. A solution consisting of 8.50% ethanol and 91.50% water by mass has a density of 0.9867 g/mL. What mass of ethanol, in kg, is present in 7.50 L of the solution? (8 pts)

$$7500\ \cancel{mL} \times \frac{0.9867\ \cancel{g\ soln}}{\cancel{mL}} \times \frac{8.50\ \cancel{g}\ ethanol}{100\ \cancel{g\ soln}} \times \frac{1\ kg}{10^3\ \cancel{g}} = \mathbf{0.629\ kg\ ethanol}$$

6. Complete the following table. (12 points)

Symbol	$^{40}Ca^{2+}$	^{75}As	$^{32}S^{2-}$
# of protons	20	33	16
# of neutrons	20	42	16
# of electrons	18	33	18
Charge	+2	0	-2
Name	calcium-40 ion	arsenic-75	sulfide-32 ion

7. Name the following compounds or provide the correct formula for the given names. (12 pts)

a. iron (III) sulfate — $Fe_2(SO_4)_3$

b. CaF_2 — calcium fluoride

c. N_2O_5 — dinitrogen pentoxide

d. diphosphorous tetrafluoride — PF_4

e. aluminum carbonate — $Al_2(CO_3)_3$

f. $Cr(PO_4)_2$ — chromium (VI) phosphate

8. How many copper-65 atoms are in a piece of copper weighing 215 µg? The percent natural abundance of copper-65 is 30.83%. (8 points)

$$215\ \cancel{\mu g\ Cu} \times \frac{10^{-6}\ g}{1\ \cancel{\mu g}} = 2.15 \times 10^{-4}\ g\ Cu$$

$$2.15 \times 10^{-4}\ \cancel{g\ Cu} \times \frac{1\ \cancel{mol\ Cu}}{63.546\ \cancel{g\ Cu}} \times \frac{6.02\times10^{23}\ atoms\ Cu}{1\ \cancel{mol\ Cu}} = 2.037 \times 10^{18}\ Cu\ atoms$$

$$2.037 \times 10^{17}\ \cancel{atoms\ Cu} \times \frac{30.83\ atoms\ ^{65}Cu}{100\ \cancel{atoms\ Cu}} = \mathbf{6.28 \times 10^{17}\ ^{65}Cu\ atoms}$$

9. The atomic mass of silver is 107.868 amu and silver exists as two isotopes with nearly equal abundance. If you were able to pick up a single silver atom, what is the chance that you would get one with a mass of 107.868 amu? No calculations are needed, but you must clearly justify your answer. (8 points)

There is zero chance of finding an atom of mass 107.868 amu. Because 107.868 amu must be the "weighted average" of the masses of individual isotopes, and because there are only two isotopes, neither can have mass 107.868 amu. One isotope must have a mass greater than 107.868 amu and one must have a mass smaller than 107.868 amu

10. Balance the reactions below: (8 points)
    a. $Mg_3N_2 + HCl \rightarrow MgCl_2 + NH_3$

$$Mg_3N_2 + 6\ HCl \rightarrow 3\ MgCl_2 + 2\ NH_3$$

    b. ammonium sulfide and iron(III) nitrate react to form ammonium nitrate and iron(III) sulfide

$$3(NH_4)_2S + 2Fe(NO_3)_3 \rightarrow 6NH_4NO_3 + Fe_2S_3$$

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

11. While Dalton's atomic theory is still the foundation for our understanding of basic chemical principles, our ability to better characterize atoms and compounds has identified a few shortcomings or errors in the theory. Identify the four key tenets of Dalton's theory and describe at least one shortcoming or error in the theory.

The four key points are

1. All matter is made of atoms, which are indivisible.
2. All atoms of a given element are identical
3. Compounds are the result of a combination of two or more different kinds of atoms
4. Chemical reactions involve the combination, separation or rearrangement of atoms

The key shortcoming is that Dalton's theory does not account for the presence of isotopes, which are atoms of the same element that are not identical because they have different numbers of neutrons.

We also now know that atoms can be split into smaller components (protons, neutrons, electrons and smaller).

12. Silicon has three stable isotopes, ^{28}Si, ^{29}Si, and ^{30}Si with masses of 27.98 amu, 28.98 amu, and 29.77 amu, respectively. If the natural abundance of ^{28}Si is 92.23%, what are the percent abundances of the other two isotopes?

The total abundance of ^{29}Si, and ^{30}Si must be: 100 – 92.23 = 7.77 %

So: $f_{29} + f_{30} = 0.0777$ where f_x is the fractional abundance of the isotope with mass # x.

And: $(0.9223 \times 27.98) + 28.98f_{29} + 29.77f_{30} = 28.0855$ (This is our definition of atomic mass)

Now we need to find f_{29} and f_{30}:

$$f_{30} = 0.0777 - f_{29}$$
$$28.98f_{29} + 29.77f_{30} = 28.0855 - (0.9223 \times 27.98) = 2.2795$$
$$28.98f_{29} + 29.77(0.0777 - f_{29}) = 2.2795$$
$$28.98f_{29} - 29.77f_{29} = 2.2795 - (29.77 \times 0.0777) = -0.03363$$
$$-0.79f_{29} = -0.03363$$
$$f_{29} = 0.04257$$
$$\text{So, } f_{30} = 0.0777 - 0.04257 = 0.03513$$

So, the percent abundance for ^{29}Si is 4.26% and the percent abundance for ^{30}Si is 3.51%

13. One of the reasons that methamphetamine is such a problem is that it is a relatively small molecule that is fairly easy to synthesize. A molecule of methamphetamine contains only carbon, hydrogen, and nitrogen and has a molar mass of 149.2 g/mol. If methamphetamine is 80.48% C and 9.39% N by mass, what is its molecular formula?

So, the percent H must be: 100-80.48-9.39 = 10.13%H
There are several ways to solve this problem. Here is one:

$$\frac{149.2\ \cancel{\text{g meth}}}{1\ \text{mol meth}} \times \frac{80.48\ \cancel{\text{g C}}}{100\ \cancel{\text{g meth}}} \times \frac{1\ \text{mol C}}{12.011\ \cancel{\text{g C}}} = \frac{9.997\ \text{mol C}}{1\ \text{mol meth}}$$

$$\frac{149.2\ \cancel{\text{g meth}}}{1\ \text{mol meth}} \times \frac{9.39\ \cancel{\text{g N}}}{100\ \cancel{\text{g meth}}} \times \frac{1\ \text{mol N}}{14.0067\ \cancel{\text{g N}}} = \frac{1.000\ \text{mol N}}{1\ \text{mol meth}}$$

$$\frac{149.2\ \cancel{\text{g meth}}}{1\ \text{mol meth}} \times \frac{10.13\ \cancel{\text{g H}}}{100\ \cancel{\text{g meth}}} \times \frac{1\ \text{mol H}}{1.00794\ \cancel{\text{g H}}} = \frac{14.995\ \text{mol H}}{1\ \text{mol meth}}$$

So, the likely formula is $C_{9.997}H_{14.995}N_{1.000}$ or, $C_{10}H_{15}N$. Is this really the molecular formula?
Check the molar mass:
10(12.011) + 15(1.00794) + 14.0067 = 149.23
Therefore, $C_{10}H_{15}N$ must be the molecular formula!

14. Iron ore is impure Fe_2O_3. When Fe_2O_3 is heated with carbon, metallic iron and carbon monoxide gas are formed. From a sample of ore weighing 895 g, 432 g of pure iron is obtained. What is the percent Fe_2O_3, by mass, in the original ore sample? (molar masses (g/mol): Fe_2O_3 = 159.6922, carbon monoxide = 28.010)

From the formula and molar mass of iron oxide, we know there are 2(55.847) = 111.694 g Fe per 159.6922 g Fe_2O_3. So if we ended up 432 g Fe, there must have been:

$$432\ \cancel{\text{g Fe}} \times \frac{159.6922\ \text{g } Fe_2O_3}{111.694\ \cancel{\text{g Fe}}} = 617.6\ \text{g } Fe_2O_3$$

Therefore, 617.6 grams of Fe_2O_3 must have been present in the original sample. In terms of percent, this corresponds to:

$$\frac{617.6\ \text{g } Fe_2O_3}{895\ \text{g ore}} \times 100\% = \mathbf{69.0\%\ Fe_2O_3}$$

Note that you can get the same mass of Fe_2O_3 using the reaction stoichiometry:

$$Fe_2O_3 + 3\ C \rightarrow 2\ Fe + 3\ CO$$

$$432\ \cancel{\text{g Fe}} \times \frac{1\ \cancel{\text{mol Fe}}}{55.847\ \cancel{\text{g Fe}}} \times \frac{1\ \cancel{\text{mol } Fe_2O_3}}{2\ \cancel{\text{mol Fe}}} \times \frac{159.6922\ \text{g } Fe_2O_3}{1\ \cancel{\text{mol } Fe_2O_3}} = \mathbf{617.6\ g\ Fe_2O_3}$$

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

Possibly Useful Information

$D = m/v$

$N_a = 6.02214 \times 10^{23}\ mol^{-1}$

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)