

CHEM 120
Fall 2009
Exam 1

Name: _____

Instructions

Write your answers in blue or black ink. Work done in pencil will be accepted, but you will not be able to appeal any apparent grading mistakes (except simple addition errors). Write neatly. If I can't read it, I can't grade it.

Show all work for full credit! For the word problems write your final answer in a complete sentence. Indicate what you are doing at important steps (you do not need to tell me about every mathematical manipulation you do). If you change your mind on a question, cross out the incorrect answer and clearly indicate your final answer.

There are **9** pages, none blank, and a periodic table.

You may use the back of any page as additional workspace. Please indicate that you have done so.

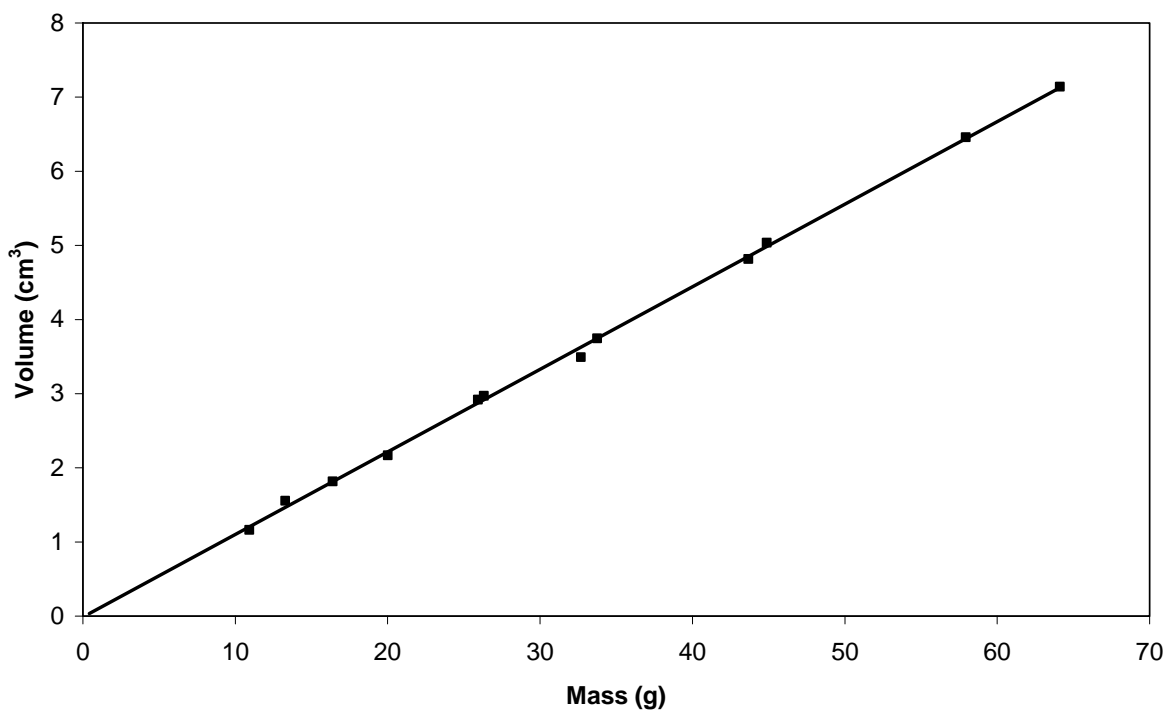
Problem	Possible Points	Points Received
1	17	
2	9	
3	10	
4	12	
5	17	
6	22	
Take-Home	63	
Total	150	
	Bonus	
	Grand Total	

1. (17 Points) Fill in the blank with the correct answer.

a. An atom/ion of iron-57 has 23 electrons. This species atom's atomic number is **26**, its mass number is **57**. The elemental symbol would be $^{57}\text{Fe}^{3+}$.

b. How many neutrons does deuterium have? **1**

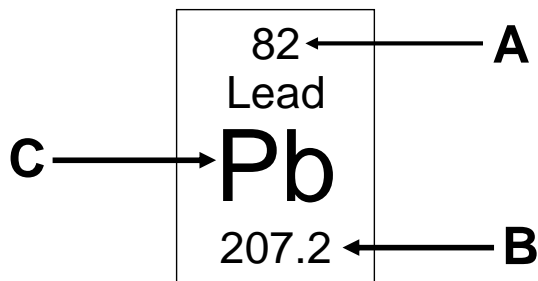
Density of Copper from Block's Mass and its Dimensions



c. The above graph shows **volume** as a function of **mass**.

d. **Allotropes** are forms of elements that differ only in how the atoms are arranged in space.

e. A measurement's precision increases as the estimated standard deviation for a set of replicate measurements **decreases**.



f. In the figure above,

A is the element's **atomic number**, and

B is the element's **atomic weight**.

g. Name of the Group 18 elements: **noble gases**

h. Name one alkali metal: **Li, Na, K, Rb, Cs, Fr**

h. Name one transition metal: **see periodic table**

i. Name the pnictogen that is a diatomic gas in its elemental state: **N₂**

j. The atomic mass unit is defined in terms of the mass of the ¹²C atom.

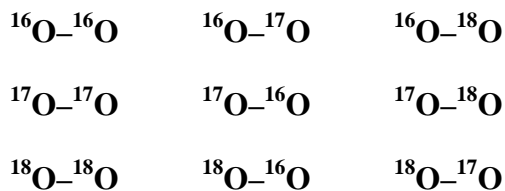
k. A positively charged ion is called a(n) **cation**.

l. A(n) **heterogeneous mixture** is a physical combination of two or more pure substances which does not have a uniform composition throughout.

m. The **atomic weight** is the mass of an average atom of an element.

2. Oxygen has three naturally occurring isotopes: ^{16}O (99.76% natural abundance), ^{17}O (0.04% natural abundance) and ^{18}O (0.02% natural abundance).

a. (3 Points) Give the different combinations of isotopes that can exist in a naturally occurring sample of O_2 . FYI different forms of a molecule that only differ in the isotopes present in the individual molecules are called isotopomers.



b. (3 Points) Which of these different ways of combining the isotopes in an O_2 molecule is the most likely to be found? Why? Hint: no detailed calculation is needed.

The combination $^{16}\text{O}-^{16}\text{O}$ would be the most likely to be found because the natural abundance of ^{16}O is so much higher than the other isotopes. Although there are more ways to make the combinations with mixed isotopes (e. g., $^{16}\text{O}-^{17}\text{O}$), the low natural abundance of the ^{17}O and ^{18}O means that they are not going to be that plentiful.

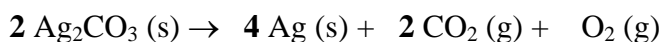
c. (3 Points) If you took a random sample of 50 O_2 molecules (i. e., 100 O atoms) from the atmosphere, would you expect to see any ^{17}O atoms in the sample? Explain.

We might have an ^{17}O atom in our sample. Given the isotope's low natural abundance and the small sample size, we may not see any at all, or we may see several. If we to have a larger sample size, we would have a greater chance of finding an ^{17}O , but even then we might not see one.

3. (10 Points) Complete the following table.

Name	Chemical Formula
mercury(I) nitrate	$\text{Hg}_2(\text{NO}_3)_2$
copper(I) perchlorate	CuClO_4
phosphorous trichloride	PCl_3
lead(II) acetate trihydrate	$\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2 \cdot 3\text{H}_2\text{O}$
sulfur hexafluoride	SF_6
mercury(II) sulfate	HgSO_4
silicon tetrachloride	SiCl_4
cobalt(III) sulfide	Co_2S_3
aluminum carbide	Al_4C_3
barium hydroxide octahydrate	$\text{Ba}(\text{OH})_2 \cdot 8\text{H}_2\text{O}$

4. The compound Ag_2CO_3 decomposes when heated according to the following unbalanced chemical reaction. Molar masses: Ag_2CO_3 275.75 g/mole, CO_2 44.009 g/mole.



a. (1 Point) Balance the chemical equation.

b. (8 Points) A 1.7510-g sample containing an unknown amount of Ag_2CO_3 is heated and 0.1375 g CO_2 are collected. What is the % Ag by mass in the sample?

Determine the mass of Ag formed from the mass of CO_2 produced. Note that the amount of Ag_2CO_3 is irrelevant since the problem asked for % Ag by mass and the mass of Ag in the sample must equal the mass of Ag produced.

$$0.1375 \text{ g CO}_2 \left(\frac{1 \text{ mole CO}_2}{44.009 \text{ g CO}_2} \right) \left(\frac{4 \text{ mole Ag}}{2 \text{ mole CO}_2} \right) \left(\frac{107.87 \text{ g Ag}}{1 \text{ mole Ag}} \right) = 0.6740_{49} \text{ g Ag}$$

From information given on the original exam the solution is as follows (yes, this number is incorrect and unreasonable because I missed the typo on the sample mass).

$$\% \text{ Ag by mass} = \frac{0.6740_{49} \text{ g Ag}}{0.7510} \times 100 = 89.75\%$$

With the corrected sample mass (as shown here), the solution is then.

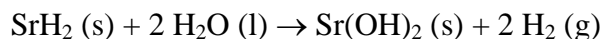
$$\% \text{ Ag by mass} = \frac{0.6740_{49} \text{ g Ag}}{1.7510} \times 100 = 38.50\%$$

The sample is 38.50% by weight Ag.

c. (3 Points) A chemical reaction that is used to analyze a sample, such as is being done in this problem, need to be quantitative. This means that their percent yield is very close to 100%. If the yield were less than 100%, would it cause your measured % Ag by mass to be higher, lower or the same? Why?

If the percent yield were less than 100%, we would obtain less CO₂ than we should have and therefore the calculated % Ag by mass would be less than what it actually is. This will lead to a systematic error in that all of our measured % Ag by mass results will be less than the true value because some of the Ag either did not react, some of the CO₂ was lost or the Ag₂CO₃ was consumed in a side reaction that did not generate CO₂.

5. Metal hydrides react with water, sometimes violently, to produce the metal hydroxide and hydrogen gas, as shown below for strontium hydride.



a. (9 Points) If 5.63 g of SrH₂ is reacted with 4.80 g H₂O, how much H₂ can be formed? Molar masses: SrH₂, 89.64 g/mole; H₂O, 18.0148 g/mole; Sr(OH)₂, 121.63 g/mole and H₂ 2.0158 g/mole.

Determine the limiting reagent and how much H₂ is formed.

$$5.63 \text{ g SrH}_2 \left(\frac{1 \text{ mole SrH}_2}{89.64 \text{ g SrH}_2} \right) \left(\frac{2 \text{ mole H}_2}{1 \text{ mole SrH}_2} \right) \left(\frac{2.0158 \text{ g H}_2}{1 \text{ mole H}_2} \right) = 0.253 \text{ g H}_2$$

$$4.80 \text{ g H}_2\text{O} \left(\frac{1 \text{ mole H}_2\text{O}}{18.0148 \text{ g H}_2\text{O}} \right) \left(\frac{2 \text{ mole H}_2}{2 \text{ mole H}_2\text{O}} \right) \left(\frac{2.0158 \text{ g H}_2}{1 \text{ mole H}_2} \right) = 0.537 \text{ g H}_2$$

Since a smaller amount of H₂ is formed if all of the SrH₂ reacts, SrH₂ is the limiting reagent and 0.253 g H₂ are formed.

b. (8 Points) Identify the reactant present in excess and calculate how much of it is left when the reaction is over.

Since SrH₂ is the limiting reagent, H₂O is present in excess. The moles of H₂O that reacted are

$$5.63 \text{ g SrH}_2 \left(\frac{1 \text{ mole SrH}_2}{89.64 \text{ g SrH}_2} \right) \left(\frac{2 \text{ mole H}_2\text{O}}{1 \text{ mole SrH}_2} \right) \left(\frac{18.0148 \text{ g H}_2\text{O}}{1 \text{ mole H}_2\text{O}} \right) = 2.26_2 \text{ g H}_2\text{O}$$

This leaves $4.80 \text{ g} - 2.26_2 \text{ g} = 2.54 \text{ g}$ of H₂O remaining.

There are 2.54 g of H₂O left when the reaction is complete.

6a. (9 Points) A compound was analyzed and found to be 26.5% C, 3.3% H, 35.2% O and 34.9% Cu by mass. What is the compound's empirical formula?

Assume 100 g of the compound so the percentages become masses, and then calculate the moles of each element present. Divide moles by moles of the element with the fewest number of moles to obtain the empirical formula.

Element	Mass (g)	Moles	Moles/Moles Cu
C	26.5	$26.5 \text{ g} \left(\frac{1 \text{ mole}}{12.011 \text{ g}} \right) = 2.20_6 \text{ mole C}$	4.02
H	3.3	$3.3 \text{ g} \left(\frac{1 \text{ mole}}{1.0079 \text{ g}} \right) = 3.2_7 \text{ mole H}$	6.0
O	35.2	$35.2 \text{ g} \left(\frac{1 \text{ mole}}{15.999 \text{ g}} \right) = 2.20_0 \text{ mole O}$	4.01
Cu	34.9	$34.9 \text{ g} \left(\frac{1 \text{ mole}}{63.546 \text{ g}} \right) = 0.549_2 \text{ mole Cu}$	1.00

The empirical formula is thus CuC₄H₆O₄.

b. (8 Points) If the molar mass of this compound is found to be 363.3 g/mole by mass spectroscopy, what is the chemical formula of the compound? Explicitly show all work for full credit.

Determine the molar mass of the empirical formula.

Element	Moles
4 C	4 mole C $\left(\frac{12.011 \text{ g}}{1 \text{ mole}}\right) = 48.044 \text{ g C}$
6 H	6 mole H $\left(\frac{1.0079 \text{ g}}{1 \text{ mole}}\right) = 6.0474 \text{ g H}$
4 O	4 mole O $\left(\frac{15.999 \text{ g}}{1 \text{ mole}}\right) = 63.996 \text{ g O}$
1 Cu	1 mole Cu $\left(\frac{63.546 \text{ g}}{1 \text{ mole}}\right) = 63.546 \text{ g Cu}$
1 mole $\text{CuC}_4\text{H}_6\text{O}_4$	181.633 g

Take the ratio of the actual molar mass to the empirical molar mass to find the whole number to multiply the empirical formula by to get the true chemical formula.

$$\frac{\text{molar mass actual}}{\text{molar mass empirical}} = \frac{363.3 \text{ g/mole}}{181.633 \text{ g/mole}} = 2.000$$

This means that the true chemical formula is twice the molar mass. Therefore the true chemical formula is $\text{Cu}_2\text{C}_8\text{H}_{12}\text{O}_8$.

c. (2 Points) This compound is known to contain only Cu^{2+} and the acetate ion, write its actual chemical formula assuming that the compound is ionic.

Acetate ion has the formula $\text{C}_2\text{H}_3\text{O}_2^-$. The amount of C, H and O present are consistent with four acetates being present ($4 \times \text{C}_2\text{H}_3\text{O}_2 = \text{C}_8\text{H}_{12}\text{O}_8$). Thus the chemical formula may be written as $\text{Cu}_2(\text{C}_2\text{H}_3\text{O}_2)_4$.

d. (3 Points) Why is your answer to part c seemingly strange, given what you know so far in this class?

For most ionic compounds the empirical formula is the same as the formula unit (the simplest combination of cation and anion that give a neutral charge). This means that the empirical formula and the chemical formula would be the same. In this case, it is not, which is seemingly at odds with what we've learned so far.

Note that this compound belongs to a family of compounds known as coordination compounds that we'll learn about next semester.