Chemistry 103, Dr. Lamont
Help Sheet #5; Chapter 4 – Part I
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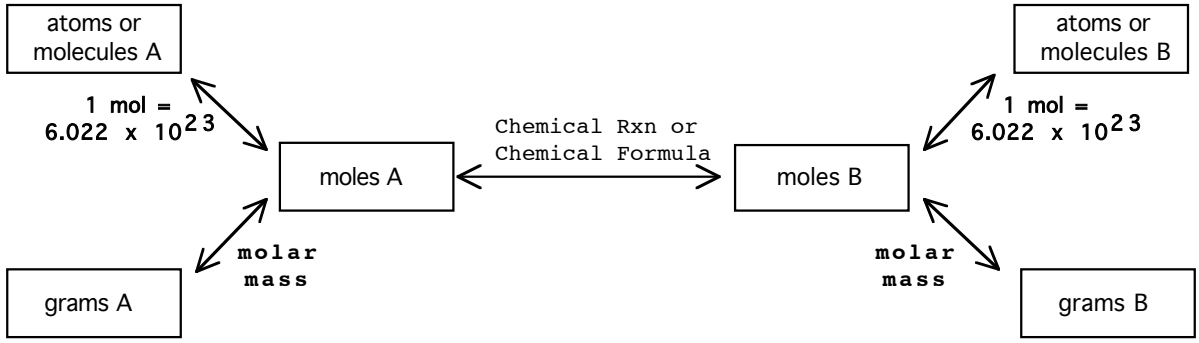
Nuggets: *Stoichiometric Calculations; Limiting reagents; Percent yield; Empirical Formulas determined from Combustion*

CHEMICAL EQUATIONS: reactants (the starting reagents) yield products (the ending materials)
Be able to balance chemical equations

STOICHIOMETRY: Given a chemical reaction and the quantity of one of the reagents in the equation, be able to determine the quantities of all the other reagents.



LIMITING REAGENTS: one reagent runs out first; this is the limiting reagent

PERCENT YIELD = $\frac{\text{actual yield}}{\text{theoretical yield}}$ x 100% where actual yield is the actual amount obtained (must be given to you) and theoretical yield is a calculated amount. If percent yield > 100% then something has been missed (e.g., the sample may be wet, etc.)

EMPIRICAL FORMULA from mass CO_2 and H_2O/chemical analysis

A. Compound contains C and H only
1. Convert gCO_2 → mol CO_2 → **mol C**
2. Convert gH_2O → mol H_2O → **mol H**
3. Write formula and divide by smallest moles
4. If needed, fractions: $^1/_2$ (0.5) → x 2; $^1/_3$ or $^2/_3$ (0.33, 0.66) → x 3; $^1/_4$ or $^3/_4$ (0.25, 0.75) → x 4

B. Compound contains C, H, and O
1. Convert gCO_2 → mol CO_2 → **mol C → gC** (need both mol C *and* gC)
2. Convert gH_2O → mol H_2O → **mol H → gH** (need both mol H *and* gH)
3. Calculate gO from: total g sample = gC + gH + gO (gO = total g sample - gC - gH)
4. Convert O → **mol O**
5. Write formula and divide by smallest moles
6. If needed, fractions: $^1/_2$ (0.5) → x 2; $^1/_3$ or $^2/_3$ (0.33, 0.66) → x 3; $^1/_4$ or $^3/_4$ (0.25, 0.75) → x 4

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1. Copper metal reacts with nitric acid. Assume that the reaction is

$$3Cu(s) + 8HNO_3(aq) \rightarrow 3Cu(NO_3)_2(aq) + 2NO(g) + 4H_2O(l)$$

a. If 10.00 g $Cu(NO_3)_2$ is obtained, how many grams of nitrogen monoxide, NO, would have also formed?

b. How many grams of water would also have formed?

2. Nitric acid, HNO_3, is manufactured by the Oswald process, in which nitrogen dioxide, NO_2, reacts with water.

$$3NO_2(g) + H_2O(l) \rightarrow 2HNO_3(aq) + NO(g)$$

How many grams of nitrogen dioxide, NO_2, are required in this reaction to produce 5.00 g HNO_3.

3. Calculate the masses (in grams) of Cr_2O_3 (chromium (III) oxide), N_2, and H_2O produced from 10.8 g of $(NH_4)_2Cr_2O_7$ (ammonium dichromate) in the following balanced reaction:

$$(NH_4)_2Cr_2O_7(s) \rightarrow Cr_2O_3(s) + N_2(g) + 4H_2O(l)$$

4. I. Given the following balanced combustion reaction below, if there were 3.0 mol of C_2H_4 and 6.0 mol of O_2, how many moles of CO_2 could theoretically be produced?

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

II. After the above reaction was completed, 3.5 mol of CO_2 were actually obtained. What is the percent yield of this reaction? (Note: You can only do this part with the correct answer to part I.)

5. A 25.00g mixture of sodium oxide, Na_2O, and sodium carbonate, Na_2CO_3, is placed in a crucible and heated. When heated, the Na_2CO_3 gives off CO_2 and forms Na_2O, with the new mass in the crucible after heating being 18.77g. The original Na_2O in the crucible is unchanged during the heating process. What was the mass percent of Na_2O in the *original mixture* before the sample was heated.

6. A 15.00g mixture of ammonium sulfate, $(NH_4)_2SO_4$, and iron(III) sulfate, $Fe_2(SO_4)_3$, is placed in a crucible and heated. When heated, the $(NH_4)_2SO_4$ gives off NH_3 and forms H_2SO_4 which remains in the crucible. The new mass after heating was 11.91g. What was the mass percent of $Fe_2(SO_4)_3$ in the original mixture before the sample was heated.

7. When hydrogen and oxygen react, water is produced as shown in the reaction below:

$$2H_2(g) + O_2(g) \rightarrow 2H_2O(g)$$

The reaction initially has 9 molecules of hydrogen and 3 molecules of oxygen. These chemicals now react to completion. **Draw a picture** of the reaction vessel initially **before** the reaction has started, and **draw a second picture** of the reaction vessel **after** the reaction is complete showing how the chemicals have changed (i.e., fewer H_2 molecules, etc. Use H–H for hydrogen, O–O for oxygen, and H–O–H for the water.

8. Given the reaction $3Ca + N_2 \rightarrow Ca_3N_2$ if 7.55g Ca and 22.5g N_2 react

a. What is the theoretical yield in grams of Ca_3N_2?
b. Which is the limiting reactant in the reaction?
c. Which is the excess reactant?
d. What mass of the excess reagent remains at the end of the reaction?
e. If 5.75g of Ca_3N_2 were recovered, what is the percent yield of the reaction?

9. Given the reaction $2C_3H_6 + 9O_2 \rightarrow 6CO_2 + 6H_2O$ if 30.75g C_3H_6 and 45.85g O_2 react

a. What is the theoretical yield in grams of CO_2?
b. Which is the limiting reactant in the reaction?
c. What mass of the excess reagent remains at the end of the reaction?

10. When a compound containing carbon and hydrogen is combusted, 3.38 g CO_2 and 0.692 g H_2O are recovered. a. What is the empirical formula? b. The MW of the compound is 78 g/mol. What is the molecular formula? (Use AW_C = 12 g/mol and AW_H = 1 g/mol)

11. When 5.00 g of a compound containing carbon, hydrogen, and oxygen is combusted, 8.911 g CO_2 and 3.648 g H_2O are recovered. a. What is the empirical formula? b. The molar mass of the compound is 74 g/mol. What is the molecular formula?

12. When 10.55g $Mn_xC_yO_z$ is heated, 5.745g manganese(III) oxide and 4.805g carbon dioxide are formed. a. Write and balance the reaction described. b. Determine the empirical formula for this compound.

13. When 15.00g of a carbon, hydrogen, and oxygen compound is combusted, 29.63g of CO_2 and 13.65g of H_2O are recovered. a. What is the empirical formula of this compound? b. If the molar mass of the compound is 267.3g/mol, what is its molecular formula?

ANSWERS

1. a. 1.06 g NO b. 1.28 g H_2O
2. 5.48
3. 6.52 g Cr_2O_3, 1.20 g N_2, 3.09 g H_2O
4. I. 4 mol II. 87.5%
5. 40.0%
6. 20.0%
7. See below.
8. a. 9.31g Ca_3N_2 b. Ca c. N_2 d. 20.7g N_2 left over e. 61.8%
9. a. 42.03g CO_2 b. O_2 c. 17.38 C_3H_6 left over
10. a. CH b. C_6H_6
11. a. $C_3H_6O_2$ b. $C_3H_6O_2$
12. a. $Mn_xC_yO_z \rightarrow Mn_2O_3(s) + CO_2(g)$ b. $Mn_2C_3O_9$
13. a. $C_4H_9O_2$ b. $C_{12}H_{27}O_6$

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