Stoichiometry

Stoichiometry is the study of quantitative relationships within chemical reactions. If you are given the mass of one substance and know the *balanced equation*, you can calculate the reactants needed for the products produced because the equation shows relative number of moles of reactants and products.

Types of Problems in Stoichiometry

1. Mole-Mole (moles are given and you need to find moles)
2. Mass-Mole (grams are given and you need to find moles)
3. Mass-mass (grams are given and you need to find grams)
4. Mass-volume (grams are given and you need to find mL or L)
5. Volume-mass (mL or L are given and you need to find grams)
6. Volume-volume (mL or L are given and you need to find mL or L)
7. Limiting Reactant (amount of both reactants are given and you need to find the one that will limit the amount of product)

**Pay attention to the units given in the problem!

MOLE-MOLE

The procedure for solving mole-mole problems:

1. Write a balanced equation
2. Determine the mole ratio from the coefficients of the balanced equation and convert from moles of **given** material to moles of **required** material.

$$\text{Mole Ratio} = \frac{\text{Number of moles required substance}}{\text{Number of moles given substance}}$$

The required substance is the substance you are trying to find; the given substance is the substance they give you in the problem with the amount

For example: If you reacted hydrogen gas and oxygen gas to form water vapor and you began with 0.5 mol of hydrogen gas, how many moles of water could be formed?

The balanced equation would be:

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

The mole ratio would be: $\frac{2\ \text{mol}\ H_2O}{2\ \text{mol}\ H_2}$

You would set your problem up as a conversion:

$$0.5\ \text{mol}\ H_2 \times \frac{2\ \text{mol}\ H_2O}{2\ \text{mol}\ H_2} = 0.5\ \text{mol}\ H_2O$$

If for the same equation you started with 0.5 mol of oxygen gas you would set it up as:

$$0.5\ \text{mol}\ O_2 \times \frac{2\ \text{mol}\ H_2O}{1\ \text{mol}\ O_2} = 1\ \text{mol}\ H_2O$$

Practice: Perform the following mole to mole conversions.

1. copper (II) sulfate reacts with aluminum to yield aluminum sulfate and copper
   If you were given 0.5 moles of aluminum how many moles would you have of:
   a. copper sulfate

   b. aluminum sulfate

   c. copper

2. calcium and aluminum chloride react to produce calcium chloride and aluminum
   If you were given 2.5 moles of calcium how many moles would you have of:
   a. aluminum chloride

   b. calcium chloride

   c. aluminum

MASS-MOLE

The procedure for solving mass-mole problems:

1. Write a balanced equation
2. Convert from mass of given material to moles (use molar mass from the periodic chart!) *If mass is not in grams convert it to grams!
3. Determine the mole ratio from the coefficients of the balanced equation and convert from moles of **given** material to moles of **required** material.

Practice: Perform the following mass-mole conversions.

1. $3\ CuSO_4 + 2\ Al \rightarrow Al_2(SO_4)_3 + 3\ Cu$
   If given 13.5 g of Al determine the moles of:
   a. $CuSO_4$

   b. $Al_2(SO_4)_3$

   c. Cu

2. $3\ Ca + 2\ AlCl_3 \rightarrow 3\ CaCl_2 + 2\ Al$
If given 5.7 g of Ca determine the moles of:
a. $AlCl_3$

b. $CaCl_2$

c. Al

MASS-MASS

The procedure for solving mass-mass problems:
1. Write a balanced equation
2. Convert from mass of given material to moles (use molar mass from the periodic chart!) *If mass is not in grams convert it to grams!
3. Determine the mole ratio from the coefficients of the balanced equation and convert from moles of **given** material to moles of **required** material.
4. Change moles of required material to grams using molar mass from the periodic chart.

For example: When hydrogen gas and oxygen gas form water vapor you used 2.6 g of hydrogen gas, how many grams of water vapor would be formed?

$$2.6\text{ g } H_2 \times \frac{1\text{ mol } H_2}{1.01\text{ g}} \times \frac{2\text{ mol } H_2O}{2\text{ mol } H_2} \times \frac{18.02\text{ g}}{1\text{ mol } H_2O} = 48\text{ g of } H_2O$$

Practice: Perform the following mass to mass conversions.

2. $3\ CuSO_4 + 2\ Al \rightarrow Al_2(SO_4)_3 + 3\ Cu$
If given 8.5 g of Al determine the masses of:
a. $CuSO_4$

b. $Al_2(SO_4)_3$

c. Cu

3. $3\ Ca + 2\ AlCl_3 \rightarrow 3\ CaCl_2 + 2\ Al$
If given 1.9 g of Ca determine the masses of:
a. $AlCl_3$

b. $CaCl_2$

c. Al

Volumes of Gases

Equal volumes of two different gases at the SAME temperature and pressure, have the SAME number of molecules (Avogadro's Hypothesis)

Molar Volume

One mole of *any* gas at standard temperature and pressure (**STP** = 0 ° C and 1 atm of pressure) occupies a volume of **22.4 L.** **the gas must be at STP

MASS-VOLUME

The procedure for solving mass-volume problems:

1. Write a balanced equation
2. Convert from mass of given material to moles (use molar mass from the periodic chart!) *If mass is not in grams convert it to grams!
3. Determine the mole ratio from the coefficients of the balanced equation and convert from moles of **given** material to moles of **required** material.
4. Change moles of required material to volume using 22.4L/mol.

For example: How many liters of hydrogen can be produced from the reaction of 21.0g of zinc with hydrochloric acid?

$$21.0\text{g} \times \frac{1\text{mol Zn}}{65.39\text{ g}} \times \frac{1\text{mol } H_2}{1\text{ mol Zn}} \times \frac{22.4\text{ L}}{1\text{ mol } H_2} = 7.91\text{ L of } H_2$$

VOLUME-MASS

1. Write a balanced equation
2. Convert from volume of given material to moles (use 1 mol/22.4 L) *If volume is not in liters convert it to liters!
3. Determine the mole ratio from the coefficients of the balanced equation and convert from moles of **given** material to moles of **required** material.
4. Change moles of required material to grams using molar mass from the periodic chart.

For example: What mass of aluminum is required to react with 4.90 L of chlorine gas to produce aluminum chloride?

$$4.90\text{ L } Cl_2 \times \frac{1\text{ mol Cl2}}{} \times \frac{2\text{ mol Al}}{} \times \frac{26.98\text{ g}}{} =$$

VOLUME-VOLUME

1. Write a balanced equation
2. Convert from volume of given material to moles (use 1 mol/22.4 L) *If volume is not in liters convert it to liters!
3. Determine the mole ratio from the coefficients of the balanced equation and convert from moles of **given** material to moles of **required** material.
4. Change moles of required material to volume using 22.4 L/mol.

Practice:

Limiting Factors – when a reaction occurs it will only continue as long as there is sufficient amounts of both reactants. When there is a limited amount of both reactants, one of the reactants will become a limiting factor. The limiting factor is the reactant that will be completely consumed during the reaction. Once the limiting factor is used up the reaction will stop.

Name: _____ Period: ___ Date: _____

Stoichiometry Homework

Complete the following problems. (complete on separate sheet of paper)

Mole to Mole

1. $Pb + 2\ HCl\ (aq) \rightarrow PbCl_2 + H_2(aq)$
   a.) How many moles of hydrochloric acid will react with 0.36 mol of lead?
   b.) How many moles of hydrogen gas can be produced if 4.3 moles of hydrochloric acid react with lead?

2. $N_2O_5 + H_20 \rightarrow 2\ HNO_3$
   a.) How many moles of HNO_3 will be produced when 0.51 mol of N_2O_5 reacts with water?
   b.) How many moles of water will be required to react with 1.2 mol of N_2O_5?

3. $C + ZnO \rightarrow Zn + CO_2\ (g)$
   a.) How many moles of carbon dioxide will be produced if 0.38 mol of zinc oxide is completely reacted?
   b.) How many moles of ZnO will be required to produce 3.7 mol of zinc?

Mass

4. $Br_2\ (g) + 2NaI \rightarrow 2NaBr + I_2\ (g)$
   a.) How many grams of NaBr will be produced when a 0.69 mol of bromine gas reacts?
   b.) How many moles of iodine gas will be produced when 20.0 g of bromine gas reacts?

5. $P + Br_2\ (g) \rightarrow PBr_3$
   a.) How many grams of phosphorous tribromide will be produced if 8.78 g of bromine is reacted?
   b.) How many grams of phosphorous tribromide will be produced if 12.87 g of phosphorous is reacted?

6. $N_2\ (g) + 3\ H_2\ (g) \rightarrow 2\ NH_3\ (g)$
   a.) How many grams of nitrogen will be needed to produce 21.48 grams of NH_3?
   b.) How many grams of nitrogen will react with 2.24 g of hydrogen?

7. $2\ Al_2O_3 \rightarrow 4\ Al + 3\ O_2\ (g)$
   a.) When 9.8 g of aluminum oxide decomposes, how many grams of aluminum metal are produced?
   b.) How many grams of aluminum oxide are needed to produce 24.97 g of oxygen gas?

Volume

8. $2\ KI + F_2\ (g) \rightarrow 2\ KF + I_2\ (g)$
   a.) How many liters of iodine are produced when 0.72 mol of fluorine react with potassium iodide?
   b.) How many moles of potassium iodide are needed to produce 56.2 L of iodine gas?

9. $2\ Na + 2\ H_2O \rightarrow 2\ NaOH + H_2\ (g)$
   a.) How many moles of sodium are required to react with water to produce 15.0 L of hydrogen gas?

10. $N_2\ (g) + 3\ H_2\ (g) \rightarrow 2\ NH_3\ (g)$
    a.) How many liters of nitrogen gas are required to form 31.8 L of ammonia?
    b.) How many liters of hydrogen gas will react with 562.7 L of nitrogen gas?

11. $CH_4\ (g) + O_2\ (g) \rightarrow H_2O\ (g) + CO_2\ (g)$
    a.) How many liters of methane will burn with 10.0 L of oxygen gas?
    b.) How many liters of carbon dioxide will form if 70.5 L of methane is burned?

Mass - Volume

12. $2\ K + 2\ H_2O \rightarrow 2\ KOH + H_2\ (g)$
    a.) How many liters of hydrogen gas will be formed when 20.0g of potassium react with water?
    b.) How many grams of water will be needed to produce 23.0 L of hydrogen gas?

13. $Zn + 2\ HCl\ (aq) \rightarrow ZnCl_2 + H_2\ (g)$
    a.) What mass of zinc is required to produce 60.70 L of hydrogen gas?
    b.) How many liters of hydrogen gas can be produced by 47.8 g of hydrochloric acid?

14. $2\ C + O_2\ (g) \rightarrow 2\ CO\ (g)$
    a.) How many grams of carbon are necessary to form 34.2 L of carbon monoxide?
    b.) How many liters of oxygen gas will react with 21.9 g of carbon?

15. $2\ NaF + Cl_2\ (g) \rightarrow 2\ NaCl + F_2\ (g)$
    a.) When 88.0 L of chlorine gas reacts, how many grams of sodium chloride will be produced?
    b.) How many liters of fluorine gas will be formed when 97.8 g of sodium fluoride reacts?

Limiting Factor:

For the following problems 1.) determine the possible yield based on each reactant 2.) determine the theoretical yield of the product and 3.) percent yield when requested.

16. $4\ HCl\ (aq) + O_2\ (g) \rightarrow 2\ H_2O + 2\ Cl_2\ (g)$
    What mass of chlorine will be formed by the oxidation of 750 g of hydrochloric acid and 320 g of oxygen?

17. $NaCl + H_2O \rightarrow NaOH + HCl\ (aq)$
    What mass of sodium hydroxide will be produced by 645g of sodium chloride and 290 g of water?

18. $2\ Na + Cl_2\ (g) \rightarrow 2\ NaCl$
    What mass of sodium chloride will be produced by 50.0 g of sodium and 30.0 L of chlorine gas?

19. $Cu + 2\ AgNO_3 \rightarrow Cu(NO_3)_2 + 2\ Ag$
    What mass of silver can be produced by 63.4 g copper and 213 g of silver nitrate? What is the percent yield if the reaction actually produced 104.9 g of silver?

20. $2\ K_3(PO_4) + 3\ Ni(ClO_3)_2 \rightarrow Ni_3(PO_4)_2 + 6\ KClO_3$
    What mass of nickel (II) phosphate would be formed if 1500 g of potassium phosphate and 1250 g of nickel (II) chlorate reacted? What is the percent yield if the reaction actually produced 658 g of $Ni_3(PO_4)_2$?