

STOCHIOMETRY NOTES



BUT FIRST A Mole Concept Review:

A Mole

Basic mole calculations: convert mass to moles, and moles to molecules or atoms.

The following equalities are used in mole calculations:
 $1 \text{ mole} = 6.02 \times 10^{23} \text{ atoms/molecules} = \text{molar mass in grams}$

Dimensional Analysis Method

1. Given 12.011 grams of carbon, how many atoms do you have?

$$\frac{12.011 \cancel{\text{g C}}}{12.001 \cancel{\text{g}}} \times \frac{1 \cancel{\text{mole C}}}{6.02 \times 10^{23} \text{ atoms}} =$$

2. Given 18 grams of water, how many molecules do you have?

$$\frac{18 \cancel{\text{g H}_2\text{O}}}{18 \cancel{\text{g H}_2\text{O}}} \times \frac{1 \cancel{\text{mole}}}{6.02 \times 10^{23} \text{ molecules}} =$$

3. Given 3.5 moles of sodium chloride, how many grams do you have?

$$\frac{3.5 \cancel{\text{mole NaCl}}}{1 \cancel{\text{mole}}} \times 58.5 \text{ g NaCl} =$$

4. What is the mass of 6.02×10^{23} molecules of silver nitrate?

$$\frac{6.02 \times 10^{23} \cancel{\text{molecules Ag NO}_3}}{6.02 \times 10^{23} \cancel{\text{molecules Ag NO}_3}} \times \frac{1 \cancel{\text{mole}}}{170 \text{ g AgNO}_3} =$$

Stoichiometry: Dimensional Analysis Method

A quantitative study of chemical changes.

The KEY to Stoichiometry is using the coefficients in the balanced chemical equation in the unit moles to convert from moles of one substance to moles of another substance.

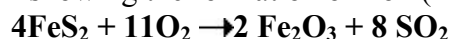
BASED UPON MOLE - MOLE RATIOS.

Basic Pattern:

1. If quantity given is grams Convert to moles
2. Perform mole \leftrightarrow mole conversion
3. Convert to desired units

EXAMPLE : If iron pyrite, FeS_2 , is not removed from coal, oxygen from the air will combine with both the iron and the sulfur as coal burns. If a furnace burns an amount of coal containing 100 g of FeS_2 , how much SO_2 (an air pollutant) is produced?

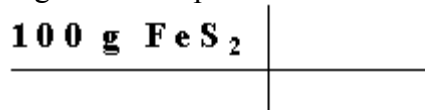
1. Write a balanced equation showing the formation of iron (III) oxide and sulfur dioxide.



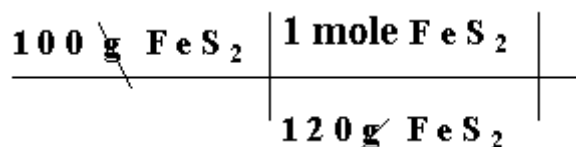
The equation will allow to convert from moles of FeS_2 to moles of SO_2



2. Write the mass information given in the problem.



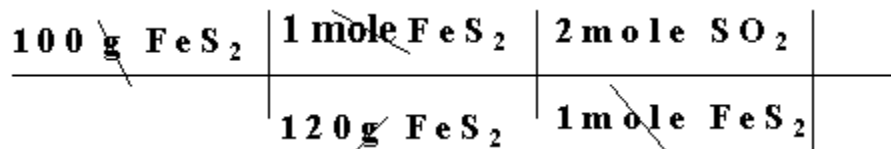
3. Convert grams of FeS_2 to moles of FeS_2 .



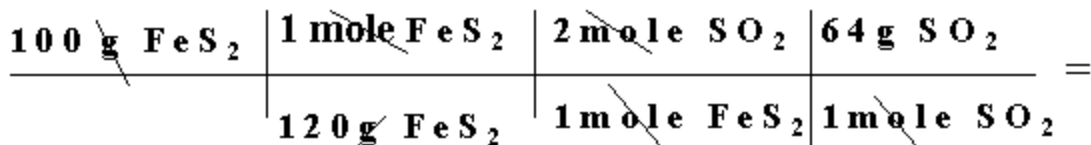
4. Change moles of FeS_2 (reactant) to moles of SO_2 (product).

This ratio comes from the **coefficients** in the balanced equation.

Notice that the ratio was reduced from 8 : 4 to 2 : 1 when placed in the factor-label form. Reducing is not necessary.



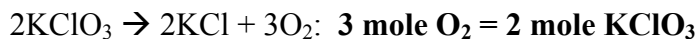
5. Convert moles of SO_2 to grams of SO_2



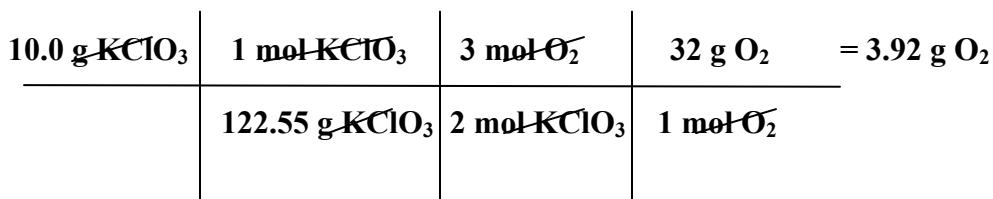
6. All units have been canceled except for grams of SO₂ (product). The problem has been solved. Pick up the calculator and do the math.

107 grams of SO₂ will be produced.

EXAMPLE : How many grams of oxygen are produced when 10.0 g of potassium chlorate are completely decomposed?



?g O₂ = 10.0g KClO₃



LIMITING REAGENT PROBLEMS

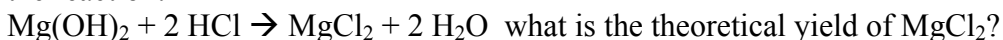
LIMITING REAGENT

- Is the reagent that is totally consumed during the reaction and therefore determines or limits the amount of product formed.

The first step in solving a limiting reagent problem is being able to recognize that you have a limiting reagent problem. Any time you are given the amount of **more than one reactant you must first determine which reactant is the limiting reagent.**

Suppose you were given the following problem:

EXAMPLE: A 50.6 g sample of Mg(OH)₂ is reacted with 45.0 g of HCl according to the reaction:



Is this a limiting reagent problem? One way to find out is to write down what is known about any component of the reaction below that component:



Notice how **quantities of both reactants are known.** Which one will be used up first? You can't tell, nor should you jump to any conclusions. Just because it looks like there is less Mg(OH)₂ present does not automatically mean it will be used up before all of the HCl is consumed. This is a limiting reagent problem.

To determine which reactant is the limiting reagent:

1. Determine moles of each reactant
2. Compare the number of moles of each reactant to the ratio in which they will react to determine which will be totally consumed. Divided the number of moles of each reactant by the reactant's coefficient in the balanced equation.
3. The smallest number refers to the limiting reagent.

Step 1.

$$50.6 \text{ g Mg(OH)}_2 \times \frac{1 \text{ mol Mg(OH)}_2}{58.3 \text{ g Mg(OH)}_2} = 0.868 \text{ mol Mg(OH)}_2$$

$$45.0 \text{ g HCl} \times \frac{1 \text{ mol HCl}}{36.5 \text{ g HCl}} = 1.23 \text{ mol HCl}$$

Again, you should not jump to any conclusions about which reactant is the limiting reagent. Just because there are fewer moles of magnesium hydroxide does not mean it is the limiting reagent.

Step 2

$$0.868 \text{ moles Mg(OH)}_2 = .869 \frac{\text{mole}}{\text{mole}}$$

$$1.23 \text{ moles HCl} = .615 \frac{\text{mole}}{\text{mole}}$$

Step 3

$0.615 < 0.868$ so HCl is the limiting reagent

Compare the moles HCl needed to the actual moles HCl available. In this case, 1.74 mol of HCl is needed and 1.23 mol HCl is available--that's not enough. So, even though it appears that there are more moles of HCl than Mg(OH)_2 , the HCl is the limiting reagent. The HCl will be run out before the magnesium hydroxide and thereby limit the amount of product formed. For this reason, use the moles of HCl to calculate the theoretical yield of magnesium chloride:

$$1.23 \text{ mol HCl} \times \frac{1 \text{ mol MgCl}_2}{2 \text{ mol HCl}} \times \frac{95.3 \text{ g MgCl}_2}{1 \text{ mol MgCl}_2} = 58.6 \text{ g MgCl}_2$$

The theoretical yield is the maximum amount of product which can be produced (in an ideal world). In the "real" world it is difficult to produce the amount obtained for the theoretical yield. A percent yield is often used to show how close to ideality one has obtained in a chemical synthesis.

PERCENT YIELD PROBLEMS:

- **Theoretical yield** – this is what you calculate from stoichiometry ☞ only in a perfect world
- **Actual yield** – what you get in a lab in the real world (*remember, energy is always lost and no process is 100% efficient, therefore no yield will be 100% ☞ useful in lab reports*)
- **Percent yield** = $\frac{\text{Actual Yield (measured amount) (real)}}{\text{Theoretical Yield (calculated value)}} \times 100$

Suppose in the reaction discussed a chemist actually obtained 55.4 g of MgCl₂. This is called the actual yield and would be given to you in the problem.

EXAMPLE : To calculate the percent yield:

$$\% \text{ yield} = \frac{55.4 \text{ g MgCl}_2 \text{ actual}}{58.6 \text{ g MgCl}_2 \text{ theoretical}} \times 100 = 94.5 \%$$

Amount of Excess Reagent Remaining Unreacted:

EXAMPLE: To determine the amount of excess reagent that remains un-reacted:

$$\text{INITIAL AMOUNT} - \text{EXCESS AMOUNT} = \text{AMOUNT UNREACTED}$$

$$50.6 \text{ g} \quad - \quad \underline{\text{????????}} \quad = \quad \underline{\text{????????}}$$

Calculate the amount consumed using the limiting reagent.

$$45.0 \text{ g of HCl} = \underline{\hspace{2cm}} \text{ Mg(OH)}_2$$

$$45.0 \text{ g HCl} \times \frac{1 \text{ mole HCl}}{36.5 \text{ g HCl}} \times \frac{1 \text{ mole Mg(OH)}_2}{2 \text{ mole HCl}} \times \frac{58.3 \text{ g Mg(OH)}_2}{1 \text{ mole Mg(OH)}_2} = 35.9 \text{ g Mg(OH)}_2$$

$$\text{INITIAL AMOUNT} - \text{EXCESS AMOUNT} = \text{AMOUNT UNREACTED}$$

$$50.6 \text{ g} - 35.9 \text{ g} = \underline{14.7 \text{ g}}$$

Practice with answers on the next page.

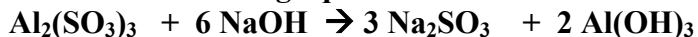
1. Given the following reaction:(hint: balance the equation first)



If you start with 14.8 g of C₃H₈ and 3.44 g of O₂,

- determine the limiting reagent
- determine the number of moles of carbon dioxide produced
- determine the number of grams of H₂O produced
- determine the number of grams of excess reagent left

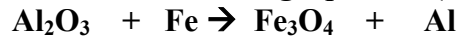
2. Given the following equation:



- If 10.0 g of Al₂(SO₃)₃ is reacted with 10.0 g of NaOH, determine the limiting reagent
- Determine the number of moles of Al(OH)₃ produced

- c) Determine the number of grams of Na_2SO_3 produced
 - d) Determine the number of grams of excess reagent left over in the reaction
-

3. Given the following equation:(hint: balance the equation first)



- a) If 25.4 g of Al_2O_3 is reacted with 10.2 g of Fe, determine the limiting reagent
- b) Determine the number of moles of Al produced
- c) Determine the number of grams of Fe_3O_4 produced
- d) Determine the number of grams of excess reagent left over in the reaction

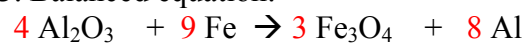
1. Balanced equation:



- a) O_2 b) 0.065 mol CO_2
c) 1.56 g H_2O d) 13.86 g C_3H_8
-

- 2a) $\text{Al}_2(\text{SO}_3)_3$ b) 0.068 mol $\text{Al}(\text{OH})_3$
c) 12.85 g Na_2SO_3 d) 1.84 g NaOH
-

3. Balanced equation:



- a) Fe b) 0.16 mol Al
c) 14.12 g Fe_3O_4 d) 17.13 g Al_2O_3