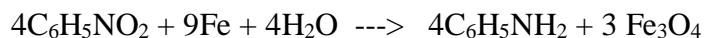


**1. Mole to Mole Conversions:**

**Objective:** Given the moles or number of atoms of one species be able to predict the moles or atoms of another species consumed or produced from a balanced chemical equation.

(in class)

Aniline, ( $C_6H_5NH_2$ ) can be formed from nitro benzene ( $C_6H_5NO_2$ ) by the following equation:



1.a. Write the conversion factor converting moles iron to moles aniline

$$\left( \frac{4 \text{ mol } C_6H_5NH_2}{9 \text{ mol } Fe} \right)$$

1.b. How many moles of aniline would be formed if 3.78 moles of iron was consumed?

$$3.78 \text{ mol } Fe \left( \frac{4 \text{ mol } C_6H_5NH_2}{9 \text{ mol } Fe} \right) = 1.68 \text{ mol } C_6H_5NH_2$$

(take home)

1.c. Write the conversion factor converting moles nitrobenzene to moles  $Fe_3O_4$ .

$$\left( \frac{3 \text{ mol } Fe_3O_4}{4 \text{ mol } C_6H_5NO_2} \right)$$

1.d. Write the conversion factor describing the ratio of the consumption of iron to the consumption of nitrobenzene.

$$\left( \frac{9 \text{ mol } Fe}{4 \text{ mol } C_6H_5NO_2} \right)$$

1.e. How many moles of nitrobenzene would be needed to produce 4.678 Mmoles of  $Fe_3O_4$ ?

$$4.678 \text{ Mmole } Fe_3O_4 \left( \frac{10^6 \text{ mol } Fe_3O_4}{\text{Mmol } Fe_3O_4} \right) \left( \frac{4 \text{ mol } C_6H_5NO_2}{3 \text{ mol } Fe_3O_4} \right)$$

$$= 6.237 \times 10^6 \text{ mol } C_6H_5NO_2 \text{ or } 6.237 \text{ Mmol } C_6H_5NO_2$$

1.f. How many moles of iron would be needed to consume  $3.56 \times 10^{22}$  molecules of nitrobenzene?

$$3.56 \times 10^{22} \text{ molecule } C_6H_5NO_2 \left( \frac{\text{mol } C_6H_5NO_2}{6.022 \times 10^{23} \text{ molecule}} \right) \left( \frac{9 \text{ mol } Fe}{4 \text{ mol } C_6H_5NO_2} \right) = 0.133 \text{ mol } Fe$$

1.g. How many atoms of iron are consumed if 3.59 nmoles of water are consumed?

$$3.59 \text{ nmol } H_2O \left( \frac{10^{-9} \text{ mol } H_2O}{\text{nmol}} \right) \left( \frac{9 \text{ mol } Fe}{4 \text{ mol } H_2O} \right) \left( \frac{6.022 \times 10^{23} \text{ atom } Fe}{\text{mol } Fe} \right) = 4.86 \times 10^{15} \text{ atom } Fe$$

## 2. Mass to Mass or Mass to Mole Conversions

**Objective:** Given the mass one species be able to predict the mass another species consumed or produced from a balanced chemical equation.

**Technique:** This is a three step process which should be done in one equation which uses three conversion factors.

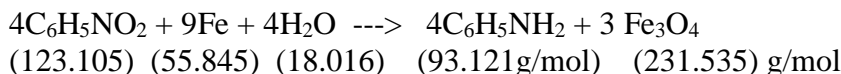
Conversion Factor #1: Use molar mass to convert mass of known material to moles.

Conversion Factor #2: Use coefficients of balanced reaction equation to convert moles of known material to moles of desired material.

Conversion Factor # 3: Use molar mass to convert moles of desired material to mass of desired material.

(in class)

Aniline, ( $C_6H_5NH_2$ ) can be formed from nitro benzene ( $C_6H_5NO_2$ ) by the following equation:



2.a. How many grams of aniline would be formed if 3.78 moles of iron was consumed?

$$3.78 \text{ mol Fe} \left( \frac{4 \text{ mol } C_6H_5NH_2}{9 \text{ mol Fe}} \right) \left( \frac{93.121 \text{ g } C_6H_5NH_2}{\text{mol}} \right) = 156 \text{ g } C_6H_5NH_2$$

2.b. How many grams of nitrobenzene would be needed to produce 4.678 kg of  $Fe_3O_4$ ?

$$4.678 \text{ kg } Fe_3O_4 \left( \frac{10^3 \text{ g } Fe_3O_4}{\text{kg}} \right) \left( \frac{\text{mol } Fe_3O_4}{231.535 \text{ g } Fe_3O_4} \right) \left( \frac{4 \text{ mol } C_6H_5NO_2}{3 \text{ mol } Fe_3O_4} \right) \left( \frac{123.105 \text{ g } C_6H_5NO_2}{\text{mol}} \right)$$

$$= 3.316 \times 10^3 \text{ g } C_6H_5NO_2 \text{ or } 3.316 \text{ kg } C_6H_5NO_2$$

(take home)

2.c. How many grams of iron would be needed to consume  $3.56 \times 10^{22}$  molecules of nitrobenzene?

$$3.56 \times 10^{22} \text{ molecule } C_6H_5NO_2 \left( \frac{\text{mol } C_6H_5NO_2}{6.022 \times 10^{23} \text{ molecule}} \right) \left( \frac{9 \text{ mol Fe}}{4 \text{ mol } C_6H_5NO_2} \right) \left( \frac{55.845 \text{ g Fe}}{\text{mol}} \right) = 7.43 \text{ g Fe}$$

2.d. How many grams of iron are consumed if 3.59 ng of water are consumed?

$$3.59 \text{ ng } H_2O \left( \frac{10^{-9} \text{ g } H_2O}{\text{ng}} \right) \left( \frac{\text{mol } H_2O}{18.016 \text{ g } H_2O} \right) \left( \frac{9 \text{ mol Fe}}{4 \text{ mol } H_2O} \right) \left( \frac{55.845 \text{ g atom Fe}}{\text{mol Fe}} \right) = 2.50 \times 10^{-8} \text{ g Fe or } 25.0 \text{ ng Fe}$$

2.e. How many grams of aniline are produced if 22.45 g of  $Fe_3O_4$  are also produced?

$$22.45 \text{ g } Fe_3O_4 \left( \frac{\text{mol } Fe_3O_4}{231.535 \text{ g } Fe_3O_4} \right) \left( \frac{4 \text{ mol } C_6H_5NH_2}{3 \text{ mol } Fe_3O_4} \right) \left( \frac{93.121 \text{ g } C_6H_5NH_2}{\text{mol}} \right) = 12.04 \text{ g } C_6H_5NH_2$$

### 3. Limiting and Excess Reagent Problems

**Objective:** Determine the quantity of product produced if given the quantity of two or more reactants.

#### Techniques and Definitions

**Limiting Reagent:** The reactant which is get's used up first. The product yield is based on the complete consumption of the limiting reagent.

**Excess Reagent:** The reactant which does not get completely consumed

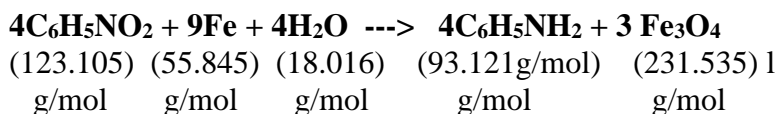
**Stoichiometric Proportions:** The ratio of the stoichiometric coefficients of two chemical species. There are no excess reagents when two or more reactants are mixed in stoichiometric proportions.

**Tips: Identify moles of all reactants present and divide by stoichiometric coefficients.** The smallest value represents the limiting reagent, the larger value(s) represent the excess reagent. If all values are the same they are in stoichiometric proportions.

**To Calculate moles of Excess reagent** you subtract the amount used with the complete consumption of the limiting reagent from the initial moles of the excess reagent.

(in class)

**Aniline, (C<sub>6</sub>H<sub>5</sub>NH<sub>2</sub>) can be formed from nitro benzene (C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>) by the following equation:**



3.a) What is the minimum mass in grams of iron which would be required to consume 3.48 grams of nitrobenzene?

$$3.48\text{g C}_6\text{H}_5\text{NO}_2 \left( \frac{\text{mol C}_6\text{H}_5\text{NO}_2}{123.105\text{g}} \right) \left( \frac{9\text{mol Fe}}{4\text{mol C}_6\text{H}_5\text{NO}_2} \right) \left( \frac{55.845\text{g Fe}}{\text{mol}} \right) = 3.55\text{g Fe}$$

3.b) What mass of iron would be left over if 5.00 g of iron reacted with 3.48 g nitrobenzene?

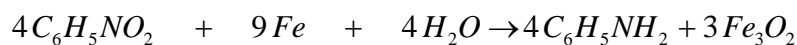
Step 1: Calculate mass of iron required to consume 3.48 g  $C_6H_5NO_2$

$$3.48 \text{ g } C_6H_5NO_2 \left( \frac{\text{mol } C_6H_5NO_2}{123.105 \text{ g}} \right) \left( \frac{9 \text{ mol Fe}}{4 \text{ mol } C_6H_5NO_2} \right) \left( \frac{55.845 \text{ g Fe}}{\text{mol}} \right) = 3.55 \text{ g Fe}$$

Step 1: Subtract that from the initial mass of iron

$$5.00 \text{ g} - 3.55 \text{ g} = 1.45 \text{ g iron in excess}$$

3.c) How many moles of aniline would be formed if 3.78 moles of iron and 5.69 moles of nitrobenzene were mixed in excess water?



*nitrobenzene*    *iron*                    *water*

$$\left( \frac{5.69 \text{ mol}}{4} \right) \quad \left( \frac{3.78 \text{ mol}}{9} \right) \quad (\text{excess})$$

$$1.4225 \quad \quad 0.42$$

As  $0.42 < 1.42$  iron is the limiting reagent

$$3.78 \text{ mol Fe} \left( \frac{4 \text{ mol } C_6H_5NH_2}{9 \text{ mol Fe}} \right) = 1.68 \text{ mole } C_6H_5NH_2$$

3.d) How many grams of aniline would be formed if 3.78 g of iron and 5.69 g of nitrobenzene were mixed in excess water?



*nitrobenzene*                                    *iron*                    *water*

$$\left( \frac{5.69 \text{ g} \left( \frac{\text{mol}}{123.105 \text{ g}} \right)}{4} \right) \quad \left( \frac{3.78 \text{ g} \left( \frac{\text{mol}}{55.845 \text{ g}} \right)}{9} \right) \quad (\text{excess})$$

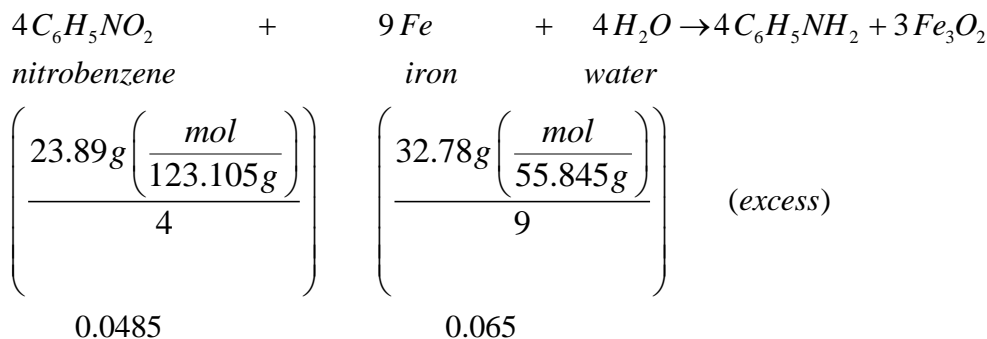
$$0.0116$$

$$0.0075$$

As  $0.007 < 0.012$  iron is the limiting reagent

$$3.78 \text{ g Fe} \left( \frac{\text{mol Fe}}{55.845 \text{ g}} \right) \left( \frac{4 \text{ mol } C_6H_5NH_2}{9 \text{ mol Fe}} \right) \left( \frac{93.121 \text{ g } C_6H_5NH_2}{\text{mol}} \right) = 2.80 \text{ g } C_6H_5NH_2$$

3.d) How many grams of aniline would be formed if 32.78g of iron were mixed with 23.89g of nitrobenzene in excess water?



As  $0.065 < 0.049$  nitrobenzene is the limiting reagent

$$23.89g C_6H_5NO_2 \left( \frac{mol C_6H_5NO_2}{123.105g} \right) \left( \frac{4mol C_6H_5NH_2}{4mol C_6H_5NO_2} \right) \left( \frac{93.121g C_6H_5NH_2}{mol} \right) = 18.07g C_6H_5NH_2$$

#### 4. Percent Yield Problems:

**Objective:** Determine the percent yield of product based on the theoretical yield and the actual yield. This type of calculation relates the result of actual real world work to the results predicted from reaction stoichiometry.

##### Techniques and Definitions

Actual Yield: The quantity of product produced in a real experiment.

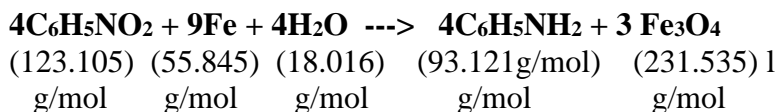
Theoretical Yield: The quantity of product production predicted by the complete consumption of the limiting reagent.

Percent Yield: The ratio of Actual Yield to the Theoretical Yield times 100.

$$\text{Percent Yield} = \left( \frac{\text{Actual Yield}}{\text{Theoretical Yield}} \right) 100$$

**Tips:** Identify moles of all reactants present and divide by stoichiometric coefficients. The smallest value represents the limiting reagent.

**Aniline, (C<sub>6</sub>H<sub>5</sub>NH<sub>2</sub>) can be formed from nitro benzene (C<sub>6</sub>H<sub>5</sub>NO<sub>2</sub>) by the following equation:**



4.a) What is the percent yield if 4.128 g of  $Fe_3O_4$  was produced if 3.320g of nitrobenzene reacted with excess iron and water?

$$\textit{Theoretical Yield} : 3.320g C_6H_5NO_2 \left( \frac{mol C_6H_5NO_2}{123.105g} \right) \left( \frac{3mol Fe_3O_4}{4mol C_6H_5NO_2} \right) \left( \frac{231.535g Fe_3O_4}{mol} \right) = 4.683g Fe_3O_4$$

$$\textit{Percent Yield} : \left( \frac{4.128g Fe_3O_4}{4.683g Fe_3O_4} \right) 100 = 88.15\%$$

4.b) What is the percent yield if 16.0g of aniline was formed after mixing 23.89g of nitrobenzene with excess iron and water?

$$\textit{Theoretical Yield} : 23.89g C_6H_5NO_2 \left( \frac{mol C_6H_5NO_2}{123.105g} \right) \left( \frac{4mol C_6H_5NH_2}{4mol C_6H_5NO_2} \right) \left( \frac{93.121g C_6H_5NH_2}{mol} \right) = 18.07g C_6H_5NH_2$$

$$\textit{Percent Yield} : \left( \frac{16.0g C_6H_5NH_2}{18.07g C_6H_5NH_2} \right) 100 = 88.53\%$$

4.c) What is the percent yield if 1.80 g of aniline was formed after mixing 3.78g of iron with excess nitrobenzene and water?

$$\textit{Theoretical Yield} : 3.78g Fe \left( \frac{mol Fe}{55.846g} \right) \left( \frac{4mol C_6H_5NH_2}{9mol Fe} \right) \left( \frac{93.121g C_6H_5NH_2}{mol} \right) = 2.80g C_6H_5NH_2$$

$$\textit{Percent Yield} : \left( \frac{1.80g C_6H_5NH_2}{2.80g C_6H_5NH_2} \right) 100 = 64.3\%$$