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

$$4C_6H_5NO_2 + 9Fe + 4H_2O \;\text{--->}\; 4C_6H_5NH_2 + 3\,Fe_3O_4$$

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

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

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

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

(take home)
1.c. Write the conversion factor converting moles nitrobenzene to moles Fe_3O_4 .

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

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

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

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

$$4.678Mmole\,Fe_3O_4\left(\frac{10^6\,mol\,Fe_3O_4}{Mmol\,Fe_3O_4}\right)\left(\frac{4mol\,C_6H_5NO_2}{3mol\,Fe_3O_4}\right)$$
$$=6.237x10^6\;mol\,C_6H_5NO_2\;or\;6.237\,Mmol\,C_6H_5NO_2$$

1.f. How many moles of iron would be needed to consume $3.56x10^{22}$ molecules of nitrobenzene?

$$3.56x10^{22}\;molecule\,C_6H_5NO_2\left(\frac{mol\,C_6H_5NO_2}{6.022x10^{23}\;molecule}\right)\left(\frac{9\,mol\,Fe}{4\,mol\,C_6H_5NO_2}\right)=0.133\,mol\,Fe$$

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

$$3.59nmol\,H_2O\left(\frac{10^{-9}\,mol\,H_2O}{nmol}\right)\left(\frac{9\,mol\,Fe}{4\,mol\,H_2O}\right)\left(\frac{6.022x10^{23}\;atom\,Fe}{Fe}\right)=4.86x10^{15}\;atom\,Fe$$

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

$4C_6H_5NO_2 + 9Fe + 4H_2O$ ---> $4C_6H_5NH_2 + 3\ Fe_3O_4$
(123.105) (55.845) (18.016) (93.121g/mol) (231.535) g/mol

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

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

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

$$4.678 kg\ Fe_3O_4\left(\frac{10^3\ g\ Fe_3O_4}{kg}\right)\left(\frac{mol\ Fe_3O_4}{231.535 g\ Fe_3O_4}\right)\left(\frac{4\ mol\ C_6H_5NO_2}{3\ mol\ Fe_3O_4}\right)\left(\frac{123.105 g\ C_6H_5NO_2}{mol}\right)$$
$$=3.316x10^3\ g\ C_6H_5NO_2\ or\ 3.316 kg\ C_6H_5NO_2$$

(take home)
2.c. How many grams of iron would be needed to consume $3.56x10^{22}$ molecules of nitrobenzene?

$$3.56x10^{22}\ molecule\ C_6H_5NO_2\left(\frac{mol\ C_6H_5NO_2}{6.022x10^{23}\ molecule}\right)\left(\frac{9\ mol\ Fe}{4\ mol\ C_6H_5NO_2}\right)\left(\frac{55.845 g\ Fe}{mol}\right)=7.43 g\ Fe$$

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

$$3.59 ng\ H_2O\left(\frac{10^{-9}\ g\ H_2O}{ng}\right)\left(\frac{mol\ H_2O}{18.016 g\ H_2O}\right)\left(\frac{9\ mol\ Fe}{4\ mol\ H_2O}\right)\left(\frac{55.845 g\ atom\ Fe}{mol\ Fe}\right)=2.50x10^{-8}\ g\ Fe\ or\ 25.0 ng\ Fe$$

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

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

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)

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$$4C_6H_5NO_2 + 9Fe + 4H_2O \longrightarrow 4C_6H_5NH_2 + 3\,Fe_3O_4$$

(123.105) g/mol (55.845) g/mol (18.016) g/mol (93.121g/mol) g/mol (231.535) l g/mol

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

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

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 $C_6H_5NO_2$

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

Step 1: Subtract that from the initial mass of iron

5.00g - 3.55g = 1.45g iron in excess

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

$$4C_6H_5NO_2 \quad + \quad 9Fe \quad + \quad 4H_2O \rightarrow 4C_6H_5NH_2 + 3Fe_3O_2$$

nitrobenzene *iron* *water*

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

1.4225 0.42

As $0.42 \langle 1.42$ iron is the limiting reagent

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

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

$$4C_6H_5NO_2 \quad + \quad 9Fe \quad + \quad 4H_2O \rightarrow 4C_6H_5NH_2 + 3Fe_3O_2$$

nitrobenzene *iron* *water*

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

0.0116 0.0075

As $0.007 \langle 0.012$ iron is the limiting reagent

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

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

$$\underset{nitrobenzene}{4C_6H_5NO_2} \quad + \quad \underset{iron}{9Fe} \quad + \quad \underset{water}{4H_2O} \rightarrow 4C_6H_5NH_2 + 3Fe_3O_2$$

$$\left(\frac{23.89g\left(\frac{mol}{123.105g}\right)}{4}\right) \qquad \left(\frac{32.78g\left(\frac{mol}{55.845g}\right)}{9}\right) \qquad (excess)$$

0.0485 0.065

As $0.065 \langle 0.049$ nitrobenzene is the limiting reagent

$$23.89gC_6H_5NO_2\left(\frac{mol\ C_6H_5NO_2}{123.105g}\right)\left(\frac{4mol\ C_6H_5NH_2}{4\,mol\,C_6H_5NO_2}\right)\left(\frac{93.121g\,C_6H_5NH_2}{mol}\right)=18.07g\,C_6H_5NH_2$$

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 stoichoimetry.

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.

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

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

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$4C_6H_5NO_2 + 9Fe + 4H_2O$ ---> $4C_6H_5NH_2 + 3\ Fe_3O_4$
(123.105) g/mol (55.845) g/mol (18.016) g/mol (93.121g/mol) g/mol (231.535) l g/mol

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?

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

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

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

$$Theoretical\ Yield: \quad 23.89g\, C_6H_5NO_2 \left(\frac{mol\, C_6H_5NO_2}{123.105g}\right)\left(\frac{4\, mol\, C_6H_5NH_2}{4\, mol\, C_6H_5NO_2}\right)\left(\frac{93.121g\ C_6H_5NH_2}{mol}\right) = 18.07g\ C_6$$

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

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

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

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