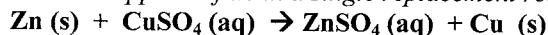


Worksheet 5: Theoretical yield and Percent Yield in chemical reactions

- Stoichiometric calculations allow us to calculate the amounts of reactants required or the amounts of products generated from a chemical reaction
- Chemical reactions frequently do not proceed to completion. Hence the amount of product recovered is often less than would be predicted from stoichiometric calculations
- The **Theoretical Yield** is defined as the amount of product(s) calculated using Stoichiometry calculations
- The **Actual Yield** is the amount of product that can actually be recovered when the reaction is done in a lab.
- The **Percent Yield** is calculated as follows
- Percent yield = $\frac{\text{actual yield}}{\text{theoretical yield}} \times 100\%$

*Example 1:**Zinc reacts with copper sulfate in a single replacement reaction as follows*

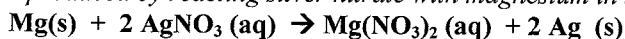
50.00 grams of zinc metal were added to excess were added to excess copper sulfate dissolved in a water solution. 42.50 grams of copper were recovered. Calculate the theoretical yield of copper in this experiment

- Solve the mass-mass Stoichiometry problem to find the theoretical yield

$$\text{Mass Cu} = \frac{50.00 \text{ g Zn}}{65.38 \text{ g mol}^{-1} \text{ Zn}} \times \frac{1 \text{ mol Cu}}{1 \text{ mol Zn}} \times 63.55 \text{ g mol}^{-1} \text{ Cu} = 48.60 \text{ g Cu}$$

- Find the percent yield

$$\text{Percent Yield of Cu} = \frac{42.50 \text{ g Cu}}{48.60 \text{ g Cu}} \times 100 = 87.44 \%$$

*Example 2:**Silver can produced by reacting silver nitrate with magnesium in the following reaction*

How much Silver can be recovered by reacting a silver nitrate solution with 50.00 grams of powdered magnesium. Assume that 95% of the silver can be recovered

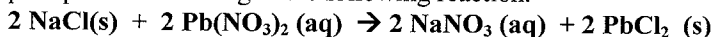
- Solve the mass-mass Stoichiometry problem to find the theoretical yield

$$\text{Mass Ag} = \frac{50.00 \text{ g Mg}}{24.31 \text{ g mol}^{-1} \text{ Mg}} \times \frac{2 \text{ mol Ag}}{1 \text{ mol Mg}} \times 107.88 \text{ g mol}^{-1} \text{ Mg} = 443.77 \text{ g Ag}$$

- Find the percent yield

$$\text{Yield of Ag} = 443.77 \text{ g Ag} \times 0.95 = 421.58 \text{ g}$$

- 4.00 grams of sodium chloride was added to a solution containing excess lead nitrate. Lead chloride was precipitated according to the following reaction.

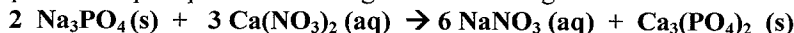


Calculate the mass of lead chloride that can be recovered assuming a 90% recovery

$$\left(\frac{4.00 \text{ g NaCl}}{58.45 \text{ g mol}^{-1} \text{ NaCl}} \right) \left(\frac{2 \text{ mol PbCl}_2}{2 \text{ mol NaCl}} \right) \left(278.1 \text{ g mol}^{-1} \text{ PbCl}_2 \right) = 19.03 \text{ g}$$

$$(19.03 \text{ g PbCl}_2) (0.90) = 17.13 \text{ g PbCl}_2 \text{ recovered}$$

2. 30.00 grams of sodium phosphate was added to a solution containing excess calcium nitrate. Calcium phosphate was precipitated according to the following reaction.

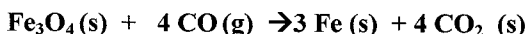


25.00 grams of Calcium phosphate were recovered. Calculate the theoretical yield and the percent yield.

$$\left(\frac{30.00 \text{ g Na}_3\text{PO}_4}{163.97 \text{ g mol}^{-1} \text{ Na}_3\text{PO}_4} \right) \left(\frac{1 \text{ mol Ca}_3(\text{PO}_4)_2}{2 \text{ mole Na}_3\text{PO}_4} \right) \left(310.18 \text{ g mol}^{-1} \text{ Ca}_3(\text{PO}_4)_2 \right) = 28.38$$

$$\% \text{ yield} = \frac{25.00 \text{ g recovered}}{28.38 \text{ g theoretical}} \times 100 = 88.1\% \text{ recovered}$$

3. In the manufacture of steel an ore containing an oxide of iron is reduced to iron metal by carbon monoxide.



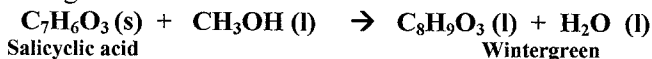
Calculate the theoretical mass of iron that could be recovered from 500 kilograms of Fe_3O_4 . Suppose that 308 kilograms of iron is actually recovered. Calculate the percent yield of iron for this process

$$\left(\frac{500000 \text{ g Fe}_3\text{O}_4}{231.55 \text{ g mol}^{-1} \text{ Fe}_3\text{O}_4} \right) \left(\frac{3 \text{ mol Fe}}{1 \text{ mol Fe}_3\text{O}_4} \right) \left(55.85 \text{ g mol}^{-1} \text{ Fe} \right) = 361800 \text{ g}$$

or 361.8 Kg

$$\% \text{ yield} = \frac{308.0}{361.8} \times 100 = 85.1\%$$

4. Wintergreen flavoring can be made by reacting salicylic acid with methanol according to the following reaction:



Salicylic acid

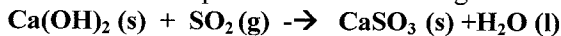
Wintergreen

What mass of wintergreen can be produced from 100 grams of salicylic acid assuming a 75% yield?

$$\left(\frac{100 \text{ g C}_7\text{H}_6\text{O}_3}{138.13 \text{ g mol}^{-1} \text{ C}_7\text{H}_6\text{O}_3} \right) \left(\frac{1 \text{ mol C}_8\text{H}_8\text{O}_3}{1 \text{ mol C}_7\text{H}_6\text{O}_3} \right) \left(153.17 \text{ g mol}^{-1} \text{ C}_8\text{H}_8\text{O}_3 \right) = 110.89$$

$$(110.89 \text{ g})(0.75) = 83.17 \text{ g C}_8\text{H}_8\text{O}_3 \text{ recovered}$$

5. Sulfur dioxide can be removed from the smokestacks of coal burning plants by reacting it with a slurry of calcium oxide in a process called scrubbing



Assuming that this process is only 80% efficient, how much $\text{Ca}(\text{OH})_2$ would be required to remove 1000 grams of SO_2 from the fumes of a smokestack.

$$\left(\frac{1000 \text{ g SO}_2}{64.06 \text{ g mol}^{-1} \text{ SO}_2} \right) \left(\frac{1 \text{ mole Ca}(\text{OH})_2}{1 \text{ mole SO}_2} \right) \left(74.10 \text{ g mol}^{-1} \text{ Ca}(\text{OH})_2 \right) =$$

assuming only 80% efficient

$$80 (\text{mass Ca}(\text{OH})_2) = 1157 \text{ g}$$