IB Chemistry 1-2 Name Answer Key

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 wouold 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 = $\frac{\text{actual yield}}{\text{theoretical yield}} x\,100\%$

Example1:
Zinc reacts with copper sulfate in a single replacement reaction as follows

$Zn\,(s) + CuSO_4\,(aq) \rightarrow ZnSO_4\,(aq) + Cu\,(s)$

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

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

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

2. Find the percent yield

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

Example2:
Silver can produced by reacting silver nitrate with magnesium in the following reaction

$Mg(s) + 2\,AgNO_3\,(aq) \rightarrow Mg(NO_3)_2\,(aq) + 2\,Ag\,(s)$

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

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

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

2. Find the percent yield

Yield of Ag= 443.77 g Ag x 0.95 =421.58 g

1. 4.00 grams of sodium chloride was added to a solution containing excess lead nitrate. Lead chloride was precipitated according to the following reaction.

$2\,NaCl(s) + 2\,Pb(NO_3)_2\,(aq) \rightarrow 2\,NaNO_3\,(aq) + 2\,PbCl_2\,(s)$

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

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

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

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.

$2\ Na_3PO_4\,(s) + 3\ Ca(NO_3)_2\,(aq) \rightarrow 6\ NaNO_3\,(aq) + Ca_3(PO_4)_2\,(s)$

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

$$\left(\frac{30.00\text{ g } Na_3PO_4}{163.97\text{ g mol } Na_3PO_4}\right)\left(\frac{1\text{ mol } Ca_3(PO_4)_2}{2\text{ mole } Na_3PO_4}\right)\left(\underset{Ca_3(PO_4)_2}{310.18\text{ g mol}^{-1}}\right) = 28.38$$

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

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

$Fe_3O_4\,(s) + 4\ CO\,(g) \rightarrow 3\ Fe\,(s) + 4\ CO_2\ (s)$

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

$$\left(\frac{500\,000\text{ g } Fe_3O_4}{\underset{Fe_3O_4}{231.55\text{ g mol}^{-1}}}\right)\left(\frac{3\text{ mol Fe}}{1\text{ mol } Fe_3O_4}\right)\left(\underset{Fe}{55.85\text{ g mol}^{-1}}\right) = 361800\text{ g}$$

or 361.8 Kg

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

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

$C_7H_6O_3\,(s) + CH_3OH\,(l) \rightarrow C_8H_9O_3\,(l) + H_2O\ (l)$

Salicyclic acid **Wintergreen**

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

$$\left(\frac{100\text{ g } C_7H_8O_3}{\underset{C_7H_8O_3}{138.13\text{ g mol}^{-1}}}\right)\left(\frac{1\text{ mol } C_8H_9O_3}{1\text{ mol } C_7H_8O_3}\right)\left(\underset{C_8H_9O_3}{153.17\text{ g mol}^{-1}}\right) = 110.89$$

$$(110.89\text{ g})(0.75) = 83.17\text{ g } C_8H_9O_3 \text{ recovered}$$

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

$Ca(OH)_2\,(s) + SO_2\,(g) \rightarrow CaSO_3\,(s) + H_2O\,(l)$

Assuming that this process is only 80% efficient, how much Ca(OH)2 would be required to remove 1000 grams of SO_2 from the fumes of a smokestack.

$$\left(\frac{1000\text{ g } SO_2}{\underset{SO_2}{64.06\text{ g mol}^{-1}}}\right)\left(\frac{1\text{ mole } Ca(OH)_2}{1\text{ mole } SO_2}\right)\left(74.10\text{ g mol}^{-1}\ Ca(OH)_2\right) =$$

assuming only 80% efficient

80 (mass $Ca(OH)_2$) = 1157g