Percentage Yield

amount of product actually produced in a chemical reaction (mol or g)
↳ this is often less than theoretical due to inefficiencies in recovering products or side reactions which reduce product
↳ calculated by determining mass or volume of product

ratio of actual and theoretical yields.
larger values = more efficient

$$\text{Percentage Yield } (\%) = \frac{\text{experimental yield}}{\text{theoretical yield}} \times 100\%$$

amount of product produced in a chemical reaction assuming the limiting reactant is completely used up. (mol or g)
↳ calculated stoichiometrically using the limiting reactant

Example problems

(i) 36 g of tin (IV) phosphate, $Sn_3(PO_4)_4$, reacts with 36g of sodium carbonate, Na_2CO_3 to make tin (IV) carbonate and sodium phosphate. If 29.8g of tin (IV) carbonate are actually formed, what is the percent yield?

1- write a chemical equation: $Sn_3(PO_4)_4 + Na_2CO_3 \longrightarrow Sn(CO_3)_2 + Na_3PO_4$

2- balance the equation: $Sn_3(PO_4)_4 + 6\,Na_2CO_3 \longrightarrow 3\,Sn(CO_3)_2 + 4\,Na_3PO_4$

3- calculate number of moles for each reactant: $36\,g\ Sn_3(PO_4)_4 \times \frac{mol}{736.01\,g} = 0.04891\,mol$; $36\,g\ Na_2CO_3 \times \frac{mol}{105.99\,g} = 0.3397\,mol$

4- divide moles of reactants by coefficient: $0.04891\,mol \div 1 = 0.04891\,mol$ ∴ limiting ; $0.3397\,mol \div 6 = 0.05662\,mol$

5- calculate mass of product (theoretical yield): $0.04891\,mol\ Sn_3(PO_4)_4 \times \frac{3\,mol\ Sn(CO_3)_2}{1\,mol\ Sn_3(PO_4)_4} \times \frac{238.73\,g}{mol} = 35.0\,g\ Sn(CO_3)_2$

6- calculate % yield: $\%\text{ yield of } Sn(CO_3)_2 = \frac{\text{experimental}}{\text{theoretical}} \times 100\% = \frac{29.8\,g}{35.0\,g} \times 100 = 85\%$

(ii) 15g of sodium sulfate, Na_2SO_4, reacts with excess iron (III) phosphate, $FePO_4$, producing a 65.0 % yield. How many grams of sodium phosphate will actually be made?

1- write a chemical equation: $Na_2SO_4 + FePO_4 \longrightarrow Fe_2(SO_4)_3 + Na_3PO_4$

2- balance the equation: $3\,Na_2SO_4 + 2\,FePO_4 \longrightarrow Fe_2(SO_4)_3 + 2\,Na_3PO_4$

3- calculate mass of product (theoretical yield): $15\,g\ Na_2SO_4 \times \frac{mol}{142.02\,g} \times \frac{2\,mol\ Na_3PO_4}{3\,mol\ Na_2SO_4} \times \frac{163.94\,g}{mol} = 11.543\,g$

4- calculate experimental yield: $\text{experimental yield} = \frac{(\%\text{ yield})(\text{theoretical})}{100} = \frac{(65\%)(11.543\,g)}{100} = 7.5\,g$

(iii) What mass of silver could be formed if a large zinc wire is placed in a beaker containing 145.0 mL of 0.095 mol dm^{-3} silver nitrate, $AgNO_3$, and allowed to react overnight? Reaction has 97% yield.

1- write and balance chemical equation: $Zn + 2\,AgNO_3 \longrightarrow 2\,Ag + Zn(NO_3)_2$

2- determine mol of given ($n = cv$): $n = cv = \left(\frac{0.095\,mol}{dm^3}\right)\left(145\,mL \times \frac{L}{1000\,mL}\right) = 0.013775\,mol\ AgNO_3$

3- calculate theoretical yield: $0.013775\,mol\ AgNO_3 \times \frac{2\,mol\ Ag}{2\,mol\ AgNO_3} \times \frac{107.87\,g}{mol} = 1.486\,g$

4- calculate experimental yield: $\text{experimental yield} = \frac{(\%\text{ yield})(\text{theoretical})}{100} = \frac{(97\%)(1.486\,g)}{100} = 1.44\,g$

Percentage Purity

Some samples of compounds are composed of a mixture of different substances.

Percentage of a sample which is a specific product:

mass of the compound of interest (g)

$$\text{Percentage Purity (\%)} = \frac{\text{mass of pure compound in sample}}{\text{total mass of sample}} \times 100\%$$

mass of the mixture in total (g)

Example problems

(i) A 12.00g sample of a crystallised pharmeceutical product was found to contain 11.57g of the active drug. Calculate the percentage purity of the sample of the drug.

use formula % purity

$$\text{Percentage Purity (\%)} = \frac{\text{mass of active drug in sample}}{\text{total mass of sample}} \times 100\% = \frac{11.57\,g}{12.00\,g} \times 100$$

$$= 96.4\%$$

(ii) 15.0g of 92.5% magnesium hydroxide, $Mg(OH)_2$, is reacted with excess H_3PO_4 to produce water and magnesium phosphate. Calculate the mass of $Mg_3(PO_4)_2$ that will be formed (assuming a 100% yield).

1- write a chemical equation

$$Mg(OH)_2 + H_3PO_4 \rightarrow Mg_3(PO_4)_2 + H_2O$$

2- balance the equation

$$3Mg(OH)_2 + 2H_3PO_4 \rightarrow Mg_3(PO_4)_2 + 6H_2O$$

3- determine mass of pure sample

$$\text{mass of } Mg(OH)_2 \text{ in sample} = \frac{(\text{Percent purity})(\text{total mass of sample})}{100} = \frac{(92.5\%)(15.0\,g)}{100}$$

$$= 13.875\,g$$

4- calculate mass of product (theoretical yield)

$$13.875\,g\ Mg(OH)_2 \times \frac{mol}{58.33\,g} \times \frac{1\ mol\ Mg_3(PO_4)_2}{3\ mol\ Mg(OH)_2} \times \frac{262.87\,g}{mol} = 20.8\,g$$

(iii) Automotive air bags inflate when solid sodium azide, NaN_3, decomposes explosively into sodium and nitrogen gas. What volume of nitrogen gas is formed if 120g of 85% pure sodium azide decomposes. Assume STP conditions.

1- write a chemical equation

$$NaN_3 \longrightarrow Na + N_2$$

2- balance the equation

$$2NaN_3 \longrightarrow 2Na + 3N_2$$

3- determine mass of pure sample

$$\text{mass of } NaN_3 \text{ in sample} = \frac{(\text{Percent purity})(\text{total mass of sample})}{100} = \frac{(85\%)(120\,g)}{100}$$

$$= 102\,g$$

4- calculate volume of product (theoretical yield)

$$102\,g\ NaN_3 \times \frac{mol}{65.02\,g} \times \frac{3\ mol\ N_2}{2\ mol\ NaN_3} \times \frac{22.7\ dm^3}{mol} = 53.4\,dm^3$$