




Calculating Yields

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Yields

Theoretical Yield:
Amount of product formed from *complete* conversion of a given amount of reactant to product (From stoichiometry calculations)

Prediction of EXPECTED Yield

Actual Yield:
Amount of product obtained in an experiment

Lower than theory:
Side Reactions
Impure Reagents
Mechanical Loss
Errors (weighing, etc.)





% Yield:
Actual yield expressed as a percentage of the theoretical yield

$$\% \text{ Yield} = \frac{\text{actual}}{\text{theoretical}} \times 100$$

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Theoretical vs. Actual

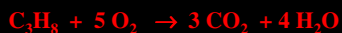
Theoretical Yield	Actual Yield
Calculated	Measured
Larger	(Should be) Smaller
Predicted	Obtained in the lab
may be supplied (given) OR calculated from $g(A) \rightarrow g(B)$	Measured in lab (given)

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Determine Percent Yield From Data

A chemist isolated 181 grams of CO₂ from the complete combustion of propane (C₃H₈). If the theoretical yield was 203 g of CO₂, what is the percent yield for this reaction?



Given: actual yield = 181 g carbon dioxide
theoretical yield = 203 g carbon dioxide
Wanted: percent yield



$$\% \text{ Yield} = \text{actual} / \text{theoretical} \times 100$$

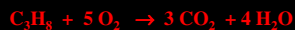
$$\% \text{ Yield} = \frac{181 \text{ g}}{203 \text{ g}} \times 100 = 89.2 \%$$

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Determine Percent Yield From Stoichiometry

Calculate the percent yield if 70.6 grams of water were obtained when 52.5 grams of propane were burned in oxygen.



Given:
actual yield = 70.6 g water
starting material = 52.5 g propane
Wanted: percent yield



Molar Mass: water = 18.02 g/mole; propane = 44.10 g/mole

Set-up conversion string for theoretical yield of water:

$$52.5 \text{ g C}_3\text{H}_8 \times \frac{1 \text{ mole C}_3\text{H}_8}{44.10 \text{ g C}_3\text{H}_8} \times \frac{4 \text{ mole H}_2\text{O}}{1 \text{ mole C}_3\text{H}_8} \times \frac{18.02 \text{ g H}_2\text{O}}{1 \text{ mole H}_2\text{O}} = 85.8 \text{ g}$$

$$\% \text{ Yield} = \text{actual/theory} \times 100$$

$$\% \text{ Yield} = \frac{70.6 \text{ g}}{85.8 \text{ g}} \times 100 = 82.3$$

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Let the units drive the solution

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Determine Percent Yield From Stoichiometry

Calculate the theoretical yield of Copper (in grams) when 85.0 g of oxygen reacts with excess (xs) copper (I) sulfide.



Molar Mass: O₂ = 32.00 g/mole; Cu = 63.55 g/mole

Set-up conversion string for theoretical yield of copper:

$$85.0 \text{ g O}_2 \times \frac{1 \text{ mol O}_2}{32.00 \text{ g O}_2} \times \frac{2 \text{ mol Cu}}{1 \text{ mol O}_2} \times \frac{63.55 \text{ g Cu}}{1 \text{ mol Cu}} = 338 \text{ g}$$

If you isolated 231 g, what was your percent yield?

$$\frac{231 \text{ g}}{338 \text{ g}} \times 100 = 68.3 \%$$



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Determine Percent Yield From Stoichiometry

Calculate the theoretical yield of H₂ gas in grams when 45.00 g of Al react with excess HBr.



Molar Mass: Al = 26.98 g/mole; H₂ = 2.016 g/mole

Theoretical Yield of Hydrogen gas:

$$45.00 \text{ g Al} \times \frac{1 \text{ mol Al}}{26.98 \text{ g Al}} \times \frac{3 \text{ mol H}_2}{2 \text{ mol Al}} \times \frac{2.016 \text{ g H}_2}{1 \text{ mol H}_2} = 5.044 \text{ g}$$

If you obtained 4.785 g H₂, what is the percent yield?

$$\frac{4.785 \text{ g H}_2}{5.044 \text{ g H}_2} \times 100 = 94.87 \%$$

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Determine Percent Yield From Stoichiometry

Lead (II) nitrate reacts with sodium iodide to form lead(II) iodide and sodium nitrate. What is the theoretical yield of lead (II) iodide if 138.820 g of sodium iodide are reacted with an excess amount of Lead(II) nitrate?

Write the balanced reaction: $\text{Pb}(\text{NO}_3)_2(\text{aq}) + 2 \text{NaI}(\text{aq}) \rightarrow \text{PbI}_2(\text{s}) + 2 \text{NaNO}_3(\text{aq})$

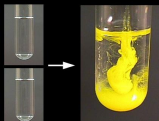
Molar Mass NaI: 149.89 g/mole; molar mass PbI₂: 460.99 g/mole

Setting up the linear string starting with given mass of NaI:

$$138.820 \text{ g NaI} \times \frac{1 \text{ mole NaI}}{149.89 \text{ g}} \times \frac{1 \text{ mole PbI}_2}{2 \text{ moles NaI}} \times \frac{460.99 \text{ g}}{\text{mole PbI}_2} = 213.47 \text{ g}$$

If 197.5 grams were isolated, what is the experimental yield?

$$\frac{197.5 \text{ g}}{213.47 \text{ g}} \times 100 = 92.5180 \rightarrow 92.52 \%$$



Let the units drive the solution

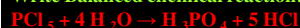
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Typical Insert Problem

Calculate theoretical yield when 24.9 g of phosphorus pentachloride reacts with water to yield phosphoric and hydrochloric acids.

Write Balanced chemical reaction:



Use stoichiometry to determine theoretical yield:

$$24.9 \text{ g PCl}_5 \times \frac{1 \text{ mole PCl}_5}{208.22 \text{ g}} \times \frac{5 \text{ moles HCl}}{1 \text{ mole PCl}_5} \times \frac{36.46 \text{ g HCl}}{\text{mole HCl}} = 21.8 \text{ g}$$

If a chemist isolated 19.234 g, what is the percent yield?

$$\frac{19.234 \text{ g}}{21.8} \times 100 = 88.2 \%$$

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Most chemical processes yield less than 100%

This becomes a severe problem for multiple-step operations

Say 90% yield for each step, then after 5 steps:

$(0.90)^5 = \sim 59\%$ of wanted product: rest may be useless

Global manufacturing (and lab research)

centers around

Increasing % yields

Separating wanted products from reactants & unwanted products



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