




## 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)<br>OR<br>calculated from $g(A) \rightarrow g(B)$ | Measured in lab (given) |

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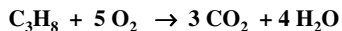
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### Determine Percent Yield From Data

A chemist isolated 181 grams of CO<sub>2</sub> from the complete combustion of propane (C<sub>3</sub>H<sub>8</sub>). If the theoretical yield was 203 g of CO<sub>2</sub>, 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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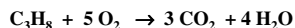
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### Determine Percent Yield From Stoichiometry

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: O<sub>2</sub> = 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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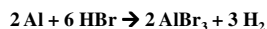
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### Determine Percent Yield From Stoichiometry

Calculate the theoretical yield of H<sub>2</sub> gas in grams when 45.00 g of Al react with excess HBr.



Molar Mass: Al = 26.98 g/mole; H<sub>2</sub> = 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 H<sub>2</sub>, 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:  $\text{Pb}(\text{NO}_3)_2(\text{aq}) + 2 \text{NaI}(\text{aq}) \rightarrow \text{PbI}_2(\text{s}) + 2 \text{NaNO}_3(\text{aq})$

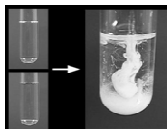
Molar Mass NaI: 149.89 g/mole; molar mass PbI<sub>2</sub>: 460.99 g/mole

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?

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



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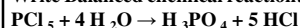
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### Typical Insert Problem

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

Write Balanced chemical reaction:



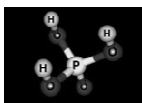
Use stoichiometry to determine theoretical yield:

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

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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