Percentage yield

4.3.3.1 · Quantitative chemistry · revision notes

The yield is the amount of product you actually obtain. Percentage yield compares it with the maximum (theoretical) amount that could be made. This is in GCSE Chemistry only, not Combined Science; calculating the theoretical mass from a balanced equation is Higher tier only.

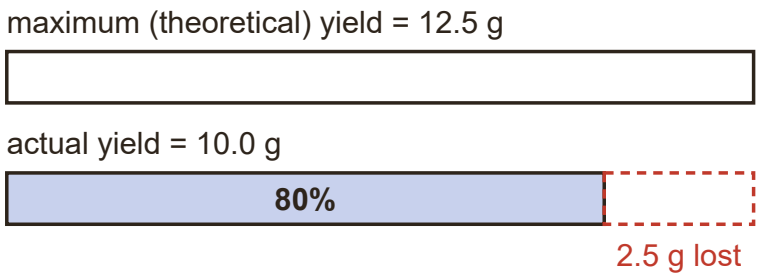
Key facts

- Yield = amount of product actually obtained
- Actual mass = % yield × theoretical mass ÷ 100
- A percentage yield cannot be more than 100% (if it is, the product is probably impure or still wet)
- % yield = actual mass ÷ theoretical mass × 100
- Low yield: reversible reaction; product lost when separated; reactants react in unexpected ways
- Grade 7+ only Theoretical mass: mass → moles → ratio → moles → mass

Notes

Yield and percentage yield

- The **yield** is the amount of product obtained.
- The **theoretical yield** is the maximum mass of product that could be made, calculated from the balanced equation.
- percentage yield = (mass of product actually made ÷ maximum theoretical mass of product) × 100
- Example: theoretical yield 12.5 g, actual yield 10.0 g: 10.0 ÷ 12.5 × 100 = 80.0%.



Percentage yield = 10.0 ÷ 12.5 × 100 = 80.0%. The missing 2.5 g is the product that was not obtained.

- Rearranged: actual mass = percentage yield ÷ 100 × theoretical mass. Example: an 85% yield of a theoretical 40.0 g is 0.85 × 40.0 = 34.0 g.
- Both masses must be in the same unit (e.g. both in g) before you divide.

Why the yield is less than 100%

- No atoms are gained or lost, but it is not always possible to obtain the calculated amount of product because:
- the reaction may not go to completion because it is **reversible**
- some of the product may be **lost when it is separated** from the reaction mixture (e.g. left on the filter paper or in the apparatus)
- some of the reactants may **react in ways different** to the expected reaction.
- A high percentage yield wastes fewer reactants and less energy, which saves resources and money.

Theoretical yield from an equation Grade 7+ only

- Use the reacting-mass method: moles of reactant → mole ratio → moles of product → mass.
- Worked example: 10.0 g of calcium carbonate is heated. $CaCO_3 \rightarrow CaO + CO_2$. Moles of $CaCO_3$ = 10.0 ÷ 100 = 0.100 mol, so 0.100 mol of CaO can form. Theoretical yield = 0.100 × 56 = 5.60 g.
- If 4.48 g of CaO is actually obtained: 4.48 ÷ 5.60 × 100 = 80.0%.

How to answer each type of question

Calculate the percentage yield 2 marks Grade 5

1. Divide the actual mass by the theoretical (maximum) mass.
2. Multiply by 100 and give the % sign.

Example. The maximum theoretical mass of magnesium sulfate that could be made in a reaction was 6.00 g. A student obtained 4.20 g of dry crystals.
Calculate the percentage yield. [2 marks]

Model answer.

4.20 ÷ 6.00 × 100 (1)
= 70.0% (1)

Give reasons why the yield is less than 100% 2 marks Grade 5

1. Choose from the three standard reasons.
2. Make each reason specific and link it to the context if one is given.

Example. Give **two** reasons why the percentage yield of a product is less than 100%. [2 marks]

Model answer.

Any two from:
the reaction is reversible, so it does not go to completion (1)
some product is lost when it is separated from the reaction mixture (1)
some reactants react in ways different to the expected reaction (1)

Calculate the actual mass from a percentage yield

2 marks | Grade 5

1. Divide the percentage yield by 100.
2. Multiply by the theoretical mass, keeping its unit.

Example. A reaction has a percentage yield of 65%. The theoretical yield is 40 kg.
Calculate the mass of product obtained. [2 marks]

Model answer.

65 ÷ 100 × 40 (1)
= 26 kg (1)

Calculate the theoretical yield, then the percentage yield

4 marks | Grade 8

1. Moles of reactant = mass ÷ M_r.
2. Use the mole ratio to find the moles of product.
3. Theoretical mass = moles × M_r.
4. % yield = actual ÷ theoretical × 100.

Example. Copper oxide is reduced by heating it with carbon.
$2CuO + C \rightarrow 2Cu + CO_2$
A student heated 7.95 g of copper oxide with excess carbon and obtained 5.08 g of copper.
Calculate the percentage yield.
A_r: O = 16; Cu = 63.5 [4 marks]

Model answer.

M_r of CuO = 79.5, so moles = 7.95 ÷ 79.5 = 0.100 mol (1)
ratio 2 : 2, so 0.100 mol of Cu can form (1)
theoretical mass = 0.100 × 63.5 = 6.35 g (1)
% yield = 5.08 ÷ 6.35 × 100 = 80.0% (1)

Don’t lose marks

- Putting the theoretical mass on top and getting an answer over 100%.
- Confusing percentage yield with atom economy: yield uses measured masses; atom economy uses M_r values from the equation.
- Giving vague reasons such as 'human error' or 'mistakes' instead of the three standard reasons.
- Saying that atoms are lost. Atoms are never lost; product is lost from the apparatus or never forms.
- Dividing masses given in different units, e.g. 900 g by 1.2 kg: convert one first so both are in g or both in kg.

More tips

Memory tricks

- Actual over theoretical: what you got goes on top, so the answer is below 100%.
- Remember the reasons as R, L, S: Reversible, Lost when separating, Side (unexpected) reactions.
- Quick check: a 50% yield is half the theoretical mass.
- A 100% yield would mean every bit of reactant became product and none was lost.

Exam technique

- Learn the three reasons for a low yield word for word; each is often worth a mark.
- Write the division before multiplying by 100 so you can earn the method mark.
- Give the % sign and round only at the end.

What each grade needs

What you need to be able to do, from the first marks up to the top grade.

Grade 4

State what is meant by yield

The amount of product obtained from a reaction.

Grade 5

Calculate percentage yield

% yield = mass of product actually made ÷ maximum theoretical mass × 100.

Grade 5

Give reasons why yield is below 100%

The reaction is reversible, some product is lost when it is separated, or some reactants react in unexpected ways.

Grade 5

Calculate actual mass from percentage yield

Actual mass = % yield ÷ 100 × theoretical mass.

Grade 7

Calculate theoretical mass from an equation

Use reacting masses: moles of reactant → mole ratio → moles of product → mass.

Grade 8

Solve multi-step percentage yield problems

Find the theoretical yield from the reactant mass first, then the percentage yield.

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