Atom economy

4.3.3.2 · Quantitative chemistry · revision notes

Atom economy measures how much of the starting materials ends up in the useful product. You calculate it from the balanced equation. This is in GCSE Chemistry only, not Combined Science; explaining why a reaction pathway is chosen using atom economy, yield, rate, equilibrium position and by-products is Higher tier only.

Key facts

- % atom economy = M_r of desired product ÷ total M_r of reactants × 100
- Total M_r of reactants = total M_r of products
- High atom economy → less waste, more sustainable, cheaper
- Use the balancing numbers: multiply each M_r by them
- Only one product → 100% atom economy
- Grade 8+ only Choosing a route: atom economy, yield, rate, equilibrium position, useful by-products

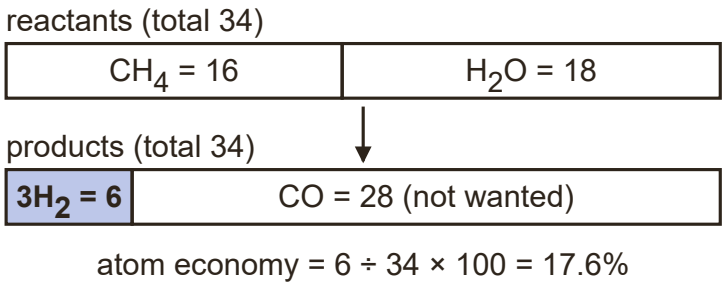
Notes

What atom economy is

- **Atom economy** (atom utilisation) is a measure of the amount of starting materials that end up as useful products.
- percentage atom economy = (M_r of desired product from the reaction ÷ sum of M_r of all reactants) × 100
- Use the balanced equation, and multiply each M_r by its balancing number.
- Mass is conserved, so the total M_r of all the products equals the total M_r of all the reactants: a useful check.
- A reaction with only one product has an atom economy of 100%.

Worked example

- Hydrogen can be made by reacting methane with steam: $CH_4 + H_2O \rightarrow CO + 3H_2$.
- Sum of reactants: 16 + 18 = 34. Desired product: $3H_2 = 3 \times 2 = 6$.
- Atom economy = 6 ÷ 34 × 100 = 17.6% (to 3 significant figures).



atom economy = 6 ÷ 34 × 100 = 17.6%

Only the blue part (hydrogen, the desired product) counts as useful; the rest of the mass is waste.

Why it matters

- Reactions with a high atom economy are important for **sustainable development** and for **economic reasons**: they use fewer resources and make less waste.
- A low atom economy means a lot of waste product, which must be disposed of unless it can be used or sold.

Choosing a reaction pathway Grade 8+ only

- To choose between ways of making a product, compare the **atom economy**, the **yield**, the **rate** of reaction, the **equilibrium position** (for reversible reactions) and whether the **by-products** are useful.
- A route with a lower atom economy may still be chosen if its yield is higher, it is faster, or its by-product can be sold.
- Atom economy and yield are different: a reaction can have 100% atom economy but a low yield if it is reversible.

How to answer each type of question

Calculate the atom economy

2 to 3 marks | Grade 5

1. Add up the M_r of all the reactants, using the balancing numbers.
2. Work out the M_r of the desired product, using its balancing number.
3. Divide, multiply by 100 and round as asked.

Example. Iron is extracted in a blast furnace.
$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$
Calculate the percentage atom economy for making iron. Give your answer to 3 significant figures.
M_r: Fe_2O_3 = 160; CO = 28. A_r: Fe = 56 [3 marks]

Model answer.

sum of M_r of reactants = 160 + (3 × 28) = 244 (1)

desired product = 2 × 56 = 112 (1)

atom economy = 112 ÷ 244 × 100 = 45.9% (1)

Explain why a high atom economy is important

2 marks | Grade 5

1. Say that more of the reactants end up in the useful product, so there is less waste.
2. Link this to using fewer resources (sustainability) and to cost.

Example. Explain why chemical companies prefer reactions with a high atom economy. [2 marks]

Model answer. More of the atoms in the reactants end up in the useful product, so less waste is made (1). Fewer raw materials are needed for the same amount of product, which is more sustainable and saves money (1).

Explain a 100% atom economy with a low yield

2 marks | Grade 7

1. Link 100% atom economy to there being only one product.
2. Explain the low yield separately, e.g. the reaction is reversible.

Example. The reaction $N_2 + 3H_2 \rightleftharpoons 2NH_3$ has an atom economy of 100% but a low percentage yield. Explain why. [2 marks]

Model answer. There is only one product, so all the atoms in the reactants end up in the desired product (1). The reaction is reversible, so it does not go to completion and not all of the reactants are converted into ammonia (1).

Evaluate two routes to a product 4 to 6 marks **Grade 8**

1. Compare the routes factor by factor, using the data given (atom economy, rate, raw materials, by-products).
2. Give an advantage and a disadvantage of each route.
3. Finish with a conclusion that follows from your points.

Example. Ethanol can be made in two ways.

	Route 1: fermentation	Route 2: hydration of ethene
Equation	$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$	$C_2H_4 + H_2O \rightarrow C_2H_5OH$
Atom economy	51%	100%
Raw material	sugar from crops (renewable)	ethene from crude oil
Process	slow, batch	fast, continuous

Evaluate the two routes. [5 marks]

Model answer. Route 2 has the higher atom economy (100% compared with 51%), so no waste product is made (1). Route 2 is faster and continuous, so more ethanol is made in a given time (1). Route 1 uses a renewable raw material, but the ethene for Route 2 comes from crude oil, which is finite (1). Route 1 makes carbon dioxide as a by-product, which is wasted unless it can be used or sold (1). Conclusion, e.g. Route 2 is better for making large amounts quickly, but Route 1 is more sustainable in the long term (1).

Don’t lose marks

- Forgetting the balancing numbers, e.g. using 56 for iron instead of 2 × 56 = 112.
- Putting only one reactant on the bottom, or the waste product on top.
- Confusing atom economy with percentage yield.
- Saying a high atom economy means a fast reaction or a high yield. It tells you nothing about either.

More tips

Memory tricks

- Wanted over total: the desired product on top, all the reactants on the bottom.
- Check your bottom number by adding up all the products: the total must be the same.
- One product → 100%. Two or more products → less than 100%.
- Atom economy needs only the equation; percentage yield needs measured masses.

Exam technique

- Write out the sum of the M_r values on the bottom so each part can earn a mark.
- In 'evaluate' questions, compare both routes for each factor, use the data given, and end with a justified conclusion.
- Give the answer to the significant figures asked for, with a % sign.
- Higher tier: you may be given the atom economy and asked for an unknown A_r. Write the atom economy expression with the unknown, set it equal to the value and rearrange.

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 atom economy measures**
The amount of the starting materials that ends up as the useful (desired) product.

Grade 5 — **Calculate atom economy from an equation**
Atom economy = M_r of desired product ÷ sum of M_r of all reactants × 100.

Grade 5 — **Use balancing numbers in atom economy**
Multiply each M_r by its balancing number before adding, e.g. 2Fe counts as 2 × 56 = 112.

Grade 5 — **Explain why high atom economy matters**
Less waste and fewer raw materials, which is better for sustainable development and cheaper.

Grade 5 — **Recognise reactions with 100% atom economy**
A reaction with only one product has an atom economy of 100%.

Grade 8 — **Evaluate reaction pathways using several factors**
Compare atom economy, yield, rate, equilibrium position and whether by-products are useful.

Free notes, Full packs, practice papers and mock exams at chhetriacademy.com. Written for this site; not taken from past papers. Stuck? 1-to-1 tutoring with a free 30-minute trial lesson.