Exercise walk-through

3.3
Yield and atom economy – chemistry only, HT (4.3.3)

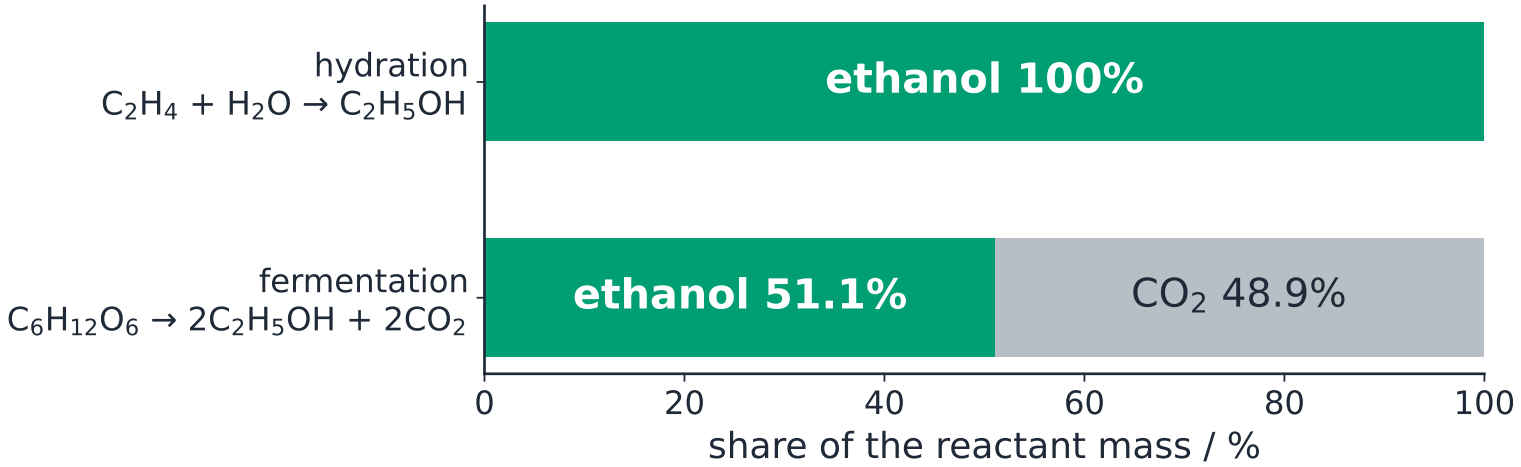
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Conservation of mass and equations

- The law of **conservation of mass** says that atoms are not made or destroyed in a chemical reaction.
- They are only rearranged, so the total mass of the products equals the total mass of the reactants.
- A symbol equation must therefore be **balanced** : the same number of each kind of atom on both sides.
- There are two kinds of number in an equation.

$$\text{percentage by mass} = \frac{A_r \times \text{number of atoms of the element}}{M_r} \times 100$$

Figure: Yield and atom economy (chemistry only)



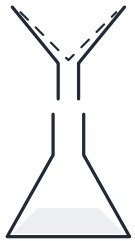
- **Atom economy** = mass of desired product ÷ total reactant mass × 100.
- Addition reactions waste nothing.

Key terms (2)

- **Limiting reactant**: the reactant that is used up first and so limits the amount of product.
- **Concentration**: the amount of **solute** in each dm^3 of solution.
- **Percentage yield**: the mass of product made as a percentage of the maximum **theoretical mass**.
- **Atom economy**: the mass of the desired product as a percentage of the total mass of the reactants.

Exercise 2.1

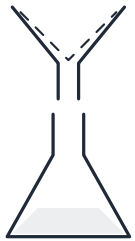
2.1 Give two reasons why yield is below 100 %. [2]



some product left behind

Exercise 2.1

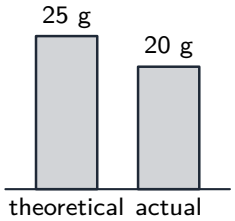
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2.1 Any two of: reversible reaction does not go to completion; product lost on separation from the mixture; reactants react in unwanted/side reactions.

Exercise 2.2

2.2 Theoretical mass 25 g, actual 20 g – percentage yield? [2]

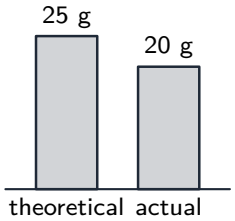


2.3 Why do industries prefer high-atom-economy processes? [1]



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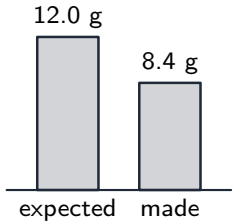


2.2 $20 \div 25 \times 100 = 80\ \%$.

2.3 Fewer raw materials are wasted and less needs disposing of – sustainable and cheaper.

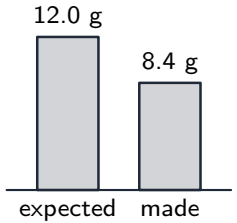
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3.1 $8.4 \div 12.0 \times 100 = 70\ \%$. Reasons: the reaction may be reversible and stop before completion; some product is lost when separated/filtered/purified; some reactants may react differently in side reactions.

Setup for exercise 3.2

3.2 Hydrogen is made from methane and steam: $CH_4 + H_2O \rightarrow CO + 3\ H_2$ (C = 12, H = 1, O = 16). Calculate the atom economy when hydrogen is the desired product. [4]

$CH_4 + H_2O \rightarrow CO + 3H_2$

3.3 State the difference between percentage yield and atom economy. [3]



Exercise 3.2

3.4 For the same desired product, route A has 90% atom economy, 40% yield and prolonged heating. Route B has 75% atom economy, 95% yield and a saleable by-product. Evaluate the routes using the data and identify one further piece of evidence needed. [4]

	A	B
atom economy	90%	75%
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3.2 $\mathrm{Mr}(CH_4) = 16$, $\mathrm{Mr}(H_2O) = 18 \rightarrow$ reactants total 34; Mr of desired product $= 3 \times 2 = 6$ for the hydrogen; atom economy $= 6 \div 34 \times 100 = 17.6\ \% \approx 18\ \%$.

3.3 Percentage yield compares what was actually made with what could theoretically be made from the reactant used – an experimental measure. Atom economy compares the coefficient-weighted relative mass of the desired product with the total coefficient-weighted relative mass of reactants from the equation – a property of the reaction itself. A reaction can run at 100 % yield yet low atom economy if by-products form as the only other outcome.

3.4 A directs a greater fraction of reactant mass to the desired product, but B recovers a greater fraction of its own theoretical product. Give a qualified judgement linking heating/energy or useful by-product to the supplied tradeoff; request relevant cost, energy, reactant quantity, rate, waste or actual by-product demand data. The percentages alone do not establish which gives more product per batch: theoretical amounts are not supplied.