

Green chemistry, atom economy and sustainable development

Learning objectives

- 1 Understand what sustainable development is and the role of green chemistry in advancing it.
- 2 Explain the importance of percentage yield and atom economy for sustainable development.
- 3 Calculate the percentage yield and atom economy of a chemical process given relevant data.

The competing needs of development and environmental protection are often mentioned in the media, and many learners have opinions on the subject. Chemistry is seen as a polluter, which partially accounts for its poor image among learners and the public.

Introduce your learners to the concept of atom economy in the context of sustainable development and green chemistry with this activity and show that development is necessary but can be achieved in a way which limits environmental damage.

You can use these student sheets and lesson slides to enrich your teaching of quantitative chemistry or when covering pollution and sustainable development. Use it either as a teacher-led activity in class or set it for independent learning.

The lesson slides include further reading for learners to find out more about how they as individuals and potential chemists of the future can contribute to sustainable development.

Highlight the range of careers available in chemistry using the article, Why the world urgently needs more chemists, featuring a diverse selection of chemists working in fields linked to sustainable development (rsc.li/4eT6BYp).

You can find further teaching activities, ideas and curriculum-linked resources on sustainable development in the Sustainability in chemistry series (rsc.li/4f3Cu0u).

Scaffolding

Scaffolded (★) and unscaffolded (★★) versions of the worksheets are included. The scaffolded version provides support for the calculations included in the resource.

The lesson slides (available to download from rsc.li/49NqSLB) provide two worked examples of how to calculate percentage yield and atom economy with an increase in challenge from the first to the second example in each case. The examples are different to those in the student worksheet to allow you to model the calculations before learners attempt the worksheet independently.

Answers

Unscaffolded student sheet (☆☆)

- Various answers are possible, including:
 - Not all pollution may be cleared up.
 - Energy will be wasted producing unwanted products.
 - It is better not to produce hazardous materials at all then there is no danger of them being spilled or falling into the wrong hands.
- Using a catalyst (or more efficient catalyst) may mean that the process can be carried out at a lower temperature, which saves energy. It may also increase the yield of one product over that of another, unwanted one.
- $(21/28) \times 100 = 75\%$
- Maximum mass of SO_2 that could be produced = 16 g
 Percentage yield = $(14/16) \times 100 = 87.5\%$
- Atom economy = 100%
- $\frac{(4 \times 56)}{2 \times [(56 \times 2) + (3 \times 16)] + (3 \times 12)} \times 100 = \frac{224}{356} \times 100 = 62.9\%$
- (a) Displacement: $\frac{48}{[48 + (2 \times 16)] + (2 \times 24)} \times 100 = \frac{48}{128} \times 100 = 37.5\%$
 Electrolysis: $\frac{48}{48 + (2 \times 16)} \times 100 = \frac{48}{80} \times 100 = 60\%$
 (b) The greener process appears to be electrolysis. Before finally deciding it might be important to know how much energy is used in each process, what (if any) solvents are used and what the yield for each reaction is.
 (c) Atom economy = 100% because both products are now useful, so all the reactants have been converted into useful products and there is no waste.
- (a) $\frac{[(2 \times 12) + (4 \times 1)]}{[(10 \times 12) + (22 \times 1)]} \times 100 = \frac{28}{142} \times 100 = 19.7\%$
 (b) Atom economy = 100%
 (c) If only one product can be sold, then the rest is wasted; if both can be sold then there is no waste product and the atom economy is greater.
- (a) Atom economy = 100%
 (b) The reversible reaction symbol ($\rightleftharpoons$) suggests that the reaction is unlikely to have a very high yield.
- Answers include:
 - more efficient use of resources
 - less waste
 - less pollution
 - less energy used

These things are important for sustainable development because they all help to make sure that we leave the planet healthy for future generations and do not use up all the available resources.

Answers

Scaffolded student sheet (✱)

1. Various answers are possible, including:

- Not all pollution may be cleared up.
- Energy will be wasted producing unwanted products.
- It is better not to produce hazardous materials at all then there is no danger of them being spilled or falling into the wrong hands.

2. Using a catalyst may mean that the process can be carried out at a lower temperature, which saves energy. It may also increase the yield of one product over that of another, unwanted one.

3.

(a) 28 kg

(b) $(21/28) \times 100 = 75\%$

4.

(a) Percentage yield = $(48/64) \times 100 = 75\%$

(b) Maximum mass of SO_2 that could be made = 16 g

(c) Percentage yield = $(14/16) \times 100 = 87.5\%$

5.

(a) Mr of $\text{SO}_2 = 32 + (2 \times 16) = 64$

(b) Mr of $\text{S} + \text{O}_2 = 32 + (2 \times 16) = 64$

(c) Atom economy = $(64/64) \times 100 = 100\%$

6. Mr of desired product (4Fe) = $4 \times 56 = 224$

Total Mr of all reactants ($2\text{Fe}_2\text{O}_3 + 3\text{C}$) = $(2 \times 160) + (3 \times 12) = 356$

% atom economy = $(224/356) \times 100 = 62.9\%$

7.

(a)

i. **Method 1:** $\frac{48}{[48 + (2 \times 16)] + (2 \times 24)} \times 100 = \frac{48}{128} \times 100 = 37.5\%$

ii. **Method 2:** $\frac{48}{48 + (2 \times 16)} \times 100 = \frac{48}{80} \times 100 = 60\%$

(b) The greener process appears to be electrolysis. Before finally deciding it might be important to know how much energy is used in each process, what (if any) solvents are used and what the yield for each reaction is.

(c) Atom economy = 100% because both products are now useful, so all the reactants have been converted into useful products and there is no waste.

8.

(a) $\frac{[(2 \times 12) + (4 \times 1)]}{[(10 \times 12) + (22 \times 1)]} \times 100 = \frac{28}{142} \times 100 = 19.7\%$

(b) Atom economy = 100%

(c) If only one product can be sold, then the rest is wasted; if both can be sold, then there is no waste product and the atom economy is greater.

9.

(a) Atom economy = 100%

(b) The reversible reaction symbol ($\rightleftharpoons$) suggests that the reaction is unlikely to have a very high yield.

10. Answers include:

- more efficient use of resources
- less waste
- less pollution
- less energy used

These things are important for sustainable development because they all help to make sure that we leave the planet healthy for future generations and do not use up all the available resources.