Percentage yield and atom economy

Worked solutions

GCSE science calculations

This topic online

1 Amira makes copper sulfate crystals in a Year 10 practical. The maximum theoretical mass of crystals she could make is 5.0 g. She actually makes 4.2 g.

Calculate the percentage yield. (2 marks)

$$\text{Percentage yield} = \frac{\text{mass actually made}}{\text{maximum theoretical mass}} \times 100$$

$$\% \text{ yield} = \frac{4.2}{5.0} \times 100$$

84%

2 Hydrogen for fuel cells can be made by reacting methane with steam.

$CH_4 + H_2O \rightarrow CO + 3H_2$

Hydrogen is the desired product.

- Sum of the relative formula masses of the reactants = 34
- Relative formula mass of $3H_2$ = 6

Calculate the atom economy for making hydrogen by this reaction. (2 marks)

$$\text{Atom economy} = \frac{\text{Mr of desired product}}{\text{sum of Mr of reactants}} \times 100$$

$$\text{atom economy} = \frac{6}{34} \times 100$$

$$\text{atom economy} = 17.647...\%$$

17.6%

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3 Callum makes zinc chloride three times using the same method. The maximum theoretical mass each time is 3.75 g.

Attempt	Mass of zinc chloride made in g
1	3.12
2	3.30
3	3.21

Calculate the mean percentage yield. (3 marks)

Find the mean mass made (not the total)

$$\text{mean} = \frac{3.12 + 3.30 + 3.21}{3}$$

$$\text{mean} = \frac{9.63}{3} = 3.21 \text{ g}$$

$$\text{Percentage yield} = \frac{\text{mass actually made}}{\text{maximum theoretical mass}} \times 100$$

$$\% \text{ yield} = \frac{3.21}{3.75} \times 100$$

85.6%

4 A fertiliser works in Lincolnshire makes ammonium nitrate in batches. For one batch, the maximum theoretical mass is 2.4 tonnes. The works actually makes 1950 kg.

1 tonne = 1000 kg

Calculate the percentage yield for this batch. (3 marks)

Put both masses in kg

$$2.4 \text{ tonnes} = 2.4 \times 1000 = 2400 \text{ kg}$$

$$\text{Percentage yield} = \frac{\text{mass actually made}}{\text{maximum theoretical mass}} \times 100$$

$$\% \text{ yield} = \frac{1950}{2400} \times 100$$

81.25%

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5 A technician in a hospital pharmacy lab makes a small sample of a painkiller. The maximum theoretical mass is 1.20 g. She actually makes 850 mg.

Calculate the percentage yield.

Give your answer to 3 significant figures.

(3 marks)

1 g = 1000 mg

850 mg = 850 ÷ 1000 = 0.850 g

$$\text{Percentage yield} = \frac{\text{mass actually made}}{\text{maximum theoretical mass}} \times 100$$

$$\% \text{ yield} = \frac{0.850}{1.20} \times 100$$

$$\% \text{ yield} = 70.833...\%$$

70.8%

6 Priya makes magnesium sulfate crystals and dries them in an evaporating basin. The maximum theoretical mass of crystals is 4.80 g.

- Mass of the empty evaporating basin = 32.40 g
- Mass of the evaporating basin and dry crystals = 36.15 g

Calculate the percentage yield.

Give your answer to 3 significant figures.

(3 marks)

Mass of crystals = (basin + crystals) − empty basin, not 36.15 g

mass made = 36.15 − 32.40 = 3.75 g

$$\text{Percentage yield} = \frac{\text{mass actually made}}{\text{maximum theoretical mass}} \times 100$$

$$\% \text{ yield} = \frac{3.75}{4.80} \times 100$$

$$\% \text{ yield} = 78.125\%$$

78.1%

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7 A chemist expects a percentage yield of 65% when making an ester. The maximum theoretical mass of the ester is 12.0 g.

Calculate the mass of ester the chemist expects to make. (2 marks)

$$\text{Percentage yield} = \frac{\text{mass actually made}}{\text{maximum theoretical mass}} \times 100$$

$$65 = \frac{m}{12.0} \times 100$$

Rearrange: $m = \frac{\text{\% yield}}{100} \times \text{theoretical mass}$

$$m = \frac{65}{100} \times 12.0$$

7.8 g

8 Tomasz heats 9.6 g of a metal carbonate and collects 5.4 g of the metal oxide. His percentage yield is 72%.

Calculate the maximum theoretical mass of the metal oxide. (3 marks)

Use the mass of oxide made (5.4 g), not the 9.6 g of carbonate

$$\text{Percentage yield} = \frac{\text{mass actually made}}{\text{maximum theoretical mass}} \times 100$$

$$72 = \frac{5.4}{M} \times 100$$

$$0.72 = \frac{5.4}{M}$$

Rearrange: $M = 5.4 \div 0.72$

$$M = 5.4 \div 0.72$$

7.5 g

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9 Railway engineers weld rails together using the thermite reaction.

$Fe_2O_3 + 2Al \rightarrow 2Fe + Al_2O_3$

Iron is the desired product.

Relative atomic masses (A_r): O = 16, Al = 27, Fe = 56

Calculate the atom economy for making iron by this reaction. (3 marks)

Use the numbers in front of each formula

$Mr \text{ of } Fe2O3 = (2 \times 56) + (3 \times 16) = 160$

$2Al = 2 \times 27 = 54$

$\text{sum of reactants} = 160 + 54 = 214$

$2Fe = 2 \times 56 = 112$

$$\text{Atom economy} = \frac{Mr \text{ of desired product}}{\text{sum of } Mr \text{ of reactants}} \times 100$$

$$\text{atom economy} = \frac{112}{214} \times 100$$

$\text{atom economy} = 52.336...\%$

52.3%

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10 **Higher tier**

Grace heats 4.94 g of copper carbonate until it has all decomposed.

$CuCO_3 \rightarrow CuO + CO_2$

She collects 2.86 g of copper oxide.

Relative atomic masses (A_r): C = 12, O = 16, Cu = 63.5

Calculate the percentage yield of copper oxide.

Give your answer to 3 significant figures. Show your working.

(4 marks)

Mr of $CuCO_3$ = 63.5 + 12 + (3 × 16) = 123.5

Moles = mass ÷ Mr

moles of $CuCO_3$ = 4.94 ÷ 123.5 = 0.04 mol

1 $CuCO_3$: 1 CuO

moles of CuO = 0.04 mol

Mr of CuO = 63.5 + 16 = 79.5

theoretical mass = 0.04 × 79.5 = 3.18 g

$$\text{Percentage yield} = \frac{\text{mass actually made}}{\text{maximum theoretical mass}} \times 100$$

$$\%\ \text{yield} = \frac{2.86}{3.18} \times 100$$

% yield = 89.937...%

89.9%

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11 Zinc sulfate is used in some dietary supplements. A company can make it by two different routes.

Route A: $ZnO + H_2SO_4 \rightarrow ZnSO_4 + H_2O$

Route B: $ZnCO_3 + H_2SO_4 \rightarrow ZnSO_4 + H_2O + CO_2$

Zinc sulfate is the desired product.

Relative atomic masses (A_r): H = 1, C = 12, O = 16, S = 32, Zn = 65

a. Calculate the atom economy for making zinc sulfate by Route A. Give your answer to 3 significant figures. Show your working.

b. Calculate the atom economy for making zinc sulfate by Route B. Give your answer to 3 significant figures.

c. Give one reason why Route B has a lower atom economy than Route A.

(5 marks)

a)

$Mr \text{ of } ZnSO4 = 65 + 32 + (4 \times 16) = 161$

$Mr \text{ of } ZnO = 65 + 16 = 81$

$Mr \text{ of } H2SO4 = (2 \times 1) + 32 + (4 \times 16) = 98$

$\text{sum of reactants} = 81 + 98 = 179$

$$\text{Atom economy} = \frac{\text{Mr of desired product}}{\text{sum of Mr of reactants}} \times 100$$

$$\text{atom economy} = \frac{161}{179} \times 100$$

$$\text{atom economy} = 89.944...\%$$

89.9%

b)

$Mr \text{ of } ZnCO3 = 65 + 12 + (3 \times 16) = 125$

$\text{sum of reactants} = 125 + 98 = 223$

$$\text{atom economy} = \frac{161}{223} \times 100$$

$$\text{atom economy} = 72.197...\%$$

72.2%

c)

Route B also makes CO_2, an extra waste product, so fewer atoms end up in zinc sulfate

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12 **Higher tier**

In a blast furnace, iron(III) oxide is reduced to iron.

$Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

In one test run, 800 kg of iron(III) oxide produced 532 kg of iron.

Relative atomic masses (A_r): O = 16, Fe = 56

Calculate the percentage yield of iron. Show your working. (5 marks)

Moles need the mass in g

800 kg = 800 × 1000 = 800 000 g

Mr of Fe2O3 = (2 × 56) + (3 × 16) = 160

Moles = mass ÷ Mr

moles of Fe2O3 = 800 000 ÷ 160 = 5000 mol

1 Fe2O3 : 2 Fe

moles of Fe = 5000 × 2 = 10 000 mol

theoretical mass = 10 000 × 56 = 560 000 g = 560 kg

$$\text{Percentage yield} = \frac{\text{mass actually made}}{\text{maximum theoretical mass}} \times 100$$

$$\% \text{ yield} = \frac{532}{560} \times 100$$

95%

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