GCSE · AQA · Chemistry

2 hours 21 questions

Exam Questions

Yield & Atom Economy

Percentage Yield / Theoretical Masses of Products / Calculating Atom Economy / Choosing a Reaction Pathway

Easy (6 questions)	/42
Medium (10 questions)	/36
Hard (5 questions)	/43
Total Marks	**/121**

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Easy Questions

1 (a) This question is about the yield of chemical reactions.

In practice, scientists aim for a 100% yield but this is rarely achieved.

Complete the sentences to explain why a 100% yield is not achieved.

Choose answers from the box.

purification	reversible	incomplete
transfer	side reactions	

Reactants and products can be left behind during _____ from one container to another.

_____ reactions can never have a 100% yield because the products are forming reactants.

A reaction might not go to completion because of _____ or the presence of an impurity. These reactions are described as _____ .

(4 marks)

(b) There are different types of yield.

The percentage yield compares the actual yield to the theoretical yield.

Draw **one** line from each yield to its description.

Yield	Description
Actual	The recorded amount of reactant obtained
Theoretical	The amount of product that could be obtained with perfect conditions
	The recorded amount of product obtained

(2 marks)

(c) What is the correct equation to calculate percentage yield?

Circle **one** equation.

$\frac{\text{actual yield}}{\text{theoretical yield}}$	$\frac{\text{actual yield}}{\text{theoretical yield}} \times 100$	$\frac{\text{theoretical yield}}{\text{actual yield}} \times 100$

.....

(1 mark)

2 (a) A student completed an experiment using magnesium to displace copper from copper(II) sulfate.

Complete the symbol equation.

$$Mg + CuSO_4 \rightarrow \_\_\_\_\_ + \_\_\_\_\_$$

(1 mark)

(b) The student added 4.8 g of magnesium to a solution of copper(II) sulfate.

Calculate the number of moles of magnesium that the student used.

Relative atomic mass (A_r): Mg = 24

Use the equation:

$$\text{moles} = \frac{\text{mass}}{M_r}$$

(1 mark)

(c) Using your answer to part (b), calculate the theoretical yield of copper.

Relative atomic mass (A_r): Cu = 63.5

Theoretical yield of copper = _____ g

(2 marks)

(d) Another student completes the same experiment using 4.8 g of magnesium.

They obtain 10.16 g of copper.

What is the percentage yield of this student's experiment?

..... **(2 marks)**

3 (a) This question is about atom economy.

What does atom economy measure?

.....

(1 mark)

(b) Silver nitrate and sodium iodide can react to form silver iodide.

The equation for the reaction is:

$$AgNO_3\ (aq) + NaI\ (aq) \rightarrow AgI\ (s) + NaNO_3\ (aq)$$

A student looks at the useful silver iodide product of this reaction and concludes that the percentage atom economy is 50%.

How might the student **mistakenly** arrive at this conclusion?

.....

.....

(2 marks)

(c) Calculate the relative formula mass of silver iodide, AgI.

Relative atomic masses (A_r): Ag = 108; I = 127

.....

(1 mark)

(d) Calculate the relative formula mass of sodium nitrate, $NaNO_3$.

Relative atomic masses (A_r): N = 14; Na = 23; O = 16

.....

.....

(2 marks)

(e) Calculate the percentage atom economy for making silver iodide.

Use the equation:

$$\text{Percentage atom economy} = \frac{\text{relative formula mass of desired product}}{\text{total mass of all products}} \times 100$$

Give your answer to 3 significant figures.

.....

.....

..... **(3 marks)**

4 (a) Copper sulfate can be made by reacting copper oxide with sulfuric acid.

$$CuO + H_2SO_4 \longrightarrow CuSO_4 + H_2O$$

Calculate the percentage atom economy for making copper sulfate.

Use the equation:

$$\text{Percentage atom economy} = \frac{\text{relative formula mass of desired product}}{\text{total mass of all reactants}} \times 100$$

Relative formula masses (M_r): $H_2SO_4 = 98$; $CuO = 79.5$; $CuSO_4 = 159.5$

Give your answer to 3 significant figures.

.....

.....

..... **(3 marks)**

(b) Reacting copper carbonate, $CuCO_3$, with sulfuric acid forms copper sulfate and two other products.

$$CuCO_3 + H_2SO_4 \rightarrow CuSO_4 + H_2O + CO_2$$

What type of reaction is this?

Tick (✓) **one** box.

Combustion	
Endothermic	
Neutralisation	
Decomposition	

(1 mark)

(c) The two methods of forming copper(II) sulfate using sulfuric acid are:

Method 1: $CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$

Method 2: $CuCO_3 + H_2SO_4 \rightarrow CuSO_4 + H_2O + CO_2$

Which method has the highest atom economy? Explain your answer.

Method: _____

Explanation: _____

.....

.....

(2 marks)

(d) High atom economy is a desirable attribute in industrial chemical processes.

Place the following attributes of chemical reactions into the correct columns in **Table 1**.

- Produce useful byproducts
- High percentage yield
- High energy costs
- Efficient reactions
- Use expensive raw materials

Table 1

Desirable attribute	Undesirable attribute

(5 marks)

5 (a) To produce a sample of hex-1-ene, 10.2 g of hexan-1-ol is dehydrated by heating with an excess of phosphoric(V) acid.

Hexan-1-ol → Hex-1-ene + water

$C_6H_{13}OH \rightarrow C_6H_{12} + H_2O$

After purification, 5.04 g of hex-1-ene was produced.

Calculate the number of moles of hexan-1-ol.

Relative molecular masses (M_r): $C_6H_{13}OH$ = 102; C_6H_{12} = 84

.....

(1 mark)

(b) Calculate the mass of hex-1-ene that could be produced.

.....

.....

(2 marks)

(c) What is the percentage yield for the production of hex-1-ene from hexan-1-ol in this experiment?

.....

.....

(2 marks)

(d) What is the percentage atom economy for the production of hex-1-ene from hexan-1-ol in this experiment?

$C_6H_{13}OH \rightarrow C_6H_{12} + H_2O$

Relative molecular masses (M_r): C_6H_{12} = 84; H_2O = 18

Give your answer to three significant figures.

.....

.....

.....

(3 marks)

6 Which of these is/are a factor(s) in choosing a reaction pathway?

	Atom economy	Percentage yield	Rate of reaction
A	✔		
B	✔	✔	
C		✔	✔
D	✔	✔	✔

(1 mark)

Medium Questions

1 (a) Nickel oxide is reduced by heating with carbon, producing nickel metal and carbon monoxide.

The equation for the reaction is as follows:

$$NiO + C \longrightarrow Ni + CO$$

Calculate the percentage atom economy for the production of nickel.

Relative atomic masses (A_r): C = 12; Ni = 59

Relative formula mass (M_r): NiO = 75; CO = 28

Give your answer correct to 3 significant figures.

Percentage atom economy = _____ %

.....

.....

..... **(3 marks)**

(b) Magnesium can be produced by reacting magnesium oxide with silicon.

The equation for the reaction is as follows:

$$Si\ (s) + 2MgO\ (s) \rightarrow SiO_2\ (s) + 2Mg\ (s)$$

A company calculated, based on the amount of reactants and the balanced equation, that they would produce 1.2 tonnes of magnesium, but only 0.9 tonnes was made.

Calculate the percentage yield of magnesium.

Percentage yield = _____ %

..... **(1 mark)**

(c) State **two** reasons why the calculated yield of magnesium might not be obtained.

.....

..... **(2 marks)**

2 (a) The extraction of titanium from titanium dioxide is carried out in a two-stage industrial process:

Stage 1 $TiO_2 + 2C + 2Cl_2 \longrightarrow TiCl_4 + 2CO$

Stage 2 $TiCl_4 + 4Na \longrightarrow Ti + 4NaCl$

In the **stage 2** reaction the percentage yield obtained by a company was 91.2%

The maximum theoretical mass of titanium for this batch was 12.5 kg.

Calculate the actual mass of titanium produced.

Mass of titanium = _____ kg

.....

..... **(2 marks)**

(b) Copper carbonate and sulfuric acid react as follows:

$$CuCO_3 + H_2SO_4 \rightarrow CuSO_4 + H_2O + CO_2$$

Relative formula masses: $CuCO_3 = 123.5$; $H_2SO_4 = 98.0$; $CuSO_4 = 159.5$

Calculate the percentage atom economy for producing copper sulfate from copper carbonate.

Atom economy = _____ %

.....

.....

..... **(3 marks)**

(c) Give **two** reasons why it is beneficial for the percentage atom economy of a reaction to be as high as possible.

.....

..... **(2 marks)**

3 A student wanted to make 15.0 g of zinc chloride. The equation for the reaction is:

$$ZnCO_3 + 2HCl \rightarrow ZnCl_2 + CO_2 + H_2O$$

What mass of zinc carbonate should the student add to the hydrochloric acid to make 15.0 g of zinc chloride?

Relative atomic masses (A_r): C = 12 Zn = 65 O= 16 Cl = 35.5 H= 1

A. 11.0 g

B. 13.8 g

C. 15.0 g

D. 22.0 g

(1 mark)

4 A student made zinc chloride by reacting 15.0 g of zinc carbonate with hydrochloric acid.

$$ZnCO_3 + 2HCl \rightarrow ZnCl_2 + CO_2 + H_2O$$

The percentage yield of zinc chloride was 82.4%.

Calculate the mass of zinc chloride the student actually produced.

Relative atomic masses (A_r): C = 12 Zn = 65 O= 16 Cl = 35.5 H= 1

A. 13.4 g

B. 15.0 g

C. 16.3 g

D. 12.4 g

(1 mark)

5 (a) In the Haber process, nitrogen and hydrogen are reacted together in conditions of high pressure and temperature to produce ammonia.

The equation for the reaction is as follows:

$$N_2 + 3H_2 \rightarrow 2NH_3$$

Calculate the percentage atom economy for the production of ammonia.

Relative formula masses (M_r): $N_2 = 28$; $H_2 = 2$; $NH_3 = 17$

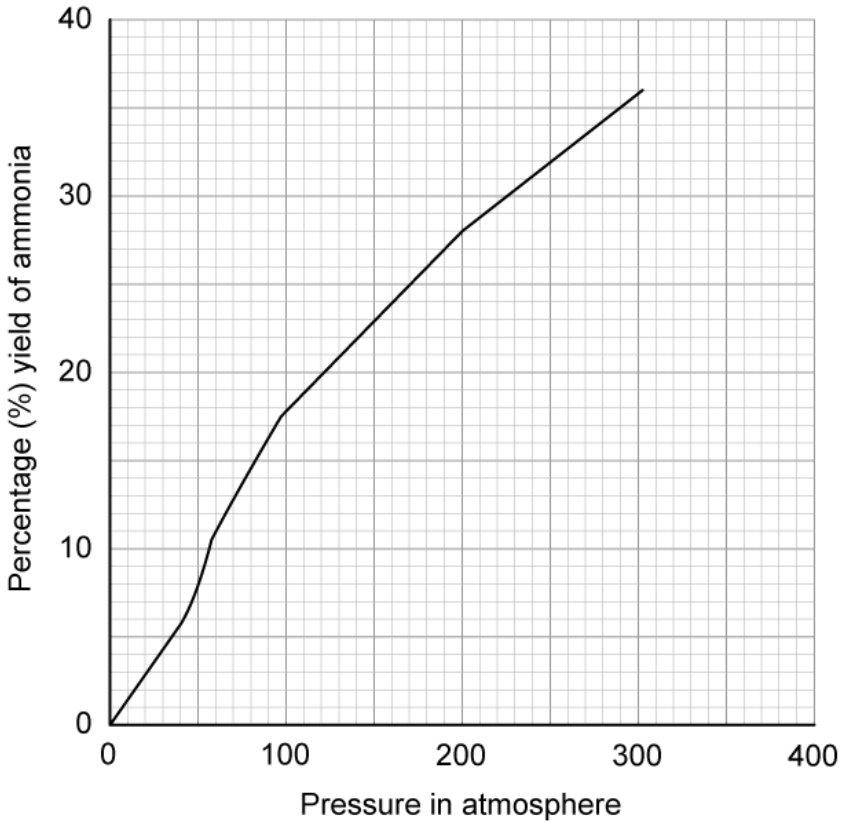
Percentage atom economy = _____ %

.....

..... **(2 marks)**

(b) **Figure 1** shows how the percentage yield of ammonia varies with changing conditions of pressure.

Figure 1



Describe the trend shown in **Figure 1**.

.....

..... **(2 marks)**

(c) Use **Figure 1** to determine the difference in percentage yield at 100 atmospheres pressure and at 250 atmospheres pressure.

Difference % yield NH_3 = _____ %

.....

..... **(2 marks)**

6 (a) A scientist makes zinc iodide by reacting zinc with iodine.

The equation for the reaction is:

$$Zn + I_2 \rightarrow ZnI_2$$

Relative atomic masses (M_r): Zn = 65; I = 127

14.5 g of zinc iodide is produced in the reaction.

The percentage yield obtained is 93.0%.

What is the maximum theoretical mass of ZnI_2 produced in this reaction?

Maximum theoretical mass = _____ g

.....

.....

..... **(3 marks)**

(b) Suggest a reason why the percentage yield is **not** 100%.

..... **(1 mark)**

7 An equation for the reaction between copper(II) oxide and carbon is:

$$2CuO + C \rightarrow 2Cu + CO_2$$

What is the percentage atom economy for the reaction to produce copper metal?

Relative atomic masses (A_r): C = 12 Cu = 64

Relative formula mass (M_r): CuO = 80

A. 64%

B. 59.3%

C. 74.4%

D. 92%

(1 mark)

8 Which of the following does **not** explain why the yield of a reaction may not be 100%?

A. The reaction may not go to completion because it is reversible

B. Some of the product may be lost when it is separated from the reaction mixture

C. Some of the reactants may react in ways different to the expected reaction

D. The reaction is endothermic and requires too much energy to complete it

(1 mark)

9 Calcium oxide can be produced by heating calcium carbonate in a rotating kiln.

$$CaCO_3 \rightarrow CaO + CO_2$$

If 120 tonnes of calcium carbonate is heated in the kiln and 53 tonnes of calcium oxide are produced, what is the percentage yield?

Relative atomic masses (A_r): Ca = 40 C = 12 O= 16

A. 53.7%

B. 62.1%

C. 78.9%

D. 84.3%

(1 mark)

10 (a) This question is about the salt zinc sulfate.

Zinc sulfate is a compound used as a dietary supplement to treat zinc deficiency.

It is also added to fertilisers, animal feeds and toothpaste. It can be made by two methods.

The equations for the two methods are as follows:

Method 1: $ZnO + H_2SO_4 \rightarrow ZnSO_4 + H_2O$

Method 2: $ZnCO_3 + H_2SO_4 \rightarrow ZnSO_4 + H_2O + CO_2$

Calculate the percentage atom economy for making $ZnSO_4$ in **Method 1** giving your answer to 3 significant figures.

Relative formula masses (*Mr*): ZnO = 81; H_2SO_4 = 98; $ZnSO_4$ = 161; $ZnCO_3$ = 125

Percentage atom economy = _____ %

.....

.....

..... **(3 marks)**

(b) Compare the atom economy of both methods and decide which method is the most desirable.

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..... **(5 marks)**

Hard Questions

1 (a) Iron is extracted from iron oxide in the blast furnace as shown.

$$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$$

1 tonne of iron oxide was reacted with carbon to produce 650 kg of molten iron.

Calculate the percentage yield for this reaction.

Relative atomic masses (A_r): Fe = 56, O = 16, C = 12

(5 marks)

(b) The temperature inside the blast furnace is so high that carbon monoxide can be used to extract iron instead of carbon.

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

Explain which reactant is oxidised in this reaction.

(1 mark)

(c) Determine if the reaction of iron oxide with carbon has a higher atom economy than the reaction of iron oxide with carbon monoxide.

Relative atomic masses (Ar): Fe = 56, O = 16, C = 12

..... **(3 marks)**

2 (a) This question is about magnesium sulfate.

Calculate, to three significant figures, the percentage by mass of oxygen in magnesium sulfate.

Relative atomic masses (A_r): Mg = 24, S = 32, O = 16

.....

..... **(2 marks)**

(b) Magnesium sulfate can be produced by reacting magnesium with sulfuric acid.

$$Mg + H_2SO_4 \rightarrow MgSO_4 + H_2$$

Write **two** balanced symbol equations, including state symbols, to show how magnesium sulfate can be produced by neutralisation reactions.

.....

.....

..... **(3 marks)**

(c) Calculate the atom economy for the formation of magnesium sulfate by the reaction of magnesium and sulfuric acid.

Relative atomic masses (A_r): Mg = 24 S = 32 O = 16

.....

..... **(2 marks)**

(d) Explain why the reaction of magnesium with sulfuric acid has a larger atom economy compared to the reactions in part (b).

.....

..... **(2 marks)**

3 (a) Rutile is a naturally occurring ore that contains titanium oxide.

Titanium can be extracted from this ore by two different methods.

Method 1 involves the electrolysis of the ore.

$$TiO_2 \rightarrow Ti + O_2$$

Method 2 involves the use of a more reactive metal to displace the titanium.

$$TiO_2 + 2Mg \rightarrow Ti + 2MgO$$

Calculate the atom economy for each reaction.

Relative atomic masses (A_r): Ti = 48, O = 16, Mg = 24

.....

.....

.....

..... **(4 marks)**

(b) Give **one** advantage and **one** disadvantage of using **Method 1** to extract titanium.

.....

..... **(2 marks)**

(c) What is the atom economy of **Method 1** if the oxygen is collected and sold?

..... **(1 mark)**

(d) Titanium is used for replacement hip joints.

Give **three** properties of titanium that make it suitable for this use.

.....

.....

..... **(3 marks)**

4 (a) A student investigated two different methods to produce zinc chloride.

Method 1 is the reaction of zinc oxide with dilute hydrochloric acid.

$$ZnO\ (s) + 2HCl\ (aq) \rightarrow ZnCl_2\ (aq) + H_2O\ (l)$$

Describe how a sample of zinc chloride crystals could be made from zinc oxide and dilute hydrochloric acid.

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.....

.....

..... **(4 marks)**

(b) A student wanted to make 15.0 g of zinc chloride using **Method 1**.

Relative atomic masses, (A_r): H = 1, Cl = 35.5, Zn = 65, O = 16

Calculate the mass of zinc oxide that the student should react with dilute hydrochloric acid to make 15.0 g of zinc chloride.

.....

.....

.....

..... **(4 marks)**

(c) The percentage yield of the student's reaction to produce zinc chloride using **Method 1** was 67.4 %.

Calculate the mass of zinc chloride the student actually produced.

.....

..... **(2 marks)**

(d) **Method 2** is the reaction of zinc carbonate with dilute hydrochloric acid.

$$ZnCO_3\,(s) + 2HCl\,(aq) \rightarrow ZnCl_2\,(aq) + H_2O\,(l) + CO_2\,(g)$$

The atom economy for **Method 1** is 88.3%.

Calculate the atom economy for **Method 2**.

Explain the difference in the atom economies for the two methods of making zinc chloride.

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.....

.....

..... **(4 marks)**

5 A student made zinc chloride by reacting 15.0 g of zinc carbonate with hydrochloric acid.

$$ZnCO_3 + 2HCl \rightarrow ZnCl_2 + CO_2 + H_2O$$

The percentage yield of zinc chloride was 82.4%.

Calculate the mass of zinc chloride the student actually produced.

Relative atomic masses (A_r): C = 12 Zn = 65 O= 16 Cl = 35.5 H= 1

A. 13.4 g

B. 15.0 g

C. 16.3 g

D. 12.4 g

(1 mark)