% Yield and Atom Economy

Q1. (2018) – 4a (ii)

4 (a) Hydrogen burns in air at a temperature well above 100 °C to form water.

(i) The boiling points of hydrogen and water are shown in Figure 3.

	boiling point in °C
hydrogen	−253
water	100

Figure 3

Use this information to add the missing state symbols to the equation for the reaction taking place as the hydrogen burns.

(2)

$2H_2($ ..... $) + O_2(g) \rightarrow 2H_2O($ ..... $)$

Question:

(ii) The atom economy for the reaction in (i) is 100%.

State how the equation shows that the atom economy is 100%.

(1)

Q2. (2018) – 4b

(b) Lead can be obtained by heating its oxide with carbon.
The balanced equation for the reaction is

$$2PbO + C \rightarrow 2Pb + CO_2$$

Calculate the atom economy for the production of lead in this reaction.
(relative atomic masses: C = 12, O = 16, Pb = 207
relative formula masses: PbO = 223, CO_2 = 44)

Give your answer to two significant figures.

(4)

Q3. (2018) – 4c

A)

(c) (i) In an experiment to produce lead, 7.67 g of lead are obtained.
The theoretical yield of lead for the experiment is 11.80 g.

Calculate the percentage yield of lead in this experiment.

(2)

B)

(ii) In most reactions, the percentage yield of any product is less than 100%.

Give **two** reasons why the percentage yield is less than 100%.

(2)

reason 1 .....

.....

reason 2 .....

.....

Q4. (2019) – 4b

4 Calcium carbonate decomposes on heating to form calcium oxide and carbon dioxide.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

(b) A second sample of calcium carbonate is strongly heated in a crucible until there is no further loss in mass.
The mass of calcium oxide remaining in the crucible is 5.450 g.

A)

(i) The theoretical yield of calcium oxide in this experiment is 5.600 g.

Calculate the percentage yield of calcium oxide.

(2)

B)

(ii) The mass of solid left in the crucible is less than the theoretical mass of calcium oxide that should be obtained.

A possible reason for this is that

(1)

- ☒ **A** some solid was lost from the crucible
- ☒ **B** the solid remaining absorbed some water from the air
- ☒ **C** some carbon dioxide remained in the crucible
- ☒ **D** the decomposition was incomplete

Q5. (2019) – 4c

4 Calcium carbonate decomposes on heating to form calcium oxide and carbon dioxide.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

(c) Another sample of calcium carbonate is heated and the mass of solid remaining is measured each minute.

The results are shown in Figure 3.

time in minutes	0	1	2	3	4	5	6	7
mass of solid remaining in g	9.0	8.1	7.2	6.4	6.0	5.6	5.3	5.2

Figure 3

(ii) It is impossible to be sure from this data that the reaction is complete.

State why.

(1)

Q6. (2019) – 4d (ii)
(2019) – 4c

4 Calcium carbonate decomposes on heating to form calcium oxide and carbon dioxide.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

(ii) Calculate the atom economy for the formation of calcium oxide in this reaction.

$$CaCO_3 \rightarrow CaO + CO_2$$

You must show your working.
(relative atomic masses: C = 12, O = 16, Ca = 40;
relative formula mass: calcium oxide = 56)

(2)

Q7. (2020) – 4b (ii, iii, iv)

4 Potassium hydroxide reacts with hydrochloric acid to form potassium chloride and water.

potassium hydroxide + hydrochloric acid → potassium chloride + water

(a) A student carried out a titration to find the exact volume of dilute hydrochloric acid that reacted with 25.0 cm^3 of potassium hydroxide solution.

There were five steps in the titration.
The steps shown are not in the correct order.

step J pour the potassium hydroxide solution into a conical flask and add a few drops of indicator to this solution

step K fill a burette with the dilute hydrochloric acid and record the initial reading from the burette

step L use a measuring cylinder to obtain 25 cm^3 of potassium hydroxide solution

step M take a final reading from the burette and calculate the volume of the dilute hydrochloric acid reacted

step N run the dilute hydrochloric acid from the burette into the conical flask until the indicator changes colour

(b) A student was then asked to produce a pure sample of solid potassium chloride.

After finding the volume of acid reacted in step M, the student added this volume of acid to a fresh 25.0 cm^3 sample of the potassium hydroxide solution.
This mixture was then evaporated.

Question:

A)

(ii) After evaporation, the mass of the potassium chloride was determined.

The theoretical yield of the experiment was 0.70 g.
The actual yield was 0.84 g.

This gave a percentage yield greater than 100%.

Calculate the percentage yield of this experiment.

(2)

B)

(iii) Suggest a reason why the actual yield was greater than the theoretical yield.

(1)

C)

(iv) The equation for the reaction between potassium hydroxide solution and dilute hydrochloric acid is

$$KOH + HCl \rightarrow KCl + H_2O$$

Calculate the atom economy for the production of potassium chloride from potassium hydroxide and hydrochloric acid.
(relative formula masses: KOH = 56.0, HCl = 36.5, KCl = 74.5, H_2O = 18.0)

Give your answer to one decimal place.

(4)

Q8. (2021) – 1b, 1c

1 When heated, zinc carbonate decomposes to form zinc oxide and carbon dioxide gas.

$$ZnCO_3 \rightarrow ZnO + CO_2$$

A)

(b) The theoretical maximum yield of zinc oxide was 1.86 g.

The actual yield was 1.63 g.

Calculate the percentage yield of zinc oxide.

(2)

B)

(c) Another student carried out the experiment using a similar method.
The student used a blue, roaring Bunsen burner flame and placed a lid on the crucible.

State why the student used a blue, roaring flame and a lid.

(2)

why a blue, roaring flame .....

.....

why a lid .....

.....

Q9. (2022)

4 Sucrose is a carbohydrate.

When a solution of sucrose is fermented using yeast, ethanol is formed.

$$\text{sucrose} + \text{water} \rightarrow \text{ethanol} + \text{carbon dioxide}$$

(a) In one experiment, 100.00 g of sucrose was dissolved in water.

Yeast was added and the mixture allowed to ferment until no more bubbles of carbon dioxide were seen to be formed.

The ethanol was obtained from the mixture and its mass determined.

The results are shown in Figure 3.

	mass in g
mass of sucrose	100.00
mass of ethanol obtained from the reaction	8.07
theoretical mass of ethanol formed	53.80

Figure 3

The percentage yield is calculated using

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

A)

(i) State the meanings of the terms **actual yield** and **theoretical yield**.

(2)

actual yield

.....

.....

theoretical yield

.....

.....

B)

(ii) Use the information in Figure 3 to calculate the percentage yield of ethanol in this experiment.

(2)

C)

(iii) State **two** reasons why the actual yield of a reaction is usually less than the theoretical yield.

(2)

1 .....

.....

2 .....

.....

D)

(b) The balanced equation for the fermentation of sucrose is

$$C_{12}H_{22}O_{11} + H_2O \rightarrow 4C_2H_5OH + 4CO_2$$

(i) Calculate the atom economy of this reaction to produce ethanol.

Give your answer to two significant figures.

(relative formula masses: $C_{12}H_{22}O_{11} = 342$, $H_2O = 18$, $C_2H_5OH = 46$, $CO_2 = 44$)

(3)

E)

(ii) Explain the effect on the atom economy of this reaction if the carbon dioxide produced was used to make fizzy drinks.

(2)

Q10. (2023)

4 There are several stages to the production of sulfuric acid in industry.

(a) Sulfur dioxide is required for the production of sulfuric acid.

Sulfur dioxide can be obtained by heating copper sulfide, Cu_2S, in excess air.

$$Cu_2S + O_2 \rightarrow 2Cu + SO_2$$

Calculate the atom economy for the production of sulfur dioxide, SO_2, in this reaction.

(relative atomic mass: Cu = 63.5
relative formula masses: $O_2 = 32.0$, $Cu_2S = 159.0$, $SO_2 = 64.0$)

Give your answer to two significant figures.

(4)

Q11. (2023) – 4c (ii, iii)

4 There are several stages to the production of sulfuric acid in industry.

(c) The equation shows a reaction forming sulfuric acid.

$$SO_3 + H_2O \rightarrow H_2SO_4$$

A)

(ii) Using a different amount of sulfur trioxide, it was calculated that 700 tonnes of sulfuric acid could be made.

The actual mass produced was 672 tonnes.

Calculate the percentage yield of sulfuric acid.

(2)

B)

(iii) State **two** reasons why the percentage yield is less than 100 %.

(2)

1 .....

.....

2 .....

.....

Q12. (2024)

A)

4 (a) Titanium can be extracted from titanium oxide, TiO_2, by reaction with magnesium.

(i) 100 tonnes of titanium oxide was heated with magnesium.
The titanium formed in the reaction was separated and purified.
The mass of titanium was then determined.

The results are shown in Figure 4.

	mass in tonnes
mass of titanium oxide	100.00
mass of titanium produced	45.26
theoretical mass of titanium formed	60.00

Figure 4

Use the information in Figure 4 to calculate the percentage yield of titanium in this process.

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

Give your answer to 1 decimal place.

(3)

B)

(ii) Give **two** reasons why the percentage yield for **this process** is less than 100%.

(2)

1 .....

.....

2 .....

.....

C)

(iii) The balanced equation for this process is

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

Calculate the atom economy of this process to produce titanium.

$$\text{atom economy (\%)} = \frac{\text{total formula mass of desired product}}{\text{total formula mass of all reactants or products}} \times 100$$

Give your answer to 2 significant figures.

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

(3)

Q13. (2024) – 4b

(b) Ethanol, C_2H_5OH, can be produced by two different methods.

- by the hydration of ethene, C_2H_4

  $C_2H_4 + H_2O \rightarrow C_2H_5OH$ atom economy = 100%

- and by the fermentation of a carbohydrate, e.g. sucrose, $C_{12}H_{22}O_{11}$

  $C_{12}H_{22}O_{11} + H_2O \rightarrow 4C_2H_5OH + 4CO_2$ atom economy = 51.1%

A)

(i) State why the hydration of ethene has an atom economy of 100%.

(1)

B)

(ii) Explain how the atom economy of the fermentation reaction can be improved.

(2)