Oxidation Yield

A Level

Oxidation of phenylethene ($12.0\,\mathrm{g}$, $\mathrm{C_8H_8}$) gave benzoic acid ($\mathrm{C_7H_6O_2}$), which needed $100\,\mathrm{cm^3}$ of $1.00\,\mathrm{mol\,dm^{-3}}$ aqueous NaOH for neutralisation. The benzoic acid only has one acidic group and so reacts with the hydroxide in a $1:1$ molar ratio.

Calculate the percentage yield of benzoic acid from phenylethene in this reaction rounding to the nearest integer.

Adapted with permission from UCLES, A Level Chemistry, November 1999, General and Organic Paper, Question 6

Yield vs Atom Economy

A Level

Identify the correct statements about percentage yield and atom economy.

1. Both percentage yield and atom economy can theoretically range from $0\,\%$ to $100\,\%$.
2. The percentage yield of a reaction is always less than or equal to its atom economy.
3. The atom economy of a reaction will always be increased by adding a catalyst.

- **1** only
- **2** only
- **3** only
- **1** and **2**
- **1** and **3**
- **2** and **3**
- None of the above
- All of the above

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Smelting

A Level

Smelting of metal ores is often carried out with carbon monoxide. The metal ore is reduced by the carbon monoxide gas, which is itself oxidised to carbon dioxide (a waste product) in the process.

Consider the above occurring for the reduction of CuO and $\mathrm{Fe_2O_3}$ to the respective metals: copper and iron. Calculate the atom economy for each of these two reactions, giving your answer as a percentage rounded to the nearest integer.

Part A CuO

Calculate the atom economy for the reduction of CuO.

Part B $\mathrm{Fe_2O_3}$

Calculate the atom economy for the reduction of $\mathrm{Fe_2O_3}$.

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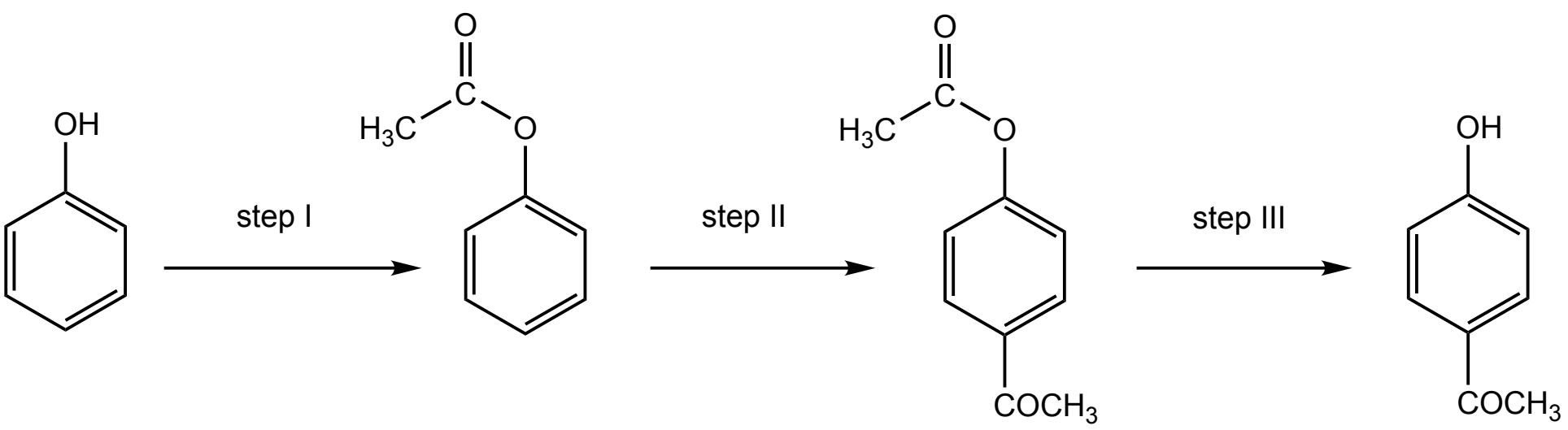
Step and Overall Yield

A Level

A synthesis from phenol (C_6H_6O) to give **G** ($C_8H_8O_2$) was carried out as shown below.



Phenol **E** **F** **G**

Figure 1: Three-step synthesis starting from phenol.

Part A Overall yield

$47.0\,\mathrm{g}$ of phenol (C_6H_6O) gave $44.5\,\mathrm{g}$ of the final product **G** ($C_8H_8O_2$). What is the overall percentage yield of **G** from phenol? Give your answer to the nearest integer.

Part B Step II yield

The yield for step I, for the conversion of phenol to **E** ($C_8H_8O_2$), was $75\,\%$, and the yield for the hydrolysis of **F** ($C_{10}H_{10}O_3$) to **G** ($C_8H_8O_2$) in step III was $100\,\%$. What is the percentage yield for step II? Give your answer to the nearest integer.

Adapted with permission from OCR, A Level Chemistry, June 1999, Further Organic Paper, Question 4

Alcohol Oxidation Efficiency

A Level

A student was given the following instructions for the preparation and identification of a carbonyl compound:

To $100\,\mathrm{cm^3}$ of water in a flask, carefully add $30\,\mathrm{cm^3}$ of concentrated sulfuric acid and set up the apparatus for distillation.

Make up a solution containing $28.0\,\mathrm{g}$ of sodium dichromate(VI), $\mathrm{Na_2Cr_2O_7}$ in $15.0\,\mathrm{cm^3}$ of water; add $18.0\,\mathrm{g}$ of the alcohol, $\mathrm{C_3H_8O}$, and pour the solution into a dropping funnel connected to the flask.

Boil the acid in the flask. Add the mixture containing the alcohol at such a rate that the product is collected slowly.

Re-distil the crude product and collect the fraction that boils between $48\,^\circ\mathrm{C}$ and $50\,^\circ\mathrm{C}$.

The balanced equation for the process taking place is shown below:

$$3\,\mathrm{C_3H_8O} + \mathrm{Na_2Cr_2O_7} + 4\,\mathrm{H_2SO_4} \longrightarrow 3\,\mathrm{C_3H_6O} + \mathrm{Na_2SO_4} + \mathrm{Cr_2(SO_4)_3} + 7\,\mathrm{H_2O}$$

The student obtained $7.20\,\mathrm{g}$ of the carbonyl compound, $\mathrm{C_3H_6O}$.

Part A Atom economy

Calculate the atom economy for this process, treating only the carbonyl compound as a useful product. Give your answer expressed as a percentage and rounded to the nearest integer.

Part B Moles of dichromate

Calculate how many moles of $\mathrm{Na_2Cr_2O_7}$ were used.

Part C Limiting reagent

Identify which reagent was limiting and fill in its molecular formula. Assume that concentrated sulfuric acid has a concentration of $18.4\,\mathrm{mol\,dm^{-3}}$.

Part D Percentage yield

Calculate the percentage yield obtained by the student. Give your answer rounded to the nearest integer.

Adapted with permission from UCLES, A Level Science (Modular), June 1997, Chains and Rings Paper, Question 3

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Reactions 4

GCSE C C C A Level P P P

Essential Pre-Uni Chemistry B6.4

Calculate the volume of $0.50\,\text{mol}\,\text{dm}^{-3}$ H_2SO_4 required to neutralize each of the following. Give your answer in cm^3 unless otherwise specified.

Part A **(a)**

$25.0\,\text{cm}^3$ of $1.0\,\text{mol}\,\text{dm}^{-3}$ $NaOH$

Part B **(b)**

$3.0\,\text{g}$ $CaCO_3$

Part C **(c)**

$1.25\,\text{g}$ $ZnCO_3$

Part D **(d)**

$4.03\,\text{kg}$ MgO. Give your answer in dm^3.

Part E **(e)**

$100\,\mathrm{cm}^3$ of $0.2\,\mathrm{mol\,dm}^{-3}$ $\mathrm{NH_3\,(aq)}$

Gameboard:

STEM SMART Chemistry Week 8

Titration 2

GCSE C C C A Level P P P

Essential Pre-Uni Chemistry B7.2

$2.50\,\mathrm{g}$ of an unknown carbonate were dissolved in $100\,\mathrm{cm^3}$ of $1.00\,\mathrm{mol\,dm^{-3}}$ hydrochloric acid (an excess). The resulting solution was made up to $250\,\mathrm{cm^3}$ in a volumetric flask. $25.00\,\mathrm{cm^3}$ aliquots of this solution were titrated against $0.250\,\mathrm{mol\,dm^{-3}}$ sodium hydroxide. Some of the results are shown below. Fill in the gaps in the table (Parts A-D), and then calculate the quantities in Parts E-L to identify the cation (Part M).

Titration	Initial burette reading / $\mathrm{cm^3}$	Final burette reading / $\mathrm{cm^3}$	Titre / $\mathrm{cm^3}$
Rough	0.60	25.10	**Part A**
1	0.15	**Part B**	24.10
2	**Part C**	25.25	24.45
3	1.35	25.45	**Part D**

Part A Rough, Titre/$\mathrm{cm^3}$

Give your answer to 4 significant figures.

Part B 1, Final burette reading/$\mathrm{cm^3}$

Give your answer to 4 significant figures.

Part C **2, Initial burette reading/cm^3**

Give your answer to 2 significant figures.

Part D **3, Titre/cm^3**

Give your answer to 4 significant figures.

Part E **Average concordant titre**

Calculate the average concordant titre. Give your answer to 4 significant figures.

Part F **Amount of sodium hydroxide**

Calculate the amount of sodium hydroxide in that volume. Give your answer to 3 significant figures.

Part G **Amount of hydrochloric acid**

The amount of hydrochloric acid in each aliquot. Give your answer to 3 significant figures.

Part H Initial amount of HCl

Calculate the initial amount of hydrochloric acid added to the carbonate. Give your answer to 3 significant figures.

Part I Final amount of HCl

Calculate the amount of hydrochloric acid remaining after reaction. Give your answer to 3 significant figures.

Part J Amount of HCl used

Calculate the amount of hydrochloric acid used in reaction with the carbonate. Give your answer to 3 significant figures.

Part K Amount of carbonate

Calculate the amount of carbonate in $2.50\,\mathrm{g}$. Give your answer to 3 significant figures.

Part L Molar mass of carbonate

Calculate the molar mass of the carbonate. Give your answer to 3 significant figures.

Part M Identity of cation

Identify the cation in the carbonate.

Gameboard:

STEM SMART Chemistry Week 8

Titrating Calcium Ions

A Level

The concentration of calcium ions in hard water can be determined by titration with a reagent X which forms a complex with $\mathrm{Ca}^{2+}(\mathrm{aq})$, giving a change of colour. Three moles of X combine with one mole of $\mathrm{Ca}^{2+}(\mathrm{aq})$.

A $25.0\,\mathrm{cm}^3$ sample of hard water reacted with $24.0\,\mathrm{cm}^3$ of $1.00 \times 10^{-4}\,\mathrm{mol\,dm}^{-3}$ $\mathrm{X}(\mathrm{aq})$.

Determine the concentration, in $\mathrm{mol\,dm}^{-3}$, of calcium ions in the hard water.

Adapted with permission from UCLES, A Level Chemistry, June 1995, Paper 3, Question 3

Gameboard:

STEM SMART Chemistry Week 8

Titrating Sulfur Dioxide

A Level

Sulfur dioxide is a by-product of the combustion of coal in power stations. It can react with oxygen and water vapour in the air to form sulfuric acid, $\mathrm{H_2SO_4}$. This is one of the causes of acid rain.

The amount of sulfur dioxide in the air may be determined by bubbling a sample of the air through sodium hydroxide solution, where it reacts according to the equation below:

$$\mathrm{SO_2\,(g) + 2\,NaOH\,(aq) \longrightarrow Na_2SO_3\,(aq) + H_2O\,(l)}$$

The concentration of the unreacted sodium hydroxide can be determined by titration against a standard solution of hydrochloric acid.

$1000\,\mathrm{dm^3}$ of air were bubbled through $200\,\mathrm{cm^3}$ of a $1.00\,\mathrm{mol\,dm^{-3}}$ solution of sodium hydroxide. The remaining solution was diluted to $1000\,\mathrm{cm^3}$ with water, and $25.0\,\mathrm{cm^3}$ of this solution was neutralised by $20.4\,\mathrm{cm^3}$ of a $0.100\,\mathrm{mol\,dm^{-3}}$ solution of hydrochloric acid.

Part A $\mathrm{H_2SO_4}$ formation

Construct an overall equation for the formation of sulfuric acid from sulfur dioxide (do not include state symbols). Balance it so as to use the smallest possible integer coefficients.

Part B Neutralisation reaction

Give the (net) ionic equation for the reaction of sodium hydroxide with hydrochloric acid.

Part C Unreacted moles

Find the amount, in moles, of unreacted sodium hydroxide.

Part D Sulfur dioxide moles

Find the amount, in moles, of sulfur dioxide in $1000\,\mathrm{dm}^3$ of air.

Part E Percentage by volume

Hence calculate the percentage by volume of sulfur dioxide in air. (You may assume $1\,\mathrm{mol}$ of any gas occupies $24\,\mathrm{dm}^3$ at this temperature and pressure.)

Adapted with permission from OCR, A Level Chemistry, June 1999, General and Physical Paper, Question 3

Gameboard:

STEM SMART Chemistry Week 8

Titration 4

A Level

C C C

Essential Pre-Uni Chemistry B7.4

Three students each prepare a standard solution by dissolving $10.6\,\mathrm{g}$ of solid from different bottles labelled 'sodium carbonate' in exactly $1\,\mathrm{dm}^3$ of water. They use this standard solution in a titration to determine the exact concentration of a solution of sulfuric acid at approximately $0.1\,\mathrm{mol\,dm}^{-3}$. They each use a pipette to measure out exactly $25.00\,\mathrm{cm}^3$ of the standard solution into a conical flask, they each use the same indicator and they each carry out their titrations with great care and accuracy.

The volumes of sulfuric acid solution that they each use are listed below. Only student A finds the correct concentration of the sulfuric acid. Student B is within $20\,\%$ but student C is so far out that they know something is wrong. Student C asks for help and is reminded that some solids can contain water of crystallisation. Student A uses anhydrous sodium carbonate, but what is x in the formula $\mathrm{Na_2CO_3 \cdot xH_2O\,(s)}$ for students B and C?

Student A: $23.75\,\mathrm{cm}^3$
Student B: $20.20\,\mathrm{cm}^3$
Student C: $8.80\,\mathrm{cm}^3$

Part A Acid concentration

Calculate the exact concentration of the sulfuric acid. Give your answer to 3 significant figures.

Part B $\mathrm{Na_2CO_3 \cdot xH_2O\,(s)}$

Find x in $\mathrm{Na_2CO_3 \cdot xH_2O\,(s)}$ for student B.

Find x in $\mathrm{Na_2CO_3 \cdot xH_2O\,(s)}$ for student C.
