

OCR A-LEVEL CHEMISTRY A • H432

CHEMISTRY



EXAM QUESTION PACK

4.2.3 ORGANIC SYNTHESIS

SCORE

/39

PERCENTAGE

%

STEMUP

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- 1 A student carries out the following experiment to investigate the reaction between hexane and chlorine. The chlorine is made by reaction of aqueous sodium chlorate(I) with dilute hydrochloric acid.

Procedure	Observations
1 cm ³ of hexane is mixed with 1 cm ³ dilute aqueous sodium chlorate(I) in a test-tube.	The mixture forms two colourless layers.
1 cm ³ dilute hydrochloric acid is slowly added to the mixture.	The acid mixes with the lower layer, which turns a pale green colour.
The tube is then stoppered and shaken.	The pale green colour moves to the upper layer, leaving the lower layer colourless.
The tube is placed under a bright light and shaken at regular intervals for about 10 minutes. The stopper is loosened regularly to release any pressure.	The pale green colour slowly disappears leaving two colourless layers after about 10 minutes.

- (i) The reaction between aqueous sodium chlorate(I) and dilute hydrochloric acid produces aqueous sodium chloride as well as chlorine.

Suggest an equation for this reaction.

-----[2]

- (ii) Outline a simple practical test that would confirm the presence of chloride ions in the lower layer, and give the expected result.

test: -----

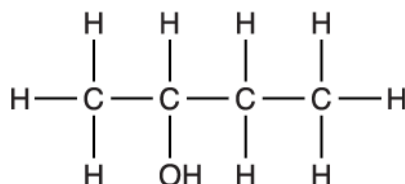
result: -----

-----[2]

- (iii) Name the apparatus that could be used to separate the two liquid layers present at the end of the experiment.

-----[1]

2 This question is about the properties and reactions of butan-2-ol.



Some properties of butan-2-ol are listed in the table.

Melting point	-115 °C
Boiling point	99.5 °C

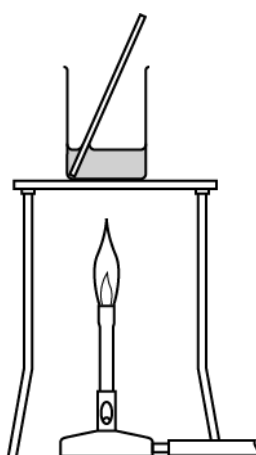
Butan-2-ol can be oxidised by heating with an oxidising agent.

(i) Write an equation for the reaction.

Use [O] to represent the oxidising agent and show the structure of the organic product.

[2]

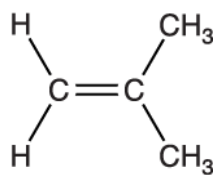
(ii) A student plans to carry out this oxidation using the apparatus shown in the diagram.



Give **one** reason why the apparatus is **not** suitable and describe a more suitable way of carrying out this oxidation.

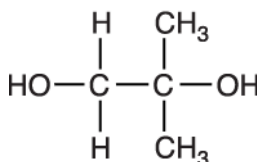
----- [2]

- 3 Compound **B**, shown below, can be used to synthesise organic compounds with different functional groups.



Compound B

The structure of compound **F** is shown below.



Compound F

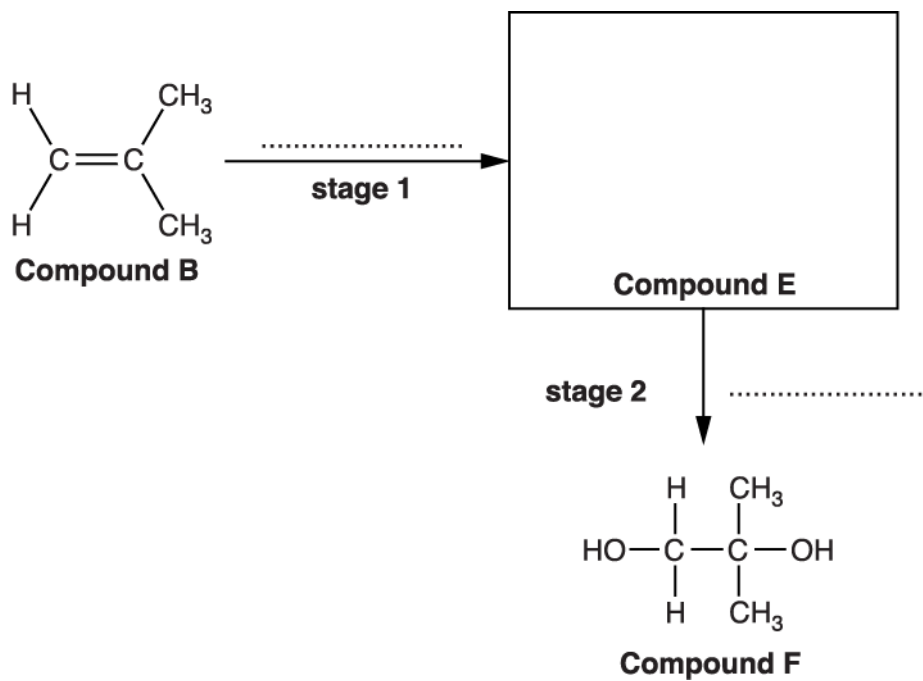
- (i) What is the empirical formula of compound **F**?

-----[2]

- (ii) A student plans a two-stage synthesis for preparing compound **F** from compound **B**.

The synthesis first prepares compound **E**, as shown in the flowchart.

Draw the structure of compound **E** in the box and state the reagents for each stage on the dotted lines.



[3]

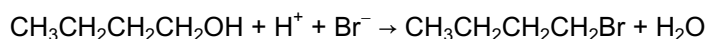
Explain, using a diagram, how the aldehyde can be produced in the laboratory by controlling the reaction conditions.

[6]

1-Bromobutane is an organic liquid with a boiling point of 102 °C.

A student prepares 1-bromobutane by reacting butan-1-ol with sulfuric acid and sodium bromide. The student boils the mixture for one hour.

The equation is shown below.



The student obtains a reaction mixture containing an organic layer (density = 1.27 g cm⁻³) and an aqueous layer (density = 1.00 g cm⁻³).

- (i) * Draw a labelled diagram to show how you would safely set up apparatus for the preparation. Outline a method to obtain a pure sample of 1-bromobutane from the reaction mixture.

----- [6]

- (ii) The student used 0.150 mol of butan-1-ol. The student obtained a 61.4% percentage yield of 1-bromobutane.

Calculate the mass of 1-bromobutane obtained.

Give your answer to **three** significant figures.

mass = ----- g [2]

6(a) This question is about hex-1-ene, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH}=\text{CH}_2$.

Hex-1-ene is a liquid with a boiling point of $63\text{ }^\circ\text{C}$ and a density of 0.67 g cm^{-3} .

Hex-1-ene can be prepared by refluxing hexan-1-ol (boiling point $157\text{ }^\circ\text{C}$) with an acid catalyst.

Hexan-1-ol is a liquid with a boiling point of $157\text{ }^\circ\text{C}$ and a density of 0.82 g cm^{-3} .

The equation is shown below.



After reflux, the resulting mixture contains unreacted hexan-1-ol, hex-1-ene and water.

The mixture is then purified.

The expected percentage yield of hex-1-ene from hexan-1-ol is 62.5%.

(i) * A student plans to prepare 4.20 g of hex-1-ene by this method.

Calculate the mass of hexan-1-ol that the student should use and explain how you could obtain pure hex-1-ene from the mixture obtained after reflux.

[6]

(ii) Another student suggested that hex-1-ene could be prepared from hexan-2-ol by the same method.

Would you expect the percentage yield of hex-1-ene to be greater than, less than or about the same as when using hexan-1-ol?

Explain your answer.

----- [2]

(b) Hex-1-ene can also be polymerised to form poly(hex-1-ene).

(i) Draw a section of poly(hex-1-ene) containing **two** repeat units.

[1]

(ii) Waste poly(hex-1-ene) can be disposed of usefully by recycling.

State **two** other methods of disposing of polymers that can be beneficial to the environment.

1 -----

2 -----

[2]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
1		i	$\text{NaClO} + 2\text{HCl} \rightarrow \text{NaCl} + \text{Cl}_2 + \text{H}_2\text{O}$ correct formulae of reactants, NaCl and chlorine (1) water and balancing (1)	2	allow $\text{NaClO}_3 + 6\text{HCl} \rightarrow \text{NaCl} + 3\text{Cl}_2 + 3\text{H}_2\text{O}$ for 1 mark
		ii	Test: add (a few drops of aqueous) silver nitrate (1) Result: white ppt (1)	2	ignore addition of dilute nitric acid before the AgNO_3 ignore redissolving in excess NH_3 or darkening of the ppt
		iii	separating funnel (1)	1	allow dropping pipette
			Total	5	
2		i	Equation $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3 + [\text{O}] \rightarrow \text{CH}_3\text{COCH}_2\text{CH}_3 + \text{H}_2\text{O} \checkmark$ Structure of product could be allowed from equation $\text{CH}_3\text{COCH}_2\text{CH}_3 \checkmark$	2	ALLOW molecular formulae: $\text{C}_4\text{H}_{10}\text{O}$ and $\text{C}_4\text{H}_8\text{O}$ ALLOW $\text{C}_4\text{H}_9\text{OH}$ ALLOW C_2H_5 for CH_3CH_2 ALLOW correct structural OR displayed OR skeletal formulae OR a combination of above as long as unambiguous Examiner's Comments The majority of candidates were able to identify the structure of the ketone formed in the oxidation of butan-2-ol but many were not able to construct a suitable equation. Water was often omitted from the equation on the right hand side whilst sometimes the equation was incorrectly balanced with a 2 being placed in front of the [O]. The most able candidates normally scored both marks.
		ii	Butan-2-ol/butanone is flammable OR Butan-2-ol / butanone is volatile / low boiling point OR	1	IGNORE vague answers about health and safety ALLOW alcohol for butan-2-ol ALLOW ketone for butanone DO NOT ALLOW the product or reactant. DO NOT ALLOW distillation
		ii	Butan-2-ol / butanone will evaporate / boil away $\checkmark$		

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(Heat under) reflux OR a description of reflux with vertical condenser and a round bottomed or pear shaped flask with source of heat. ✓	1	DO NOT ALLOW any reference to closed system. Examiner's Comments Another question requiring candidates to evaluate a practical activity where responses were on the whole disappointing. Very few candidates were able to access both of the marks with the harder of the two marks being for suggesting why the apparatus was not suitable for the experiment. Clearly many candidates were able to suggest a better method of carrying out the experiment with reflux being often quoted.
			Total	4	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
3		i	C ₂ H ₅ O ✓	1	ALLOW elements in any order DO NOT ALLOW any other answer <u>Examiner's Comments</u> This part was answered well by most candidates. Some candidates however wrote the molecular rather than the empirical formula, or attempted to show the empirical formula as C₂H₄OH instead of C₂H₅O.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Compound E: $ \begin{array}{c} \text{H} \quad \text{CH}_3 \\ \quad \\ \text{Br}-\text{C}-\text{C}-\text{Br} \\ \quad \\ \text{H} \quad \text{CH}_3 \end{array} \quad \checkmark $ Stage 1: Compound E: Bromine/Br₂ ✓ Stage 2: NaOH/KOH OR OH⁻ ✓ <i>Only award if intermediate contains at least one halogen atom</i>	3	For structures: ALLOW correct structural OR skeletal OR displayed formula OR mixture of the above ALLOW dichloro/diiodo compound IGNORE connectivity of bonds to CH₃ ALLOW chlorine/Cl₂ OR iodine/I₂ IGNORE conditions, e.g. u.v. DO NOT ALLOW H₂O IGNORE conditions NOTE: Max of 2 marks available for monobrominated intermediate 1 mark Reagent: HBr AND Intermediate: CH₃C(CH₃)₂Br OR BrCH₂CH(CH₃)₂ 1 mark Intermediate: CH₃C(CH₃)₂Br OR BrCH₂CH(CH₃)₂ AND Reagent: NaOH <u>Examiner's Comments</u> This demanding part was answered poorly by weaker candidates and was good for differentiating higher ability candidates. The mark scheme allowed some credit for using a hydrogen halide to obtain a monosubstituted haloalkane for compound E. Surprisingly, reaction mechanism names were often given instead of reagents. Many candidates seemed to guess, sometimes showing the same reagents for both stages in the hope of getting a mark. Many showed an intermediate containing no halogen atom.
			Total	4	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
4	<i>Please refer to the marking instructions on page 5 of the mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) A comprehensive explanation with all three scientific points covered thoroughly. <i>There is a well-developed description with a logical structure including correct chemical equations and an explanation with a clear line of reasoning including a fully labelled diagram.</i> Level 2 (3–4 marks) The candidate attempts all three scientific points but explanations are incomplete. OR Explains two scientific points thoroughly with no omissions. <i>The description has a line of reasoning presented with some structure and includes correct structural formulae and an accurate diagram of a distillation apparatus.</i> Level 1 (1–2 marks) A simple explanation based on at least two of the main scientific points OR The candidate explains one scientific point thoroughly with few omissions. <i>The description may be communicated in an unstructured way but it includes the correct reagents and conditions for the formation of the aldehyde.</i> <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks—No response or no response worthy of credit.	6	Indicative scientific points 1. Oxidation reaction forming aldehyde - acid / H⁺ AND dichromate / Cr₂O₇²⁻ - heat AND distillation - organic product is butanal / CH₃CH₂CH₂CHO - CH₃CH₂CH₂CH₂OH + [O] → CH₃CH₂CH₂CHO + H₂O 2. Oxidation reaction forming carboxylic acid - acid / H⁺ AND dichromate / Cr₂O₇²⁻ - heat under reflux - organic product is butanoic acid / CH₃CH₂CH₂COOH - CH₃CH₂CH₂CH₂OH + 2[O] → CH₃CH₂CH₂COOH + H₂O 3. Distillation - diagram of apparatus with condenser - condenser has water flow - collection of organic product - product is separated to prevent further oxidation (to carboxylic acid) Examiner's Comment: A very wide range of responses was seen in the second question marked using a level of response mark scheme and a greater proportion of candidates were able to access the highest level in this question. Diagrams of a distillation apparatus were

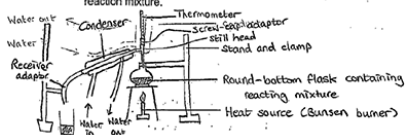
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					often disappointing and many poor answers failed to identify the oxidation products. A Level 1 response usually named the oxidising agent and included a crude diagram of a distillation apparatus. Diagrams in Level two responses often included more detail with a condenser cooled by water flow and an indication of where butanal can be collected. A Level three response was expected to include balanced equations for the oxidation reactions.
			Total	6	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
5	<i>Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Correctly labelled diagram of reflux apparatus that works, with no safety problems AND An appreciation of most of the purification steps required to gain a pure sample <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Labelled diagram of apparatus (either reflux or distillation) but with safety/procedural problems OR clear diagram of reflux apparatus without labelling AND Some details of further purification steps <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Diagram of apparatus (reflux OR separation OR distillation) drawn with no labelling OR labelled diagram with significant safety/procedural AND / OR Few or imprecise details about further purification stages <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: Apparatus set up for reflux: • round-bottom/pear shaped flask • heat source • condenser <i>Detail: water flow in condenser bottom to top; open system.</i> Purification • Use of a separating funnel to separate organic and aqueous layers <i>Detail: Collect lower organic layer density greater</i> • Drying with an anhydrous salt, <i>Detail: e.g. MgSO_4, CaCl_2, etc.</i> • Redistillation <i>Detail: Collect fraction distilling at 102°C.</i> <u>Examiner's Comments</u> Candidates were not prepared to answer this type of question and the diagrams were hard to give credit to. Many had significant safety implications such as open beakers of butan-1-ol being heated by a Bunsen burner. Most mis-read the question and just outlined the method for purification and struggled to recall the practical details. Very few candidates mentioned the use of anhydrous salts, referring instead to 'boiling off' the water.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Exemplar 4 $\text{Alcohol} \xrightarrow[\text{10}]{\text{Reflux}} \text{Halalkane}$ 5 (a) 1-Bromobutane is an organic liquid with a boiling point of 102°C. A student prepares 1-bromobutane by reacting butan-1-ol with sulfuric acid and sodium bromide. The student boils the mixture for one hour. The equation is shown below. $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH} + \text{H}^+ + \text{Br}^- \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{Br} + \text{H}_2\text{O}$ The student obtains a reaction mixture containing an organic layer (density = 1.27 g cm⁻³) and an aqueous layer (density = 1.00 g cm⁻³). (i)* Draw a labelled diagram to show how you would safely set up apparatus for the preparation. Outline a method to obtain a pure sample of 1-bromobutane from the reaction mixture.  Heat under reflux. Do perform a distillation. Heat the reaction mixture in a round-bottom flask at just over 102°C. The butan-1-ol will react with sulfuric acid and sodium bromide to form 1-bromobutane, which evaporates and condenses and is collected in a flask. Water has a boiling point of 100°C so also evaporates and condenses and collects in the flask. Add the mixture in the collecting flask to a separating funnel. The organic layer should settle below the aqueous layer as it is denser. To confirm, add distilled water to the separating funnel, invert the funnel, and allow the layers to settle. The layer that gets bigger is the aqueous layer. Open the tap and run off the lower organic layer into a conical flask. Add drying agent to remove traces of water.

This candidate was credited 4 marks for this level 2 answer. Although they have drawn distillation apparatus instead of reflux, they have considered the boiling point of the product, detailed using a separating funnel, a drying agent and that the lower organic layer would be drawn off first.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST, CHECK THE ANSWER ON ANSWER LINE IF answer = 12.6 (g) award 2 marks • $n(1\text{-bromobutane}) = 0.150 \times \frac{61.4}{100} = 0.0921 \text{ (mol)} \checkmark$ • Mass 1-bromobutane = $0.0921 \times 136.9 = 12.6 \text{ (g)} \checkmark$ 3 SF required	2	Common errors: 33.4 ($0.150 \times 100/61.4 = 0.244 \times 136.9$) 1 mark ALLOW ECF for incorrect moles or incorrect M_r of 1-bromobutane (provided answer is to 3 SF) DO NOT ALLOW 6.82 (using M_r of butan-1-ol) ALLOW calculation using masses, e.g. • Theoretical = $0.150 \times 136.9 = 20.535 \text{ (g)} \checkmark$ (ALLOW 20.535 rounded back to 20.5) • Actual mass = $20.535 \times \frac{61.4}{100} = 12.6 \text{ (g)} \checkmark$ (20.5 also gives 12.6) <u>Examiner's Comments</u> This question was well answered, but a significant number of candidates incorrectly used the M_r of butan-1-ol when calculating the mass of 1-bromobutane.
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6	a	i	<i>Please refer to the marking instructions on this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Calculates the correct mass of hexan-1-ol. AND Explains the purification steps, with most fine detail. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Attempts a calculation of the mass of hexan-1-ol which is partly correct. OR Outlines the purification steps, with some fine detail. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Attempts the calculation but makes little progress. OR Briefly outlines the purification steps, which may be incomplete. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit	6 (AO2.8×2) (AO3.3×4)	Indicative scientific points may include: Calculation from moles $n(\text{hex-1-ene}) = \frac{4.20}{84.0} = 0.0500 \text{ (mol)}$ $n(\text{hexan-1-ol})$ needed $= 0.0500 \times \frac{100}{62.5} = 0.0800 \text{ (mol)}$ - mass needed = $0.0800 \times 102 = 8.16 \text{ g}$ OR volume $\frac{8.16}{0.82} = 9.95 \text{ cm}^3$ CHECK for extent of errors by ECF. Calculation from mass - Theoretical mass hex-1-ene $= 4.20 \times \frac{100}{62.5} = 6.72 \text{ g}$ - Theoretical $n(\text{hex-1-ene})$ $= \frac{6.72}{84} = 0.0800 \text{ (mol)}$ - Mass of hexan-1-ol = $102 \times 0.0800 = 8.16 \text{ g}$ ALLOW small slip/rounding errors such as errors on M_r (e.g. use of 83 instead of 84 for hex-1-ene M_r) Purification - Use of a separating funnel to separate organic and aqueous layers Drying with an anhydrous salt Distillation Fine detail - Collection of upper layer (less dense from separating funnel) - Example of drying agent, e.g. MgSO_4, CaCl_2 - Collection of fraction distilling at 63°C (boiling point of hex-1-ene) Incorrect purification method NOT creditworthy Examples of partly correct calculations Mass = 5.1 g from 0.0500×102 % yield omitted

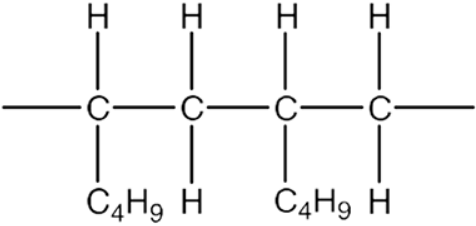
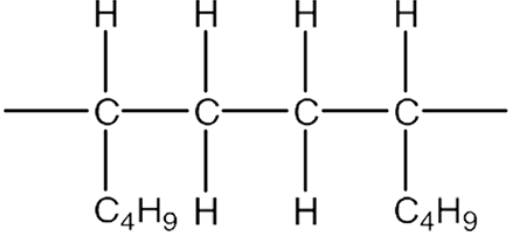
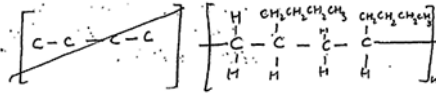
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Mass = 3.1875 g from $0.0500 \times \frac{62.5}{100} \times 102$ % yield inverted Examiner's Comments This question discriminated well and most were able to attempt to calculate a mass and explain the purification steps with some fine detail. It was evident that most candidates were aware of the apparatus required but the logic in the order was sometimes out of sequence. Drying agents were mentioned, some of the examples used were incorrect and errors were made with the boiling points if candidates mentioned distillation. Exemplar 5 <i>1. yield = $\frac{\text{Actual value}}{\text{Theoretical value}} \times 100$</i> <i>62.5 mass of 4.20 = $\frac{4.20}{84}$</i> <i>= 0.05</i> <i>1 mole of alcohol forms 1 mole of Hex-1-ene</i> <i>62.5 = $\frac{0.05}{T.V} \times 100$</i> <i>T.V = $\frac{0.05 \times 100}{62.5} = 0.08$</i> <i>Mass of hexan-1-ol = 0.08×102</i> <i>= 8.16 g of hexan-1-ol.</i> <i>Obtaining pure hex-1-ene</i> <i>First student plans the</i> <i>Additional answer space if required: Q 5.1b continued</i> <i>mixture into separating</i> <i>funnel. Close the top of separating</i> This in a response of an excellent approach to this question, it was given 6 marks. The correct mass has been calculated and all of the fine detail, except distilling at 63°C

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Yield of hex-1-ene is less ✓ A mixture of hex-1-ene and hex-2-ene forms ✓	2(AO3.2× 2)	ALLOW hex-2-ene also forms <u>Examiner's Comments</u> Most candidates obtained the first mark, but very few stated that hex-2-ene forms which is why the yield is less. Many candidates stated this was due to secondary alcohols being more stable than primary ones and a significant number thought the yield would be the same as they had the same M_r.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	b	i	 ✓ NOTE: C₄H₉– is allowed for CH₃CH₂CH₂CH₂–	1(AO2.5)	ALLOW correct structural OR displayed OR skeletal formula Must show two repeat units Polymer must have side links IGNORE brackets and use of 'n' ALLOW alternating side chains, i.e.  <u>Examiner's Comments</u> Over half of the candidates answered this question incorrectly. Many drew the wrong repeat units or did not show two repeat units. The structural diagrams were very hard to decipher and not well drawn. Exemplar 6  Although the connectivity is not exact, this was allowed. Many students drew full displayed structures which were very difficult to decipher as they often encroached over the writing in the question.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Combustion for energy production ✓ for production of plastics OR other useful organic compounds ✓	2(AO1.1× 2)	For energy production, ALLOW generate electricity/heating ALLOW as an (organic) feedstock <u>Examiner's Comments</u> Most students did not gain many marks on this question, with a significant number stating that the plastics could be used to feed livestock or as fertilisers. Those that mentioned combustion, merely stated plastics could be used as a fuel. Some candidates made references to making them biodegradable or recycling, but these answers were not given.
			Total	11	