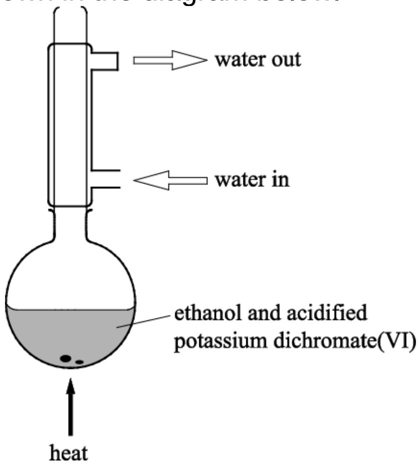
1. Ethanol is oxidised to ethanoic acid using acidified potassium dichromate(IV) solution. The reaction is heated under reflux using the equipment shown in the diagram below.



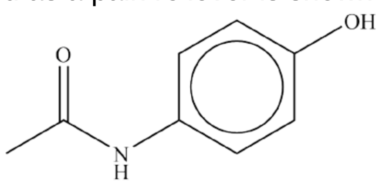
What is the reason for heating under reflux?

A. to ensure even heating
B. to prevent any substances escaping
C. to boil the mixture at a higher temperature
D. to allow efficient mixing

Your answer

[1]

2. The structure of a molecule that is used as a pain reliever is shown below.



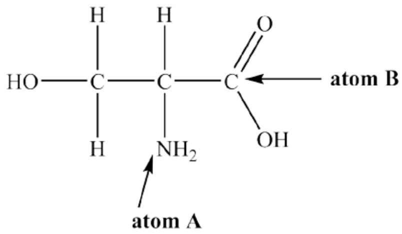
Which statement about this molecule is **not** true?

A. It has the molecular formula $C_8H_9NO_2$.
B. It reacts with bases to form salts.
C. It has a ketone functional group.
D. It can be hydrolysed with aqueous acid.

Your answer

[1]

3. Serine, shown below, is an amino acid.



i.

Use electron repulsion theory to predict the shape of the bonds around atoms **A** and **B**.

Give relevant bond angles around atoms **A** and **B**.

Give reasons for your answers.

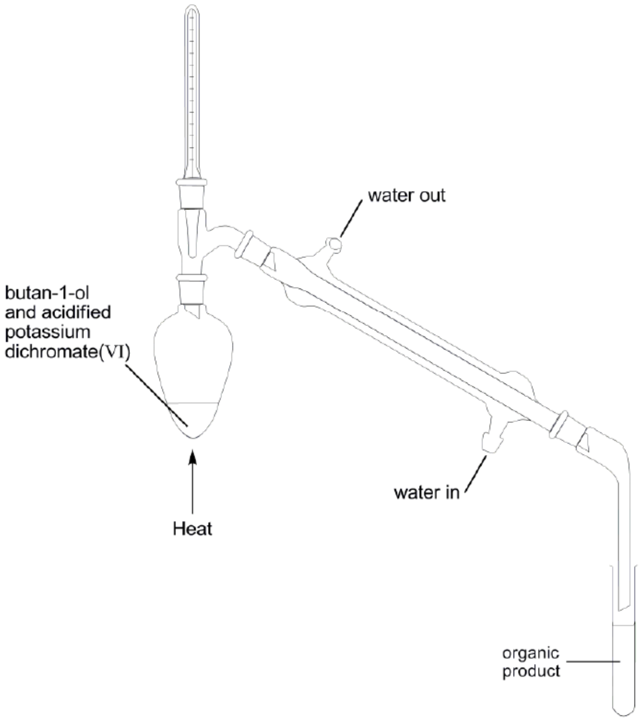
[4]

ii. A student adds an excess of aqueous sodium hydroxide to a sample of solid serine.
The student then purifies the resulting reaction mixture to obtain a pure sample of an ionic organic product.

- Draw the structure of the ionic organic compound obtained.
- Outline the steps that the student could carry out to obtain a pure sample of the organic product from the reaction mixture.

[3]

4. Butan-1-ol is reacted with acidified potassium dichromate(VI) using the apparatus shown below.



What is the organic product of this reaction?

A. But-1-ene
B. Butanone
C. Butanal
D. Butanoic acid

Your answer

[1]

5. A student wants to remove an acid impurity from an organic liquid.

What should the student do?

A. Add $Na_2CO_3(aq)$
B. Reflux the mixture
C. Add Br_2
D. Add $MgSO_4$

Your answer

[1]

6. This question is about alkenes.

When alcohol **A** is heated with an acid catalyst, a reaction takes place forming alkene **B**.
The equation for this reaction is shown below as **Equation 16.1**.

$CH_3CH(CH_3)CH_2CHOHCH_3$ → $CH_3CH(CH_3)CHCHCH_3 + H_2O$ **Equation 16.1**

alcohol A **alkene B**

i. State the type of reaction in **Equation 16.1**.

[1]

ii. Alkene **B** has two stereoisomers.

Explain what is meant by the term *stereoisomers*, and draw the **skeletal** formulae of the two stereoisomers of alkene **B**.

[3]

iii. The reaction of **A** with an acid catalyst also forms another alkene, **C**.

Alkene **C** is a structural isomer of alkene **B**.

Suggest the structure of alkene **C**.

[1]

iv. * A student carries out the reaction in **Equation 16.1** using 9.26 g of alcohol **A**.

The student obtains a liquid reaction mixture containing a mixture of organic products and the acid catalyst.

The student purifies the reaction mixture to obtain the liquid alkene **B** with a percentage yield of 75.0%.

Describe a method to obtain a pure, dry sample of alkene **B** from the reaction mixture and calculate the mass of alkene **B** that the student produced.

[6]

7. 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.

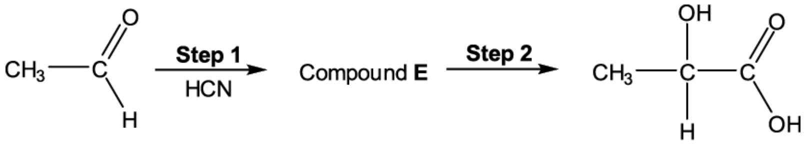
test:
....
result:
....

[2]

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

-- **[1]**

8(a). Lactic acid is a naturally occurring chemical, which can be synthesised from ethanal, CH_3CHO, as shown in the steps below.



lactic acid

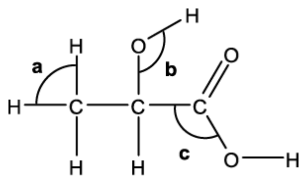
i. Draw the structure for compound **E**.

[1]

ii. Suggest a reagent that could be used for **Step 2**.

-- **[1]**

iii. The displayed formula of lactic acid is shown below.



lactic acid

Suggest a value for each bond angle **a**–**c**.

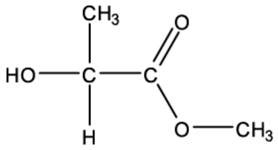
Bond angle **a**: ....

Bond angle **b**: ....

Bond angle **c**: ....

[2]

(b). Methyl lactate is an ester of lactic acid which is used as a solvent.



methyl lactate

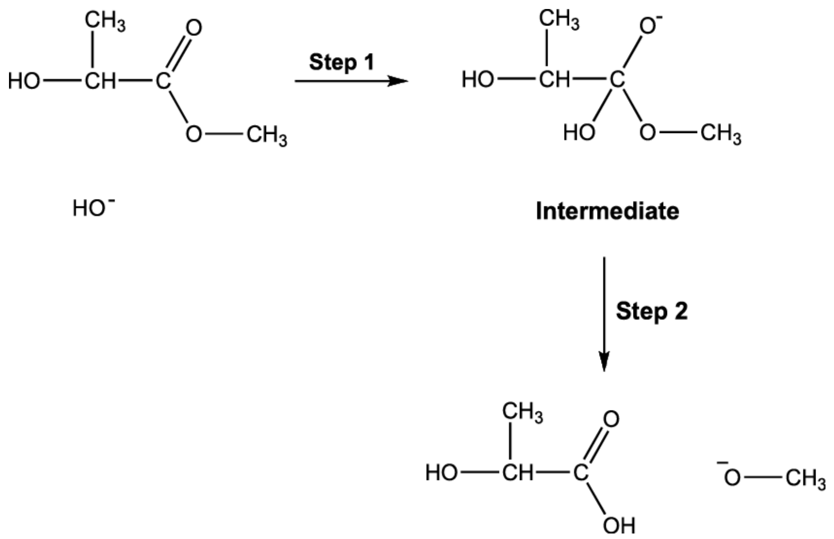
Methyl lactate can be hydrolysed by refluxing with sodium hydroxide solution.

In this reaction the hydroxide ion acts as a nucleophile.

i. Suggest how the hydroxide ion can act as a nucleophile.

[1]

ii. Part of the mechanism for the hydrolysis is shown below.

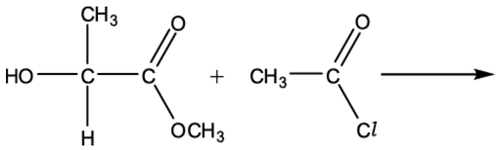


- Add relevant dipoles and curly arrows to show how the intermediate is formed in **Step 1** of the mechanism.
- Add curly arrows to show how the carboxylic acid and $^{-}OCH_3$ ion are formed from the intermediate in **Step 2** of the mechanism.

[4]

iii. Methyl lactate can also react with ethanoyl chloride.

Complete the equation for this reaction.



[2]

9(a). Cyclohexanone can be prepared in the laboratory by reacting cyclohexanol with concentrated sulfuric acid and sodium dichromate.

Ethanedioic acid is added to the reaction mixture to react with any excess dichromate.

The mixture is then distilled. The impure distillate is a mixture of cyclohexanone and water.

You will need to refer to some or all of the following data to answer these questions.

	Boiling point / °C	**Density / g cm^{-3}**	M_r
Cyclohexanol	161	0.962	100.0
Cyclohexanone	156	0.948	98.0

* Draw a labelled diagram to show how you would safely set up apparatus for distillation and describe a method to obtain a pure sample of cyclohexanone from the distillate.

[6]

(b). Ethanedioic acid removes excess dichromate ions, $Cr_2O_7^{\,2-}$, as in the equation below.

$$3(COOH)_2 + Cr_2O_7^{\,2-} + 8H^+ \rightarrow 6CO_2 + 2Cr^{3+} + 7H_2O$$

Suggest how you could tell when the excess dichromate has completely reacted with the ethanedioic acid.

[1]

(c). A student monitors the course of this reaction using thin-layer chromatography (TLC).

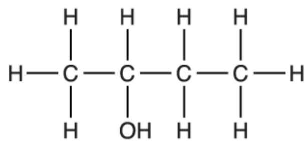
Outline how TLC could be used to monitor the course of the reaction.

[2]

(d). Plan an experiment that would allow the student to confirm the identity of the pure organic product by means of a chemical test.

[3]

10. 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

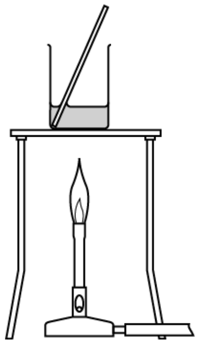
Butan-2-ol can be oxidised by heating with an oxidising agent.

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.

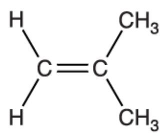
____

____

[2]

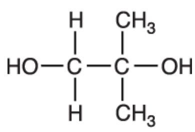
---

11. 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

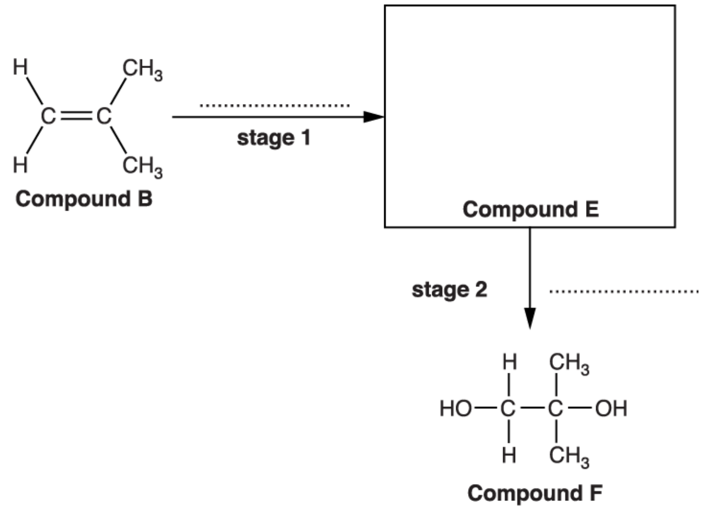
i. What is the empirical formula of compound **F**?

-- **[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]

12. A student plans the two-step synthesis below.

$HOCH_2CH{=}CHCH_2OH$ → **intermediate** → $HOOCCH_2COCOOH$

Which compound could be the student's intermediate?

A $HOOCCH{=}CHCOOH$
B $HOCH_2CH_2CHICOOH$
C $HOCH_2CH_2CH(OH)CH_2OH$
D $HOCH_2CH(OH)CH(OH)CH_2OH$

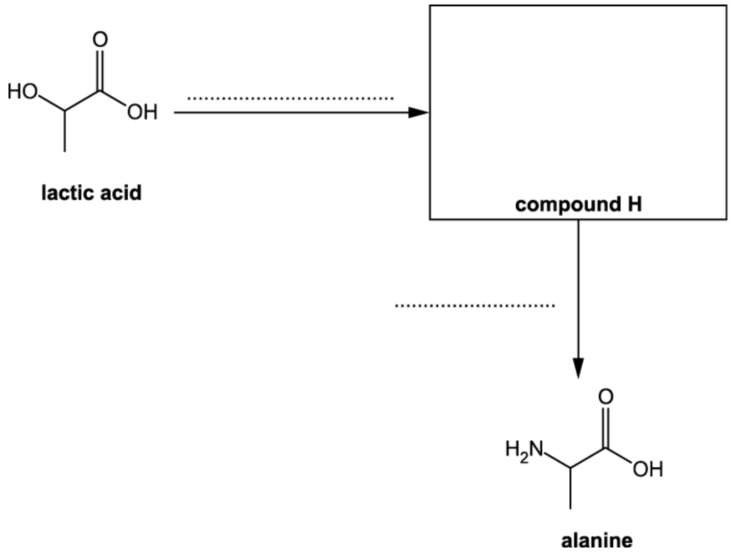
Your answer ☐

[1]

13. A student plans a two-stage synthesis of alanine from lactic acid, $CH_3CH(OH)COOH$.

The synthesis first prepared compound **H**, as shown in the flowchart.

Draw the structure of compound **H** in the box and add the formulae of the reagents for each stage on the dotted lines.



[3]

14. Describe the oxidation reactions of butan-1-ol forming an aldehyde and a carboxylic acid.

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

[6]

15.

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.

$$CH_3CH_2CH_2CH_2OH + H^+ + Br^- \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$$

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]**

16. A student hydrolyses a haloalkane, **E**, using the following method.

- 0.0100 mol of haloalkane **E** is refluxed with excess NaOH(aq) to form a reaction mixture containing an organic product **F**.
- The reaction mixture is neutralised with dilute nitric acid.
- Excess $AgNO_3$(aq) is added to the reaction mixture. 1.88 g of a precipitate **G** forms.

Organic product, **F**, has a molar mass of 74.0 g mol^{-1} and has a chiral carbon atom.

i. Draw a **labelled** diagram to show how the student would carry out the hydrolysis of haloalkane **E**.

[2]

ii. Analyse the information to identify **E**, **F** and **G**.

Show your working.

[3]

17(a). This question is about hex-1-ene, $CH_3CH_2CH_2CH_2CH{=}CH_2$.

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

Hex-1-ene can be prepared by refluxing hexan-1-ol (boiling point 157 °C) with an acid catalyst.

Hexan-1-ol is a liquid with a boiling point of 157 °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

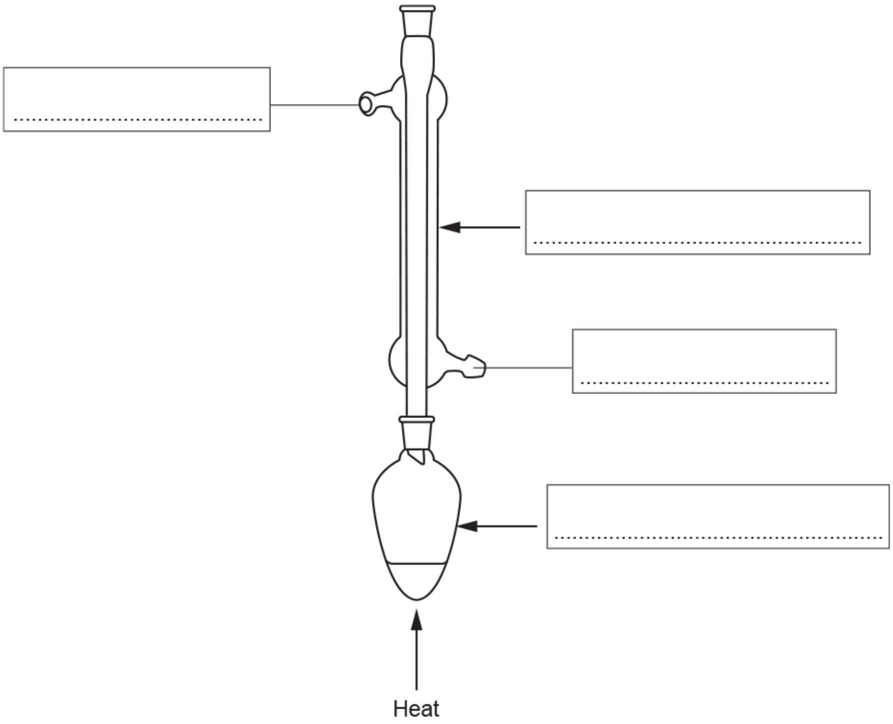
2

[2]

18. This question is about organic chemistry.

This part is about two practical techniques used in organic preparations.

i. Complete the missing labels on the diagram and name the technique.



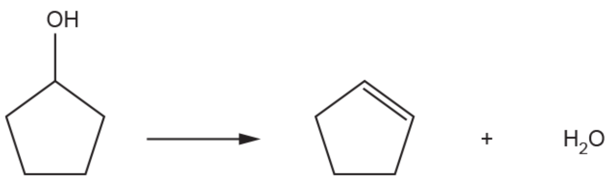
Name of technique: .... **[2]**

ii. Draw a labelled diagram to show apparatus set up for filtration under reduced pressure (vacuum filtration).

[2]

19. Cyclopentanol can be reacted to form cyclopentene.
Cyclopentene is a liquid with a boiling point of 44 °C and a density of 0.74 g cm^{-3}.
A student plans to prepare 4.00 g of cyclopentene by reacting cyclopentanol (boiling point 140 °C) with an acid catalyst.

Equation

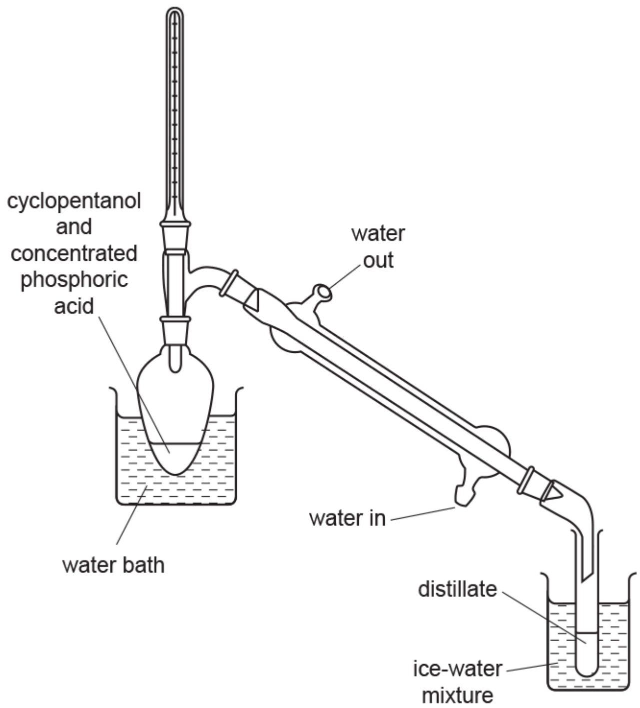


The expected percentage yield of cyclopentene is 64.0%.

Method

The student carries out the preparation using apparatus set up for distillation, as shown below.

1 The reaction mixture is heated gently, and a distillate containing impure cyclopentene is collected.



2 The distillate has an aqueous layer and an organic layer.
The student purifies the cyclopentene from the distillate.

* Calculate the mass of cyclopentanol that the student should use and explain how pure cyclopentene could be obtained from the distillate.

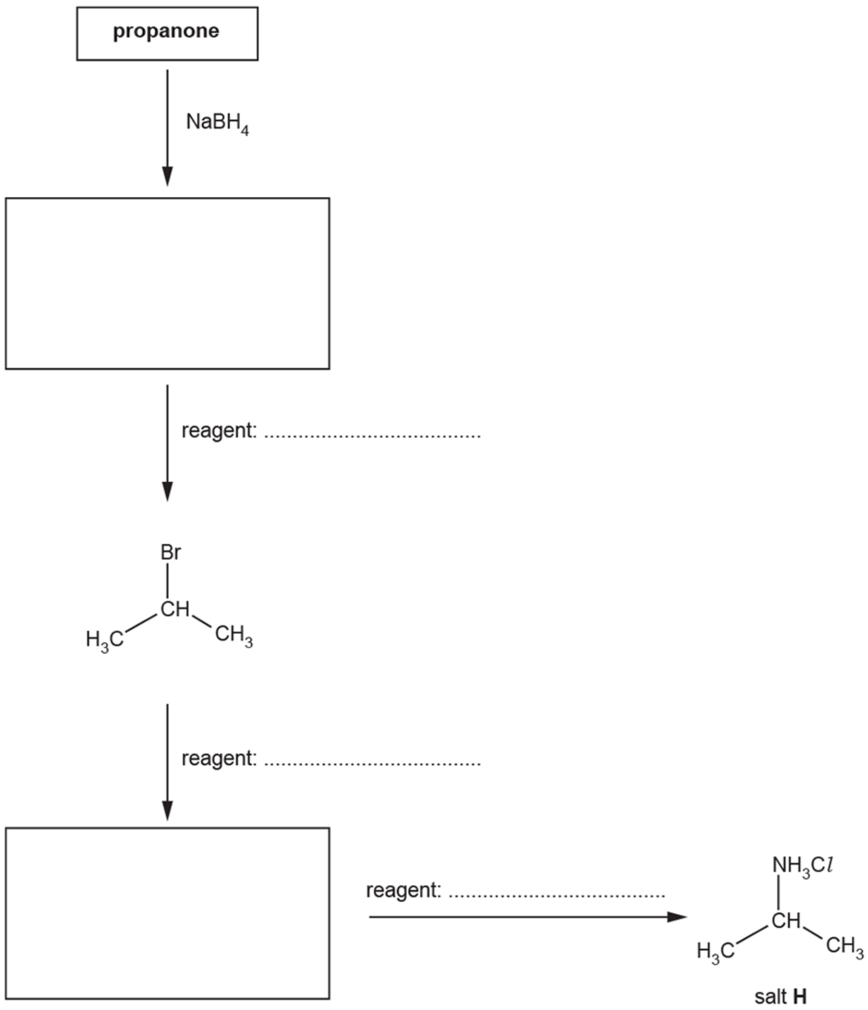
[6]

20. This question is about organic compounds containing nitrogen.

Salt **H**, $(CH_3)_2CHNH_3Cl$, is used in the manufacture of garden weedkillers.

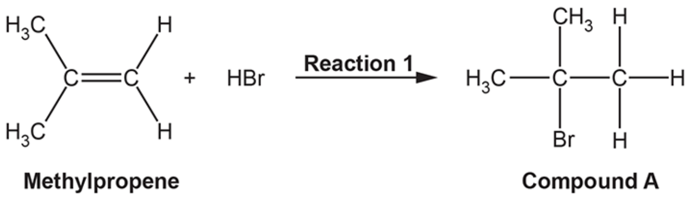
The flowchart shows the synthesis of the salt **H** from propanone.

Complete the flowchart.
Show structures for organic compounds.



[5]

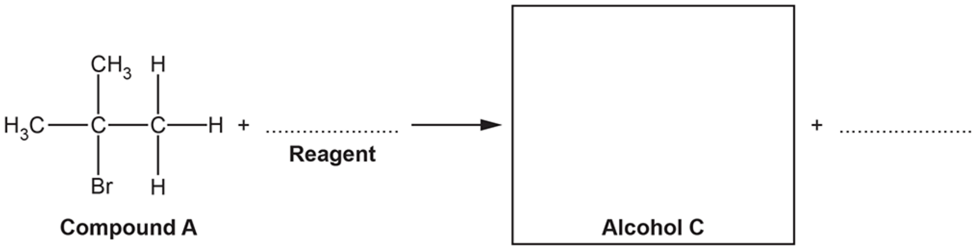
21. A student reacts methylpropene with hydrogen bromide, HBr, as shown in **Reaction 1**.



Compound A can be refluxed with a reagent to make alcohol C.

i. Choose a reagent for this reaction and complete the equation for this reaction.

Your equation should show the structure of alcohol **C**.



[2]

ii. Draw a labelled diagram to show how you would set up apparatus for reflux.

[2]

22. 2-Chloro-2-methylpropane, $(CH_3)_3CCl$, is an organic liquid with a boiling point of 50 °C.

A student prepares $(CH_3)_3CCl$ by reacting 2-methylpropan-2-ol, $(CH_3)_3COH$, with concentrated hydrochloric acid.

The student's method for the preparation is outlined below.

- Add 10.0 cm^3 (7.70 g) of $(CH_3)_3COH$ and 30 cm^3 concentrated hydrochloric acid (an excess) to a round-bottom flask. Stopper the flask.
- Shake the flask until the mixture separates into two layers.

Densities: $(CH_3)_3CCl$: 0.85 g cm^{-3}; concentrated HCl : 1.18 g cm^{-3}

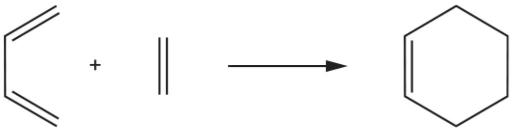
After purification, the percentage yield of $(CH_3)_3CCl$ is 76%.

Explain how the student could obtain a pure, dry sample of $(CH_3)_3CCl$ from the mixture in the flask and calculate the mass of pure $(CH_3)_3CCl$ that would be expected from this preparation.

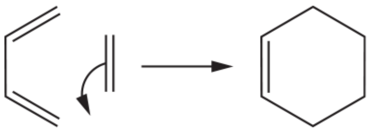
[6]

23. 'Diels-Alder' reactions are used in the synthesis of many important organic compounds.

The Diels-Alder reaction of buta-1,3-diene with ethene is shown below.



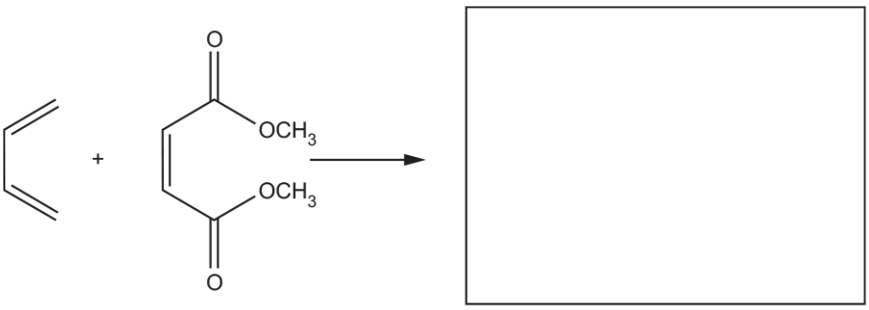
i. Add curly arrows to the diagram below to complete the mechanism for this Diels-Alder reaction.

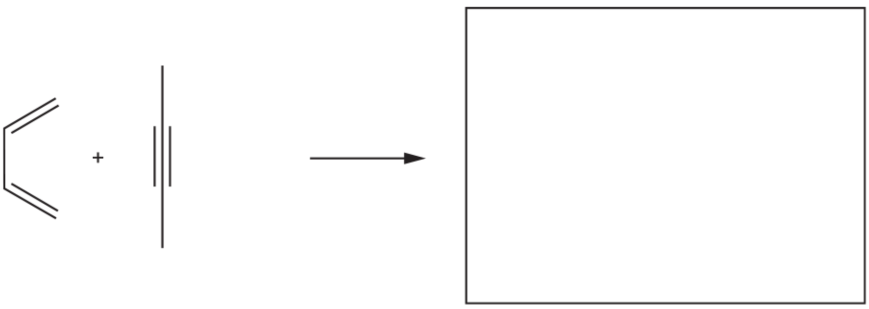


[2]

ii. Two more Diels-Alder reactions of buta-1,3-diene are shown below.

In the boxes, draw the organic product of each reaction.





[2]

24. 2-Bromobutane, $CH_3CH_2CHBrCH_3$, can be prepared by several different methods.

The relative molecular mass, M_r, of 2-bromobutane is 136.9.

2-Bromobutane can be prepared by reacting butan-2-ol, $CH_3CH_2CHOHCH_3$, with sodium bromide and sulfuric acid (**Reaction 5.3**).

$CH_3CH_2CHOHCH_3 + H^+ + Br^- \rightarrow CH_3CH_2CHBrCH_3 + H_2O$ **Reaction 5.3**

2-Bromobutane is a liquid with a boiling point of 91 °C and does not mix with water.

i. A student plans to prepare 10.0 g of 2-bromobutane using **Reaction 5.3**.

The percentage yield is 67.0%.

Calculate the mass of $CH_3CH_2CHOHCH_3$ needed for this preparation.

Give your answer to **3** significant figures.

mass = ... g **[3]**

ii. The student mixes butan-2-ol, sodium bromide and sulfuric acid in a pear-shaped flask, and refluxes the mixture.

After 1 hour, the mixture in the flask has separated into two layers: an aqueous layer and an organic layer.

Describe the procedures the student would need to carry out to obtain a pure, dry sample of 2-bromobutane from this mixture.

[3]

25. Information about 1-bromobutane and butan-1-ol is shown in the table.

Compound	Melting point /°C	Boiling point / °C	Density / g cm^{-3}
1-bromobutane	-113	102	1.268
butan-1-ol	-90	118	0.810

A student prepares a sample of 1-bromobutane by refluxing 9.25 g of butan-1-ol with sodium bromide and sulfuric acid.

After reflux, the reaction mixture is purified.

The student obtains 6.10 cm^3 of pure 1-bromobutane.

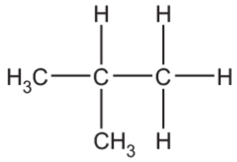
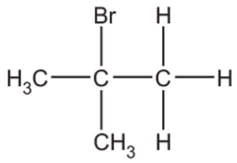
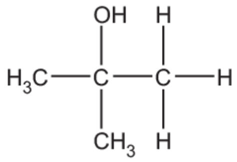
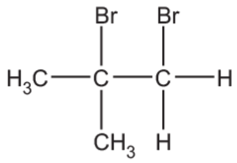
***** Draw a diagram to show how the student would have carried out the reflux and calculate the percentage yield of 1-bromobutane that the student obtains.

Describe how the student could have obtained pure 1-bromobutane from the reaction mixture obtained after reflux.

[6]

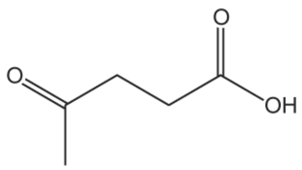
26. A student has planned the two-stage synthesis shown below.

Which compound could be the intermediate for this synthesis?

A	
B	
C	
D	

Your answer **[1]**

27. Which functional groups are present in the compound below?



A Alcohol and aldehyde.
B Alcohol and ketone.
C Carboxylic acid and aldehyde.
D Carboxylic acid and ketone.

Your answer **[1]**

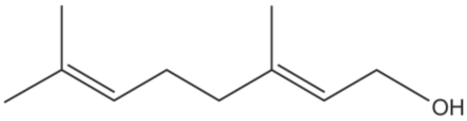
28. A student investigates the rate of hydrolysis of different iodoalkanes using aqueous silver nitrate in ethanol.

What colour of precipitate is seen?

A Brown
B Cream
C White
D Yellow

Your answer **[1]**

29. Geraniol, shown below, is a component in many natural oils.



Geraniol

Which pair of reagents identifies both functional groups in geraniol?

A Acidified dichromate(VI) and 2,4-dinitrophenylhydrazine.
B Bromine water and 2,4-dinitrophenylhydrazine.
C Bromine water and acidified dichromate(VI).
D Tollens' reagent and aqueous silver nitrate in ethanol.

Your answer ☐ **[1]**

30. 4.30 g of the alcohol C_5H_9OH, (M_r = 86.0), is burned in oxygen.

$C_5H_9OH(l) + 7O_2(g) \rightarrow 5CO_2(g) + 5H_2O(l)$

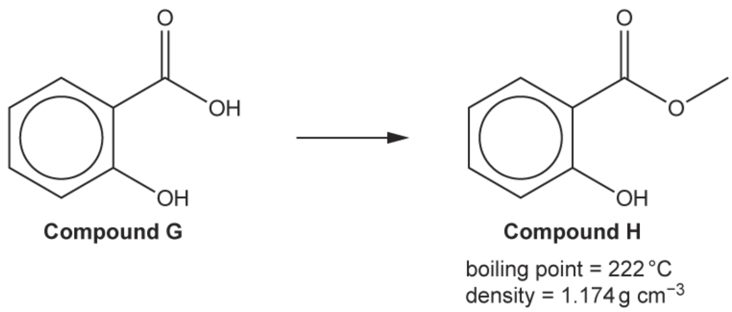
Which volume of oxygen gas is needed, in dm^3, for this complete combustion of C_5H_9OH, at RTP?

A 1.2
B 2.4
C 5.8
D 8.4

Your answer ☐ **[1]**

31(a). Oil of wintergreen is a liquid used in medicine to relieve muscle pain.

Compound **H** is a component in oil of wintergreen and can be synthesised from compound **G**, as shown below. The boiling point and density of compound **H** are stated.



A student prepares a sample of compound **H** by the method below.

Step 1	Reflux 8.97 g of compound **G** for 30 minutes with an excess of methanol in the presence of a small amount of sulfuric acid as a catalyst.
Step 2	Add an excess of aqueous sodium carbonate, Na_2CO_3(aq). Two layers are obtained.
Step 3	Purify the impure compound **H** that forms from the resulting mixture.

The student follows this method and obtains 5.32 g of pure compound **H**.

Why does the student use reflux in **Step 1**?

[1]

(b). Describe how to purify the impure compound **H** from the two layers in **Step 2**.

[4]

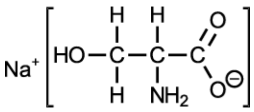
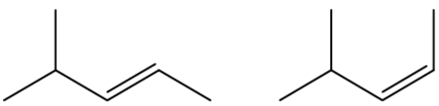
32. Primary alcohols can be oxidised under distillation to make aldehydes.

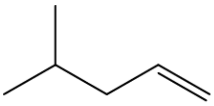
Draw a labelled diagram to show how you would set up apparatus for distillation.

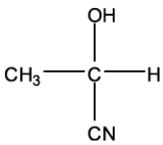
[2]

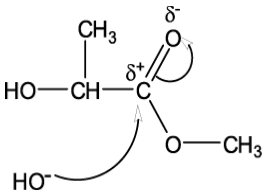
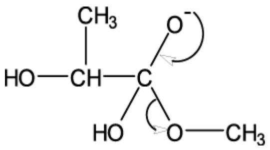
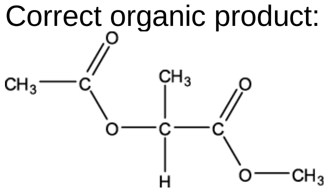
END OF QUESTION PAPER

Mark scheme

Question			Answer/Indicative content	Marks	Guidance
1			B	1	
			Total	**1**	
2			C	1	
			Total	**1**	
3		i	Atom **A**: 3 bonding pairs **AND** 1 lone pair (therefore) pyramidal **AND** 107° Atom **B**: 3 bonding centres (and 0 lone pairs) (therefore) trigonal planar **AND** 120°	4	**ALLOW** 106–108° **ALLOW** 4 bonding pairs but with 1 double / π−bond (therefore 3 bonding centres)
		ii	 filter solution recrystallise	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formulae **OR** a combination of above as long as unambiguous.
			Total	**7**	
4			C	1	
			Total	**1**	
5			A	1	
			Total	**1**	
6		i	Elimination	1	**ALLOW** Dehydration
		ii	Same structural formula **AND** Different arrangement (of atoms) in **space** **OR** different **spatial** arrangement 	3	**ALLOW** have the same structure / displayed formula / skeletal formula **DO NOT ALLOW** same empirical formula **OR** same general formula Stereoisomers have the same formula or molecular formula is **not** sufficient Reference to *E/Z* isomerism or optical isomerism is **not** sufficient

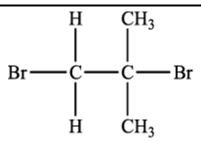
					IGNORE names **IF** skeletal formula is not used **ALLOW** one mark if both stereoisomers of alkene **B** are shown clearly.
		iii		1	**ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above **IGNORE** names
		iv	** Please refer to the marking instruction point 10 for guidance on how to mark this question.* **Level 3 (5–6 marks)** Outlines full details of how a pure sample of **B** is obtained from the reaction mixture. **AND** Correctly calculates mass of **B** • *Purification steps are clear, in the correct order, using appropriate scientific terms.* • *Calculation shows all relevant steps and mass given to 3 significant figures.* **Level 2 (3–4 marks)** Some details of how a sample of **B** is obtained from the reaction mixture. **AND** Attempts a calculation which is mostly correct. • *Purification steps lack detail, e.g. no drying agent or no explanation of separation, or only some scientific terms used.* • *Calculation can be followed but unclear.* **Level 1 (1–2 marks)** Few or imprecise details of how a sample of **B** is obtained from the reaction mixture. **AND** Attempts to calculate the mass of B using mole approach but makes little progress with only 1 step correct.	6	**Indicative scientific points, with bulleted elements, may include:** **1. Purification** • Use of a **separating funnel** to separate organic and aqueous layers • **Drying** with an anhydrous salt, e.g. $MgSO_4$, $CaCl_2$, etc. • **Redistillation** Incorrect purification method is **NOT** worthy of credit. **2. Mass of B obtained** • $n(\mathbf{A})$ used $= \frac{9.26}{102} = 0.0908$ (mol) = theoretical $n(\mathbf{B})$ • **Actual** $n(\mathbf{B})$ obtained $= n(0.908) \times \frac{75}{100} = 0.0681$ (mol) • mass **B** = 84 × 0.0681 = **5.72 g** **CHECK** for extent of errors by **ECF** Alternative correct calculation may calculate the mass of **B** as 0.0908 × 84 = 7.63 g, followed by $7.63 \times \frac{75}{100} = 5.72$ g Calculation must attempt to calculate $n(\mathbf{A})$ in mol. Simply finding 75% of the initial mass of alcohol A, 9.26, is **NOT** worthy of credit.

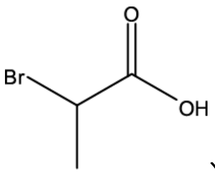
			• *Purification step is unclear with few scientific terms and little detail, e.g. just 'separate the layers and dry'.* • *Calculation is difficult to follow and lacking clarity* **0 marks** No response or no response worthy of credit.		
			Total	**11**	
7		i	$NaClO + 2HCl \rightarrow NaCl + Cl_2 + H_2O$ correct formulae of reactants, NaCl and chlorine (1) water and balancing (1)	2	**allow** $NaClO_3 + 6HCl \rightarrow NaCl + 3Cl_2 + 3H_2O$ 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**	
8	a	i		1	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
		ii	**aqueous** acid **OR** H^+ / $\mathbf{H_2O}$	1	**ALLOW** $H^+(aq)$ / $H_2SO_4(aq)$ / $HCl(aq)$
		iii	Angle a = 109.5° Angle b = 104.5° Angle c = 120° **Two** correct All **three** correct	2	**ALLOW** 109–110° **ALLOW** 104–105°
	b	i	It is an electron pair donor **OR** donates a lone pair	1	

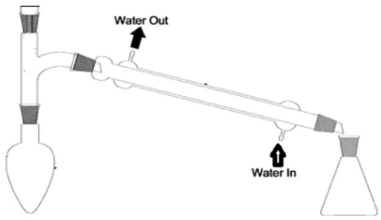
		ii	 Curly arrow from HO^- to carbon atom of C=O bond Correct dipole **AND** curly arrow from C=O bond to $O^{\delta-}$ ……………………………………………………  Curly arrow from negative charge on oxygen to C–O bond (to reform carbonyl π-bond) Curly arrow from C–O single bond to oxygen atom (to form methoxide ion)	4	Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus sign on HO^- ion (No need to show lone pair if curly arrow came from negative charge on O) **IGNORE** dipole on C–O single bond Curly arrow must come from lone pair on O **OR** from minus sign on O^- ion (No need to show lone pair if curly arrow came from negative charge on O)
		iii	Correct organic product:  HCl	2	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous
			Total	**11**	
9	a		** Please refer to the marking instruction point 10 for guidance on how to mark this question.* **Level 3 (5–6 marks)** Correctly labelled diagram of apparatus that works, with no safety problems **AND** Full appreciation of further two steps required to gain pure sample *There is a well-developed diagram which is clear and structured. The information on further purification is detailed and relevant.*	6	**Indicative scientific points may include:** **Diagram** Includes following components: distillation flask heat source thermometer at outlet (bulb **level** with outlet) still-head water condenser (**correct direction** of water flow) receiving vessel **open** system. **Further purification** Shake and leave to settle in a separating funnel Separate layers by tapping off

			Level 2 (3–4 marks) Labelled diagram of apparatus but with safety / procedural problems **OR** clear diagram of functional apparatus without labelling **AND** Some details of further purification steps *The diagram presents apparatus that is in the most-part relevant with some correct labelling, and supported by some details of further purification steps.* **Level 1 (1–2 marks)** Diagram of apparatus drawn with no labelling **OR** labelled diagram with significant safety / procedural problems **AND** Few or imprecise details about further purification stages *The diagram is basic and unstructured. Any mention of purification steps is limited to generic term, e.g. 'drying', without relevant detail.* **0 marks** No response or no response worthy of credit.		Add (a small amount of) anhydrous magnesium sulfate / anhydrous calcium chloride to organic layer (in a dry conical flask) (Re)distil the organic layer Collect fraction distilling at (between 150 °C and) 156 °C.
	b		Lack of (further) effervescence	1	**ALLOW** fizzing / bubbling stops
	c		Take samples from reaction mixture at regular intervals Spot / run on a TLC plate, alongside cyclohexanol (and cyclohexanone) controls	2	**ALLOW** "frequent" for "regular" **ALLOW** measure / compare R_f value to cyclohexanol **IGNORE** reference to solvent or visualising chemicals / UV
	d		React (sample of distillate) with 2,4-dinitrophenylhydrazine recrystallise **AND** determine the melting point Compare melting point to known / library value for cyclohexanone (derivative)	3	**ALLOW** (2,4-)DNPH / Brady's reagent
			Total	**12**	
10		i	**Equation** $CH_3CH(OH)CH_2CH_3 + [O] \rightarrow CH_3COCH_2CH_3 + H_2O$ ✓ **Structure of product could be allowed from equation**	2	**ALLOW** molecular formulae: $C_4H_{10}O$ and C_4H_8O **ALLOW** C_4H_9OH **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

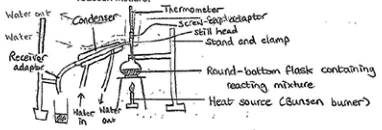
			$CH_3COCH_2CH_3$ ✓		**Examiner's Comments** The majority of candidates were able to identify the structure of the ketone formed in the oxidation of butan-2-ol but many were not able to construct a suitable equation. Water was often omitted from the equation on the right hand side whilst sometimes the 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**		**IGNORE** vague answers about health and safety **ALLOW** alcohol for butan-2-ol **ALLOW** ketone for butanone
		ii	Butan-2-ol / butanone will evaporate / boil away ✓	1	**DO NOT ALLOW** the product or reactant. **DO NOT ALLOW** distillation
		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**	
11		i	C_2H_5O ✓	1	**ALLOW** elements in any order **DO NOT ALLOW** any other answer **Examiner's Comments** 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 C_2H_4OH instead of C_2H_5O.
		ii	Compound E:	3	**For structures:** **ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above

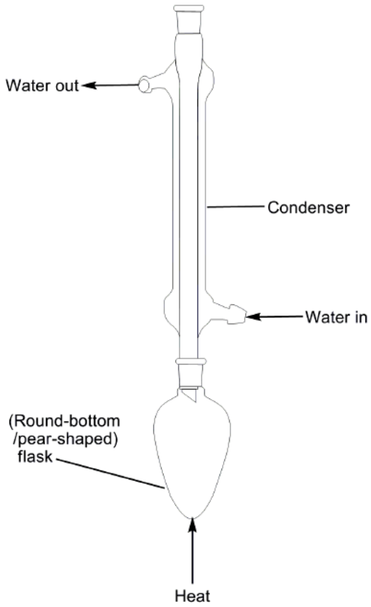
			 ✓ **Stage 1**: Compound **E**: Bromine/Br_2 ✓ **Stage 2**: NaOH/KOH **OR** OH^- ✓ *Only award if intermediate contains at least **one** halogen atom*		**ALLOW** dichloro/diiodo compound **IGNORE** connectivity of bonds to CH_3 **ALLOW** chlorine/Cl_2 **OR** iodine/I_2 **IGNORE** conditions, e.g. u.v. **DO NOT ALLOW** H_2O **IGNORE** conditions **NOTE:** Max of **2 marks** available for **monobrominated** intermediate **1 mark** Reagent: HBr **AND** Intermediate: $CH_3C(CH_3)_2Br$ **OR** $BrCH_2CH(CH_3)_2$ **1 mark** Intermediate: $CH_3C(CH_3)_2Br$ **OR** $BrCH_2CH(CH_3)_2$ **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**	
12			**C**	1	
			Total	**1**	

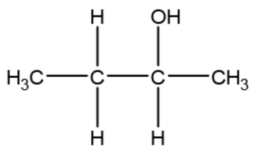
13			**Reagents for first stage** NaBr/H_2SO_4 ✓ **Compound H**  ✓ **Reagent for second stage** (excess ethanolic) NH_3 ✓	3	**ALLOW** any suitable halide salt/sulfuric acid combination **ALLOW** HC*l* **OR** HBr **OR** HI **ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Note:** the halogen in compound **H** can be C*l*, Br or I, but **must** be consistent with halide salt used
			Total	**3**	
14			*Please refer to the marking instructions on page 5 of the mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** A comprehensive explanation with all three scientific points covered thoroughly. *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.* **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. *The description has a line of reasoning presented with some structure and includes correct structural formulae and an accurate diagram of a distillation apparatus.* **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.	**6**	**Indicative scientific points** **<u>1. Oxidation reaction forming aldehyde</u>** • acid / H+ **AND** dichromate / $Cr_2O_7^{2-}$ • heat **AND** distillation • organic product is butanal / $CH_3CH_2CH_2CHO$ • $CH_3CH_2CH_2CH_2OH$ + [O] → $CH_3CH_2CH_2CHO$ +H2O **<u>2. Oxidation reaction forming carboxylic acid</u>** • acid / H+ **AND** dichromate / $Cr_2O_7^{2-}$ • heat under reflux • organic product is butanoic acid / $CH_3CH_2CH_2COOH$ • $CH_3CH_2CH_2CH_2OH$ + 2[O] → $CH_3CH_2CH_2COOH$ + H_2O **<u>3. Distillation</u>** • diagram of apparatus with condenser • condenser has water flow • collection of organic product • product is separated to prevent further oxidation (to carboxylic acid)

			The description may be communicated in an unstructured way but it includes the correct reagents and conditions for the formation of the aldehyde. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks–***No response or no response worthy of credit.*		 **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 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**	
15		i	*Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question.* **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 *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **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	6	**Indicative scientific points may include:** **Apparatus set up for reflux:** • round-bottom/pear shaped flask • heat source • condenser *Detail: water flow in condenser bottom to top; open system.* **Purification** • Use of a **separating funnel** to separate organic and aqueous layers *Detail: Collect lower organic layer density greater* • **Drying** with an anhydrous salt, *Detail: e.g. $MgSO_4$, $CaCl_2$, etc.* • **Redistillation** *Detail: Collect fraction distilling at 102°C.*

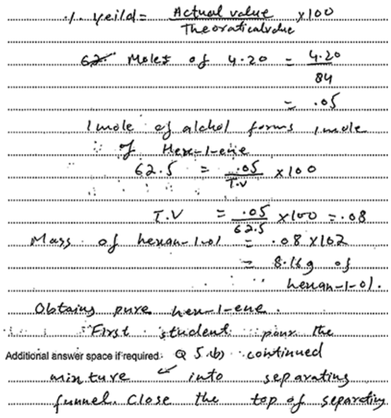
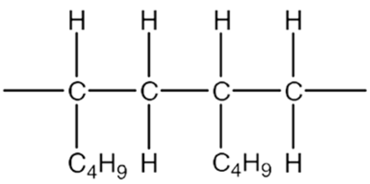
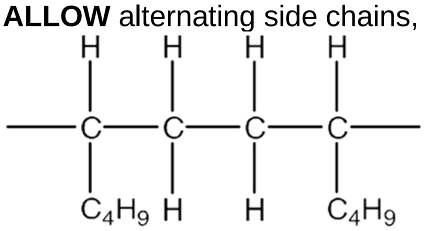
			There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. **Level 1 (1–2 marks)** Diagram of apparatus (**reflux OR separation OR distillation**) drawn with no labelling **OR** labelled diagram with significant safety/procedural **AND / OR** Few or imprecise details about further purification stages *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.		**<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. **Exemplar 4**

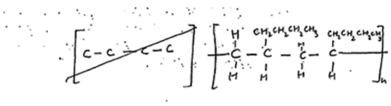
					Alcohol $\xrightarrow{\text{Reflux}}$ Haloalkane 10 5 (a) 1-Bromobutane is an organic liquid with a boiling point of 102 °C. A student prepares 1-bromobutane by reacting butan-1-ol with sulfuric acid and sodium bromide. The student boils the mixture for one hour. The equation is shown below. 1-bromobutane $CH_3CH_2CH_2CH_2OH + H^+ + Br^- \rightarrow CH_3CH_2CH_2CH_2Br + H_2O$ 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~~ ~~Dis~~ 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. L2 Add the mixture in the collecting flask to a separating funnel. The organic layer should ~~s the~~ 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. [6] ©OCR 2016 Add a 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.
		ii	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 12.6 (g) award 2 marks** • n(1-bromobutane) = $0.150 \times \frac{61.4}{100}$ = 0.0921 (mol) ✓ • **Mass 1-bromobutane = 0.0921 × 136.9 = 12.6 (g) ✓** **3 SF required**	2	**Common errors:** 33.4 (0.150 × 100/61.4 = 0.244 × 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 × 136.9 = 20.535 (g) ✓** ***(ALLOW 20.535 rounded back to 20.5)*** • Actual mass = $20.535 \times \frac{61.4}{100}$ = 12.6 (g) ✓ *(20.5 also gives 12.6)* **<u>Examiner's Comments</u>** This question was well answered, but a significant number of candidates incorrectly used

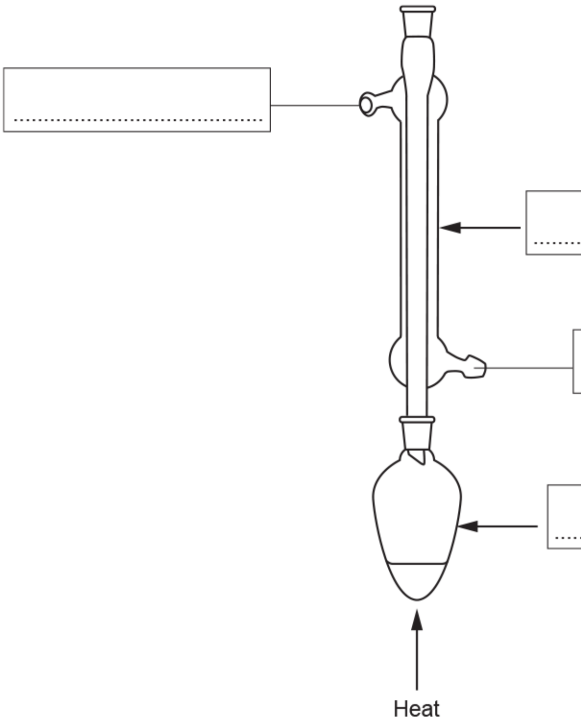
					the Mr of butan-1-ol when calculating the mass of 1-bromobutane.
			Total	**8**	
16		i	**Diagram** Diagram showing round bottom/pear shaped flask **AND** upright condenser ✓  **Labels** (Round-bottom/pear-shaped) flask **AND** condenser **AND** water in at bottom and out at top **AND** heat (source) ✓	**2**	**DO NOT ALLOW** conical flask, volumetric flask, beaker in place of round bottom/pear shaped flask **DO NOT ALLOW** distillation **DO NOT ALLOW** stopper/bung on top of condenser **IGNORE** a thermometer in condenser **IGNORE** a small gap between flask and condenser **ALLOW** diagram of heating apparatus as an alternative to heat label **<u>Examiner's Comments</u>** Most candidates were able to draw a suitable diagram to show the apparatus required for reflux but some included a stopper on top of the condenser. Many of the diagrams were labelled appropriately but common errors included incorrect direction of water flow or omission of the 'flask' label. A small but significant proportion of candidates drew a diagram showing distillation.
		ii	**Precipitate G** **1 mark** silver bromide/AgBr **AND**	**3**	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **Note:** working is **required** for first mark

			M = 1.88/0.01 = 188 (g mol^{-1}) 188 – 107.9 = 80.1 (so halide is Br^-)✓ **Alcohol F and Haloalkane E** **2 marks** **E** and **F** clearly identified **F/alcohol:** butan-2-ol  **E/haloalkane:** E is haloalkane of C_4H_9X with • same halogen as **G** **AND** • same carbon chain as **F** ✓		**ALLOW** use of 108 as *Ar* of Ag **Note: E** and **F** can be identified by correct name or structure **BUT IGNORE** incorrect names **<u>Examiner's Comments</u>** This question, requiring candidates to analyse the information to identify compounds **E**, **F** and **G**, discriminated well. Many candidates deduced that G was a silver halide but not all provided working to back up their choice of AgBr. Some candidates appeared to guess and Ag*Cl* was commonly seen. Some candidates used the molar mass of **F** provided to deduce the molecular formula of $C_4H_{10}O$ but lower ability responses did not process this further. Higher ability candidates identified **F** as butan-2-ol, showing the chiral carbon clearly. Other alcohols were also seen including butan-1-ol and methylpropan-2-ol. The highest ability candidates linked all the information and provided a structure for **E** that was consistent with their suggestions for **F** and **G**.
			Total	**5**	
17	a	i	*Please refer to the marking instructions on this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Calculates the correct mass of hexan-1-ol. **AND** Explains the purification steps, with most fine detail. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **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.	6 (AO2.8 ×2) (AO3.3 ×4)	**Indicative scientific points may include:** **Calculation from moles** • *n*(hex-1-ene) = $\frac{4.20}{84.0}$ = 0.0500 (mol) • *n*(hexan-1-ol) needed = 0.0500 × $\frac{100}{62.5}$ = 0.0800 (mol) • mass needed = 0.0800 × 102 = **8.16** g • **OR** volume $\frac{8.16}{0.82}$ = 9.95 cm^3 **CHECK** for extent of errors by **ECF**. **Calculation from mass** • Theoretical mass hex-1-ene = 4.20 × $\frac{100}{62.5}$ = 6.72 g

			There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. **Level 1 (1–2 marks)** Attempts the calculation but makes little progress. **OR** Briefly outlines the purification steps, which may be incomplete. *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit		• Theoretical *n*(hex-1-ene) $= \frac{6.72}{84} = 0.0800$ (mol) • Mass of hexan-1-ol = 102 × 0.0800 = **8.16** 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 63ºC (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* Mass = 3.1875 g from $0.0500 \times \frac{62.5}{100} \times 102$ *% yield inverted* <u>**Examiner's Comments**</u> 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**

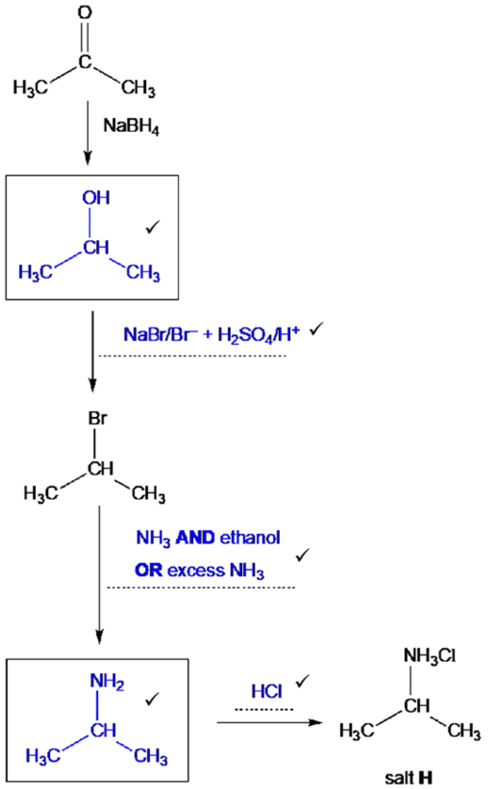
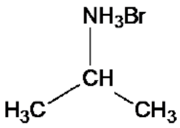
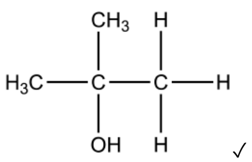
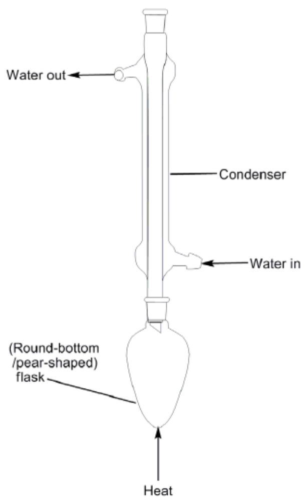
					 % yeild = Actual value / Theoraticalvalue x100 ~~62~~ Moles of 4.20 = 4.20 / 84 = .05 1 mole of alchol forms 1 mole of Hex-1-ene 62.5 = .05 / T.V x100 T.V = .05 / 62.5 x100 = .08 Mass of hexan-1-ol = .08 x102 = 8.16g of hexan-1-ol. Obtaing pure hex-1-ene. First student pour the Additional answer space if required: Q 5.(b) continued mixture into separating funnel. Close the top of separating 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
		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.
	b	i	 ✓ **NOTE**: C4H9– is allowed for $CH_3CH_2CH_2CH_2$–	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.
		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 **Examiner's Comments** 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**	
18		i		2 (AO 1.2x2)	

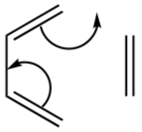
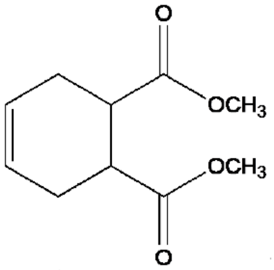
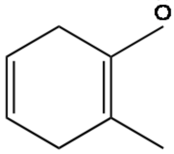
			 **Water flow AND condenser** Water in at bottom and out at top **AND** condenser ✓ **Flask and technique** Pear-shaped/round-bottom flask **AND** reflux ✓		**DO NOT ALLOW** conical flask, volumetric flask, beaker in place of round bottom/pear shaped flask **Examiner's Comments** Most candidates labelled some of the apparatus correctly and identified the reflux technique. A significant number showed water flowing in the wrong direction and 'distillation' was given as the name of the technique. The 'condenser' was sometimes labelled incorrectly, e.g. 'condensation tube, 'distillation tube' and 'water jacket'. Only just over half the candidates were given both marks. **OCR support** Candidates are advised to learn the names of chemical apparatus and the practical techniques involved. Diagrams of distillation and reflux apparatus are provided in our Practical Activities Support Guide: https:/www.ocr.org.uk/Images/598371-practical-activities-support-guide.pdf
		ii	**Diagram showing knowledge of filtration under reduced pressure** Diagram showing Buchner flask *must have* ***ONE*** *side arm* **AND** Buchner/Hirsh funnel on top of flask ✓ *Labels not required* --------------------------------- **Further details:** • Funnel sealed or stoppered to flask **AND** • Apparatus capable of filtering under reduced pressure **AND**	2 (AO 2.3)	Labels **NOT** required for diagram **ALLOW** diagram of a conical flask with a filtering setup above **AND** Side arm either in conical flask **OR** between flask and filter paper of funnel **IGNORE** absence of seals --------------------------------- **MUST** imply some type of seal between filter setup and flask. **ALLOW** **small** gaps Examples of suitable labels (may have arrow from side arm or tube attached) • to pump • to vacuum

			• Label for setup from side arm to indicate reduced pressure **AND** • Label for Buchner flask **OR** Buchner/Hirsh funnel ✓ *ALLOW slips in spelling of 'Buchner'*	(AO 2.7)	• air out • suction • reduced pressure • etc. For Buchner flask and Buchner funnel **DO NOT ALLOW** just 'flask **OR** 'funnel' *Flask and funnel used in normal filtration* **<u>Examiner's Comments</u>** Many diagrams were incomplete and it was comparatively rare for both of the two available marks to be given. Important labels were often missing. Some candidates drew diagrams of other techniques, such as distillation. Many responses were not credited with marks and this question was often omitted. Candidates need practice in recognising practical techniques and in drawing acceptable diagrams.
			Total	**4**	
19			*Refer to marking instructions on page 4 of mark scheme for guidance on marking this question.* **Level 3 (5-6 marks)** A correct calculation of the mass of cyclopentanol **AND** A **detailed** description of most purification steps *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Calculates the mass of cyclopentanol with some errors **AND** A **detailed** description of some purification steps **OR** A correct calculation of the mass of cyclopentanol AND A **detailed** description of a few purification steps	6 (AO2.8 ×2) (AO3.3 ×4)	**Indicative scientific points may include:** **<u>Calculation of mass of cyclopentanol</u>** **Using moles** • *n*(cyclopentene) = $\frac{4.00}{68}$ = 0.0588.... (mol) • *n*(cyclopentanol) = 0.0588 × $\frac{100}{64}$ = 0.0919....(mol) • Mass of cyclopentanol = 86 × 0.0919 = **7.90** g **Using mass** • Theoretical mass cyclopentene= 4.00 × $\frac{100}{64}$ = 6.25 g • Theoretical n(cyclopentanol) = $\frac{6.25}{68}$ = 0.0919 (mol) • Mass of cyclopentanol = 86 × 0.0919 = **7.90** g **ALLOW** for small slip in Mr / rounding errors **<u>Examples of some calculation errors</u>** **Incorrect inverse ratio:** • 0.0588 × $\frac{64}{100}$ = 0.0376.... (mol)

			There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence. **Level 1 (1-2 marks)** Calculates the mass of cyclopentanol with some errors **OR** A **detailed** description of some purification steps *There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.* **0 marks** No response or no response worthy of credit.		• Mass = 86 × 0.0376 = 3.24 g **Ignoring % yield gives:** • $\frac{4.00}{68}$ = 0.0588.... (mol) • Mass = 86 × 0.0588 = 5.06 g **<u>Purification</u>** • Add a neutralising agent **by formula or name** e.g. Na_2CO_3 • In separating funnel, **organic layer is on top** • Drying with an **anhydrous salt by formula or name**, e.g. $MgSO_4$, Na_2SO_4, $CaCl_2$ • Redistil **at approx. 44ºC** **Examples** of detail in **bold (NOT INCLUSIVE)** **<u>Examiner's Comments</u>** This question differentiated well. Those that did not achieve a mark often provided a mass of 6.25g of cyclopentanol, with no purification steps provided. Many candidates incorrectly described the purification steps for an organic solid and checking of purity via melting point analysis. Candidates that answered this question well calculated the mass of cyclopentanol required and described the steps required for purification accurately and with enough detail. Candidates achieving Level 1 or 2, did not provide detail or explanation of the purification steps.
			Total	**6**	

20				5 (AO2.5 ×5)	**ALLOW** any combination of skeletal **OR** structural **OR** displayed formula as long as unambiguous **ALLOW** HBr **ALLOW** for the bottom left structure 
			Total	**5**	
21		i	Alcohol **C**:  Reagent **AND** product: NaOH **AND** NaBr **OR** KOH **AND** KBr **OR** OH– **AND** Br– ✓	2 AO2.5 ×2	**ALLOW** Reagent: H_2O/water **AND** Product: HBr
		ii	 **1st mark:** **Labelled condenser** above a flask ✓ **2nd mark:** *Only available if 1st mark has been awarded* Flask **AND** heat labelled ✓	2 AO3.3 ×2	**For condenser label, ALLOW** 'condenser' **OR** water in **AND** water out (May be implied by connection to tap and sink).
			Total	**4**	

2 2			*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.* **Level 3 (5–6 marks)** Explains the purification steps with most fine detail. **AND** Calculates correct mass of 2-chloro-2-methylpropane, $(CH_3)_3CCl$ *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3–4 marks)** Describes some purification steps, with some detail. **AND** Calculates the mass of $(CH_3)_3CCl$ with some errors. *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1–2 marks)** Describes few purification steps. **OR** Attempts to calculate the mass of $(CH_3)_3CCl$ with little progress. *There is an attempt at a logical structure with a line of reasoning.* *The information is in the most part relevant.* **0 marks** *No response or no response worthy of credit.*	6 (AO1.2 × 2) (AO2.7 × 2) (AO3.3 × 2)	**Indicative scientific points may include:** **<u>Main purification stages</u>** • Separating funnel to remove organic layer from aqueous layer • Anhydrous salt to dry organic layer • Distillation to purify the product **Fine detail** • Organic layer is the top layer • Name of a drying agent e.g. anhydrous MgSO4 or CaCl2 • Collect fraction at 50 °C **IGNORE** washing with carbonate/water *not in spec*. **<u>Calculation of mass of $(CH_3)_3CCl$</u>** • $n((CH_3)_3COH) = \frac{7.70}{74.0} = 0.10405$ (mol) • expected $n((CH_3)_3CCl)$ $= 0.10405 \times \frac{76}{100} = 0.0791$ (mol) • expected mass = 0.0791 × 92.5 = 7.315 g **ALLOW** 7.31–7.32 for small slip/rounding **Using mass** ○ Theoretical mass $(CH_3)_3CCl$ $= 7.70 \times \frac{92.5}{74.0} = 9.625$ g • Mass of $(CH_3)_3CCl = 9.625 \times \frac{76}{100} =$ **7.315** g **NOTE**: Incorrect inverse ratio of gives: • $0.10405 \times \frac{76}{100} = 0.137$ (mol) • Mass = 92.5 × 0.137 = 12.7 g
			Total	**6**	

2 3		i	 1 mark for each curly arrow ✓✓	2 (AO2.5 ×2)	**IGNORE** any dipoles shown **NOTE**: curly arrows can be straight, snake-like, etc. but **NOT** half headed or double headed arrows **Curly arrow** from C=C bond must start from, **OR** be traced back to, **Lower left: any part of** C=C bond and go to C–C **Upper left: any part of** C=C bond and go to gap between C=C and C=C **Examiner's Comments** Many candidates did not apply their knowledge of curly arrows to this unfamiliar context. Those that scored a mark often did so for the top curly arrow but missed the requirement of the second curly arrow.
		ii		2 (AO3.2 ×2)	**Examiner's Comments** Many candidates did not correctly answer this question with products being given that had too few carbon atoms.
			Total	**4**	
2 4		i	**FIRST CHECK THE ANSWER ON ANSWER LINE** **If answer = 8.07 g award 3 marks** **CARE: Intermediate rounding may give 8.06 g which is acceptable for 3 marks** -- *n*(2-bromobutane) $= \frac{10.0}{136.9} = 0.073(0)....$ (mol) ✓ *n*($CH_3CH_2CHOHCH_3$) $= 0.0730.... \times \frac{100}{67.0} = 0.109$ (mol) ✓	3 (AO 2.4 × 3)	**ALLOW ECF throughout** **IGNORE** trailing zeroes in intermediate working, e.g. 0.073 for 0.0730 **ALLOW** 3 SF or more, correctly rounded Calculator: 0.7304601899 Calculator: 0.1089552239 **ALLOW alternative method mass** • Theoretical mass of 2-bromobutane $= 100 \times \frac{10.0}{67.0} = 14.9.....$ (g)

			mass $CH_3CH_2CHOHCH_3$ = 0.109 × 74.0 = **8.07** g ✓ **3 SF** required		Calculator: 14.925373 • Theoretical $n(CH_3CH_2CHBrCH_3)$ $= \frac{14.923373}{136.9} = 0.1902$ (mol) • Mass of $CH_3CH_2CHOHCH_3$ = 0.109 × 74.0 = **8.07** g ✓ **Common Errors for 2 marks** 5.41 g (no % yield) 3.62 g (inverted yield) **<u>Examiner's Comments</u>** The most common errors were omitting the yield or inverting the yield, as given on mark scheme, resulting in 2 marks. Clear working was vital here to help marks to be given even if the final answer was incorrect. Many candidates did not gain the final mark due to incorrect significant figures. As with other multi-step calculations, rounding of intermediate values could also cause marks to be lost.
		ii	Separating funnel (to separate aqueous and organic layers) ✓ Dry organic layer with anhydrous salt ✓ Distil and collect fraction at 91°C ✓	3 (AO 3.3 × 3)	**ALLOW** Use a drying agent **ALLOW** appropriate example of an anhydrous salt e.g. $MgSO_4$, $CaCl_2$ **<u>Examiner's Comments</u>** This question was not answered well with over half the candidates failing to score any marks. While some candidates seemed familiar with the techniques required, describing the process to separate the layers, they often struggled to name the separating funnel. Common approaches were to attempt to 'filter' the layers or to use heat (via evaporation or distillation) to drive off the water. Some attempted to use Na_2CO_3 or NaOH to dry the organic layer – perhaps confusing neutralisation of any remaining acid. Although distillation appeared

					frequently many did not give the temperature so did not gain marks. The order of the procedure was also not always clear with distillation before using a drying agent. Some described attempts to crystallise the organic layer. The range of answers suggests students may need more practical experience with separating organic liquids.
			Total	**6**	
25			**Level 3 (5-6 marks**) Diagram showing reflux with most labels **AND** A **CORRECT** calculation of the % yield of 1-bromobutane **AND** A **detailed** description of most purification steps. *There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.* **Level 2 (3-4 marks)** Diagram showing reflux with some labels **AND** Calculates the % yield of 1-bromobutane with some errors **OR** Diagram showing reflux with most labels **AND** describes some purification steps, with some detail **OR** Calculates the % yield of 1-bromobutane with some errors **AND** describes some purification steps, with some detail *There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.* **Level 1 (1-2 marks)** Diagram showing reflux **OR** Attempts to calculate the % yield of 1-bromobutane **OR** Describes few purification steps.	6 (AO2.8 ×2) (AO3.3 ×4)	**Indicative scientific points may include:** <u>Diagram</u> Diagram draw with condenser above flask Labels including • condenser • water in at bottom and out at top • pear-shaped or round-bottom flask ***<u>Calculation of % yield of 1-bromobutane</u>*** • $n(\text{butan-1-ol}) = \frac{9.25}{74.0} = 0.125$ (mol) • mass 1-bromobutane = 6.10 × 1.268 = 7.7348 g • $n(\text{1-bromobutane}) = \frac{7.7348}{136.9} = 0.0565$ (mol) • % yield $= \frac{0.0565}{0.125} \times 100 = 45.2\%$ **ALLOW** 45.2 ± 0.2 for small slip/rounding **NOTE Use of 6.1 g (omission of density)** • $n(\text{1-bromobutane}) = \frac{6.10}{136.9} = 0.044558\ldots$ (mol) • % yield $= \frac{0.044558\ldots}{0.125} \times 100 = 35.6\%$ ***<u>Purification</u>*** • In separating funnel, **organic layer is on bottom** • Drying with an **anhydrous salt by formula or name**, e.g. $MgSO_4$, Na_2SO_4, $CaCl_2$ • Redistil **at 102°C**

			There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant. **0 marks** No response or no response worthy of credit.		**Examples** of detail in **bold** (**NOT INCLUSIVE**) **NOTE**: 'Use a separating funnel', dry, and 'redistil' on their own are **NOT** detailed descriptions **<u>Examiner's Comments</u>** This question was assessed by level of response (LoR). Candidates were required to describe key features in a procedure to prepare a pure organic liquid, including a labelled diagram for reflux, a calculation of the percentage yield and the procedural steps for purification. Levels were determined using these three features. Marks within a level were determined by communication. This question discriminated extremely well. Level 3 candidates would draw a clear diagram with all key items labelled and the set up being capable of being used safely. The percentage yield calculation would be correct, producing a percentage yield close to 45.2%. The steps for the purification: use of a separating funnel, drying and redistillation would be described in the correct order and with some detail. Level 2 candidates would have obtained some of the features required for Level 3 but there would be some key omissions or errors. The diagram may have been drawn clearly but labelling may have been incomplete or a thermometer with bung may have been inserted into the top of the condenser, a very hazardous arrangement. The calculation would be attempted but with some errors, such as omitting to use the density, or using a mixture of moles and masses. The purification steps may have been described but in the wrong order. Purification steps would be incomplete, perhaps only including distillation. Level 1 candidates often drew a diagram resembling a tube above a flask, with water often flowing in the wrong direction. The percentage yield may have been a simple mass ratio with no moles being used. A significant number of candidates described the purification steps for an organic solid, including recrystallisation. The preparation of an organic liquid is a key practical procedure that will have been experienced by students during their A

					Level studies (PAG 5). The overall standard of drawing diagrams was poor, an area that needs improvement.
			Total	**6**	
26			**D**	1 (AO 2.7)	**<u>Examiner's Comments</u>** Candidates find it difficult to identify an intermediate within a synthesis and less than half selected the correct option, D.
			Total	**1**	
27			**D**	1	**<u>Examiner's Comments</u>** Many candidates wrote the functional groups on the structure shown on their scripts, which reflects good exam technique. Most correctly identified that the compound contains ketone and carboxylic acid functional groups (D). This was an excellent discriminator.
			Total	**1**	
28			**D**	1	**<u>Examiner's Comments</u>** Most correctly identified the colour of the precipitate as yellow, D. The most common incorrect response was brown, A, possibly linking to the colour of iodine.
			Total	**1**	
29			**C**	1	**<u>Examiner's Comments</u>** The majority of candidates were able to correctly identify the two functional groups and the correct corresponding test i.e. alkene using bromine water and primary alcohol using 2,4-dinitrophenylhydrazine. The most common incorrect response was B.
			Total	**1**	
30			**D**	1	**<u>Examiner's Comments</u>**

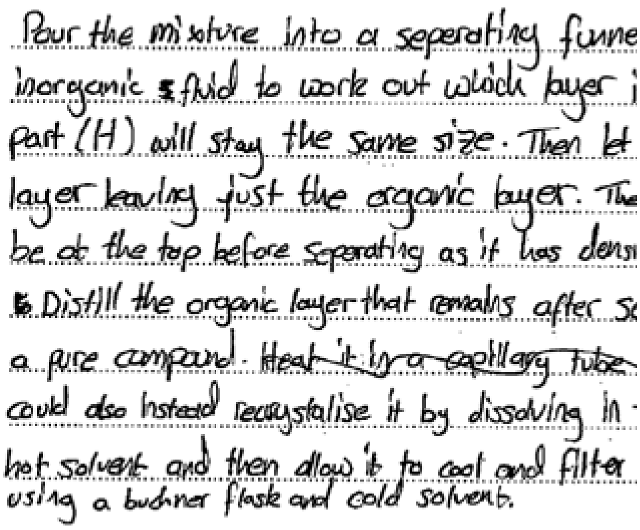
					Most were able to correctly calculate the moles of alcohol using the mass and M_r provided and then multiply by 24 dm^3 mol^{-1} to give the correct answer D. All other distractors were seen as incorrect responses from calculations involving the incorrect molar ratio.
			Total	**1**	
31	a		Idea that reflux is used to prevent loss by evaporation ✓ e.g. prevents reaction mixture boiling dry e.g. prevents loss of (volatile) compounds / products / reactants e.g. prevent methanol escaping	1	**IGNORE** responses related to rate of reaction **IGNORE** responses related to ensuring complete reaction **DO NOT ALLOW** reference to incorrect reaction e.g. oxidation, combustion (flammability) **<u>Examiner's Comments</u>** An unfamiliar question that proved challenging with only around a fifth of candidates obtaining the mark for correctly suggesting that reflux would prevent loss of volatile compounds. Many candidatessuggested that reflux ensures the reaction goes to completion but here this was insufficient asesterification is an equilibrium reaction and additional information in (b)(i) indicates that there isunreacted compound **G** present. It was necessary to focus on the purpose for reflux rather than other ways of heating a reaction, such asthe energy needed to break bonds or speed up the rate of reaction. Some less successful responseslinked to oxidation reactions, presumably as they understand the importance of either reflux or distillationin this context. For example, 'reflux is required for complete oxidation' or 'if distillation had been used analdehyde would have been formed'.
	b		Steps must be given in correct order: **Step 1** (Add to) separating funnel ✓ (Use of) bottom layer (containing H / organic) ✓ **Step 2** **Dry** with an <u>anhydrous salt</u>	4	**Mark each step in order but then don't mark any further if response refers to purification of a solid** e.g. dissolve in minimum amount of hot solvent, evaporate off water to allow solid to crystalise **IGNORE** use of carbonate (to remove excess acid) **OR** (saturated) NaCl **ALLOW** (remove) aqueous layer on the top **ALLOW** description that aqueous layer can be determined by adding water and seeing which

			OR **Dry** with $MgSO_4$ /magnesium sulfate **OR** $CaCl_2$ /calcium chloride ✓ **Step 3** (Re)Distil at 222 °C ✓		layer increases in size **IGNORE** distillation **OR** filtration prior to **step 1 OR step 2** **ALLOW** 'to remove water' instead of 'dry' **IGNORE** any other named salt, e.g. 'an anhydrous salt e.g. $CaCO_3$' is acceptable **IGNORE** filtration to remove anhydrous salt after **step 2** **ALLOW** termperature range of 220-224°C for distillation **DO NOT ALLOW** if forms a solid product **<u>Examiner' Comments</u>** Many candidates identified the need to describe the isolation and purification of a liquid in response to this question. Some struggled to remember the name of the apparatus required i.e. 'separating funnel' but could describe the separation of layers. The best responses used the density data provided to explain that the lower layer would contain compound **H**. A few gained a mark for a description of the addition of water to identify the correct layer to discard. In generally, candidates only have experience of the organic layer being less dense in their practical work which was reflected in their responses. The use of an anhydrous salt to dry the organic layer was well-known, but many candidates gave vagueanswers such as 'add anhydrous salt' failing to justify why the salt was needed. Many recognised the need to purify the resultant liquid by distillation, but not all linked to the boiling point of compound **H** to secure this final mark. Some who didn't dry with an anhydrous salt said to heat to 100°C to remove water. Approximately a third of candidates gained no marks here. Candidates thought that compound **H** would form crystalsso described recrystallisation rather than a method to purify an organic liquid. Other responses attempted to merge both methods together. **OCR support**

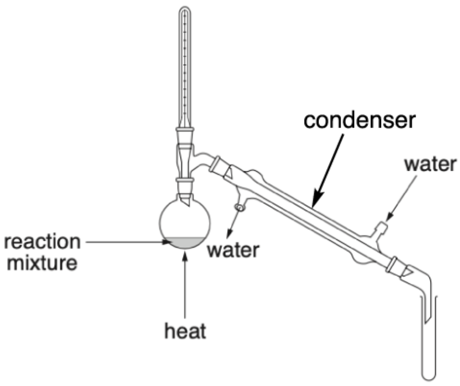
The method to purify an organic liquid was poorly understood by many candidates. Many of the candidates answered this question using techniques to purify an organic solid which is covered in the second year of A Level, rather than an organic liquid which is covered in the first year. It is important to spend time comparing both methods and helping candidates identify when each method is required.

OCR have produced a range of practice exam questions linked to the purification of an organic liquid (PAG5). These can be found on Teach Cambridge.

Exemplar 2


Pour the mixture into a seperating funne
inorganic fluid to work out which layer i
part (H) will stay the same size. Then let
layer leaving just the organic layer. The
be at the top before seperating as it has densi
Distill the organic layer that remains after se
a pure compound. ~~Heat it in a capillary tube~~
could also instead recrystalise it by dissolving in
hot solvent and then allow it to cool and filter
using a buchner flask and cold solvent.

This candidate scored 1 mark for this response for the use of a ‘separating funnel’. They have attempted to use the density information but have incorrectly identified that the density of **H** as being low which would make it the top layer. Candidates needed to know that the density of water is 1 g cm^{-3} to be able to make a correct comparison. There is no addition of an anhydrous salt to dry the organic layer. They have recognised the need to distil but have not given the correct temperature at which to collect the pure compound. However, if they had given the boiling point fordistillation no mark would have been given as they would lose this final

					mark for describing the purification of a solid. It was very common to see responses which described the purification of a solid, often in addition to that of a liquid.
			Total	**5**	
3 2			 **Workable set up** • Flask with 'horizontal' **OR** 'angled down' condenser ✓ • **NOT a sealed system for collection vessel** • **NOT open at the top above flask** **Key labels for distillation set up** • Water in at bottom and out at top • **AND** condenser label ✓	2	**DO NOT ALLOW ANY MARKS FOR A REFLUX SET UP** **IGNORE** • no heat *question about apparatus* • no thermometer *istopper is fine* **<u>Examiner's Comments</u>** The presentation of many candidates' diagrams in questions such as this one requires improvement. The mark scheme was generous, requiring to first see that a candidate knew what distillation is. A first mark was given for a set up comprising a flask connected to a roughly horizontal condenser. There had to be no gap above the condenser and the overall set up could not be a closed system. A second mark was given for minimal labels: condenser and correct direction of water flow. Nearly half the candidates received no marks for their diagram with only just over a quarter being given both marks. Typical errors included: • a reflux set up • open above the flask • a closed system • water flowing the wrong way • the condenser labelled as condensation tube, cooling tube, cooling funnel, distiller, etc.

					Less successful responses showed a conical flask, beaker or test tube being heated. The best advice is to spend some time instructing students how to draw diagrams and to label the apparatus using the accepted scientific names. Students increasingly appear to be finding these questions challenging. **Assessment for learning** Practise the drawing of common organic apparatus as part of the practical work carried out for the practical endorsement.
			Total	**2**	