Candidate Name	Centre Number					Candidate Number				

A LEVEL CHEMISTRY

COMPONENT 2

Organic Chemistry and Analysis

SPECIMEN PAPER

2 hours 30 minutes

	For Examiner's use only		
	Question	**Maximum Mark**	**Mark Awarded**
Section A	**1. to 9.**	**15**	
Section B	**10.**	**18**	
	11.	**18**	
	12.	**17**	
	13.	**11**	
	14.	**14**	
	15.	**15**	
	16.	**12**	
	Total	**120**	

ADDITIONAL MATERIALS

In addition to this examination paper, you will need a data sheet and a calculator.

INSTRUCTIONS TO CANDIDATES

Use black ink or black ball-point pen. Do not use gel pen. Do not use correction fluid.

Write your name, centre number and candidate number in the spaces at the top of this page.

Answer **all** questions in the spaces provided in this booklet.

INFORMATION FOR CANDIDATES

The number of marks is given in brackets at the end of each question or part-question.

You are reminded of the need for good English and orderly, clear presentation in your answers.

No certificate will be awarded to a candidate detected in any unfair practice during the examination.

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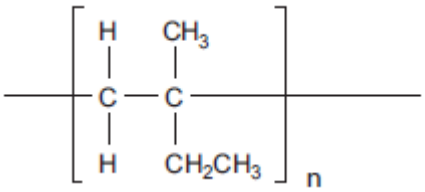
SECTION A

Answer **all** *questions in the spaces provided.*

1. Draw the structural formula of a compound that has the same molecular formula as pentane. [1]

2. Name the compound that can be polymerised to give



[1]

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3. In the upper atmosphere chlorofluoromethane undergoes homolytic fission of the C—Cl bond. Give the formulae of the resulting species. [1]

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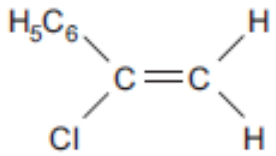
4. The reaction of 2-methylpropene with hydrogen bromide is similar to that of propene with hydrogen bromide. Draw the structure of the main product of the reaction of 2-methylpropene with hydrogen bromide. [1]

5. The formula for 1-phenyl-1-chloroethene is shown below.



State why this compound does not exist as *E–Z* isomers. [1]

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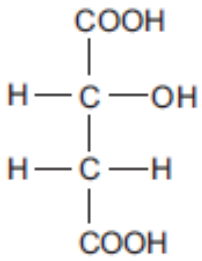
6. Malic acid, isolated from apples, is the enantiomer which has the structure



(a) State why malic acid has two enantiomers. [1]

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(b) State a physical property of the two enantiomers that could be used to distinguish between them. [1]

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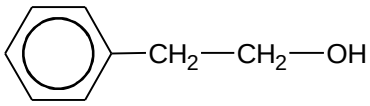
7. *(a)* Use the formula of 2-phenylethanol below to state why it is a primary alcohol. [1]



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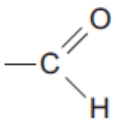
(b) Give the displayed formula of an isomer of formula $C_8H_{10}O$ that can be oxidised to a ketone. [1]

8. *(a)* Methanoic acid is unusual for a carboxylic acid because it contains a 

group.

This group will react with Tollens' reagent on warming. Give the result of this test and explain why it occurs. [2]

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(b) Use your answer to *(a)* to suggest why it is unlikely that silver methanoate, $HCOO^-Ag^+$, can exist. [1]

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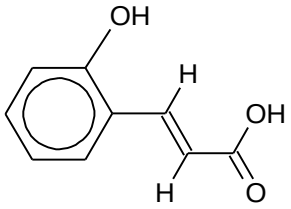
9. Complete the table below to show how you would test for each of the **three** functional groups present in the following compound.

[3]



Reagent(s)	Functional group identified	Observation

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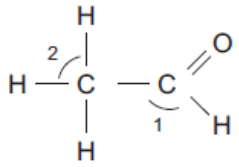
SECTION B

Answer **all** *questions in the spaces provided.*

10. *(a)* The displayed formula for ethanal is shown below.



The molecular shape of the aldehyde group is trigonal planar and the molecular shape of the methyl group is tetrahedral.
Suggest values for the

C – Ĉ – H angle 1 ……..

H – Ĉ – H angle 2 ……..…….. [2]

(b) State a reagent that can be used to oxidise ethanal to ethanoic acid. [1]

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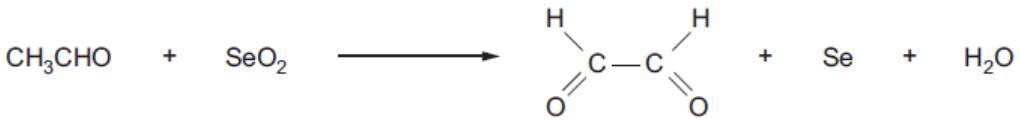
(c) Ethanal can be oxidised to ethanedial by selenium dioxide.



(i) Give the oxidation numbers of selenium in both selenium dioxide and selenium itself. State how this shows that reduction has occurred during this reaction. [2]

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(ii) State a piece of evidence that suggests that selenium dioxide is a less powerful oxidising agent than the one used in *(b)* above. [1]

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(iii) In an experiment 22.0 g of ethanal was oxidised by selenium dioxide to produce 20.0 g of ethanedial. Calculate the percentage yield of ethanedial. [3]

Percentage yield = ... %

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(d) One method of identifying aldehydes and ketones is to make a 2,4-dinitrophenylhydrazine derivative. The melting temperature of the purified derivative is then compared with its book value.

(i) State the type of reaction that occurs when an aldehyde or ketone reacts with 2,4-dinitrophenylhydrazine. [1]

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(ii) The melting temperatures of some 2,4-dintrophenylhydrazine derivatives are shown in the table.

Aldehyde / Ketone	Melting temperature (°C)
cyclopentanone	147
propanal	155
ethanal	168

A student made a 2,4-dinitrophenylhydrazine derivative of compound **A**, which is one of the three carbonyl compounds given in the table. The melting temperature of his derivative was 160-164 °C.

He decided that compound **A** must be ethanal. Comment on why he came to this conclusion and on the purity of his product. You should consider all three carbonyl compounds in your answer. [3]

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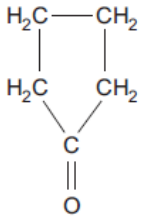
(e) State a test that would give a positive result with ethanal but **not** with propanal or cyclopentanone. [2]



cyclopentanone

Reagent(s) ……

Observation with ethanal ……

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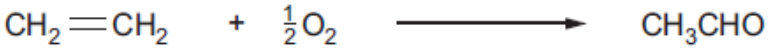
(f) In industry ethanal is made from ethene and air/oxygen by the Wacker process.



The process uses an aqueous solution containing palladium(II) chloride and copper(II) chloride. This corrosive solution acts as a homogeneous catalyst, as the gases react in the solution. A 95% yield of ethanal is obtained. As part of her research training, Emily was asked to evaluate this process with a view to any improvements that could be made.

Suggest **three** factors (apart from cost) that Emily would need to know before she could form an opinion about any possible improvements. [3]

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18

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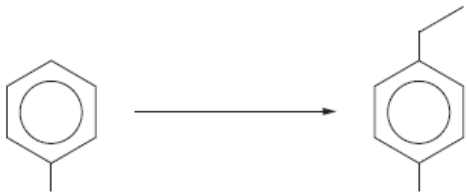
11. *(a)* Aluminium chloride is used as a catalyst in the alkylation and acylation of aromatic hydrocarbons.

(i) State the name of an organic compound that reacts with methylbenzene to produce compound **F**.



compound **F** [1]

…….....

(ii) Draw the **skeletal** formula of another possible organic product of this reaction. [1]

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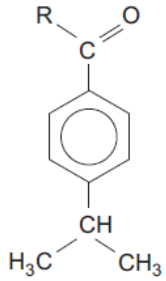
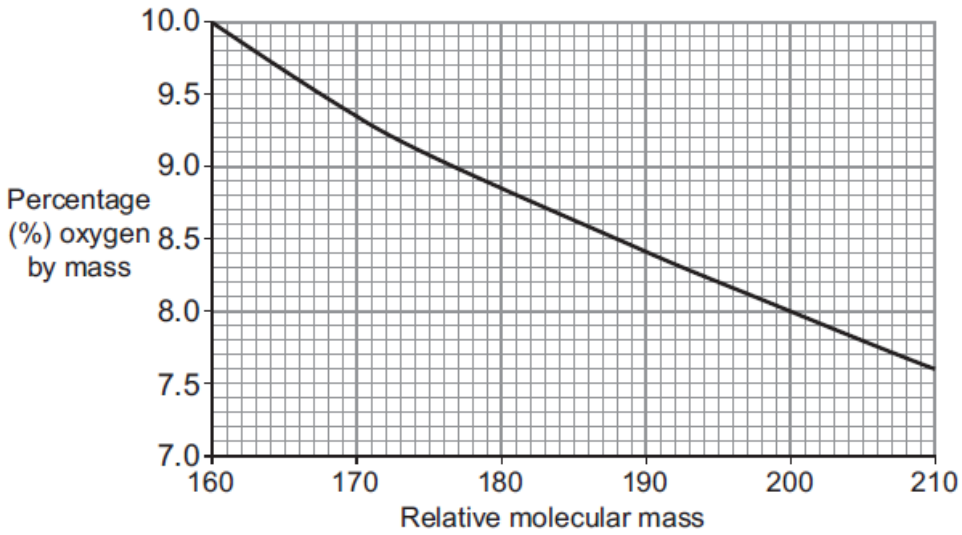
(iii) Compound **H** is formed when the acid (acyl) chloride (RCOCl), compound **G**, reacts with 2-propylbenzene (M_r 120.1) in the presence of aluminium chloride.



compound **H**

Analysis of compound **H** showed that it contained 8.41% of oxygen by mass. Use the graph to help you find the formula of the alkyl group **R**.



[3]

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(iv) The acid chloride used in (iii) opposite is a liquid with a boiling temperature of 102 °C. Before it was used in (iii) it was purified by fractional distillation.

I Suggest a method used to heat the flask containing the impure acid chloride, giving a reason for your answer. [2]

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II State why it was important to exclude moisture from the apparatus during the distillation of the acid chloride. [1]

……..

(b) Primary amines are organic compounds that contain the functional group $–NH_2$.

(i) Amines can behave as bases. Complete the equations to show the reaction between amines and acids. [2]

$C_2H_5NH_2 + CH_3COOH \rightarrow$

$C_6H_5NH_2 + H_2SO_4 \rightarrow$

(ii) If the basic character of ethylamine ($C_2H_5NH_2$), ammonia (NH_3) and phenylamine ($C_6H_5NH_2$) is investigated, it is found that their strength as a base varies as shown.

strongest base …… weakest base

ethylamine ammonia phenylamine

Suggest why this is the order of basic character. [3]

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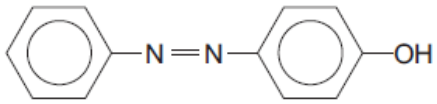
(c) (i) A student was given the following reagents and a method in order to make an azo dye.

Reagents provided:
Phenylamine dissolved in ethanol
Solid sodium nitrite, $NaNO_2$
Dilute hydrochloric acid
Phenol dissolved in water

'Add some sodium nitrite crystals to some hydrochloric acid in a beaker. Quickly add some of the phenylamine solution and stir well. Now add a little of the phenol solution to the mixture and stir. You should see a yellow precipitate of 4-(phenylazo)phenol.'



4-(phenylazo)phenol

The student tried this method and did not obtain any of the yellow azo dye. Assuming that he used the correct amounts of each reagent, state **two** other important details that are missing from these instructions, so that the experiment can be successful. [2]

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(ii) The student was eventually successful in his preparation of the yellow dye and was asked to purify it using the following method.

'Add a sample of the yellow dye to some aqueous sodium hydroxide and stir it until the dye dissolves. Now add dilute hydrochloric acid until no more yellow dye is precipitated. Filter off the yellow solid, wash and dry.'

I Use the formula of 4-(phenylazo)phenol to help you suggest why the yellow dye is able to dissolve in aqueous sodium hydroxide. [2]

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II State why the dye is again produced when dilute hydrochloric acid is added to the mixture. [1]

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12. *(a)* Draw diagrams to show the mechanism of the reaction between aqueous sodium hydroxide and 1-chloropropane. You should include relevant dipoles and curly arrows. [4]

(b) State the type of reaction mechanism occurring in *(a)*. [1]

……..

(c) When 1-chloropropane, 1-bromopropane and 1-iodopropane are reacted separately with aqueous sodium hydroxide it is found that 1-iodopropane reacts most rapidly and 1-chloropropane reacts most slowly.

To make these results valid it is important that a number of experimental factors are kept constant. Identify these factors stating how they would affect the reaction. Consider how differences in the bonding present in each compound have led to the differences in observed reaction rates. [6]

(Your ability to construct an extended response will be assessed in this question).

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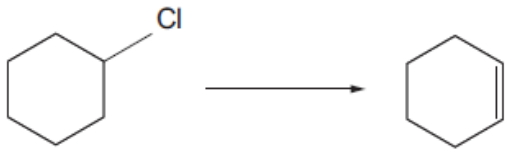
(d) The equation shows the use of chlorocyclohexane to produce cyclohexene.



(i) State the reagent and the conditions needed to convert chlorocyclohexane into cyclohexene. [1]

Reagent ……..

Conditions ……..

(ii) What type of reaction is shown in the equation? [1]

……

(iii) Calculate the atom economy of this process. [2]

Atom economy = ... %

(iv) When chlorobenzene, C_6H_5Cl, is treated in the same way as described in parts *(a)* and *(d)* no reaction occurs in either case. For **each** reagent explain the reason for this. [2]

Reason in *(a)* .....……..

……

……

Reason in *(d)* ……...

……

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17

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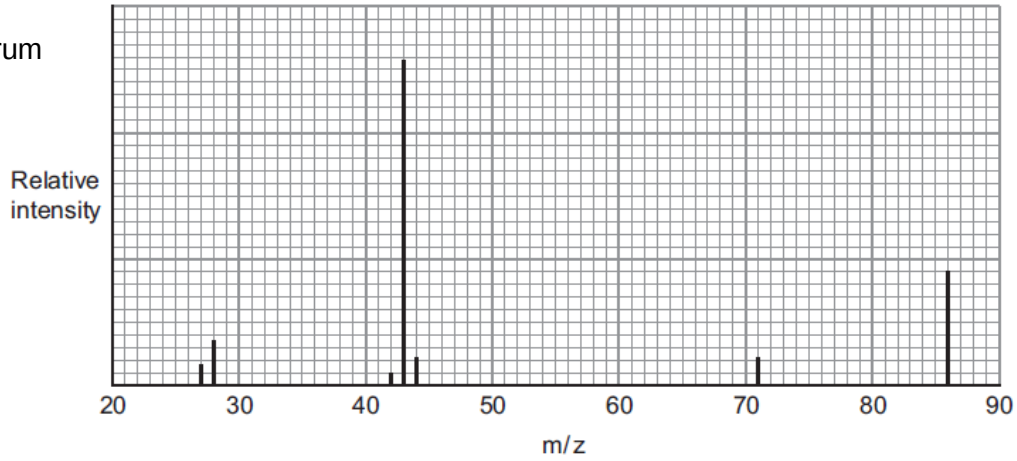
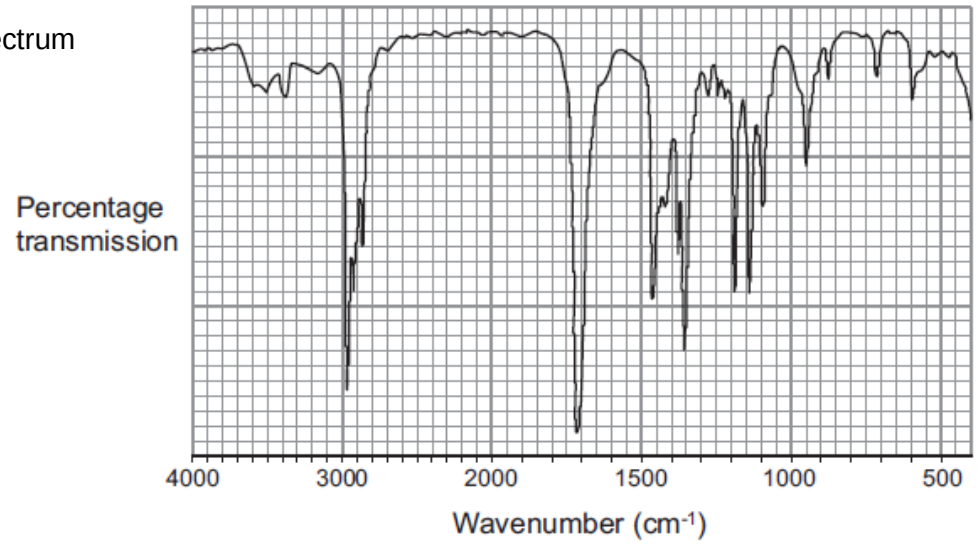
13. In recent times it has become more usual to identify compounds using various types of spectroscopic methods. The spectra below are all produced from the same organic substance, compound **T**, which contains only carbon, hydrogen and oxygen.

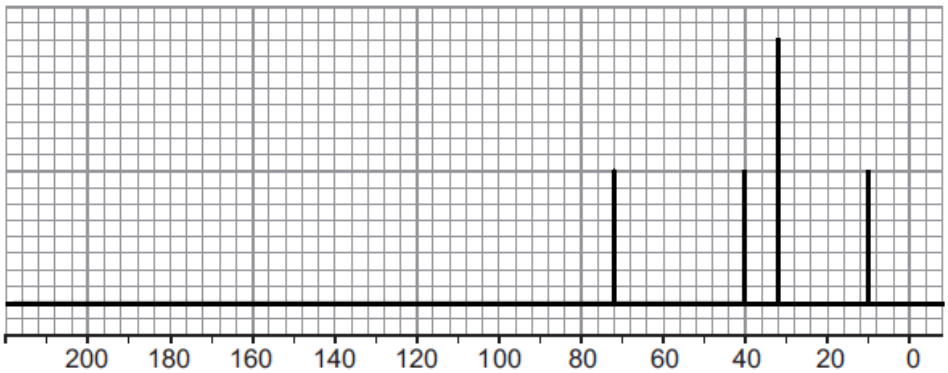
Mass spectrum



IR spectrum



^{13}C NMR spectrum



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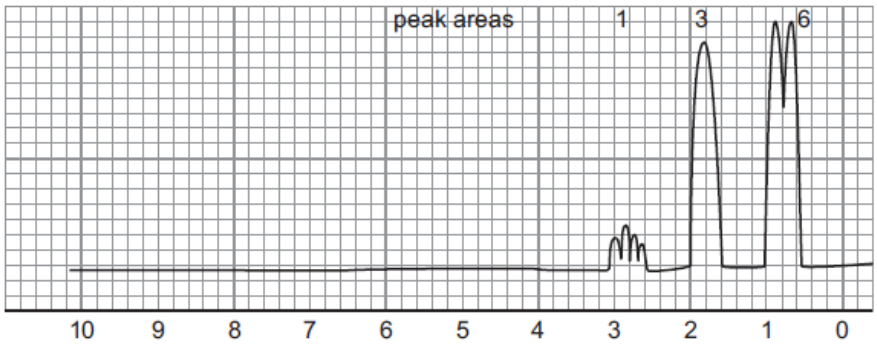
^{1}H NMR spectrum



Chemical shift (ppm)

Use these spectra to identify compound **T**. In your answer you should refer to **all** the spectra provided. In each case you should give an indication of what information about compound **T** is given by the spectrum and how you used this information to identify compound **T**. [11]

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14. *(a)* Gas oil is one of the fractions obtained from the distillation of crude oil. It consists largely of a mixture of alkanes of formulae $C_{14}H_{30}$ to $C_{20}H_{42}$. This fraction can be cracked in the presence of hydrogen (hydrocracking) to produce alkanes with a smaller relative molecular mass.

(i) State why it is unlikely that an alkene would be produced as a result of hydrocracking. [1]

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(ii) Compound **X** is a gaseous branched-chain product of hydrocracking gas oil. 2.09 kg of compound **X** occupies 960 dm^3 at 101000 Pa and 323 K. Use all this information to identify compound X. [4]

(gas constant, R = 8.31 J K^{-1} mol^{-1})

Compound **X** .....

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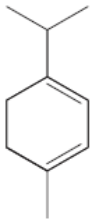
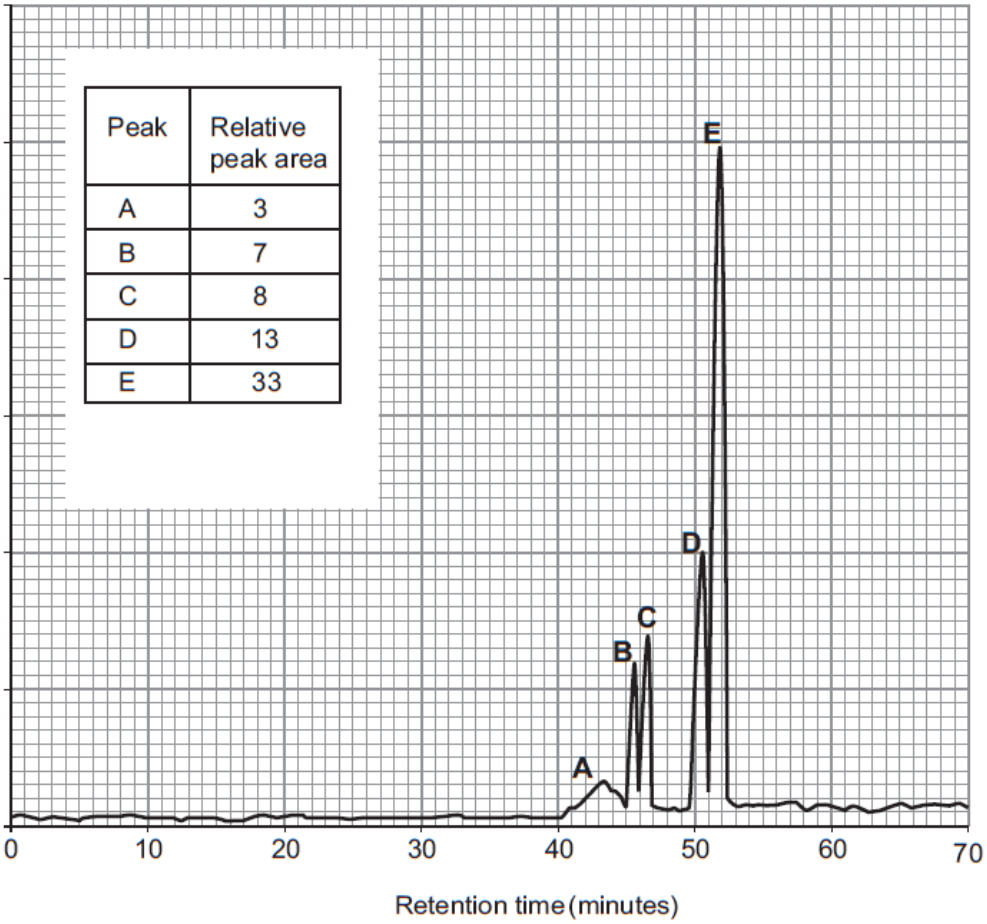
(b) Terpenes are an important group of compounds that are often found in plants. For example, α-terpinene is found in lemon peel.



(i) The HPLC chromatogram of the hydrocarbon fraction of a citrus oil (extracted from lemon peel) is shown below.

Peak	Relative peak area
A	3
B	7
C	8
D	13
E	33



The retention value for α-terpinene is 46.5 minutes. Calculate the percentage of α-terpinene in this hydrocarbon fraction. [2]

Percentage of α-terpinene = …… %

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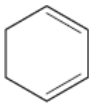
(ii) Further analysis showed that 95 % of the compounds in the citrus oil were present in the hydrocarbon fraction and 5 % were present in an aqueous fraction. If 3.2 g of lemon peel was used to obtain the citrus oil, use your answer to (ii) to calculate the mass of α-terpinene in the peel. [2]

Mass of α-terpinene = …….g

(c) α-Terpinene is a derivative of cyclohexa-1,3-diene.



cyclohexa-1,3-diene

Another student reacted a sample of cyclohexa-1,3-diene with an excess of bromine in an attempt to make 1,2,3,4-tetrabromocyclohexane, $C_6H_8Br_4$. A solid was obtained that contained 75.0 % of bromine by mass.

She suggested that this percentage of bromine was correct for the compound 1,2,3-tribromocyclohexane.

(i) Discuss her conclusion and then use the information to suggest **your** answer to the probable compound(s) present, giving reasons for your answer. [3]

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(ii) Name a technique that could be used to confirm your conclusion to part (i), giving the evidence that you would expect to find. [2]

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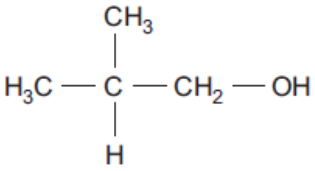
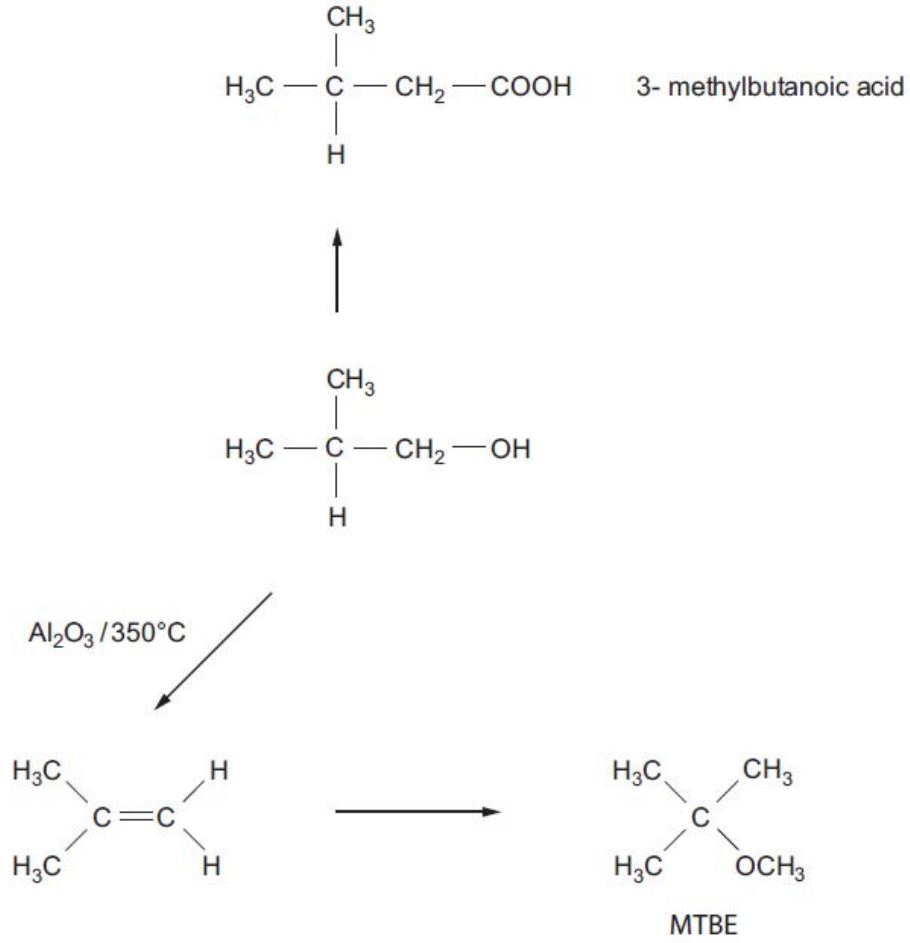
15. There is increasing interest in developing biochemical processes for the manufacture of organic compounds that have traditionally been made from fossil fuels. One compound that can be made using biotechnology is 2-methylpropan-1-ol.



Study the reaction sequences below and then answer the questions that follow.



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(a) State the type of reaction that occurs when 2-methylpropan-1-ol vapour is passed over aluminium oxide at 350 °C. [1]

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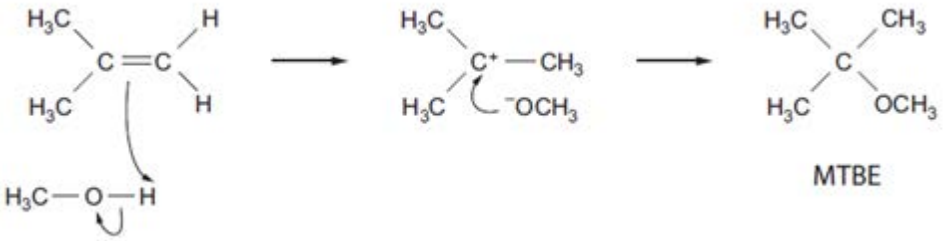
(b) State another reagent that could be used in place of aluminium oxide in the reaction in *(a)* above. [1]

……

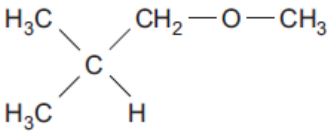
(c) The reaction of 2-methylpropene with methanol to produce MTBE is an example of an electrophilic addition reaction to an alkene.
A possible mechanism for this reaction is shown below.



Comment on this proposed mechanism by considering the points below:

- any partial charges present in the reactants
- the name/type of the intermediate carbocation
- why the product is MTBE and not 1-methoxy-2-methylpropane, shown below.

[5]



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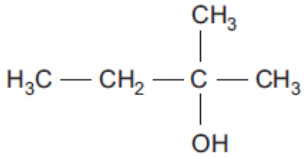
(d) Suggest and explain why MTBE has a boiling temperature of 55 °C but 2-methylbutan-2-ol has a boiling temperature of 102 °C. [2]



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(e) 3-Methylbutanoic acid can be prepared in a three-stage reaction from 2-methylpropan-1-ol. Describe the basic details of each stage, identifying reagents, conditions and intermediate products. [6]

(Your ability to construct an extended response will be assessed in this question.)

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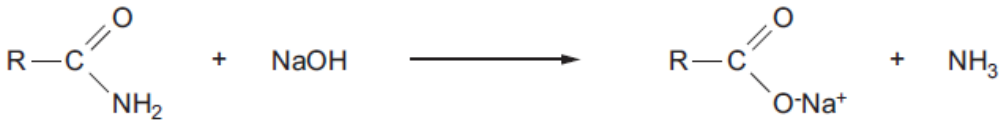
16. *(a)* Amides are hydrolysed to the salts of carboxylic acids by warming them with aqueous sodium hydroxide. During this process ammonia gas is given off.



In an experiment Julie reacted a known mass of an aliphatic amide with an excess of aqueous sodium hydroxide. After the reaction was over, the excess sodium hydroxide was neutralised by hydrochloric acid. She obtained the following results.

Mass of the amide	= 2.34 g
Concentration of the aqueous sodium hydroxide	= 1.25 mol dm^{-3}
Volume of aqueous sodium hydroxide used	= 50.00 cm^3
Volume of hydrochloric acid used	= 30.50 cm^3
Concentration of hydrochloric acid	= 1.00 mol dm^{-3}

(i) Find the relative molecular mass of the amide and hence its formula. [5]

Formula …….....…….

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(ii) Edward repeated a similar experiment using benzamide ($C_6H_5CONH_2$). He carried out the calculations correctly but arrived at an incorrect value of 130 for the relative molecular mass.

Suggest **two** possible errors in his practical work. Explain how these errors would account for the value calculated. [5]

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(b) Esters have extensive uses in the food industry as flavourings. One of these esters is 1-butyl methanoate. This ester can be made from butan-1-ol and methanoic acid in the presence of sulfuric acid, which acts as a catalyst.

1-Butyl methanoate and methanoic acid have similar boiling temperatures. As a result, when the ester is distilled from the reaction mixture, the ester may contain some unreacted methanoic acid. Give a chemical test, naming the reagent and stating the result, which will show that methanoic acid is present in this impure sample of 1-butyl methanoate. [2]

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