

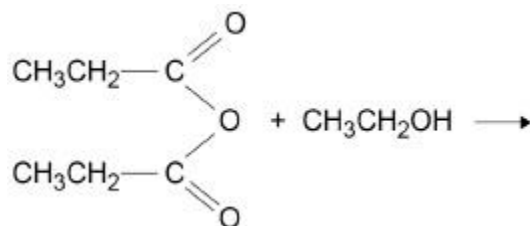
**Q15.**

This question is about esters including biodiesel.

- (a) An ester is formed by the reaction of an acid anhydride with  $\text{CH}_3\text{CH}_2\text{OH}$

Complete the equation. In your answer show clearly the structure of the ester.  
Give the IUPAC name of the ester.

Equation



Name of ester \_\_\_\_\_

(3)

- (b) In a reaction to form biodiesel, one mole of a vegetable oil reacts with an excess of methanol to form two moles of an ester with molecular formula  $\text{C}_{19}\text{H}_{34}\text{O}_2$  and one mole of an ester with molecular formula  $\text{C}_{19}\text{H}_{36}\text{O}_2$

Draw the structure of the vegetable oil showing clearly the ester links.

You should represent the hydrocarbon chains in the form  $\text{C}_x\text{H}_y$  where  $x$  and  $y$  are the actual numbers of carbon and hydrogen atoms.

(2)

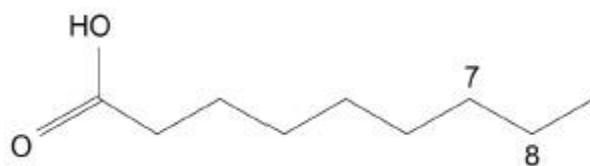


- (c) The compound  $C_{19}H_{34}O_2$  is the methyl ester of Z,Z-octadeca-9,12-dienoic acid.

Part of the structure of the acid is shown.

Complete the skeletal formula to show the next part of the hydrocarbon chain to carbon atom number 14.

In your answer, show the Z stereochemistry around both C=C double bonds.



(2)

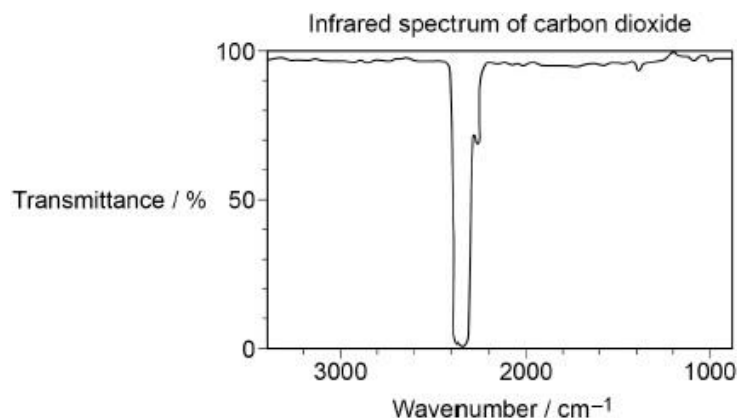
- (d) Give an equation for the complete combustion of the ester  $C_{19}H_{34}O_2$

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(1)

- (e) Combustion of biodiesel produces greenhouse gases such as carbon dioxide that cause global warming.

Part of the infrared spectrum of carbon dioxide is shown in the diagram.



State how the infrared spectrum of carbon dioxide in the diagram above is **not** what you might predict from the data provided in **Table A** in the Data Booklet.

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- (b) Give **two** ways of maximising the yield of propanal obtained by distillation of the reaction mixture.

1. \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

2. \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(2)

- (c) Describe how you would carry out a simple test-tube reaction to confirm that the sample of propanal obtained by distillation does **not** contain any propanoic acid.

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(2)



- (d) A student carried out an experiment to determine the enthalpy of combustion of ethanol. Combustion of 457 mg of ethanol increased the temperature of 150 g of water from 25.1 °C to 40.2 °C

Calculate a value, in  $\text{kJ mol}^{-1}$ , for the enthalpy of combustion of ethanol in this experiment.

Give your answer to the appropriate number of significant figures.

(The specific heat capacity of water is  $4.18 \text{ J K}^{-1} \text{ g}^{-1}$ )

Enthalpy of combustion \_\_\_\_\_  $\text{kJ mol}^{-1}$

**(3)**

- (e) A mixture of isomeric alkenes is produced when pentan-2-ol is dehydrated in the presence of hot concentrated sulfuric acid. Pent-1-ene is one of the isomers produced.

Name and outline a mechanism for the reaction producing pent-1-ene.

Name of mechanism \_\_\_\_\_

Mechanism

**(4)**



- (f) A pair of stereoisomers is also formed in the reaction in **part (e)**.

Name the less polar stereoisomer formed.  
Explain how this type of stereoisomerism arises.

Name \_\_\_\_\_

Explanation \_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

\_\_\_\_\_

(2)

(Total 16 marks)

### Q17.

This question is about the structures of some organic molecules.

- (a) Draw the **skeletal** formula of 3-methylbutanal.

(1)

- (b) Draw the **displayed** formula of  $C_5H_{11}Br$  that is the major product of the reaction of 2-methylbut-2-ene with hydrogen bromide.

(1)



- (c) Thermal cracking of hydrocarbons produces molecules that are attacked by electrophiles because they have a region of high electron density.

Draw the structure of one of these molecules that contains four carbon atoms.

(1)

(Total 3 marks)

### Q18.

This question is about isomerism.

- (a) How many isomers are represented by the formula  $C_5H_{12}$ ?

Tick (✓) **one** box.

2     3     4     5

- (b) Name the type of structural isomerism shown by the isomers of  $C_5H_{12}$

\_\_\_\_\_

(1)

- (c) 2-Hydroxypropanenitrile displays optical isomerism.

Draw three-dimensional representations of the two enantiomers of 2-hydroxypropanenitrile, showing how the two structures are related to each other.

(2)

- (d) Describe how separate samples of each of these enantiomers could be distinguished.

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

(2)



- (e) Butan-2-ol reacts with concentrated sulfuric acid to produce three isomeric alkenes.

Name and outline a mechanism to show how any **one** of the alkenes is formed.

Explain how this reaction can lead to the formation of each of these **three** alkenes.

Name of mechanism \_\_\_\_\_

Mechanism

Explanation \_\_\_\_\_

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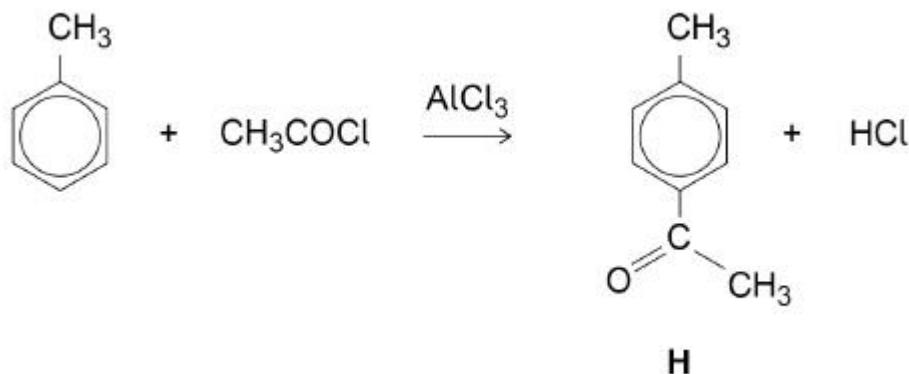
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**(8)**

**(Total 13 marks)**

**Q19.**

When methylbenzene reacts with ethanoyl chloride in the presence of aluminium chloride, the product, **H**, is formed.



- (a) Deduce the molecular formula of **H**.

\_\_\_\_\_

(1)

- (b) Two other isomers are also produced in the reaction.

Draw the structure of **one** of the other isomers.

Name the type of structural isomerism shown by these three products.

Structure

Type of isomerism \_\_\_\_\_

(2)



- (c) Name and outline the mechanism for the reaction of ethanoyl chloride with methylbenzene to produce **H**.

Include an equation for the formation of the reactive intermediate that is involved in the reaction.

Name \_\_\_\_\_

Equation \_\_\_\_\_

Mechanism

(5)

(Total 8 marks)

**Q20.**

Compound **J**, known as leaf alcohol, has the structural formula  $\text{CH}_3\text{CH}_2\text{CH}=\text{CHCH}_2\text{CH}_2\text{OH}$  and is produced in small quantities by many green plants. The *E* isomer of **J** is responsible for the smell of freshly cut grass.

- (a) Give the structure of the *E* isomer of **J**.

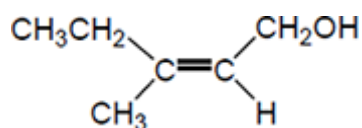
(1)

- (b) Give the **skeletal formula** of the organic product formed when **J** is dehydrated using concentrated sulfuric acid.

(1)



- (c) Another structural isomer of **J** is shown below.



Explain how the Cahn-Ingold-Prelog (CIP) priority rules can be used to deduce the full IUPAC name of this compound.

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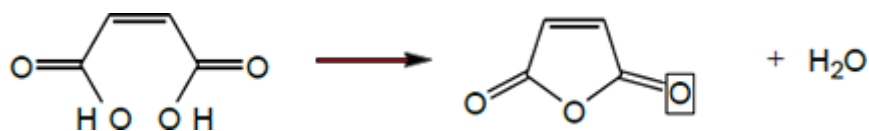
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(6)

- (d) The effect of gentle heat on maleic acid is shown below.



A student predicted that the yield of this reaction would be greater than 80%.

In an experiment, 10.0 g of maleic acid were heated and 6.53 g of organic product were obtained.

Is the student correct? Justify your answer with a calculation using these data.

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(2)



(Total 10 marks)

**Q21.**

2-bromo-2-methylpentane is heated with potassium hydroxide dissolved in ethanol. Two structural isomers are formed.

- (a) State the meaning of the term **structural isomers**.

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(1)

- (b) Name and draw the mechanism for the formation of **one** of the isomers.

Name of mechanism \_\_\_\_\_

Mechanism

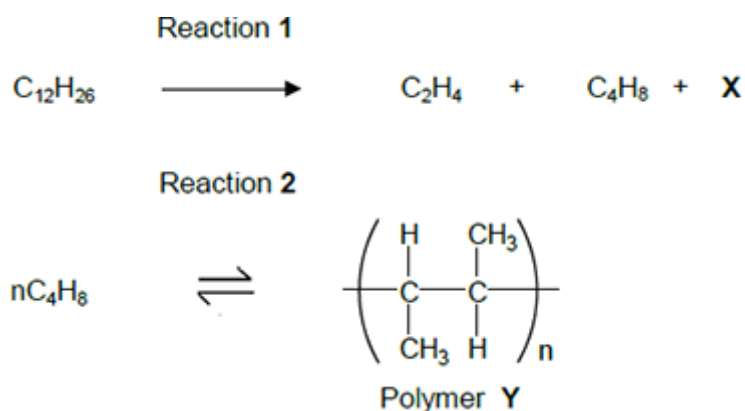
(5)

(Total 6 marks)



## Q22.

Dodecane ( $C_{12}H_{26}$ ) is a hydrocarbon found in the naphtha fraction of crude oil. Dodecane can be used as a starting material to produce a wide variety of useful products. The scheme below shows how one such product, polymer **Y**, can be produced from dodecane.



- (a) Name the homologous series that both  $C_2H_4$  and  $C_4H_8$  belong to.  
Draw a functional group isomer of  $C_4H_8$  that does **not** belong to this homologous series.

Name \_\_\_\_\_

Functional group isomer

(2)

- (b) Identify compound **X**.

\_\_\_\_\_

(1)

- (c) Name polymer **Y**.

\_\_\_\_\_

(1)

- (d) Reaction 1 is an example of thermal cracking and is carried out at a temperature of  $750\text{ }^\circ\text{C}$ .

State **one other** reaction condition needed.

\_\_\_\_\_

(1)

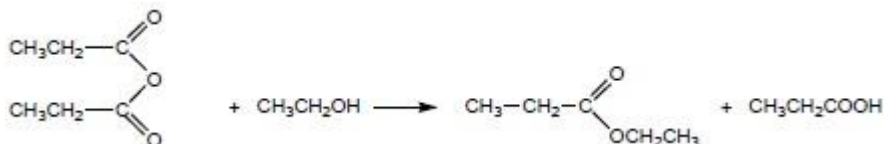




## Mark Scheme

## Q15.

(a)



Ethyl propanoate only

**M1** Structure of ester (allow  $C_2H_5CO_2C_2H_5$ )

1

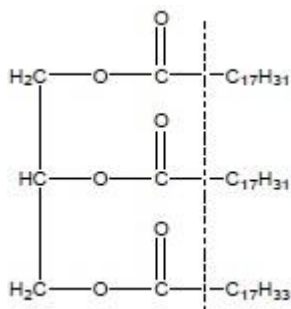
**M2** propanoic acid formula (allow  $C_2H_5CO_2H$ ) and correctly balanced equation

1

**M3** Ethyl propanoate only

1

(b)

**M1** for all except  $C_{17}H_{3x}$  (i.e. all to the left of the dotted line)Allow  $-O_2C-$ ,  $-OOC-$ ,  $-OCO-$ Not  $-CO_2-$ ,  $-COO-$ 

1

**M2** for two  $C_{17}H_{31}$  and one  $C_{17}H_{33}$  in any order top to bottom

1

(c)

**M1** for skeleton

1

**M2** for both Z correct

Independent marks

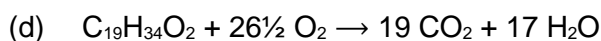
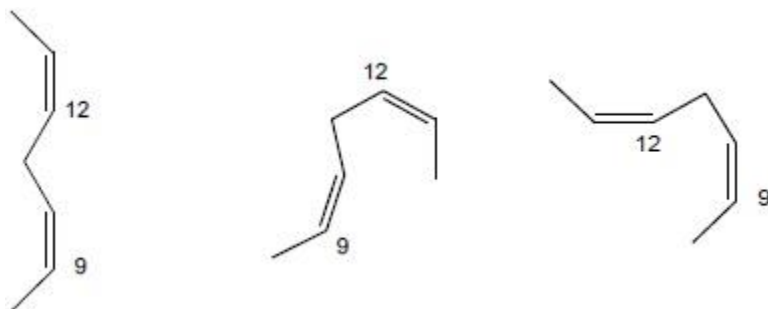
1

C9 – C14 shown with double bonds in the correct place

Ignore structure beyond carbon 14

If hydrogens shown or not skeletal can only score **M2**

Other representations include



*Allow 53/2 or all doubled*

1

- (e) Absorption in spectrum at  $2350\text{ cm}^{-1}$  does not correspond to data booklet value of  $1680 - 1750\text{ cm}^{-1}$  or for C=O bonds in organic compounds)

*Allow would expect a peak at  $1680 - 1750\text{ cm}^{-1}$*

1

- (f) C=O Bonds in  $CO_2$  absorb infrared radiation (of  $2350\text{ cm}^{-1}$ )

1

IR radiation emitted by the earth does not escape (from the atmosphere)

OR

This energy is transferred to other molecules in the atmosphere by collisions (so all atmosphere is warmed)

*Ignore IR reflected*

1

[11]

### Q16.

- (a) Aldehyde/propanal has dipole-dipole forces (between molecules)

*If any 'covalent bonds broken' CE=0 for clip.*

*Ignore Van der Waal forces*

M1

Alcohol/propan-1-ol AND Carboxylic acid/ propanoic acid have hydrogen bonding (between molecules).

*Ignore reference to energy*

M2

The forces between the molecules in aldehyde are weaker (than those in alcohol and acid so it will evaporate first.)

*M3 only awarded following correct M1 OR M2*

*Allow converse for M3*

M3

- (b) Keep the temperature of the reaction mixture below the boiling point of propan-1-ol/below  $97\text{ }^\circ\text{C}$

*Allow temperature in range 49-96 inclusive*

*Allow description of cooling the vessel*

M1



Cool the distillate / collecting vessel

*Ignore reference to oxidising agents*

*Penalise lid / sealed container*

M2

- (c) Add named carbonate/hydrogencarbonate OR magnesium to a sample of the distillate.

*Incorrect chemical CE=0*

*Allow formula (mark on for incorrect formula)*

*Allow blue litmus or correct named indicator*

M1

Effervescence/fizz/bubbles would confirm presence of acid or converse

*Blue litmus turns red confirms acid present or converse*

*Allow gas/CO<sub>2</sub> produced which turns lime water cloudy OR gas/H<sub>2</sub> produced which burns with a squeaky pop*

M2

- (d) (Temperature difference = 15.1 °C)

*If ΔT wrong – AE mark on otherwise can only award M2*

*If use 457 in M1, can only score M2*

$$q = 150 \times 4.18 \times 15.1 \text{ or } 9467.7 \text{ J or } 9.4677\text{kJ}$$

M1

$$\text{amount ethanol burned} = 0.457/46.0 = 9.93 \times 10^{-3} \text{ mol}$$

*If use 457 in M2 can score 2 for - 0.953 kJ mol<sup>-1</sup>*

M2

$$\text{Heat change per mole} = (M1/1000)/M2 = 952.99 \text{ kJ mol}^{-1}$$

$\Delta H = -953 \text{ kJ mol}^{-1}$  must be 3sfs and must be negative

(allow range -953 to -954)

*BEWARE if they miss conversion to kJ and also miss*

*conversion to g, they get answer = - 953 which scores 1*

*+953 can score M1 and M2*

*Allow -950 or -960 for rounding to 2sf*

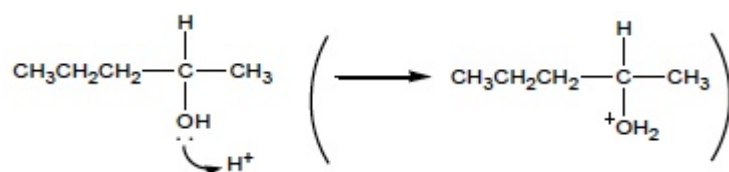
M3

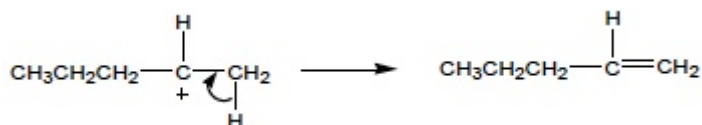
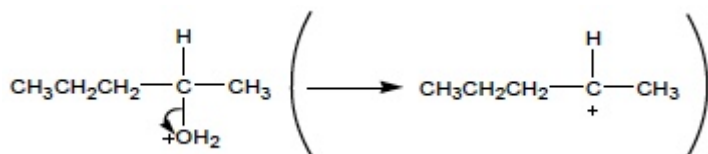
- (e) Elimination

*Penalise base elimination*

M1

Mechanism : Either (E1)

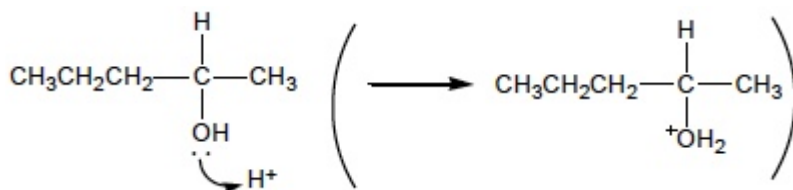




M2 for protonation of alcohol, i.e. lp plus arrow to H<sup>+</sup> or to H of H-O- in H<sub>2</sub>SO<sub>4</sub> and from H-O bond to O  
 M3 for protonated alcohol plus arrow showing loss of water  
 M4 for arrow showing loss of H<sup>+</sup>  
 From correct carbocation (E1)  
 wrong alcohol used / alkene formed loses M4

3

OR (E2)



M2 for protonation of alcohol, i.e. lp plus arrow to H<sup>+</sup> or to H of H-O- in H<sub>2</sub>SO<sub>4</sub> and from H-O bond to O  
 M3 for protonated alcohol plus arrow showing loss of water  
 M4 for arrow showing simultaneous loss of H<sup>+</sup>  
 wrong alcohol used / alkene formed loses M4

3

(f) E-pent-2-ene

Allow trans

M1

C=C bond cannot rotate and

Each carbon in the double bond has (2) different groups attached.

Allow (two) different groups on each/either side of the double bond.

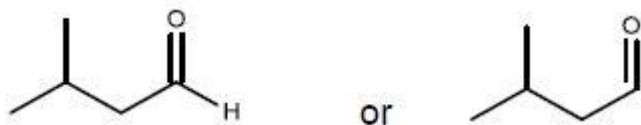
M2

[16]



## Q17.

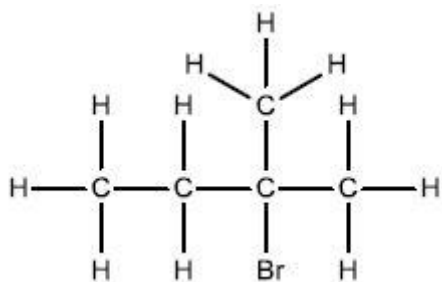
(a)



Must be a skeletal structure

1

(b)



Must be a displayed structure

1

(c) Any correct structural representation of alkene with 4 C atoms, either:

but-1-ene or  
but-2-ene or  
methylpropene

allow butadiene

1

[3]

## Q18.

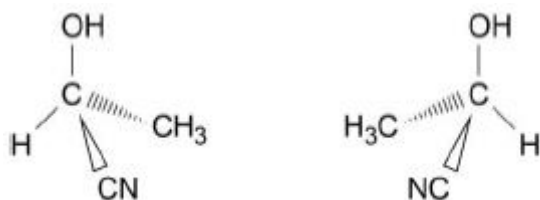
(a) 3

1

(b) Chain.

1

(c)



One 3D enantiomer.

1

Second enantiomer correctly drawn as 3D mirror image of first.

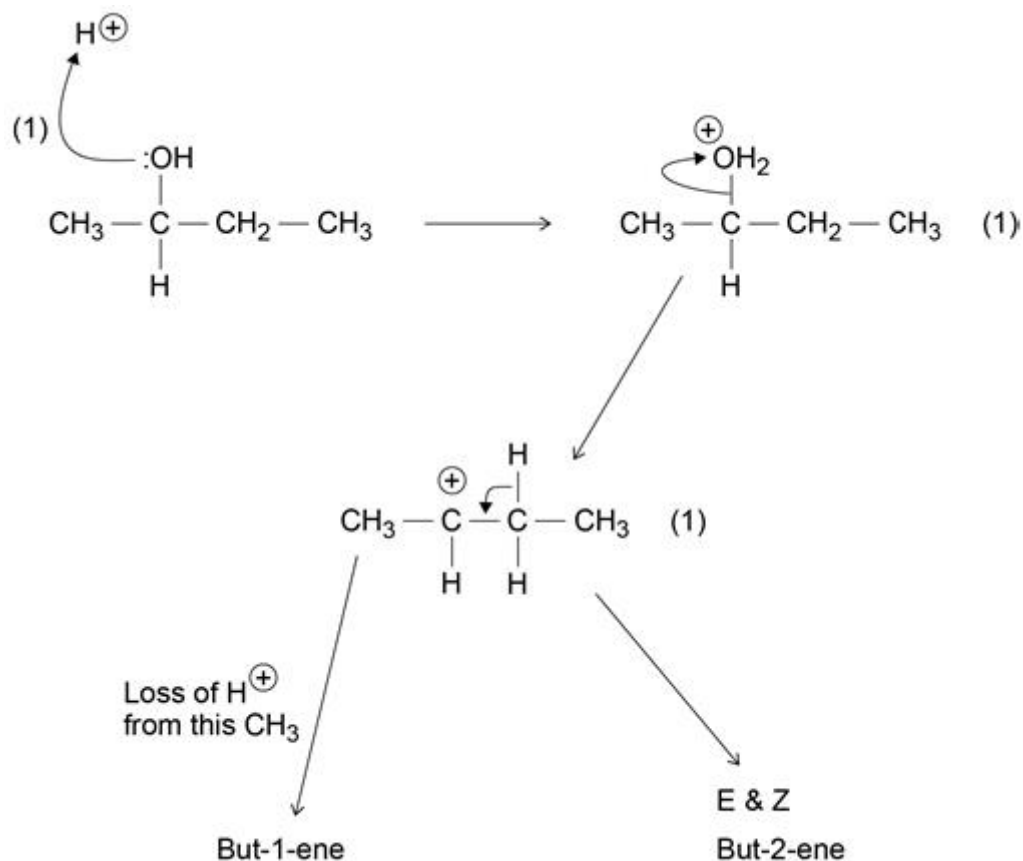
1



(d) Plane-polarised light. 1

Rotated in opposite directions. 1

(e) Elimination



Extended response question

M1

**Mechanism** (3 marks)

M2 arrow from lone pair on O to  $\text{H}^+$

M3 1<sup>st</sup> intermediate **and** arrow from  $\text{C}-\text{O}^+\text{H}_2$  bond to O (with loss of  $\text{H}_2\text{O}$ )

M4 2<sup>nd</sup> intermediate (carbocation) **and** arrow from  $\text{C}-\text{H}$  bond to  $\text{C}-\text{C}$  (with loss of  $\text{H}^+$ ) to form  $\text{C}=\text{C}$

M3 and M4 can be scored in one step (see alternative mechanism below).

If carbocation incorrect then answer cannot score maximum marks.

**Explanation** of formation of 3 alkenes



M5 loss of  $H^+$  from C (in carbocation) adjacent to  $^+C$  (to which  $-OH$  was attached)

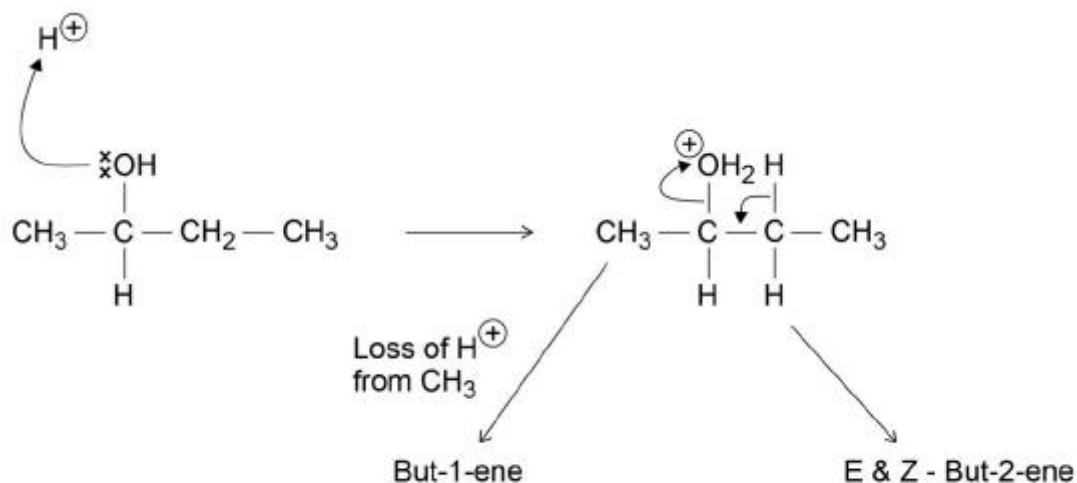
M6 From  $^1C-^2C+^3C-^4C$  leads to but-1-ene

M7 From  $^1C-^2C+^3C-^4C$  leads to but-2-ene

M8 But-2-ene formed as mixture of *E-Z* isomers

8

### Alternative mechanism



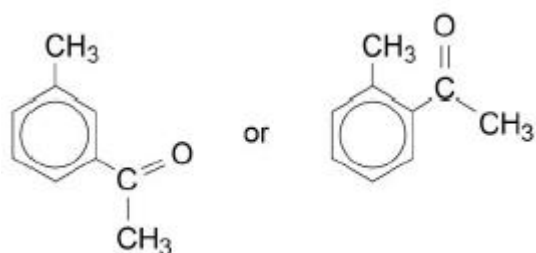
[14]

### Q19.

(a)  $C_9H_{10}O$

1

(b)



1

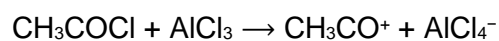
Position (isomerism).

*Allow Positional.*

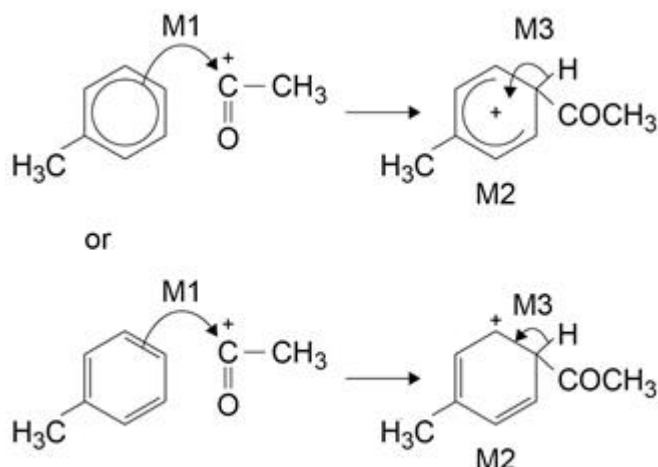
1

(c) Electrophilic substitution

1



1



Mechanism 3 marks:

**M1** arrow from circle or within it to C of  $\text{CH}_3\text{C}^+\text{O}$  (+ must be on C of  $\text{CH}_3\text{C}^+\text{O}$ ).

1

**M2** for Intermediate (**must** be 4-isomer)  
 $\text{CH}_3\text{CO}$  must be correctly positioned and bonded to gain M2  
 horseshoe must not extend beyond C2 to C6 but can be smaller  
 + not too close to C1.

1

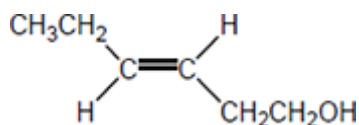
**M3** arrow into hexagon unless Kekule  
 Loss of  $\text{H}^+$  (allow from incorrect isomer)  
 Allow M3 arrow independent of M2 structure  
 Ignore base removing H in M3.  
 Allow Kekule structures (which must be correct).

1

[8]

### Q20.

(a)



1

(b)



1

(c) **Stage 1:** consider the groups joined to right hand carbon of the  $\text{C}=\text{C}$  bond

*Extended response*

*Maximum of 5 marks for answers which do not show a sustained line of reasoning which is coherent, relevant, substantiated and logically structured.*

Consider the atomic number of the atoms attached

M1 can be scored in stage 1 or stage 2

1



- C has a higher atomic number than H, so CH<sub>2</sub>OH takes priority 1
- Stage 2:** consider the groups joined to LH carbon of the C=C bond
- Both groups contain C atoms, so consider atoms one bond further away 1
- C, (H and H) from ethyl group has higher atomic number than H, (H and H) from methyl group, so ethyl takes priority 1
- Stage 3:** conclusion
- The highest priority groups, ethyl and CH<sub>2</sub>OH are on same side of the C=C bond so the isomer is Z
- Allow M5 for correct ECF conclusion using either or both wrong priorities deduced in stages 1 and 2* 1
- The rest of the IUPAC name is 3-methylpent-2-en-1-ol 1
- (d) Moles of maleic acid =  $10.0 / 116.0 = 8.62 \times 10^{-2}$
- AND mass of organic product expected =  $(8.62 \times 10^{-2}) \times 98.0 = 8.45 \text{ g}$
- Or moles of organic product formed =  $6.53 / 98.0 = 6.66 \times 10^{-2}$  1
- % yield =  $100 \times 6.53 / 8.45$
- OR =  $100 \times (6.66 \times 10^{-2}) / (8.62 \times 10^{-2})$
- =  $77.294 = 77.3\%$
- AND** statement that the student was NOT correct 1
- [10]**

**Q21.**

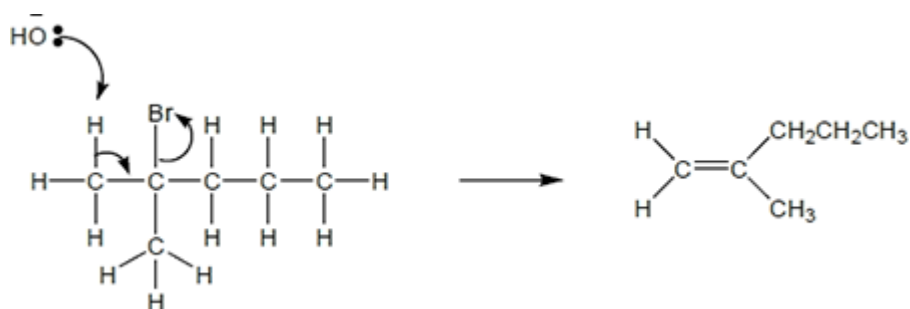
- (a) (Compounds with the) same molecular formula but different structural / displayed / skeletal formula 1
- (b) (basic) elimination 1
- Mechanism points:
- Correct arrow from lone pair on :OH<sup>-</sup> to H on C adjacent to C-Br 1
- Correct arrow from C-H bond to C-C 1
- Correct arrow from C-Br bond to Br



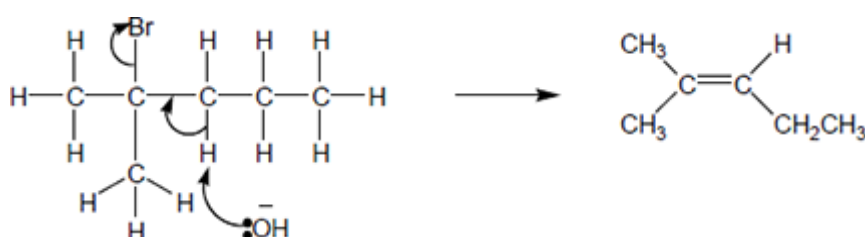
Structure of chosen product

1

1



OR

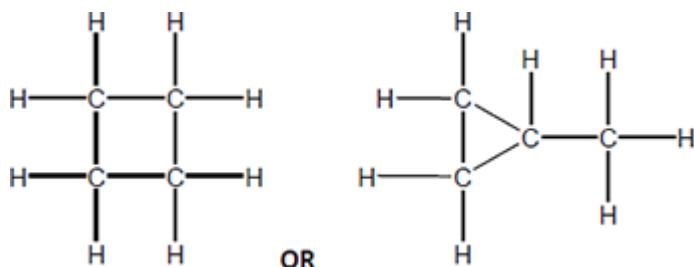


[6]

## Q22.

(a) Alkenes

1



Correctly drawn molecule of cyclobutane or methyl cyclopropane,  
need not be displayed formula

1

(b) C<sub>6</sub>H<sub>14</sub> (or correct alkane structure with 6 carbons)

Allow hexane or any other correctly named alkane with 6 carbons

1

(c) Poly(but-2-ene)

1

(d) High pressure

Allow pressure  MPa

Mention of catalyst loses the mark

1

(e) This question is marked using levels of response. Refer to the Mark Scheme



Instructions for Examiners for guidance on how to mark this question.

### Level 3

All stages are covered and the explanation of each stage is generally correct and virtually complete.

Answer communicates the whole process coherently and shows a logical progression from stage 1 and stage 2 (in either order) to stage 3.

5–6 marks

### Level 2

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows progression. Some steps in each stage may be out of order and incomplete.

3–4 marks

### Level 1

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes isolated statements but these are not presented in a logical order or show confused reasoning.

1–2 marks

### Level 0

Insufficient correct chemistry to gain a mark.

0 marks

#### **Indicative chemistry content**

**Stage 1:** consider effect of higher temperature on yield  
(Or vice versa for lower temperature)

- Le Chatelier's principle predicts that equilibrium shifts to oppose any increase in temperature
- Exothermic reaction, so equilibrium shifts in endothermic direction / to the left
- So a Higher  $T$  will reduce yield

**Stage 2:** consider effect of higher temperature on rate  
(Or vice versa for lower temperature)

- At higher temperature, more high energy molecules
- more collisions have  $E > E_a$
- So rate of reaction increases / time to reach equilibrium decreases

**Stage 3:** conclusion

Industrial conditions chosen to achieve (cost-effective) balance of suitable yield at reasonable rate

