OCR
RECOGNISING ACHIEVEMENT

SPECIMEN

Advanced Subsidiary GCE

F322 QP

CHEMISTRY A

Unit F322: Chains, Energy and Resources

Specimen Paper

Candidates answer on the question paper.

Time: 1 hour 45 minutes

Additional Materials:
Data Sheet for Chemistry (Inserted)
Scientific calculator

Candidate Name	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name, Centre number and Candidate number in the boxes above.
- Answer **all** the questions.
- Use blue or black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure you know what you have to do before starting your answer.
- Do **not** write in the bar code.
- Do **not** write outside the box bordering each page.
- WRITE YOUR ANSWER TO EACH QUESTION IN THE SPACE PROVIDED.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets [ ] at the end of each question or part question.
- ✎ You will be awarded marks for the quality of written communication where this is indicated in the question.
- You may use a scientific calculator.
- A copy of the Data Sheet for Chemistry is provided as an insert with this question paper.
- You are advised to show all the steps in any calculations.
- The total number of marks for this paper is **100**.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	**14**	
2	**13**	
3	**15**	
4	**13**	
5	**12**	
6	**16**	
7	**17**	
TOTAL	**100**	

This document consists of **18** printed pages, **2** blank pages and a *Data Sheet for Chemistry*.

[Turn Over

Answer **all** the questions.

1 The table below lists the boiling points of some alkanes.

alkane	number of carbon atoms	molecular formula	boiling point /°C
butane	4	C_4H_{10}	0
pentane	5	C_5H_{12}	36
hexane	6	C_6H_{14}	69
heptane	7	C_7H_{16}	99
octane	8	C_8H_{18}	
nonane	9	C_9H_{20}	152
decane	10	$C_{10}H_{22}$	175

(a) **(i)** Predict the boiling point of octane.

.... **[1]**

(ii) State and explain the trend in the boiling points of these alkanes.

....

....

.... **[2]**

(b) Predict the molecular formula of an alkane with 13 carbon atoms.

.... **[1]**

(c) Long chain alkanes, such as nonane, are cracked into shorter chain alkanes and alkenes.

Write a balanced equation for the cracking of nonane into heptane and ethene.

.... **[1]**

(d) Straight chain alkanes such as heptane, C_7H_{16}, are processed into branched-chain alkanes and cyclic compounds. These products are required to make petrol burn better in car engines than when using unbranched alkanes.

(i) Draw the skeletal formula of a branched structural isomer of heptane and state its name.

skeletal formula:

name: .... **[2]**

(ii) Write a balanced equation to show the formation of the cyclic compound methylcyclohexane from heptane.

[2]

(e) Butane, C_4H_{10}, reacts with chlorine to produce a chloroalkane with molecular formula C_4H_9Cl.

The reaction is initiated by the formation of chlorine radicals from chlorine.

(i) What is meant by the term *radical*?

.... **[1]**

(ii) State the conditions necessary to bring about the formation of the chlorine free radicals from Cl_2.

.... **[1]**

(iii) State the type of bond fission involved in the formation of the chlorine radicals.

.... **[1]**

(iv) The chlorine radicals react with butane in several steps to produce C_4H_9Cl.

Write equations for the two propagation steps.

....

.... **[2]**

[Total: 14]

2 Bromobutane, $CH_3CH_2CH_2CH_2Br$, can be reacted with hot aqueous sodium hydroxide to prepare butan-1-ol.

$$CH_3CH_2CH_2CH_2Br + OH^- \longrightarrow CH_3CH_2CH_2CH_2OH + Br^-$$

(a) A student reacted 8.72 g of bromobutane with an excess of OH^-. The student produced 4.28 g of butan-1-ol.

(i) Calculate the amount, in mol, of $CH_3CH_2CH_2CH_2Br$ reacted.

$CH_3CH_2CH_2CH_2Br$, M_r = 136.9

answer = ... mol **[1]**

(ii) Calculate the amount, in mol, of $CH_3CH_2CH_2CH_2OH$ produced.

answer = ... mol **[2]**

(iii) Calculate the percentage yield.

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

answer = ... % **[1]**

(b) In this reaction the hydroxide ion acts as a nucleophile.

(i) What name is given to this type of reaction?

.... **[1]**

(ii) Explain the term *nucleophile*.

.... **[1]**

(iii) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles.

[4]

(c) The butan-1-ol produced in **(a)** can be analysed by mass spectrometry.

(i) Predict **two** fragment ions that you would expect to see in the mass spectrum of butan-1-ol and state the *m*/*z* value of each ion.

....

.... **[2]**

(ii) State a use of mass spectrometry outside of the laboratory.

.... **[1]**

[Total: 13]

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3 Ethanol, C_2H_5OH, is manufactured on a large scale for a wide range of uses such as alcoholic drinks, as an industrial solvent and as a raw material for the synthesis of many organic compounds.

(a) Ethanol, C_2H_5OH, is manufactured on a large scale by two methods:

- Fermentation, using yeast, of sugars, such as glucose, $C_6H_{12}O_6$.

$$C_6H_{12}O_6(aq) \longrightarrow 2C_2H_5OH(aq) + 2CO_2(g)$$

The ethanol is then distilled off.

- Hydration of ethene, C_2H_4, with steam in the presence of an acid catalyst.

$$C_2H_4(g) + H_2O(g) \longrightarrow C_2H_5OH(g)$$

Compare the sustainability of these methods of manufacturing ethanol in terms of:

- availability of starting materials and energy requirements;
- atom economy.

In your answer, you should make clear how the atom economy of the processes links with chemical theory.

.... **[7]**

[Turn over

In the laboratory, ethanol can be oxidised with acidified potassium dichromate(VI).

(b) The ethanol can be oxidised to form either ethanal, CH_3CHO (**Fig. 3.1**), or ethanoic acid, CH_3COOH (**Fig. 3.2**).

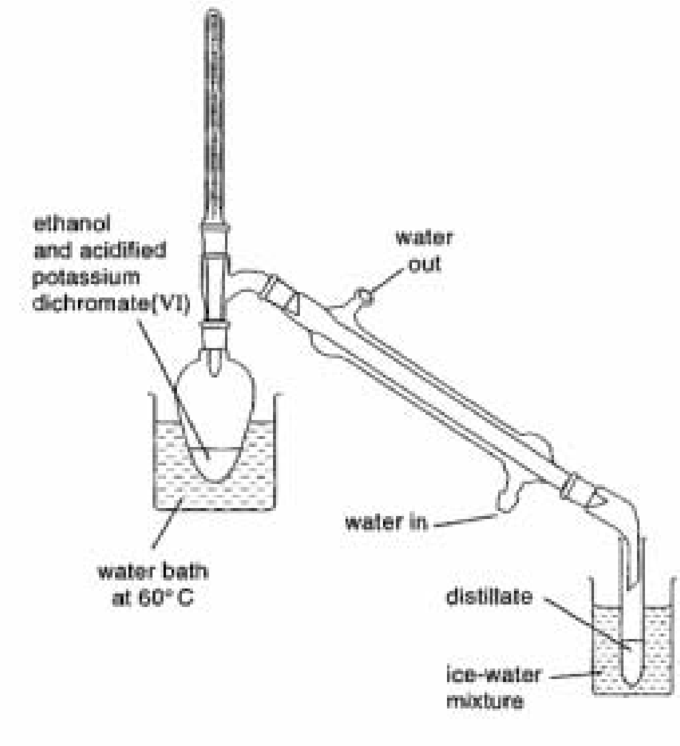


Fig. 3.1

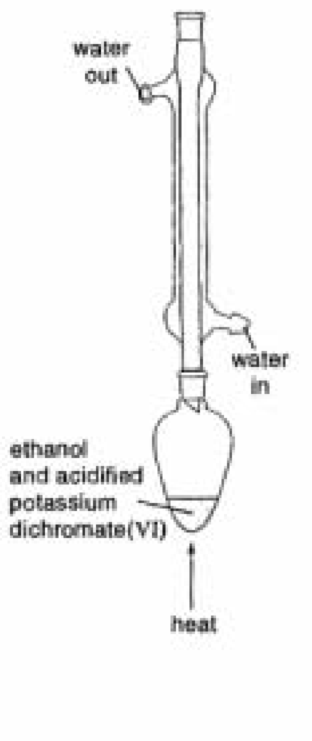


Fig. 3.2

The boiling points of ethanol, ethanal and ethanoic acid are given in the table below.

	CH_3CH_2OH	CH_3CHO	CH_3COOH
boiling point / °C	78	21	118

Use this table of boiling points to explain:

(i) why the organic product is likely to be ethanal if the apparatus shown in **Fig. 3.1** is used,

....

.... **[2]**

(ii) why the organic product is likely to be ethanoic acid if the apparatus shown in **Fig. 3.2** is used.

....

.... **[2]**

(c) Write a balanced equation for the oxidation of ethanol to ethanoic acid. Use [O] to represent the oxidising agent.

.... **[2]**

(d) The ethanal collected using the apparatus shown in **Fig. 3.1** was analysed by infrared spectroscopy.

Use your *Data Sheet* to justify which of the three spectra shown below is most likely to be that of ethanal.

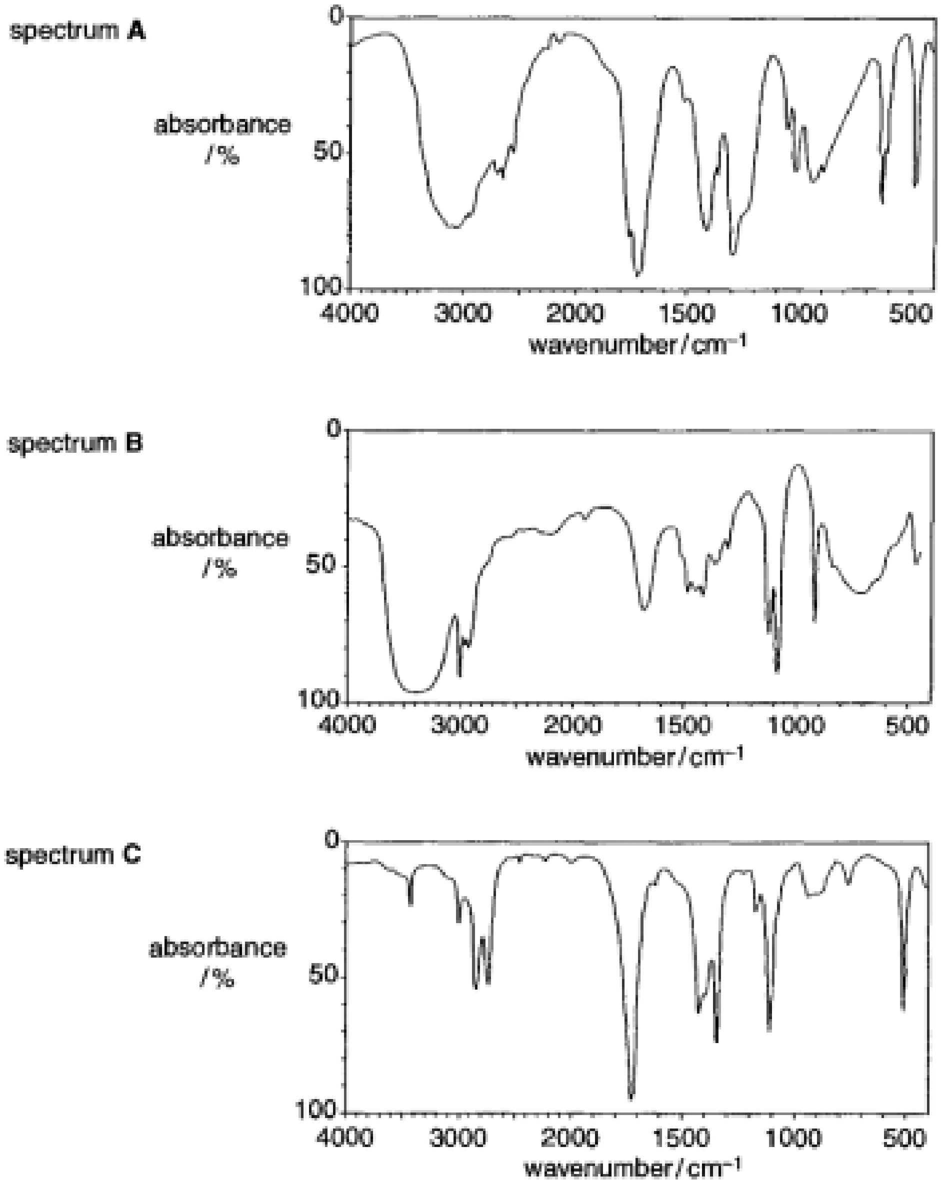


Fig 3.1 © SDBS, National Institute of Science and Technology, 2007

The organic product collected when using the apparatus shown in **Fig. 3.1** is most likely to be that shown by spectrum .... because ....

....

.... **[2]**

[Total: 15]

[Turn over

4 Enthalpy changes of reaction can be determined indirectly from average bond enthalpies and standard enthalpy changes.

(a) The table below shows the values of some average bond enthalpies.

bond	**average bond enthalpy /kJ mol^{-1}**
C–H	+410
O–H	+465
O=O	+500
C=O	+805
C–O	+336

(i) Why do bond enthalpies have positive values?

....

.... **[1]**

(ii) The equation below shows the combustion of methanol, CH_3OH, in the gaseous state.

$$CH_3OH(g) + 1\tfrac{1}{2}O_2(g) \longrightarrow CO_2(g) + 2H_2O(g)$$

Using the average bond enthalpies in the table above, calculate the enthalpy change of combustion, ΔH_c, of gaseous methanol.

ΔH_c = ... kJ mol^{-1} **[3]**

(b) Methane reacts with steam to produce carbon monoxide and hydrogen. The equation for this process is given below.

$$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g)$$

The table below shows the standard enthalpy changes of formation for CH_4, H_2O and CO.

compound	**$\Delta H_f^{\ominus}$/kJ mol^{-1}**
CH_4	–75
H_2O	–242
CO	–110

(i) Define the term *enthalpy change of formation*.

....

....

.... **[2]**

(ii) In $\Delta H_f^{\ominus}$, what are the conditions indicated by the symbol $\ominus$?

....

.... **[1]**

(iii) Write the equation, including state symbols, that represents the standard enthalpy change of formation for carbon monoxide, CO.

.... **[2]**

(iv) Using the $\Delta H_f^{\ominus}$ values in the table above, calculate the enthalpy change for the reaction of methane with steam.

$$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g)$$

ΔH = ... kJ mol^{-1} **[3]**

(c) State one important manufacturing process in which hydrogen is used.

.... **[1]**

[Total: 13]

[Turn over

5 Nitrogen dioxide, NO_2, and dinitrogen tetroxide, N_2O_4, take part in the following equilibrium.

$$2NO_2(g) \rightleftharpoons N_2O_4(g) \qquad \Delta H = -58\ \text{kJ mol}^{-1}$$

(a) State le Chatelier's principle.

....

....

.... **[2]**

(b) Describe, and explain, what would happen to the position of the NO_2/N_2O_4 equilibrium if the following changes are made.

(i) The temperature is increased.

....

....

.... **[2]**

(ii) The pressure is increased.

....

....

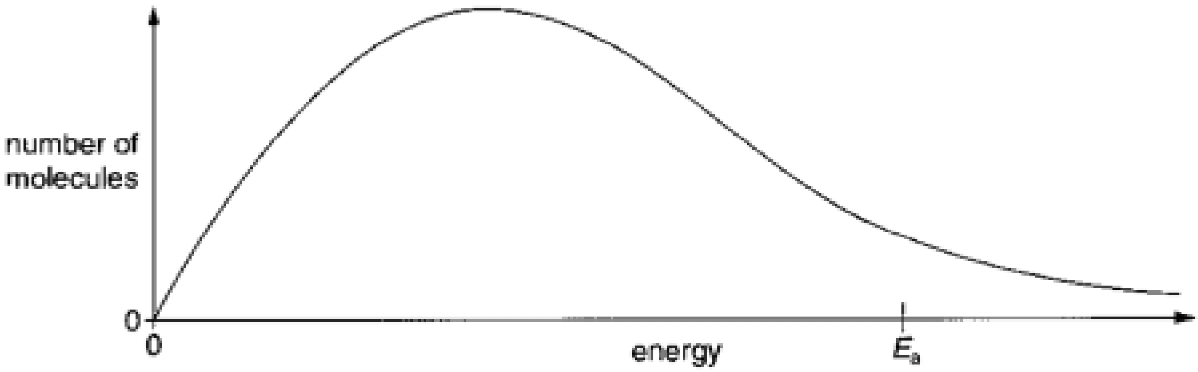
.... **[2]**

(iii) A catalyst is added.

....

.... **[2]**

(c) The diagram below shows the energy distribution of molecules at a particular temperature. E_a represents the activation energy of the reaction.



(i) On the diagram, draw a second curve to represent the energy distribution of the same number of molecules at a higher temperature. **[2]**

(ii) Using your completed diagram, explain how an increase in temperature causes the rate of reaction to increase.

....

....

....

.... **[2]**

[Total: 12]

6 CFCs and carbon dioxide affect the Earth's atmosphere.

(a) CFCs form chlorine radicals, Cl, in the atmosphere. Chlorine radicals are one of the factors responsible for depleting the ozone layer in the stratosphere.

The equations below represent two steps that occur during this process.

Complete these equations and construct an overall equation for the reaction.

$$Cl + O_3 \longrightarrow ClO + \ldots\ldots\ldots$$

$$\ldots\ldots\ldots + O \longrightarrow Cl + O_2$$

……………………….....................overall equation **[2]**

(b) Concern about the consumption of fossil fuels and excessive emissions of carbon dioxide from cars has led to moves to cut down on car usage.

(i) Heptane, C_7H_{16}, is a component in petrol.

Construct a balanced equation for the complete combustion of heptane.

.... **[2]**

(ii) Gases such as CO_2 contribute towards the 'Greenhouse Effect'.

What happens to CO_2 molecules in this process?

....

.... **[2]**

(c) Two workers decide to car-share on a 25 mile journey to work and back. On this journey, each of their cars uses petrol equivalent to 2.0 kg of heptane.

Assuming such car-sharing, use your equation from **b(i)** to:

(i) calculate the amount, in mol, of heptane, C_7H_{16}, saved;

[2]

(ii) calculate the energy saved ($\Delta H_c^{\ominus}$ [C_7H_{16}] = – 4817 kJ mol^{-1});

[1]

(iii) calculate the decrease in volume of CO_2(g) emitted into the atmosphere.

Assume that the conditions are the same as room temperature and pressure.

[2]

(d) Compound **X** is an atmospheric pollutant emitted from fuel combustion of petrol and diesel vehicles. Compound **X** is a potent human carcinogen.

- Analysis of compound **X** showed the following percentage composition by mass: C, 88.89%; H, 11.1%.
- Mass spectrometry showed a molecular ion peak at *m/z* = 54.
- Compound **X** reacts with H_2 in the presence of a nickel catalyst in a 1 : 2 molar ratio.

Analyse and interpret this information to determine a possible structure for compound **X**.

Show all your working.

[5]

[Total: 16]

7 But-1-ene is just one isomer with the molecular formula C_4H_8.

(a) Using C_4H_8 as your example, describe and explain what is meant by structural isomerism and *cis-trans* isomerism.

Include diagrams in your answer.

✎ In your answer you should make clear how each type of isomerism is related to structural features.

[7]

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(b) The chemical properties of but-1-ene are similar to those of ethene.

- Using this information, predict the organic products in, and the equations for, the reactions of but-1-ene with bromine, hydrogen bromide and steam.
- Draw a section of the polymer formed from but-2-ene by showing two repeat units.
- Discuss **two** ways in which chemists are trying to minimise the damage to the environment caused by the disposal of polymers.

[10]

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[Total: 17]

Paper Total [100]

END OF QUESTION PAPER

Copyright Acknowledgements:

Sources

Fig 3.1 © SDBS, National Institute of Science and Technology, 2007

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OXFORD CAMBRIDGE AND RSA EXAMINATIONS

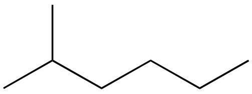
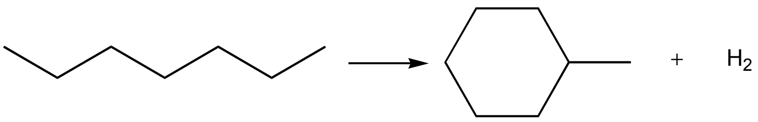
Advanced Subsidiary GCE

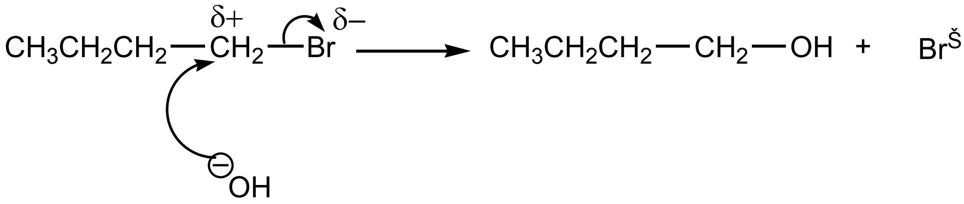
CHEMISTRY A F322 QP

Unit F322: Chains, Energy and Resources

Specimen Mark Scheme

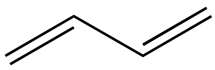
The maximum mark for this paper is **100**.

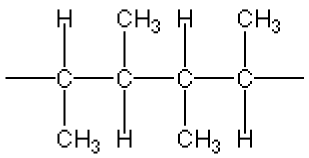
Question Number	Answer	Max Mark
1(a)(i)	120–130 ✓	[1]
(ii)	boiling point increases with increase in M_r/molecular formula/number of carbon atoms/chain length✓ more intermolecular forces/electrons/surface area/ surface interactions/van der Waal forces ✓	[2]
(b)	$C_{13}H_{28}$ ✓	[1]
(c)	$C_9H_{20} \rightarrow C_7H_{16} + C_2H_4$ ✓	[1]
(d)(i)	Any branched isomer of heptane with correct name, e.g.  ✓ 2-methylhexane ✓	[2]
(ii)	 ✓ ✓	[2]
(e)(i)	species with an unpaired electron ✓	[1]
(ii)	uv (light)/high temperature/min of 400 ^{o}C/sunlight✓	[1]
(iii)	homolytic (fission) ✓	[1]
(iv)	$C_4H_{10} + Cl\bullet \longrightarrow C_4H_9\bullet + HCl$ ✓ $C_4H_9\bullet + Cl_2 \longrightarrow C_4H_9Cl + Cl\bullet$ ✓	[2]
2(a)(i)	8.72/136.9 = 0.0637 mol ✓	[1]
(ii)	M_r butan-1-ol = 74(.0) ✓ moles = 4.28/74.0 = 0.0578 mol ✓	[2]
(iii)	0.0578/0.0637 x 100 = 90.7% ✓	[1]

Question Number	Answer	Max Mark
(b)(i)	substitution/hydrolysis ✓	**[1]**
(ii)	electron pair donor ✓	**[1]**
(iii)	 correct dipole ✓ curly arrow from the O in the OH- to C in the CH_2 ✓ curly arrow to show movement of bonded pair in the C–Br bond ✓ Br^- as a product ✓	**[4]**
(c)(i)	Any two realistic fragments, *e.g*. CH_3^+: 15; $C_2H_5^+$: 29; $C_3H_7^+$: 43; $C_4H_9^+$: 57; OH^+: 17, *etc*. ✓✓ Do not penalise missing charge.	**[2]**
(ii)	breathalysers/monitoring of air pollution, MOT emission testing, *etc*. ✓	**[1]**
3(a)	**Availability of starting materials:** availability sugar is renewable because it can be grown ✓ ethane is finite because it is obtained by processing of crude oil ✓ energy: fermentation: energy is required for distillation/ hydration: energy is required to generate steam ✓ **atom economy and waste products:** atom economy for fermentation < atom economy hydration ✓ In fermentation, CO_2 is produced in addition to ethanol/ethanol is not the only product ✓ In hydration, ethanol is the only product/hydration is an addition reaction ✓ Atom economy of fermentation could be increased by finding a use CO_2 ✓ ✎ Atom economy linked to a chemical equation to show that hydration has 100% atom economy/fermentation has 51% atom economy ✓	**[7max]**

Question Number	Answer	Max Mark
(b)(i)	(volatile components) can escape/distil out✓ ethanal is most volatile/bpt less than 60 °C/partial oxidation✓	[2]
(ii)	(volatile components) cannot escape/ refluxed✓ complete oxidation will be achieved/oxidised to the acid ✓	[2]
(c)	$C_2H_5OH + 2[O] \longrightarrow CH_3COOH + H_2O$ C_2H_5OH, 2[O] and CH_3COOH ✓ rest of equation ✓	[2]
(d)	spectrum C: only shows absorption at 1700 cm^{-1} for the C=O✓ the other two spectra contain the OH group absorption at approx 3000 cm^{-1}✓	[2]
4(a)(i)	bond breaking is endothermic/ energy has to be put in to break a bond ✓	[1]
(ii)	bonds broken: 3(C–H) + (C–O) + (O–H) + 1.5 (O=O) = 2781 kJ ✓ bonds made: 2(C=O) + 4(O–H) = 3470 kJ ✓ $\Delta H_c = -689$ (kJ mol^{-1}) ✓	[3]
(b)(i)	(heat/energy change) when 1 mole of substance is formed ✓ from its elements ✓	[2]
(ii)	1 atm/101 kPa and a stated temperature/25 °C/298 K ✓	[1]
(iii)	$C(s) + \frac{1}{2} O_2(g) \rightarrow CO(g)$ balanced equation forming 1 mol CO ✓ state symbols ✓	[2]
(iv)	cycle drawn/sum of ΔH(products) – ΔH(products) ✓ –75 – 242 + x = –110 ✓ ΔH = (+)207 kJ mol^{-1} ✓	[3]
(c)	production of margarine/ammonia/Haber process ✓	[1]

Question Number	Answer	Max Mark
5(a)	when the conditions on a system in equilibrium are changed ✓ the equilibrium moves to minimise the effects of the change/ counteract/ resist/ oppose the change ✓	[2]
(b)(i)	equilibrium moves towards LHS/ towards NO_2 ✓ forward reaction is exothermic/ reverse reaction is endothermic ✓	[2]
(ii)	equilibrium moves towards RHS/ towards N_2O_4 (1) fewer moles on RHS (1)✓	[2]
(iii)	no change in equilibrium position ✓ catalyst speeds up forward ad reverse reactions by same amount ✓	[2]
(c)(i)	curve displaced to the right ✓ maximum is lower ✓	[2]
(ii)	area under curve exceeding E_a = number of molecules that can react ✓ at higher temperature, area under curve > E_a is greater so more can react ✓	[2]
6(a)	O_2 ClO ✓ (both needed) $O_3 + O \rightarrow 2O_2$ ✓	[2]
(b)(i)	$C_7H_{16} + 11\frac{1}{2} O_2 \longrightarrow 7CO_2 + 8H_2O$ products ✓ balance ✓	[2]
(ii)	absorb IR ✓ C=O bonds vibrate. ✓	[2]
(c)(i)	M_r C_7H_{16} = 100 ✓ amount = 2000/100 = 20 mol ✓	[2]
(ii)	energy saved = 20 x 4817 = 9634 kJ ✓	[1]
(iii)	moles CO_2 = 7 x 20 = 140 mol ✓ decrease in CO_2 = 140 x 24 = 3360 dm^3 ✓	[2]

Question Number	Answer	Max Mark
(d)	mole ratio = 88.89/12 : 11.1/1 = 7.41 : 11.1 ✓ empirical formula = C_2H_3 ✓ relative mass of C_2H_3 = 27. M_r = 2 x 29 so molecular formula = C_4H_6 ✓ **X** reacts with 2 mol H_2 so there are 2 double bonds ✓ Possible structure = 1,3-butadiene /  ✓	**[5]**
7(a)	structural isomerism: structural isomers: same molecular formula, different structural formula ✓ structural isomers of but-1-ene: but-2-ene ✓ and methylpropene ✓ geometric isomerism C=C prevents rotation of the double bond✓ each C in the C=C double bond bonded to 2 different atoms or groups ✓ a clear statement that links non-rotation of the double bond to the idea of groups being trapped on one side of the double bond✓ *cis* but-2-ene clearly identified ✓ *trans* but-2-ene clearly identified ✓	**[7]**
7 (b) 1st bullet	product: $CH_3CH_2CHBrCH_2Br$ ✓ equation: $CH_3CH_2CH{=}CH_2 + Br_2 \longrightarrow CH_3CH_2CHBrCH_2Br$ ✓ products: $CH_3CH_2CHBrCH_3$ **and** $CH_3CH_2CH_2CH_2Br$ ✓ (or statement that 2-bromo- is formed) equation: $CH_3CH{=}CHCH_3 + HBr \longrightarrow CH_3CH_2CHBrCH_3$ ✓ (*i.e*. for one product) products: $CH_3CH_2CHOHCH_3$ **and** $CH_3CH_2CH_2CH_2OH$ ✓ (or statement that 2-ol is formed) equation: $CH_3CH{=}CHCH_3 + H_2O \longrightarrow CH_3CH_2CHOHCH_3$ ✓ (*i.e.* for one product)	**[6]**

Question Number	Answer	Max Mark
7 (b) 2nd bullet	 1 mark for skeleton with two repeat units ✓ 1 mark for correct groups on side chains ✓	**[2]**
7 (b) 3rd bullet	two ✓✓ from energy from incineration development of biodegradable polymers cracking of waste polymers	**[2]**
	Paper Total	**[100]**

Assessment Objectives Grid (includes QWC)

Question	AO1	AO2	AO3	Total
1(a)(i)		1		**1**
1(a)(ii)	2			**2**
1(b)		1		**1**
1(c)		1		**1**
1(d)(i)	2			**2**
1(d)(ii)		2		**2**
1(e)(i)	1			**1**
1(e)(ii)	1			**1**
1(e)(iii)	1			**1**
1(e)(iv)		2		**2**
2(a)(i)		1		**1**
2(a)(ii)		2		**2**
2(a)(iii)		1		**1**
2(b)(i)	1			**1**
2(b)(ii)	1			**1**
2(b)(iii)	2	2		**4**
2(c)(i)		2		**2**
2(c)(ii)	1			**1**
3(a)	4	3		**7**
3(b)(i)			2	**2**
3(b)(ii)			2	**2**
3(c)		2		**2**
3(d)			2	**2**
4(a)(i)	1			**1**
4(a)(ii)		3		**3**
4(b)(i)	2			**2**
4(b)(ii)	1			**1**
4(b)(iii)		2		**2**
4(b)(iv)		3		**3**
4(c)	1			**1**
5(a)	2			**2**
5(b)(i)		2		**2**
5(b)(ii)		2		**2**
5(b)(iii)		2		**2**
5(c)(i)	2			**2**
5(c)(ii)	2			**2**
6(a)		2		**2**
6(b)(i)		2		**2**

Question	AO1	AO2	AO3	Total
6(b)(ii)	2			**2**
6(c)(i)		2		**2**
6(c)(ii)		1		**1**
6(c)(iii)		2		**2**
6(d)			5	**5**
7(a)	7			**7**
7(b1)	3	3		**6**
7(b2)	1	1		**2**
7(b3)	2			**2**
Totals	**42**	**47**	**11**	**100**

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