OCR A-LEVEL CHEMISTRY A

CHEMISTRY



EXAM QUESTION PACK

UNIT F322 OLD SPECIFICATION PAPERS

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OCR
Oxford Cambridge and RSA

Friday 10 June 2016 – Afternoon

AS GCE CHEMISTRY A

F322/01 Chains, Energy and Resources

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry A* (inserted)

Other materials required:
- Scientific calculator

Duration: 1 hour 45 minutes

F3220 1

5878514104

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found inside this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

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



Where you see this icon you will be awarded marks for the quality of written communication in your answer.

This means for example you should:
- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- organise information clearly and coherently, using specialist vocabulary when appropriate.

- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **24** pages. Any blank pages are indicated.

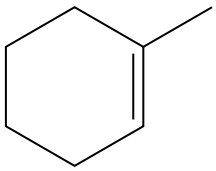
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Answer **all** the questions.

1 Compound **A** is an unsaturated hydrocarbon that can be used as the starting material for the production of organic compounds.



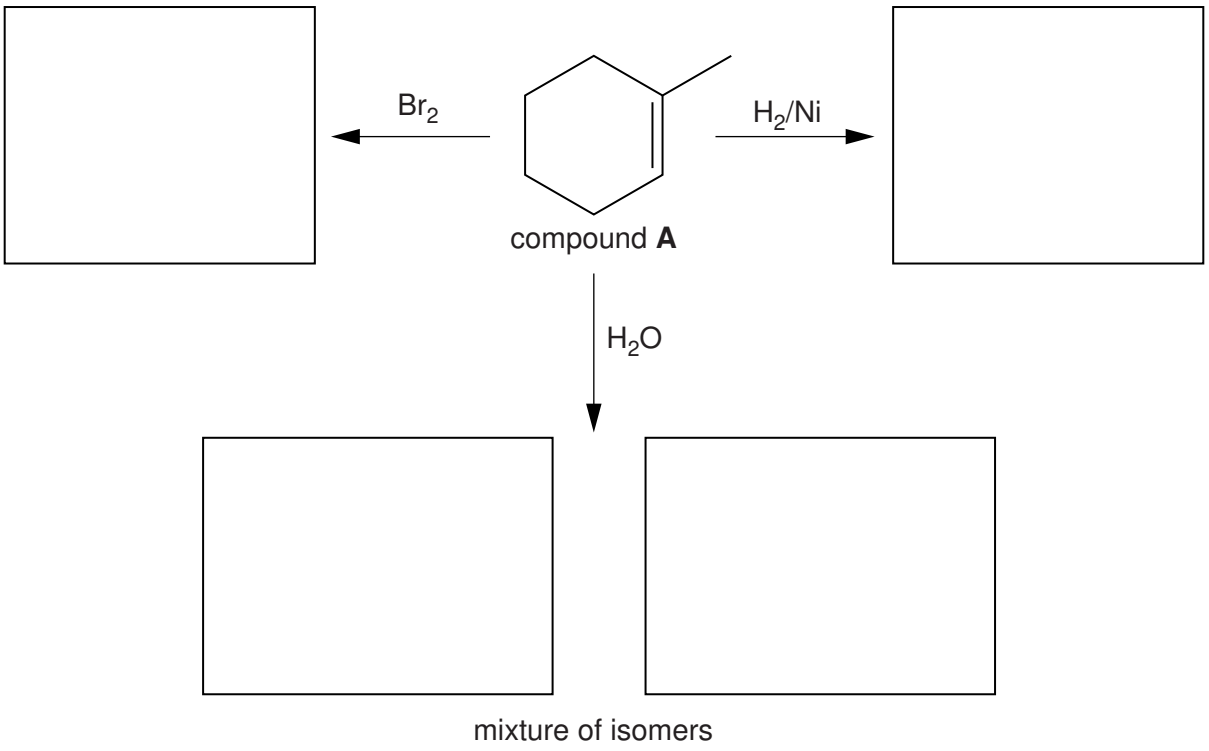
compound **A**

(a) What is the molecular formula of compound **A**?

..... **[1]**

(b) The flowchart shows three **addition** reactions of compound **A**.

(i) In the boxes below, show the structures of the organic products formed in the reactions.



[4]

(ii) What are the essential conditions for the reaction of compound **A** with H_2O?

..... **[2]**

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(iii) Using curly arrows, outline the mechanism for the reaction of compound **A** with Br_2.

[3]

(iv) Name the mechanism in part **(iii)**.

..... **[1]**

[Total: 11]

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2 This question is about the homologous series of alcohols.

(a) What is meant by the term *homologous series*?

.....

.....

.....

..... **[2]**

(b) Ethanol is used more than any other alcohol. One method of preparing ethanol uses yeast.

Write the equation for this preparation and state the essential conditions.

.....

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..... **[2]**

(c) At room temperature and pressure, the first four members of the alkanes are all gases but the first four alcohols are all liquids.

Explain this difference in terms of intermolecular forces.

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..... **[2]**

(d) The boiling points of 2-methylpropan-1-ol and butan-1-ol are shown below.

Alcohol	**Boiling point / °C**
2-methylpropan-1-ol	108
butan-1-ol	117

Explain why the boiling points are different.

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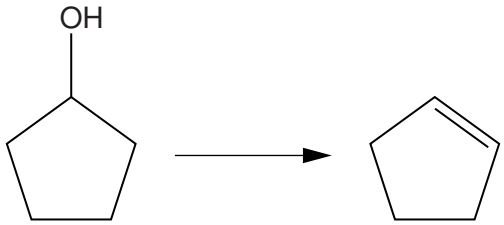
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..... **[2]**

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(e) Alkenes can be prepared from alcohols. Cyclopentene can be prepared from cyclopentanol as shown in the equation below.



A student plans to prepare 5.00 g of cyclopentene from cyclopentanol. The percentage yield of this reaction is 45.0%.

(i) What is the name of this type of reaction?

..... **[1]**

(ii) Calculate the mass of cyclopentanol that the student should use.

Show your working.

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

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(f) Alcohols can be prepared from halogenoalkanes. 2,2-dimethylpropan-1-ol can be prepared by hydrolysis of a chloroalkane with aqueous sodium hydroxide.

(i) Write the equation for this reaction.

Use structures for the organic compounds.

[1]

(ii) Outline the mechanism for this reaction.

Show curly arrows and relevant dipoles.

[2]

[Total: 15]

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3 This question is about different ways of determining enthalpy changes.

(a) A student carries out an experiment to determine directly the enthalpy change of reaction, ΔH_r, shown below.

$$Mg(s) + CuSO_4(aq) \longrightarrow MgSO_4(aq) + Cu(s)$$

- The student measures the initial temperature of 25.0 cm^3 of 0.500 $mol\,dm^{-3}$ $CuSO_4(aq)$.
- The student adds an excess of magnesium powder and stirs the mixture.
- The student measures the maximum temperature of the solution.

Results

Initial temperature of solution = 21.5 °C
Maximum temperature of solution = 63.0 °C

Density of the solution = 1.00 $g\,cm^{-3}$; specific heat capacity of the solution = 4.18 $J\,g^{-1}\,K^{-1}$.

(i) Calculate the enthalpy change of reaction, ΔH_r, in $kJ\,mol^{-1}$.

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

ΔH_r = ... kJ mol^{-1} **[4]**

(ii) The student weighed out enough magnesium so that it would be in excess by **at least** 25%. The student had access to a two decimal-place balance.

Calculate the minimum mass of magnesium that the student would need to weigh out on this balance.

mass = ... g **[1]**

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(b) Enthalpy changes of formation can be determined indirectly from standard enthalpy changes of combustion, $\Delta H_c^{\ominus}$.

Three enthalpy changes of combustion are shown below.

Substance	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
C(s)	–394
$H_2(g)$	–286
$C_9H_{20}(l)$	–6125

(i) Define *standard enthalpy change of combustion*.

Include the standard conditions that are used.

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.....

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..... **[3]**

(ii) The equation that represents the enthalpy change of formation, ΔH_f, of nonane is shown below.

Calculate the standard enthalpy change of formation of nonane.

$$9C(s) + 10H_2(g) \longrightarrow C_9H_{20}(l)$$

ΔH_f = ... kJ mol^{-1} **[2]**

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(c) The bond enthalpy for the bond in carbon monoxide can be calculated from the information below.

$$CH_4(g) + H_2O(g) \longrightarrow CO(g) + 3H_2(g) \qquad \Delta H = +210\,kJ\,mol^{-1}$$

Bond	Average bond enthalpy / kJ mol^{-1}
C–H	413
O–H	464
H–H	436

(i) What is meant by the term *average bond enthalpy*?

.....

.....

..... **[2]**

(ii) Calculate the bond enthalpy for the bond in carbon monoxide.

Show your working.

bond enthalpy = ... kJ mol^{-1} **[3]**

[Total: 15]

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4 This question is about equilibrium and catalysts.

(a) The equilibrium between NO_2 and N_2O_4 gases is set up in a gas syringe at room temperature. The two gases are different in appearance.

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

Using le Chatelier's principle, predict and explain how the following changes would affect the appearance of the equilibrium mixture.

(i) The gas mixture is compressed by pushing in the plunger of the gas syringe.

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..... **[2]**

(ii) The gas syringe is placed in a warm water bath.

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..... **[2]**

(b) When potassium chromate(VI), K_2CrO_4, is dissolved in water an equilibrium is set up. The position of equilibrium is well to the left and the solution is a yellow colour.

$$\underset{\text{yellow}}{2CrO_4^{2-}(aq)} + 2H^+(aq) \rightleftharpoons \underset{\text{orange}}{Cr_2O_7^{2-}(aq)} + H_2O(l)$$

The addition of aqueous acid turns the solution an orange colour.
Aqueous alkali is then added and the solution turns a yellow colour.

Explain these observations in terms of le Chatelier's principle.

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..... **[2]**

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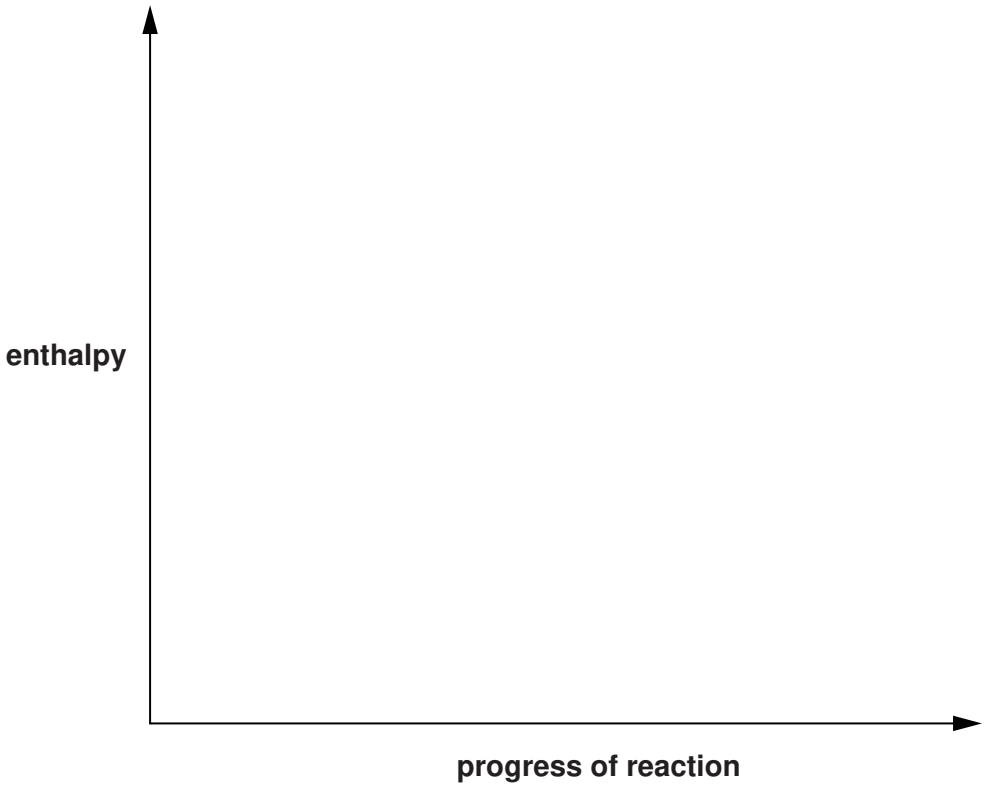
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(c) Catalysts can be used to change the rate of some chemical reactions.

(i) Zinc and sulfuric acid react together to form a solution of zinc sulfate, $ZnSO_4$, and hydrogen gas. The reaction is exothermic.

The rate of the reaction increases when a catalyst is added.

- Complete the enthalpy profile diagram for this reaction using the formulae of the reactants and products.
- Label activation energies, E_a (without catalyst) and E_c (with catalyst).
- Label the enthalpy change of reaction, ΔH.



[3]

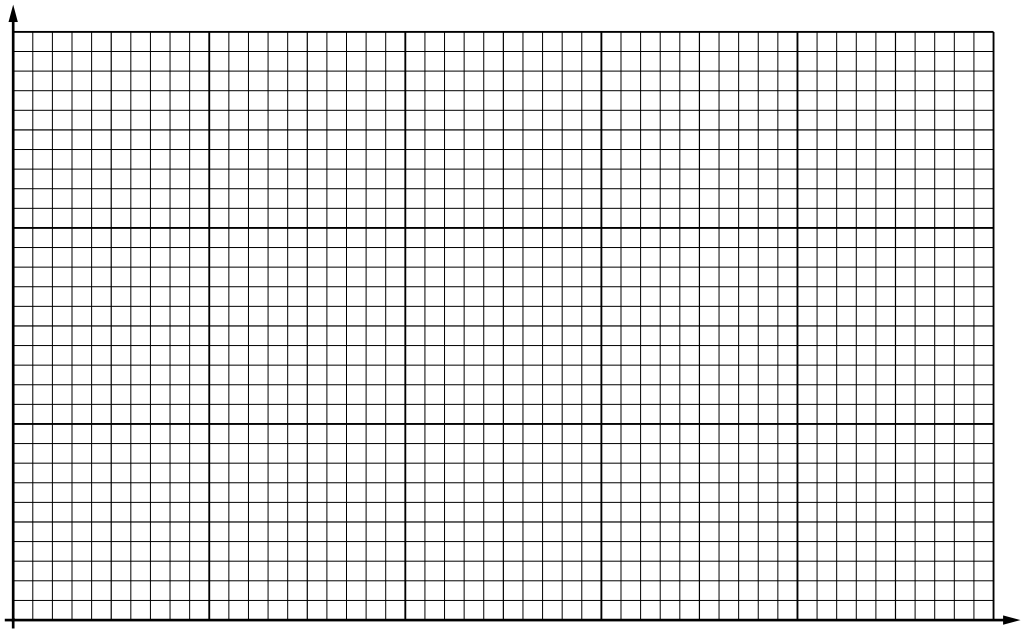
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(ii) Using a Boltzmann distribution, explain how a catalyst increases the rate of a chemical reaction.

Include a labelled sketch of your Boltzmann distribution on the grid below. Label the axes and any other important features.

Your answer needs to be clear and well organised using the correct terminology.



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..... **[4]**

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(d) The chemical industry uses catalysts for many of its reactions.

(i) State an example of a catalyst used by the chemical industry and write the equation for the reaction that is catalysed.

catalyst .....

equation .....

[1]

(ii) State **two** ways that the use of catalysts helps chemical companies to make their processes more sustainable and less harmful to the environment.

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..... **[2]**

(e) In the stratosphere, nitrogen oxides can catalyse the breakdown of ozone.

(i) State **two** sources of nitrogen oxides in the stratosphere.

.....

..... **[1]**

(ii) Write equations to show how nitrogen monoxide catalyses the breakdown of ozone.

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..... **[2]**

[Total: 19]

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5 The hydrocarbons present in crude oil are processed to obtain useful materials, including many fuels.

Alkanes with 6–10 carbon atoms are used in petrol.

(a) What is the general formula of an alkane?

..... **[1]**

(b) Carbon monoxide and nitrogen monoxide are pollutants formed in internal combustion engines, using petrol as their fuel.

- Explain how carbon monoxide and nitrogen monoxide are formed in internal combustion engines.
- Describe the stages that allow a catalytic converter to reduce carbon monoxide and nitrogen monoxide emissions.
- Include equations for any reactions and use octane to represent the alkanes present in petrol.

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..... **[6]**

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(c) Oil companies process alkanes into branched and cyclic hydrocarbons to promote efficient combustion in petrol.

- Draw the structure of one branched and one cyclic saturated hydrocarbon that contains **8** carbon atoms.
- Name each hydrocarbon.

Branched	**Cyclic**
name:	*name:* .....

[3]

(d) The greenhouse effect of a gas in the atmosphere is dependent on two factors.

State these **two** factors.

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..... **[2]**

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(e) By 2020, the EU has regulated that a car must emit less CO_2 per kilometre than in 2015. A typical car will need to emit 5.6×10^5 g less CO_2 in 2020 compared with 2015.

Calculate how much less petrol would be consumed by a typical car in 2020 to meet this regulation.

Give your answer in litres of petrol (1 litre of petrol has a mass of 700 g).

Assume that petrol is liquid octane and that complete combustion takes place, as in the equation below.

$$C_8H_{18}\,(l) + 12.5\,O_2\,(g) \longrightarrow 8CO_2\,(g) + 9H_2O\,(l)$$

volume of petrol = ... litres **[4]**

[Total: 16]

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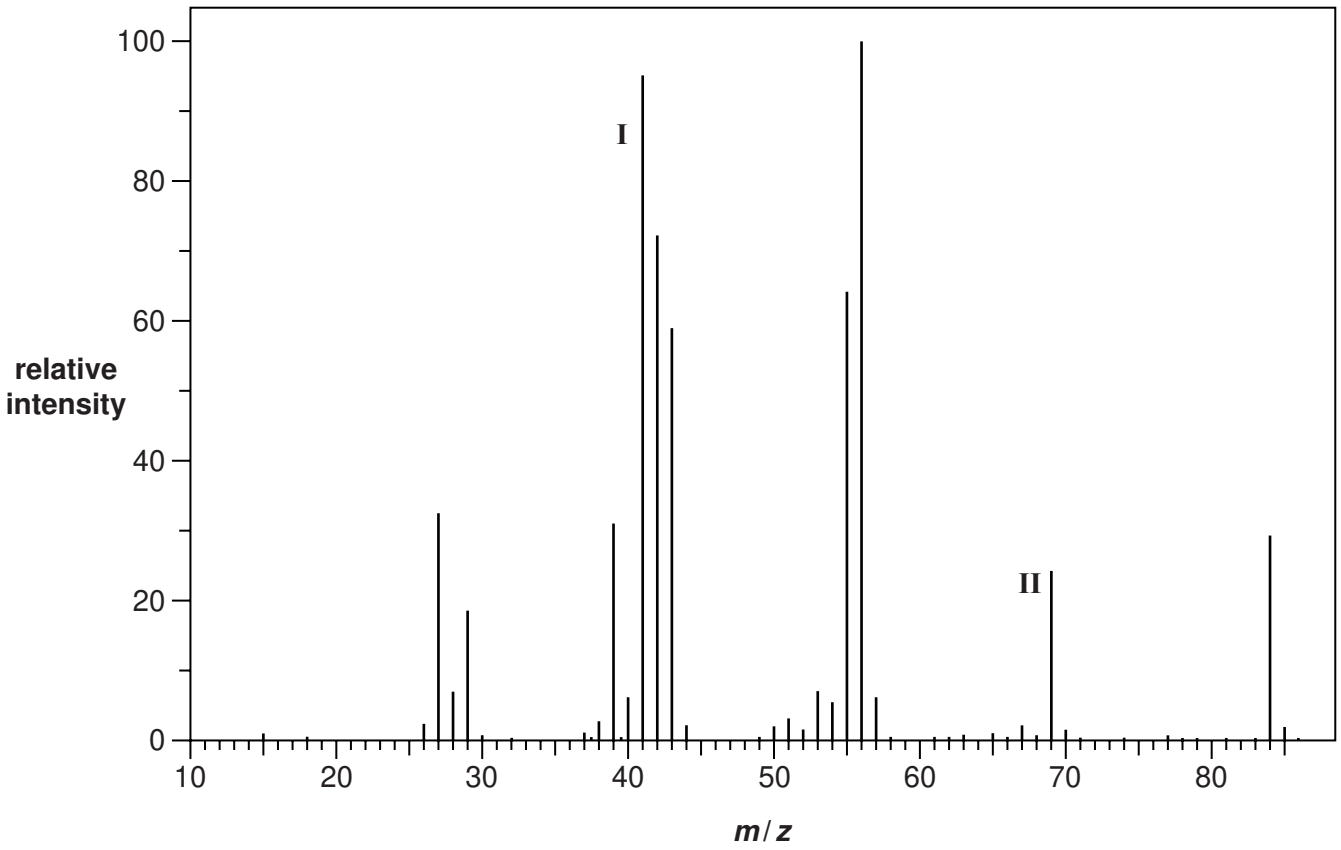
Turn over for the next question

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6 This question is about several unsaturated hydrocarbons.

(a) The mass spectrum of an alkene is shown below.



(i) The empirical formula of the alkene is CH_2.

Use the empirical formula and the mass spectrum to confirm the molecular formula as C_6H_{12}.

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..... **[1]**

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(ii) Further analysis showed that the alkene was hex-2-ene.

Suggest possible structures for the species responsible for the labelled peaks **I** and **II** in the mass spectrum of hex-2-ene shown opposite.

peak I	**peak II**

[3]

(b) Hex-2-ene shows *E*/*Z* isomerism.

(i) Draw the skeletal formulae of *E*-hex-2-ene and *Z*-hex-2-ene.

E-hex-2-ene	*Z*-hex-2-ene

[2]

(ii) State and explain the features of a hex-2-ene molecule that lead to *E* and *Z* isomers.

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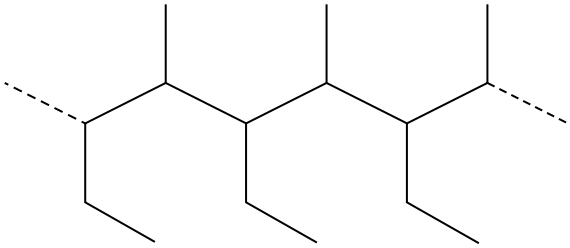
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..... **[2]**

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(c) A section of a polymer that can be made from an unsaturated hydrocarbon **B** is shown below.



(i) Add brackets to the section of the polymer to show **one** repeat unit. **[1]**

(ii) Draw the structure of hydrocarbon **B**.

[1]

(iii) The polymer has a relative molecular mass of 50,000.

Calculate the number of monomer molecules required to make one molecule of the polymer.

number of monomer molecules = ... **[1]**

[Total: 11]

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7 A student was provided with a mixture of two structural isomers. Each isomer has the percentage composition by mass C, 29.29%; H, 5.70%; Br, 65.01%. The relative molecular mass of each isomer is less than 150.

(a) Determine the structures of the two structural isomers.

Show your working.



In your answer you should link the evidence with your explanation.

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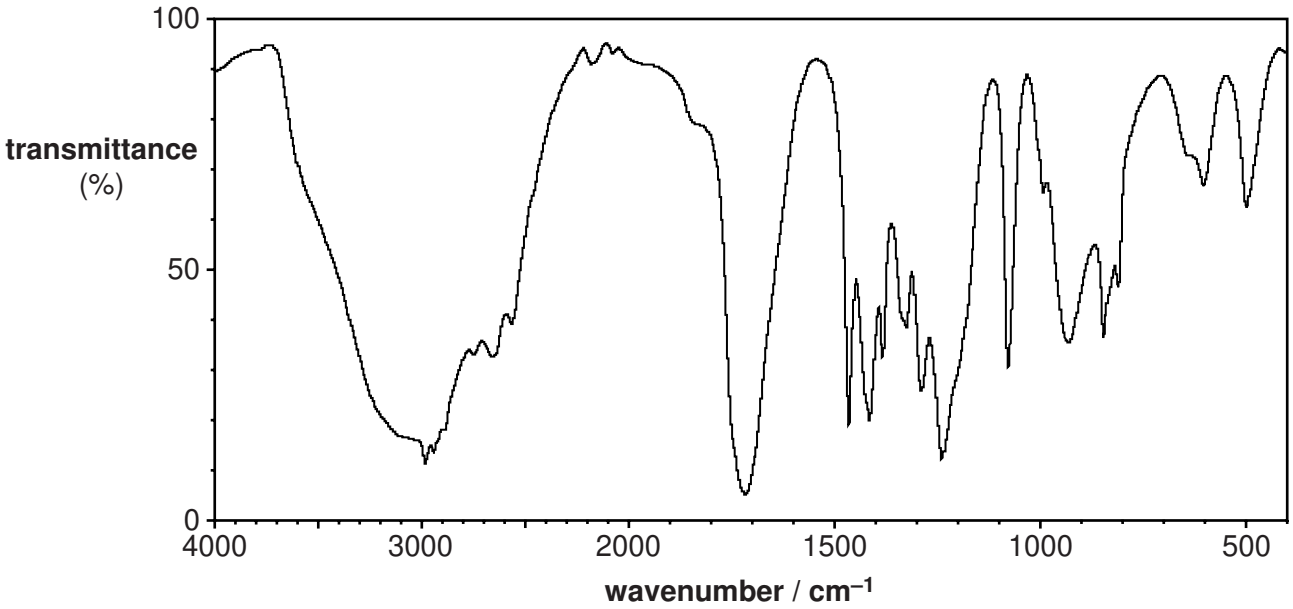
[5]

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(b) The student heats the mixture of the two structural isomers from **(a)** under reflux with aqueous sodium hydroxide to form two compounds, **E** and **F**. The student separates the two compounds.

Compound **E** is heated under reflux with acidified potassium dichromate(VI) to form compound **G**, which gives the infrared spectrum below.



(i) Analyse the information and spectrum to determine the structures of **E**, **F** and **G**.

Include an equation for the formation of **G** from **E**.

In your answer you should link the evidence with your explanation.

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..... **[6]**

(ii) Compound **G** is heated with compound **F** in the presence of a small amount of concentrated sulfuric acid to form organic compound **H**.

Draw the structure of the organic compound **H**.

[2]

[Total: 13]

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margin(s).

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GCE

Chemistry A

Unit **F322:** Chains, Energy and Resources

Advanced Subsidiary GCE

Mark Scheme for June 2016

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotations

Annotation	Meaning
BP	Blank Page – this annotation must be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
I	Ignore
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct response

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Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

The following questions should be marked using **ALL** appropriate annotations to show where marks have been awarded in the body of the text:

1(b)(iii),
2(c), 2(d), 2e(ii),
3(a)(i), 3(b)(ii), 3(c)(ii),
4(b), 4(c)(i), 4(c)(ii)
5(b), 5(e)
7(a), 7b(i), 7b(ii)

All questions where an ECF has been applied.

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Checking additional pages

All the Additional Pages in the examination script must be checked to see if any candidates include any answers.

When you open question **1(a)** you will see a view of page 24 one of the Additional Pages.
If the page is blank then, using the marking mode, annotate the page with the BP annotation
You may need to contact your Team Leader if you do not know how to do this.

Generic comments

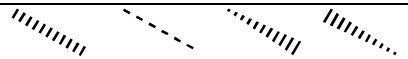
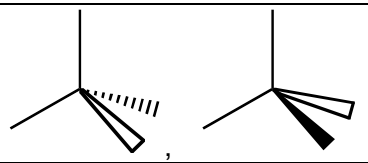
ORGANIC STRUCTURES
For a 'structure' or 'structural formula',
ALLOW correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)

For an alkyl group shown within a structure,
ALLOW bond drawn to C or H,
e.g. **ALLOW** CH_3–,CH_2–, C_3H_7–, etc
ALLOW vertical 'bond' to any part of an alkyl group

For an OH group shown within a structure,
DO NOT ALLOW formula with horizontal —HO **OR** OH –
ALLOW vertical 'bond' to any part of the OH group

For a CHO group shown within a structure,
DO NOT ALLOW COH

For a 3D structure,

• For bond in the plane of paper, a solid line is expected:	
• For bond out of plane of paper, a solid wedge is expected:	
• For bond into plane of paper, **ALLOW**:	
• **ALLOW** a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge e.g.:	 ,

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NAMES

Names including alkyl groups:
ALLOW alkanyl, e.g. ethanyl (i.e. **IGNORE** 'an')
DO NOT ALLOW alkol, e.g. ethol (ie 'an' is essential)

Names of esters:
Two words are expected, e.g. ethyl ethanoate
ALLOW one word, e.g. ethylethanoate

Names with multiple numbers and hyphens:
Use of 'e'
ALLOW superfluous 'e' , e.g. propane-1-ol ('e' is kept if followed by consonant)
ALLOW absence of 'e', e.g. propan-1,2-diol ('e' is omitted if followed by vowel)

Hyphens separate name from numbers:
ALLOW absence of hyphens, e.g. propane 1,2 diol

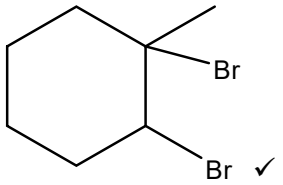
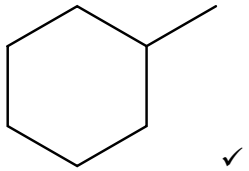
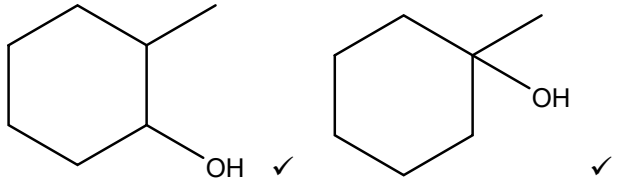
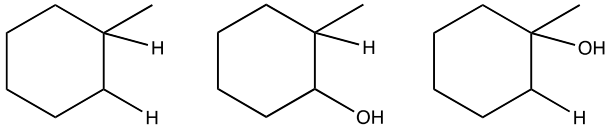
Multiple locant numbers must be clearly separated:
ALLOW full stops: e.g. 1.2 OR spaces: 1 2
DO NOT ALLOW e.g. 12

Locant numbers in formula must be correct
DO NOT ALLOW propan-3-ol

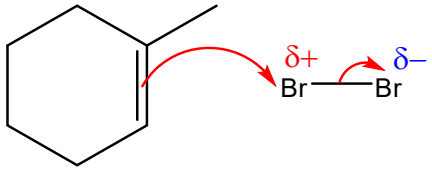
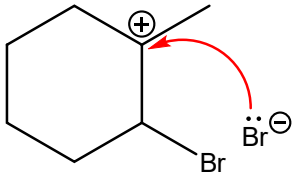
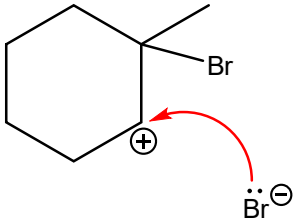
Order of substituents should be alphabetical:
ALLOW any order (as long as unambiguous), e.g. 2-chloro-3-bromobutane

ABBREVIATIONS
van der Waal's forces
ALLOW vdw forces **OR** VDW forces (and any combination of upper and lower cases)

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Question			Answer	Marks	Guidance
1	(a)		C_7H_{12} ✓	1	
1	(b)	(i)	**Product from Br_2**  ✓ **Product from H_2/Ni**  ✓ **Mixture of isomers from H_2O**  ✓ ✓	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **IGNORE** names **WATCH** for missed methyl stick **ALLOW** added H shown, i.e.  **ALLOW** in either order
1	(b)	(ii)	Steam **OR** temperature ≥ 100 ºC ✓ acid (catalyst) ✓	2	**ALLOW** $H_2O(g)$ **IGNORE** pressure **IGNORE** High temperature / reflux **ALLOW** H^+ / named mineral acid / H_2SO_4 / H_3PO_4 **DO NOT ALLOW** 'weak acid' e.g. ethanoic acid

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Question			Answer	Marks	Guidance
1	(b)	(iii)	Curly arrow from double bond to Br of Br–Br ✓ Correct dipole shown on Br–Br **AND** curly arrow showing breaking of Br–Br bond ✓  --- Correct carbocation with + charge on C **AND** curly arrow from Br^- to C^+ of carbocation ✓  **OR**  **Note:** '+' and '–' are fine for charge (circles used for clarity)	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** Curly arrow **must** start from bond and go to correct atom **DO NOT ALLOW** any other partial charges e.g. shown on C=C bond **DO NOT ALLOW** δ+ on C of carbocation. **IF** C atoms are displayed **IGNORE** missing bonds to H atoms Curly arrow must come from a lone pair on Br^- **OR** from the negative sign of Br^- ion (then lone pair on Br^- ion does not need to be shown)
1	(b)	(iv)	electrophilic addition ✓	1	
			Total	11	

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Question			Answer	Marks	Guidance
2	(a)		(series of compounds with the) same functional group **OR** same/similar chemical properties/reactions ✓ each **successive/subsequent** member differs by CH_2 ✓	2	**IGNORE** reference to physical properties **IGNORE** same general formula Differs by CH_2 is **not** sufficient (*no successive*) **DO NOT ALLOW** same empirical **OR** molecular formula
2	(b)		$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓ warm **OR** stated temperature between 20 ºC and 45 ºC **AND** anaerobic **OR** absence of air/oxygen ✓	2	**ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **IGNORE** state symbols **DO NOT ALLOW** acidic or alkaline conditions **ALLOW** conditions shown in the equation A limited supply of oxygen is **NOT** sufficient **IGNORE** pressure **IGNORE** yeast *(in question)*

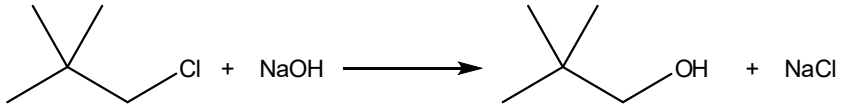
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Question			Answer	Marks	Guidance
2	(c)		Alcohols have hydrogen bonds (and van der Waals' forces) ✓ Hydrogen bonds are stronger than van der Waals' forces (in alkanes) ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** reference to specific compounds e.g. comparing methane and methanol Second marking point requires **BOTH** types of intermolecular forces in response i.e comparison of hydrogen bonds **AND** van der Waals is **essential** **DO NOT ALLOW** the second mark for a comparison of van der Waals' and hydrogen bonds between alcohols and water **ALLOW** more energy required to break hydrogen bonds than van der Waals' forces **ALLOW** it is harder to overcome the hydrogen bonds than van der Waals' forces **IGNORE** more energy is needed to break bonds
2	(d)		2-methylpropan-1-ol has less surface (area of) contact **OR** fewer points of contact ✓ 2-methylpropan-1-ol has fewer/weaker van der Waals' forces **OR** less energy required to break van der Waals' forces in 2-methylpropan-1-ol ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **Both answers need to be comparisons** **ALLOW ORA** throughout Reference to just surface area / closeness of molecules is **not** sufficient **IGNORE** reference to H bonds **IGNORE** less energy is needed to break bonds
2	(e)	(i)	Elimination **OR** dehydration ✓	1	

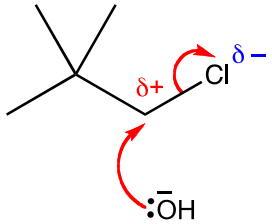
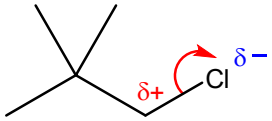
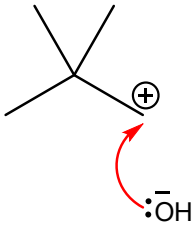
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Question			Answer	Marks	Guidance
2	(e)	(ii)	**IF answer = 14.0 OR 14.1 g award 3 marks** --- **actual** $n(C_5H_8)$ produced = $\frac{5.00}{68.0}$ = 0.0735 (mol) ✓ **theoretical** $n(C_5H_9OH) = n(C_5H_8) = 0.0735 \times \frac{100}{45.0}$ = 0.163 (mol) ✓ Mass of C_5H_9OH = 0.163 × 86.0 = 14.0 (g) **OR** 14 g **OR** 14.1 g ✓ (*use of unrounded values in calculator throughout)*	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW ECF** at each stage **ALLOW 3 SF** up to calculator value correctly rounded for intermediate values **ALLOW** expected mass C_5H_8 = 5.00 × $\frac{100}{45.0}$ = 11.111 (g) **ALLOW** Mass C_5H_9OH reacted = 0.0735 × 86.0 = 6.321 (g) **ALLOW** Mass of C_5H_9OH used = 6.321 × $\frac{100}{45.0}$ = 14.0 **OR** 14 (g) **ALLOW 2 SF** up to calculator value correctly rounded for mass of C_5H_9OH **Note:** 2.84 **OR** 2.85 g would get 2 marks *(use of 45.0/100 instead of 100/45.0)* 13.76 **OR** 13.8 would get 2 marks *(use of 0.16 for moles C_5H_9OH)*

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Question			Answer	Marks	Guidance
2	(f)	(i)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **ALLOW** equation with OH^- as reactant and Cl^- product e.g $(CH_3)_3CCH_2Cl + OH^- \rightarrow (CH_3)_3CCH_2OH + Cl^-$ **IGNORE** equations with KOH/H_2O as reactant *(question states sodium hydroxide)* **IGNORE** molecular formulae *(question requires structures)*

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Question			Answer	Marks	Guidance
2	(f)	(ii)	 curly arrow from HO^- to carbon atom of C−Cl bond ✓ Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$ **AND** curly arrow from C−Cl bond to Cl atom ✓	**2**	Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus sign on O of HO^- ion (No need to show lone pair if curly arrow came from negative charge) **NOTE:** **ALLOW** mechanism involving **ANY** halogenoalkane as structures have been assessed in **2(f)(i)** --- **ALLOW** S_N1 mechanism: **First mark** Dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$ **AND** curly arrow from C−Cl bond to Cl atom ✓  **Second mark** Correct carbocation **AND** curly arrow from HO^- to carbocation  **Note:** '+' is fine for charge (circle used for clarity) Curly arrow must come from lone pair on O of HO^- **OR** OH^- **OR** from minus sign on O of HO^- ion (No need to show lone pair if curly arrow came from negative charge) ✓ ---
			Total	**15**	

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Question			Answer	Marks	Guidance
3	(a)	(i)	**IF ΔH_r = –347 (kJ mol^{-1}) award 4 marks** **IF ΔH_r = (+)347 (kJ mol^{-1}) award 3 marks (incorrect sign)** --- **Moles** Amount, $n(CuSO_4)$, calculated correctly = 0.0125 (mol) ✓ **Energy** q calculated correctly = 4336.75 (J) **OR** 4.33675 (kJ) ✓ **Calculating ΔH** correctly calculates ΔH in kJ mol^{-1} to 3 or more sig figs ✓ **Rounding and Sign** calculated value of ΔH rounded to 3 sig. fig. with minus sign ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **Note:** q = 25.0 × 4.18 × 41.5 **ALLOW** 3 SF up to calculator value of 4336.75 J **IGNORE** sign **IGNORE** working **Note:** from 4336.75 J and 0.0125 mol ΔH = (-)346.940 kJ mol^{-1} **IGNORE** sign at this intermediate stage **ALLOW ECF** from $n(CuSO_4)$ and/or energy released Final answer must have **correct sign** and **three sig figs** Answer is still –347 from rounding of q to 4340 J
3	(a)	(ii)	Minimum mass = 0.0125 × 24.3 × 1.25 = 0.38(0) g ✓	1	**ALLOW ECF** for mass correctly rounded to 2 dp from incorrect moles of $CuSO_4$ in **3(a)(i)**

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Question			Answer	Marks	Guidance
3	(b)	(i)	(enthalpy change that occurs) when one mole of a substance ✓ completely combusts **OR** reacts fully with oxygen ✓ 298 K / 25 °C **AND** 1 atm / 100 kPa / 101 kPa / 10^5 Pa / 1 bar ✓	3	**ALLOW** energy required **OR** energy released **ALLOW** one mole of a compound **OR** one mole of an element **ALLOW** combusts in excess oxygen **ALLOW** burns in excess oxygen Combusts in excess air is **not** sufficient **IGNORE** reference to concentration
3	(b)	(ii)	**IF answer = –281 (kJ mol^{-1}), award 2 marks** **IF answer = (+)281 (kJ mol^{-1}), award 1 mark** --- Working for C **AND** H_2 seen anywhere 9 × (–)394 **AND** 10 × (–)286 **OR** (–)3546 **AND** (–)2860 **OR** (–)6406 ✓ Calculates ΔH_c correctly –6406 – –6125 = –281 kJ mol^{-1} ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IF there is an alternative answer, check to see if there is any ECF credit possible** **Common incorrect answers are shown below** **Award 1 mark for** 5445 (not used × 9 and × 10) 2871 (not used × 9**)** 2293 (not used × 10)
3	(c)	(i)	(Average enthalpy change) when one mole of bonds ✓ of (gaseous covalent) bonds is broken ✓	2	**IGNORE** energy required **OR** energy released **DO NOT ALLOW** bonds formed **IGNORE** heterolytic/homolytic

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Question			Answer	Marks	Guidance
3	(c)	(ii)	**IF answer = (+)1062 (kJ mol^{-1}), award 3 marks** **IF answer = –1062 (kJ mol^{-1}), award 2 marks** --- (ΔH for bonds broken =) 2580 (kJ mol^{-1}) **OR** 1652 **AND** 928 (kJ mol^{-1}) ✓ (ΔH for bonds formed =) 1308 (kJ mol^{-1}) ✓ (bond enthalpy CO = 2580 – 1308 – 210) = (+)1062 (kJ mol^{-1}) ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** sign **IGNORE** sign **ALLOW ECF** **IGNORE** rounding of 1062 to 1060 and credit 1062 from working **Award 2 marks for** ±1272 (from ±(2580 – 1308)) ±1482 (from ±(2580 – 1308 + 210))
			Total	**15**	

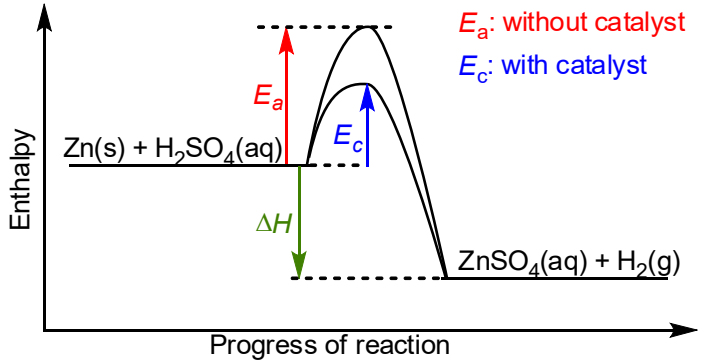
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Question			Answer	Marks	Guidance
4	(a)	(i)	Equilibrium (position) shifts to right **AND** turns paler (brown) ✓ Right-hand side has fewer (gaseous) moles/molecules **OR** left-hand side has more (gaseous) moles/molecules ✓	2	**ALLOW** turns colourless **IGNORE** initially goes darker (brown) **Note: ALLOW** suitable alternatives for 'to right', e.g.: towards products **OR** towards N_2O_4 **OR** in forward direction **OR** favours the right **IGNORE** responses in terms of rate
4	(a)	(ii)	Equilibrium (position) shifts to left **AND** turns darker/deeper (brown) ✓ (Forward) reaction is exothermic **OR** (forward) reaction gives out heat **OR** reverse reaction is endothermic **OR** reverse reaction takes in heat ✓	2	**ALLOW** turns brown **Note: ALLOW** suitable alternatives for 'to left', e.g.: towards reactants **OR** towards NO_2 **OR** in reverse direction **OR** favours the left **IGNORE** comments about the 'exothermic side' or 'endothermic side' **ALLOW** 'equilibrium (position) shifts left **AND** in the endothermic direction' for second marking point **IGNORE** responses in terms of rate

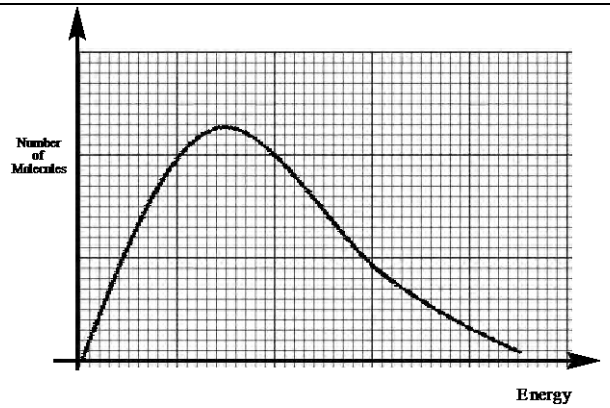
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Question			Answer	Marks	Guidance
4	(b)		**Addition of acid** $[H^+]$ **OR** H^+ increases **AND** equilibrium (position) shifts to right ✓ **Addition of alkali** Alkali reacts with H^+ **OR** alkali removes H^+ **AND** equilibrium (position) shifts to left ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** amount of acid increases *(in question)* **ALLOW** (added) acid reacts with CrO_4^{2-} **Note: ALLOW** suitable alternatives for 'to right', e.g.: towards products **OR** towards $Cr_2O_7^{2-}$ / H_2O **OR** in forward direction **OR** favours the right **ALLOW** $H^+ + OH^- \rightarrow H_2O$ **ALLOW** alkali reacts with (added) acid **Note: ALLOW** suitable alternatives for 'to left', e.g.: towards reactants **OR** towards CrO_4^{2-} / H^+ **OR** in reverse direction **OR** favours the left **IGNORE** just H^+ concentration decreases *(needs role of alkali)* **IGNORE** concentration of water increases *(needs role of alkali)*

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Question			Answer	Marks	Guidance
4	(c)	(i)	 Zn and H_2SO_4 on LHS **AND** $ZnSO_4$ + H_2 on RHS✓ ΔH labelled with product below reactant **AND** arrow downwards ✓ E_a **AND** E_c correctly labelled with E_c below E_a ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** state symbols. ΔH: **DO NOT ALLOW** $-\Delta H$ **ALLOW** this arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line E_a: **ALLOW** no arrowhead or arrowheads at both ends of activation energy line The E_a line must point to maximum (or near to the maximum) on the curve **OR** span approximately 80% of the distance between reactants and maximum regardless of position **ALLOW** AE or A_E for E_a

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Question			Answer	Marks	Guidance
4	(c)	(ii)	 Correct drawing of a Boltzmann distribution curve ✓ Axes labelled y axis: (number of) molecules **AND** x axis: (kinetic) energy ✓ Catalyst lowers the activation energy (by providing an alternative route) ✓ **QWC** – (With a catalyst a) greater proportion of molecules with energy greater than activation energy **OR** (With a catalyst a) greater proportion of molecules with energy equal to the activation energy **OR** (With a catalyst there is a) greater area under curve above the activation energy ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES** Curve must start at origin. The limit of acceptability is that the curve must start within the first small square nearest the origin. Curve must not touch the x-axis at higher energy **IGNORE** a slight inflexion on the curve **DO NOT ALLOW** two curves **DO NOT ALLOW** a curve that bends up at the end by more than one small square **ALLOW** particles instead of molecules on y axis **DO NOT ALLOW** enthalpy for x-axis label **DO NOT ALLOW** atoms instead of particles or molecules **ALLOW ECF** for the subsequent use of atoms (instead of molecules or particles) **ALLOW** annotations on Boltzmann distribution diagram **QWC** requires more molecules have/exceed activation energy/E_a. **IGNORE** more molecules have enough energy to react for the **QWC** mark (as not linked to E_a) **ORA** if states the effect with no catalyst **IGNORE** (more) successful collisions

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Question			Answer	Marks	Guidance
4	(d)	(i)	Catalyst (name or correct formula) **AND** balanced equation for the reaction catalysed ✓	1	Many possible responses but in practice it is likely that examples will be few, e.g. Fe **AND** $N_2 + 3H_2 \rightarrow 2NH_3$ V_2O_5/Pt **AND** $2SO_2 + O_2 \rightarrow 2SO_3$ H_2SO_4/H_3PO_4 **AND** $C_2H_4 + H_2O \rightarrow C_2H_5OH$ Hydrogenation of an alkene: e.g. Ni **AND** $C_2H_4 + H_2 \rightarrow C_2H_6$ Esterification: e.g. H_2SO_4 **AND** $CH_3COOH + C_2H_5OH \rightarrow CH_3COOC_2H_5 + H_2O$ **ALLOW** multiples for equation **Note:** the reaction chosen must be a feasible industrial reaction. If you see an alternative from the list above please contact your TL
4	(d)	(ii)	**Any two from:** lower temperatures/lower pressures (can be used) ✓ lower energy demand **OR** uses less fuel **OR** reduces CO_2 emissions ✓ (different reactions can be used with) greater atom economy **OR** less waste **OR** can reduce use of toxic solvents **OR** can reduce use of toxic reactants ✓ (catalysts are often enzymes) generating specific products ✓	2	**IGNORE** catalyst not used up in reaction **IGNORE** catalyst can be re-used **IGNORE** lower activation energy **IGNORE** cheaper **IGNORE** less greenhouse gases **OR** reduces global warming **ALLOW** increases atom economy **ALLOW** reduce use of hazardous/toxic/harmful/poisonous chemicals

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Question			Answer	Marks	Guidance
4	(e)	(i)	Thunderstorms/lightning **AND** aircraft ✓	1	**IGNORE** car engines
4	(e)	(ii)	$NO + O_3 \rightarrow NO_2 + O_2$ ✓ $NO_2 + O \rightarrow NO + O_2$ ✓	2	**ALLOW** $NO_2 + O_3 \rightarrow NO + 2O_2$ **IGNORE** dots **IGNORE** $O + O_3 \rightarrow 2O_2$ **IGNORE** $2O_3 \rightarrow 3O_2$
			Total	19	

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Question			Answer	Marks	Guidance
5	(a)		C_nH_{2n+2} ✓	1	
5	(b)		***Formation of NO and CO 2 marks*** $N_2 + O_2 \rightarrow 2NO$ **AND** $C_8H_{18} + 8½O_2 \rightarrow 8CO + 9H_2O$ ✓ (N_2 and O_2 react in) hot conditions (to form NO) **OR** incomplete combustion (of C_8H_{18} produces CO) ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** state symbols **ALLOW** multiples, e.g. $½N_2 + ½O_2 \rightarrow NO$ $2C_8H_{18} + 17O_2 \rightarrow 16CO + 18H_2O$ **ALLOW** equations for incomplete combustion that give CO with CO_2 and/or C e.g. $C_8H_{18} + 10½O_2 \rightarrow 4CO + 4CO_2 + 9H_2O$ **ALLOW** $C_8H_{18} + N_2 + 9½O_2 \rightarrow 8CO + 9H_2O + 2NO$ **IGNORE** NO/CO form in engine *(in question)*
			Reducing NO and CO by catalytic converter 4 marks CO and NO/reactants are adsorbed (onto surface) ✓ Bonds in reactants weaken **OR** activation energy decreases ✓ Reaction: $2CO + 2NO \longrightarrow 2CO_2 + N_2$ ✓ CO_2 and N_2 desorb (from surface) **OR** products desorb (from surface)✓		**ALLOW** CO and NO /reactants bond to surface (of catalyst) **DO NOT ALLOW** absorbed **ALLOW** bonds weaken in CO **OR** bonds weaken in NO **IGNORE** state symbols **ALLOW** multiples, e.g. $CO + NO \rightarrow CO_2 + ½N_2$ **ALLOW** products leave the surface/catalyst **OR** CO_2 and N_2 no longer bonded to surface/catalyst **ALLOW** deadsorption **ALLOW** diffuse away for desorption

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Question			Answer	Marks	Guidance
5	(c)		structure of a branched saturated hydrocarbon with **8 C** atoms ✓ structure of a cyclic saturated hydrocarbon with **8 C** atoms ✓ Correct name for **BOTH** structures given ✓	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **DO NOT ALLOW** names for hydrocarbons that do not have **8 C** atoms
5	(d)		**ANY TWO from** abundance (in atmosphere) **OR** amount (in atmosphere) **OR** (atmospheric) concentration **OR** percentage (in air) ✓ **OR** ability to absorb **infrared/IR** (radiation)✓ **OR** residence time ✓	2	 **ALLOW** absorption of infrared/IR

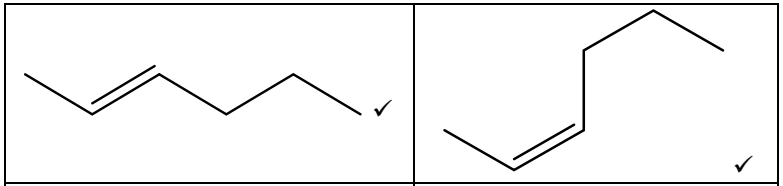
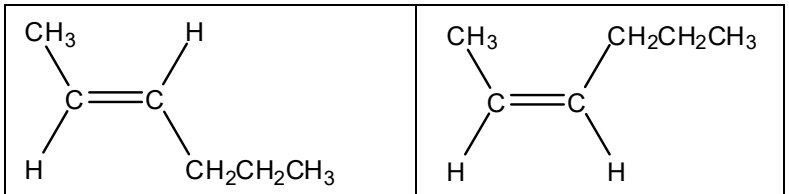
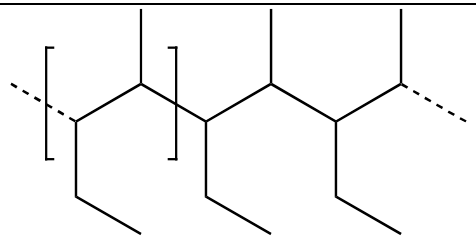
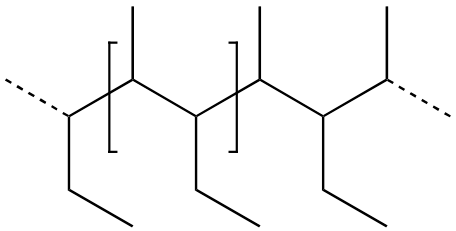
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Question			Answer	Marks	Guidance
5	(e)		**IF answer = 259 (litres), award 4 marks** --- ($n(CO_2)$ decrease = $5.6 \times 10^5/44.0$) = 12727.27273 (mol) ✓ ($n(C_8H_{16})$ decrease = 12727 ÷ 8) = 1590.909091 (mol) ✓ (mass of C_8H_{18} decrease) = 1591 × 114 = 181363.6364 (g) ✓ (C_8H_{18} decrease) = 181363.6364 ÷ 700 g = 259 (litres) ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW 3 SF** up to calculator value correctly rounded throughout. **NOTE:** Be generous for values. Depending on any intermediate rounding, you may see a range of values for each stage. For guidance, the expected answers give unrounded values throughout. **ALLOW ECF** throughout for approaches that use moles CO_2/C_8H_{18} **IGNORE** rounding of 259 to 260 and credit 259 from working **ALLOW** the following alternate method --- (n C_8H_{18} in a litre = 700 ÷ 114) = 6.140350877 (mol) ✓ ($n(CO_2)$ produced per litre = 6.14 × 8) = 49.12280702 (mol) ✓ (mass CO_2 produced per litre = 49.12 × 44) = 2161.403509 (g) ✓ (annual reduction = $5.6 \times 10^5/2161$) = 259.0909091 (litres) ✓ ---
			Total	**16**	

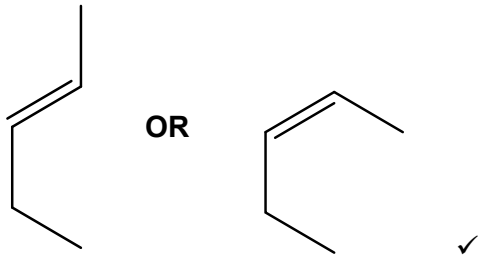
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Question			Answer	Marks	Guidance
6	(a)	(i)	Evidence that 84 (M^+ peak) = 6 × 14 (mass of CH_2) ✓ e.g. $\frac{84}{14} = 6$	1	**IGNORE** use of molecular formula e.g (6 × 12) + (12 × 1) = 84 *(use of empirical formula required)*
6	(a)	(ii)	***Structures of species 2 marks*** **peak I** $CH_3CH{=}CH$ ✓ **peak II** $CH_3CH{=}CHCH_2CH_2$ **OR** $CH{=}CHCH_2CH_2CH_3$ ✓ ***+ charge on BOTH CORRECT species 1 mark*** $CH_3CH{=}CH^+$ **AND** $CH_3CH{=}CHCH_2CH_2^+$ ✓ **peak I** **peak II**	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **ALLOW** 1 mark if both correct structures are shown but in the incorrect columns **ALLOW** 1 mark for both correct structures if one or both have an 'end bond' **ALLOW** 1 mark for **BOTH** molecular formulae correct C_3H_5 **AND** C_5H_9 **peak I** **peak II** **ALLOW** 'charge mark' for + charge on **BOTH** fragments with **correct** molecular formulae **ALLOW** 'charge mark' for + charge on **BOTH CORRECT** molecular formulae **ALLOW** + change anywhere in structures **OR** outside brackets

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Question			Answer	Marks	Guidance
6	(b)	(i)	 *E*-hex-2-ene | *Z*-hex-2-ene	2	**ALLOW** 1 mark if skeletal formulae of both *E* and *Z* hex-2-ene are shown but in the incorrect columns **IF** correct unambiguous structural **OR** displayed **OR** mixture of formulae are shown **ALLOW** 1 mark if both stereoisomers are in the correct columns e.g the following scores 1 mark  *E*-hex-2-ene | *Z*-hex-2-ene **IF** the skeletal formula of *E* hex-3-ene is shown in the first box **ALLOW** 1 mark for the skeletal formula of *Z* hex-3-ene as **ECF**
6	(b)	(ii)	(carbon-carbon) double bond does not rotate **OR** has restricted rotation ✓ Each carbon atom of the double bond attached to (two) different groups/atoms ✓	2	
6	(c)	(i)	 One repeat unit shown ✓ *(could be any of the three repeat units shown)*	1	**ALLOW** repeat unit at any point along the section provided that it works, e.g. 

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Question			Answer	Marks	Guidance
6	(c)	(ii)	Structure of pent-2-ene:  **OR** ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)
6	(c)	(iii)	(50,000/70 =) 714 **OR** 715 ✓	1	**MUST** be a whole number
			Total	11	

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Question			Answer	Marks	Guidance
7	(a)		***Empirical/molecular formula*** ***3 marks*** Mole ratio C : H : Br is 2.44 : 5.70 : 0.814 ✓ (Empirical formula) = C_3H_7Br ✓ **QWC** (Molecular formula) = C_3H_7Br **AND** relative mass linked to 150 evidence ✓ ***Structural isomers*** ***2 marks*** $CH_3CH_2CH_2Br$ ✓ $CH_3CHBrCH_3$ ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** $\frac{29.29}{12.0} : \frac{5.70}{1.0} : \frac{65.01}{79.9}$ Evidence could include a calculation of the relative mass of C_3H_7Br as 122.9 linking to M_r being less than 150 **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **DO NOT ALLOW** missing H atom(s) in a displayed formula for one structure but **ALLOW** missing H atoms in subsequent structure **Note:** structures from an incorrect molecular formula will be credited on their merits. Please consult TL for advice on how to mark the subsequent parts of this question

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Question			Answer	Marks	Guidance
7	(b)	(i)	***Infrared for G*** ***2 marks*** 1700 cm^{-1} **AND** C=O/carbonyl group ✓ (broad) 2300–3600 cm^{-1} **AND** O–H in carboxylic acid ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **LOOK ON THE SPECTRUM** for labelled peaks which can be given credit **ALLOW** ranges from *Data Sheet*: C=O within range 1640–1750 cm^{-1}; (broad) O–H within range 2500–3300 cm^{-1}
			Structures ***3 marks*** $CH_3CH_2CH_2OH$ ✓ $CH_3CHOHCH_3$ ✓ CH_3CH_2COOH ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** $CH_3CH_2CO_2H$ for carboxylic acid **IGNORE** names **IGNORE** labels **DO NOT ALLOW** missing H atom(s) in a displayed formula for one structure but **ALLOW** missing H atoms in subsequent structures
			Equation for formation of G ***1 mark*** $C_3H_8O + 2[O] \rightarrow C_3H_6O_2 + H_2O$ ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above in equation

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Question			Answer	Marks	Guidance
7	(b)	(ii)	2 marks for correct ester. $CH_3CH_2COOCH(CH_3)_2$ ✓✓ Award 1 mark for: $CH_3CH_2COOCH_2CH_2CH_3$ **OR** Ambiguous ester: $CH_3CH_2COOC_3H_7$ ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** $C_2H_5CO_2CH(CH_3)_2$ **IF** there is one bond and its H missing from the correct ester award 1 mark
			Total	13	

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Tuesday 2 June 2015 – Afternoon

AS GCE CHEMISTRY A

F322/01 Chains, Energy and Resources

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry A* (inserted)

Other materials required:
- Scientific calculator

Duration: 1 hour 45 minutes

* F 3 2 2 0 1 *

* 4 9 8 9 2 7 8 2 3 3 *

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found inside this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

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



Where you see this icon you will be awarded marks for the quality of written communication in your answer.

This means for example you should:
- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- organise information clearly and coherently, using specialist vocabulary when appropriate.

- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **24** pages. Any blank pages are indicated.

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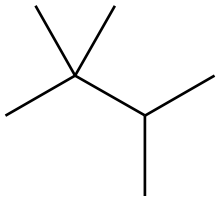
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Answer **all** the questions.

1 This question is about different alkanes present in crude oil.

(a) Compound **A**, shown below, is one of the structural isomers of C_7H_{16}.



Compound A

(i) What is meant by the term *structural isomers*?

.....

.....

..... **[1]**

(ii) Name compound **A**.

..... **[1]**

(b) The structural isomers of C_5H_{12} have different boiling points.

Draw the **skeletal formula** of the structural isomer of C_5H_{12} with the highest boiling point.

[1]

(c) A molecule of an alkane has 24 carbon atoms.

State the empirical formulae of this alkane.

.....

[1]

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(d) Alkanes are used as fuels.

(i) Construct an equation for the complete combustion of octane C_8H_{18}.

..... **[1]**

(ii) Combustion of 36.48 g of octane produced 2.50 mol of carbon dioxide.

Show that this combustion was incomplete.

[2]

(e) Alkanes in crude oil can be used to manufacture ethene. Two stages are required.

(i) Name the **two** stages.

.....

..... **[1]**

(ii) Write an equation for the preparation of ethene from an alkane.

..... **[1]**

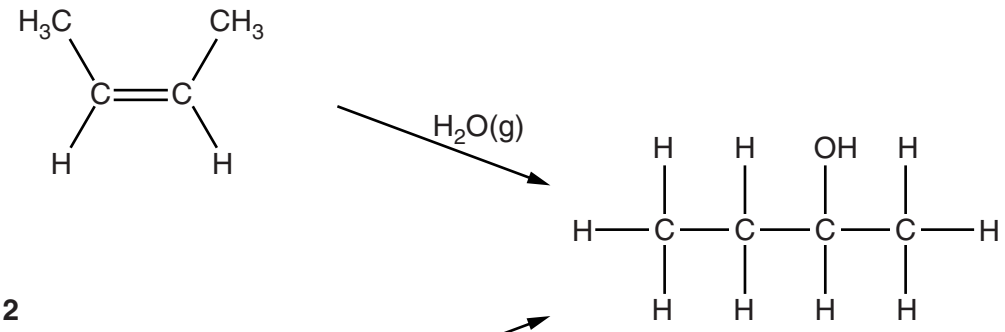
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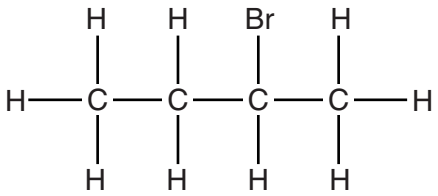
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2 Butan-2-ol can be prepared using two different methods.

Method 1



Method 2



butan-2-ol

(a) Comment on the atom economy of each method, giving your reasons.

.....

.....

.....

.....

..... **[2]**

(b) State the catalyst required for **Method 1**.

..... **[1]**

(c) Average bond enthalpies can be used to calculate enthalpy changes.

(i) What is meant by the term *average bond enthalpy*?

.....

.....

.....

..... **[2]**

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(ii) Calculate the enthalpy change of reaction, ΔH_r, for preparing 1 mol of butan-2-ol by **Method 1**.

Average bond enthalpies are given below.

Bond	Average bond enthalpy / kJ mol^{-1}
O–H	464
C–H	413
C–C	347
C–O	358
C=C	612

ΔH_r = ... kJ mol^{-1} **[3]**

(d) A student uses **Method 2** to prepare 3.552 g of butan-2-ol from 2-bromobutane.
The percentage yield of butan-2-ol is 80.0%.

Calculate the mass of 2-bromobutane that the student uses.
Give your answer to **three** significant figures.

mass of 2-bromobutane = ... g **[3]**

[Total: 11]

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3 Methanol, CH_3OH, is an important feedstock for the chemical industry.

In the manufacture of methanol, carbon dioxide and hydrogen are reacted together in the reversible reaction shown below.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \qquad \Delta H = -49\,kJ\,mol^{-1}$$

(a) Describe and explain the effect of increasing the pressure on the reaction **rate**.

.....

.....

..... **[2]**

(b) State le Chatelier's principle.

.....

.....

..... **[1]**

(c) High pressures and low temperatures would give a maximum equilibrium yield of methanol.

(i) Explain this statement in terms of le Chatelier's principle.

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..... **[3]**

(ii) Explain why the actual conditions used by the chemical industry might be different.

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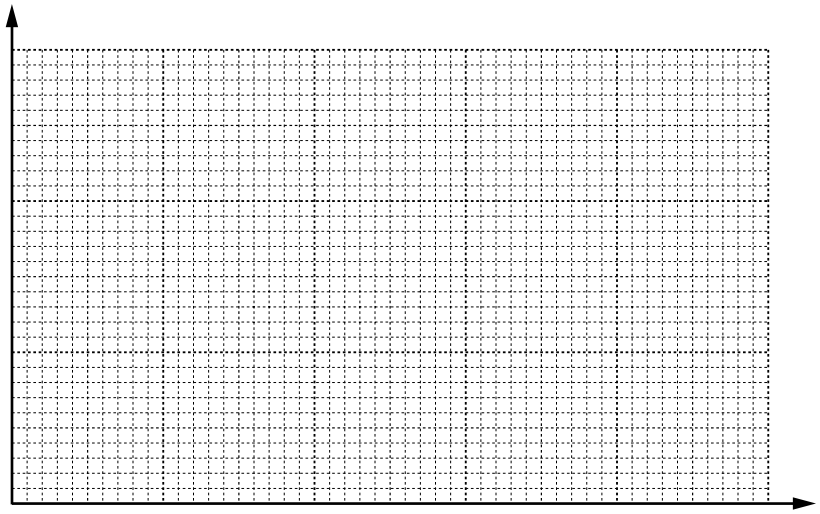
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(d) The manufacture of methanol uses a catalyst.

- Sketch a labelled diagram of the Boltzmann distribution on the grid provided.
- Label your axes.
- Using your Boltzmann distribution, explain how the catalyst increases the rate of reaction.



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..... **[4]**

(e) Explain why the use of a catalyst can reduce the demand for energy.

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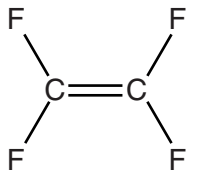
..... **[1]**

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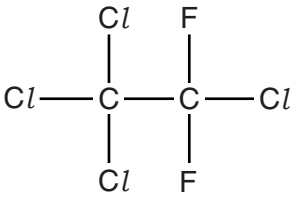
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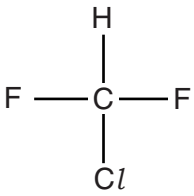
4 This question is about the compounds shown below.



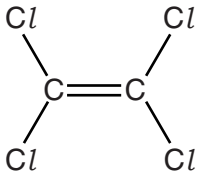
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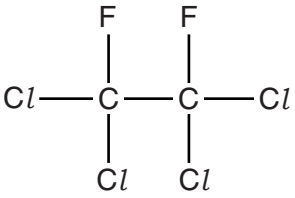
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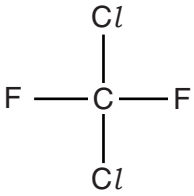
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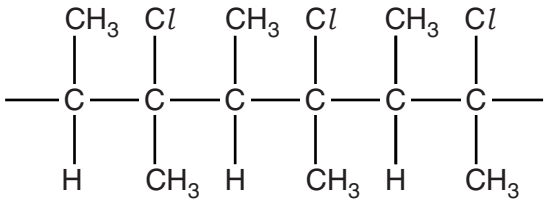
E



F



G



H

(a) Which compound, **B** to **H**, could be used to make the polymer PTFE?

..... **[1]**

(b) Polymer **H** can be disposed of by combustion. One environmental problem is the production of toxic gases, such as CO.

(i) Draw the structure of the monomer needed to produce polymer **H**.

[1]

(ii) Give the formula of an acidic toxic gas that could form during combustion of polymer **H**.

..... **[1]**

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(c) Compound **G** was once used as a propellant in aerosols. Compound **G** has been linked with depletion of the ozone layer in the stratosphere.

(i) State **two** properties that made compound **G** suitable for use as an aerosol.

1 .....

2 .....

[1]

(ii) Explain the following statements, using equations where appropriate.

- Life on Earth benefits from the presence of an ozone layer.
- The concentration of ozone is maintained in the ozone layer.
- Compound **G** produces radicals which catalyse the breakdown of ozone.

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..... **[5]**

(iii) Alternative 'ozone-friendly' compounds are now used as propellants instead of compound **G**.

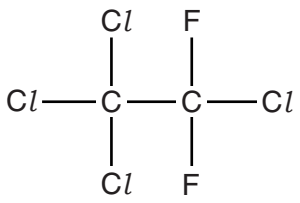
Which compound, **B** to **H**, might be suitable as an 'ozone-friendly' propellant?

..... **[1]**

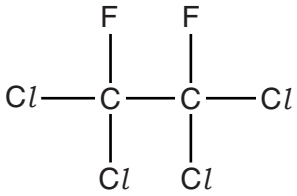
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(d) Compounds **C** and **F** can be analysed to obtain infrared and mass spectra.



C



F

(i) What happens to molecules when infrared radiation is absorbed?

..... **[1]**

(ii) Suggest the molecular formulae of **two** ions responsible for peaks in the mass spectrum of **C** that are **not** in the mass spectrum of **F**.

.....

..... **[2]**

[Total: 13]

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Question 5 starts on page 12

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5 Allyl bromide, $CH_2=CHCH_2Br$, is used in the production of polymers.

(a) Part of the C=C double bond in allyl bromide is called a π-bond.

Draw a labelled diagram to show the formation of the π-bond.

[2]

(b) Allyl bromide is a member of a homologous series. Compounds in this series have the same general formula.

(i) What is meant by the term *homologous series*?

.....

.....

.....

..... **[2]**

(ii) What is the general formula of the homologous series that has allyl bromide as a member?

..... **[1]**

(iii) Give the systematic name for allyl bromide.

..... **[1]**

(c) Reaction mechanisms use curly arrows and can involve electrophiles and nucleophiles.

(i) What does a *curly arrow* represent in mechanisms?

.....

..... **[1]**

(ii) What is meant by the term *nucleophile*?

.....

..... **[1]**

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(d) Allyl bromide, $CH_2=CHCH_2Br$, reacts with aqueous sodium hydroxide.

(i) Outline the mechanism of this reaction.

Include curly arrows, relevant dipoles and final product(s).

[3]

(ii) Name the type of mechanism.

..... **[1]**

(e) Allyl bromide, $CH_2=CHCH_2Br$, reacts with bromine, Br_2.

(i) Outline the mechanism of this reaction.

Include curly arrows, relevant dipoles and the structures of the intermediate and final product(s).

[4]

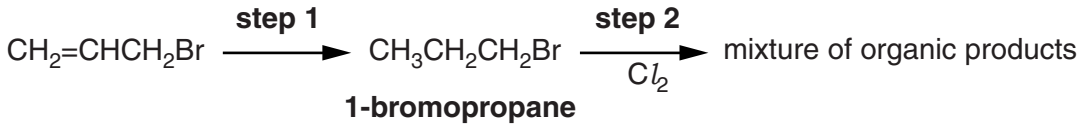
(ii) Name the type of mechanism.

..... **[1]**

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(f) Allyl bromide is reacted as shown below.



(i) State the reagents and conditions for **step 1**.

..... **[1]**

(ii) In **step 2**, 1-bromopropane reacts with chlorine by radical substitution.

Outline the mechanism for the monochlorination of 1-bromopropane.
In your mechanism, you can show the formula of 1-bromopropane as C_3H_7Br.

Include the names of the three stages in this mechanism, state the essential conditions and all termination steps.

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..... **[5]**

(iii) Radical substitution produces a mixture of organic products.

Suggest **two** reasons why.

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..... **[2]**

[Total: 25]

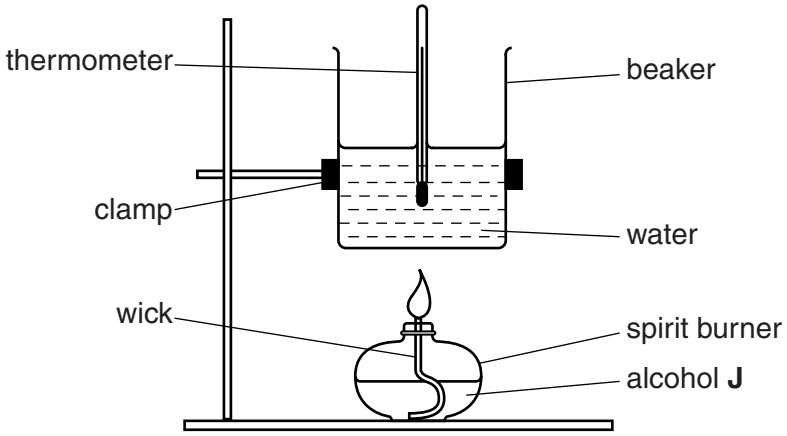
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6 A branched-chain alcohol **J** is a liquid and has the molecular formula $C_5H_{12}O$.

(a) A student does an experiment to measure the enthalpy change of combustion, ΔH_c, of alcohol **J**.

(i) The student burns alcohol **J** using the apparatus below.



The student found that combustion of 1.54 g of alcohol **J** changes the temperature of 180 g of water from 22.8 °C to 75.3 °C.

The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

- Calculate the amount, in mol, of alcohol **J** that burns.
- Calculate the enthalpy change of combustion, ΔH_c, of alcohol **J**, in kJ mol^{-1}.

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

ΔH_c = ... kJ mol^{-1} **[4]**

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(ii) The calculated value of ΔH_c from this experiment is different from the value obtained from data books.

Apart from heat loss, suggest **two** reasons for the difference.

Assume that the calculation has been carried out correctly.

.....

.....

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..... **[2]**

(b) The enthalpy change of combustion for alcohol **J** can also be determined indirectly from standard enthalpy changes of formation.

(i) Write an equation, including state symbols, for the chemical change that represents the standard enthalpy change of formation of the liquid alcohol **J**, $C_5H_{12}O$.

..... **[1]**

(ii) The equation for the complete combustion of alcohol **J** is shown below.

$$C_5H_{12}O(l) + 7½O_2(g) \longrightarrow 5CO_2(g) + 6H_2O(l)$$

Enthalpy changes of formation, ΔH_f, are shown in the table.

Substance	**$C_5H_{12}O(l)$**	**$CO_2(g)$**	**$H_2O(l)$**
ΔH_f / kJ mol^{-1}	–366	–394	–286

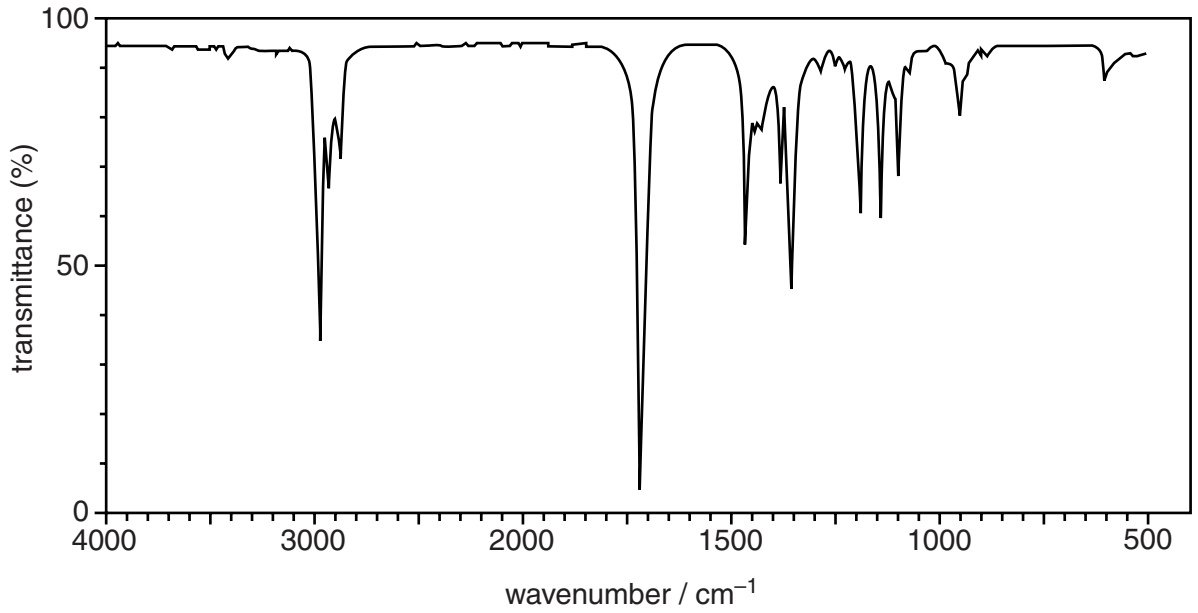
Calculate the enthalpy change of combustion, ΔH_c, of alcohol **J** from the information given above.

ΔH_c = ... kJ mol^{-1} **[3]**

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(c) The branched-chain alcohol **J**, $C_5H_{12}O$, was heated under reflux with excess $H_2SO_4/K_2Cr_2O_7$ to form an organic compound **K** with the infrared spectrum below.



- Determine the structures for the branched-chain alcohol **J** and compound **K**.
  Your answer should explain all your reasoning using the evidence given.

- Write an equation for the reaction of **J** when heated under reflux with excess $H_2SO_4/K_2Cr_2O_7$ to form **K**.
  Use [O] to represent the oxidising agent.

Your answer needs to be clear and well organised using the correct terminology.

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..... **[6]**

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(d) The alcohol **J** is soluble in water.

Explain why alcohol **J** is soluble in water.

Use a labelled diagram to support your answer.

Include relevant dipoles and lone pairs.

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..... **[1]**

[Total: 17]

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Question 7 starts on page 20

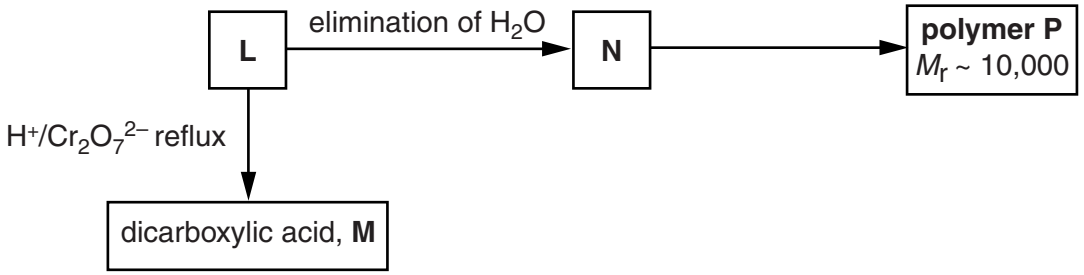
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7 **L**, **M**, **N** and **P** are straight-chain organic compounds containing C, H and O only.

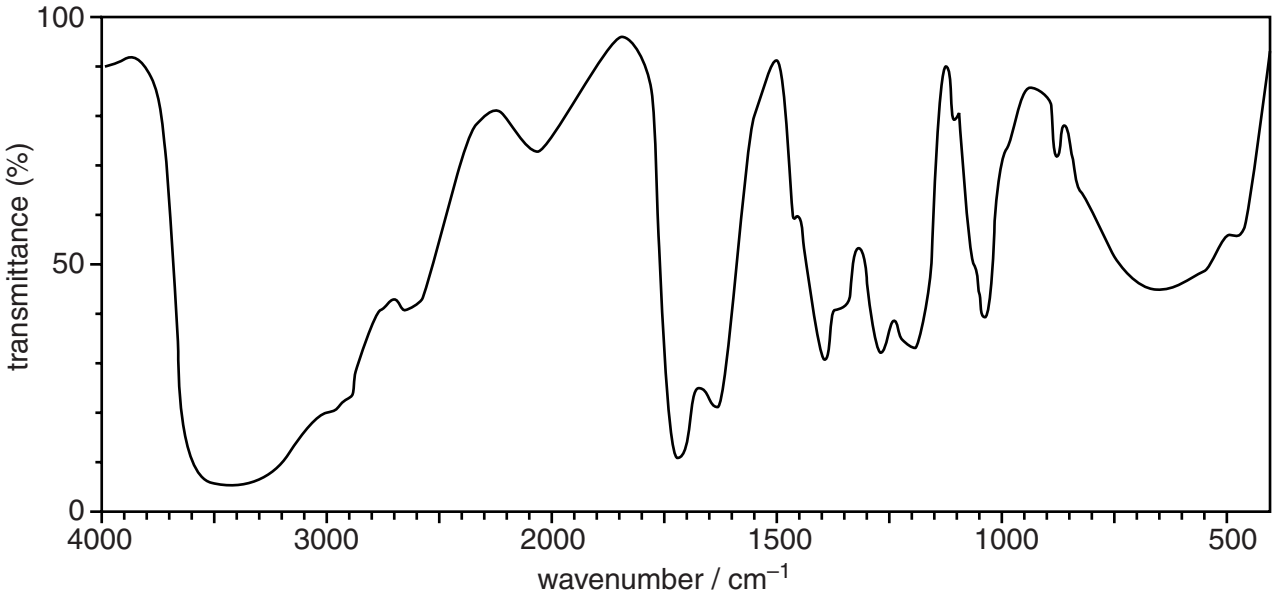
The flowchart shows reactions involving these compounds.



Analysis of compound **L** shows the following.

- Percentage composition by mass: C, 40.00%; H, 6.67%; O, 53.33%.
- Relative molecular mass of 90.0.
- The infrared spectrum below.

IR spectrum of **L**



(a) Calculate the empirical and molecular formulae of compound **L**.

Show your working.

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..... **[3]**

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(b) Analyse the information and spectrum to determine the structures of **L** and **M**.

Include an equation for the reaction of **L** to form **M**.

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..... **[5]**

(c) Determine the structures of compounds **N** and **P**.

Estimate the number of repeat units in polymer **P** and write the equation for the formation of **P** from **N**.

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..... **[4]**

[Total: 12]

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following line page(s). The question number(s) must be clearly shown in the margins.

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GCE

Chemistry A

Unit **F322:** Chains, Energy and Resources

Advanced Subsidiary GCE

Mark Scheme for June 2015

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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1. **Annotations**

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
I	Ignore
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct response

Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

12 **Subject-specific Marking Instructions**

The following questions should be annotated with ticks and crosses to show how marks have been awarded in the body of the text:

3(c)(i), 3(d), 4(c)(ii) 5(d)(i), 5(e)(i), 5(f)(ii), 6(a)(i), 6(b)(ii), 6(c) and 7(b)

All questions where an ECF has been applied.

Checking additional pages

All the Additional Pages in the examination script must be checked to see if any candidates include any answers.

- When you open question **1(a)** you will see a view of page 22 one of the Additional Pages.
- If the page is blank then, using the marking mode, annotate the page with an omission mark, ^, or the BP annotation
- Scroll down to page 24 and annotate with a ^ if the page is blank.
- If pages 22, 23 or 24 are not blank then use the paper clip icon to link the pages to the correct questions.
- You may need to contact your Team Leader if you do not know how to do this.

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Generic comments

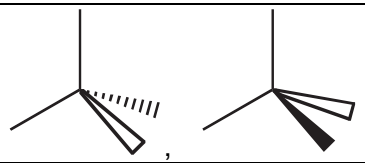
ORGANIC STRUCTURES
For a 'structure' or 'structural formula',
- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)

For an alkyl group shown within a structure,
- **ALLOW** bond drawn to C or H,
  e.g. **ALLOW** CH_3–,CH_2–, C_3H_7–, etc
- **ALLOW** vertical 'bond' to any part of an alkyl group

For an OH group shown within a structure,
- **DO NOT ALLOW** formula with horizontal —HO **OR** OH –
- **ALLOW** vertical 'bond' to any part of the OH group

For a CHO group shown within a structure,
- **DO NOT ALLOW** COH

For a 3D structure,

• For bond in the plane of paper, a solid line is expected:	
• For bond out of plane of paper, a solid wedge is expected:	
• For bond into plane of paper, **ALLOW**:	
• **ALLOW** a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge e.g.:	

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NAMES

Names including alkyl groups:
- **ALLOW** alkanyl, e.g. ethanyl (i.e. **IGNORE** 'an')
- **DO NOT ALLOW** alkol, e.g. ethol (ie 'an' is essential)

Names of esters:
- Two words are expected, e.g. ethyl ethanoate
- **ALLOW** one word, e.g. ethylethanoate

Names with multiple numbers and hyphens:
Use of 'e'
- **ALLOW** superfluous 'e' , e.g. propane-1-ol ('e' is kept if followed by consonant)
- **ALLOW** absence of 'e', e.g. propan-1,2-diol ('e' is omitted if followed by vowel)

Hyphens separate name from numbers:
- **ALLOW** absence of hyphens, e.g. propane 1,2 diol

Multiple locant numbers must be clearly separated:
- **ALLOW** full stops: e.g. 1.2 OR spaces: 1 2
- **DO NOT ALLOW e.g.** 12

Locant numbers in formula must be correct
- **DO NOT ALLOW** propan-3-ol

Order of substituents should be alphabetical:
- **ALLOW** any order (as long as unambiguous), e.g. 2-chloro-3-bromobutane

ABBREVIATIONS
van der Waal's forces
ALLOW vdw forces **OR** VDW forces (and any combination of upper and lower cases)

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Question			Answer	Mark	Guidance
1	(a)	(i)	(compounds or molecules having the) same molecular formula but different structural formulae ✓	1	**ALLOW** different structure **OR** different displayed formula **OR** different skeletal formula for structure **DO NOT ALLOW** any reference to spatial/space Same formula is **not** sufficient *(no reference to molecular)* Different arrangement of atoms is **not** sufficient (*no reference to structure/structural)*
		(ii)	2,2,3-trimethylbutane ✓	1	**ALLOW** trimethylbutane as the **ONLY** alternative response
	(b)		 ✓	1	**DO NOT ALLOW** molecular formulae **OR** structural formula **OR** displayed formula **OR** mixture of the above
	(c)		$C_{12}H_{25}$ ✓	1	**IGNORE** $C_{24}H_{50}$
	(d)	(i)	$C_8H_{18} + 12½O_2 \longrightarrow 8CO_2 + 9H_2O$ ✓	1	**ALLOW** multiples e.g. $2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$ **IGNORE** state symbols

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Question			Answer	Mark	Guidance
	(ii)		(n(C_8H_{18}) burned) = 0.32 (mol) ✓ (n(CO_2) from complete combustion) = 2.56 **or** 2.6 mol **OR** (ratio nCO_2/nC_8H_{18}) = 7.8(125) **OR** (n C_8H_{18} produce 2.5 mol CO_2) = 0.31(25) ✓	**2**	**DO NOT ALLOW ECF** from an incorrect moles of octane **DO NOT ALLOW ECF** from incorrect ratio from equation in **(i)** **ALLOW** the following alternate methods --- **Method 1** (mass CO_2 produced) = 110 g ✓ (mass CO_2 from complete combustion) = 8 × 0.32 × 44 = 112.64 **or** 112.6 **or** 113 g✓ --- **Method 2** (n C_8H_{18} to produce 2.5 mol CO_2) = 0.31(25) ✓ (mass of octane required to produce 2.50 mol CO_2) = 35.6 **OR** 35.63 **OR** 35.625 g ✓

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Question			Answer	Mark	Guidance
	(e)	(i)	Fractional distillation **AND** cracking ✓	1	**ALLOW** either order
		(ii)	Correct equation showing cracking of an alkane to form ethene ✓	1	**ALLOW** any correct equation with correct formulae to show cracking forming C_2H_4 of the type: alkane $\longrightarrow$ shorter alkane(s) + alkene, e.g. $C_{10}H_{22} \longrightarrow C_8H_{18} + C_2H_4$ $C_{10}H_{22} \longrightarrow C_6H_{14} + 2C_2H_4$ **ALLOW** $C_2H_6 \longrightarrow C_2H_4 + H_2$ **ALLOW** correct molecular formulae **OR** structural **OR** displayed **OR** skeletal **OR** mixture of the above. **IGNORE** state symbols
			Total	9	

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Question			Answer	Mark	Guidance
2	(a)		Method 1: 100% **OR** (only) one product **OR** no waste product **OR** addition (reaction) ✓ Method 2: < 100% **AND** two products **OR** (also) produces NaBr **OR** (There is a) waste product **OR** substitution (reaction) ✓	2	**ALLOW** co-product or by-product for waste product For '< 100%' **ALLOW** not 100% **OR** method 2 has a low(er) atom economy (compared to method 1) **IGNORE** produces Br^-/ Na^+ **DO NOT ALLOW** incorrect waste products e.g. Br_2, HBr, Br, Na **ALLOW** correctly calculated value of 42 or 41.8 up to calculator value of 41.83154324 correctly rounded for second mark **DO NOT ALLOW** incorrect values for the atom economy of method 2. **ALLOW ONLY** 1 mark for a statement that both methods have 100% atom economy.
	(b)		Acid ✓	1	**ALLOW** H^+ / named mineral acid / H_2SO_4 / H_3PO_4 **DO NOT ALLOW** 'weak acid' e.g. ethanoic acid **IGNORE** pressure **IGNORE** temperature

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Question			Answer	Mark	Guidance
	(c)	(i)	(Average enthalpy change) when one mole of bonds ✓ of (gaseous covalent) bonds is broken ✓	2	**IGNORE** energy required **OR** energy released **DO NOT ALLOW** bonds formed
		(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF enthalpy change = –42 (kJ mol^{-1}) award 3 marks** **IF enthalpy change = +42 (kJ mol^{-1}) award 2 marks** (Energy for bonds broken) = 5538 (kJ) ✓ (Energy for bonds made) = 5580 (kJ) ✓ ΔH_r = –42 (kJ mol^{-1}) ✓	3	**IF there is an alternative answer, check to see if there is any ECF credit possible.** two common incorrect answers are: –970 (kJ mol^{-1}) award 2 marks +970 (kJ mol^{-1}) award 1 mark **IGNORE** signs **ALLOW** 1076 (bonds broken); 1118 (bonds made) Correct sign required **ALLOW ECF** for bonds broken – bonds made **IF** at least one molar ratio is used e.g. 8 x C–H

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Question			Answer	Mark	Guidance
	(d)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF mass = 8.21 (g) award 3 marks** **Actual** $n(C_4H_9OH)$ produced = $\frac{3.552}{74}$ = 0.048 (mol) ✓ **theoretical** $n(C_4H_9OH) = n(C_4H_9Br) = 0.048 \times \frac{100}{80}$ = 0.06 (mol) ✓ Mass of C_4H_9Br = 0.06 × 136.9 = 8.21 (g) ✓ ***3 SF required***	**3**	**ALLOW ECF** at each stage **ALLOW** expected mass $C_4H_9OH = 3.552 \times \frac{100}{80}$ = 4.44 (g) **ALLOW** Mass C_4H_9Br reacted = 0.048 × 136.9 = 6.5712 (g) **ALLOW** Mass of C_4H_9Br used $= 6.5712 \times \frac{100}{80}$ = 8.21 (g) **DO NOT ALLOW** 8.22 (*from use of 137 as M_r of C_4H_9Br*)
			Total	**11**	

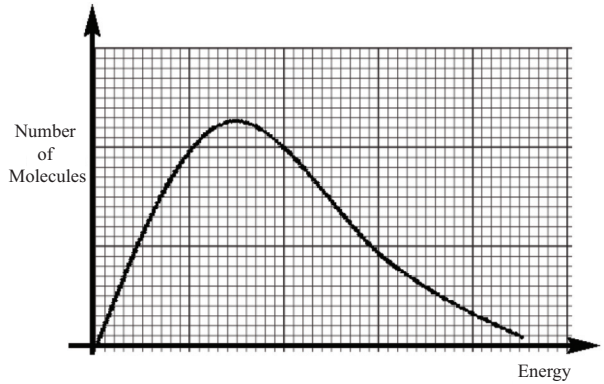
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Question			Answer	Mark	Guidance
3	(a)		Increased rate **AND** greater concentration of molecules / more molecules per (unit) volume ✓ More collisions per second **/** more frequent collisions ✓	2	**ALLOW** particles for molecules **IGNORE** atoms **Response must imply a volume and not area** **ALLOW** more molecules in the **same space** **OR** more molecules in the **same volume** **OR** same number of molecules in a **smaller volume** **IGNORE** molecules are closer together *(no idea of volume)* **ALLOW** collisions more often **OR** increased rate of collision **IGNORE** more chance of collisions 'more collisions' alone is **not** sufficient *(no rate)* **IGNORE** 'successful'
3	(b)		The (position of a dynamic) equilibrium shifts to minimise (the effect of) any change ✓	1	**ALLOW** suitable alternatives for 'shifts' and 'minimises' **IGNORE** **'**reaction shifts'

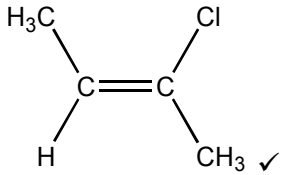
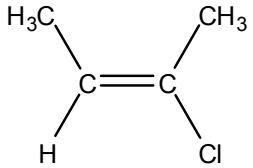
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Question			Answer	Mark	Guidance
	(c)	(i)	**Pressure**: Right-hand side has fewer (gaseous) moles/molecules **OR** left-hand side has more (gaseous) moles/molecules ✓ **Temperature**: Statement that: (Forward) reaction is exothermic **OR** (forward) reaction gives out heat **OR** reverse reaction is endothermic **OR** reverse reaction takes in heat ✓ **Equilibrium** Lower temperature/cooling **AND** increasing pressure shifts (equilibrium position) to the right ✓	3	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC **DO NOT ALLOW** fewer atoms on right-hand side **OR** more atoms on left-hand side. **IGNORE** comments about the 'exothermic side' or 'endothermic side' **Equilibrium mark** is for stating that **BOTH** low temperature and high pressure shift equilibrium to the right (Could be separate statements) **Note: ALLOW** suitable alternatives for 'to right', e.g.: towards products **OR** towards CH_3OH / H_2O **OR** in forward direction **OR** favours the right **IGNORE** Increases yield of CH_3OH/products *(in question)* **IGNORE** responses in terms of rate
	(ii)		Low temperature gives a slow rate **OR** high temperatures needed to increase rate ✓ High pressure is expensive (to generate) **OR** high pressure provides a safety risk ✓	2	 **ALLOW** high pressure is dangerous **IGNORE** high pressure is explosive

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Question	Answer	Mark	Guidance
(d)	 Correct drawing of Boltzmann distribution curve ✓ Axes labelled: y axis: (number of) molecules **AND** x axis: energy ✓ Catalyst lowers the activation energy (by providing an alternative route) ✓ (With a catalyst a) greater proportion of molecules with energy greater than activation energy **OR** (With a catalyst a) greater proportion of molecules with energy equal to the activation energy ✓	4	ANNOTATE ANSWER WITH TICKS AND CROSSES ETC Curve must start at origin. The limit of acceptability is that the curve must start within the first small square nearest the origin. Curve must not touch the x-axis at higher energy **IGNORE** a slight inflexion on the curve **DO NOT ALLOW** two curves **DO NOT ALLOW** a curve that bends up at the end by more than one small square **ALLOW** particles instead of molecules on y axis **DO NOT ALLOW** enthalpy for x-axis label **DO NOT ALLOW** atoms instead of particles or molecules **ALLOW ECF** for the subsequent use of atoms (instead of molecules or particles) **ALLOW** annotations on Boltzmann distribution diagram **ALLOW** (with a catalyst) more molecules have sufficient energy to react **IGNORE** (more) successful collisions
(e)	Allows reactions to take place at lower temperatures ✓	1	**ALLOW** less heat (required) **IGNORE** references to pressure **IGNORE** references to less energy (*in question)* e.g. lowers E_a
	Total	13	

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Question			Answer	Mark	Guidance
4	(a)		**B** ✓	1	**ALLOW** CF_2CF_2 **OR** C_2F_4 **OR** tetrafluoroethene
	(b)	(i)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal **OR** mixture of the above **ALLOW** *E* isomer 
		(ii)	HCl ✓	1	**DO NOT ALLOW** Cl_2 **IGNORE** names **IGNORE** nitrogen oxides / NO_x
	(c)	(i)	**ANY TWO FROM THE FOLLOWING** ✓ Low reactivity **OR** will not burn/non-flammable Volatile **OR** low boiling point non-poisonous **OR** non-toxic	1	 **ALLOW** inert **OR** stable **DO NOT ALLOW** inflammable **ALLOW** it is a gas **IGNORE** easily compressed **IGNORE** not harmful **IGNORE** references to solubility

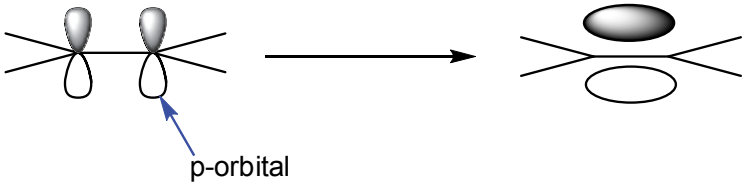
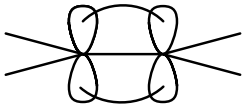
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Question	Answer	Mark	Guidance
(ii)	*Benefit of ozone layer to life (1 mark)* Ozone absorbs **UV** (radiation) **UV** at Earth's surface is reduced ✓ **OR** *Maintenance of O_3 concentration* (1 mark) $_3 \rightleftharpoons O_2 + O$ ✓ O *Production of radicals from **G** (1 mark)* $_2Cl_2 \longrightarrow C\ l + CF_2Cl$ ✓ CF *Breakdown of O_3 (2 marks)* $l + O_3 \longrightarrow C\ lO + O_2$ ✓ $lO + O \longrightarrow Cl + O_2$ C **OR** $ClO + O_3 \longrightarrow Cl + 2O_2$ ✓ C	**5**	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** For all equations, **IGNORE** dots on radicals --- Essential idea for first mark is that **UV** is removed in some way. **ALLOW** Prevents **UV** damaging life or stated type of damage, e.g. cataracts, skin cancer, mutation, crop damage **DO NOT ALLOW** ozone absorbs IR --- **ALLOW** $_3 \longrightarrow O_2 + O$ $_2 + O \longrightarrow O_3$ O **AND** **DO NOT ALLOW** $2O_3 \rightleftharpoons 3O_2$ O **OR** $O_3 + O \longrightarrow 2O_2$ for this mark --- **DO NOT ALLOW** equations with other CFCs **DO NOT ALLOW** $CF_2Cl_2 \longrightarrow 2C\ l + CF_2$ --- These are the only acceptable equations **IGNORE** overall equation *(does not show role of catalyst)* e.g. $O_3 + O \longrightarrow 2O_2$

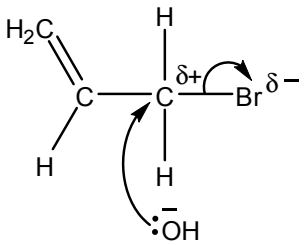
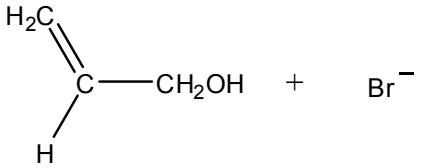
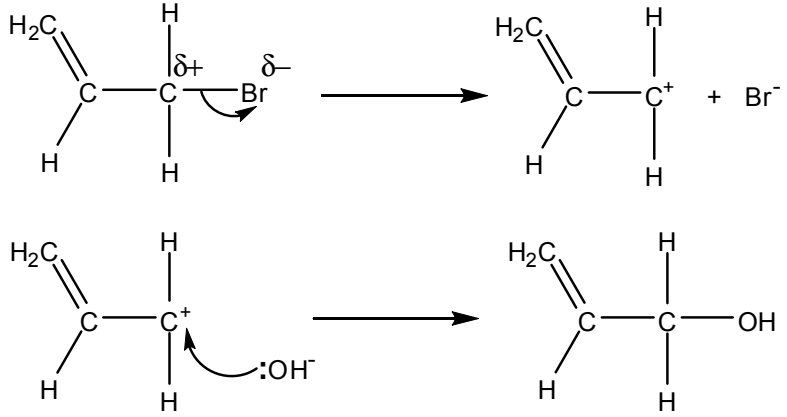
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Question			Answer	Mark	Guidance
	(iii)		**D** ✓	1	**ALLOW** CHF_2Cl **ALLOW B OR** C_2F_4 **OR** CF_2CF_2
	(d)	(i)	**bond** vibrates (more) **OR bond** bends (more) **OR bond** stretches (more) ✓	1	**BOND essential** **IGNORE** molecule vibrates/rotates Assume "It" refers to the molecule and is insufficient **DO NOT ALLOW** any reference to bond breaking **DO NOT ALLOW** a stated bond if **not** present in **C** and **F** e.g. C–O, C–H not present
	(ii)		Cl_3C^+ ✓ $CF_2\ Cl^+$ ✓	2	**ALLOW** 1 mark for Cl_3C **AND** $CF_2\ Cl$ *i.e. no + charge used* **ALLOW** 1 mark for Cl_3C^- **AND** $CF_2\ Cl^-$ *i.e. – charge used on both*
			Total	13	

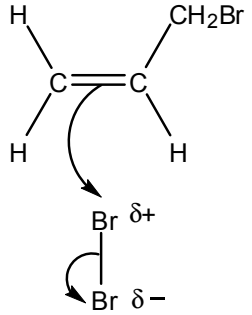
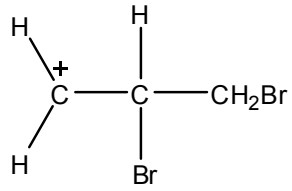
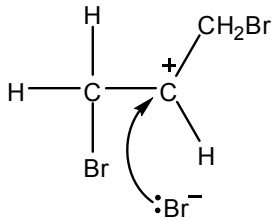
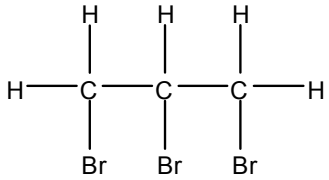
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			Answer	Mark	Guidance
5	(a)		 **First mark** diagram on left with p-orbitals labelled **OR** unlabelled diagram **AND** the statement: (sideways) overlap of p orbitals ✓ **Second mark** (labelled) diagram on right showing π-bond ✓	**2**	**Note:** A diagram is required for **each** mark **DO NOT ALLOW** C=C in one diagram but **ALLOW ECF** for subsequent use in another diagram. The bonds shown in the diagram are **required** **ALLOW ECF** for missing bonds in second diagram **IGNORE** any atoms joined to the bonds **ALLOW** a diagram where the p-orbitals are linked for second mark. e.g. 
	(b)	**(i)**	(series of compounds with the) same functional group **OR** same/similar chemical properties **OR** same/similar chemical reactions ✓ each **successive/subsequent** member differing by CH_2 ✓	**2**	**IGNORE** reference to physical properties **IGNORE** same general formula *(in question)* Differs by CH_2 is **not** sufficient (*no successive*) **DO NOT ALLOW** same empirical **OR** have the same molecular formula
		(ii)	$C_nH_{2n-1}Br$ ✓	**1**	**ALLOW** $\mathbf{C_nH_{2n-1}X}$ **ONLY** if X is specified as Br (*question asks for bromide)*
		(iii)	3-bromoprop(-1-)ene ✓	**1**	**ALLOW** 1-bromoprop-2-ene
	(c)	**(i)**	Movement of an electron pair ✓	**1**	**ALLOW** movement of a lone pair **OR** movement of a bond
		(ii)	Electron pair donor ✓	**1**	**ALLOW** can donate a lone pair

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			Answer	Mark	Guidance
	(d)	(i)	 curly arrow from HO^- to carbon atom of C−Br bond ✓ Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C−Br bond to Br atom ✓ ---  correct organic product **AND** Br^- ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** 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) --- **ALLOW** S_N1 mechanism: Dipole shown on C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$, **AND** curly arrow from C−Br bond to Br atom ✓ Correct carbocation **AND** curly arrow from HO^- to carbocation 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) ✓ correct organic product **AND** Br^- ✓  ---
		(ii)	Nucleophilic substitution ✓	1	

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			Answer	Mark	Guidance
(e)		(i)		4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**
			Curly arrow from double bond to Br of Br–Br ✓		Curly arrow **must** start from bond and go to correct atom
			Correct dipole shown on Br–Br **AND** curly arrow showing breaking of Br–Br bond ✓		**DO NOT ALLOW** any other partial charges e.g. shown on double bond
					
			---		**ALLOW** carbocation on terminal CH_2
			Correct carbocation with + charge on C with 3 bonds **AND** curly arrow from Br^- to C^+ of carbocation ✓		
					**DO NOT ALLOW** δ+ on C of carbocation.
			---		Curly arrow must come from a lone pair on Br^- **OR** from the negative sign of Br^- ion (then lone pair on Br^- ion does not need to be shown)
			Correct product: ✓		
					
		(ii)	Electrophilic addition ✓	1	

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			Answer	Mark	Guidance
	(f)	(i)	H_2 **AND** Ni (catalyst) ✓	1	**ALLOW** name or formula for each **IGNORE** any stated temperature and pressure
		(ii)	(Initiation) $Cl_2 \longrightarrow 2Cl$ **AND** UV ✓ (Propagation) $C_3H_7Br + Cl \longrightarrow C_3H_6Br + HCl$ ✓ $C_3H_6Br + Cl_2 \longrightarrow C_3H_6BrCl + Cl$ ✓ (Termination) Two from the three termination equations below ✓ $2Cl \longrightarrow Cl_2$ $C_3H_6Br + Cl \longrightarrow C_3H_6BrCl$ $2C_3H_6Br \longrightarrow C_6H_{12}Br_2$ names of steps initiation, propagation and termination linked to one correct equation for each step in this mechanism✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **DO NOT ALLOW** any ECF in this question **IGNORE** references to temperature **THROUGHOUT, ALLOW** correct molecular formulae **OR** structural **OR** displayed **OR** skeletal **OR** mixture of the above **IGNORE** dots **IGNORE** state symbols **IGNORE** one incorrect termination equation
		(iii)	further substitution **OR** produces different termination products **OR** More than one termination step✓ substitution at different positions along chain ✓	2	**IGNORE** mixture of organic products (*in question*) **ALLOW** dichloro/multichloro/dibromo/multibromo compounds formed **OR** an example of a further substitution product **OR** an example of a different termination product **ALLOW** more than one hydrogen (atom) can be replaced **ALLOW** radicals react with each other to form other product**s** **ALLOW** forms different structural isomers **ALLOW** a hydrogen (atom) on a different carbon (atom) can be replaced
			Total	25	

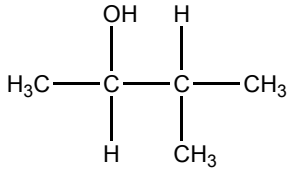
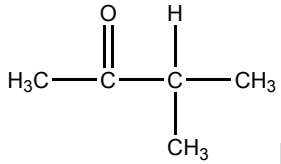
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Question			Answer	Mark	Guidance
6	(a)	(i)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF ΔH_c = –2260 (kJ mol $^{-1}$) award 4 marks** **IF ΔH_c = (+)2260 (kJ mol $^{-1}$) award 3 marks (incorrect sign)** **IF ΔH_c = (±)2257(.2) (kJ mol $^{-1}$) award 3 marks (not 3 sf)** **Moles** Amount, n, $C_5H_{12}O$ calculated correctly = 0.0175 (mol) ✓ **Energy** q calculated correctly = 39501 (J) **OR** 39.5(01) (kJ) ✓ **Calculating ΔH** correctly calculates ΔH in kJ mol^{-1} to 3 or more sig figs ✓ **Rounding and Sign** calculated value of ΔH rounded to 3 sig. fig. with minus sign✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **Note:** q = 180 × 4.18 × 52.5 **ALLOW** 39501 **OR** correctly rounded to 3 sig. fig. (J) **IGNORE** sign **IGNORE** working **Note:** from 39501 J and 0.0175 mol ΔH = (-)2257.2 kJ mol^{-1} **IGNORE** sign at this intermediate stage **ALLOW** ECF from incorrect q and/or incorrect n Final answer must have **correct sign** and **three sig figs**
		(ii)	**ANY TWO FROM THE FOLLOWING** ✓✓ incomplete combustion non-standard conditions evaporation of alcohol/water specific heat capacity of beaker/apparatus	2	**IGNORE** heat loss (*in question*) **ALLOW** burns incompletely **IGNORE** incomplete reaction

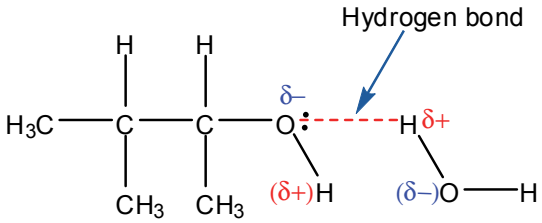
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Question			Answer	Mark	Guidance
	(b)	(i)	$5C(s) + 6H_2(g) + \frac{1}{2}O_2(g) \longrightarrow C_5H_{12}O(l)$ ✓	1	Balancing numbers **AND** species **AND** states all required **DO NOT ALLOW** multiples of this equation
		(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF enthalpy change = –3320 (kJ mol^{-1}) award 3 marks** **IF enthalpy change = (+)3320 (kJ mol^{-1}) award 2 marks** --- Working for CO_2 **AND** H_2O seen anywhere 5 × (–)394 **AND** 6 × (–)286 **OR** (–)1970 **AND** **OR** (–)3686 ✓ (–)1716 Calculates ΔH_c **A further 2 marks** for correct answer **AND** correct sign = 5 × –394 + 6 × –286 – –366 = –3320 (kJ mol^{-1}) ✓✓ **A further 1 mark** for correct answer **AND** incorrect or no sign = (+)3320 (kJ mol^{-1}) ✓ *Cycle wrong way around:* *–366 – (5 × –394 + 6 × –286)*	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IF there is an alternative answer, check to see if there is any ECF credit possible** **Common incorrect answers are shown below** **Award 2 marks for** –1744 **OR** –1890 **OR** –314 **OR** –4052 **Award 1 mark for** 1744 **OR** 1890 **OR** 314 **OR** 4052

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Question	Answer	Mark	Guidance
(c)	**QWC:** Evidence of the **IR** absorption at 1720 (cm^{-1}) for presence of C=O/carbonyl group ✓ **QWC**: No carboxylic acid OH absorption in IR **OR** no peak between 2500–3300 cm^{-1} **AND** so **J** is a secondary alcohol **OR** so **K** is a ketone ✓ **Alcohol J**  ✓✓ **Compound K** Structure of a carbonyl compound that could be obtained from alcohol **J** ✓ **Equation** Balanced equation for conversion of **J** to **K** ✓ e.g. $CH_3CHOHCH(CH_3)_2 + [O] \longrightarrow CH_3COCH(CH_3)_2 + H_2O$	**6**	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **LOOK ON THE SPECTRUM** for labelled peaks which can be given credit **BOTH IR** at ~1720 (cm^{-1}) **AND** C=O required **ALLOW** ranges from *Data Sheet*, i.e. C=O within range 1640–1750 cm^{-1}; **IGNORE** any reference to C-O absorption For structures of **J** and **K**, **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **IGNORE** any names given for **J** and **K** **ALLOW** 1 mark for the structure of an alcohol with the molecular formula $C_5H_{12}O$ **DO NOT ALLOW** pentan-1-ol (*primary and unbranched*) or 2-methylbutan-2-ol (*branched but tertiary*) **DO NOT ALLOW** any marks for **J** and **K** if more than one structure is given for **J** **Note:** 'sticks' in either **J** and/or **K** will lose only 1 mark **ALLOW** 1 mark for:  **IF** a structure is not given for **J** **NOTE:** structures for **J** and **K** could be awarded from the equation, even if not labelled. **ALLOW** molecular formulae in equation i.e. $C_5H_{12}O + [O] \longrightarrow C_5H_{10}O + H_2O$ **DO NOT ALLOW** equations that form a carboxylic acid

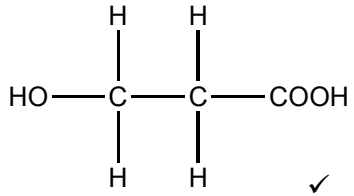
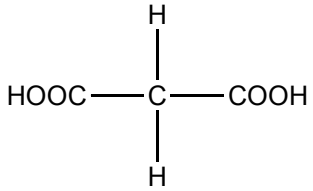
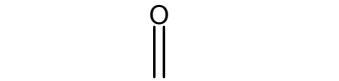
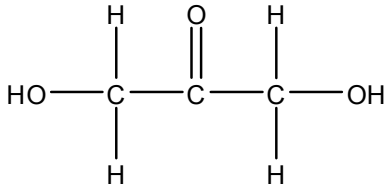
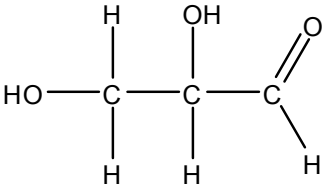
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Question			Answer	Mark	Guidance
	(d)		**Labelled** diagram showing at least one H-bond between alcohol molecule and water ✓ e.g.  	1	**IF** diagram is not labelled **ALLOW** Hydrogen bonds / H bonds from text Diagram should include role of an O lone pair and dipole charges on each end of H bond. **IGNORE** alcohol R group, even if wrong **ALLOW** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above
			Total	17	

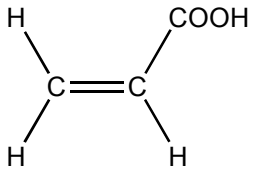
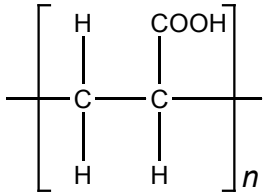
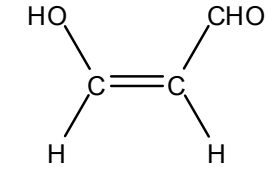
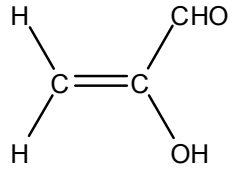
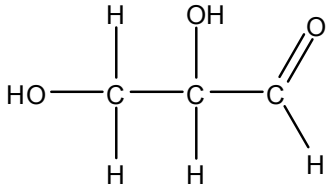
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Question			Answer	Mark	Guidance
7	(a)		Mole ratio C : H : O is 3.33 : 6.67 : 3.33 ✓ Empirical formula is CH_2O ✓ Molecular formula is $C_3H_6O_3$ **AND** use of 90 **OR** 3 × 30 ✓	**3**	**ALLOW** $\frac{40.00}{12.0} : \frac{6.67}{1.0} : \frac{53.33}{16.0}$ **ALLOW** mass of C = 0.400 x 90 **or** 36 **AND** mass of H = 0.06677 x 90 **or** 6 **AND** mass of O = 0.5333 x 90 **or** 48

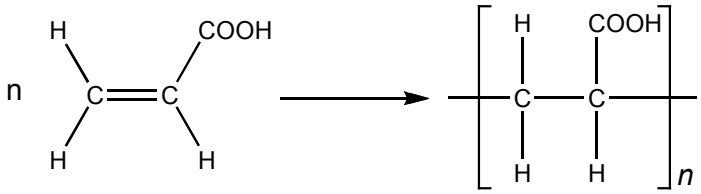
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Question	Answer	Mark	Guidance
(b)	**Evidence of carboxylic acid (1 mark)** **IR:** 1550–1800 cm^{-1} **AND** C=O/carbonyl **AND** 2300–3700 cm^{-1} **AND** O–H in carboxylic acid ✓ **Evidence of alcohol (1 mark)** (broad) 3200–3700 cm^{-1} linked to O–H in alcohol **OR** (is a primary) alcohol as oxidised (to a COOH) **OR** is an alcohol as it forms a carboxylic acid **OR** is an alcohol as water is eliminated. ✓ **Identifications (2 marks)** **L**:  ✓ **M**:  ✓ **Equation (1 mark)** $C_3H_6O_3 + 2[O] \longrightarrow C_3H_4O_4 + H_2O$ ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **LOOK ON THE SPECTRUM** for labelled peaks which can be given credit **ALLOW** ranges from *Data Sheet*: C=O within range 1640–1750 cm^{-1}; (broad) O–H within range 2500–3300 cm^{-1} (broad) O–H within range 3200–3550 cm^{-1} **For ALL structures:** **ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above **IGNORE** names --- **FOR M: ALLOW 1 mark for**  ✓ **AS ECF from L as either**  **OR**  **Equation:** $C_3H_6O_3 + 4[O] \longrightarrow C_3H_2O_5 + 2H_2O$ ✓ --- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above in equation

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Question	Answer	Mark	Guidance
(c)	**Monomer N: (1 mark)**  ✓ **Polymer P: (1 mark)** Section showing at least one repeat unit of a polymer formed from **N** with side links ✓ e.g. 	4	**For ALL structures:** **ALLOW** correct structural **OR** skeletal **OR** displayed formula **OR** mixture of the above **IGNORE** names **ALLOW 1 mark for either**  **OR**  **AS ECF** from **L:**  --- **For P: ALLOW ECF** from an alkene with molecular formula $C_3H_4O_2$ **ALLOW** one or more repeat units but has to have a whole number of repeat units **ALLOW** repeat unit with no brackets and absence of *n*

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Question	Answer	Mark	Guidance
	Repeat units (1 mark) n = 10000/72 = 139 ✓ **Equation (1 mark)** Balanced equation for formation of P from N✓ e.g.  		**MUST** be a whole number. **ALLOW** 138 **OR**140 --- **For equation, ALLOW** molecular **OR** structural **OR** skeletal **OR** displayed formulae **OR** mixture of the above e.g. **ALLOW** $n C_3H_4O_2 \longrightarrow (C_3H_4O_2)_n$ n on LHS can be at any height to the left of formula **AND** n on the RHS must be a subscript (essentially below the side link if displayed/skeletal formula is used) **ALLOW** use of calculated value for n in equation e.g. $139C_3H_4O_2 \longrightarrow (C_3H_4O_2)_{139}$
	Total	**12**	

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Tuesday 3 June 2014 – Afternoon

AS GCE CHEMISTRY A

F322/01 Chains, Energy and Resources

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry A* (inserted)

Other materials required:
- Scientific calculator

Duration: 1 hour 45 minutes

* F 3 2 2 0 1 *

* 1 3 9 3 4 3 7 8 3 7 *

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found inside this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

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



Where you see this icon you will be awarded marks for the quality of written communication in your answer.

This means for example you should:
- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- organise information clearly and coherently, using specialist vocabulary when appropriate.

- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **24** pages. Any blank pages are indicated.

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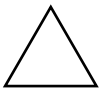
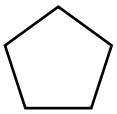
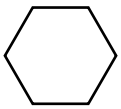
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Answer **all** the questions.

1 This question is about cyclic organic compounds.

The table shows some information about cycloalkanes.

Cycloalkane	Skeletal formula	Boiling point/°C
Cyclopropane		–33
Cyclopentane		49
Cyclohexane		81

(a) These cycloalkanes are members of the same homologous series and have the same general formula.

(i) What is meant by the term *homologous series*?

.....

.....

.....

..... **[2]**

(ii) State the general formula for these cycloalkanes.

..... **[1]**

(iii) Explain the increase in boiling points of the cycloalkanes shown in the table.

.....

.....

.....

.....

..... **[2]**

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(b) The C–C–C bond angles in **cyclohexane** are 109.5°.

State and explain the shape around each carbon atom in cyclohexane.

shape .....

explanation .....

.....

[2]

(c) In the absence of ultraviolet radiation, **cyclopropane** undergoes an addition reaction with bromine.

Suggest the structure of the organic product formed in this reaction.

[1]

(d) Petrol contains both **cyclohexane**, C_6H_{12}, and hexane.

Cyclohexane can be prepared from hexane.

(i) Construct the equation for this reaction.

..... **[1]**

(ii) Suggest **one** advantage of adding cyclohexane to hexane in petrol.

.....

..... **[1]**

(e) **Cyclobutane** is another cycloalkane.

There are several **unsaturated** isomers of cyclobutane that are alkenes.

Two of these isomers are stereoisomers.

(i) Explain what is meant by the term *stereoisomers*.

.....

..... **[1]**

(ii) Draw these **two** stereoisomers.

[2]

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(f) In the presence of ultraviolet radiation, **cyclohexane** reacts with bromine.

A mixture of cyclic organic compounds is formed, including $C_6H_{11}Br$.

(i) Complete the table below to show the mechanism of the reaction between bromine and cyclohexane to form $C_6H_{11}Br$.

Include all possible termination steps in your answer.

Step	Equation
Initiation	.....
Propagation	....
Termination	....

[5]

(ii) The initiation step involves homolytic fission.

Explain why the initiation step is an example of *homolytic fission*.

.....

.....

..... **[1]**

(g) The reaction between cyclohexane and bromine in **(f)** also forms $C_6H_{10}Br_2$.

(i) Write an equation, using molecular formulae, for the reaction of cyclohexane and bromine in the presence of ultraviolet radiation to form $C_6H_{10}Br_2$.

..... **[1]**

(ii) Name **one** of the structural isomers of $C_6H_{10}Br_2$ formed in the reaction between cyclohexane and bromine.

..... **[1]**

[Total: 21]

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2 1-Bromobutane, $CH_3CH_2CH_2CH_2Br$, reacts with methoxide ions, CH_3O^-, by nucleophilic substitution.

(a) Suggest how the methoxide ion can act as a nucleophile.

.....

..... **[1]**

(b) Using the 'curly arrow' model, suggest the mechanism for this reaction.

Show any relevant dipoles.

[3]

(c) 1-Iodobutane also reacts with methoxide ions.

Indicate, by placing a tick in one of the boxes, how the use of 1-iodobutane would affect the rate of reaction compared with that of 1-bromobutane.

1-Iodobutane does not change the rate	
1-Iodobutane increases the rate	
1-Iodobutane decreases the rate	

Explain your answer.

.....

.....

..... **[1]**

(d) The ethanoate ion, CH_3COO^- also acts as a nucleophile when reacting with 1-bromobutane in a substitution reaction.

Draw the skeletal formula and give the name of the organic product formed in this reaction.

skeletal formula

name of product ..... **[2]**

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(e) 1-Bromobutane (M_r, 136.9) can be made from a reaction of butan-1-ol, C_4H_9OH, as shown in the equation below.

$$C_4H_9OH + KBr + H_2SO_4 \longrightarrow C_4H_9Br + KHSO_4 + H_2O$$

(i) Calculate the atom economy for the formation of 1-bromobutane in this reaction.

atom economy = ... % **[1]**

(ii) Suggest a reactant, other than a different acid, that could be used to improve the atom economy of making 1-bromobutane by the same method.

..... **[1]**

(iii) A student prepares a sample of 1-bromobutane.

5.92 g of butan-1-ol are reacted with an excess of sulfuric acid and potassium bromide. After purification, 9.72 g of 1-bromobutane are collected.

Calculate the percentage yield.

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

percentage yield = ... % **[3]**

[Total: 12]

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3 Hydrogen iodide, HI, is a colourless gas that can be made from the reaction of hydrogen, H_2, and iodine, I_2.

This reversible reaction is shown in **equilibrium 3.1** below.

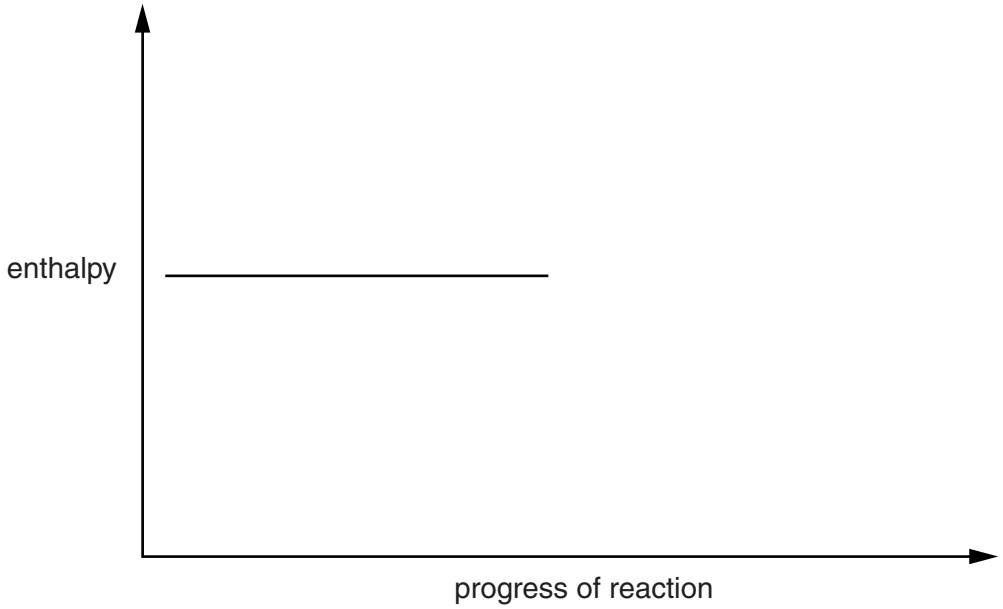
$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H = -9\,kJ\,mol^{-1} \qquad \textbf{equilibrium 3.1}$$

The activation energy for the forward reaction is $173\,kJ\,mol^{-1}$.

(a) Complete the enthalpy profile diagram below for the forward reaction in **equilibrium 3.1**.

On your diagram:

- Label the activation energy, E_a
- Label the enthalpy change of reaction, ΔH
- Include the formulae of the reactants and products.



[2]

(b) Calculate the activation energy, E_a, for the reverse reaction.

E_a (reverse reaction) = ... $kJ\,mol^{-1}$ **[1]**

(c) When the reverse reaction takes place hydrogen iodide, HI, decomposes to form iodine and hydrogen.

Calculate the enthalpy change when $336\,dm^3$ of hydrogen iodide, measured at room temperature and pressure, decomposes.

Include the sign for enthalpy change in your answer.

enthalpy change ..... kJ **[2]**

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(d) A student mixes hydrogen and iodine at room temperature and pressure and allows the mixture to reach dynamic equilibrium.

$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$ $\Delta H = -9\,kJ\,mol^{-1}$ **equilibrium 3.1**

(i) A closed system is required for dynamic equilibrium to be established.

State **one** other feature of this dynamic equilibrium.

.....

..... **[1]**

(ii) The student heats the equilibrium mixture keeping the volume constant.

Predict how the composition of the equilibrium mixture changes on heating.

Explain your answer.

.....

.....

.....

..... **[2]**

(iii) Predict and explain what effect, if any, an increase in the pressure would have on the position of the equilibrium.

effect .....

explanation .....

..... **[1]**

(e) Calculate the bond enthalpy for the H–I bond in **equilibrium 3.1**, given the following information.

Bond	Bond Enthalpy / kJ mol^{-1}
H–H	436
I–I	151

bond enthalpy ..... kJ mol^{-1} **[2]**

[Total: 11]

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4 This question is about the determination of enthalpy changes.

(a) A student carries out an experiment to find the enthalpy change of reaction, ΔH_r, for the reaction below.

$$Na_2CO_3(s) + 2HCl(aq) \longrightarrow 2NaCl(aq) + CO_2(g) + H_2O(l)$$

In the experiment, 3.18 g of Na_2CO_3 are added to 50.0 g of 2.00 mol dm^{-3} HCl, an excess. The temperature of the reaction mixture increases by 5.5 °C.

Calculate ΔH_r, in kJ mol^{-1}.

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

The specific heat capacity, c, of the reaction mixture is 4.18 J g^{-1} K^{-1}.

ΔH_r = ... kJ mol^{-1} **[4]**

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(b) The booster rocket of a spacecraft uses a mixture of aluminium and ammonium chlorate(VII), NH_4ClO_4, as a fuel. The equation and some enthalpy changes are shown below.

$$3Al(s) + 3NH_4ClO_4(s) \longrightarrow Al_2O_3(s) + AlCl_3(s) + 6H_2O(g) + 3NO(g) \qquad \Delta H = -2677\,kJ\,mol^{-1}$$

Substance	Standard enthalpy change of formation, ΔH_f / kJ mol^{-1}
$NH_4ClO_4(s)$	–295
$Al_2O_3(s)$	–1676
$AlCl_3(s)$	–704
$H_2O(g)$	–242

(i) What is meant by the term *standard enthalpy change of formation*?

Give the standard conditions.

.....

.....

.....

.....

..... **[3]**

(ii) Write the equation, including state symbols, for the reaction that represents the standard enthalpy change of formation of $NH_4ClO_4(s)$.

..... **[2]**

(iii) Calculate the enthalpy change of formation of NO(g) using the data above.

enthalpy change of formation of NO(g) = ... kJ mol^{-1} **[3]**

[Total: 12]

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5 Chloroethene, CH_2CHCl, can be polymerised to form poly(chloroethene).

(a) Write an equation, using displayed formulae, to show the formation of this polymer.

[2]

(b) Incineration of plastics containing poly(chloroethene) produces waste gases that can damage the environment.

Incineration carried out in the presence of oxygen produces carbon dioxide, carbon monoxide and hydrogen chloride as waste gases and one other non-toxic product.

(i) Write an equation for the incineration of the monomer, chloroethene, with oxygen.

[1]

(ii) Chemists have developed ways of removing hydrogen chloride from these waste gases. Sodium hydrogencarbonate, $NaHCO_3(s)$, is frequently used in industry for this purpose.

Explain how sodium hydrogencarbonate removes hydrogen chloride.

..... **[1]**

(c) Carbon dioxide is a greenhouse gas that is linked to global warming.

The greenhouse effect of carbon dioxide in the atmosphere is dependent on two factors.

What are these **two** factors?

1 .....

.....

2 .....

.....

[2]

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(d) Chemists are trying to minimise climate change as a result of global warming.

One way is to use Carbon Capture and Storage (CCS). One method of CCS is to react the carbon dioxide with metal oxides.

(i) Write an equation to illustrate this method of CCS.

..... **[1]**

(ii) State one other method of CCS.

.....

..... **[1]**

[Total: 8]

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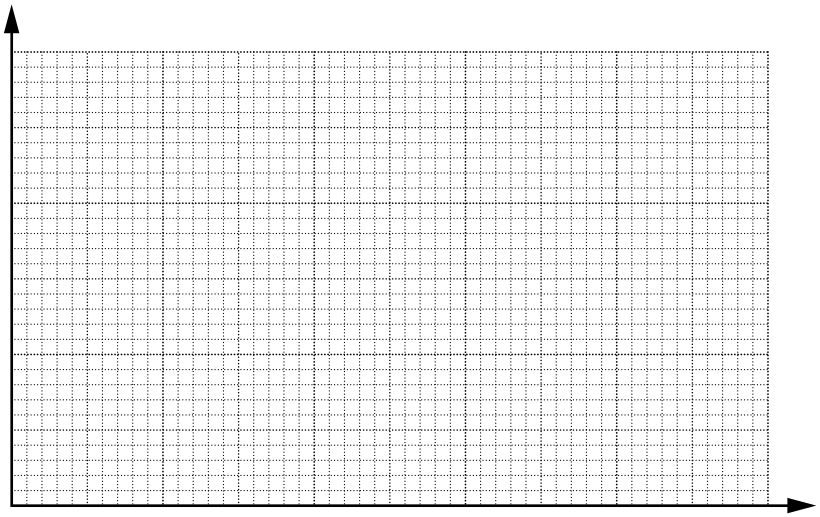
6 **(a)** Reaction rates can be increased or decreased by changing conditions of temperature and pressure.

(i) Explain how increasing the temperature increases the rate of reaction.

Include a labelled sketch of the Boltzmann distribution, on the grid below.

Label the axes.

Your answer needs to be clear and well organised using the correct terminology.



.....

.....

.....

.....

.....

..... **[4]**

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(ii) Describe and explain the effect of decreasing the pressure on the rate of a reaction.

.....

.....

.....

.....

..... **[2]**

(b) Catalysts are used to speed up chemical reactions.

(i) Write an equation for an industrial preparation of ethanol which involves the use of an enzyme in yeast.

State a suitable temperature for this reaction and **one** other essential condition.

equation .....

temperature .....°C.

condition .....

[2]

(ii) Catalytic converters are used to decrease the emission of nitrogen monoxide and carbon monoxide from the internal combustion engine. These two gases react together on the surface of the catalyst.

Write an equation for this reaction.

..... **[1]**

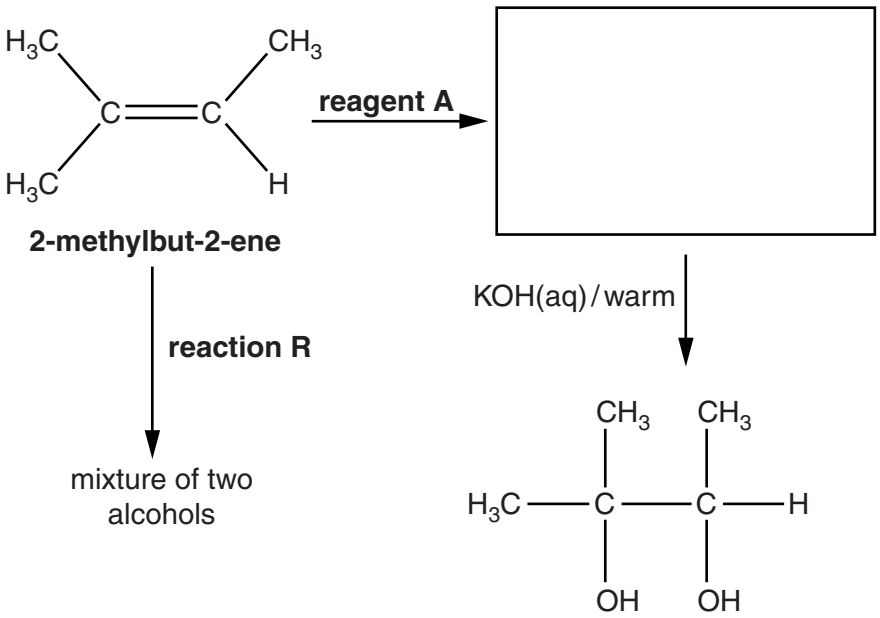
[Total: 9]

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7 The flowchart shows how 2-methylbut-2-ene can be converted into a number of organic products.

(a) Complete the flowchart by drawing an organic structure in the box below.



[1]

(b) Identify reagent **A**.

..... **[1]**

(c) In the flowchart, **reaction R** forms a mixture of two alcohols that are structural isomers of $C_5H_{12}O$.

(i) State the reagents and conditions needed for **reaction R**.

..... **[1]**

(ii) What is meant by the term *structural isomers*?

.....

..... **[1]**

(iii) Draw the two structural isomers of $C_5H_{12}O$ formed in **reaction R**.

[2]

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(iv) Suggest why 2-methylbut-2-ene is less soluble in water than either of the structural isomers formed.

.....

.....

..... **[2]**

(d) Describe the oxidation reactions of propan-1-ol when using a suitable oxidising agent.

Indicate how the use of different reaction conditions can control which organic product forms.

Include reagents, observations and equations in your answer.

In your equations, use structural formulae and use [O] to represent the oxidising agent.

.....

.....

.....

.....

.....

.....

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.....

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.....

.....

..... **[6]**

[Total: 14]

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8 **(a)** Compound **B**, C_xH_yO, can be oxidised to form a ketone **C**.

0.035 mol of **B** has a mass of 2.59 g.

Compound **B** reacts with compound **D**, $C_3H_6O_2$, in the presence of an acid catalyst to form two compounds **E** and **F**.

- Calculate the molar mass of compound **B**.
- Give the structures of compounds **B**, **C**, **D**, **E** and **F**.

.... **[6]**

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Question 8 continues on page 20

PLEASE DO NOT WRITE ON THIS PAGE

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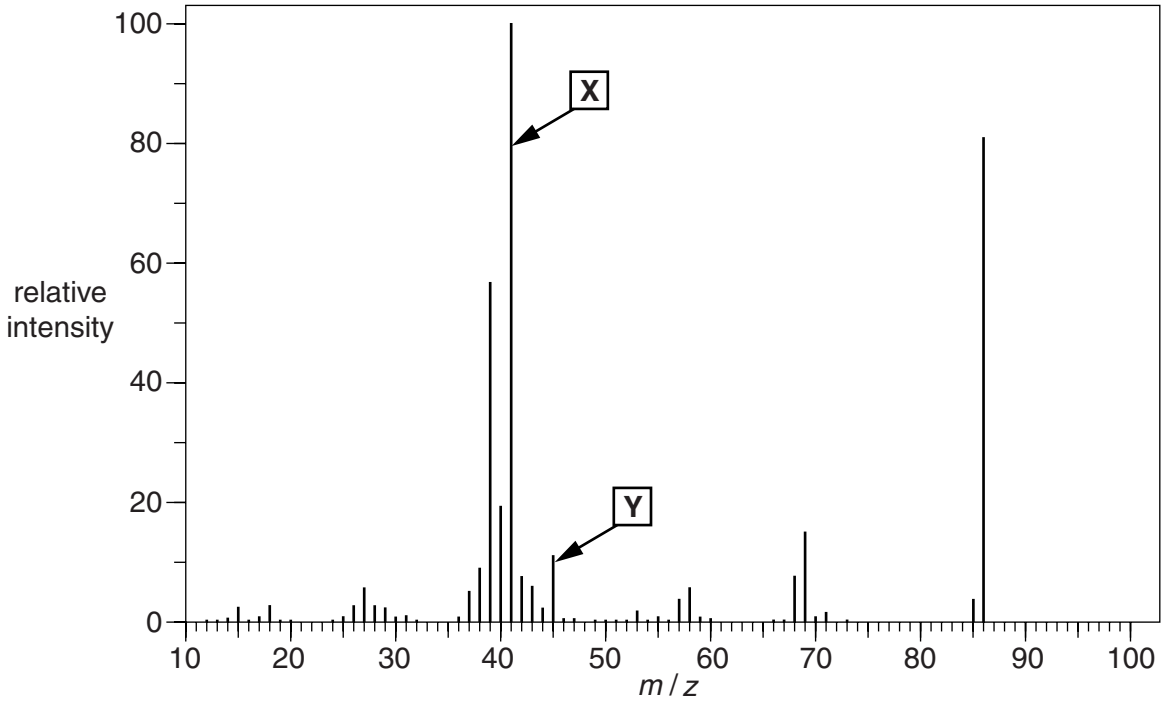
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(b) Compound **G** is a branched-chain organic compound that does **not** have *E* and *Z* isomers.

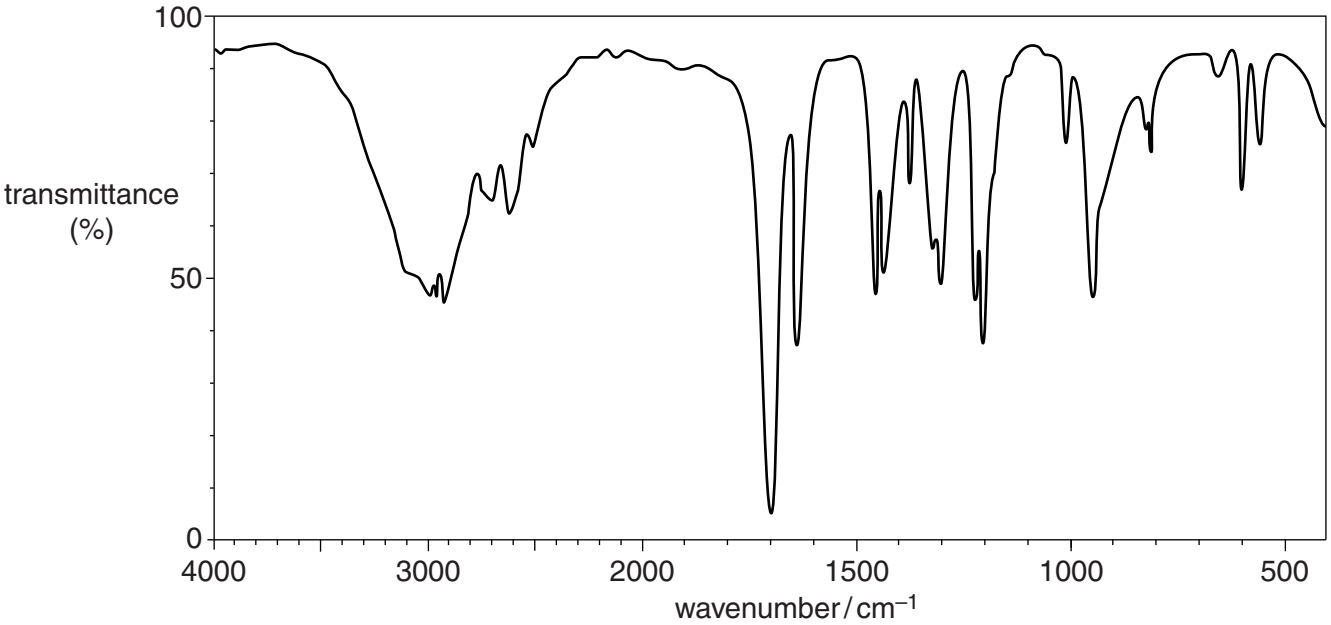
Elemental analysis of compound **G** gave the following percentage composition by mass: C, 55.8%; H, 7.0%; O, 37.2%.

The mass spectrum and infrared spectrum of compound **G** are shown below.

Mass spectrum



Infrared spectrum



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- Calculate the empirical and molecular formulae for compound **G**.
- Write the formulae for the particles responsible for peak **X** and peak **Y** in the mass spectrum.
- Draw the structure of compound **G**.

*Explain fully how you arrive at a structure for compound **G** using all the evidence provided.*

[7]

[Total: 13]

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional answer space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margins.

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GCE

Chemistry A

Unit **F322:** Chains, Energy and Resources

Advanced Subsidiary GCE

Mark Scheme for June 2014

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This mark scheme is published as an aid to teachers and students, to indicate the requirements of the examination. It shows the basis on which marks were awarded by examiners. It does not indicate the details of the discussions which took place at an examiners' meeting before marking commenced.

All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotation	Meaning
BP	Blank Page – this annotation must be used on all blank pages within an answer booklet (structured or unstructured) and on each page of an additional object where there is no candidate response.
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
I	Ignore
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct response

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Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:

2(b), 3(a), 4(a), 4(b)(iii), 6(a)(i), 7(d), 8(a), 8(b)

All questions where an ECF has been applied.

Checking additional pages

All the Additional Pages in the examination script must be checked to see if any candidates include any answers.

- When you open question **1(a)(i)** you will see a view of page 22 one of the Additional Pages.
- If the page is blank then, using the marking mode, annotate the page with an omission mark, ^.
- Scroll down to page 24 and annotate with a ^ if the page is blank.
- If pages 23 or 24 are not blank then use the paper clip icon to link the pages to the correct questions.

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- You may need to contact your Team Leader if you do not know how to do this.

Generic comments

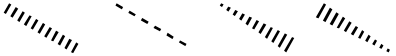
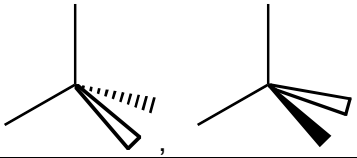
ORGANIC STRUCTURES
For a 'structure' or 'structural formula',
- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)

For an alkyl group shown within a structure,
- **ALLOW** bond drawn to C or H,
  e.g. **ALLOW** CH_3–,CH_2–, C_3H_7–, etc.
- **ALLOW** vertical 'bond' to any part of an alkyl group

For an OH group shown within a structure,
- **DO NOT ALLOW** formula with horizontal —HO **OR** OH –
- **ALLOW** vertical 'bond' to any part of the OH group

For a CHO group shown within a structure,
- **DO NOT ALLOW** COH

For a 3D structure,

• For bond in the plane of paper, a solid line is expected:	
• For bond out of plane of paper, a solid wedge is expected:	
• For bond into plane of paper, **ALLOW**:	
• **ALLOW** a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge e.g.:	 ,

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NAMES

Names including alkyl groups:
- **ALLOW** alkanyl, e.g. ethanyl (i.e. **IGNORE** 'an')
- **DO NOT ALLOW** alkol, e.g. ethol (ie 'an' is essential)

Names of esters:
- Two words are expected, e.g. ethyl ethanoate
- **ALLOW** one word, e.g. ethylethanoate

Names with multiple numbers and hyphens:
Use of 'e'
- **ALLOW** superfluous 'e' , e.g. propane-1-ol ('e' is kept if followed by consonant)
- **ALLOW** absence of 'e', e.g. propan-1,2-diol ('e' is omitted if followed by vowel)

Hyphens separate name from numbers:
- **ALLOW** absence of hyphens, e.g. propane 1,2 diol

Multiple locant numbers must be clearly separated:
- **ALLOW** full stops: e.g. 1.2 OR spaces: 1 2
- **DO NOT ALLOW e.g.** 12

Locant numbers in formula must be correct
- **DO NOT ALLOW** propan-3-ol

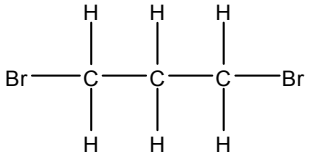
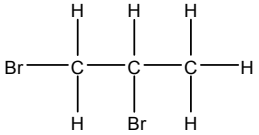
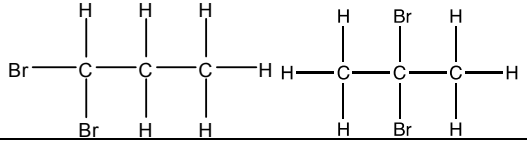
Order of substituents should be alphabetical:
- **ALLOW** any order (as long as unambiguous), e.g. 2-chloro-3-bromobutane

ABBREVIATIONS
van der Waal's forces
ALLOW vdw forces **OR** VDW forces (and any combination of upper and lower cases)

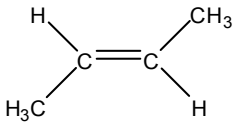
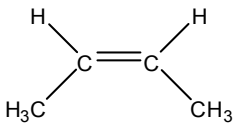
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Question			Answer	Mark	Guidance
1	(a)	(i)	(series of compounds with the) same functional group **OR** same/similar chemical properties **OR** same/similar chemical reactions ✓ each **successive/subsequent** member differing by CH_2 ✓	2	**IGNORE** references to physical properties **IGNORE** has same general formula (in question) **DO NOT ALLOW** have the same empirical formula **OR** have the same molecular formula
		(ii)	C_nH_{2n} ✓	1	
		(iii)	More carbons (in ring) **OR** more (surface area of) contact **AND** **more van der Waals** forces **OR stronger van der Waals** forces ✓ More energy needed to break the intermolecular forces ✓	2	**Both answers need to be comparisons** **ALLOW** ORA throughout **ALLOW** has more electrons **OR** larger (carbon) ring **OR** higher molecular mass **IGNORE** bigger molecule **IGNORE** chain instead of ring **DO NOT ALLOW** 'more contact between atoms' **ALLOW** 'VDW' for van der Waals 'More intermolecular forces' is **not** sufficient **ALLOW** it is harder to overcome the intermolecular forces **ALLOW** intermolecular bonds / van der Waals bonds **ALLOW** more energy is needed to separate molecules **IGNORE** more energy is needed to break bonds

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Question			Answer	Mark	Guidance
	(b)		tetrahedral ✓ four **bonding** pairs repel **OR** four **bonds** repel ✓	2	**Mark each point independently** **IGNORE** surrounded by four atoms **IGNORE** four areas of electron charge repel **IGNORE** four electron pairs repel (*one could be lp*) **DO NOT ALLOW** atoms repel
	(c)		 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** structure of 1,2-isomer  **IGNORE** molecular formula **DO NOT ALLOW,** structure of 1,1-isomer **OR** 2,2-isomer 
	(d)	(i)	$C_6H_{14} \rightarrow C_6H_{12} + H_2$ ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** any correct multiple **IGNORE** state symbols

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Question			Answer	Mark	Guidance
		(ii)	Cyclohexane will burn more efficiently ✓	1	**KEY IDEA IS COMBUSTION OR BURNING** **Assume 'it' refers to cyclohexane** **ALLOW ORA** for hexane **ALLOW** cyclohexane allows smoother burning **OR** promotes more efficient combustion **OR** increases octane number **OR** reduces knocking **OR** less likely to produce pre-ignition **OR** burns better **OR** easier to burn **OR** combusts more easily **OR** improves combustion **OR** burns more cleanly **DO NOT ALLOW** cyclohexane ignites more easily **IGNORE** cyclohexane increase volatility of fuel **IGNORE** reference to boiling points **IGNORE** cyclohexane gives a better fuel
	(e)	(i)	(Compounds with the) same structural formula but a different arrangement (of atoms) in space ✓	1	**ALLOW** different spatial arrangement of atoms. **DO NOT ALLOW** different displayed formula.
		(ii)	 ✓  ✓	2	**ALLOW** displayed **OR** skeletal formula **OR** mixture of the above. **ALLOW** structures in either order **IGNORE** molecular formula **IGNORE** structural formula **IGNORE** names **IGNORE** E/Z and cis/trans labels **ALLOW** 1 mark for a pair of E/Z isomers of an incorrect hydrocarbon structure with **four** C atoms e.g. C, or CH or CH_2 instead of CH_3 groups.

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<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Mark</th><th>Guidance</th></tr>
<tr><td></td><td>(f)</td><td>(i)</td><td>
<table>
<tr><th>Step</th><th>Equation</th></tr>
<tr><td>Initiation
(1 mark)</td><td>$Br_2 \rightarrow 2Br\bullet$ ✓</td></tr>
<tr><td>Propagation
(2 marks)</td><td>$C_6H_{12} + Br\bullet \rightarrow C_6H_{11}\bullet + HBr$ ✓

$C_6H_{11}\bullet + Br_2 \rightarrow C_6H_{11}Br + Br\bullet$ ✓</td></tr>
<tr><td>Termination
(2 marks)</td><td>$C_6H_{11}\bullet + Br\bullet \rightarrow C_6H_{11}Br$

$C_6H_{11}\bullet + C_6H_{11}\bullet \rightarrow C_{12}H_{22}$

$Br\bullet + Br\bullet \rightarrow Br_2$

Two correct ✓
All three correct ✓✓</td></tr>
</table>
</td><td>5</td><td>IGNORE state symbols

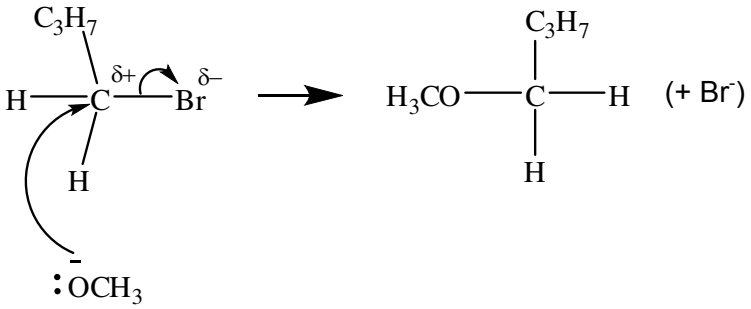
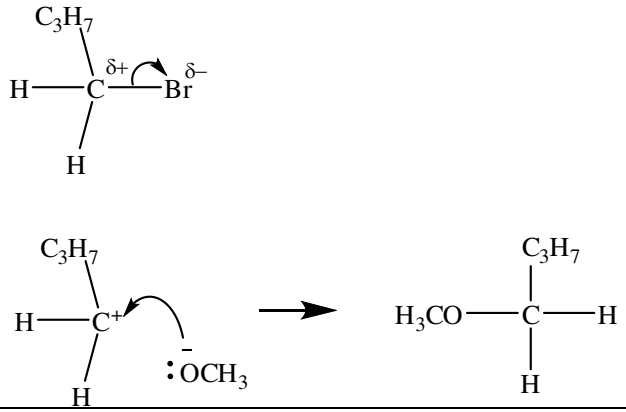
IGNORE dots

If an incorrect hydrocarbon with six C atoms is used:
DO NOT ALLOW any marks for the propagation steps but
ALLOW ECF for termination steps (i.e. 3 max)</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>The breaking of a (Br-Br) bond AND forms (two) radicals
OR
the breaking of a (Br-Br) bond AND one electron (from the bond pair) goes to each atom/bromine ✓</td><td>1</td><td>ALLOW ‘the breaking of a covalent bond’
ALLOW the splitting of the bond in bromine

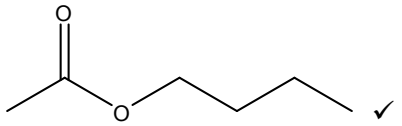
ALLOW the breaking of a covalent bond where each atom keeps one of the bonding electrons
IGNORE particle for atom
ALLOW one electron goes to each product / species
DO NOT ALLOW molecule or compound for atom
IGNORE homolytic fission equations</td></tr>
<tr><td></td><td>(g)</td><td>(i)</td><td>$C_6H_{12} + 2Br_2 \rightarrow C_6H_{10}Br_2 + 2HBr$ ✓</td><td>1</td><td>ALLOW molecular formula only.</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>1,1-dibromocyclohexane
OR 1,2-dibromocyclohexane
OR 1,3-dibromocyclohexane
OR 1,4-dibromocyclohexane ✓</td><td>1</td><td>Locant numbers MUST lowest possible e.g. DO NOT ALLOW 2,4-dibromocyclohexane etc.

IGNORE structures</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>21</td><td></td></tr>
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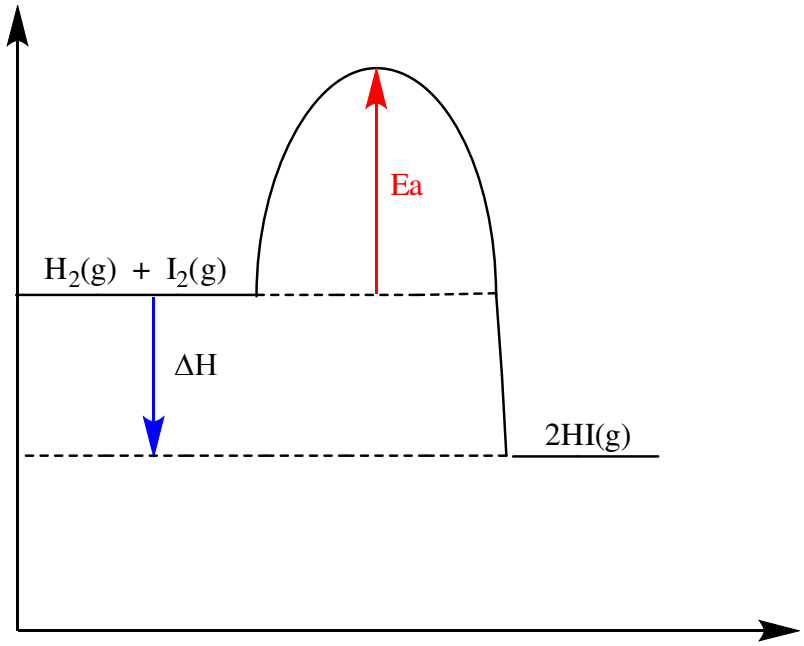
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Question			Answer	Mark	Guidance
2	(a)		It is an electron pair donor **OR** can donate a lone pair ✓	1	
	(b)		 Dipole shown on the C-Br bond, $C^{\delta+}$ and $Br^{\delta-}$ and curly arrow from the C-Br bond to the Br atom ✓ Curly arrow from $:\bar{O}CH_3$ to carbon atom in the C-Br bond ✓ Correct organic product ✓ **S_N1 mechanism** 	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** connectivity to C_3H_7 throughout **IGNORE** alkyl group in first marking point. Curly arrow must start from C–Br bond and not from C atom. Dipole must be partial charge and not full charge CH_3O^- curly arrow must come from one lone pair on O of CH_3O^- ion **OR** from negative sign on O of the CH_3O^- ion **ALLOW** arrow from lone pair on O in OCH_3^- Lone pair not required **DO NOT ALLOW** $CH_3O^{\delta-}$ **DO NOT ALLOW** incorrect connectivity of CH_3O group in the final product $-CH_3O$ **IGNORE** $Br^{\delta-}$ as a product **ALLOW S_N1 mechanism** Dipole shown on the C–Br bond, $C^{\delta+}$ and $Br^{\delta-}$ and curly arrow from C–Br bond to the Br atom ✓ curly arrow from CH_3O^- to carbonium ion✓ correct organic product ✓

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Question			Answer	Mark	Guidance
	(c)		1-Iodobutane increases the rate ✓ **AND** C—I bonds are weaker (than C—Br) **OR** C—I bond has a lower bond enthalpy **OR** C—I bond needs a smaller amount of energy to break **OR** C—I bond is easier to break ✓	1	All statements must be **comparative** **ALLOW ORA** **IGNORE** C—I bond is longer **IGNORE** polarity and references to electronegativity
	(d)		 butyl ethanoate ✓	2	**ALLOW** only skeletal formula **DO NOT ALLOW ECF** from incorrect structure. **ALLOW** butylethanoate **ALLOW** butanyl for butyl **DO NOT ALLOW** but**ly**
	(e)	(i)	($\frac{136.9}{291.1}$ × 100) = 47% ✓	1	**ALLOW** 47 up to calculator value correctly rounded. 47.0 or 47.03 or 47.029 will be correct common answers **IGNORE** any working shown.
	(e)	(ii)	NaBr **OR** LiBr ✓	1	**ALLOW** correct name or formula **DO NOT ALLOW** HBr (it is an acid)
	(e)	(iii)	**Look at answer if 88.8% AWARD 3 marks** **if 88.75% AWARD 2 marks (not 3 sig. fig.)** Moles of butan-1-ol = 0.08(00) ✓ Moles of 1-bromobutane = 0.071(0) ✓ % yield = 88.8% ✓	3	Answer **MUST** be to 3 significant figures. **ALLOW** ECF but do not allow a yield >100% **ALLOW** Mass of 1-bromobutane expected = 10.952 g
			Total	12	

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Question			Answer	Mark	Guidance
3	(a)		**There are 3 marking points required for 2 marks**  H_2 and I_2 on LHS **AND** 2HI on RHS **AND** correctly labelled Ea ✓ Δ*H* labelled with product below reactant **AND** arrow downwards ✓	2	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** state symbols. ***E_a*:** **ALLOW** (+)173 only as an alternative label for Ea **ALLOW** no arrowhead or arrowheads at both ends of activation energy line The E_a line must point to maximum (or near to the maximum) on the curve **OR** span approximately 80% of the distance between reactants and maximum regardless of position **ALLOW** AE or A_E for E_a ***ΔH:*** **IF** there is no Δ*H* labelled **ALLOW** –9 as an alternative label for Δ*H*. **IF** Δ*H* is labelled **IGNORE** any numerical value. **DO NOT ALLOW** –ΔH. **ALLOW** this arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line
	(b)		(+)182 ✓	**1**	This is the **ONLY** acceptable answer

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Question			Answer	Mark	Guidance
	(c)		**Look at answer if +63 kJ AWARD 2 marks** **If 63 (no sign) OR-63 (incorrect sign) AWARD 1 mark** No of moles of HI = 14 moles ✓ Enthalpy Change = +63 kJ ✓	2	**ALLOW** one mark for +126 kJ Sign and value required. **ALLOW** ECF from incorrect number of moles of HI
	(d)	(i)	Rate of the forward reaction is equal to the rate of the reverse reaction ✓ **OR** concentrations do not change✓	1	**ALLOW** both reaction**s** occur at same rate **IGNORE** conc. of reactants = conc. of products
		(ii)	 More H_2 and I_2 **OR** less HI ✓ (equilibrium position shifts) to the left **AND** (Forward) reaction is exothermic **OR** reverse reaction is endothermic **OR** in the endothermic direction✓	2	**Mark each point independently** **ALLOW** more reactants **OR** less products **Note: ALLOW** suitable alternatives for to the left e.g. towards reactants **OR** towards H_2 / I_2 **OR** in reverse direction **OR** favours the left. **ALLOW** gives out heat for exothermic **ALLOW** takes in heat for endothermic **IGNORE** responses in terms of rate
		(iii)	No effect **AND** Same number of (gaseous) moles on both sides ✓	1	 **ALLOW** same number of molecules on each side

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Question			Answer	Mark	Guidance
	(e)		**Look at answer if (+)298 AWARD 2 marks** **If answer is -298 AWARD 1 mark (incorrect sign)** **2 x H-I bond enthalpy correctly calculated** (436 +151-(-9) =) (+)596 ✓ **H-I bond enthalpy correctly calculated** (Bond energy for H-I $\frac{(+)596}{2}$ =) (+)298 kJ mol^{-1} ✓	**2**	**ALLOW** 1 mark for (+)293.5 kJ mol^{-1} (bonds broken divided by 2) **ALLOW** 1 mark for (+)289 kJ mol^{-1} (incorrect expression i.e. [$\frac{436 +151+(-9)}{2}$])
			Total	**11**	

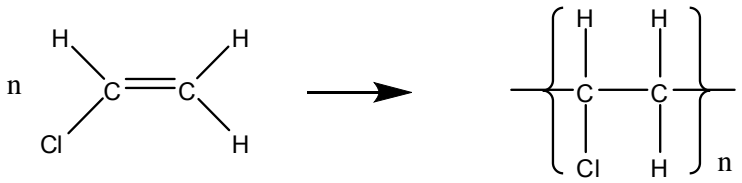
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Question			Answer	Mark	Guidance
4	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –38.3 (kJ mol^{-1}) award 4 marks** **IF answer = (+)38.3 (kJ mol^{-1}) award 3 marks (incorrect sign)** **IF answer = -38,300 (kJ mol^{-1}) award 3 marks (used J instead of kJ).** **Energy** q calculated correctly = 1149.5(J)✓ **OR** 1.1495 (kJ) ✓ **Moles** Amount, n, of Na_2CO_3 calculated correctly= 0.03(00) ✓ **Calculating ΔH** correctly calculates ΔH in kJ mol^{-1} to 3 or more sig figs✓ **Rounding and Sign** calculated value of ΔH rounded to 3 sig. fig. with minus sign✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **Note**: q = 50.0 × 4.18 × 5.5 **ALLOW** 1149.5 **OR** correctly rounded to 3 sig figs (J) **IGNORE** sign **IGNORE** working **ALLOW** 53.18 × 4.18 × 5.5 **OR** 1222.6082 **OR** 1220 **OR** correctly rounded to 3 or more sig figs in J or kJ **IGNORE** working **IGNORE** trailing zeros **IGNORE** sign at this intermediate stage **ALLOW** ECF from incorrect q and/or incorrect n Final answer must have **correct sign** and **three sig figs** **ALLOW** –40.8 kJ mol^{-1} if 53.18 used in calculation of q **ALLOW** –40.7 kJ mol^{-1} if q is rounded to 1220 from 53.18 earlier
	(b)	(i)	(Enthalpy change) when one mole of a compound ✓ is formed from its elements ✓ 298 K / 25 °C **AND** 1 atm / 100 kPa / 101 kPa / 1 bar ✓	3	**ALLOW** energy required **OR** energy released **ALLOW** one mole of substance **OR** one mole of product **DO NOT ALLOW** one mole of element **IGNORE** reference to concentration

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Question			Answer	Mark	Guidance
		(ii)	$\frac{1}{2}N_2(g) + 2H_2(g) + \frac{1}{2}Cl_2(g) + 2O_2(g) \rightarrow NH_4ClO_4(s)$ correct species ✓ correct state symbols **and** balancing ✓	**2**	**Second mark can only be awarded if all species in the equation are correct** **DO NOT ALLOW** multiples of this equation
		(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = (+)90 award 3 marks** **IF answer = –90 award 2 marks** **IF answer = ±270 award 2 marks** **IF answer = ±2947 award 1 mark** **Processing ΔH_f values** ±(3832 – 885) ±2947✓ **OR** ± (3832 – 885) **subtraction using ΔH reaction** ±(2947-2677)= ±270 ✓ **Calculation of ΔH formation NO** 270/3 = (+)90 ✓	**3**	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **Note:** ±2947 = ± [–1676 + (–704) + (6 x –242)] – (3 x –295)] **ALLOW ECF** for dividing by 3 from working that includes at least one ΔH_f and one balancing number and ΔH (-2677) for 1 mark
			Total	**12**	

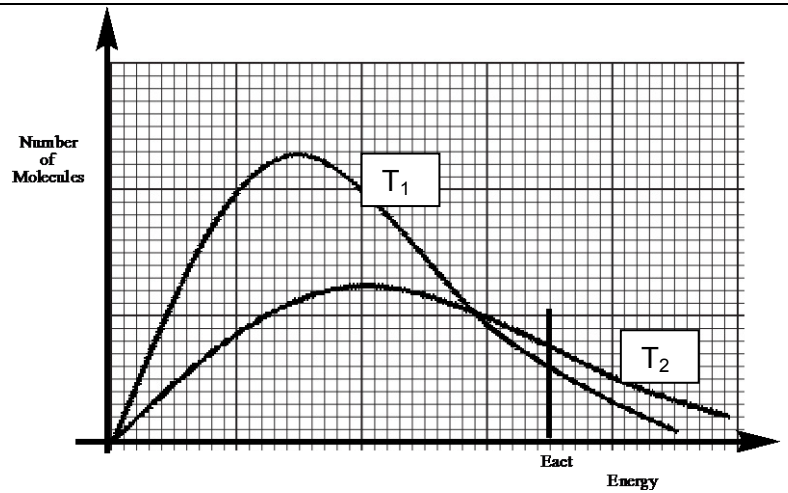
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Question			Answer	Mark	Guidance
5	(a)		 Correct polymer with side links ✓ Balanced equation for formation of correct polymer - correct use of *n* in the equation and brackets ✓	2	**Displayed formulae MUST be used to award each mark** *n* on LHS can be at any height to the left of formula **AND** *n* on the RHS must be a subscript (essentially below the side link)
	(b)	**(i)**	$CH_2CHCl + 2O_2 \longrightarrow CO + CO_2 + HCl + H_2O$ ✓	1	**ALLOW** any other correctly balanced equation with the same reactants and products **ALLOW** C_2H_3Cl for CH_2CHCl
		(ii)	Sodium hydrogencarbonate neutralises HC*l* ✓	1	**Assume that 'it' refers to sodium hydrogencarbonate but DO NOT ALLOW** other chemicals e.g. sodium **ALLOW** $NaHCO_3$ is a base **ALLOW** forms a salt or sodium chloride or NaCl **ALLOW** equation to show formation of NaCl from $NaHCO_3$ and HCl even if not balanced. **IGNORE** reacts

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Question			Answer	Mark	Guidance
	(c)		**ANY TWO from** abundance (in atmosphere) **OR** amount (in atmosphere) **OR** (atmospheric) concentration **OR** percentage (in air) ✓ **OR** ability to absorb **infrared/IR** (radiation)✓ **OR** residence time ✓	**2**	 **ALLOW** absorption of infrared/IR
	(d)	**(i)**	Any balanced equation between a metal oxide and carbon dioxide to form a carbonate e.g $CaO + CO_2 \longrightarrow CaCO_3$ ✓	**1**	**ALLOW** MO for metal oxide
		(ii)	**ANY ONE FROM** deep in oceans **OR** in geological formations **OR** (deep) in rocks **OR** in mines **OR** in oil wells **OR** in gas fields ✓	**1**	**Assume that 'it' refers to carbon dioxide but DO NOT ALLOW** carbon **DO NOT ALLOW** reacted with oxides or stored as carbonates.
			Total	**8**	

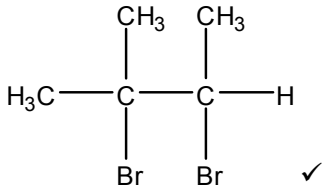
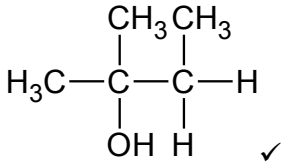
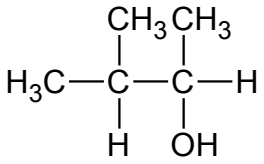
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Question			Answer	Mark	Guidance
6	(a)	(i)	 axes labelled (number of) molecules and (kinetic) energy ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** Candidates do not need Ea on graph **ALLOW** particles instead of molecules on the y axis **DO NOT ALLOW** atoms instead of particles/molecules **ALLOW ECF** for the incorrect use of atoms (instead of molecules/particles) **DO NOT ALLOW** enthalpy on the x-axis
			Correct drawing of a two Boltzmann distributions i.e. both curves must start within the first small square nearest to the origin **AND** must not touch the x axis at high energy ✓		**DO NOT ALLOW** increase of more than one small square at high energy end of curve. Maximum of curve for higher temperature to right **AND** lower than maximum of lower temperature curve **AND** above lower temp line at higher energy Higher temp line should intersect lower temp line once
			Drawing of Boltzmann distribution at **two** different temperatures with higher and lower temperature clearly identified (ie $T_2>T_1$) ✓		**DO NOT ALLOW** lower activation energy **QWC** requires more molecules have or exceed activation energy/E_a. **IGNORE** more molecules have enough energy to react for the **QWC** mark (as not linked to E_a) **ORA** if states the effect when the temperature is lower **IGNORE** (more) successful collisions
			QWC - (At a higher temperature) more molecules have energy above activation energy **OR** greater area under the curve above the activation energy✓		

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Question			Answer	Mark	Guidance
	(a)	(ii)	(Decreasing the pressure) decreases the rate of reaction **AND** Decreased concentration of molecules **OR** Number of molecules remains the same but the volume increases **OR** Less molecules per (unit) volume ✓ Less **frequent** collisions ✓	2	**Correct effect on rate must be linked to reason for the first marking point.** **ALLOW** molecules are further apart **IGNORE** less crowded **ALLOW** particles or atoms for molecules **ALLOW** 'space' for volume **DO NOT ALLOW** area instead of volume **ALLOW** collisions occur less often **OR** decreased rate of collision **IGNORE** less chance of collisions 'less collisions' alone is **not** sufficient **IGNORE** successful
	(b)	(i)	$C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + 2CO_2$ ✓ Temperature: Between 20 °C and 45 °C inclusive **AND** Condition: Absence of oxygen **OR** anaerobic ✓	2	**ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **IGNORE** state symbols **DO NOT ALLOW** acidic or alkaline conditions **If there is a contradiction or an incorrect answer in any condition given then do not award this mark.** **ALLOW** conditions shown in the equation A limited supply of oxygen is **not** sufficient **IGNORE** pressure **IGNORE** yeast (in question) **ALLOW** Lack of oxygen
	(b)	(ii)	$2NO + 2CO \longrightarrow 2CO_2 + N_2$ ✓	1	**ALLOW** multiples **IGNORE** state symbols
			Total	9	

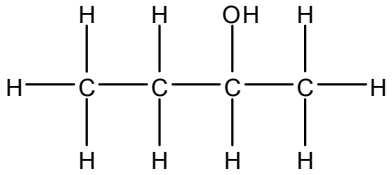
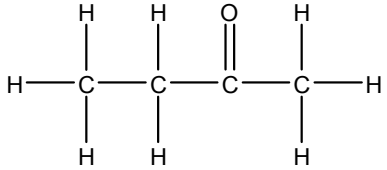
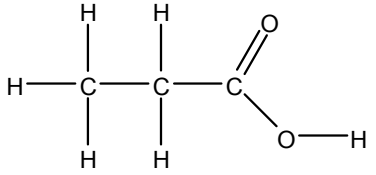
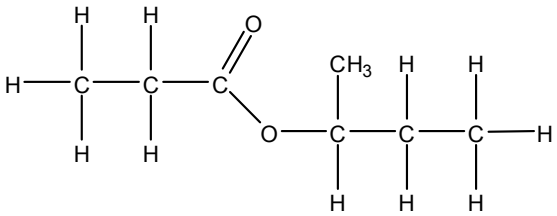
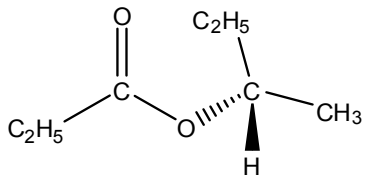
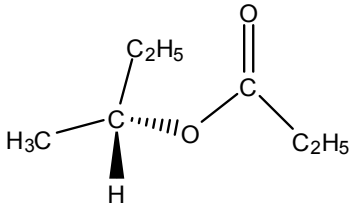
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Question			Answer	Mark	Guidance
7	(a)		 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **DO NOT ALLOW** molecular formula **ALLOW** dichloro or diiodo compound instead of the dibromo compound as the **only** alternatives.
	(b)		Reagent **A**: correct halogen✓ e.g. Br_2 / bromine	1	**ALLOW** Cl_2 if dichloro compound drawn **ALLOW** I_2 if diiodo compound drawn **IGNORE** state symbols Answer must match box from **(a)** to score
	(c)	(i)	Steam **AND** acid catalyst ✓	1	**ALLOW** H^+ / named acid / H_2SO_4 / H_3PO_4 **ALLOW** $H_2O(g)$ **ALLOW** water only if a temperature of 100 °C or above is quoted. **IGNORE** any temperature given with steam **IGNORE** pressure
		(ii)	(compounds or molecules) having the same molecular formula but different structural formulae ✓	1	**ALLOW** different structure **OR** different displayed formula **OR** different skeletal formula for structure Same formula is **not** sufficient Different arrangement of atoms is **not** sufficient
		(iii)	 ✓  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **ALLOW** any vertical bond to OH **DO NOT ALLOW** OH–
		(iv)	Does not contain OH group(s) **OR** does not contain hydroxyl group(s) **OR** is not an alcohol ✓ Does not form hydrogen bonds with water ✓	2	**ALLOW ORA** throughout **DO NOT ALLOW** OH^- (ions) / hydroxide (ions) 'Does not form hydrogen bonds' is **not** sufficient

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Question			Answer	Mark	Guidance
	(d)		Reagents: Acid/H^+ and (potassium or sodium) dichromate/$Cr_2O_7^{2-}$ seen **once**✓ Observations: Orange to Green **OR** Orange to Blue✓ Distillation / Distil produces aldehyde/CH_3CH_2CHO: ✓ $CH_3CH_2CH_2OH + [O] \longrightarrow CH_3CH_2CHO + H_2O$ ✓ Reflux (of propan-1-ol) produces carboxylic acid/CH_3CH_2COOH✓ $CH_3CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2COOH + H_2O$ ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** H_2SO_4 and $K_2Cr_2O_7$ **ALLOW** correct displayed formula **OR** correct structural formula **OR** skeletal formula **OR** a mixture of the above **DO NOT ALLOW** molecular formulae **ALLOW** C_3H_7OH for propan-1-ol in equations **DO NOT ALLOW** CH_3CH_2COH for aldehyde **IGNORE** further oxidation of aldehyde **ALLOW** $CH_3CH_2CO_2H$ for carboxylic acid
			Total	**14**	

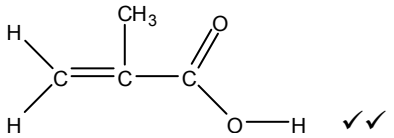
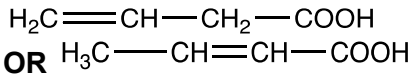
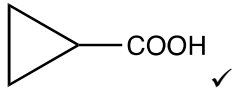
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Question			Answer	Mark	Guidance
8	(a)		Molar mass of **B** = 74 ✓ **B-F** clearly identified **B/alcohol:**  ✓ **C/ketone:**  ✓ **D/carboxylic acid:**  ✓ **E and F:**  ✓ H_2O/water ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **Check and annotate page 19 below this response** Molar mass = $\frac{2.59}{0.035}$ = 74 For structure of **B, C, D** or **E/F ALLOW** correct displayed **OR** correct structural formula **OR** correct skeletal formula **OR** mixture of the above as long as unambiguous**.** **DO NOT ALLOW** missing H atom(s) in a displayed formula for one structure but **ALLOW** missing H atoms in subsequent structures. **IGNORE** names of organic compounds **E** and **F** can be identified either way round **ALLOW** H_2O or displayed formula for mark For **E** and **F** – **ALLOW** the two optical isomers  

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Question			Answer	Mark	Guidance
8	(b)			7	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**
			Molecular formula for G: 2 marks		
			Mole ratio C : H : O = $\frac{55.8}{12.0} : \frac{7.0}{1.0} : \frac{37.2}{16.0}$		
			OR 4.65 : 7.0 : 2.33/2.325 **OR** 2 : 3 : 1 **OR** C_2H_3O ✓		**ALLOW** mass of C = 0.558 x 86 **or** 48 **AND** mass of H = 0.07 x 86 **or** 6 **AND** mass of O = 0.372 x 86 = 32
			Molecular formula of **G** $C_4H_6O_2$ ✓		
			Mass spectrum for G: 2 marks		
			Peak **X or peak 41** indicates $C_3H_5^+$ ✓		+ charge required for each response **ALLOW** one mark if both formulae are correct but with no charge/incorrect charge
			Peak **Y or peak 45** indicates $COOH^+$ ✓		**ALLOW** any possible fragments that contain C, H and/or O that have the correct mass. E.g. Peak X indicates C_2OH^+, Peak **Y** indicates $C_2H_5O^+$ Unfeasible fragments are not allowed e.g. $C_3H_9^+$ (too many H atoms)
			Infrared for G: 1 mark		
			Peak at 1640–1750 cm^{-1} indicates presence of C=O **AND** Peak at 2500–3300 cm^{-1} (indicates the presence of) –OH group linked carboxylic acid/COOH **QWC** ✓		**LOOK ON THE SPECTRUM** for labelled absorbance which can be given credit Candidates must link absorbance to bond in order to gain the mark **ALLOW** 1700 cm^{-1} For 2500–3300 cm^{-1}, **ALLOW** 2900 cm^{-1} or any stated wavenumber with range 2500–3300 cm^{-1} **ALLOW** wavenumber range up to 2400–3500 cm^{-1}

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Question	Answer	Mark	Guidance
	<u>Structure of G: 2 marks</u> Correct structure:  ✓✓ 1 mark for one of the following structures of $C_4H_6O_2$:  **OR** **OR**  ✓		**ALLOW** structural, skeletal or displayed formula. **DO NOT ALLOW ECF** from incorrect molecular formula
	Total	**13**	

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OCR
RECOGNISING ACHIEVEMENT

Tuesday 4 June 2013 – Afternoon

AS GCE CHEMISTRY A

F322/01 Chains, Energy and Resources

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry A* (inserted)

Other materials required:
- Scientific calculator

Duration: 1 hour 45 minutes

F 3 2 2 0 1

F3146201613

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined page at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

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



Where you see this icon you will be awarded marks for the quality of written communication in your answer.

This means for example you should:
- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- organise information clearly and coherently, using specialist vocabulary when appropriate.

- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **24** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 Crude oil is a complex mixture of many hydrocarbons.

Crude oil is processed by the petroleum industry to make fuels and petrochemicals.

(a) The straight-chain alkane, **A**, is present in crude oil.
A has molecules with ten carbon atoms.

(i) What is the molecular formula of **A**?

..... **[1]**

(ii) **B** is a branched-chain isomer of **A**.

Draw the skeletal formula of a possible structure for **B**.

Name your structure.

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

(iii) The branched-chain isomer **B** has a lower boiling point than the straight chain alkane **A**.

Explain why.

.....

.....

.....

..... **[2]**

(b) A chemist heats a pure sample of $C_{15}H_{32}$ in the presence of a catalyst.

A reaction called cracking happens.

(i) Construct an equation to show the cracking of $C_{15}H_{32}$.

..... **[1]**

(ii) When cracking takes place, a large number of products are formed.

Suggest why a large number of products are formed.

.....

.....

..... **[1]**

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(c) The petroleum industry processes straight-chain alkanes into cyclic hydrocarbons.

For example, octane can be processed into a cyclic hydrocarbon and hydrogen.

(i) Suggest the structure of this cyclic hydrocarbon.

[1]

(ii) Why does the petroleum industry process straight-chain alkanes into cyclic hydrocarbons?

.....

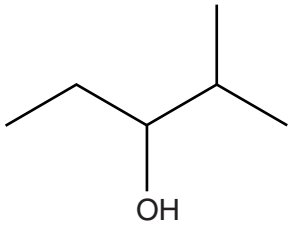
..... **[1]**

[Total: 9]

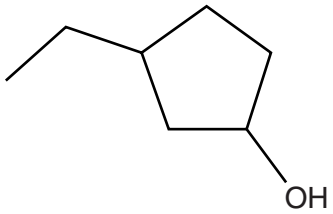
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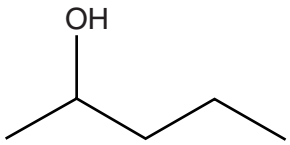
2 The skeletal formulae of six alcohols, **C**, **D**, **E**, **F**, **G** and **H**, are shown below.



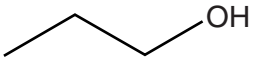
C



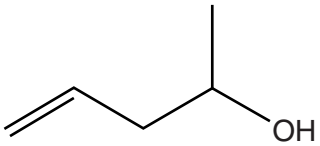
D



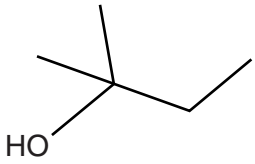
E



F



G



H

(a) (i) Which **two** alcohols are structural isomers of one another?

.....

[1]

(ii) Which alcohol is a tertiary alcohol?

.....

[1]

(iii) Which alcohol can be oxidised to a carboxylic acid using acidified $K_2Cr_2O_7$?

.....

[1]

(b) (i) What is the molecular formula of alcohol **G**?

..... **[1]**

(ii) What is the name of alcohol **C**?

..... **[1]**

(c) The alcohols are members of a homologous series.

Explain the term *homologous series*.

.....

.....

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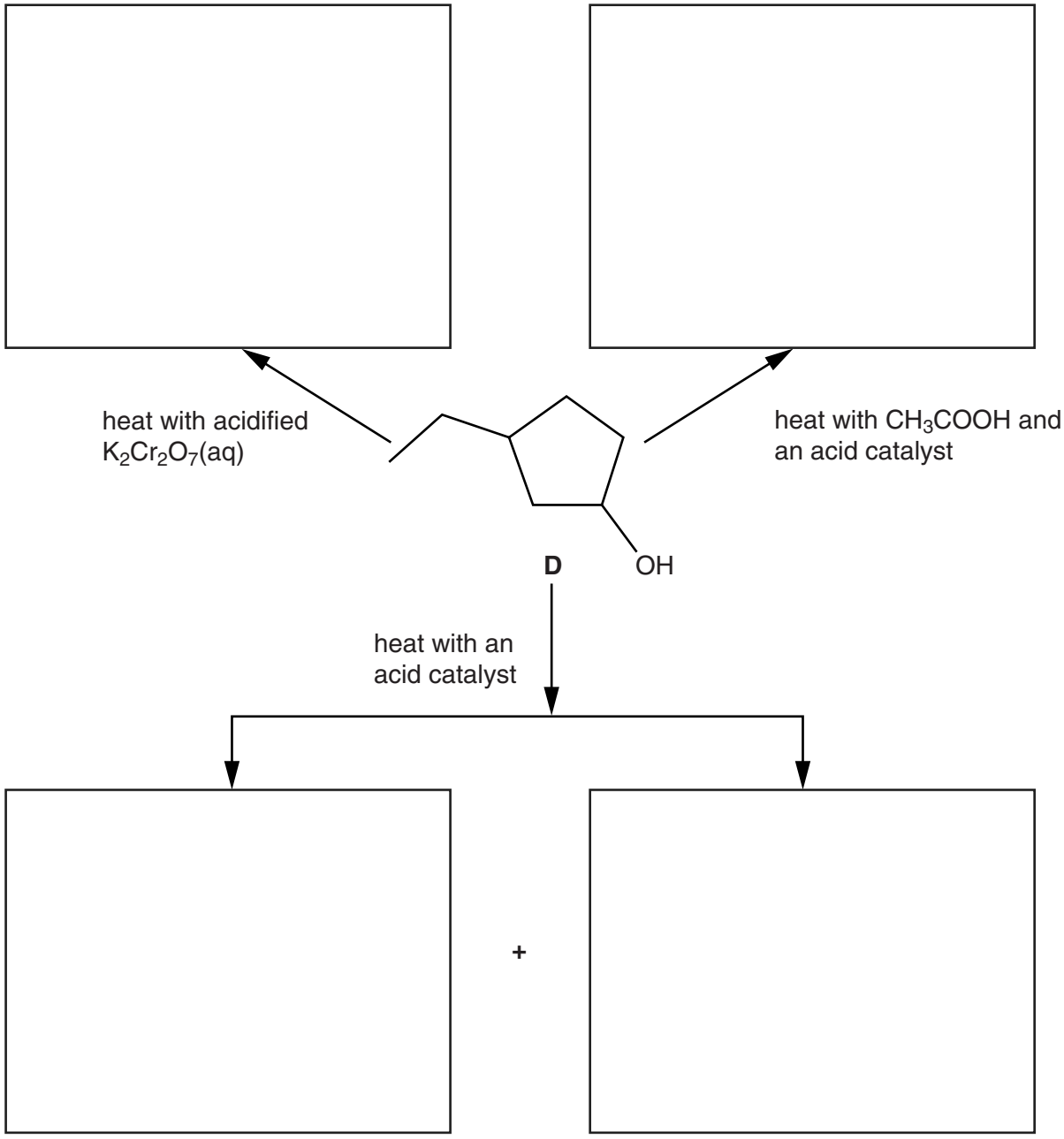
..... **[2]**

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(d) Alcohol **D** is reacted with three different reagents.

Complete the flowchart below to show the organic product(s) formed in each of the reactions of alcohol **D**.



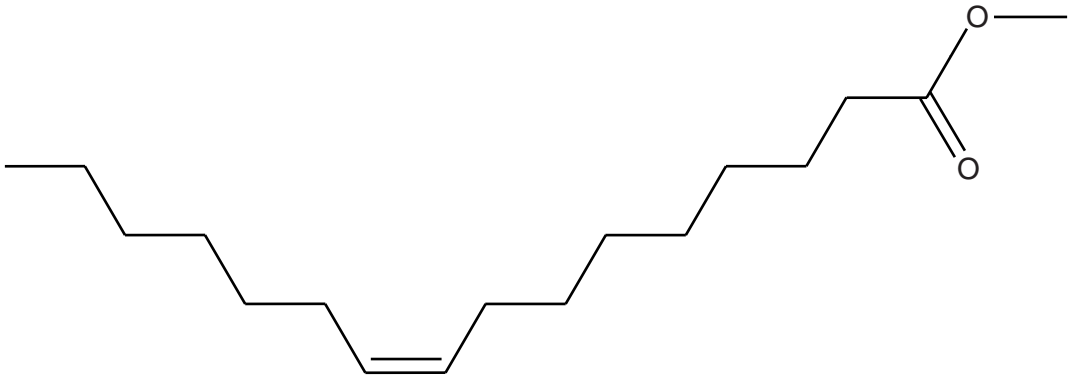
[4]

[Total: 11]

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3 Compound **I** is found in biodiesel. It has the skeletal formula shown below.



(a) Name the **two** functional groups that are present in a molecule of **I**.

.....

..... **[2]**

(b) Why is compound **I** unsaturated?

.....

..... **[1]**

(c) A sample of compound **I** is shaken with aqueous bromine.

What colour change would you see?

from ..... to ..... **[1]**

(d) Compound **J** is a stereoisomer of compound **I**.

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

.....

.....

..... **[1]**

(ii) Draw or describe how the structure of **J** differs from that of **I**.

.....

.....

..... **[1]**

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(e) A student determined the enthalpy change of combustion for compound **I**.

In her experiment, 1.34 g of compound **I** was used to heat 50.0 g of water.

The temperature of the water changed from 20.2 °C to 54.0 °C.

(i) What is meant by the term *enthalpy change of combustion*, ΔH_c?

.....

.....

..... **[2]**

(ii) Calculate the energy released, in kJ, in the student's experiment.

The specific heat capacity of water is 4.18 J g^{-1} K^{-1}.

energy = ... kJ **[2]**

(iii) The molecular formula of compound **I** is $C_{17}H_{32}O_2$.

Calculate the amount, in moles, of compound **I** used by the student.

amount = ... mol **[2]**

(iv) Calculate the enthalpy change of combustion of compound **I**.

ΔH_c = ... kJ mol^{-1} **[3]**

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(v) The student noticed that compound **I** burnt with a yellow flame and produced black smoke.

Suggest an explanation for these observations.

.....

.....

..... **[1]**

(f) Some scientists believe that we should use more biofuels such as biodiesel and bioethanol.

Bioethanol is made by the fermentation of plant sugars such as glucose.

Write the equation for the fermentation of glucose to make ethanol and state **two** essential conditions for this fermentation.

equation

.....

essential conditions

.....

..... **[3]**

[Total: 19]

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4 Iodine monobromide, IBr, has a permanent dipole.

Alkenes react with IBr in a similar way to the reactions of alkenes with HBr.

(a) Propene reacts with IBr to make two possible organic products.

One of these products is 2-bromo-1-iodopropane.

(i) Using the curly arrow model, complete the mechanism to make 2-bromo-1-iodopropane.



[3]

(ii) What is the name of this mechanism?

..... **[1]**

(iii) Draw the structure of the other possible organic product of the reaction of propene with IBr.

[1]

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(b) Methane reacts with IBr to form many products.

Two of these products are iodomethane and hydrogen bromide.

(i) Suggest the essential condition needed for this reaction.

..... **[1]**

(ii) The mechanism of the reaction involves three steps, one of which is called termination.

Describe the mechanism of the reaction that forms iodomethane and hydrogen bromide.

Include in your answer:

- the name of the mechanism
- the names for the **other two** steps of the mechanism
- equations for these two steps of the mechanism
- the type of bond fission
- one equation for a termination step.



Your answer should link the named steps to the relevant equations.

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..... **[7]**

[Total: 13]

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5 Nitrogen forms several oxides including N_2O_4, N_2O and NO.

(a) A rocket uses the reaction between N_2O_4 and methylhydrazine, CH_3NHNH_2, **equation 5.1**, to release a large amount of energy.

$$4CH_3NHNH_2(l) + 5N_2O_4(l) \longrightarrow 4CO_2(g) + 12H_2O(g) + 9N_2(g) \quad \textbf{equation 5.1}$$

Some enthalpy changes of formation, ΔH_f, are shown in the table.

Substance	ΔH_f / kJ mol^{-1}
$CH_3NHNH_2(l)$	+54
$N_2O_4(l)$	–20
$CO_2(g)$	–394
$H_2O(g)$	–242

Using the enthalpy changes of formation, ΔH_f, calculate the enthalpy change of reaction in **equation 5.1**.

enthalpy change of reaction = ... kJ mol^{-1} **[3]**

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(b) Under certain conditions nitrogen reacts with oxygen to make N_2O.

$$2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g) \quad \textbf{equation 5.2}$$

The enthalpy profile diagram for this reaction is shown in **Fig. 5.3**.

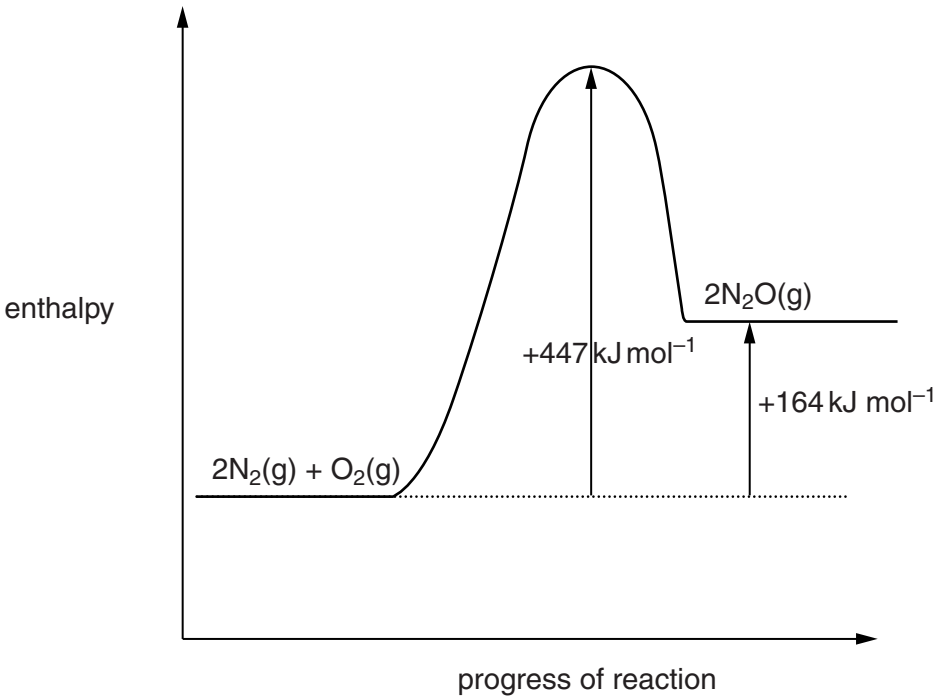


Fig. 5.3

(i) Calculate the enthalpy change when 240 dm^3 of $N_2O(g)$, measured at room temperature and pressure, is formed from N_2 and O_2.

enthalpy change = ... kJ **[2]**

(ii) What is the enthalpy change of formation, ΔH_f, of $N_2O(g)$?

ΔH_f = ... $kJ\,mol^{-1}$ **[1]**

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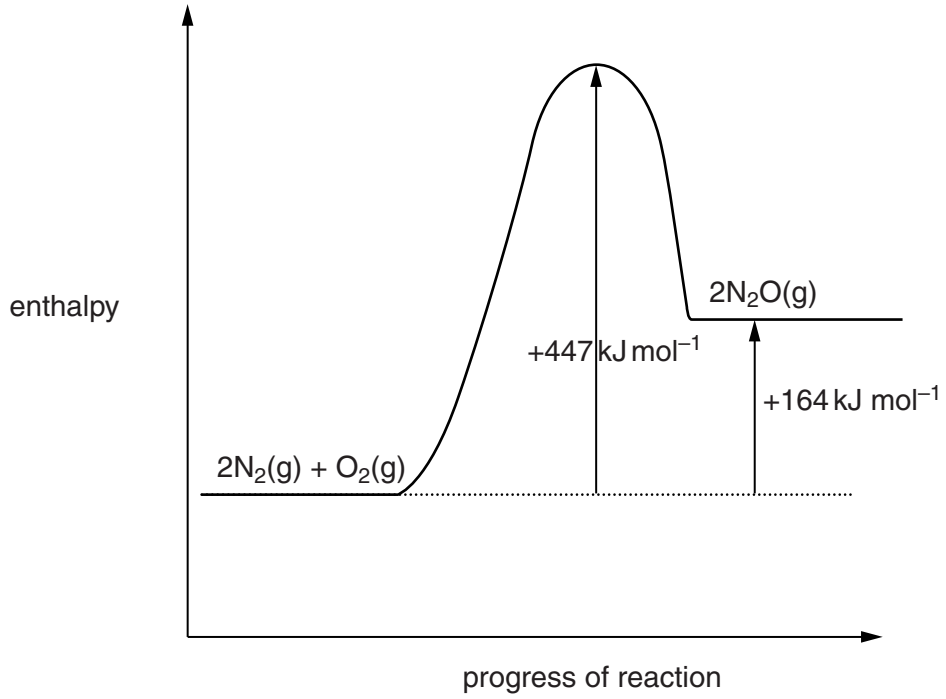


Fig. 5.3 (repeated)

(iii) The reaction in **equation 5.2** is reversible.

$$2N_2(g) + O_2(g) \rightleftharpoons 2N_2O(g) \quad \textbf{equation 5.2}$$

Calculate the activation energy, E_a, for the reverse reaction.

E_a (reverse reaction) = ... kJ mol^{-1} **[1]**

(c) Describe and explain, using equations, how the concentration of ozone in the stratosphere is maintained.

.....

.....

.....

..... **[2]**

(d) In the stratosphere, NO catalyses the breakdown of ozone.

Write **two** equations to show how NO catalyses this breakdown.

.....

..... **[2]**

[Total: 11]

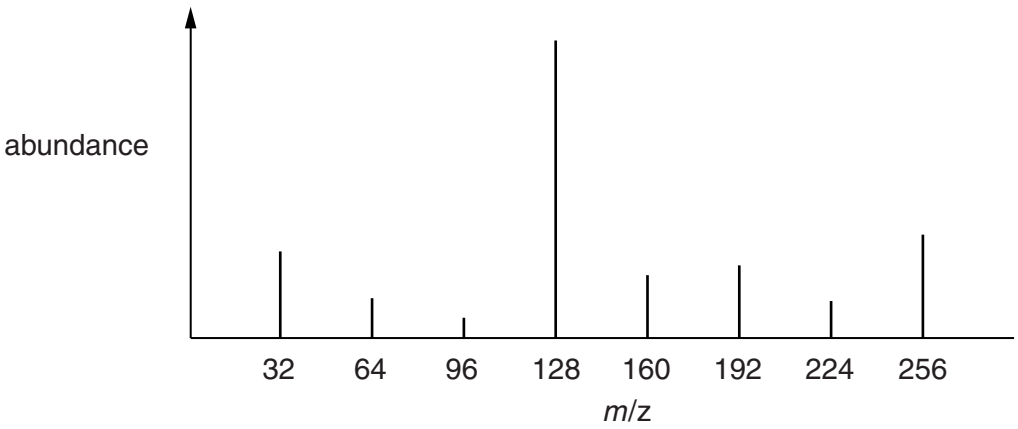
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6 Mass spectrometry and infrared spectroscopy are used in analysis.

(a) The element sulfur exists as molecules, S_n.

The mass spectrum that would be given by a sample of sulfur is shown below.
All the sulfur atoms are the same isotope.



(i) State the *m/z* value of the molecular ion.

..... **[1]**

(ii) Suggest the formula for a molecule of sulfur.

..... **[1]**

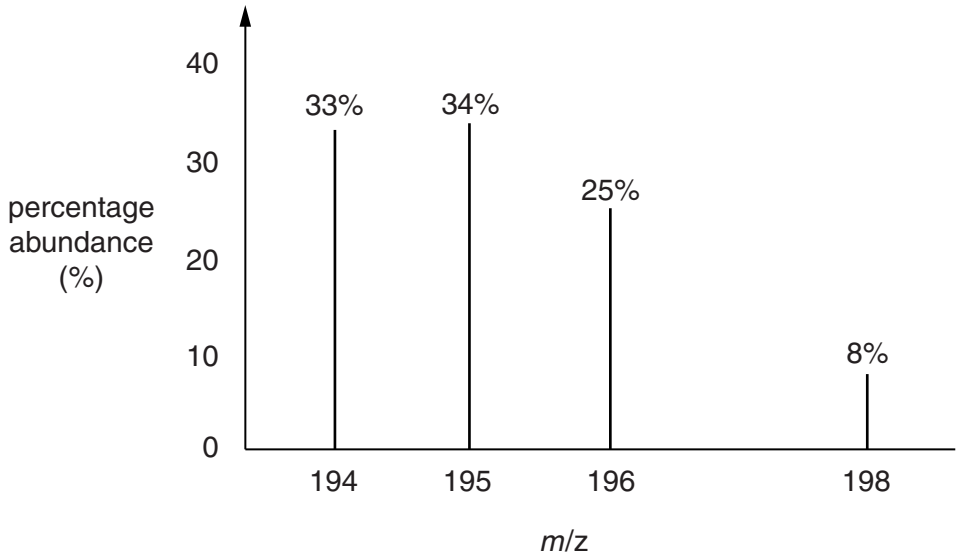
(iii) What is the formula for the fragment ion with *m/z* = 128?

..... **[1]**

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(b) A sample of an element, **L** is analysed using mass spectrometry.
The mass spectrum is shown below.



Calculate the relative atomic mass of **L**.
Give your answer to **one** decimal place.

relative atomic mass of **L** = ... **[2]**

(c) Give an everyday use for infrared spectroscopy.

.....

..... **[1]**

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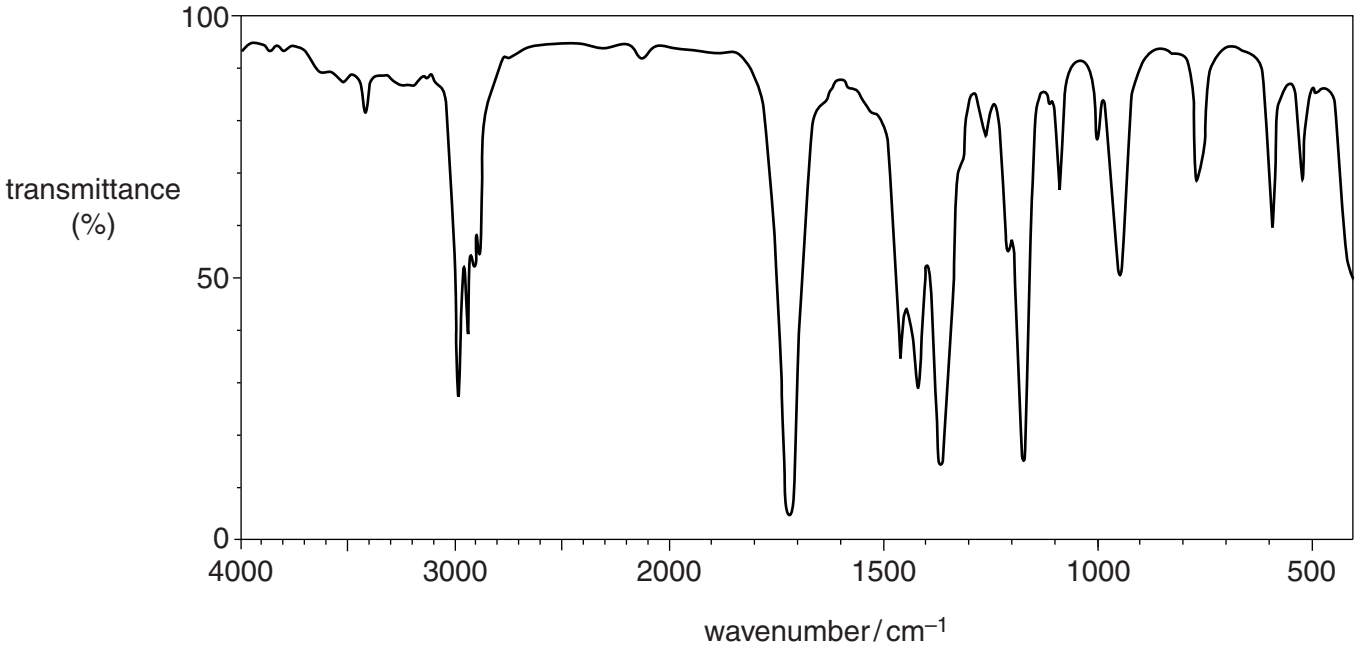
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(d) The solvent, **M**, is an organic compound used in paints. The solvent **M** was analysed.

M has a relative molecular mass of 72.0.

The percentage composition by mass of **M** is C, 66.7%; H, 11.1%; O, 22.2%.

The infrared spectrum of **M** is shown below.



The analysis produces several possible organic structures.

Suggest, with reasons, **two** possible structures for **M**.

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..... **[5]**

[Total: 11]

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7 The list shows the structural formulae of some halogenoalkanes.

N	CF_3CFCl_2	**R**	$CH_3CH_2CHClCH_3$
O	CH_3CH_2Br	**S**	$CH_3CHBrCH_2CHICH_3$
P	$CH_3CH_2CH_2CH_2Br$	**T**	$(CH_3)_3CBr$
Q	$CH_3CH_2CH_2CH_2I$		

(a) Choose from the list above, the **letter** of the halogenoalkane that is extremely unreactive.

..... **[1]**

(b) Halogenoalkanes react with hot KOH(aq) to make alcohols.

(i) Choose from the list above, the **letter** of the halogenoalkane which reacts with hot KOH(aq) to form a diol (a molecule with two OH groups).

..... **[1]**

(ii) Using the curly arrow model, describe the mechanism of the reaction between $CH_3CH_2CH_2CH_2Br$ and hot KOH(aq) to make an alcohol.

Include relevant dipoles and the name of the mechanism.

name of mechanism ..... **[4]**

(iii) Why is the reaction of **P** with hot KOH(aq) slower than the reaction of **Q** with hot KOH(aq)?

.....

.....

..... **[1]**

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(c) Write one equation, using structural formulae, to show how but-2-ene can be converted into one of the listed halogenoalkanes, **N**, **O**, **P**, **Q**, **R**, **S** or **T**.

[2]

(d) CFCs were once used as propellants but have now been replaced by biodegradable alternatives.

State **one** type of a biodegradable alternative.

..... **[1]**

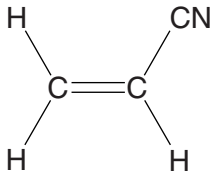
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8 Poly(propenenitrile) is used to make acrylic fibres for clothing.

Poly(propenenitrile) is a polymer manufactured from propenenitrile.



propenenitrile

(a) Draw a section showing **two** repeat units of poly(propenenitrile).

[1]

(b) Explain why this manufacture of poly(propenenitrile) has a 100% atom economy.

.....

..... **[1]**

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(c) Propenenitrile is manufactured from propene as shown in the equation.

$$C_3H_6(g) + NH_3(g) + 1\frac{1}{2}O_2(g) \rightleftharpoons CH_2CHCN(g) + 3H_2O(g) \quad \Delta H = -540\,kJ\,mol^{-1}$$

The conditions used are 450 °C and 2.5 atmospheres in the presence of a catalyst.

Describe and explain, using le Chatelier's principle, the effect on the position of equilibrium of the following changes:

- a temperature above 450 °C
- a pressure above 2.5 atmospheres
- the absence of a catalyst.



In your answer you should link the effects you describe with your explanations.

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..... **[5]**

Question 8 continues on page 22

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(d) A factory is able to make 11.13 kg of propenenitrile from 220 mol of propene.

Calculate the percentage yield of the reaction to form propenenitrile from propene.

percentage yield = ... % **[2]**

(e) The chemical industry uses temperature and catalysts to control the rate of reactions.

Using Boltzmann distribution diagrams, explain the effect on the rate of a reaction of:

- increasing the temperature
- adding a catalyst.

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..... **[7]**

[Total: 16]

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page. The question number(s) must be clearly shown in the margin.

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GCE

Chemistry A

Advanced Subsidiary GCE

Unit **F322:** Chains, Energy and Resources

Mark Scheme for June 2013

Oxford Cambridge and RSA Examinations

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes should be read in conjunction with the published question papers and the report on the examination.

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Annotations

Annotations available in Scoris.

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
I	Ignore
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct response
SEEN	Noted but no credit given
REP	Repeat

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Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

All questions should be annotated with ticks to show where marks have been awarded in the body of the text.

All questions where an ECF has been applied should also be annotated with the ECF annotation.

Use the omission mark where the answer is not sufficient to be awarded a mark.

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Generic comments

ORGANIC STRUCTURES

For a 'structure' or 'structural formula',

- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)

For an alkyl group shown within a structure,

- **ALLOW** bond drawn to C or H,

eg **ALLOW** CH_3–,CH_2–, C_3H_7–, etc

- **ALLOW** vertical 'bond' to any part of an alkyl group

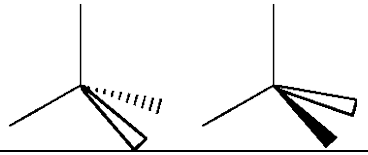
For an OH group shown within a structure,

- **DO NOT ALLOW** formula with horizontal —HO **OR** —HO
- **ALLOW** vertical 'bond' to any part of the OH group

For a CHO group shown within a structure,

- **DO NOT ALLOW** COH

For a 3D structure,

• For bond in the plane of paper, a solid line is expected:	
• For bond out of plane of paper, a solid wedge is expected:	
• For bond into plane of paper, **ALLOW**:	
• **ALLOW** a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge eg:	

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NAMES
Names including alkyl groups:
- **ALLOW** alkanyl, eg ethanyl (ie **IGNORE** 'an')
- **DO NOT ALLOW** alkol, eg ethol (ie 'an' is essential)

Names of esters:
- Two words are expected, eg ethyl ethanoate
- **ALLOW** one word, eg ethylethanoate

Names with multiple numbers and hyphens:
Use of 'e'
- **ALLOW** superfluous 'e' , eg propane-1-ol ('e' is kept if followed by consonant)
- **ALLOW** absence of 'e', eg propan-1,2-diol ('e' is omitted if followed by vowel)

Hyphens separate name from numbers:
- **ALLOW** absence of hyphens, eg propane 1,2 diol

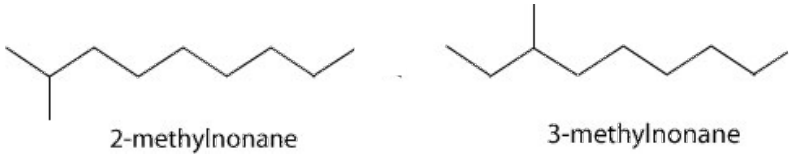
Multiple locant numbers must be clearly separated:
- **ALLOW** full stops: eg 1.2 OR spaces: 1 2
- **DO NOT ALLOW eg** 12

Locant numbers in formula must be correct
- **DO NOT ALLOW** propan-3-ol

Order of substituents should be alphabetical:
- **ALLOW** any order (as long as unambiguous), eg 2-chloro-3-bromobutane

ABBREVIATIONS
van der Waal's forces
ALLOW vdw forces **OR** VDW forces (and any combination of upper and lower cases)

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Question			Answer	Marks	Guidance
1	(a)	(i)	$C_{10}H_{22}$ ✓	1	**IGNORE** the name decane
		(ii)	Correct skeletal formula ✓ Correct name for structure drawn providing the structure is a branched chain isomer of $C_{10}H_{22}$ ✓	2	**DO NOT ALLOW** structural formula **OR** displayed formula Examples of skeletal formulae:  **ALLOW** name even if structural or displayed formula drawn **DO NOT ALLOW** incorrect nomenclature eg 2-ethyloctane, 6-methylnonane, 2-methnonane, 2-methylnonan, 2-methynonane There are many more isomers that can be drawn

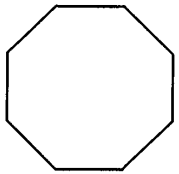
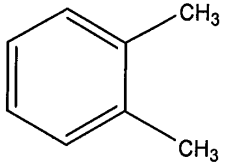
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Question			Answer	Marks	Guidance
1	(a)	(iii)	**B** has less surface (area of) contact **OR** ORA **AND** **B** has fewer **van der Waals**' forces **OR B** has weaker **van der Waals**' forces **OR** ORA ✓	2	**Both answers need to be comparisons** Assume 'it' refers to **B** **ALLOW B** has less points of contact **AND** fewer VDW **DO NOT ALLOW** less points of contact between atoms Reference to just surface area or closeness of molecules is **not** sufficient. **IGNORE** if not qualified **IGNORE B** more compact **OR B** has a shorter chain **DO NOT ALLOW B** is a smaller molecule **DO NOT ALLOW B** has fewer electrons Intermolecular forces is **not** sufficient for the first marking point must refer to van der Waals' **ALLOW** ORA throughout in terms of **A** if specified
			So less energy needed to break the intermolecular forces in **B OR** ORA ✓		**ALLOW** in **B** it takes less energy to overcome the intermolecular forces **ALLOW** it is easier to overcome the intermolecular forces **DO NOT ALLOW** so less energy is needed to break bonds **DO NOT ALLOW** intermolecular bonds

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Question			Answer	Marks	Guidance
1	(b)	(i)	Correct equation for the cracking of $C_{15}H_{32}$ ✓ eg $C_{15}H_{32} \rightarrow C_{13}H_{28} + C_2H_4$	1	**ALLOW** molecular formula **OR** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** any correct equation that has an alkane and alkene(s) (and hydrogen) as products **OR** has alkenes and hydrogen as products e.g. $C_{15}H_{32} \rightarrow C_{11}H_{24} + 2C_2H_4$ $C_{15}H_{32} \rightarrow C_6H_{12} + C_9H_{18} + H_2$ **IGNORE** state symbols
		(ii)	(idea that) any **carbon–carbon** bond (in the chain) can break ✓	1	**ALLOW carbon chain** can break in many different places **ALLOW** the position of breakdown of the **carbon chain** is random **ALLOW** the **carbon chain** can break in many different places **ALLOW** carbon chain can split in many different places Carbon chain is cracked in many places is **not** sufficient Molecule can break anywhere is **not** sufficient / cannot control where the molecule breaks is not sufficient Molecule can form many different chain lengths is **not** sufficient

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Question			Answer	Marks	Guidance
1	(c)	(i)	Any cyclic hydrocarbon with eight carbon atoms in all ✓ eg   	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** equation with the correct product **DO NOT ALLOW** if any other extra structure is included which is incorrect **DO NOT ALLOW** 'aromatic cyclooctatetraene' but **ALLOW** this as a normal structural formula **IGNORE** hydrogen as an extra product **IGNORE** any name given

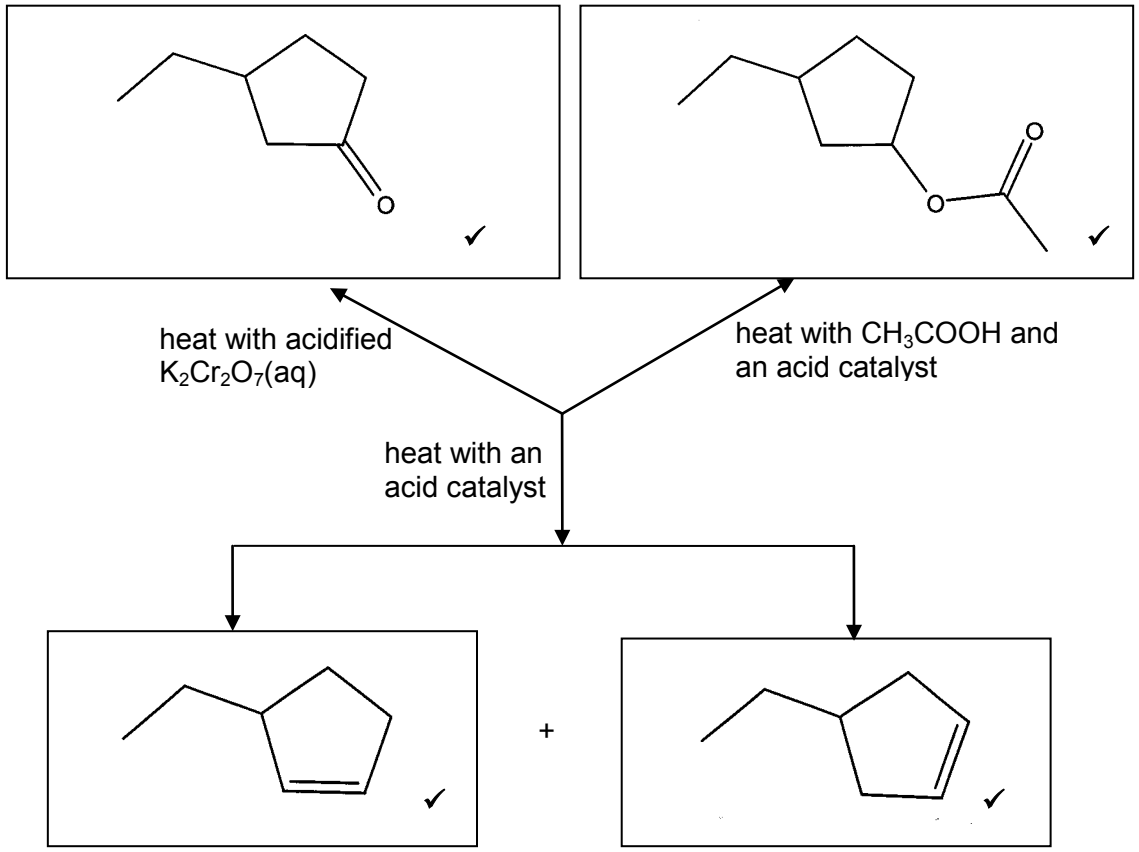
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Question			Answer	Marks	Guidance
1	(c)	(ii)	Cyclic hydrocarbons promote efficient combustion ✓	1	**The answer must relate to combustion or burning** **ALLOW** cyclic hydrocarbons allow smoother burning **OR** cyclic hydrocarbons increase octane number **OR** cyclic hydrocarbons reduce knocking **OR** cyclic hydrocarbons are less likely to produce pre-ignition **OR** cyclic hydrocarbons are more efficient fuels **OR** cyclic hydrocarbons burn better **OR** easier to burn **OR** cyclic hydrocarbon combust more easily **OR** improves combustion **DO NOT ALLOW** cyclic hydrocarbons ignite more easily **ALLOW** ora for straight chain hydrocarbons **IGNORE** cyclic hydrocarbons increase volatility of fuel **IGNORE** cyclic hydrocarbons have a lower boiling point Cyclic hydrocarbons are a better fuel on their own is **NOT** sufficient Cyclic hydrocarbons burn more cleanly on their own is **NOT** sufficient
			Total	**9**	

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Question			Answer	Marks	Guidance
2	(a)	(i)	**E** and **H** ✓	1	**ALLOW** pentan-2-ol **and** 2-methylbutan-2-ol
		(ii)	**H** ✓	1	**ALLOW** 2-methylbutan-2-ol
		(iii)	**F** ✓	1	**ALLOW** propan-1-ol
	(b)	(i)	$C_5H_{10}O$ ✓	1	**ALLOW** any order of atoms **DO NOT ALLOW** C_5H_9OH
		(ii)	2-methylpentan-3-ol ✓	1	**ALLOW** 2-methylpentane-3-ol **ALLOW** absence of hyphens or use of commas **ALLOW** space between methyl and pentan **DO NOT ALLOW** 2-methylpent-3-ol **OR** 2-methypentan-3-ol **OR** 2-metpentan-3-ol, 4-methylpentan-3-ol etc
	(c)		(series of compound) with same functional group ✓ and each **successive** member differing by CH_2 ✓	2	**IGNORE** with same or similar chemical properties **OR** same or similar chemical reactions **IGNORE** references to physical properties or named physical properties vary with an observable trend. **IGNORE** have similar or the same physical properties **IGNORE** has same general formula **ALLOW** each subsequent member varying by CH_2 **DO NOT ALLOW** have the same empirical formula **OR** have the same molecular formula

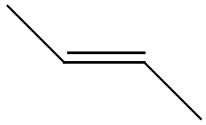
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Question	Answer	Marks	Guidance
2 (d)		4	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **IGNORE** inorganic products if written in, eg H_2O for the elimination reactions **IGNORE** names of compounds **ALLOW** in either order
	Total	**11**	

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Question			Answer	Marks	Guidance
3	(a)		alkene ✓ ester ✓	2	**ALLOW** carbon–carbon double bond **OR** a C-C double bond A double bonded carbon is **not** sufficient C=C is **not** sufficient Carbon-carbon multiple bond is **not** sufficient Ketone / carbonyl / aldehyde / carboxylic acid contradicts the ester mark
	(b)		contains a C=C bond ✓	1	Contains a double bond is **not** sufficient Carbon-carbon multiple bond is **not** sufficient **DO NOT ALLOW** contains a C=O bond
	(c)		(from) orange (to) colourless ✓	1	**ALLOW** shades of orange **OR** yellow **OR** brown **ALLOW** orange to decolourised **DO NOT ALLOW** red alone **DO NOT ALLOW** any response that includes precipitate **OR** solid, irrespective of colour **DO NOT ALLOW** clear for colourless
	(d)	(i)	Same structural formula **AND** different arrangement (of atoms) **in space OR** different **spatial** arrangement ✓	1	**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 Different three dimensional arrangement is **not** sufficient Reference to *E*/*Z* isomerism or optical isomerism is **not** sufficient

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Question			Answer	Marks	Guidance
3	(d)	(ii)	 ✓	1	**Any writing must not contradict the diagram** **IGNORE** any other feature of the structure drawn **ALLOW** the **J** will be the *E* isomer and **I** is the *Z* isomer **ALLOW** the **J** will be the *trans* isomer and **I** is the *cis* isomer **ALLOW** a description, eg the other isomer will have (carbon) chains diagonally arranged across the C=C or the other isomer will have hydrogen atoms diagonally arranged across the C=C bond **DO NOT ALLOW** draw *trans* but label as *cis*
	(e)	**(i)**	(Enthalpy change that occurs) when one mole of a substance ✓ completely combusts **OR** reacts fully with oxygen ✓	2	**ALLOW** energy required **OR** energy released **ALLOW** (energy change) when one mole of an element / compound / molecule / reactant **DO NOT ALLOW** one mole of reactant**s** / product / substance**s** / fuel / atoms **ALLOW** combusts in excess oxygen **ALLOW** burns in excess oxygen **DO NOT ALLOW** combust in excess air **IGNORE** fully oxidised **IGNORE** any conditions stated

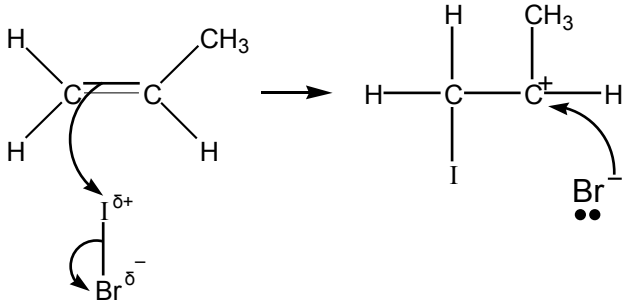
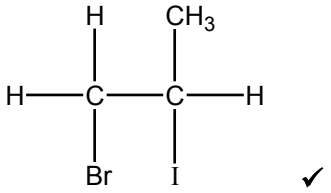
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Question			Answer	Marks	Guidance
3	(e)	(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 7.06(42), award **2 marks.** **IF** answer = 7.1, award **1 mark.** q = 50.0 × 4.18 × 33.8 **OR** 7064.2 (J) ✓ = 7.06(42) (kJ) ✓	2	 **ALLOW** 7.06 up to calculator value of 7.0642 correctly rounded **DO NOT ALLOW ECF** from marking point 1 **IGNORE** negative sign in answer
		(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 0.005(00), award **2 marks.** M_r = 268.0 ✓ amount used = 0.005(00) (mol) ✓	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **ALLOW** 268 **ALLOW** 5 x 10^{-3} **ALLOW** ECF from incorrect M_r **IGNORE** trailing zeros
		(iv)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = -1413, award **3 marks.** **IF** answer = 1413, award **2 marks.** $\Delta H = \frac{\text{answer to (ii)}}{\text{answer to (iii)}}$ **OR** $\frac{7.0642}{0.005}$ ✓ 1413 ✓ minus sign (this is an independent mark) ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **ALLOW** ECF from **(ii)** and **(iii)** **ALLOW** 1410 up to calculator value of 1412.84 correctly rounded **ALLOW** answers in standard form 1.41 x 10^3 up to calculator value of 1.41284 x 10^3 correctly rounded Answer must be at least **three** significant figures **ALLOW** 1412 if answer to (ii) is 7.06 **ALLOW** 1420 if answer to (ii) is 7.1

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Question			Answer	Marks	Guidance
3	(e)	(v)	incomplete combustion **OR** not sufficient oxygen available **AND** carbon is formed ✓	1	**IGNORE** soot is formed, carbon monoxide is formed or carbon dioxide is formed
	(f)		$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$ ✓ use of yeast **OR** zymase ✓ anaerobic **OR** absence of oxygen **OR** any temperature between 20 and 45 ^{o}C **OR** water **OR** aqueous ✓	3	**ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **IGNORE** state symbols Enzyme is **not** sufficient **DO NOT ALLOW** acid catalyst **If there is a contradiction or an incorrect answer in any condition given then do not award this mark.** **ALLOW** room temperature Temperature quoted **must** include unit **ALLOW** conditions shown in the equation **IGNORE** warm temperature **IGNORE** heat / warm Body temperature is **not** sufficient A limited supply of oxygen is **not** sufficient **IGNORE** low pressure **OR** atmospheric pressure **DO NOT ALLOW** high pressure **OR** a pressure above 2 atmospheres
			Total	**19**	

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Question			Answer	Marks	Guidance
4	(a)	(i)	correct curly arrow from double bond to iodine atom and curly arrow from the I–Br bond to the bromine atom ✓ correct carbonium ion **OR** correct carbocation ✓ correct curly arrow from bromide ion to the (positive) carbon ✓ 	3	Curly arrow must start from bond and go to correct atom **DO NOT ALLOW** partial charges on carbon–carbon double bond **DO NOT ALLOW** δ+ on carbon atom The positive charge must be associated with the carbon atom and not with a bond Make certain the carbonium ion includes the iodine atom Curly arrow must come from any lone pair or the negative sign of the bromide ion The lone pair on the bromide ion does not need to be shown
		(ii)	Electrophilic addition ✓	1	
		(iii)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) eg $CH_2BrCHICH_3$ **IGNORE** any name given

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Question			Answer	Marks	Guidance
	(b)	(i)	Ultraviolet **OR** UV ✓	1	**ALLOW** high temperature **OR** 300 ^{o}C **IGNORE** light/radiation **DO NOT ALLOW** any catalyst
		(ii)		7	**Use the SEEN annotation on page 11 if blank or no credit can be given**
			(free) radical substitution ✓		**IGNORE** any state symbols in equations Radicals do **NOT** need a single dot
			(Initiation step) IBr → Br + I ✓		**IGNORE** dots
			homolytic fission ✓		**DO NOT ALLOW** homolytical fission Heterolytic anywhere in the answer contradicts this mark
			(Propagation steps) Br + CH_4 → HBr + CH_3 ✓		**IGNORE** I + CH_4 → HI + CH_3
			CH_3 + IBr → CH_3I + Br ✓		**IGNORE** CH_3 + IBr → CH_3Br + I **DO NOT ALLOW** equations with H **OR** any other incorrect equation (i.e. not one of the four propagation steps shown)
			(Termination steps) I + CH_3 → CH_3I **OR** Br + Br → Br_2 **OR** I + I → I_2 **OR** Br + CH_3 → CH_3Br **OR** CH_3 + CH_3 → C_2H_6 **OR** I + Br → IBr ✓		**ALLOW** any other suitable termination steps **DO NOT ALLOW** termination steps with H
			QWC propagation linked to **correct** equations Br + CH_4 → HBr + CH_3 CH_3 + IBr → CH_3I + Br **AND** initiation linked to **correct** equation IBr → Br + I ✓		**QWC** can only be given if marking points 2, 4 and 5 have been awarded
			Total	**13**	

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Question			Answer	Marks	Guidance
5	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = –4596, award **3 marks.** **IF** answer = +4596 award **2 marks.** (–)116 ✓ (–)4480 ✓ –4596 ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **ALLOW** 116 **OR** –4(+54) –5(–20) **OR** –216 + 100 **ALLOW** 4480 **OR** 4(–394) + 12(–242) **OR** –1576 – 2904 **ALLOW** ecf from $\Delta H_{products} - \Delta H_{reactants}$ **ALLOW for 2 marks** (+)4596 (cycle the wrong way round) **OR** –4364 ($\Delta H_{reactants}$ the incorrect sign) **OR** (+)4364 ($\Delta H_{products}$ the incorrect sign) **OR** –752 (moles not used for products) **OR** –4514 (moles not used for reactants) **ALLOW for 1 mark** (+)752 (moles not used for products and the cycle the wrong way round) **OR** (+)4514 (moles not used for reactants and the cycle the wrong way round) **OR** –670 (moles not used for reactants and products) **Note:** There may be other possibilities

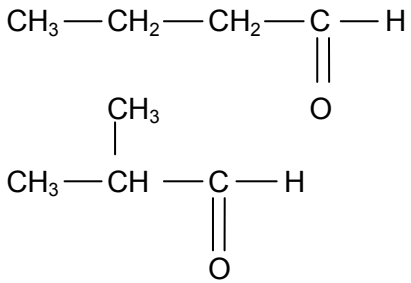
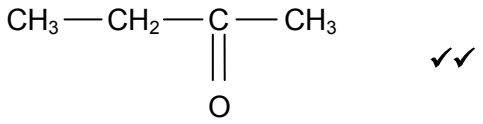
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Question			Answer	Marks	Guidance
5	(b)	(i)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = +820, award **2 marks.** **IF** answer = –820 or +1640 award **1 mark.** amount of N_2O = 10 (mol) ✓ enthalpy change = (+)820 ✓	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **ALLOW** ECF, ie moles of N_2O x enthalpy of formation
		(ii)	(+)82 ✓	1	
		(iii)	(+)283 ✓	1	
	(c)		$O_3 \rightarrow O_2 + O$ **AND** $O + O_2 \rightarrow O_3$ ✓ rate of ozone decomposition (almost) equals rate of ozone formation ✓	2	**ALLOW** $O_3 \rightleftharpoons O_2 + O$ **ALLOW** $O_3 \rightarrow O_2 + O$ is reversible **ALLOW** $O + O_2 \rightarrow O_3$ is reversible **IGNORE** dots **IGNORE** other equations involving ozone, eg $O + O_3 \rightarrow 2O_2$ **IGNORE** comments about an equilibrium **ALLOW** rate of forward reaction is similar to the rate of the backward reaction if marking point 1 is awarded
	(d)		$NO + O_3 \rightarrow NO_2 + O_2$ ✓ $NO_2 + O \rightarrow NO + O_2$ ✓	2	**ALLOW** $NO_2 + O_3 \rightarrow NO + 2O_2$ ✓ **IGNORE** dots **IGNORE** $O + O_3 \rightarrow 2O_2$ **IGNORE** $2O_3 \rightarrow 3O_2$
			Total	**11**	

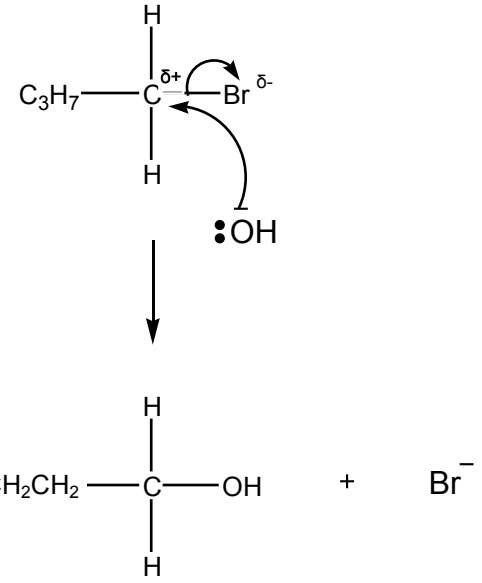
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Question			Answer	Marks	Guidance
6	(a)	(i)	256 ✓	1	
		(ii)	S_8 ✓	1	**ALLOW** $^{32}S_8$ **OR** $^{32}_{16}S_8$ **DO NOT ALLOW** $^{33}S_8$ **OR** $^{30}_{16}S_8$ etc
		(iii)	S_4^+ ✓	1	Positive ion must be present **ALLOW** $^{32}S_4^+$ **OR** $^{32}_{16}S_4^+$ **DO NOT ALLOW** $^{33}S_4^+$ **OR** $^{30}_{16}S_4^+$ etc
	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 195.2, award **2 marks.** **IF** answer = 195.16 award **1 marks.** $= \frac{(194\times33)+(195\times34)+(196\times25)+(198\times8)}{100}$ ✓ 195.2 ✓	2	195 on its own with no working scores 0 marks
	(c)		Monitor **air** pollution **OR** breathalysers ✓	1	**ALLOW** measure the concentration or abundance of atmospheric pollutants **ALLOW** measure concentration of named atmospheric pollutant **ALLOW** monitoring of gases in car exhaust fumes **ALLOW** drug detection or drug identification **IGNORE** night vision goggles, identifying gases on distant planets / ice samples

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Question			Answer	Marks	Guidance
6	(d)		mole ratio C : H : O $\frac{66.7}{12.0} : \frac{11.1}{1.0} : \frac{22.2}{16.0}$ **OR** 5.56 :11.1 : 1.39 ✓ 4 : 8 : 1 **OR** C_4H_8O ✓ contains a C=O or carbonyl because of absorbance at about 1710 cm^{-1} ✓ ***Any two from:***   ✓✓ 	5	**PLEASE LOOK AT THE SPECTRA AND ABOVE THE SPECTRA FOR POSSIBLE ANSWERS** **ALLOW** two marks for 72 x 66.7/100 = 48/12 = 4 (C) 72 x 11.1/100 = 8 = 8 (H) 72 x 22.2/100 = 16 = 1 (O) **ALLOW** C=O or carbonyl since has absorbance within the range 1640 to 1750 cm^{-1} **ALLOW** ketone **OR** aldehyde linked to correct absorbance **ALLOW** 'could be aldehyde, ketone, carboxylic acid, ester (or amide) because of absorbance between range 1640 to 1750 cm^{-1}' (ie direct quote from the data book) **DO NOT ALLOW** reference to **M** being a carboxylic acid, ester or amide **unless** they are included in a list with aldehyde/ketone in which case **IGNORE** carboxylic acid/ester/amide **IGNORE** reference to C—O / absence of O—H **DO NOT ALLOW** has O—H **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **eg** $CH_3CH_2CH_2CHO$, $CH_3COCH_2CH_3$ **OR** $(CH_3)_2CHCHO$ **DO NOT ALLOW** C_3H_7CHO **IGNORE** incorrect name correct name on its own is **not** sufficient
			Total	**11**	

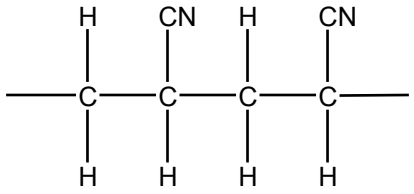
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Question			Answer	Marks	Guidance
7	(a)		**N** ✓	1	**ALLOW** CF_3CFCl_2
	(b)	(i)	**S** ✓	1	**ALLOW** $CH_3CHBrCH_2CHICH_3$
		(ii)	curly arrow from HO^- to carbon atom of C−Br bond ✓ Dipole shown on C−Br bond, $C^{\delta+}$ and $Br^{\delta-}$, and curly arrow from C−Br bond to the halogen atom – arrow must be very close to the bond ✓ correct products of the reaction – not ambiguous with the C_3H_7 ✓  nucleophilic substitution ✓	4	The curly arrow must start from the **oxygen atom** of the OH^-, and must start either from a lone pair or from the negative charge. No need to show lone pair if curly arrow came from negative charge **DO NOT ALLOW** attack by KOH or K^+OH^- **ALLOW** S_N1 Dipole shown on C−Br bond, $C^{\delta+}$ and $Br^{\delta-}$, and curly arrow from C–Br bond to the halogen atom – arrow must be very close to the bond ✓ Correct carbocation drawn **AND** curly arrow from HO^- to the carbocation (the curly arrow must start from the **oxygen atom** of the OH^-, and must start either from a lone pair or from the negative charge. No need to show lone pair if curly arrow came from negative charge) ✓ Correct products of the reaction – not ambiguous with the C_3H_7 ✓ nucleophilic substitution ✓

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Question			Answer	Marks	Guidance
7	(b)	(iii)	C−I bond is weaker than C−Br bond **OR** C−I has a lower bond enthalpy than C−Br bond **OR** C−I bond is longer than C−Br bond **AND** C−I bond is easier to break than C−Br bond **OR** less energy is needed to break the C−I bond ✓	1	Answer must refer to the correct bond **ALLOW** ora **IGNORE** references to electronegativity
	(c)		HC*l* + $CH_3CHCHCH_3$ → CH_3CH_2CHC/CH_3 Correct structural formula of product ✓ Equation with structural formulae ✓	2	Must use **structural formulae** for both organic compounds in the equation **ALLOW** $CH_3CH{=}CHCH_3$ for but-2-ene **ALLOW** two marks for correct equation with structural formulae **ALLOW** one mark for correct equation with displayed formulae **IGNORE** any mechanisms
	(d)		HCFCs **OR** hydrocarbons **OR** HFCs ✓	1	**ALLOW** alkanes **DO NOT ALLOW** specific alkanes
			Total	**10**	

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Question			Answer	Marks	Guidance
8	(a)		 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** two or more repeat units but has to be a whole number of repeat units **ALLOW** vertical bond to CN to any part of the CN End bonds **MUST** be shown as either dotted or normal line **IGNORE** brackets **IGNORE** *n*
	(b)		All the reactants are made into the desired product **OR** it is an addition reaction ✓	1	**ALLOW** there are no waste (products) **OR** there are no by-products **OR** only one product is made **ALLOW** an addition polymer is made **DO NOT ALLOW** all the product**s** are useful **IGNORE** additional reaction

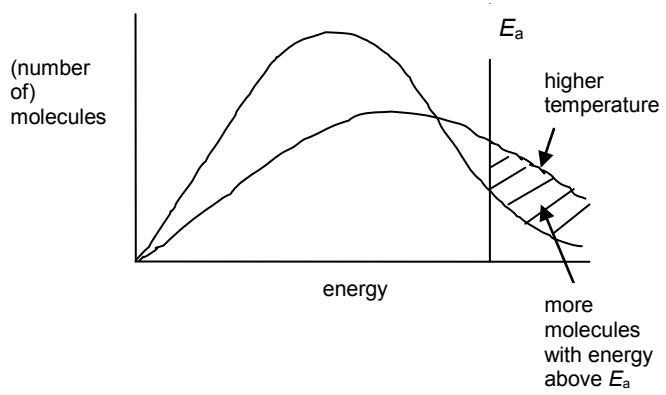
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Question			Answer	Marks	Guidance
8	(c)		**QWC – Linking effect with explanation**	5	
			(as temperature rises) position of equilibrium changes to **minimise effect** of temperature rise by **absorbing energy** **OR** (as pressure rises) position of equilibrium changes to **minimise** the pressure increase by **reducing the pressure** and making fewer gas molecules ✓		
			as temperature rises the position of equilibrium shifts to the left **AND** increase in pressure shifts the equilibrium to the left ✓		**ALLOW** suitable alternatives for 'to the left' eg moves to the reactant side **OR** towards $C_3H_6(g)$ or $NH_3(g)$ or O_2 **OR** moves in reverse direction **IGNORE** responses in terms of rate
			relates change with temperature to the (forward) reaction being exothermic **OR** reaction releases energy or heat **OR** **reverse** reaction is endothermic **OR reverse** reaction takes in heat or energy ✓		This mark is dependent on correct change in position of equilibrium Moves towards the endothermic direction is **not** sufficient
			change with pressure because there are fewer moles of reactants **OR** more moles of products ✓		**ALLOW** fewer molecules of reactant This mark is dependent on correct change in position of equilibrium
			removing the catalyst does not change the position of equilibrium ✓		**ALLOW** equilibrium does not move **OR** catalyst has no effect on the equilibrium

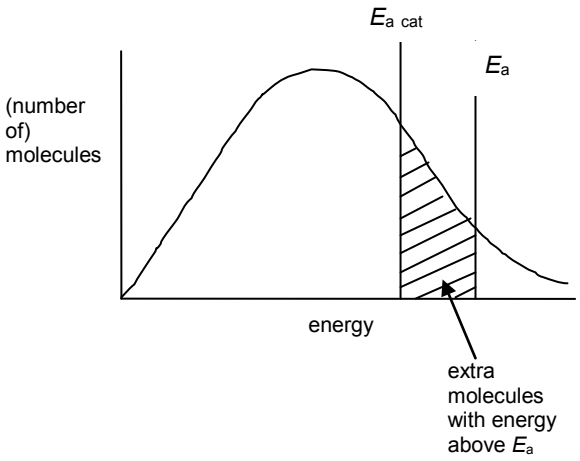
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Question			Answer	Marks	Guidance
8	(d)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF** answer = 95.5, award **2 marks.** actual amount propenenitrile is 210 (mol) ✓ % yield = 95.454545 ✓	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **ALLOW** theoretical mass of propenenitrile = 11660 g **OR** 11.66 kg **ALLOW** 11700 **OR** 11.7kg **ALLOW** 95 up to calculator value of 95.454545 correctly rounded up **ALLOW** 95 up to calculator value of 95.128205 correctly rounded up if 11.7kg is used' **ALLOW** ecf from wrong actual mass or actual amount **DO NOT ALLOW** ecf if percentage yield is above 100%

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Question	Answer	Marks	Guidance
(e)	***Boltzmann distribution*** Correct drawing of one Boltzmann distribution (could be temperature or catalyst) ✓ axes labelled (number of) molecules and energy ✓ ***Increasing the temperature*** Correct drawing of Boltzmann distribution at **two** different temperatures with higher and lower temperature clearly identified ✓  	7	Look at the first Boltzmann distribution on the paper: If it is the temperature one then both curves will have to be correct Boltzmann distribution – must start at origin and must not end up at 0 on y-axis ie must not touch x-axis **ALLOW** a slight inflexion in the Boltzmann curve **ALLOW** particles instead of molecules **DO NOT ALLOW** atoms instead of particles or molecules **DO NOT ALLOW** number of particles at activation energy **DO NOT ALLOW** enthalpy **ONLY** penalise the incorrect use of atoms (instead of molecules or particles) the first time it is seen Maximum of curve for higher temperature to right **AND** lower than maximum of lower temperature curve **AND** above lower temp line at higher energy as shown in diagram below Higher temperature line should intersect the lower temperature only once

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Question			Answer	Marks	Guidance
			Adding a catalyst  idea that activation energy is lowered with a catalyst ✓		**ALLOW** E_c **OR** E_{cat} for activation energy of catalysed reaction **ALLOW** activation lowered shown on Boltzmann distribution diagram
			Collision theory reaction is faster with catalyst **AND** when temperature is increased ✓ Greater proportion of molecules with energy above activation energy (with increased temperature or when catalyst is used) ✓ more effective collisions **OR** more successful collisions (with increased temperature or when catalyst is used) ✓		**ALLOW** more molecules with energy above activation energy **OR** more molecules that overcome the activation energy **OR** more molecules have enough energy to react **ALLOW** this marking point **once** either in terms of using a catalyst or increasing the temperature **ALLOW** this marking point **once** either in terms of using a catalyst or increasing the temperature **ALLOW** more collisions involving particles with energy above the activation energy More collisions per second is **not** sufficient
			Total	**16**	

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OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
Cambridge
CB1 2EU

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RECOGNISING ACHIEVEMENT

Wednesday 16 January 2013 – Morning

AS GCE CHEMISTRY A

F322/01 Chains, Energy and Resources

F3144401133

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry A* (inserted)

Other materials required:
- Scientific calculator

Duration: 1 hour 45 minutes

F3220 1

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

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



Where you see this icon you will be awarded marks for the quality of written communication in your answer.

This means for example you should:
- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- organise information clearly and coherently, using specialist vocabulary when appropriate.

- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **24** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 Crude oil contains many hydrocarbons.

The table shows information about some of these hydrocarbons.

Hydrocarbon	Molecular formula	Boiling point / °C
Hexane	C_6H_{14}	69
3-Methylpentane	C_6H_{14}	63
2,2-Dimethylbutane	C_6H_{14}	50

(a) What is the empirical formula of hexane?

..... **[1]**

(b) Explain why hexane is both *saturated* and a *hydrocarbon*.

saturated

.....

.....

hydrocarbon

.....

..... **[2]**

(c) Draw the skeletal formula for 2,2-dimethylbutane.

[1]

(d) Describe and explain the trend shown by the boiling points of the hydrocarbons in the table.

.....

.....

.....

.....

.....

..... **[3]**

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(e) Decane, $C_{10}H_{22}$, can be cracked to form hexane and **one** other product.

Write an equation for this reaction.

..... **[1]**

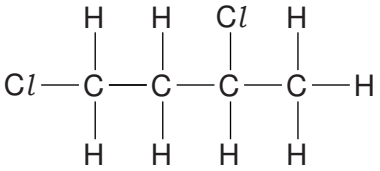
(f) In the presence of ultraviolet radiation, butane, C_4H_{10}, reacts with chlorine to form a large number of organic products.

Several of these products are structural isomers of $C_4H_8Cl_2$.

(i) Write an equation, using molecular formulae, for the formation of $C_4H_8Cl_2$ from butane.

..... **[1]**

(ii) Complete the table below about two of the structural isomers of $C_4H_8Cl_2$.

	Isomer 1	**Isomer 2**
Name	1,4-Dichlorobutane	.....
Displayed formula		

[2]

(g) The reaction between butane and chlorine is an example of radical substitution.

Initially, chlorobutane, C_4H_9Cl, is formed, which then reacts with more chlorine to form $C_4H_8Cl_2$.

(i) The first step of the reaction of C_4H_9Cl with chlorine is the homolytic fission of a chlorine molecule.

What is meant by the term *homolytic fission*?

.....

.....

..... **[2]**

(ii) Complete the missing species in the propagation steps below.

$$Cl \quad + \quad C_4H_9Cl \quad \rightarrow \quad \text{.....} \; + \; \text{.....}$$

$$\text{.....} \; + \; \text{.....} \quad \rightarrow \quad C_4H_8Cl_2 \; + \; \text{.....}$$

[2]

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(h) Butane, C_4H_{10}, undergoes incomplete combustion when there is a shortage of oxygen.

Write an equation for the incomplete combustion of butane.

..... **[1]**

[Total: 16]

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2 Phosphoric acid, H_3PO_4, can be manufactured by a two step process involving the reaction of phosphorus with oxygen, followed by a reaction with water.

$$P_4(s) + 5O_2(g) \longrightarrow P_4O_{10}(s) \qquad \Delta H_1 = -2984\,kJ\,mol^{-1}$$

$$P_4O_{10}(s) + 6H_2O(l) \longrightarrow 4H_3PO_4(l) \qquad \Delta H_2$$

(a) Explain why ΔH_1 represents the enthalpy change of formation of P_4O_{10}.

.....

.....

..... **[2]**

(b) Enthalpy changes of formation are shown in the table below.

Substance	Enthalpy change of formation, ΔH_f / kJ mol^{-1}
$P_4O_{10}(s)$	–2984
$H_2O(l)$	–286
$H_3PO_4(l)$	–1267

Calculate the enthalpy change of reaction, ΔH_2.

ΔH_2 = ... kJ mol^{-1} **[3]**

(c) Write the overall equation for the manufacture of H_3PO_4 from P_4.

Use this equation to explain why this process has a 100% atom economy.

.....

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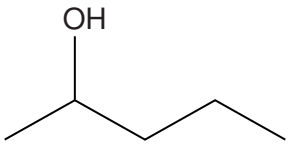
..... **[2]**

[Total: 7]

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3 Pentan-2-ol, shown below, is a secondary alcohol.



(a) Pentan-2-ol can be converted into three alkenes, **A**, **B** and **C**, by the elimination of water.

- Two of the alkenes, **A** and **B**, are stereoisomers.
- The third alkene, **C**, is a structural isomer of both **A** and **B**.

This elimination often uses a catalyst.

(i) What is a suitable catalyst for this reaction?

..... **[1]**

(ii) Construct an equation, using molecular formulae, for the elimination of water from pentan-2-ol.

..... **[1]**

(iii) Explain what is meant by the terms *structural isomers* and *stereoisomers*.

structural isomers

.....

.....

.....

stereoisomers

.....

.....

.....

[4]

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(iv) In the boxes below:

- draw the structures of stereoisomers **A** and **B**
- draw the structure of isomer **C**.

stereoisomer A

stereoisomer B

isomer C

[3]

(v) Stereoisomers **A** and **B** show *E*/*Z* isomerism.

State **two** features of these molecules that enable them to show *E*/*Z* isomerism.

.....

.....

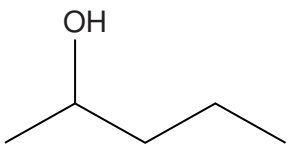
..... **[2]**

(b) Pentan-2-ol can be oxidised by heating under reflux with acidified aqueous potassium dichromate(VI).

Complete the equation for this oxidation.

Use a skeletal formula for the organic product.

Use [O] to represent the oxidising agent.



→

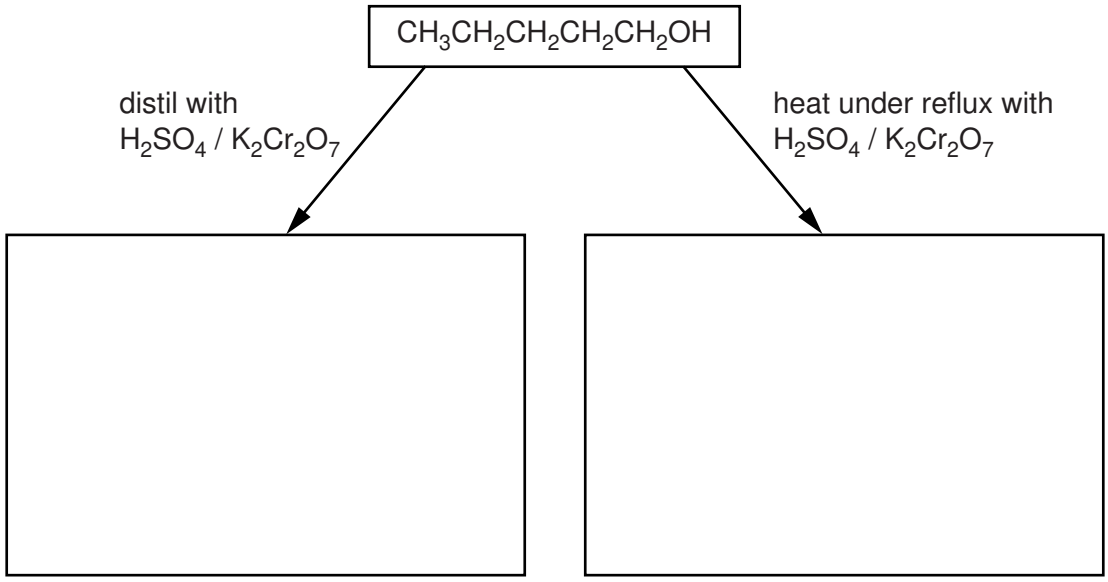
[2]

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(c) Pentan-1-ol can also be oxidised but it gives two different products.

Complete the flowchart below to show the structures of the two organic products formed.



[2]

[Total: 15]

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Question 4 begins on page 10

PLEASE DO NOT WRITE ON THIS PAGE

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4 Methanol can be manufactured by the reaction of carbon dioxide with hydrogen.

$$3H_2(g) + CO_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g) \quad \textbf{equation 4.1}$$

In this reaction, 49.0 kJ of energy are released when 3 moles of H_2 react completely. This enthalpy change is called the enthalpy change of reaction, ΔH_r.

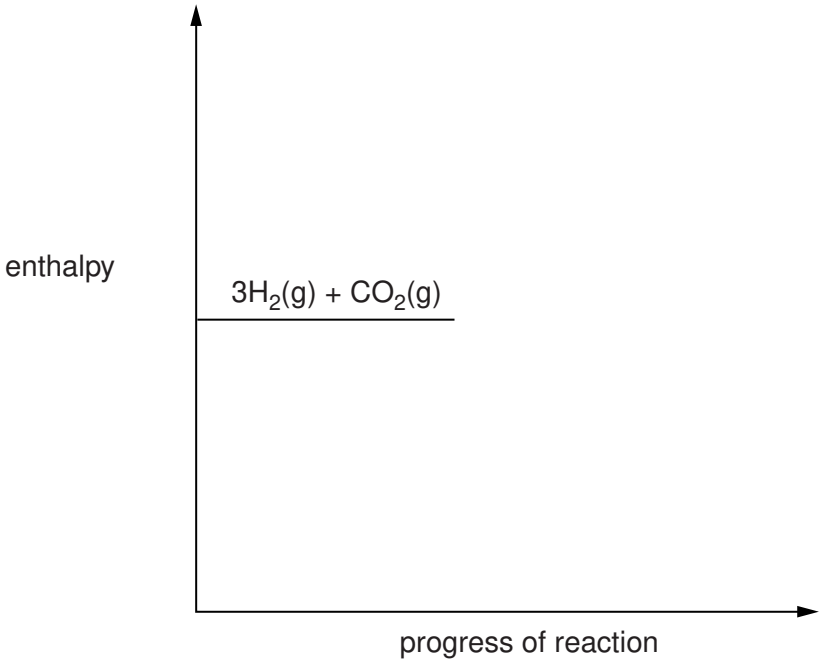
(a) Calculate the energy released when 1000 dm^3 of hydrogen, measured at room temperature and pressure, react completely with carbon dioxide.

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

energy released = ... kJ **[3]**

(b) Complete the enthalpy profile diagram for the forward reaction.

Label the activation energy, E_a, and the enthalpy change, ΔH_r.



[3]

(c) What is the enthalpy change of reaction for the **reverse** reaction?

enthalpy change = ... kJ mol^{-1} **[1]**

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(d) A scientist estimates the activation energy for the forward reaction as +225 kJ mol^{-1}.

Using this information, estimate the activation energy of the **reverse** reaction.

activation energy = ... kJ mol^{-1} **[1]**

(e) The temperature of the equilibrium mixture in **equation 4.1** is **increased**.

Describe and explain what happens to the position of equilibrium.

.....

.....

..... **[2]**

(f) The total pressure of the equilibrium mixture in **equation 4.1** is **decreased**.

Describe and explain what happens to the position of equilibrium.

.....

.....

..... **[2]**

(g) The reaction uses a solid catalyst. This catalyst functions in a similar way to the catalyst used in catalytic converters.

Outline the stages that allow H_2 to react with CO_2 in the presence of a solid catalyst.

.....

.....

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.....

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..... **[3]**

[Total: 15]

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5 Chloroethene, CH_2CHCl, is made from 1,2-dichloroethane, CH_2ClCH_2Cl.

$$CH_2ClCH_2Cl \longrightarrow CH_2CHCl + HCl \quad \textbf{equation 5.1}$$

(a) A chemical plant uses 19.80 tonnes of 1,2-dichloroethane to make 11.25 tonnes of chloroethene.

Calculate the percentage yield of chloroethene.

(1 tonne = 1.00×10^6 g)

percentage yield = ... % **[3]**

(b) The table below shows some average bond enthalpies.

Bond	Average bond enthalpy / kJ mol^{-1}
C–H	+413
C–C	+347
C=C	+612
C–Cl	+346
H–Cl	+432

Using the average bond enthalpies in the table above, calculate the enthalpy change of reaction, ΔH_r, for **equation 5.1**.

ΔH_r = ... kJ mol^{-1} **[3]**

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(c) Chloroethene is used to make poly(chloroethene), PVC.

Write an equation, using **displayed formulae**, for the reaction to form poly(chloroethene) from its monomer.

[3]

(d) Waste polymers are often disposed of by combustion. The heat released can be used to generate electricity.

(i) Hydrogen chloride, HC*l*, is a toxic waste product formed by combustion of PVC.

Suggest how the HC*l* can be removed from the gases produced during the combustion of PVC.

.....

..... **[1]**

(ii) Some waste polymers are put into landfill sites. This uses up a valuable resource.

State **two** ways, other than landfill and combustion, of processing waste polymers.

1 .....

.....

2 .....

..... **[2]**

(iii) Chemists are trying to minimise the environmental damage caused by the disposal of waste polymers by developing new types of polymers.

Give an example of a type of polymer being developed to minimise environmental damage.

..... **[1]**

[Total: 13]

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6 Many reactions are catalysed by biological catalysts called enzymes.

Ethanol is manufactured by the enzyme-catalysed fermentation of glucose.

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

(a) Fermentation is an **exothermic** reaction.

Explain why. Use ideas about the enthalpy changes associated with bond breaking and bond making in your answer.

.....

.....

.....

..... **[2]**

(b) Carbon dioxide is a greenhouse gas that has been linked to climate change.

(i) What happens within a carbon dioxide molecule when it absorbs infrared radiation?

.....

..... **[1]**

(ii) Chemists are developing methods for carbon capture and storage to minimise climate change.

Give **two** examples of carbon capture and storage.

1 .....

.....

2 .....

.....

[2]

(c) One benefit of using an enzyme to catalyse a reaction is that there is a large increase in the rate of reaction without the enzyme being used up.

State **two** other benefits, other than cost, of using enzymes to catalyse reactions.

1 .....

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2 .....

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[2]

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(d) Catalysts, such as enzymes, increase the rate of a reaction.

Explain why. Use a labelled Boltzmann distribution of molecular energies in your answer.

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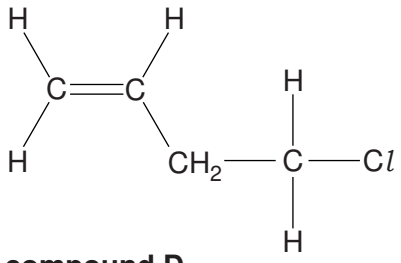
..... **[5]**

[Total: 12]

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7 Compound **D** reacts by nucleophilic substitution and electrophilic addition.



compound D

Compound **D** reacts with KOH(aq) and with HBr(g).

The reaction with KOH(aq) is an example of a nucleophilic substitution and the reaction with HBr(g) is an example of electrophilic addition.

Describe these two reactions. For each reaction, include:

- an equation
- the structure of each organic product
- the mechanism, using the curly arrow model, showing any relevant dipole
- the type of bond fission that occurs.

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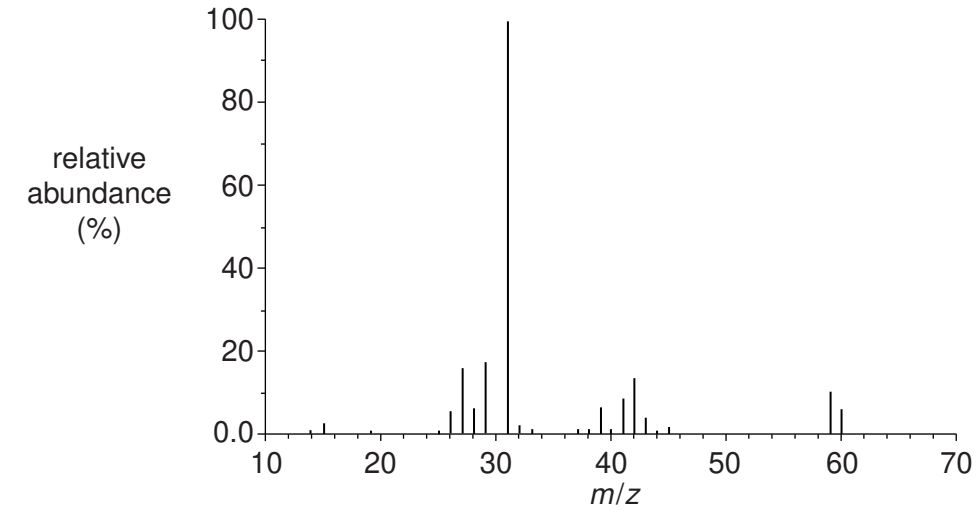
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8 Compound **X** is a saturated compound that contains carbon, hydrogen and oxygen only.

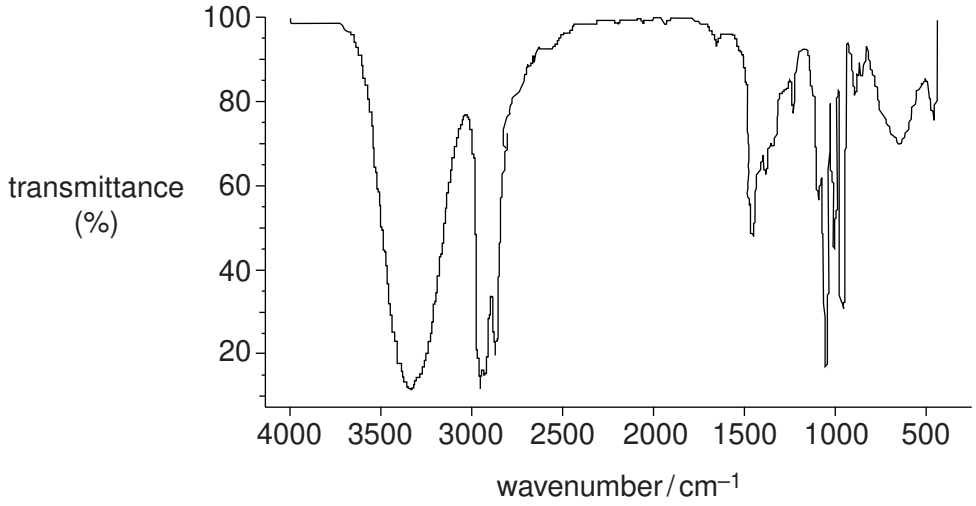
A scientist analyses a 1.00 g sample of compound **X** and finds it contains 0.133 g of hydrogen and 0.600 g of carbon.

The scientist also analyses compound **X** using mass spectrometry and infrared spectroscopy.

mass spectrum of X



IR spectrum of X



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19

The scientist finds that compound **X** reacts with ethanoic acid in the presence of a concentrated sulfuric acid catalyst to make compound **Y**.

Compound **Y** has the molecular formula $C_5H_{10}O_2$.

Using all the information, show the structures of compounds **X** and **Y**.
Include an equation for the reaction of compound **X** with ethanoic acid to make compound **Y**.

In your answer you should link the evidence with your explanation.

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[10]

[Total: 10]

END OF QUESTION PAPER

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ADDITIONAL ANSWER SPACE

If additional space is required, you should use the following lined page(s). The question number(s) must be clearly shown in the margins.

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RECOGNISING ACHIEVEMENT

GCE

Chemistry A

Advanced Subsidiary GCE

Unit **F322:** Chains, Energy and Resources

Mark Scheme for January 2013

Oxford Cambridge and RSA Examinations

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All examiners are instructed that alternative correct answers and unexpected approaches in candidates' scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

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Annotations

Annotations available in Scoris.

Annotation	Meaning
BOD	Benefit of doubt given
CON	Contradiction
	Incorrect response
ECF	Error carried forward
I	Ignore
NAQ	Not answered question
NBOD	Benefit of doubt not given
POT	Power of 10 error
^	Omission mark
RE	Rounding error
SF	Error in number of significant figures
	Correct response

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Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

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Generic comments

ORGANIC STRUCTURES

For a 'structure' or 'structural formula',

- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)

For an alkyl group shown within a structure,

- **ALLOW** bond drawn to C or H,
  eg **ALLOW** CH_3–,CH_2–, C_3H_7–, etc
- **ALLOW** vertical 'bond' to any part of an alkyl group

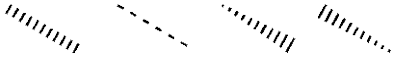
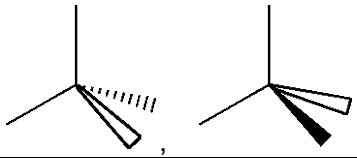
For an OH group shown within a structure,

- **DO NOT ALLOW** formula with horizontal —HO **OR** OH—
- **ALLOW** vertical 'bond' to any part of the OH group

For a CHO group shown within a structure,

- **DO NOT ALLOW** COH

For a 3D structure,

• For bond in the plane of paper, a solid line is expected:	
• For bond out of plane of paper, a solid wedge is expected:	
• For bond into plane of paper, **ALLOW**:	
• **ALLOW** a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge eg:	

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NAMES
Names including alkyl groups:
- **ALLOW** alkanyl, eg ethanyl (ie **IGNORE** 'an')
- **DO NOT ALLOW** alkol, eg ethol (ie 'an' is essential)

Names of esters:
- Two words are expected, eg ethyl ethanoate
- **ALLOW** one word, eg ethylethanoate

Names with multiple numbers and hyphens:
Use of 'e'
- **ALLOW** superfluous 'e' , eg propane-1-ol ('e' is kept if followed by consonant)
- **ALLOW** absence of 'e', eg propan-1,2-diol ('e' is omitted if followed by vowel)

Hyphens separate name from numbers:
- **ALLOW** absence of hyphens, eg propane 1,2 diol

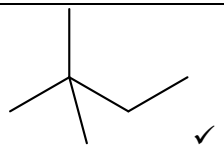
Multiple locant numbers must be clearly separated:
- **ALLOW** full stops: eg 1.2 **OR** spaces: 1 2
- **DO NOT ALLOW eg** 12

Locant numbers in formula must be correct
- **DO NOT ALLOW** propan-3-ol

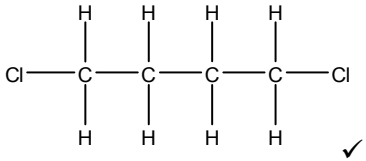
Order of substituents should be alphabetical:
- **ALLOW** any order (as long as unambiguous), eg 2-chloro-3-bromobutane

ABBREVIATIONS
van der Waal's forces
ALLOW vdw forces **OR** VDW forces (and any combination of upper and lower cases)

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Question			Answer	Marks	Guidance
1	(a)		C_3H_7 ✓	1	**ALLOW** H_7C_3
	(b)		***Saturated*** **Only** has (carbon to carbon) single bonds ✓ ***Hydrocarbon*** Contains (the elements) hydrogen and carbon **only** ✓	2	**ALLOW** does not contain any (carbon to carbon) double bonds **ALLOW** all of the carbon atoms are bonded to four other atoms **DO NOT ALLOW** contains hydrogen and carbon **DO NOT ALLOW** a mixture of carbon and hydrogen only **DO NOT ALLOW** hydrogen and carbon molecules only
	(c)		 ✓	1	
	(d)		as branching increases the boiling point decreases **OR** the more branched the isomers of hexane are the lower the boiling point ✓ branched isomers have less surface (area) of contact **OR** branched fewer points of contact (than unbranched) ✓ (the more branched the) **fewer** van der Waals' forces **OR** (the more branched) has **weaker** van der Waals' forces **OR** Less energy required to break van der Waal's forces ✓	3	**ALLOW** ORA throughout *First marking point must compare boiling point **and** branching for **all** three isomers* Reference to just surface area / closeness of molecules is **not** sufficient **ALLOW** vdw forces **OR** VDW forces (and any combination of upper and lower cases) **DO NOT ALLOW** VDW mark if answer states that these are between atoms or answer implies that these are bonds
	(e)		$C_{10}H_{22} \rightarrow C_6H_{14} + C_4H_8$ **OR** $C_{10}H_{22} \rightarrow C_6H_{14} + 2C_2H_4$ ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **IGNORE** state symbols

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<table>
<tr><th colspan="3">Question</th><th>Answer</th><th>Marks</th><th>Guidance</th></tr>
<tr><td>1</td><td>(f)</td><td>(i)</td><td>C_4H_{10} + 2Cl_2 → $C_4H_8Cl_2$ + 2HCl ✓</td><td>1</td><td>IGNORE state symbols</td></tr>
<tr><td></td><td></td><td>(ii)</td><td><table><tr><th>Isomer 1</th><th>Isomer 2</th></tr><tr><td></td><td>1,3-dichlorobutane ✓</td></tr><tr><td>Correct displayed formula eg:
 
✓</td><td></td></tr></table></td><td>2</td><td>Must be a displayed formula

ALLOW absence of hyphens
1 and 3 must be clearly separated:
ALLOW full stops: 1.3 OR spaces: 1 3
DO NOT ALLOW 13</td></tr>
<tr><td></td><td>(g)</td><td>(i)</td><td>covalent bond breaking ✓

one electron (from the bond pair) goes to each atom
OR
makes (two) radicals ✓</td><td>2</td><td>ALLOW covalent bond is split

IGNORE particle for atom
DO NOT ALLOW molecule or compound for atom
DO NOT ALLOW to each molecule or to each reactant
ALLOW one electron goes to each product / species
IGNORE homolytic fission equations</td></tr>
<tr><td></td><td></td><td>(ii)</td><td>Cl + C_4H_9Cl → C_4H_8Cl + HCl ✓

C_4H_8Cl + Cl_2 → $C_4H_8Cl_2$ + Cl ✓</td><td>2</td><td>IGNORE dots even if incorrect</td></tr>
<tr><td></td><td>(h)</td><td></td><td>C_4H_{10} + 4½O_2 → 4CO + 5H_2O
OR
C_4H_{10} + 2½O_2 → 4C + 5H_2O ✓</td><td>1</td><td>ALLOW any correct multiples for these equations eg
2C_4H_{10} + 9O_2 → 8CO + 10 H_2O
IGNORE state symbols

ALLOW equations for incomplete combustion that give CO_2 with CO and/or C eg
C_4H_{10} + 4O_2 → 3CO + C + 5H_2O</td></tr>
<tr><td></td><td></td><td></td><td>Total</td><td>16</td><td></td></tr>
</table>

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Question			Answer	Marks	Guidance
2	(a)		(enthalpy change for the) formation of one mole (of P_4O_{10}) ✓ from (constituent) elements **OR** from P_4/phosphorus and O_2/oxygen ✓	2	**ALLOW** energy required **OR** energy released **ALLOW** makes one mole of product/substance/molecule/ compound **ALLOW** made from P and O_2 **OR** made from two elements **IGNORE** comments related to standard conditions
	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –368 (kJ mol^{-1}) award 3 marks** (+)2984 +(+)6 × 286 **OR** (+)2984 +(+)1716 **OR** (+)4700 ✓ (−)1267 × 4 **OR** (–)5068 ✓ −368 ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. **See list below for marking of answers from common errors.** **IGNORE** sign **IGNORE** sign **ALLOW ECF** for enthalpy change of products – enthalpy change of reactants **ALLOW for 2 marks:** +368 cycle wrong way around **OR** −1798 no × 6 **OR** (+)3433 no x 4 **OR** −3352 missing 2984 **OR** (+) 9768 product the wrong sign around **OR** (−) 9768 reactants the wrong sign **ALLOW for 1 mark:** (+)1798 no x 6 and cycle wrong way around **OR** –3433 cycle wrong way around and not × 4 **OR** (+)3352 missing 2984 and cycle wrong way around **OR** (+)2003 no x 6 or x 4 **OR** (+)449 missing 2984 and x 4 **OR** −4782 missing 2984 and x 6 **Note:** There may be other possibilities.

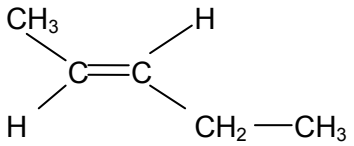
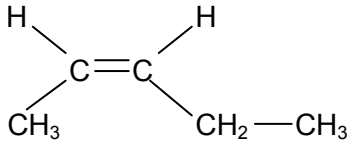
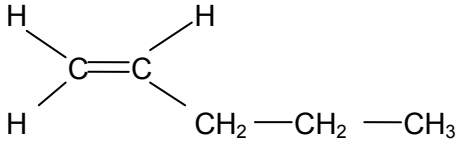
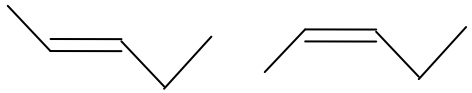
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Question			Answer	Marks	Guidance
	(c)		$P_4 + 5O_2 + 6H_2O \rightarrow 4H_3PO_4$ ✓ Only the **desired product** is made ✓ **Second marking point can only be awarded if the equation is correct.**	2	**ALLOW** there are no waste products **OR** there are no by-products **OR** there is only one product. **DO NOT ALLOW** it is an addition reaction
			Total	**7**	

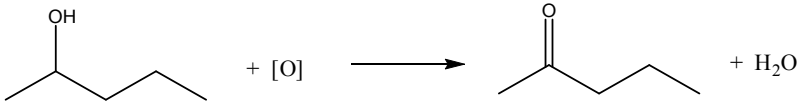
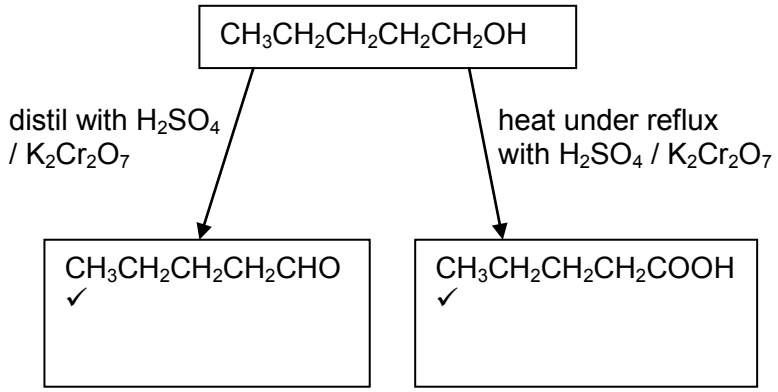
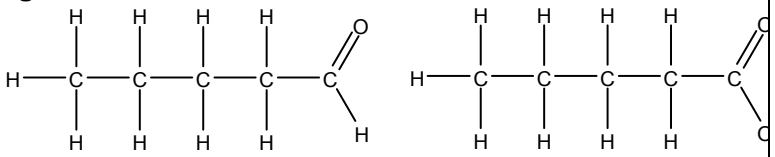
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Question			Answer	Marks	Guidance
3	(a)	(i)	acid ✓	1	**ALLOW** named mineral acid or correct formula eg phosphoric acid, H_3PO_4, sulfuric acid, H_2SO_4 or H^+ **DO NOT ALLOW** any carboxylic acids
		(ii)	$C_5H_{12}O \rightarrow C_5H_{10} + H_2O$ ✓	1	**DO NOT ALLOW** use of $C_5H_{11}OH$
		(iii)	***structural isomerism*** have the same molecular formula ✓ but different structural formulae ✓ ***stereoisomerism*** have the same structural formula ✓ but different arrangement (of atoms) in space ✓	4	Same formula is **not** sufficient **ALLOW** different structure **OR** different displayed formula **OR** different skeletal formula Different formula or different arrangement of atoms is **not** sufficient **ALLOW** different **structural** arrangement (of atoms) **ALLOW** have the same structure Stereoisomers have the same formula or molecular formula is **not** sufficient **ALLOW** different spatial arrangements (of atoms)

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Question			Answer	Marks	Guidance
3	(a)	(iv)	 **A**  **B**  **C** Correct structure for **A** ✓ Correct structure for **B** ✓ Correct structure for **C** ✓	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **A** and **B** must clearly show cis and trans configuration **eg**  **A** ***B*** **Answers to A and B are interchangeable** **C:** $CH_2CHCH_2CH_2CH_3$ **ALLOW** $-C_2H_5$ group in A or B or $-CH_2C_2H_5$ in C **DO NOT ALLOW** $-C_3H_7$ group in C

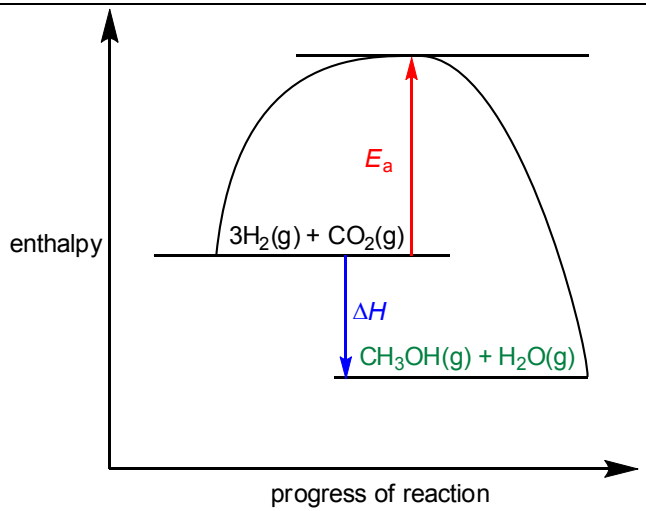
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Question			Answer	Marks	Guidance
3	(a)	(v)	carbon–carbon double bond ✓ **Each** carbon atom in the double bond is attached to (two) different groups/atoms ✓	2	**IGNORE** comments about rotation **ALLOW** carbon double bond **ALLOW Each** carbon atom of the double bond is attached to a H and an alkyl group **DO NOT ALLOW** functional groups for groups **DO NOT ALLOW** the carbon atoms are attached to different groups "**Each** carbon atom in the double bond" implies a carbon–carbon double bond for the first marking point
	(b)		 Correct **skeletal** structure of product ✓ Balanced equation ✓	2	Balancing mark can only be awarded if the equation has a correct **skeletal** formula for the product
	(c)		 	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **eg**  **ALLOW** CO_2H for the carboxylic acid **DO NOT ALLOW** COH for aldehyde **IGNORE** names
			Total	**15**	

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Question			Answer	Marks	Guidance
4	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 681 (kJ) award 3 marks** Evidence of dividing 1000 by 24 Evidence of dividing by 3 and multiplying by 49 in the calculation energy released = 681 (kJ) ✓ **(MUST BE TO 3 SIG FIGS)** --- **Alternative Working** 3 moles = 72 dm^3 ✓ So $\frac{1000}{72}$ or 13.9 ✓ Energy released = 13.9 × 49 = 681 (kJ)	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. **ALLOW** 41.7 up to calculator value 41.6666667 correctly rounded. **ALLOW** $\frac{1000}{24}$ for first marking point if not calculated **ALLOW** energy released per mole = 16.3 ✓ **IGNORE (–) sign in the answer** **Common Incorrect answers** **0.392** scores 2 marks **392000** scores 2 marks

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Question	Answer	Marks	Guidance
4 (b)		3	**IGNORE** state symbols for the products
	CH_3OH and H_2O added as product **AND** shown below the reactants ✓		
	ΔH labelled with arrow pointing towards products or the product line if no products stated ✓		**IF** there is **no ΔH labelled** then **ALLOW** –49 only as an alternative label for ΔH **IF ΔH is labelled** then **IGNORE** any numerical value **DO NOT ALLOW** $-\Delta H$ **ALLOW** this arrow even if it has a small gap at the top and bottom i.e. does not quite reach reactant or product line
	E_a labelled correctly **AND** above reactants ✓		**ALLOW** (+) 225 only as an alternative label for E_a **ALLOW** arrows at both ends of activation energy line The E_a line must point to maximum (or near to the maximum) on the curve **ALLOW** this line even if it has a small gap at the top and bottom ie does not quite reach the maximum or reactant line **ALLOW** A_E or E_a for activation energy

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Question	Answer	Marks	Guidance
(c)	(+)49 ✓	1	**DO NOT ALLOW** –49
(d)	(+)274 ✓	1	**DO NOT ALLOW –**274 **ALLOW** answer to **(c)** + 225 as **ECF**
(e)	(equilibrium position shifts) to the left ✓ (Forward) reaction is exothermic **OR** reaction gives out heat **OR** reverse reaction is endothermic **OR** reverse reaction takes in heat ✓ **The explanation mark is dependent on the correct shift of the equilibrium**	2	**ALLOW** 'favours the left', as alternative for 'shifts equilibrium to left' **Note: ALLOW** suitable alternatives for 'to left', eg: towards CO_2 / H_2 **OR** towards reactants **OR** in backward direction **OR** in reverse direction **OR** decreases yield of CH_3OH /products **IGNORE** responses in terms of rate
(f)	(equilibrium position) shifts to the left ✓ Right-hand side has fewer (gaseous) moles/molecules ✓ **ORA** **The explanation mark is dependent on the correct shift of the equilibrium**	2	**ALLOW** 'favours the left', as alternative for 'shifts equilibrium to left' **Note: ALLOW** suitable alternatives for 'to left', eg: towards CO_2 / H_2 **OR** towards reactants **OR** in backward direction **OR** in reverse direction **OR** decreases yield of CH_3OH /products **IGNORE** responses in terms of rate **ALLOW** four moles on the left and two moles on the right **ALLOW** more moles of reactants or fewer moles of products **ASSUME** "goes the side with more gas molecules" implies from equation that more molecules on the left **OR** "goes to side with fewer gas molecules" implies from equation that fewer molecules are on the right

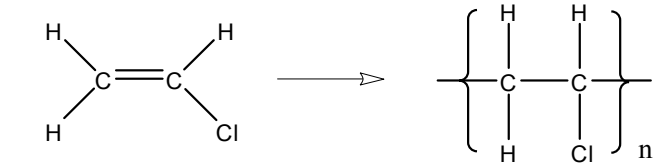
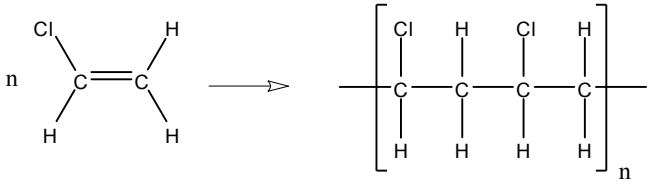
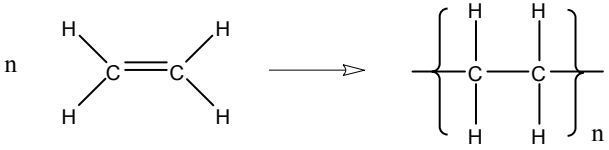
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Question			Answer	Marks	Guidance
	(g)		Adsorption of reactants **OR** adsorption of gases **OR** H_2 and CO_2 attached to surface ✓ Bonds weaken in reactants **OR** chemical reaction **OR** activation energy decreases ✓ Desorption of products **OR** desorption of H_2O and CH_3OH ✓	3	**ALLOW** CO_2 and H_2 (weakly) bonded to surface **OR** reactants bond to surface **OR** CO_2 and H_2 form temporary bonds with the catalyst **DO NOT ALLOW** absorption **ALLOW** bonds weaken in H_2 **OR** bonds weaken in CO_2 **OR** C=O bonds weaken **OR** bonds break and new bonds made in product **OR** H_2O and CH_3OH made **ALLOW** products leave the surface/catalyst **OR** H_2O and CH_3OH no longer bonded to surface/catalyst **ALLOW** deadsorption **OR** adsorb from for desorption **ALLOW** diffuse away for desorption
			Total	**15**	

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Question			Answer	Marks	Guidance
5	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 90% award 3 marks** amount of dichloroethane $= \frac{19800000}{99.0}$ **OR** 200000 (mol) **OR** 2×10^5 (mol) ✓ amount of chloroethene $= \frac{11250000}{62.5}$ **OR** 180000 (mol) **OR** 1.8×10^5 (mol) ✓ Calculates percentage yield $= \frac{180000}{200000} \times 100 = 90\ \%$ ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. ***ALLOW approach based on mass for 2nd and 3rd marks*** Theoretical mass of chloroethene = 200000 × 62.5 **OR** 12500000 (g) **OR** 1.25×10^7 (g) ✓ Calculates percentage yield $= \frac{11250000}{12500000} \times 100 = 90\ \%$ ✓ --- ***ALLOW approach based on grams rather than tonnes:*** n(dichloroethane) $= \frac{19.80}{99.0}$ **OR** 0.2 (mol) ✓ n(chloroethane) $= \frac{11.25}{62.5}$ **OR** 0.18 (mol) **OR** theoretical mass chloroethane = 0.2 × 62.5 **OR** 12.5 g ✓ % yield $= \frac{0.18}{0.20} \times 100 = 90\ \%$ **OR** $\frac{11.25}{12.5} \times 100 = 90\ \%$ ✓ --- **ALLOW ECF** throughout from wrong M_r value(s) with final % yield to 2 or more significant figures **DO NOT ALLOW** final mark for an answer above 100% --- **Note**: If this is the only working seen award no marks ie $\frac{11.25 \times 10^6}{19.80 \times 10^6} \times 100 = 56.81\%$

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Question			Answer	Marks	Guidance
5	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = (+)62 award 3 marks** ΔH for bonds broken = 2691 (kJ mol^{-1}) ✓ ΔH for bond formed = 2629 (kJ mol^{-1}) ✓ ΔH = (+)62 (kJ mol^{-1}) ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible. **IGNORE** sign **ALLOW** 1106 (C–Cl, C–C and C–H bonds) **IGNORE** sign **ALLOW** 1044 (H–Cl and C=C bonds) **ECF** based on bonds broken – bonds formed **ALLOW** 2 marks for –62
	(c)		Displayed formulae of monomer and polymer required for the marks.  Only chloroethene on left hand side ✓ Only the correct polymer on right hand side ✓ A correctly balanced equation using displayed formulae for any monomer and matching polymer including the correct use of *n* ✓	3	Polymer must have **side** links (do not have to cut through bracket and can be dotted lines) **ALLOW** a correct section of the polymer with side links as below would score two marks as the equation is not balanced  **DO NOT ALLOW ECF** from wrong monomer *n* on LHS can be at any height to the left of formula **AND** *n* on the RHS must be a subscript (essentially below the side link) The equation below would be worth 1 mark for balancing 

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Question			Answer	Marks	Guidance
	(d)	(i)	React with an alkali **OR** react with a base/carbonate **OR** Bubble through water (to make HCl(aq)) **OR** dissolve in water ✓	1	**ALLOW** react with a named alkali or base eg calcium carbonate, calcium hydroxide, magnesium oxide, ammonia **ALLOW** an appropriate chemical formula **IGNORE** use of gas scrubbers
		(ii)	Sort and recycle ✓ Organic feedstock **OR** cracked ✓	2	**ALLOW** separate and recycle or sorting and remoulding **ALLOW** use for the production organic compounds **OR** synthesis gas **ALLOW** the production of plastics or monomers or new polymers
		(iii)	(Bio) degradable (polymers) **OR** compostable (polymers) **OR** soluble (polymers) **OR** photodegradable (polymers) ✓	1	**IGNORE** a named polymer if degradable **DO NOT ALLOW** any addition polymer eg PTFE
			Total	**13**	

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Question			Answer	Marks	Guidance
6	(a)		Bond breaking absorbs energy **AND** bond forming releases energy ✓ More energy released than absorbed ✓ The second marking point is **dependent** on the correct identification of the energy changes during bond breaking and bond making	2	**ALLOW** bond breaking is endothermic **AND** bond forming is exothermic **DO NOT ALLOW** bond forming requires energy **ALLOW** more energy is released when the bond in the products are formed than is required to break the bonds in the reactants **ALLOW** exothermic change transfers more energy than endothermic change **OR** bond forming transfers more energy than bond breaking **OR** '(the sum of the) bond enthalpies in the products is greater than the (sum of the) bond enthalpies in the reactants' **OR** '(the sum of the) bond enthalpies of the bonds made is greater than (the sum of) the bond enthalpies of the bonds broken' **OR** more energy associated with bond making than with bond breaking **IGNORE** reference to strong and weak bonds **IGNORE** reference to number of bonds broken or made **IGNORE** enthalpy of products is less than enthalpy of reactants
	(b)	(i)	(C=O) **bond** vibrates (more) **OR bond** bends (more) **OR bond** stretches (more) ✓	1	**IGNORE** molecule vibrates/rotates "It" refers to the molecule and is insufficient **DO NOT ALLOW** any reference to bond breaking. **DO NOT ALLOW** a stated bond if **not** present in CO_2 eg C–O, C–H

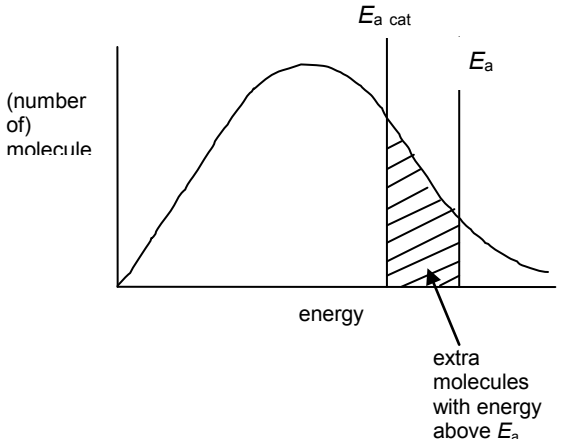
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Question			Answer	Marks	Guidance
		(ii)	***Any two from:*** (injected) **deep** into the oceans / sea ✓ (Stored) in geological formations **OR** (stored) deep in rocks **OR** (stored) in old mines **OR** (stored) in old oil wells **OR** old gas fields ✓ (Stored) by reaction with metal oxides **OR** reaction to form (solid) carbonates **OR** (stored) as a carbonate **OR** equation to show formation of metal carbonate ✓	2	**DO NOT ALLOW** reference to carbon being stored – the answer must either refer to carbon dioxide or not mention the name of the stored substance. Assume "it" refers to CO_2 **DO NOT ALLOW** dumping waste at the bottom of the sea **ALLOW on** the **sea-bed** **DO NOT ALLOW** dissolve CO_2 in the sea **OR** (stored) in ocean **DO NOT ALLOW** geographical formations **ALLOW** stored **under** the sea (bed) **ALLOW** pumped into oil wells to force last bit of oil out **DO NOT ALLOW** buried underground **DO NOT ALLOW** react with **metals** to form carbonates **IGNORE** mineral storage

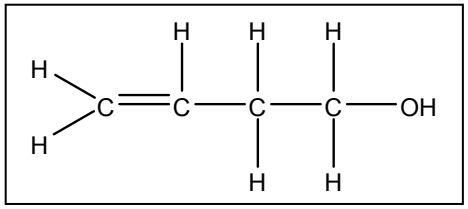
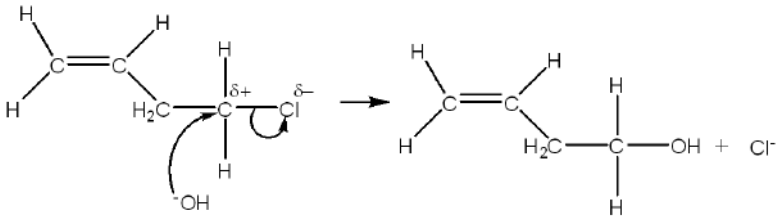
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Question	Answer	Marks	Guidance
(c)	***Any two from:***	2	
	Energy demand Low(er) temperature (can be used) **OR** reduces CO_2 emissions (from burning fossil fuels) ✓		**ALLOW** 'allows use of room temperature' **OR** 'allows use of a lower pressure' **OR** uses less fuel **IGNORE** lower energy demand **OR** lower activation energy **IGNORE** cheaper **IGNORE** less greenhouse gases **OR** reduces global warming
	Specificity enzymes have a great deal of specificity ✓		**ALLOW** making specific isomers / enantiomers **ALLOW** for making pure products **ALLOW** generating specified products
	Atom economy greater atom economy **OR** less waste ✓		**ALLOW** increases atom economy
	Toxicity can reduce use of toxic solvents **OR** reduces use of toxic catalysts **OR** reduces the use of toxic reactants ✓		**ALLOW** reduce use of hazardous/toxic/harmful/poisonous chemicals **ALLOW** enzymes are non toxic **IGNORE** can be reused

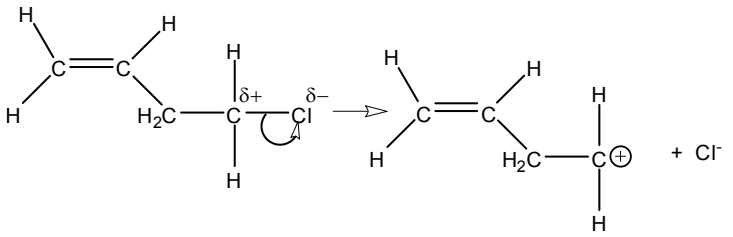
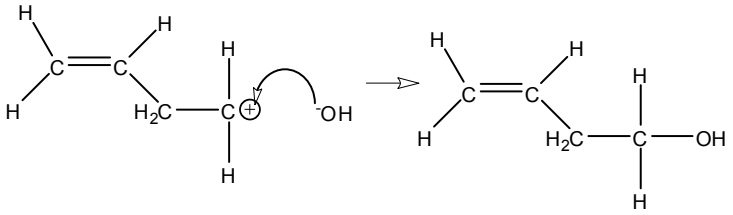
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Question	Answer	Marks	Guidance
(d)	Catalyst lowers the activation energy (because of a different reaction pathway) ✓	5	Can be scored from the diagram by correctly labelling $E_{a\ cat}$ closer to the origin than E_a
	Diagram of Boltzmann distribution ✓		Boltzmann distribution must start at origin **AND** must not touch *x*-axis at high energy
	axes labelled (number of) molecules and energy ✓		**DO NOT ALLOW** Boltzmann distribution mark if **two** curves drawn
			**DO NOT ALLOW Boltzmann distribution** curve bending upwards at higher energy **ALLOW** particles instead of molecules **DO NOT ALLOW** the first use of atoms but credit atoms if used in a subsequent marking point **DO NOT ALLOW** enthalpy on x-axis instead of energy
	Greater proportion of molecules with energy above activation energy with catalyst ✓		**ALLOW** more molecules with energy above activation energy (with a catalyst) **OR** more molecules overcome the activation energy (with a catalyst) **OR** more molecules have enough energy to react (with a catalyst) **OR** more molecules are able to react at lower energies
	more **effective** collisions **OR** more **successful** collisions **OR** increased frequency of **successful** collisions ✓		More collisions **OR** more frequent collisions are **not** sufficient
	Total	**12**	

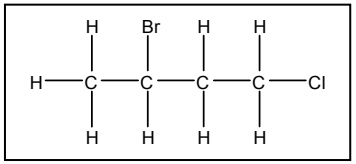
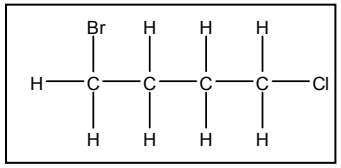
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Question			Answer	Marks	Guidance
7			**Nucleophilic substitution reaction** **correct equation for the reaction** ✓ $CH_2CHCH_2CH_2Cl$ + KOH → $CH_2CHCH_2CH_2OH$ + KCl **OR** C_4H_7Cl + KOH → C_4H_7OH + KCl **correct product of the reaction** ✓  **Mechanism**  dipole shown on C—Cl bond: $C^{\delta+}$ and $Cl^{\delta-}$ in the correct chloroalkene ✓ curly arrow from HO^- to carbon atom of C–Cl bond **AND** curly arrow from C–Cl bond to chlorine atom ✓ formation of Cl^- ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** $CH_2CHCH_2CH_2Cl + OH^- \rightarrow CH_2CHCH_2CH_2OH + Cl^-$ **ALLOW** $C_4H_7Cl + OH^- \rightarrow C_4H_7OH + Cl^-$ **ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **For structure of the product** **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) if seen **ONCE** in equation, mechanism or drawn out eg $CH_2CHCH_2CH_2OH$ curly arrow must start from one lone pair on O atom of ^-OH ion **OR** from negative charge on the O atom of the ^-OH ion Lone pair does **not** need to be shown on ^-OH ion

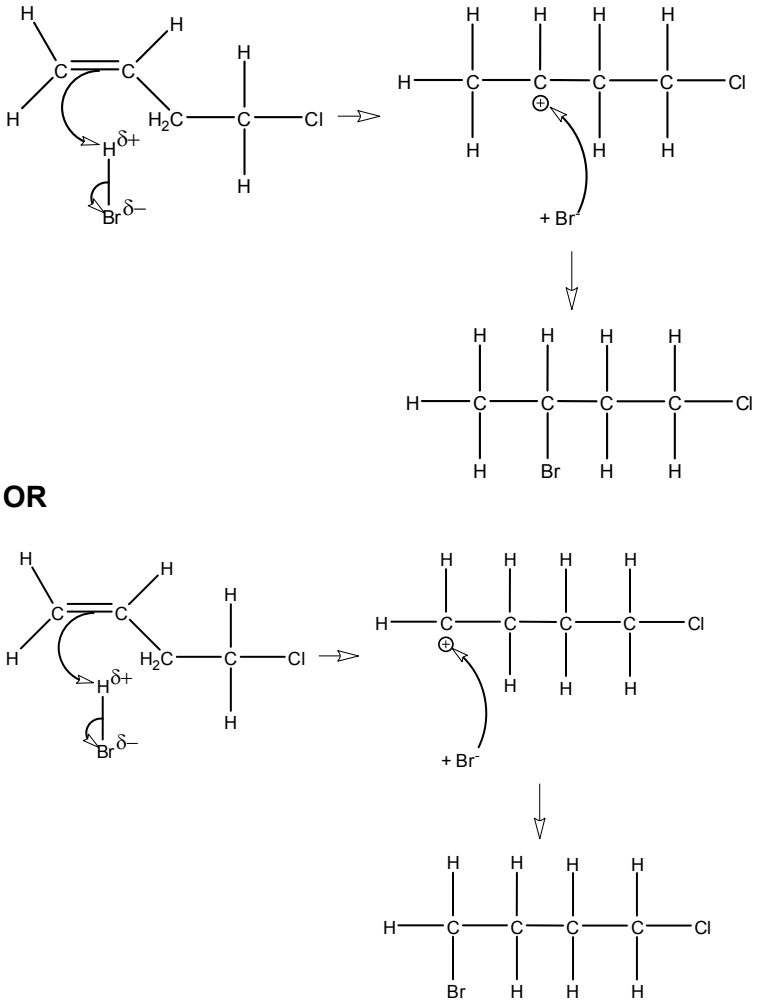
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Question	Answer	Marks	Guidance
	Nucleophilic substitution continued (S_N1) **Step 1:**  **Step 2:** 		**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW S_N1 mechanism** dipole shown on C–Cl bond, $C^{\delta+}$ and $Cl^{\delta-}$ in correct chloroalkene ✓ curly arrow from C–Cl bond to halogen atom and Cl^- ✓ curly arrow from ^-OH to **correct** carbocation ✓ curly arrow must start from one lone pair on O atom of ^-OH ion **OR** from negative charge on the O atom of the ^-OH ion Lone pair does **not** need to be shown on ^-OH ion

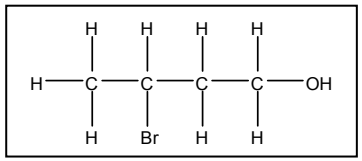
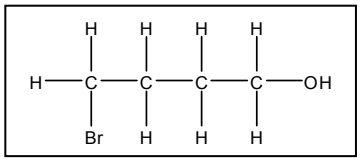
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Question			Answer	Marks	Guidance
7			**Electrophilic addition** **correct equation for the reaction** ✓ $CH_2CHCH_2CH_2Cl + HBr \longrightarrow CH_3CHBrCH_2CH_2Cl$ **OR** $CH_2CHCH_2CH_2Cl + HBr \longrightarrow CH_2BrCH_2CH_2CH_2Cl$ Indication that there are two possible addition products ✓ **Correct product** ✓  **OR**  **Mechanism** Curly arrow from C=C of correct chloroalkene to attack the H atom in HBr ✓ Correct dipole on H–Br: $H^{\delta+}$ and $Br^{\delta-}$ **AND** curly arrow from H–Br bond to Br ✓ Correct carbocation / carbonium ion with the **full** positive charge shown: C^+ **AND** correct curly arrow from lone pair of Br^- to correct carbon atom **OR** correct curly arrow from negative charge of Br^- to correct carbon atom ✓	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** correct molecular **OR** structural **OR** displayed **OR** skeletal formula **OR** mixture of the above. **eg** $C_4H_7Cl + HBr \rightarrow C_4H_8BrCl$ For the structure of the product **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) if seen **ONCE** in equation, mechanism or drawn out eg $CH_2BrCH_2CH_2CH_2Cl$ or $CH_3CHBrCH_2CH_2Cl$ curly arrow must start from covalent bonds and not atoms Lone pair does **not** need to be shown on ion or used in mechanism **DO NOT ALLOW** any other partial charges eg shown on double bond **DO NOT ALLOW** $C^{\delta+}$ for charge on carbonium ion. Curly arrow from Br^- can start from the negative charge or the lone pair **DO NOT ALLOW** delta negative, i.e. $Br^{\delta-}$

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Question			Answer	Marks	Guidance
7			**Electrophilic addition continued**  **OR** 		
			heterolytic fission for **both** mechanisms and **not** contradicted ✓	1	

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Question			Answer	Marks	Guidance
			ALTERNATIVE APPROACH **The Candidate who reacts with KOH followed by HBr** • Award all marks for the nucleophilic substitution mechanism as per the marking scheme • You can award all marks for the electrophilic addition mechanism; however the product will be one of the following:  **OR**  • The mechanism will be the same except the –C*l* will now be replaced by –OH at every stage		
			Total	**12**	

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Question			Answer	Marks	Guidance
8			**IR spectrum** (absorbance between) 3200–3550 cm^{-1} indicates –OH **AND** X is an alcohol ✓	1	**LOOK ON THE SPECTRUM** for labelled absorbance which can be given credit **ALLOW** an absorbance within the range 3100 to 3700cm^{-1} from the spectrum. Answer must give –OH and alcohol for the mark. **IGNORE** phenol **DO NOT ALLOW** carboxylic acid (there is no carbonyl group present in the spectrum)
			Formula **mole ratio C : H : O** $\frac{0.600}{12} : \frac{0.133}{1.0} : \frac{0.267}{16}$ **OR** 0.0500 :0.133 : 0.0167 ✓ $\frac{0.05}{0.0167} : \frac{0.133}{0.0167} : \frac{0.0167}{0.0167}$ **OR** 3 : 8 : 1 **OR** C_3H_8O ✓ Candidate links $\mathbf{C_3H_8O}$ to 60 such as $\mathbf{C_3H_8O}$ has M_r 60 **OR** $\mathbf{C_3H_8O}$ has m/z = 60 ✓	3	Must be a clear link between the **formula** and the M_r **OR** m/z **ALLOW** evidence of M_r , eg (12 x 3) + (8 x 1) + 16; 36 + 8 + 16 = 60 **ALLOW** alternative approach for empirical formula and evidence that 60 is equal to C_3H_8O M_r = 60 Carbon: $60 \times \frac{60}{100} = 36$ Hydrogen: $60 \times \frac{13.3}{100} = 8$ 36/12 = 3 C 8/1 = 8H 36 + 8 = 44 60 – 44 = 16 so 1 O C_3H_8O

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Question			Answer	Marks	Guidance
8			**Identification and equation**	6	
			X is $CH_3CH_2CH_2OH$ **OR** $CH_3CHOHCH_3$ **OR** either $CH_3CH_2CH_2OH$ or $CH_3CHOHCH_3$ ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **IGNORE** names
			QWC Stated in words that **Y** must be an ester because it is made from the reaction of a **carboxylic acid** **AND X (propan-1-ol OR propan-2-ol OR** an **alcohol**) ✓		**ALLOW** a carboxylic acid reacts with an alcohol to give an ester. **IGNORE** ethanoic acid (as this is stated in the question)
			Y is $CH_3COOCH_2CH_2CH_3$ **OR** $CH_3COOCH(CH_3)_2$ **OR** either $CH_3COOCH_2CH_2CH_3$ or $CH_3COOCH(CH_3)_2$ ✓ Must be consistent with a structure of alcohol **X**		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) If no structure of **X** is provided one mark can be awarded for a correct structure of $CH_3COOCH_2CH_2CH_3$ **OR** $CH_3COOCH(CH_3)_2$
			m/*z* = 31 is CH_2OH^+ ✓		**DO NOT ALLOW** CH_3O^+
			QWC *m*/*z* = 31 or CH_2OH indicates that X must be $CH_3CH_2CH_2OH$ **OR** cannot be $CH_3CH(OH)CH_3$ **OR** shows that X is the primary alcohol ✓		**QWC** must link the evidence to the structure of propan-1-ol.
			$C_3H_8O + C_2H_4O_2 \rightarrow C_5H_{10}O_2 + H_2O$ ✓		In equation **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above
			Total	**10**	

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OCR (Oxford Cambridge and RSA Examinations)
1 Hills Road
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CB1 2EU

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RECOGNISING ACHIEVEMENT

Wednesday 23 May 2012 – Afternoon

AS GCE CHEMISTRY A

F322 Chains, Energy and Resources

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry A* (inserted)

Other materials required:
- Scientific calculator

Duration: 1 hour 45 minutes

F3146206122

F322

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. Additional paper may be used if necessary but you must clearly show your candidate number, centre number and question number(s).
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **20** pages. Any blank pages are indicated.

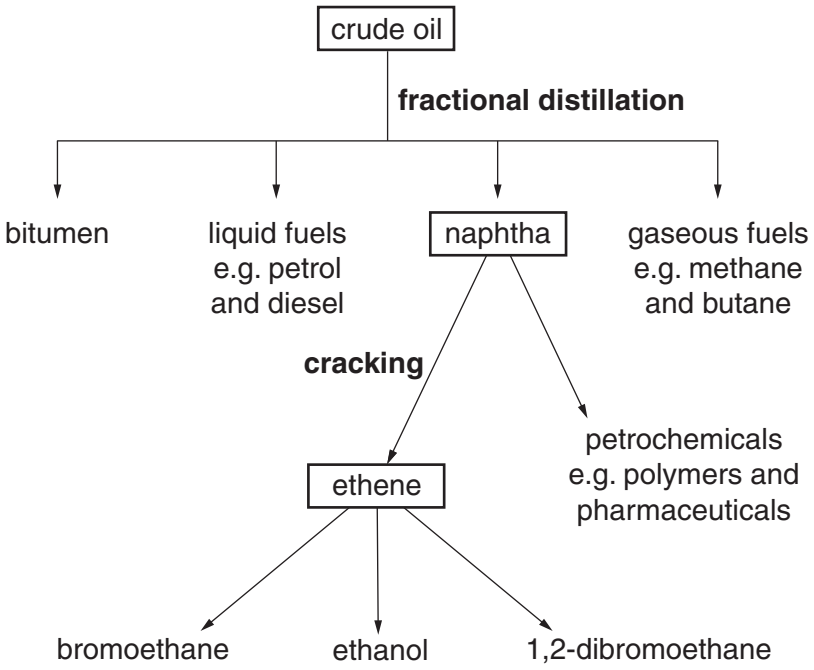
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Answer **all** the questions.

1 Crude oil is a source of many important petrochemicals.

The flow chart shows some of the petrochemicals that can be made and the processes used to make them.



(a) Explain why crude oil can be separated into different fractions.

.....

..... **[1]**

(b) Many scientists believe that we should use more fuels such as biodiesel or bio-ethanol rather than petrol and diesel.

Suggest **one** reason why these scientists take this view.

.....

..... **[1]**

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(c) Cracking converts the alkane dodecane, $C_{12}H_{26}$, into more useful short chain alkanes and alkenes.

(i) When $C_{12}H_{26}$ is cracked, a variety of alkanes and alkenes are formed with different chain lengths.

Explain why a variety of alkanes and alkenes are formed with different chain lengths.

.....

.....

..... **[1]**

(ii) One molecule of $C_{12}H_{26}$ is cracked to produce one molecule of propane and several molecules of an alkene, **A**.

The mass spectrum of **A** contains peaks with the following *m*/*z* values: 15, 27 and 42. There are no *m*/*z* values above 42.

- Write the formula of the particle responsible for the peak at *m*/*z* = 27.
- Identify, with a reason, alkene **A**.
- Write an equation to show this cracking of $C_{12}H_{26}$ to form alkene **A**.

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..... **[4]**

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(d) Ethene can be converted into petrochemicals.

- Describe how ethene can be converted into 1,2-dibromoethane, bromoethane and ethanol.

- Name and describe the mechanism for the conversion of ethene into 1,2-dibromoethane using the 'curly arrow' model.
  Include any relevant dipoles.

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..... **[9]**

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(e) Draw and explain the shape of an ethene molecule.
State the H–C–H bond angle in ethene.

.....

.....

.....

..... **[3]**

(f) Addition polymers are made by the polymerisation of alkenes.

E-Pent-2-ene can be made into an addition polymer.

(i) Draw the structure of *E*-pent-2-ene.

[1]

(ii) Draw the structure of poly(pent-2-ene).
Include **two** repeat units.

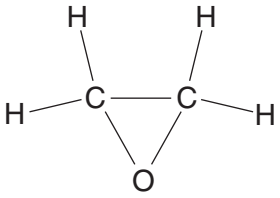
[1]

[Total: 21]

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2 Epoxyethane, C_2H_4O, is a synthetic intermediate that is used to make ethane-1,2-diol and some polymers. The structure of epoxyethane is shown below.



(a) The controlled catalysed reaction of ethene with oxygen forms epoxyethane as the only product.

(i) Write the equation for this reaction.

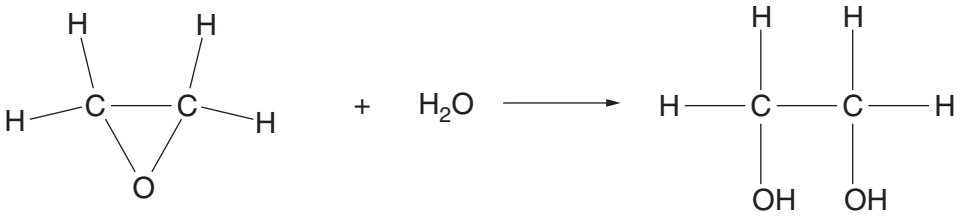
[1]

(ii) When burnt in excess oxygen, ethene completely combusts.

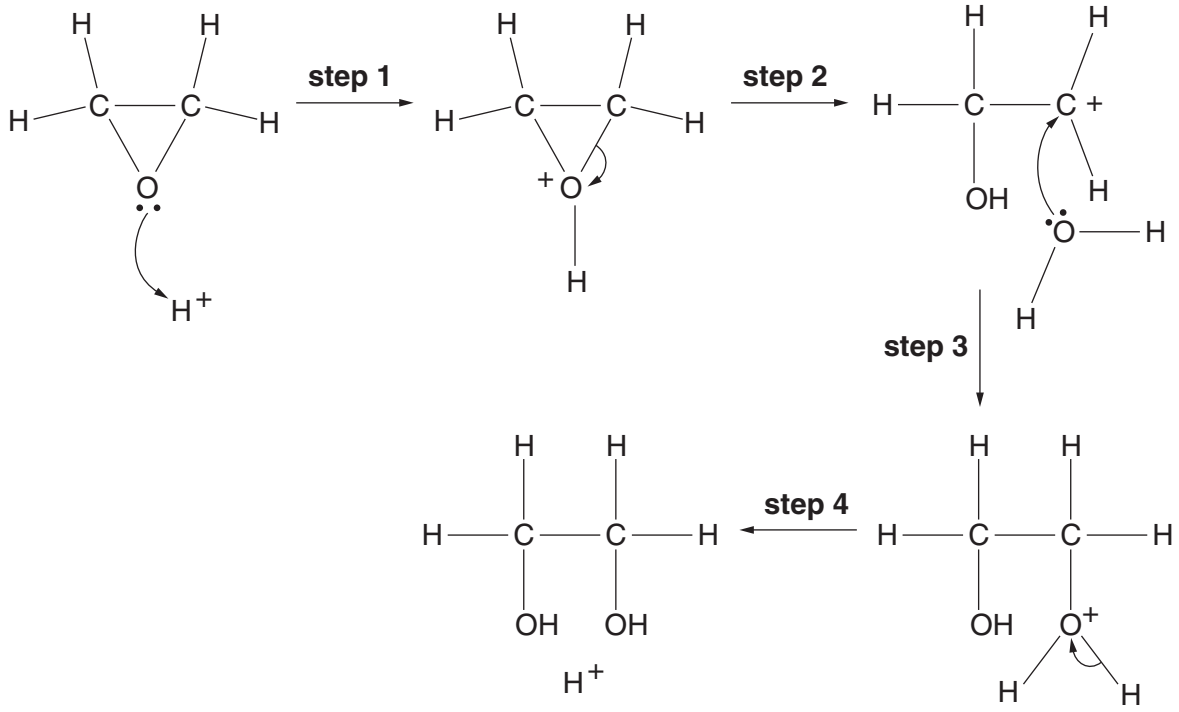
Write the equation for the complete combustion of ethene.

..... **[1]**

(b) Epoxyethane reacts with water in the presence of an acid catalyst to form ethane-1,2-diol.



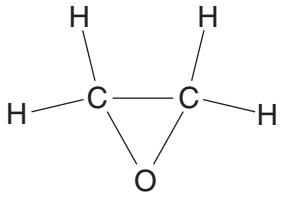
The mechanism for this reaction is shown below.



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(i) Draw dipoles on the carbon and oxygen atoms on the displayed formula of epoxyethane.



[1]

(ii) The mechanism uses the 'curly arrow' model.

What does a '*curly arrow*' represent?

.....

..... **[1]**

(iii) What type of bond fission occurs in **step 2**?

Explain your answer.

.....

.....

..... **[2]**

(iv) How can you tell that water is behaving as a nucleophile in **step 3**?

.....

..... **[1]**

(v) How does the mechanism show that H^+ ions act as a catalyst in this reaction?

Refer to the steps in the mechanism in your answer.

.....

..... **[1]**

(vi) Epoxyethane reacts with methanol, CH_3OH, to form a compound with the molecular formula $C_3H_8O_2$.

Suggest the structure of this compound.

[1]

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(c) Ethane-1,2-diol is much less volatile than ethanol.

Suggest why.

.....

.....

.....

.....

..... **[2]**

(d) Ethane-1,2-diol reacts with an excess of ethanoic acid, CH_3COOH, in the presence of an acid catalyst. A compound is formed with the molecular formula $C_6H_{10}O_4$.

Draw the structure of this compound.

[2]

(e) Ethane-1,2-diol reacts with warm acidified potassium dichromate(VI). A number of different organic products are formed.

Draw the displayed formulae of **two** of these organic products.

[2]

[Total: 15]

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3 Hydrogen has many industrial uses including making margarine and ammonia.

Hydrogen can be made by the reaction between methane and steam.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +210\,kJ\,mol^{-1}$$

(a) The pressure of the equilibrium mixture is **increased**.

Explain what happens to the position of the equilibrium.

.....

.....

..... **[2]**

(b) The temperature of the equilibrium mixture is **increased**.

Explain what happens to the position of the equilibrium.

.....

.....

..... **[2]**

(c) The reaction is actually carried out in the presence of a nickel catalyst at a pressure of 30 atmospheres.

(i) Suggest why the manufacturer uses a pressure of 30 atmospheres.

.....

.....

..... **[1]**

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(ii) The nickel catalyst increases the rate.

Use a labelled diagram of the Boltzmann distribution of molecular energies to explain why.

.....

.....

.....

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..... **[3]**

(d) A chemical factory uses 200 tonnes of methane a day. The factory produces 68.4 tonnes of hydrogen per day by reacting methane with steam.

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

Calculate the percentage yield of hydrogen.

Give your answer to **three** significant figures. (1 tonne = 1×10^6 g)

percentage yield of hydrogen = ... % **[3]**

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(e) The carbon monoxide produced in the equation below can be reacted with hydrogen to make methanol.

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

(i) Construct the equation for the reaction of carbon monoxide with hydrogen to make methanol.

..... **[1]**

(ii) Suggest **two** reasons why it is important to use the carbon monoxide to make methanol.

.....

.....

.....

..... **[2]**

(f) Describe how hydrogen can be used in the manufacture of margarine.

.....

.....

.....

..... **[2]**

[Total: 16]

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4 The uses of catalysts have great economic and environmental importance. For example, catalysts are used in ammonia production and in catalytic converters.

(a) Nitrogen and hydrogen react together in the production of ammonia, NH_3.

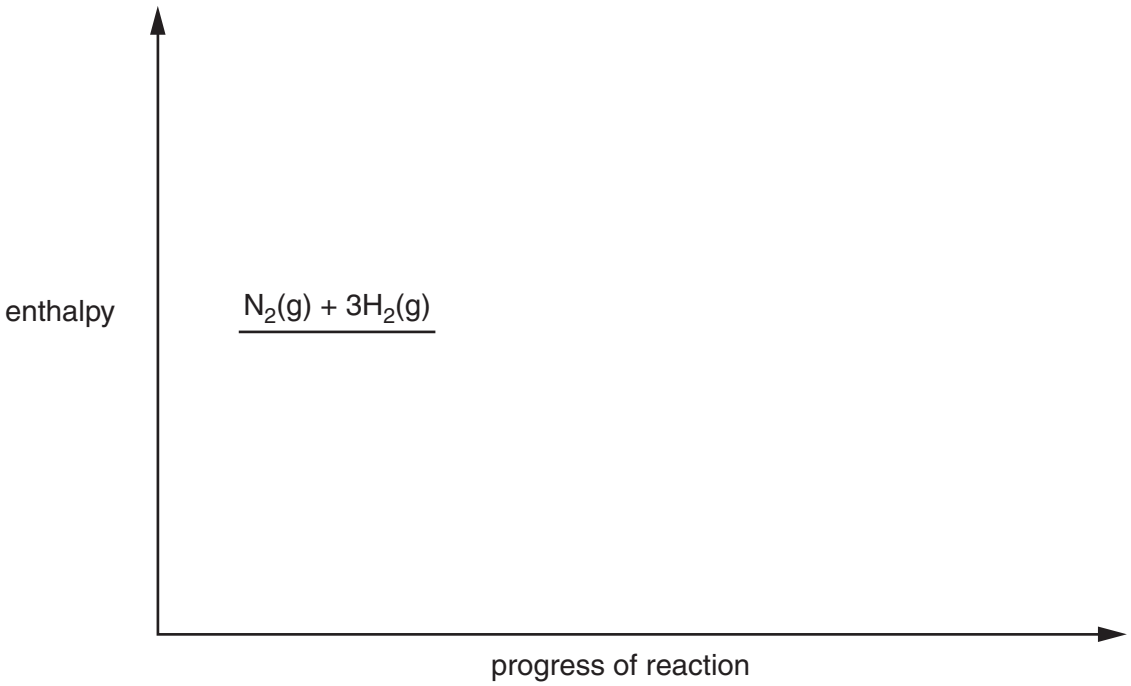
$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H = -92\,kJ\,mol^{-1}$$

The activation energy for the forward reaction, E_a, is $+250\,kJ\,mol^{-1}$.

(i) Complete the enthalpy profile diagram for this reaction between nitrogen and hydrogen.

Include the

- products
- enthalpy change of reaction, ΔH
- activation energy for the forward reaction, E_a.



[3]

(ii) What is the value of the enthalpy change of formation of ammonia?

answer = ... $kJ\,mol^{-1}$ **[1]**

(iii) The reaction between nitrogen and hydrogen can be catalysed.

Suggest a possible value for the activation energy of the **catalysed** forward reaction.

answer = ... $kJ\,mol^{-1}$ **[1]**

(iv) What is the value of the activation energy for the uncatalysed **reverse** reaction (the decomposition of ammonia into nitrogen and hydrogen)?

answer = ... $kJ\,mol^{-1}$ **[1]**

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(b) In a catalytic converter, nitrogen monoxide reacts with carbon monoxide.

(i) Write the equation for this reaction.

..... **[1]**

(ii) Outline the stages that allow nitrogen monoxide and carbon monoxide to react in a catalytic converter.

.....

.....

.....

.....

.....

.....

..... **[3]**

(c) Scientists monitor pollutant gases in the atmosphere.

(i) State **two** modern analytical techniques that scientists can use to monitor environmental pollution.

.....

..... **[2]**

(ii) Explain why it is important to establish **international** cooperation to reduce pollution levels.

.....

.....

..... **[1]**

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(d) In the stratosphere, nitrogen monoxide, NO, is linked with ozone depletion.

Complete the equations below that describe how NO contributes to ozone depletion.

step 1 $NO + O_3 \longrightarrow$ ..... + ...

step 2 NO_2 + ... $\longrightarrow NO$ + ...

overall ..... + ... $\longrightarrow 2O_2$

[3]

(e) Hess' law can be used to calculate enthalpy changes of reaction.

The equation for the reaction that gives the enthalpy change of formation, ΔH_f, of $N_2O(g)$ is as follows.

$$N_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow N_2O(g)$$

(i) It is not possible to measure the enthalpy change of formation of $N_2O(g)$ directly.

Suggest why it is **not** possible.

.....

..... **[1]**

(ii) The data below can be used to calculate the enthalpy change of formation, ΔH_f, of $N_2O(g)$.

reaction	enthalpy change of reaction / kJ mol^{-1}
$C(s) + N_2O(g) \longrightarrow CO(g) + N_2(g)$	–193
$C(s) + \tfrac{1}{2}O_2(g) \longrightarrow CO(g)$	–111

Calculate ΔH_f for $N_2O(g)$.

ΔH_f = ... kJ mol^{-1} **[2]**

[Total: 19]

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5 Methane and ethane are important fuels.

(a) Methane could be manufactured by the reaction between carbon dioxide and hydrogen.

$$CO_2(g) + 4H_2(g) \rightarrow CH_4(g) + 2H_2O(g)$$

Using the table of bond enthalpies, calculate the enthalpy change of reaction for this manufacture of methane.

bond	average bond enthalpy / kJ mol^{-1}
C–H	+415
H–H	+436
C=O	+805
O–H	+464

enthalpy change of reaction = ... kJ mol^{-1} **[3]**

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(b) Methane is a greenhouse gas. Scientists are concerned that the concentration of methane in the atmosphere is slowly increasing.

(i) Explain how atmospheric methane molecules can contribute to global warming.

.....

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.....

..... **[2]**

(ii) One way that scientists hope to minimise global warming is by developing Carbon Capture and Storage, CCS, techniques.

Describe **two** of these CCS techniques.

.....

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..... **[2]**

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(c) Ethane reacts with bromine in the presence of ultraviolet radiation to form many organic products.

(i) Two of these products are bromoethane and hydrogen bromide.

Describe the mechanism of the reaction between ethane and bromine that forms bromoethane and hydrogen bromide.

Include in your answer

- the type of bond fission that occurs
- equations for each step of the reaction
- the name of each step of the reaction.



Your answer needs to be clear and well organised using the correct terminology.

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..... **[7]**

(ii) Give **two** reasons why there are many organic products of the reaction between bromine and ethane.

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..... **[2]**

[Total: 16]

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6 A student carries out an investigation on some halogenoalkanes.

(a) She decided to hydrolyse 1-bromopentane and 1-chloropentane using aqueous sodium hydroxide.

State and explain the difference in the rates of hydrolysis of 1-bromopentane and 1-chloropentane.

.....

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..... **[2]**

(b) A student wants to determine the structure of an unknown iodoalkane **B**.

She knows that the molecular formula of **B** is C_4H_9I.

The student heats **B** with aqueous sodium hydroxide. A reaction mixture forms containing the organic compound **C** and $I^-(aq)$.

(i) Draw all of the possible structural isomers for **B**.

[4]

(ii) What is the molecular formula for compound **C**?

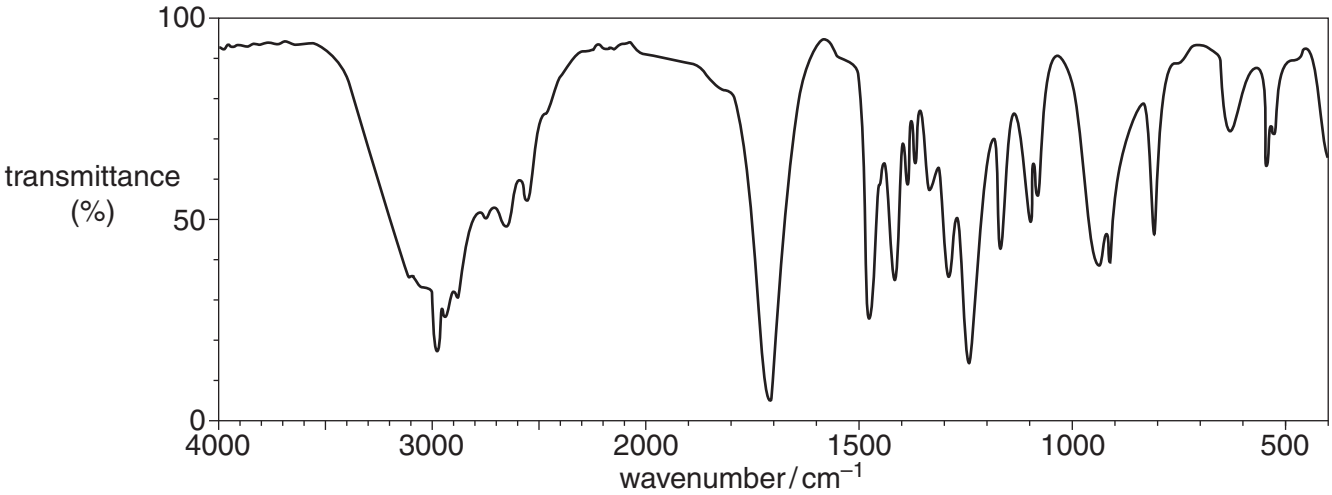
..... **[1]**

(iii) The student purifies compound **C** and splits it into two portions.

- She heats one portion of **C** with concentrated sulfuric acid. The product of this reaction is methylpropene.
- To the other portion of **C**, she adds acidified potassium dichromate(VI) and heats the mixture under reflux. The product of this reaction is compound **D**.
- The infrared spectrum for compound **D** is shown at the top of page 19.

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Use this evidence to suggest structures for **B**, **C** and **D**.

In your answer you should make clear how your explanations are linked to the evidence.

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..... **[6]**

[Total: 13]

END OF QUESTION PAPER

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RECOGNISING ACHIEVEMENT

GCE

Chemistry A

Advanced Subsidiary GCE

Unit **F322:** Chains, Energy and Resources

Mark Scheme for June 2012

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Annotations

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Ignore
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response

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Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

Annotations should be placed to clearly show where they apply within the body of the text (ie not in margins)

Question 1 **(c)(ii), (d)**
Question 3 **(c)(ii)**
Question 4 **(a)(i)**
Question 5 **(c)(i)**
Question 6 **(b)(iii)**

All questions where an ECF has been applied.

Checking additional pages

All the Additional Pages in the examination script must be checked to see if any candidates include any answers.

The only additional page is part of the last question, **6(b)(iii)**.

You must annotate page 20 with an omission mark ^ if the page is blank to show that you have checked this page.

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Generic comments

ORGANIC STRUCTURES

For a 'structure' or 'structural formula',

- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)

For an alkyl group shown within a structure,

- **ALLOW** bond drawn to C or H,
  eg **ALLOW** CH_3–,CH_2–, C_3H_7–, etc
- **ALLOW** vertical 'bond' to any part of an alkyl group

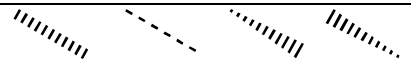
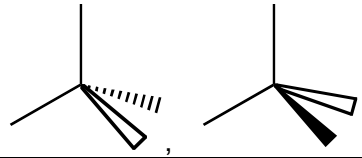
For an OH group shown within a structure,

- **DO NOT ALLOW** formula with horizontal –HO **OR**
- **ALLOW** vertical 'bond' to any part of the OH group

For a CHO group shown within a structure,

- **DO NOT ALLOW** COH

For a 3-D structure,

• For bond in the plane of paper, a solid line is expected:	
• For bond out of plane of paper, a solid wedge is expected:	
• For bond into plane of paper, **ALLOW**:	
• **ALLOW** a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge eg:	

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NAMES

Names including alkyl groups:

- **ALLOW** alkanyl, eg ethanyl (ie **IGNORE** 'an')
- **DO NOT ALLOW** alkol, eg ethol (ie 'an' is essential)

Names of esters:

- Two words are expected, eg ethyl ethanoate
- **ALLOW** one word, eg ethylethanoate

Names with multiple numbers and hyphens:

Use of 'e'

- **ALLOW** superfluous 'e' , eg propane-1-ol ('e' is kept if followed by consonant)
- **ALLOW** absence of 'e', eg propan-1,2-diol ('e' is omitted if followed by vowel)

Hyphens separate name from numbers:

- **ALLOW** absence of hyphens, eg propane 1,2 diol

Multiple locant numbers must be clearly separated:

- **ALLOW** full stops: eg 1.2 **OR** spaces: 1 2
- **DO NOT ALLOW** eg 12

Locant numbers in formula must be correct

- **DO NOT ALLOW** propan-3-ol

Order of substituents should be alphabetical:

- **ALLOW** any order (as long as unambiguous), eg 2-chloro-3-bromobutane

ABBREVIATIONS

van der Waals' forces

- **ALLOW** vdw forces **OR** VDW forces (and any combination of upper and lower cases)

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Question			Answer	Marks	Guidance
1	(a)		Because hydrocarbons have different boiling points ✓	1	**ALLOW** each fraction / component / substance / molecule / compound / fuel has a different boiling temperatures **ALLOW** condense at different temperatures **ALLOW** because van der Waals' forces differ with molecular size **IGNORE** references to volatility different strength of intermolecular forces is **not** sufficient
	(b)		***Any one from:*** Bio-fuels produce less carbon dioxide (overall) **OR** petrol or diesel produce more carbon dioxide (overall) ✓ Bio-fuels are renewable **OR** petrol and diesel are non-renewable ✓ Allows crude oil to be used to make other products **OR** petrochemicals (rather than petrol) **OR** Save crude oil **OR** no risk of large scale pollution from exploitation of crude oil ✓	1	**ASSUME** 'they' or 'it' refers to biofuels **ALLOW** bio-fuels are (more) carbon-neutral **OR** plants take up the carbon dioxide released during combustion **ALLOW** lower carbon footprint **ALLOW** plants are a renewable resource / crude oil non-renewable resource / bio-diesel is more sustainable / diesel is not sustainable / petrol and diesel are made from a finite resource / petrol and diesel will run out / bio-fuels will not run out **ALLOW** decrease the need for fossil fuels **IGNORE** can be used by diesel powered cars with or without any conversion
	(c)	(i)	Idea that **carbon–carbon** bonds can break anywhere ✓	1	The answer must refer to carbon–carbon bonds or the carbon chain **ALLOW** (carbon) **chain** can break anywhere Bonds can break anywhere is not sufficient

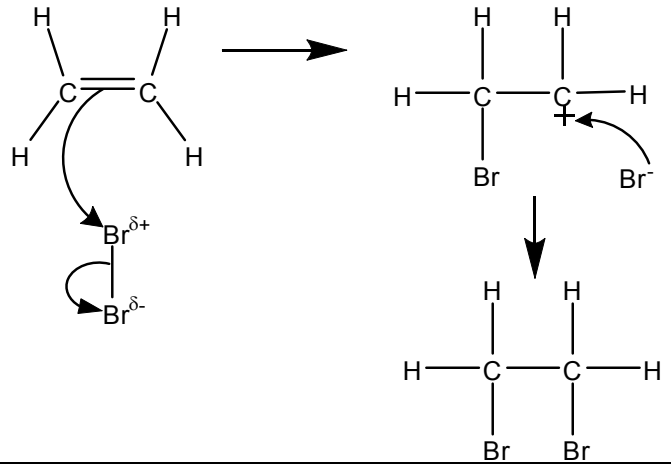
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Question			Answer	Marks	Guidance
1	(c)	(ii)		4	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**
			Correct identification of $C_2H_3^+$ for $m/z = 27$ ✓		**ALLOW** $CHCH_2^+$ **DO NOT ALLOW** C_2H_3 (the positive charge is essential) **OR** CCH_3^+
			Some indication to explain how the identity of propene was deduced **OR** further analysis of the mass spectrum ✓		**ALLOW** Molecular ion/M^+/M is $m/z = 42$ **OR** $m/z = 15$ is CH_3 **ALLOW** mass spectrum shows $M_r = 42$ **ALLOW** idea that alkane $C_{12}H_{26} – C_3H_8$ can only give $3C_3H_6$
			Correct identification of the alkene as C_3H_6 **OR** propene ✓		**ALLOW** prop-1-ene An incorrect formula for the alkene in the equation will not contradict this answer
			$C_{12}H_{26} \rightarrow C_3H_8 + 3C_3H_6$ ✓		**ALLOW** C_3H_6 from its use in an equation even if the equation is wrong providing there has not been an attempt elsewhere to identify the alkene **ALLOW** correct displayed **OR** structural **OR** skeletal **OR** molecular formulae in the equation

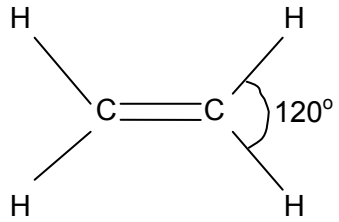
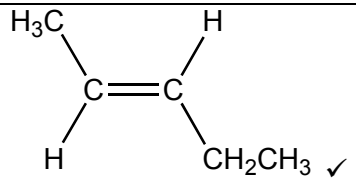
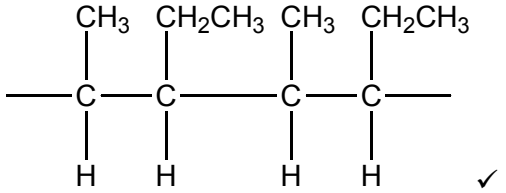
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Question			Answer	Marks	Guidance
1	(d)			9	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **ALLOW** reactants even from incorrect equations **ALLOW** reactants or conditions over the arrow
			React with bromine **OR** $C_2H_4 + Br_2 \rightarrow C_2H_4Br_2$ ✓		**ALLOW** Br_2 mark from the mechanism even if the mechanism is incorrect **IGNORE** conditions unless they would lead to a different reaction with ethene
			React with hydrogen bromide **OR** $C_2H_4 + HBr \rightarrow C_2H_5Br$ ✓		**IGNORE** conditions unless they would lead to a different reaction with ethene
			React with steam **OR** heat with water **OR** $C_2H_4 + H_2O(g) \rightarrow C_2H_5OH$ ✓		**ALLOW** temperature range between 100–400 ^oC if quoted **IGNORE** reference to pressure **IGNORE** hydrolysis Hydration is not sufficient but **DO NOT ALLOW** hydrogenation
			acid (catalyst) ✓		**ALLOW** H_2SO_4 **OR** H_3PO_4 **OR** H^+ **DO NOT ALLOW** HC*l*, HBr etc. **ALLOW** two stage process e.g. react with HBr one mark followed by KOH(aq) one mark

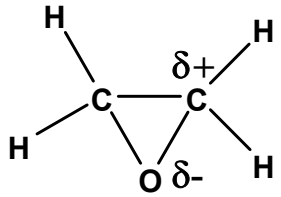
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Question	Answer	Marks	Guidance
	Electrophilic addition ✓		
	Curly arrow from double bond to attack $Br^{\delta+}$ of Br–Br and breaking of Br–Br bond ✓		Curly arrow must start from the double bond and not a carbon atom and go the $Br^{\delta+}$; other curly arrow must start from Br–Br bond. **ALLOW** attack of Br–Br if dipoles not shown **DO NOT ALLOW** attack of $Br^{\delta-}$
	Correct dipoles shown on $Br^{\delta+}$–$Br^{\delta-}$ ✓		Dipole must be partial charge and not full charge **DO NOT ALLOW** any other partial charges eg on the double bond
	Correct carbonium / carbocation ion drawn ✓		Carbocation needs a full charge and not a partial charge (charges do not need to be surrounded by a circle) All atoms in the carbocation must be shown
	Curly arrow from Br^- to the carbonium ion **and** correct product shown ✓		Br^- curly arrow must come from one lone pair on Br^- ion **OR** from minus sign on Br^- ion Lone pair does not need to be shown on Br^- ion
			**ALLOW** mechanism which goes via a cyclic bromonium ion instead of the carbocation **SEE EXTRA ADVICE ABOUT CURLY ARROWS ON PAGE 30**

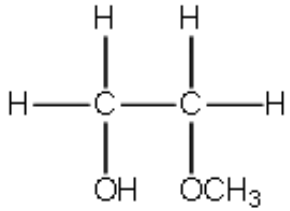
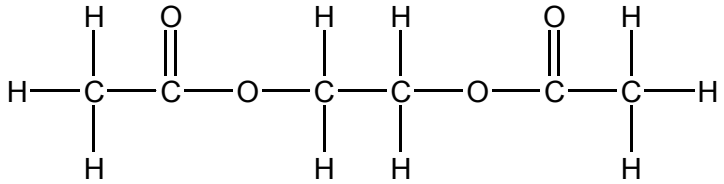
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Question			Answer	Marks	Guidance
1	(e)		Correct shape ✓  120° ✓ Three areas of electron density repel each other ✓	3	**IGNORE** any name of shape given **ALLOW** 115–125° **ALLOW** even if it is the C–C–H shown on a diagram. **ALLOW** three or four electron pairs repel **OR** three or four bonds repel **IGNORE** does not have any lone pairs **DO NOT ALLOW** atoms repel / electrons repel **DO NOT ALLOW** has lone pair which repels more
	(f)	(i)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)
		(ii)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** CH_3 and C_2H_5 groups above or below chain **ALLOW** bond to ethyl and methyl group to any part of ethyl or methyl group **IGNORE** any brackets drawn **ALLOW two** or more repeat units but has to have a whole number of repeat units (*ie* does not have to be two) 'End bonds' **MUST** be shown and can be dotted **IGNORE** *n*
			Total	**21**	

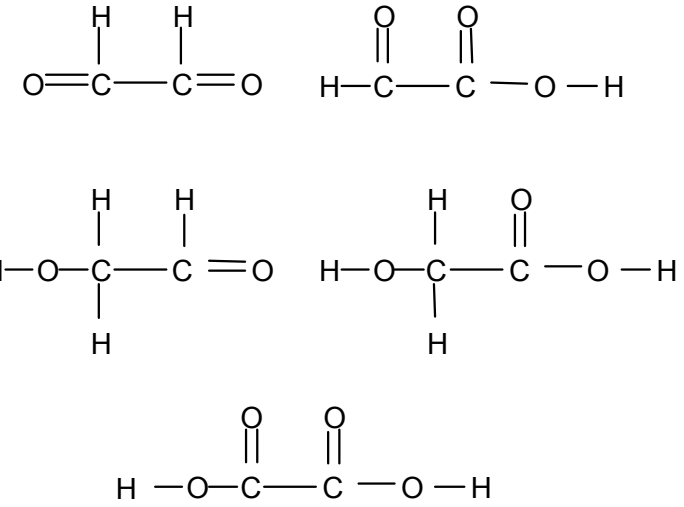
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Question			Answer	Marks	Guidance
2	(a)	(i)	$2C_2H_4 + O_2 \rightarrow 2C_2H_4O$ ✓	1	**ALLOW** molecular formulae **OR** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** correct multiples, including fractions, of this equation **IGNORE** state symbols **DO NOT ALLOW** [O]
		(ii)	$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$ ✓	1	**ALLOW** molecular formulae **OR** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** correct multiples of this equation **IGNORE** state **symbols** **DO NOT ALLOW** [O]
	(b)	(i)	✓  	1	Only one carbon atom needs to have the correct partial charge **DO NOT ALLOW** partial charges on hydrogen atoms
		(ii)	Movement of an electron pair ✓	1	**ALLOW** movement of a lone pair **OR** movement of a bond **ALLOW** movement of two electrons
		(iii)	Heterolytic ✓ Both electrons (in the bond) go to the same atom **OR** (bond breaks) to make a cation and (a lone pair on the oxygen atom) **OR** bond pair becomes a lone pair on oxygen ✓	2	**MARK INDEPENDENTLY** **ALLOW** one atom gets none of the bonded electrons **DO NOT ALLOW** both electrons go to a molecule **DO NOT ALLOW** makes a positive and a negative ion because in this example this is **not** true
		(iv)	It donates a **pair** of electrons ✓	1	**ALLOW** donates a lone pair **DO NOT ALLOW** it donates electrons
		(v)	idea that H^+ ion is used in **step 1 AND** made in **step 4** ✓	1	**ALLOW** H^+ ion is used at the **start AND** made at the **end** **IGNORE** overall H^+ is not used up in the mechanism

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Question			Answer	Marks	Guidance
2	(b)	(vi)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) eg $CH_2OHCH_2OCH_3$ **ALLOW** vertical 'bond' to any part of the OH or OCH_3 group **DO NOT ALLOW** formula with horizontal –HO **OR** OH– **DO NOT ALLOW** formula with horizontal $–CH_3O$ **OR** $OCH_3–$
	(c)		Ethane-1,2-diol has more OH groups (than ethanol) ✓ Stronger hydrogen bonding (between ethane-1,2-diol molecules) ✓	2	**ALLOW** has more hydroxyl groups **OR** has more hydroxy groups **OR** has more alcohol groups Ethane-1,2-diol has two OH groups is **NOT** sufficient but **ALLOW** ethane-1,2-diol has two OH groups and ethanol has one **DO NOT ALLOW** it has hydroxide (ions) **ALLOW** more hydrogen bonds (between ethane-1,2-diol molecules) **IGNORE** hydrogen bonds with water
	(d)		One ester linkage drawn despite the rest of the structure ✓ Correct structure for example $CH_3COOCH_2CH_2OOCCH_3$ **OR**  ✓	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** ester shown as all the atoms **OR** as –COOC– **OR** $–CH_2OOC–$ **OR** $–CH_2OCOC–$ **IGNORE** molecular formula

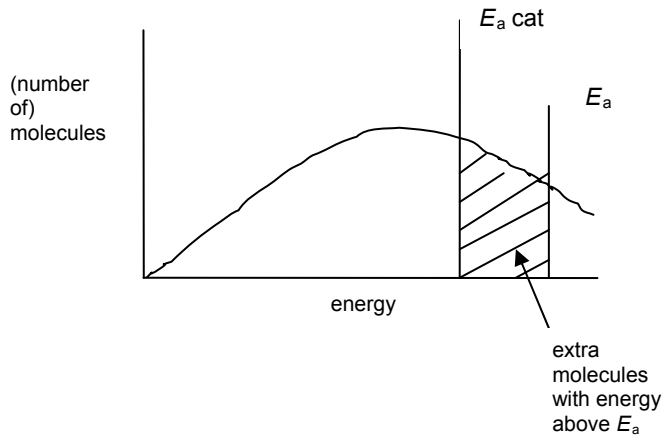
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Question			Answer	Marks	Guidance
2	(e)		***Any two from:***  ✓✓	2	Mark incorrect answers first • If one incorrect answer maximum of 1 mark • If two incorrect answers award 0 marks **ALLOW** OH instead of –O—H **ALLOW** vertical 'bond' to any part of the OH **DO NOT ALLOW** formula with horizontal —HO **OR** OH— but **ALLOW ECF** if both displayed formulae are drawn this way **ALLOW one mark if two correct** structural **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) are drawn
			Total	**15**	

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Question			Answer	Marks	Guidance
3	(a)		(equilibrium position shifts) to the left ✓ (because there are) fewer moles (of gas) on the reactant side **OR** (there are) more moles (of gas) on product side ✓ This explanation mark is dependent on the correct shift of the equilibrium	2	**Note: ALLOW** suitable alternatives for 'to left', eg: towards CH_4 or H_2O / towards reactants **OR** in backward direction **OR** in reverse direction **OR** decreases yield of CO or H_2/products **ALLOW** 'favours the left', as alternative for 'shifts equilibrium to left' **ALLOW** fewer molecules on reactant side **OR** smaller volume on the left hand side **ALLOW ORA** if specified **IGNORE** responses in terms of rate
	(b)		(equilibrium position shifts) to the right ✓ (because forward) reaction is endothermic **OR** **reverse** reaction is exothermic ✓ This explanation mark is dependent on the correct shift of the equilibrium	2	**Note: ALLOW** suitable alternatives for 'to right', eg: towards CO or H_2 / towards products **OR** in forward direction **OR** increases yield of CO or H_2/products **OR** decreases amount of CH_4 or H_2O/reactants **ALLOW** 'favours the right', as alternative for 'shifts equilibrium to right' **ALLOW** reaction takes in heat **ALLOW reverse** reaction gives out heat **ALLOW ORA** if specified **IGNORE** responses in terms of rate
	(c)	(i)	Gives a high rate of reaction **OR** reaction is fast **OR** reasonable rate of reaction without shifting equilibrium too much to the left ✓	1	**ALLOW** if greater pressure used it increases safety risk **ALLOW** if greater pressure used it is more expensive **ALLOW** higher pressure will shift equilibrium position even more to the left It is a compromise on its own is **not** sufficient but **ALLOW** compromise between rate and yield **OR** between rate and safety

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Question			Answer	Marks	Guidance
3	(c)	(ii)		3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**
			y-axis label is '(fraction of or number of) molecules' **AND** *x*-axis label is 'energy' **AND** correct curve ✓		Boltzmann distribution - must start at origin and must not end up at 0 on *y*-axis ie must not touch *x*-axis **ALLOW** particles **OR** moles as *y*-axis label **IGNORE** minor point of inflexion in the curve **DO NOT ALLOW** two curves **DO NOT ALLOW** atoms but credit atoms if used in a second marking point **DO NOT ALLOW** enthalpy for *x*-axis label
			Lowers activation energy ✓		**ALLOW** this mark from a labelled diagram
			More molecules with energy above activation energy with a catalyst **OR** more **effective** collisions **OR** more **successful** collisions ✓		more collisions per second is not sufficient
					

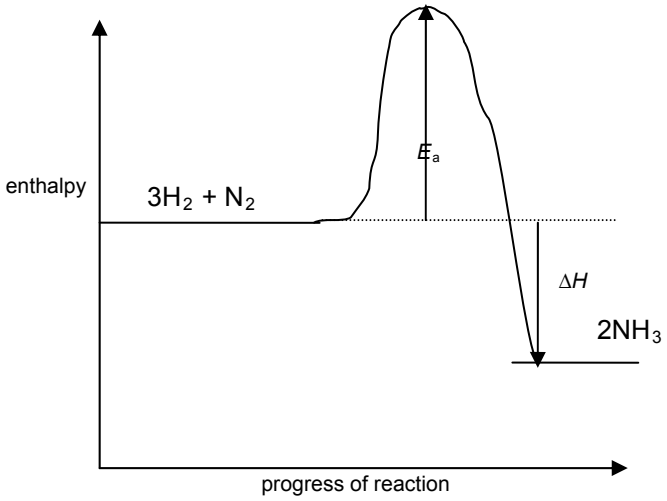
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Question			Answer	Marks	Guidance
3	(d)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 91.2 (%) award 3 marks** theoretical amount of hydrogen = 3.75×10^7 (mol) ✓ actual amount of hydrogen made = 3.42×10^7 (mol) ✓ % = 91.2 ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below IF ECF, **ANNOTATE WITH TICKS AND CROSSES, etc** Answer must have **three** significant figures **ALLOW** ECF from incorrect theoretical and actual amounts of hydrogen **ALLOW** answer that uses grams rather than tonnes where theoretical amount of hydrogen = 37.5 (mol) and actual amount of hydrogen = 34.2 (mol) **ALLOW** alternative approach based on the mass of hydrogen rather than the amount of hydrogen Theoretical amount of hydrogen = 3.75×10^7 (mol) ✓ Theoretical mass of hydrogen made = 75 (tonnes) ✓ Percentage = 91.2 ✓
	(e)	(i)	$CO + 2H_2 \rightarrow CH_3OH$ ✓	1	**ALLOW** correct multiples **ALLOW** CH_4O **IGNORE** state symbols
		(ii)	***Any two from:*** Carbon monoxide is toxic **OR** poisonous ✓ Increases atom economy of the process **OR** gives 100% atom economy ✓ Methanol is a fuel ✓	2	 **IGNORE** harmful or dangerous **ALLOW** uses a waste product **OR** CO is then a desired product **OR** CO is no longer a waste product **OR** reduces amount of waste product **ALLOW** other uses of methanol eg petrol additive, solvent or organic feedstock

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Question			Answer	Marks	Guidance
3	(f)		Unsaturated (vegetable) oils **OR** oils containing C=C bonds ✓ (reacted with hydrogen) in the presence of a nickel catalyst ✓	2	**ALLOW** unsaturated fats **OR** unsaturated lipids **OR** unsaturated ester **ALLOW** oils become more saturated **IGNORE** unsaturated compound **DO NOT ALLOW** unsaturated hydrocarbon **ALLOW** Pt **OR** Pd
			Total	**16**	

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Question			Answer	Marks	Guidance
4	(a)	(i)		3	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**
			$2NH_3$ added as product ✓		**IGNORE** state symbol **ALLOW** product mark even if product line above the reactant line
			ΔH labelled with product below reactant **AND** arrow downwards ✓		**ALLOW** –92 as a label for ΔH **ALLOW** this line even if it has a small gap at the top and bottom ie does not quite reach reactant or product line
			E_a labelled correctly **AND** above reactants ✓		The curve must be drawn for this marking point
					**IGNORE** arrows at both ends of activation energy line but **DO NOT ALLOW** arrow pointing down The E_a line must go to maximum (or near to the maximum) on the curve **ALLOW** if the line clearly shows an activation energy and is not an enthalpy change **ALLOW** this line even if it has a small gap at the top and bottom ie does not quite reach the maximum or reactant line

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Question			Answer	Marks	Guidance
4	(a)	(ii)	–46 (kJ mol^{-1}) ✓	1	**DO NOT ALLOW** 46 with no sign
		(iii)	Any value between +1 to +249 (kJ mol^{-1}) ✓	1	+ sign is not needed
		(iv)	+342 (kJ mol^{-1}) ✓	1	+ sign is not needed
	(b)	(i)	$2CO + 2NO \rightarrow 2CO_2 + N_2$ ✓	1	**ALLOW** correct multiples

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Question			Answer	Marks	Guidance
4	(b)	(ii)	CO and NO are adsorbed (onto surface) **OR** reactants are adsorbed (onto surface) ✓	3	**ALLOW** CO and NO stick onto surface **OR** CO and NO form weak attractions to the surface **OR** gases are adsorbed onto surface **OR** gases bond to surface **NOT** absorb but **allow** ecf for deabsorb later on
			weakening of bonds **OR** chemical reaction **OR** new bonds are made **OR** carbon dioxide and nitrogen are made ✓		**ALLOW** lowers activation energy **IGNORE** alternative pathway Requires less energy is not sufficient
			CO_2 and N_2 desorbs (from the surface) **OR** products desorbs (from the surface) ✓		**ALLOW** products leave (the surface) **OR** products diffuse away (from surface) **OR** weak attraction to surface is broken **ALLOW** deadsorb

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Question			Answer	Marks	Guidance
4	(c)	(i)	***Any two from:*** IR (spectroscopy) ✓ Mass spectrometry ✓ UV (spectroscopy) ✓ NMR ✓ GC ✓	2	 **ALLOW** mass spec / MS / mass spectroscopy **ALLOW** atomic absorption / AAS **IGNORE** satellite imaging or thermal imaging
		(ii)	***Any one from:*** Idea that pollution travels (across country) borders **OR** idea that all countries contribute towards pollution **OR** Cooperation means that scientists can share ideas **OR** scientists can warn governments of risk **OR** world-wide legislation can be introduced **OR** allows monitoring of pollution in different countries **OR** richer countries can help poorer countries introduce pollution controls **OR** One country cannot control pollution unless all countries do ✓	1	 **ALLOW** some countries produce more pollution than others **ALLOW** so protocols can be developed
	(d)		**Step 1** $NO + O_3 \rightarrow NO_2 + O_2$ ✓ **Step 2** $NO_2 + O \rightarrow NO + O_2$ ✓ **overall** $O_3 + O \rightarrow 2O_2$ ✓	3	

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Question			Answer	Marks	Guidance
4	(e)	(i)	Reaction gives NO **OR** reaction gives NO_2 **OR** reaction gives a mixture of oxides **OR** activation energy too high **OR** rate of reaction is too slow ✓	1	**ALLOW** makes a mixture of oxides/products **ALLOW** reaction cannot be carried out experimentally **ALLOW** reaction does not take place nitrogen and oxygen do not react together is **not** sufficient **IGNORE** heat loss to surroundings **IGNORE** reference to bond enthalpy being a mean value
		(ii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = +82 (kJ mol^{-1}) award 2 marks** **IF answer = –82 (kJ mol^{-1}) award 1 mark** ΔH = 193 – 111 ✓ = +82 ✓	2	 **ALLOW** 82 **ALLOW** one mark for –82 **ALLOW** one mark for +304 / –304
			Total	**19**	

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Question			Answer	Marks	Guidance
5	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = –162 (kJ mol^{-1}) award 3 marks** Energy associated with bond breaking = 3354 **OR** (2 × 805) + (4 × 436) ✓ Energy associated with bond making = 3516 **OR** (4 × 415) + (4 × 464) ✓ Enthalpy change = –162 ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below. IF ECF, **ANNOTATE WITH TICKS AND CROSSES, etc** **IGNORE** sign **IGNORE** sign **ALLOW** ECF from wrong additions of energy associated with bond breaking and/or from bond making **ALLOW** two marks for (+)162, (+)6870, –6870 or (+)766 **ALLOW** one mark for –766
	(b)	(i)	Absorbs IR radiation ✓ Bonds vibrate ✓	2	**IGNORE absorbs heat** **ALLOW** IR re-radiated **DO NOT ALLOW** absorbs UV radiation **DO NOT ALLOW** blocks IR radiation **ALLOW** bonds stretch **OR** bonds bend **IGNORE** molecule vibrates/rotates **DO NOT ALLOW** bonds break

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Question			Answer	Marks	Guidance
5	(b)	(ii)	***Any two from:***	2	
					DO NOT ALLOW reference to carbon being stored – the answer must either refer to carbon dioxide or not mention the name of the stored substance
			(liquid) injected deep into the oceans ✓		**ALLOW store deep** in the oceans **OR** on the **sea-bed** ✓ **ALLOW** stored deep under the sea **DO NOT ALLOW** dissolve CO_2 in the sea **OR** stored in ocean
			Stored in (old) geological formations **OR** stored underground in rocks **OR** stored in (old) mines **OR** stored in (old) oil wells ✓		**ALLOW** stored under the sea bed **ALLOW** pumped into oil wells to force last bit of oil out
			Stored by reaction with metal <u>oxides</u> **OR** reaction to form (solid) <u>carbonates</u> **OR** stored as a <u>carbonate</u> **OR** equation to show formation of metal carbonate ✓		**IGNORE** mineral storage

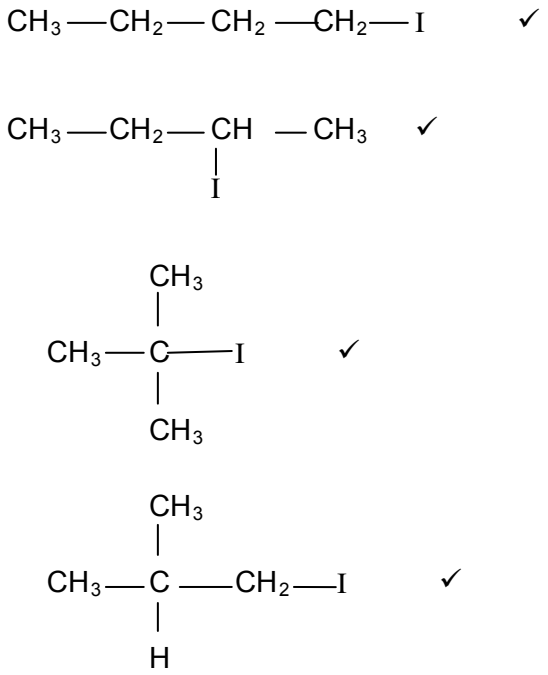
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Question			Answer	Marks	Guidance
5	(c)	(i)		7	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **IGNORE** dot for radical and any state symbols for all equations
			Homolytic ✓		
			$Br_2 \longrightarrow 2Br$ ✓		
			$Br + C_2H_6 \longrightarrow HBr + C_2H_5$ ✓ $C_2H_5 + Br_2 \longrightarrow C_2H_5Br + Br$ ✓		If more than one termination step is written they must all be correct to be awarded the mark **DO NOT ALLOW** termination steps with H
			$Br + C_2H_5 \longrightarrow C_2H_5Br$ **OR** $Br + Br \longrightarrow Br_2$ **OR** $C_2H_5 + C_2H_5 \longrightarrow C_4H_{10}$ ✓		
			Two names of steps linked to appropriate equations ✓ **OR** **three** names of steps linked to appropriate equations ✓✓		initiation step linked to correct equation propagation step linked to one equation in which there is a radical on the left and a radical on the right termination step linked to equation involving two radicals: If no equations are given to link the names of the step then award one mark for mention of all three steps If halogen other than bromine do not give equation mark for initiation and only give one mark for all three terms linked to appropriate equations If hydrocarbons other than ethane are used **DO NOT ALLOW** any marks for the equations in the propagation steps

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Question			Answer	Marks	Guidance
5	(c)	(ii)	***Any two from:***	2	
			More than one C–H bond can be substituted **OR** multi-substitution can occur **OR** more than one substitution can happen ✓		**ALLOW** equations or examples of multi substitution
			Lots of termination steps ✓		**ALLOW** an equation to illustrate formation of other products eg butane **ALLOW** examples of other products that can be formed in termination steps eg bromobutane
			termination steps can give products that will also react with (bromine) radicals ✓		**ALLOW** examples of products eg butane reacting with bromine radicals to give bromobutane
			Total	**16**	

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Question			Answer	Marks	Guidance
6	(a)		1-bromopentane reacts faster **OR** 1-chloropentane reacts slower ✓ C–C*l* stronger bond (than C–Br bond) **OR** C–C*l* shorter bond (than C–Br bond) **OR** C–C*l* bond is harder to break **OR** needs more energy to break C–C*l* bond **OR** bond enthalpy of C–C*l* greater (than C–Br bond) ✓	2	**ALLOW** takes more time to react **ALLOW** chloro compound reacts slower than bromine compound **DO NOT ALLOW** bromine reacts faster than chlorine **ALLOW** ORA Answer must refer to the C–C*l* bond or C–Br bonds
	(b)	(i)	 ✓ ✓ ✓ ✓	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) n.b. C_2H_5 is unambiguous but C_3H_7 is ambiguous **IGNORE** incorrect name Mark incorrect answers first of all. • One incorrect answers maximum 3 marks • Two incorrect answers maximum 2 marks • Three incorrect answers maximum 1 mark • Four incorrect answers scores 0 mark **ALLOW** as a slip one stick with no H on in a displayed formula

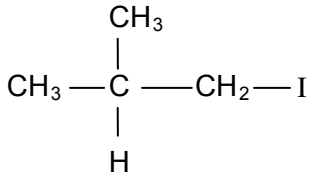
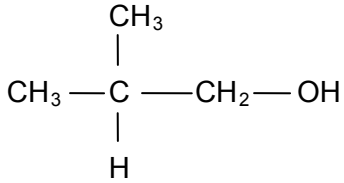
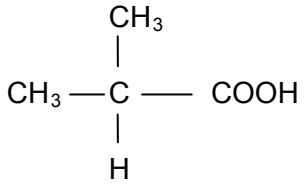
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Question			Answer	Marks	Guidance
6	(b)	(ii)	$C_4H_{10}O$ ✓	1	**IGNORE** any structures drawn **DO NOT ALLOW** C_4H_9OH

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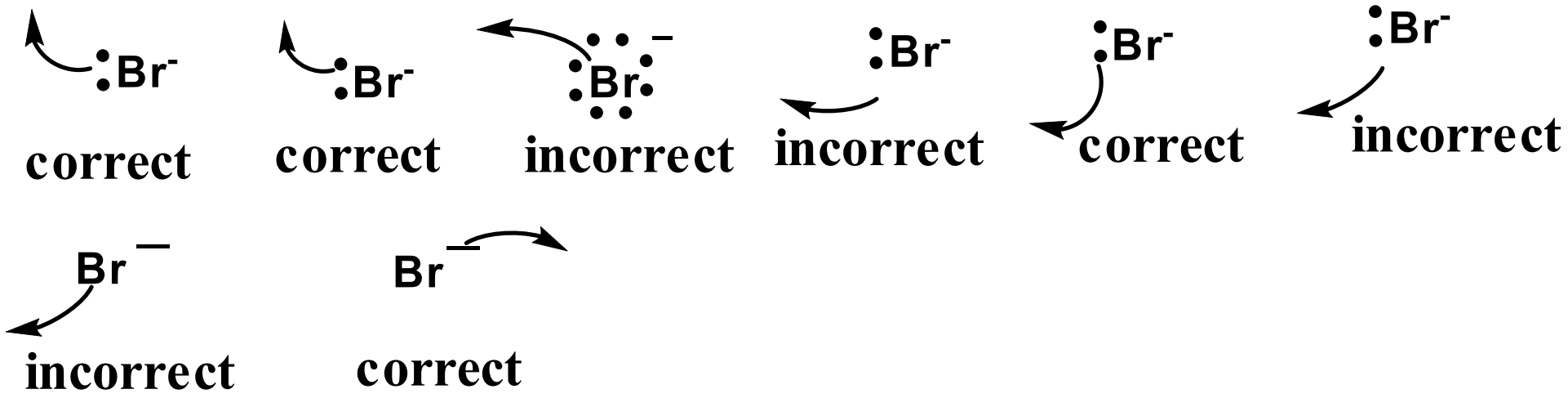
Question			Answer	Marks	Guidance
6	(b)	(iii)	**infrared**	6	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** **LOOK ON THE SPECTRUM** for labeled absorbances which can be given credit
			1700–1730 cm^{-1} indicates carbonyl group ✓		**ALLOW** has a C=O bond because it has absorbance within range 1640–1750 cm^{-1}
			broad 2900 cm^{-1} indicates O–H bond **AND** it is a **carboxylic acid** ✓		**ALLOW** 2900 cm^{-1} indicates O–H in carboxylic acid **ALLOW** has O–H bond in carboxylic aid because it has absorbance within range 2500–3300 cm^{-1} The presence of carboxylic acid can be anywhere in the text including the structure for **D**
			explanation mark **B** has a branched structure because of relationship to methylpropene **OR** **C** has a branched structure because of relationship to methylpropene **OR** **C** must be a primary alcohol because it is oxidised to a carboxylic acid **OR** a primary alcohol because it reacts with acidified dichromate to make a carboxylic acid **OR** **C** cannot be a tertiary alcohol because it is oxidised **OR** cannot be a tertiary alcohol because it does react with acidified dichromate ✓		If two marking points from the explanation mark are given both must be correct

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Question	Answer	Marks	Guidance
	B is  ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)
	C is  ✓		**IGNORE** incorrect names for **B**, **C** and **D**
	D is  ✓		Mark correct branched structures first of all. If there are no correct branched structures and **C** is $CH_3CH_2CH_2CH_2OH$ then **ALLOW** one mark for $CH_3CH_2CH_2COOH$ and one mark for $CH_3CH_2CH_2CH_2I$
	Total	**13**	

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APPENDIX 1



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RECOGNISING ACHIEVEMENT

Thursday 19 January 2012 – Afternoon

AS GCE CHEMISTRY A

F322 Chains, Energy and Resources

Candidates answer on the Question Paper.

OCR supplied materials:
- *Data Sheet for Chemistry A* (inserted)

Other materials required:
- Scientific calculator

Duration: 1 hour 45 minutes

F 3 1 4 4 4 0 1 1 2

F 3 2 2

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The Insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. HB pencil may be used for graphs and diagrams only.
- Answer **all** the questions.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

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

Where you see this icon you will be awarded marks for the quality of written communication in your answer.

This means for example you should:
- ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
- organise information clearly and coherently, using specialist vocabulary when appropriate.

- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **24** pages. Any blank pages are indicated.

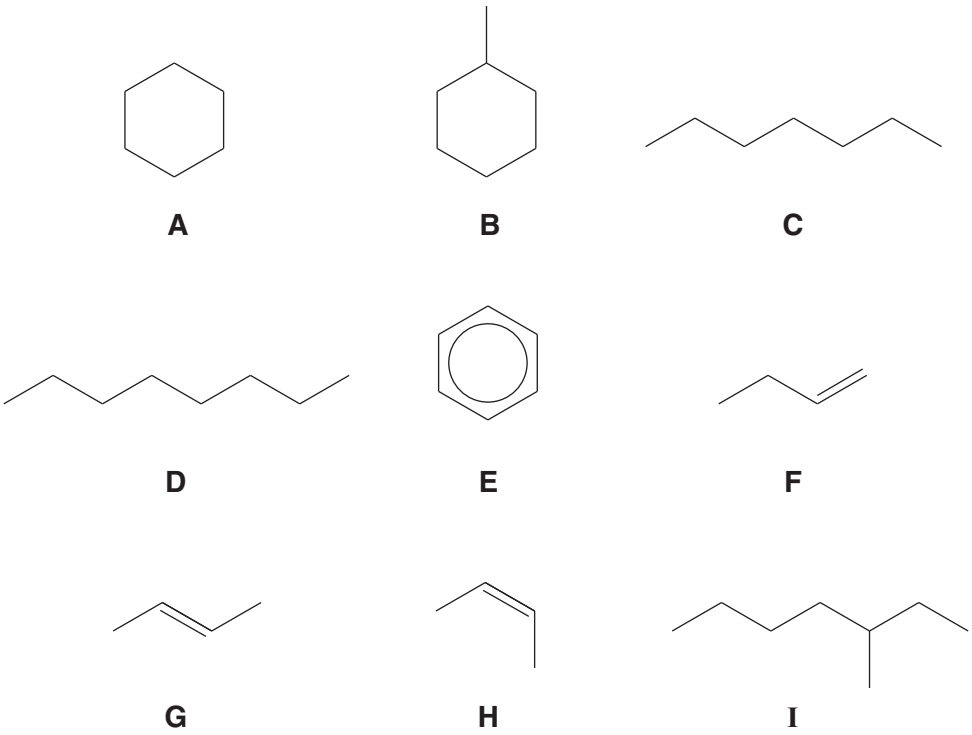
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Answer **all** the questions.

1 Crude oil is a source of many hydrocarbons.

The skeletal formulae of some of these hydrocarbons are shown below.



(a) Explain why compound **A** is both *saturated* and a *hydrocarbon*.

.....

.....

.....

..... **[2]**

(b) What is the empirical formula for compound **A**?

..... **[1]**

(c) Give the letters, **A**, **B**, **C**, **D**, **E**, **F**, **G**, **H** or **I**, of two hydrocarbons that are structural isomers of each other.

..... and ..... **[1]**

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(d) The petroleum industry processes straight chain alkanes into cyclic hydrocarbons such as **A**, **B** and **E**.

(i) Explain why the petroleum industry processes straight chain alkanes into cyclic hydrocarbons.

.....

..... **[1]**

(ii) Hydrocarbon **C** can be processed into the cyclic hydrocarbon **B**.

Construct an equation for this reaction.

[1]

(e) Explain why hydrocarbon **D** has a higher boiling point than hydrocarbon **C**.

.....

.....

.....

..... **[2]**

(f) Hydrocarbons **G** and **H** are stereoisomers of each other.

Explain what is meant by the term *stereoisomerism*.

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..... **[2]**

(g) Construct the equation for the **complete** combustion of hydrocarbon **C**.

..... **[2]**

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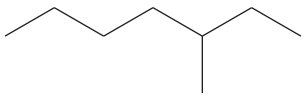
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(h) A hydrocarbon molecule, $C_{16}H_{34}$, is cracked to form an octane molecule and two molecules of but-2-ene.

Construct the equation for this reaction.

..... **[1]**

(i) Compound **I** is 3-methylheptane. It does not contain a functional group.



I

(i) What is meant by the term *functional group*?

.....

.....

..... **[1]**

(ii) Compound **I** reacts with chlorine in the presence of ultraviolet radiation to give several structural isomers of $C_8H_{17}Cl$.

How many **structural** isomers could be formed in this reaction?

..... **[1]**

(iii) The mechanism of the reaction involves radicals.

What is meant by the term *radical*?

.....

..... **[1]**

[Total: 16]

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2 Ethanoic acid, CH_3COOH, is used to make esters.

Some information about two of the processes used to make ethanoic acid is given below.

Process 1

This is a one-step process that involves the reaction of methanol with carbon monoxide.

$$CH_3OH + CO \rightarrow CH_3COOH$$

The conditions used are 180 °C and 30 atmospheres pressure. A rhodium/iodine catalyst is used.

The percentage yield for this process is 99%.

Process 2

This involves the oxidation of naphtha, a fraction obtained from crude oil.

Liquid naphtha is oxidised using air at a temperature of 180 °C and 50 atmospheres pressure. No catalyst is needed.

A large variety of other products are also formed in this oxidation.

(a) Suggest **three** advantages of making ethanoic acid using **Process 1** rather than **Process 2**.

.....

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..... **[3]**

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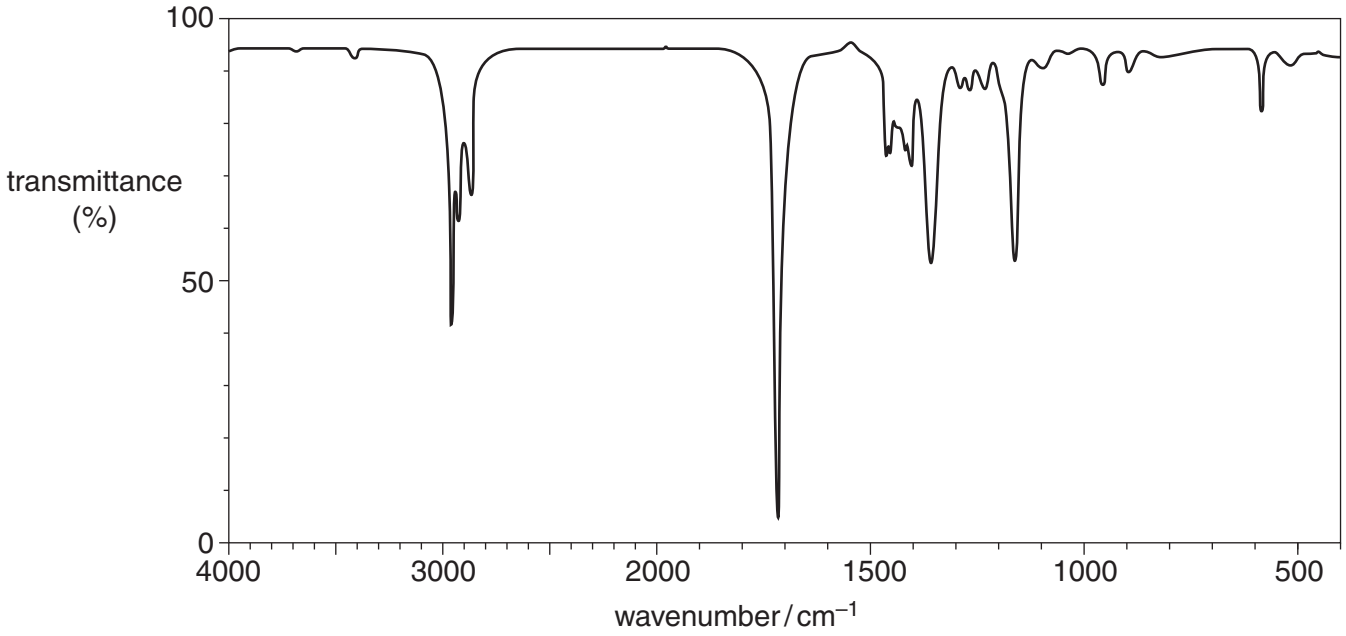
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(b) The other products formed in **Process 2** are carboxylic acids, aldehydes and ketones.

A research chemist investigates some of these other products of **Process 2**.

(i) The research chemist isolates product, **J**.

The infrared spectrum of **J** is shown below.



The chemist also finds that 0.172 g of a pure sample of **J** contains 2.00×10^{-3} mol of **J**.

Suggest, with reasons, **one** possible structure for **J**.

In your answer you should link the evidence with your explanation.

.....

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..... **[5]**

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(ii) The chemist isolates another product, the carboxylic acid, **K**.

K has the molecular formula $C_4H_8O_2$.

Suggest a possible structure and name for **K**.

structure

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

(c) Ethanoic acid is used in the manufacture of the ester, propyl ethanoate.

Describe how ethanoic acid is converted into propyl ethanoate.
Include an equation in your answer.

.....

.....

.....

.....

.....

..... **[4]**

[Total: 14]

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3 Enthalpy changes can be determined directly or indirectly.

(a) A student investigates the reaction between magnesium and dilute hydrochloric acid.

$$Mg(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

The student determines the enthalpy change for this reaction.

In her experiment, she reacts 0.486 g of magnesium with 50.0 cm^3 of 2.00 mol dm^{-3} HCl(aq). The HCl(aq) is in excess.

The temperature of the solution changes from 19.2 °C to 32.0 °C.

(i) Calculate the energy released, in kJ, during this reaction.

The specific heat capacity of the solution = 4.18 J g^{-1} K^{-1}.

The density of the solution is 1.00 g cm^{-3}.

energy = ...kJ **[2]**

(ii) Calculate the amount, in moles, of magnesium used by the student.

amount = ... mol **[1]**

(iii) Calculate the enthalpy change of reaction.

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

enthalpy change of reaction = ...kJ mol^{-1} **[3]**

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(b) The student wants to determine the enthalpy change of formation of calcium carbonate, $CaCO_3(s)$.

$$Ca(s) + C(s) + 1\tfrac{1}{2}O_2(g) \rightarrow CaCO_3(s)$$

(i) What is meant by the term *standard enthalpy change of formation*?
You should state the standard conditions in your answer.

.....

.....

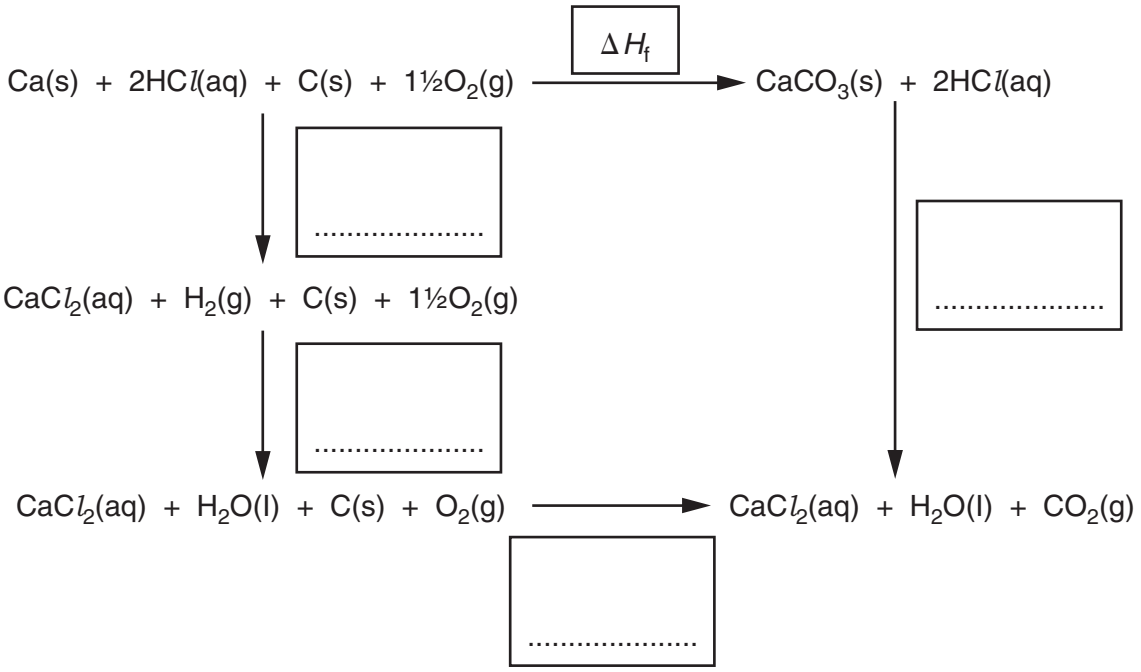
.....

..... **[3]**

(ii) Using the following data and enthalpy cycle,

- fill in the boxes on the enthalpy cycle with the correct enthalpy change values
- calculate the enthalpy change of formation, ΔH_f, of $CaCO_3(s)$.

reaction	enthalpy change, ΔH / kJ mol^{-1}
$C(s) + O_2(g) \rightarrow CO_2(g)$	–393
$H_2(g) + \frac{1}{2}O_2(g) \rightarrow H_2O(l)$	–285
$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$	–54
$Ca(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2(g)$	–168



ΔH_f = ... kJ mol^{-1} **[3]**

[Total: 12]

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4 Hydrogen and chlorine are reacted together to form hydrogen chloride.

$$H_2(g) + Cl_2(g) \longrightarrow 2HCl(g) \qquad \Delta H = -184 \text{ kJ mol}^{-1}$$

(a) Calculate the bond enthalpy for the H–C*l* bond using the information in the table below.

bond	bond enthalpy / kJ mol^{-1}
H–H	+436
C*l*–C*l*	+243

bond enthalpy = ... kJ mol^{-1} **[2]**

(b) The reaction is repeated at a **higher** pressure.

Describe and explain what happens to the rate of the reaction between $H_2(g)$ and $Cl_2(g)$.

.....

.....

.....

.....

..... **[2]**

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(c) The reaction is repeated again. This time the temperature is **decreased**.

Describe and explain, by drawing appropriately labelled Boltzmann distributions, what happens to the rate of reaction between $H_2(g)$ and $Cl_2(g)$.

.....

.....

.....

.....

..... **[5]**

(d) The mechanism of the reaction between $H_2(g)$ and $Cl_2(g)$ involves initiation, propagation and termination.

(i) The initiation step is the homolytic fission of the covalent bond in a chlorine molecule.

Write an equation to show this homolytic fission.

..... **[1]**

(ii) Complete the following equations which show the propagation steps.

$Cl + H_2 \rightarrow$ ..... + ...

$H + Cl_2 \rightarrow$ ..... + ... **[2]**

(iii) Suggest equations for **two** termination steps.

.....

..... **[2]**

[Total: 14]

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5 Sulfuric acid is made from sulfur, oxygen and water in a three-stage process.
This can be represented by the following overall equation.

$$2S(s) + 3O_2(g) + 2H_2O(l) \rightarrow 2H_2SO_4(l)$$

(a) Explain why the overall process to make sulfuric acid has an atom economy of 100%.

.....

.....

..... **[1]**

(b) A factory uses 51.4 tonnes of sulfur to manufacture 147 tonnes of H_2SO_4.

What is the percentage yield of H_2SO_4?

Give your answer to **two** significant figures. (1 tonne = 1×10^6 g)

percentage yield = ... % **[3]**

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(c) One of the reactions involved in making sulfuric acid converts sulfur dioxide, SO_2, into sulfur trioxide, SO_3.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \quad \Delta H = -197 \text{ kJ mol}^{-1}$$

This reaction can be carried out at 450 °C and 3 atmospheres pressure in the presence of a V_2O_5 catalyst.

Under these conditions the position of equilibrium is almost completely on the right-hand side.

(i) A research chemist investigates this reaction.
He uses a temperature of 450 °C and 3 atmospheres pressure.
The research chemist does **not** use the catalyst.

Predict the changes, if any, on each of the following.

position of equilibrium .....

rate of backward reaction ..... **[2]**

(ii) The temperature of the reaction mixture is **increased** to 600 °C.

State and explain what will happen to the position of equilibrium.

.....

.....

.....

..... **[1]**

(iii) The pressure of the reaction mixture is **decreased** to 2 atmospheres.

State and explain what will happen to the position of equilibrium.

.....

.....

.....

..... **[1]**

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(d) Concentrated H_2SO_4 is used as an acid catalyst in the elimination of water from alcohols.

There are several alcohols that are structural isomers with the formula $C_5H_{11}OH$. When these alcohols are heated with H_2SO_4 they form alkenes.

$$C_5H_{11}OH \longrightarrow C_5H_{10} + H_2O$$

(i) Pentan-1-ol is a structural isomer of $C_5H_{11}OH$ that is a primary alcohol.

Draw the structure of another structural isomer of $C_5H_{11}OH$ that is a primary alcohol.

[1]

(ii) Pentan-2-ol is a structural isomer of $C_5H_{11}OH$ that is a secondary alcohol.
Pentan-2-ol is heated with H_2SO_4.

Three alkenes are formed, **L**, **M** and **N**.

- **L** and **M** are stereoisomers.
- **N** is a structural isomer of the stereoisomers **L** and **M**.

Draw the structures for alkenes **L**, **M** and **N**.

alkene **L**

alkene **M**

alkene **N**

[3]

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(iii) One structural isomer of $C_5H_{11}OH$ is an alcohol that **cannot** be oxidised by heating with acidified potassium dichromate(VI).

Draw the structure of this alcohol.

[1]

[Total: 13]

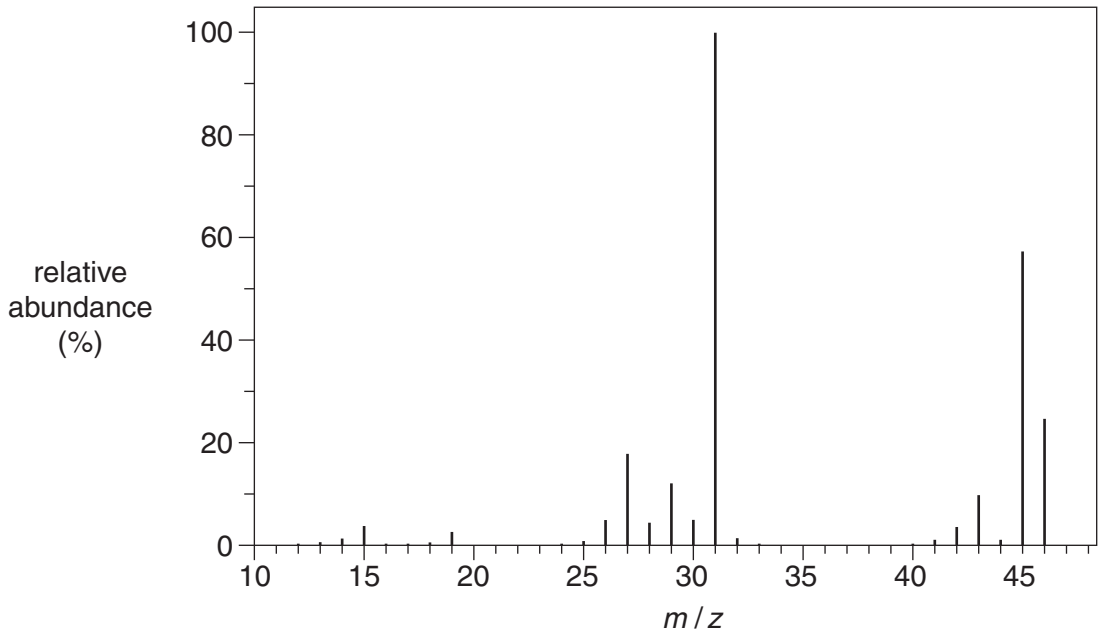
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6 Mass spectrometry is used in analysis.

(a) Compound **O** contains carbon, hydrogen and oxygen.

The mass spectrum of compound **O** is shown below.



(i) Identify the *m*/*z* value that corresponds to the molecular ion.

..... **[1]**

(ii) Write the formula of the ion that gives rise to the peak at *m*/*z* = 31.

..... **[1]**

(iii) Suggest the molecular formula for **O**.

..... **[1]**

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(b) A scientist analyses a sample of Moon rock. She uses mass spectrometry to find out which metal the sample contains.

The mass spectrum of the sample shows *m*/*z* peaks as shown in the table.

***m*/*z* value**	**percentage abundance (%)**
63	72.2
65	27.8

Positive ions, $\mathbf{X}^+$, of the metal were responsible for the two *m*/*z* peaks.

Identify the metal **X** by calculating its relative atomic mass to **one decimal place**.

relative atomic mass of **X** = ...

metal **X** = ... **[3]**

[Total: 6]

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7 Chlorofluorocarbons, CFCs, were once used as propellants in aerosols. CFCs contribute to ozone depletion in the upper atmosphere.

(a) A CFC has the formula CF_2Cl_2.

State the three-dimensional shape of a CF_2Cl_2 molecule and the F–C–C*l* bond angle.

shape .....

bond angle ..... **[2]**

(b) Two reasons that CF_2Cl_2 was used as an aerosol propellant are that it has low reactivity and will not hydrolyse in water.

(i) State **one** other reason why CF_2Cl_2 was developed for use as an aerosol.

.....

..... **[1]**

(ii) Suggest why CF_2Cl_2 does **not** hydrolyse in water.

.....

.....

..... **[1]**

(c) Explain, with the aid of equations, how the presence of CFCs in the upper atmosphere leads to ozone depletion.

.....

.....

.....

.....

..... **[3]**

(d) Why are scientists concerned about ozone depletion?

.....

.....

..... **[1]**

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(e) International agreements have reduced the use of CFCs. However the concentration of atmospheric CFCs has hardly changed.

Suggest **two** reasons why.

.....

.....

.....

.....

..... **[2]**

[Total: 10]

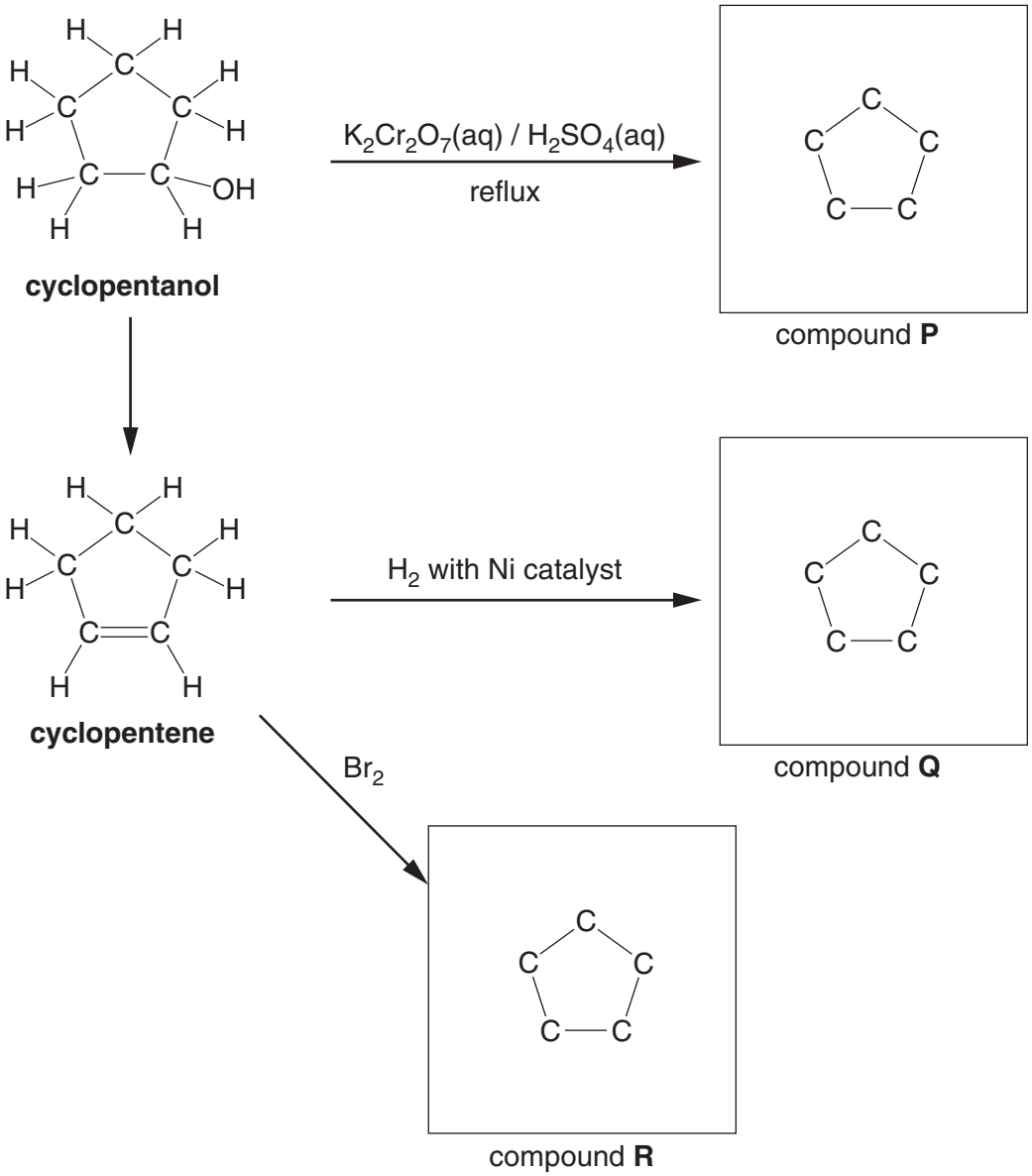
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8 Cyclopentene is a cyclic alkene.

(a) The flowchart shows some reactions involving cyclopentene and cyclopentanol.

Complete the partial structures in the boxes to show compounds **P**, **Q** and **R**, the main organic products of the reactions.



[3]

(b) What would be the colour change in the reaction between cyclopentene and bromine?

..... to ..... **[1]**

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(c) Cyclopentene can be polymerised to give poly(cyclopentene).

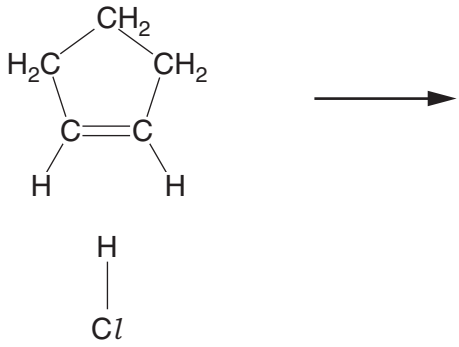
Draw a section of poly(cyclopentene) to show **two** repeat units.

[1]

(d) Cyclopentene reacts with HC*l* by electrophilic addition.

Use the curly arrow model to complete the mechanism for this reaction.

In your answer include any relevant dipoles, the intermediate and the product.



intermediate

product

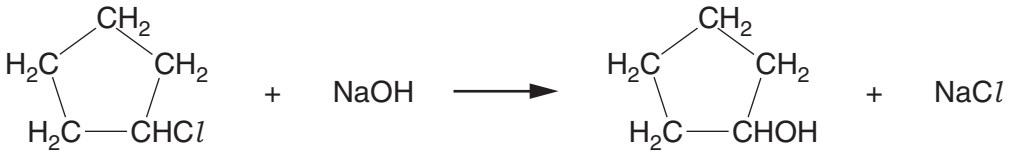
[5]

TURN OVER FOR QUESTION 8(e)

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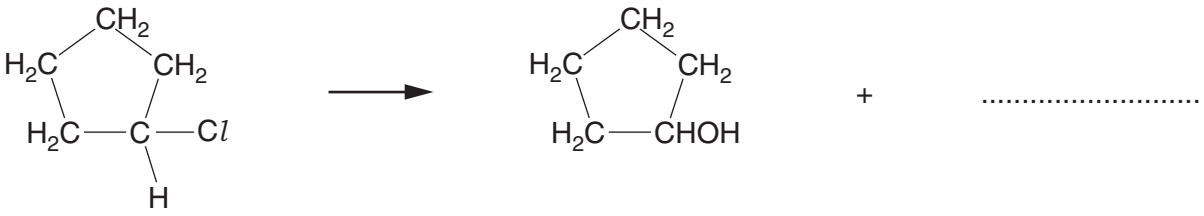
(e) Chlorocyclopentane can be hydrolysed by heating with aqueous sodium hydroxide.



Use the curly arrow model to complete the mechanism for this hydrolysis reaction.

Include in your answer, relevant dipoles, the name of the mechanism and the type of bond fission.

*In your answer you should use the correct technical terms, spelled correctly***.**



HO^- **products**

name of mechanism .....

type of bond fission ..... **[5]**

[Total: 15]

END OF QUESTION PAPER

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ADDITIONAL PAGE

If additional space is required, you should use the lined pages below. The question number(s) must be clearly shown.

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ADDITIONAL PAGE

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GCE

Chemistry A

Advanced Subsidiary GCE

Unit **F322:** Chains, Energy and Resources

Mark Scheme for January 2012

Oxford Cambridge and RSA Examinations

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Annotations

Annotation	Meaning
	Benefit of doubt given
	Contradiction
	Incorrect response
	Error carried forward
	Ignore
	Not answered question
	Benefit of doubt not given
	Power of 10 error
	Omission mark
	Rounding error
	Error in number of significant figures
	Correct response

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Abbreviations, annotations and conventions used in the detailed Mark Scheme (to include abbreviations and subject-specific conventions).

Annotation	Meaning
DO NOT ALLOW	Answers which are not worthy of credit
IGNORE	Statements which are irrelevant
ALLOW	Answers that can be accepted
( )	Words which are not essential to gain credit
__	Underlined words must be present in answer to score a mark
ECF	Error carried forward
AW	Alternative wording
ORA	Or reverse argument

Subject-specific Marking Instructions

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:

Q2 (b)(i)
Q4 (c)
Q8 (d)
Q8 (e)

All questions where an ECF has been applied.

Checking additional pages

All the Additional Pages in the examination script must be checked to see if any candidates include any answers.

- When you open question **1(a)** you will see a view of page 23 one of the Additional Pages.
- If the page is blank then, using the marking mode, annotate the page with an omission mark, ^.
- Scroll down to page 24 and annotate with a ^ if the page is blank.
- If pages 23 or 24 are not blank then use the paper clip icon to link the pages to the correct questions.
- You may need to contact your Team Leader if you do not know how to do this.

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Generic comments

ORGANIC STRUCTURES

For a 'structure' or 'structural formula',

- **ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous)

For an alkyl group shown within a structure,

- **ALLOW** bond drawn to C or H,
  e.g.**ALLOW** CH_3–,CH_2–, C_3H_7–, etc
- **ALLOW** vertical 'bond' to any part of an alkyl group

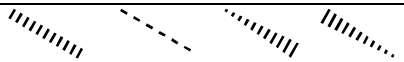
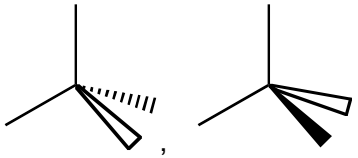
For an OH group shown within a structure,

- **DO NOT ALLOW** formula with horizontal —HO **OR** OH –
- **ALLOW** vertical 'bond' to any part of the OH group

For a CHO group shown within a structure,

- **DO NOT ALLOW** COH

For a 3D structure,

• For bond in the plane of paper, a solid line is expected:	
• For bond out of plane of paper, a solid wedge is expected:	
• For bond into plane of paper, **ALLOW**:	
• **ALLOW** a hollow wedge for 'in bond' OR an 'out bond', provided it is different from the other in or out wedge e.g.:	

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NAMES

Names including alkyl groups:
- **ALLOW** alkanyl, e.g. ethanyl (i.e. **IGNORE** 'an')
- **DO NOT ALLOW** alkol, e.g. ethol (ie 'an' is essential)

Names of esters:
- Two words are expected, e.g. ethyl ethanoate
- **ALLOW** one word, e.g. ethylethanoate

Names with multiple numbers and hyphens:
Use of 'e'
- **ALLOW** superfluous 'e' , e.g. propane-1-ol ('e' is kept if followed by consonant)
- **ALLOW** absence of 'e', e.g. propan-1,2-diol ('e' is omitted if followed by vowel)

Hyphens separate name from numbers:
- **ALLOW** absence of hyphens, e.g. propane 1,2 diol

Multiple locant numbers must be clearly separated:
- **ALLOW** full stops: e.g. 1.2 OR spaces: 1 2
- **DO NOT ALLOW e.g.** 12

Locant numbers in formula must be correct
- **DO NOT ALLOW** propan-3-ol

Order of substituents should be alphabetical:
- **ALLOW** any order (as long as unambiguous), e.g. 2-chloro-3-bromobutane

ABBREVIATIONS
van der Waal's forces
ALLOW vdw forces **OR** VDW forces (and any combination of upper and lower cases)

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Question			Answer	Marks	Guidance
1	(a)		(a compound) with no double bond (or triple bond) ✓ containing hydrogen and carbon **only** ✓	2	**ALLOW** contains single bonds only **ALLOW** it contains just carbon and hydrogen **DO NOT ALLOW** a mixture of carbon and hydrogen **OR** only carbon and hydrogen molecules
	(b)		CH_2 ✓	1	**ALLOW** H_2C
	(c)		**D** and **I** **OR** **F** and **G** **OR** **F** and **H** ✓	1	**DO NOT ALLOW G** and **H**
	(d)	(i)	Cyclic hydrocarbons have more efficient combustion ✓	1	**The answer must relate to combustion or burning** **Assume 'they' refers to the cyclic hydrocarbons** **ALLOW** cyclic hydrocarbons allow smoother burning **OR** cyclic hydrocarbons increase octane number **OR** cyclic hydrocarbons reduce knocking **OR** cyclic hydrocarbons are less likely to produce pre-ignition **OR** cyclic hydrocarbons are more efficient fuels **OR** cyclic hydrocarbons burn better **OR** easier to burn **OR** cyclic hydrocarbon combust more easily **OR** improves combustion **DO NOT ALLOW** cyclic hydrocarbons ignite more easily **ALLOW** ora for straight chain hydrocarbons **IGNORE** cyclic hydrocarbons increase volatility of fuel **IGNORE** cyclic hydrocarbons have a lower boiling point cyclic hydrocarbons are a better fuel on their own is **NOT** sufficient cyclic hydrocarbons burn more cleanly on their own is **NOT** sufficient

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Question			Answer	Marks	Guidance
1	(d)	(ii)	$C_7H_{16} \rightarrow C_7H_{14} + H_2$ ✓	1	**ALLOW** molecular formulae **OR** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **DO NOT ALLOW** cycloheptane structure in equation
	(e)		**D** has more surface (area of) contact **OR D** is a bigger molecule ✓ **D** has more van der Waals' forces **OR C** have fewer van der Waals' forces ✓	2	**Both answers need to be comparisons** Assume 'it' refers to **D** **ALLOW** has more electrons **OR** longer (carbon) chain **OR** higher molecular mass **IGNORE** surface area **ALLOW** ORA **ALLOW D** has stronger van der Waals' forces / larger VDW / greater VDW **OR C** has weaker van der Waals' forces **OR C** has smaller VDW **ALLOW** more VDW forces More intermolecular forces is **not** sufficient **DO NOT ALLOW** reference to bonds breaking or more bonds present unless it is clear that that the bonds are VDW
	(f)		Same structural formula ✓ Different arrangement of groups around a double bond **OR** different arrangement (of atoms) in space ✓	2	**ALLOW** have the same structure / displayed formula / skeletal formula Stereoisomers have the same formula or molecular formula is **not** sufficient **ALLOW** different three dimensional arrangement

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Question			Answer	Marks	Guidance
1	(g)		$C_7H_{16} + 11O_2 \rightarrow 7CO_2 + 8H_2O$ Correct reactants and products ✓ Balancing ✓	2	**ALLOW** molecular formulae **OR** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** any correct multiple **IGNORE** state symbols Balancing is **dependent** on correct formulae
	(h)		$C_{16}H_{34} \rightarrow C_8H_{18} + 2C_4H_8$ ✓	1	**ALLOW** molecular formulae **OR** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** any correct multiple **ALLOW** structural **OR** displayed **OR** skeletal formulae in equation **ALLOW** but-1-ene **IGNORE** state symbols
	(i)	(i)	Group of atoms (in a molecule or compound) that is responsible for the reactions ✓	1	**ALLOW** the 'part' (of the molecule or compound) that reacts **ALLOW** the group of atoms that gives the chemical properties **ALLOW** group of atoms which indicates the homologous series
		(ii)	8 ✓	1	
		(iii)	has an unpaired electron ✓	1	**ALLOW** plural i.e. unpaired electrons has a lone **OR** single **OR** free electron is **not** sufficient
			Total	**16**	

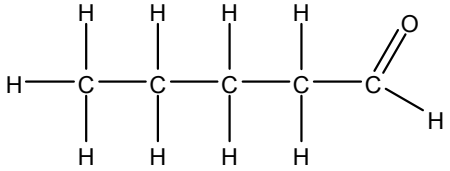
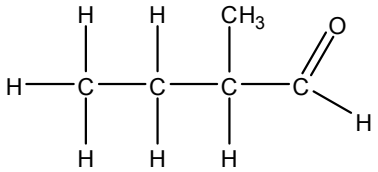
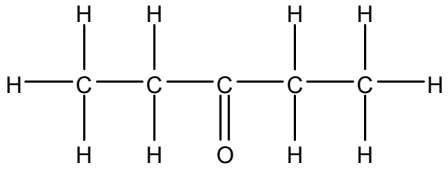
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Question			Answer	Marks	Guidance
2	(a)		***Any three from:***	3	Assume it refers to **Process 1**
			Process 1 has a high atom economy **OR** has 100% atom economy **OR** a greater atom economy **OR** makes only the desired product ✓		**ALLOW** process **1** has no waste **OR** process **1** has no co-products **OR** process **1** needs less separation **OR** process **1** has fewer other products **OR** gives only one product **ALLOW** ORA if process **2** is specified
			Process 1 has a very efficient conversion of reactants to products **OR** not much waste of **starting material** ✓		**ALLOW** ORA if process **2** is specified high percentage yield is **not** sufficient **DO NOT ALLOW** if percentage yield is explicitly linked to more waste (products) e.g. process **1** has a high percentage yield so makes little waste (product) scores **0 marks** but process **1** makes no waste (product) and it has a high percentage yield scores **1 mark**
			Process 1 uses a low**er** pressure ✓		**ALLOW** ORA if process **2** is specified
			Process 1 uses up **toxic** carbon monoxide ✓		
			Process 1 uses methanol which can be produced from biomass ✓		**IGNORE** process **2** comes from crude oil a non-renewable source **ALLOW** process **1** starts from a renewable source if the source is specified e.g. wood, municipal waste or sewage **IGNORE** reference to catalyst and rate of reaction

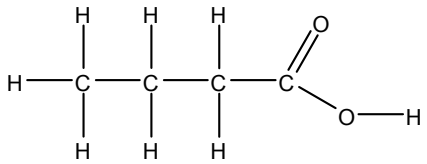
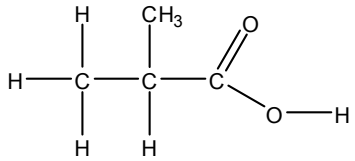
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Question			Answer	Marks	Guidance
2	(b)	(i)		5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**
			Contains C=O bond because of absorption between 1700 and 1740 cm^{-1} (from the spectrum) ✓		**ALLOW** contains a carbonyl group because of absorption within range 1640–1750 cm^{-1} **OR** contains an aldehyde, ketone or carboxylic acid because of absorption within range 1640–1750 cm^{-1} ✓ Mention of only an aldehyde or a ketone is not sufficient it needs reference to the wavenumber **LOOK FOR THIS MARK ON THE SPECTRUM**
			does not contain an O–H bond ✓		**ALLOW** not a carboxylic acid ✓ **ALLOW** does not have any other characteristic absorbance due to other functional groups
			(So was a) ketone **OR** aldehyde ✓		**ALLOW (**so was a) carbonyl compound **ALLOW** this mark if a structure of an aldehyde or a ketone is given even if the structure has an incorrect number of carbon atoms
			M_r = 86 ✓		
			Correct structure ✓		**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) LOOK FOR AN **ALDEHYDE** or **KETONE** with **FIVE** carbon atoms **OR** a **DIALDEHYDE**, **DIONE OR** an **OXOALDEHYDE** with **FOUR** carbon atoms – a comprehensive list of correct structures is shown on page 34 **IGNORE** incorrect name **DO NOT ALLOW** COH for an aldehyde

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Question	Answer	Marks	Guidance
	 pentanal **OR**  2-methylbutanal **OR**  pentan-3-one		**ALLOW** as a slip one stick with no H on in a displayed formula

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Question			Answer	Marks	Guidance
2	(b)	(ii)	Correct structure ✓ Name of the structure drawn ✓  butanoic acid **OR**  2-methylpropanoic acid	2	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) All bonds and all hydrogen atoms must be shown in a displayed formula within this question Name must correspond to the correct structure for two marks **ALLOW** butanoic acid or 2-methylpropanoic acid if the structure drawn is incorrect There is **no** ECF in this question **ALLOW** $CH_3CH_2CH_2COOH$ **ALLOW** $(CH_3)_2CHCOOH$ **ALLOW** methylpropanoic acid

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Question			Answer	Marks	Guidance
2	(c)		Use of propan-1-ol ✓	4	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** from the equation propanol **OR** C_3H_7OH is **not** sufficient
			$CH_3COOH + C_3H_7OH \rightarrow CH_3COOCH_2CH_2CH_3 + H_2O$ Correct formulae for the ester ✓ Correctly balanced equation ✓		**ALLOW** molecular formula **OR** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above **ALLOW** propan-2-ol in the equation
			Add H_2SO_4 **OR** acid catalyst **OR** H^+ ✓		**ALLOW** conditions mark over the arrow in the equation
			Total	**14**	

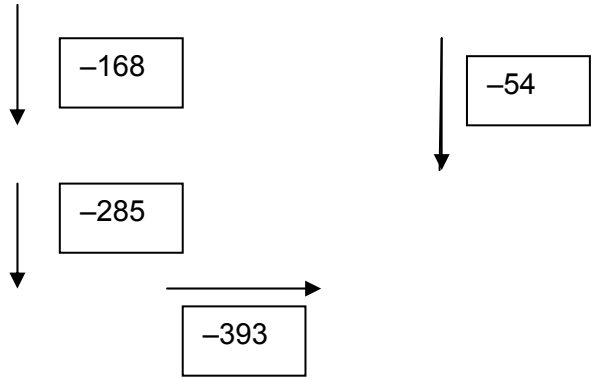
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Question			Answer	Marks	Guidance
3	(a)	(i)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 2.68 (kJ) award 2 marks** $q = mc\Delta T$ **OR** = 50.0 × 4.18 × 12.8 ✓ = 2.68 (kJ) ✓	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below IF ECF, **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** ecf only from using mass of 50.486 **ALLOW** 2675.2 J **IGNORE** sign If mass used is 50.486 answer is 2701.202944 **ALLOW** 2.7 **OR** 2.675 **OR** 2.6752 **DO NOT ALLOW** 3 **IGNORE** sign If mass used is 50.486 answer is 2.7, 2.70, 2.701 up to calculated value of 2.701202944 correctly rounded **ALLOW** one mark for using 4.2 and correctly calculating q in kJ to at least 2 sig figs
		(ii)	amount = 0.02(00) (mol) ✓	1	**ALLOW** $1/50$ **IGNORE** trailing zeroes

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Question			Answer	Marks	Guidance
3	(a)	(iii)	**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = -134 (kJ) award 3 marks** **IF answer = +134 (kJ) award 2 marks**	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below IF ECF, **ANNOTATE WITH TICKS AND CROSSES, etc**
			2.68 ÷ 0.02 ✓		**ALLOW** ECF i.e. $\frac{(i)}{(ii)}$
			Correctly calculates the value to 3 sig figs ✓		This is dependant on the previous mark **ALLOW** ECF If 2.68, 2.675 or 2.6752 and moles of 0.02answer is (-)134 If mass of magnesium included answer is (-)135 If 2.7 kJ and moles of 0.02 used answer is (-)135 **ALLOW** only answers to three significant figures
			– sign ✓		**–** sign is **independent** of answer
	(b)	(i)	(Enthalpy change) when one mole of a compound ✓	3	**ALLOW** energy required **OR** energy released **ALLOW** (energy change) when one mole of a substance/molecule/product **DO NOT ALLOW** enthalpy change for one mole of product**s** **DO NOT ALLOW** one mole of reactants
			is formed from its elements ✓		
			at 25 ^{o}C/298 K **AND** 1 atmosphere/101 kPa ✓		**ALLOW** any stated temperature and 1 bar/1000/mb/100kPa/100000Pa/101000Pa/101000Nm^{-2} etc **IGNORE** reference to concentration

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Question			Answer	Marks	Guidance
3	(b)	(ii)	Correct labelling of enthalpy cycle  Two or three boxes correct ✓ **BUT** all four boxes correct ✓✓ ΔH_f –792 (kJ mol^{-1}) ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below IF ECF, **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** ECF from wrong enthalpy changes in the boxes
			Total	**12**	

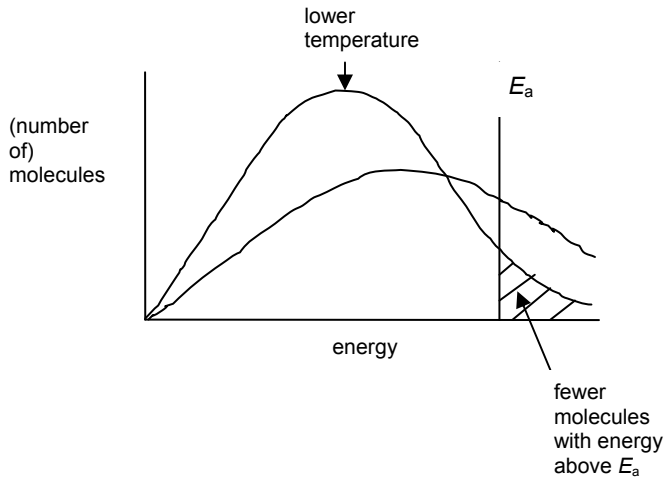
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Question			Answer	Marks	Guidance
4	(a)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 431.5 (kJ mol^{-1}) award 2 marks** Energy required to break bonds = (+)679 kJ ✓ so bond enthalpy = (+)431.5 ✓	2	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below IF ECF, **ANNOTATE WITH TICKS AND CROSSES, etc** **ALLOW** (+)432 **ALLOW** one mark in this question for –431.5 **OR** (+)863 **ALLOW** ecf for bond enthalpy = 0.5 x (–184 + energy required to break bonds)
	(b)		more concentrated (particles) **OR** more particles per (unit) volume ✓ more collisions per second **OR** more frequent collisions ✓	2	**Must state somewhere in the answer that the rate is faster for full marks** **ALLOW ORA** if lower pressure is specified **ALLOW** particles are closer together **OR** more crowded particles **OR** more particles in the same space **OR** same number of particles in a smaller volume **ALLOW** molecules for particles but **DO NOT ALLOW** atoms **DO NOT ALLOW** 'area' instead of 'volume' **ALLOW** collisions more often **OR** increased rate of collision **OR** collisions are more likely **OR** there is a greater chance of collisions 'More collisions' is **not** sufficient **IGNORE** successful

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Question			Answer	Marks	Guidance
4	(c)			5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** Assume answers refer to lower temperature and rate decreases unless specified otherwise **ALLOW** ORA i.e. correct explanation for why higher temperatures increase rate if clearly specified **ALLOW** particles instead of molecules throughout question **DO NOT ALLOW** atoms the first time it appears in the answer
			y-axis label is '(number of) molecules' **AND** *x*-axis label is 'energy' **AND** one correct curve ✓		Boltzmann distribution - must start at origin and must not end up at 0 on *y*-axis i.e. must not touch *x*-axis
			Correct curve for lower temperature (labelled) ✓		Maximum of curve to left **AND** higher than maximum of higher temperature curve **AND** below higher temp line at higher energy as shown in diagram below **IGNORE** minor point of inflexion of both curves
			Activation energy does not change **OR** clearly labelled on diagram, e.g. E_a **OR** *E* ✓		
			Fewer molecules have energy above activation energy **OR** fewer molecules have enough energy to react ✓		**ALLOW** ORA for higher temperature if specified Fewer molecules have enough energy to collide successfully is worth one mark
			So fewer **successful** collisions ✓		Fewer collisions per second is **not** sufficient

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Question			Answer	Marks	Guidance
					
	(d)	(i)	$Cl_2 \rightarrow 2Cl$ ✓	1	No need to show radicals with a 'dot'
		(ii)	HCl + H ✓ HCl + Cl ✓	2	No need to show radicals with a 'dot'
		(iii)	***Any two from:*** $H + H \rightarrow H_2$ ✓ $Cl + Cl \rightarrow Cl_2$ ✓ $H + Cl \rightarrow HCl$ ✓	2	No need to show radicals with a 'dot'
			Total	**14**	

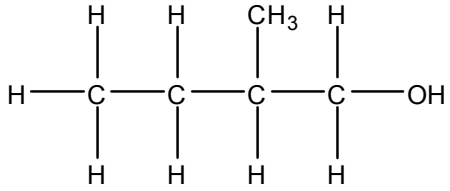
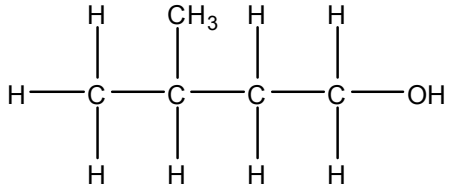
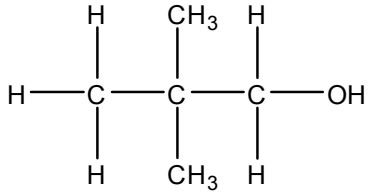
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Question			Answer	Marks	Guidance
5	(a)		Only one (desired) product formed ✓	1	**ALLOW** no waste products **OR** no co-product **OR** all atoms on left hand side are in the desired product **OR** sulfuric acid is the only product **IGNORE** it is an addition reaction
	(b)		**FIRST, CHECK THE ANSWER ON ANSWER LINE** **IF answer = 94% award 3 marks** Moles of sulfur reacted or theoretical moles of H_2SO_4 = 1.60×10^6 ✓ Actual moles of H_2SO_4 = 1.50×10^6 ✓ % yield = 94 ✓	3	**IF** there is an alternative answer, check to see if there is any **ECF** credit possible using working below **ALLOW** 1.6×10^6 to the calculator value 1.601246106×10^6 correctly rounded **ALLOW** 1.60 up to calculator value 1.601246106 correctly rounded **ALLOW** 1.5×10^6 to the calculator value 1.498470948×10^6 correctly rounded **ALLOW** 1.5 up to calculator value 1.498470948 correctly rounded **ALLOW** theoretical mass of H_2SO_4 = 157 (tonnes) up to the calculator value of 157.0822430 correctly rounded for two marks **ALLOW** ECF for a percentage yield from wrong moles above but answer must have two significant figures
	(c)	(i)	Position of equilibrium – unchanged ✓ Rate of backward reaction – decreases ✓	2	

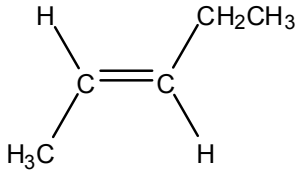
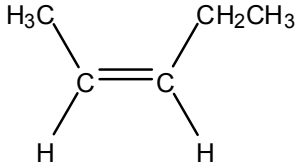
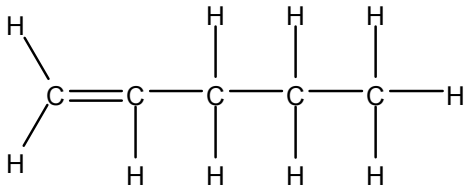
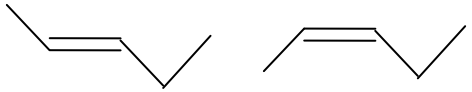
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Question			Answer	Marks	Guidance
5	(c)	(ii)	(equilibrium position shifts) to the left **because** (forward) reaction is exothermic **OR** equilibrium position shifts) to the left **because reverse** reaction is endothermic ✓	1	Both position of equilibrium **AND** explanation needed for one mark **Note: ALLOW** suitable alternatives for 'to left', e.g. towards SO_2 or O_2 / towards reactants **OR** in backward direction **OR** in reverse direction **OR** decreases yield of SO_3/products **ALLOW** 'favours the left', as alternative for 'shifts equilibrium to left' **ALLOW** reaction gives out heat for exothermic **ALLOW** reaction takes in heat for endothermic **ALLOW** moves to the left in the endothermic direction **ALLOW ORA** if specified **IGNORE** responses in terms of rate
		(iii)	(equilibrium position shifts) to the left **because** there are more moles (of gas) on the reactant side **OR** (equilibrium position shifts) to the left because there are fewer moles (of gas) on product side ✓	1	Both position of equilibrium **AND** explanation needed for one mark **Note: ALLOW** suitable alternatives for 'to left', e.g.: towards SO_2 or O_2 / towards reactants **OR** in backward direction **OR** in reverse direction **OR** decreases yield of SO_3/products **ALLOW** 'favours the left', as alternative for 'shifts equilibrium to left' **ALLOW** correct reference to volume of gases e.g. shifts to the left because there is a smaller volume of gas on the product side **ALLOW ORA** if specified **IGNORE** responses in terms of rate

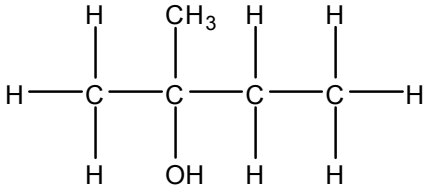
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Question			Answer	Marks	Guidance
5	(d)	(i)	Correct structure ✓  **OR**  **OR** 	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** bonds going to any part of the CH_3, CH_2 and CH bonds **ALLOW** vertical 'bond' to any part of the OH group **DO NOT ALLOW** horizontal –HO in the formula **ALLOW** as a slip one stick with no H on in a displayed formula **IGNORE** name

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Question			Answer	Marks	Guidance
5	(d)	(ii)	Correct structure for **L** ✓  Correct structure for **M** ✓  Correct structure for **N** ✓  	3	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) for **L**, **M** and **N** **e.g.**  **L or M** ***L or M*** **N –** $CH_2CHCH_2CH_2CH_3$ Answers to **L** and M are interchangeable **IGNORE** *cis*/*trans* **OR** *E*/*Z* labels **ALLOW** as a slip one stick with no H on in a displayed formula **ALLOW** 2 marks if three correct structures are drawn but some are in the wrong boxes **ALLOW** 1 mark if two correct structures are drawn but in the wrong boxes

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Question			Answer	Marks	Guidance
5	(d)	(iii)	 ✓	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) **ALLOW** vertical 'bond' to any part of the OH group **DO NOT ALLOW** horizontal –HO in the formula **ALLOW** as a slip one stick with no H on in a displayed formula
			Total	**13**	

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Question			Answer	Marks	Guidance
6	(a)	(i)	(*m*/*z* =) 46 ✓	1	
		(ii)	CH_3O^+ **OR** CH_2OH^+ ✓	1	**MUST** show '+'
		(iii)	C_2H_6O ✓	1	**ALLOW** H_2CO_2
	(b)		$\frac{63 \times 72.2 + 65 \times 27.8}{100}$ **OR** 63.556 **OR** 63.56✓ A_r = 63.6 ✓ Copper / Cu ✓	3	**ALLOW** two marks for 63.6 with no working out
			Total	**6**	

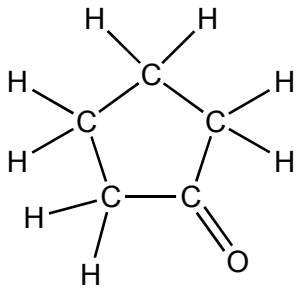
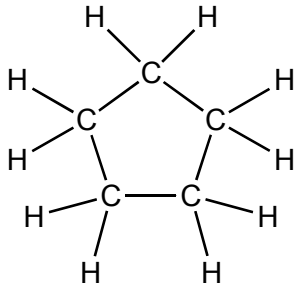
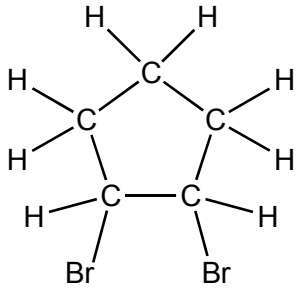
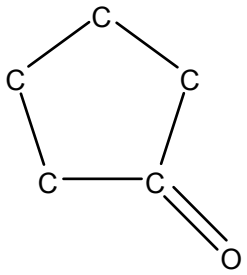
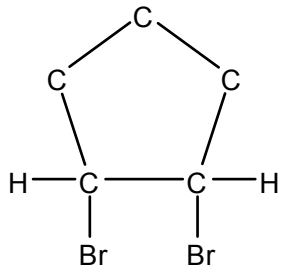
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Question			Answer	Marks	Guidance
7	(a)		Shape – tetrahedral ✓ Bond angle 109.5^{o} ✓	2	 **ALLOW** 109–110°
	(b)	(i)	Volatile **OR** non-toxic **OR** non-flammable **OR** easily vaporised ✓	1	**ALLOW** not carcinogenic / not an irritant / not harmful / not hazardous **IGNORE** cheap / not dangerous / gas / low boiling point **DO NOT ALLOW** inflammable
		(ii)	(C–F or C–C*l*) bonds need a large amount of energy to break ✓	1	**ALLOW (**the C–F or C–C*l*) bonds are strong / bonds have a large bond enthalpy **ALLOW** the molecule is not polar enough / non-polar molecule is **not** sufficient **ALLOW** the activation energy is too high **DO NOT ALLOW dissolves** **IGNORE** references to hydrogen bonding
	(c)		$CF_2Cl_2 \rightarrow CF_2Cl + Cl$ ✓ **AND ANY TWO FROM** C*l* catalyses the decomposition of ozone ✓ $Cl + O_3 \rightarrow ClO + O_2$ ✓ $ClO + O \rightarrow Cl + O_2$ ✓	3	**ALLOW** CF_2Cl_2 (breaks down to) produces **chlorine** atoms/radicals **ALLOW** equation with any CFC **ALLOW** $ClO + O_3 \rightarrow Cl + 2O_2$ **ALLOW** $O_3 + O \rightarrow 2O_2$ **OR** $3O_2 \rightarrow 2O_3$ for one mark if the two equations for the steps have not been given **IGNORE** other propagation equations

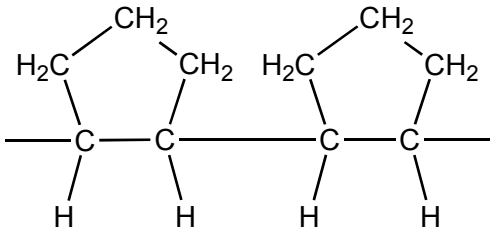
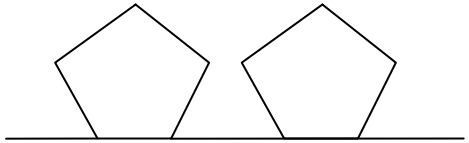
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Question			Answer	Marks	Guidance
7	(d)		Because (more) UV will reach the Earth's surface **and** risk of (skin) cancer increased/risk of cataracts/crop mutation increased ✓	1	**DO NOT ALLOW** global warming **ALLOW** protects from UV which causes skin cancer etc
	(e)		***Ideas related to uses*** CFCs are still entering the atmosphere (from disused items) **OR** CFCs are still used (for some purposes and by some countries) ✓ ***Ideas relating to lifetime within the atmosphere*** CFCs have a long lifetime in the atmosphere **OR** it takes a long time for CFCs to reach upper atmosphere **OR** CFCs are inert ✓	2	**ALLOW** 'stratosphere' for 'upper atmosphere' **ALLOW** CFCs are still entering the ozone layer
			Total	**10**	

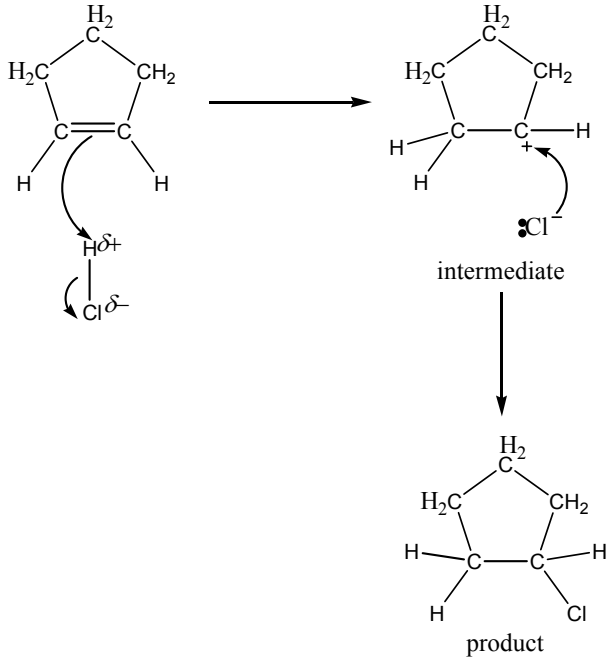
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Question			Answer	Marks	Guidance
8	(a)		 **compound P ✓**  **compound Q ✓**  **compound R ✓**	3	**ALLOW** structures with missing hydrogen atoms on the carbon atoms that do not take part in the reaction. i.e. all hydrogen atoms must be shown in **Q** but not in **P** and **R** For example for the structures of **P** and **R**  

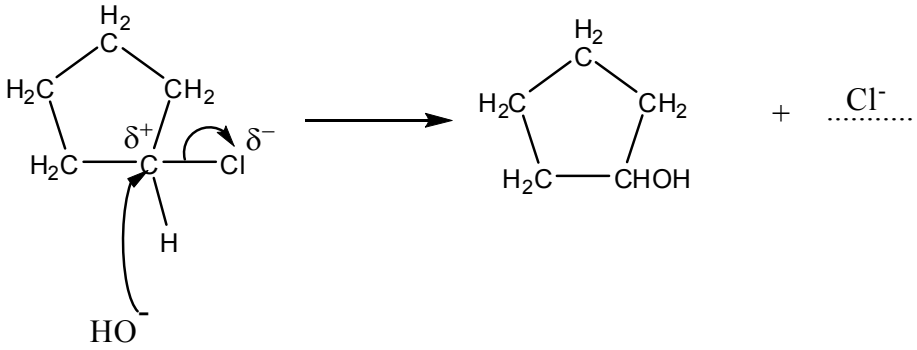
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Question			Answer	Marks	Guidance
8	(b)		Orange **OR** brown to colourless ✓	1	**ALLOW** shades of orange **OR** yellow **OR** brown **DO NOT ALLOW** red alone **DO NOT ALLOW** any response that includes precipitate **OR** solid, irrespective of colour
	(c)		Two or more repeat units ✓ 	1	**ALLOW** correct structural **OR** displayed **OR** skeletal formula **OR** mixture of the above (as long as unambiguous) Must have at least two repeat units and the free bonds at the end **ALLOW** free bonds with dotted lines All carbon–carbon bonds in the polymer chain must be shown **IGNORE** any brackets drawn **IGNORE** any missing hydrogen atoms on the CH_2 groups **ALLOW** skeletal formula 

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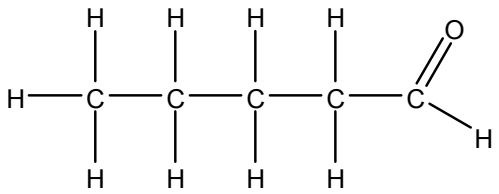
Question			Answer	Marks	Guidance
8	(d)		Curly arrow from double bond to attack hydrogen of H–C*l* and breaking of H–C*l* bond ✓ Correct dipole shown on H–Cl ✓ Correct carbonium ion drawn ✓ Curly arrow from Cl^- to the carbonium ion ✓  Correct product ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC** Curly arrow must start from the double bond and not a carbon atom; other curly arrow must start from H–C*l* bond **DO NOT ALLOW** dipoles on double bond Dipole must be partial charge and not full charge Carbocation needs a full charge and not a partial charge (charges do not need to be in a circle) C*l*$^-$ curly arrow must come from one lone pair on C*l*$^-$ ion **OR** from minus sign on C*l*$^-$ ion Lone pair does not need to be shown on C*l*$^-$ ion **ALLOW** structures with missing hydrogen atoms on the CH_2 groups

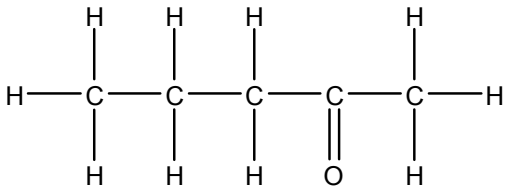
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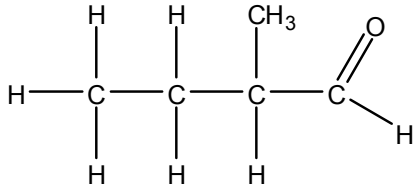
Question			Answer	Marks	Guidance
8	(e)			5	**ANNOTATE ANSWER WITH TICKS AND CROSSES ETC**
			Nucleophilic substitution ✓		
			Heterolytic (fission) spelt correctly ✓		
			dipole shown on C—C*l* bond, $C^{\delta+}$ and $Cl^{\delta-}$✓		Dipole must be partial charge and not full charge
			curly arrow from HO^- to carbon atom of C—C*l* bond ✓		HO^- curly arrow must come from one lone pair on O of HO^- ion **OR** from minus sign on HO^- ion
			curly arrow from C—C*l* bond to the chlorine atom **and** formation of Cl^- ✓		curly arrow must start from C–C*l* bond and not from C atom
					**ALLOW** structures with missing hydrogen atoms on the CH_2 groups
					ALLOW S_N1 mechanism dipole shown on C—C*l* bond, $C^{\delta+}$ and $Cl^{\delta-}$ ✓ curly arrow from C—C*l* bond to the Cl atom and Cl^- shown✓ curly arrow from HO^- to correct carbonium ion ✓
			Total	**15**	

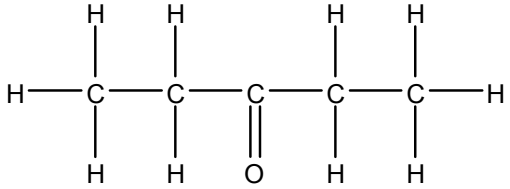
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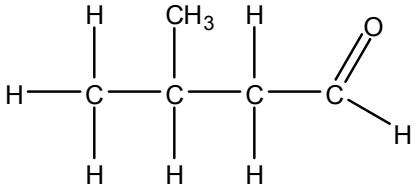
APPENDIX 1

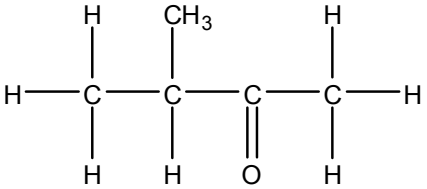


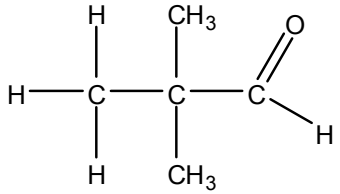


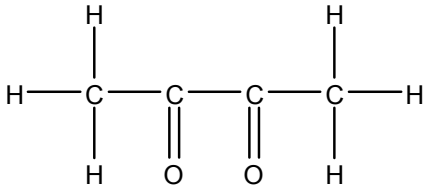


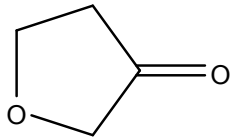


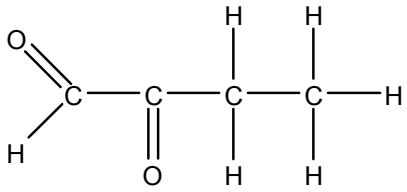


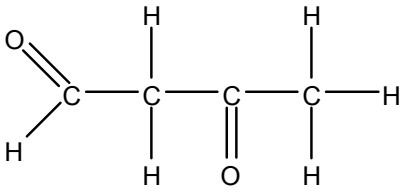


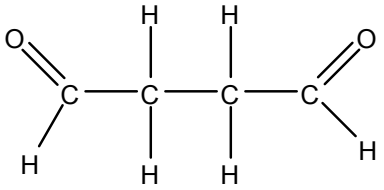












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RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE

CHEMISTRY A

Chains, Energy and Resources

F322

Candidates answer on the question paper.

OCR Supplied Materials:
- *Data Sheet for Chemistry A* (inserted)

Other Materials Required:
- Scientific calculator

Friday 27 May 2011
Afternoon

Duration: 1 hour 45 minutes

F3185306111

F322

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Answer **all** the questions.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
-  Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **24** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 Many organisms use the aerobic respiration of glucose, $C_6H_{12}O_6$, to release useful energy.

(a) The overall equation for aerobic respiration is the same as for the complete combustion of $C_6H_{12}O_6$.

(i) Write the equation for the aerobic respiration of $C_6H_{12}O_6$.

..... **[1]**

(ii) Explain, in terms of bond breaking and bond forming, why this reaction is exothermic.

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..... **[2]**

(b) The table shows some enthalpy changes of combustion, ΔH_c.

substance	ΔH_c **/ kJ mol^{-1}**
C(s)	–394
$H_2(g)$	–286
$C_6H_{12}O_6(s)$	–2801

(i) What is meant by the term *enthalpy change of combustion*, ΔH_c?

.....

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..... **[2]**

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(ii) The enthalpy change of formation, ΔH_f, of glucose, $C_6H_{12}O_6$, cannot be determined directly. The equation for this enthalpy change is shown below.

$$6C(s) + 6H_2(g) + 3O_2(g) \longrightarrow C_6H_{12}O_6(s)$$

Suggest why the enthalpy change of formation of $C_6H_{12}O_6$ **cannot** be determined directly.

.....

.....

..... **[1]**

(iii) Use the ΔH_c values in the table to calculate the enthalpy change of formation of $C_6H_{12}O_6$.

ΔH_f = ... kJ mol^{-1} **[3]**

[Total: 9]

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2 The alcohols are an example of an homologous series.

The table shows the boiling points for the first four members of straight-chain alcohols.

alcohol	structural formula	boiling point / °C
methanol	CH_3OH	65
ethanol	CH_3CH_2OH	78
propan-1-ol	$CH_3CH_2CH_2OH$	97
butan-1-ol	$CH_3CH_2CH_2CH_2OH$	118

(a) (i) What is the general formula of a member of the alcohol homologous series?

..... **[1]**

(ii) Deduce the molecular formula of the alcohol that has 13 carbon atoms per molecule.

..... **[1]**

(b) Alcohols contain the hydroxyl functional group.

What is meant by the term *functional group*?

.....

.....

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..... **[2]**

(c) (i) At room temperature and pressure, the first four members of the alcohol homologous series are liquids whereas the first four members of the alkanes homologous series are gases.

Explain this difference.

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..... **[3]**

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(ii) Methylpropan-1-ol and butan-1-ol are structural isomers. Methylpropan-1-ol has a lower boiling point than butan-1-ol.

Suggest why.

.....

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..... **[2]**

(d) Alcohols, such as methanol, can be used as fuels.

(i) Write equations for the complete and incomplete combustion of methanol.

complete: .....

incomplete: ..... **[2]**

(ii) Suggest what conditions might lead to incomplete combustion of methanol.

.....

..... **[1]**

(iii) In addition to its use as a fuel, methanol can be used as a solvent and as a petrol additive to improve combustion.

State **another** large-scale use of methanol.

..... **[1]**

(e) Butan-1-ol can be oxidised by heating under reflux with excess acidified potassium dichromate(VI).

Write an equation for the reaction that takes place.
Use [O] to represent the oxidising agent.

..... **[2]**

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(f) Butan-1-ol is one of the structural isomers of $C_4H_{10}O$.

(i) Write the name and draw the structure of the structural isomer of $C_4H_{10}O$ that is a tertiary alcohol.

name: ……

structure:

[2]

(ii) Draw the structure of the structural isomer of $C_4H_{10}O$ that can be oxidised to form butanone.

[1]

[Total: 18]

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3 Nitrogen monoxide is an atmospheric pollutant, formed inside car engines by the reaction between nitrogen and oxygen.

$$N_2(g) + O_2(g) \longrightarrow 2NO(g) \qquad \Delta H = +66\,kJ\,mol^{-1}$$

This reaction is endothermic.

(a) (i) Explain the meaning of the term *endothermic*.

.....

..... **[1]**

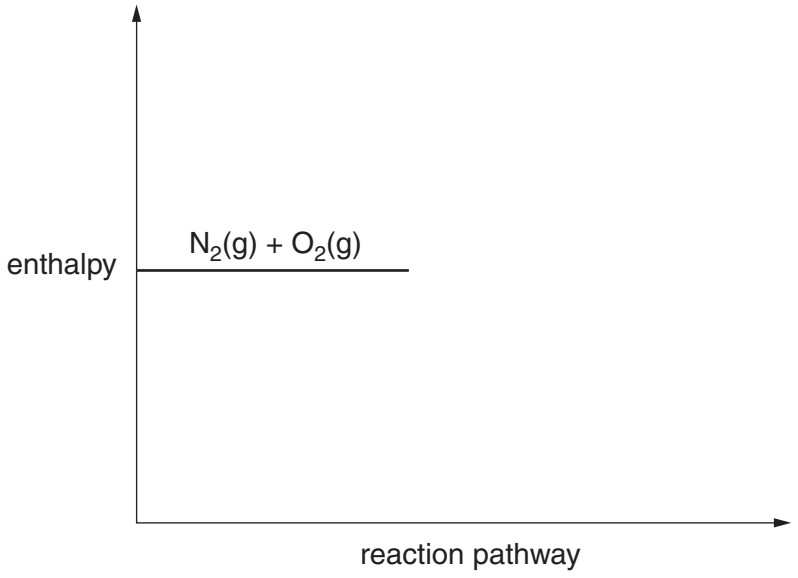
(ii) What is the value for the enthalpy change of formation of nitrogen monoxide?

answer = ... kJ mol^{-1} **[1]**

(b) (i) Complete the enthalpy profile diagram for the reaction between nitrogen and oxygen.

On your diagram

- add the product
- label the activation energy as E_a
- label the enthalpy change as ΔH.



[3]

(ii) Explain the meaning of the term *activation energy*.

.....

.....

..... **[1]**

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(c) A research chemist investigates the reaction between nitrogen and oxygen.
She mixes nitrogen and oxygen gases in a sealed container.
She then heats the container at a constant temperature for one day until the gases reach a dynamic equilibrium.

(i) Explain, in terms of the rate of the forward reaction and the rate of the backward reaction, how the mixture of $N_2(g)$ and $O_2(g)$ reaches a dynamic equilibrium containing $N_2(g)$, $O_2(g)$ **and** NO(g).

.....

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..... **[2]**

(ii) The research chemist repeats the experiment at the same temperature using the same initial amounts of $N_2(g)$ and $O_2(g)$. This time she carries out the experiment at a much **higher pressure**.

Suggest why

- much less time is needed to reach dynamic equilibrium
- the composition of the equilibrium mixture is the same as in the first experiment.

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..... **[5]**

(iii) The reaction between nitrogen and oxygen in a car engine does not reach a dynamic equilibrium.

Suggest why not.

.....

.....

..... **[1]**

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(d) Nitrogen monoxide is a radical.

What does this tell you about a molecule of nitrogen monoxide?

.....

..... **[1]**

(e) Oxides of nitrogen, NO_x, are atmospheric pollutants.

(i) Nitrogen monoxide reacts with oxygen to form NO_2.

Write an equation for the formation of NO_2 from nitrogen monoxide and oxygen.

..... **[1]**

(ii) Aeroplane engines produce nitrogen monoxide.

Describe, with the aid of equations, how nitrogen monoxide catalyses ozone depletion in the stratosphere.

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..... **[3]**

(iii) Outline the use of infrared spectroscopy in identifying air pollutants such as NO_x.

.....

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..... **[2]**

[Total: 21]

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4 Atom economy and percentage yield are important factors in deciding the sustainability of a manufacturing process.

(a) Complete the expression below for atom economy.

$$\text{atom economy} = \frac{\text{sum of } \ldots\ldots\ldots\ldots}{\text{sum of } \ldots\ldots\ldots\ldots} \times 100\%$$

[1]

(b) The following five reactions all represent important industrial processes.

Process 1 $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3 \longrightarrow (CH_3)_2CHCH_2CH_2CH(CH_3)_2$

Process 2 $CH_3CH_2OH + CH_3COOH \longrightarrow CH_3COOCH_2CH_3 + H_2O$

Process 3 $CH_2CH_2 + H_2O \longrightarrow CH_3CH_2OH$

Process 4 $NH_3 + HNO_3 \longrightarrow NH_4NO_3$

Process 5 $C_8H_{18} \longrightarrow C_2H_4 + C_6H_{14}$

(i) Which process is an example of cracking?

..... **[1]**

(ii) Which process makes a structural isomer of the reactant?

..... **[1]**

(iii) Which process does **not** have an atom economy of 100%?

Explain your answer.

.....

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..... **[2]**

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(c) The manufacture of ethanol by the fermentation of glucose can be represented by the following equation.

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

The atom economy is 51.1% and the percentage yield is 88.6%.

(i) Suggest **two** reasons why it is a good idea to find uses for the carbon dioxide produced.

.....

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..... **[2]**

(ii) Some scientists believe that it is more important to have a high percentage yield in fermentation but others think that a high atom economy is more important.

Is it more important to have high percentage yield or a high atom economy in fermentation?

Explain your answer.

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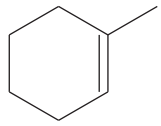
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[Total: 9]

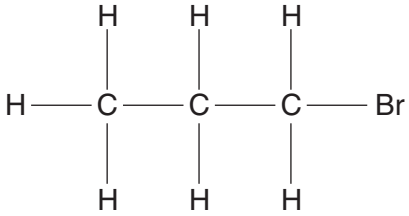
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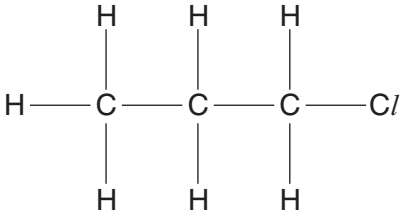
5 This question is about the following organic compounds.



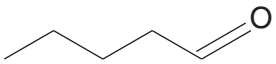
A



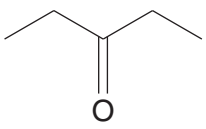
B



C



D



E



F

$CH_3CH = CHCH_3$

G

$CH_3CH = CH_2$

H

You will have to refer to these compounds throughout the question.

(a) Explain why compound **A** is a hydrocarbon.

.....

..... **[1]**

(b) Which compound is a saturated hydrocarbon?

..... **[1]**

(c) What is the molecular formula for compound **E**?

..... **[1]**

(d) Which compounds are structural isomers of one another?

..... **[1]**

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(e) In compound **G**, there are different shapes around different carbon atoms.

(i) State and explain the shape around carbon atom number **1** in compound **G**.

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.....

.....

..... **[2]**

(ii) State the shape around carbon atom number **2** in compound **G**.

..... **[1]**

(f) **(i)** Which compound shows *E*/*Z* isomerism?

..... **[1]**

(ii) Explain why some molecules show *E*/*Z* isomerism.

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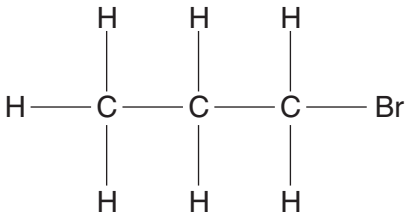
..... **[2]**

TURN OVER FOR PART (g)

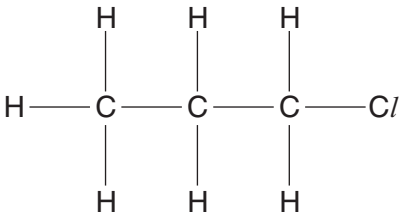
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(g) Compounds **B** and **C** are halogenoalkanes. Both compounds can be hydrolysed with aqueous potassium hydroxide, KOH(aq).



B



C

Describe and explain the hydrolysis of **B** and **C**.

In your answer, include

- one equation including the structure of the organic product
- the reaction mechanism, using the curly arrow model, showing any relevant dipoles
- the type of bond fission that occurs
- the reasons for the difference in the rate of hydrolysis.

Your answer needs to be clear and well organised using the correct terminology.

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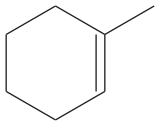
..... **[10]**

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(h) Compound **A** is 1-methylcyclohex-1-ene.



A

Compound **A** reacts with H_2 to give one product and with HBr to give two products.

Draw the structures of the products of these reactions.

product of reaction of H_2 with **A**

two products of reaction of HBr with **A**	

[3]

[Total: 23]

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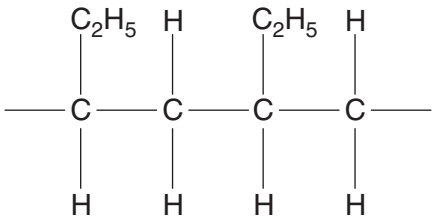
TURN OVER FOR QUESTIONS 6 AND 7

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6 Plastics contain polymer molecules. The disposal of waste plastics is causing many environmental problems. In the middle of the Pacific Ocean, there is a huge area of sea water contaminated with very small pieces of plastic waste. In some parts of the Pacific Ocean, there are as many as one third of a million of small pieces of plastic waste per square kilometre of ocean.

(a) A short section of one of the polymers found in the Pacific Ocean is shown below.



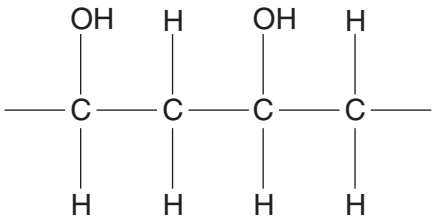
(i) Name and draw the structure of the monomer used to produce this polymer.

name of monomer: .....

structure:

[2]

(ii) The short section of poly(ethenol) is shown below.



Large quantities of poly(ethene) and poly(ethenol) are disposed of each year.

Poly(ethene) is found as a waste plastic in the Pacific Ocean but poly(ethenol) is not because it slowly dissolves in water.

Suggest why poly(ethenol) dissolves in water.

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..... **[2]**

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(b) One way of disposing of poly(chloroethene) is incineration.

This process can cause environmental damage. Incineration produces a mixture of carbon dioxide, carbon monoxide and hydrogen chloride.

Carbon dioxide can cause climate change because it is a greenhouse gas.

- Describe examples of environmental damage that may result from carbon monoxide and hydrogen chloride.
- Outline the methods developed by chemists to reduce environmental damage caused by incineration.

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..... **[4]**

(c) Explain why it is important to establish international cooperation to reduce the pollution levels of waste plastics.

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..... **[2]**

[Total: 10]

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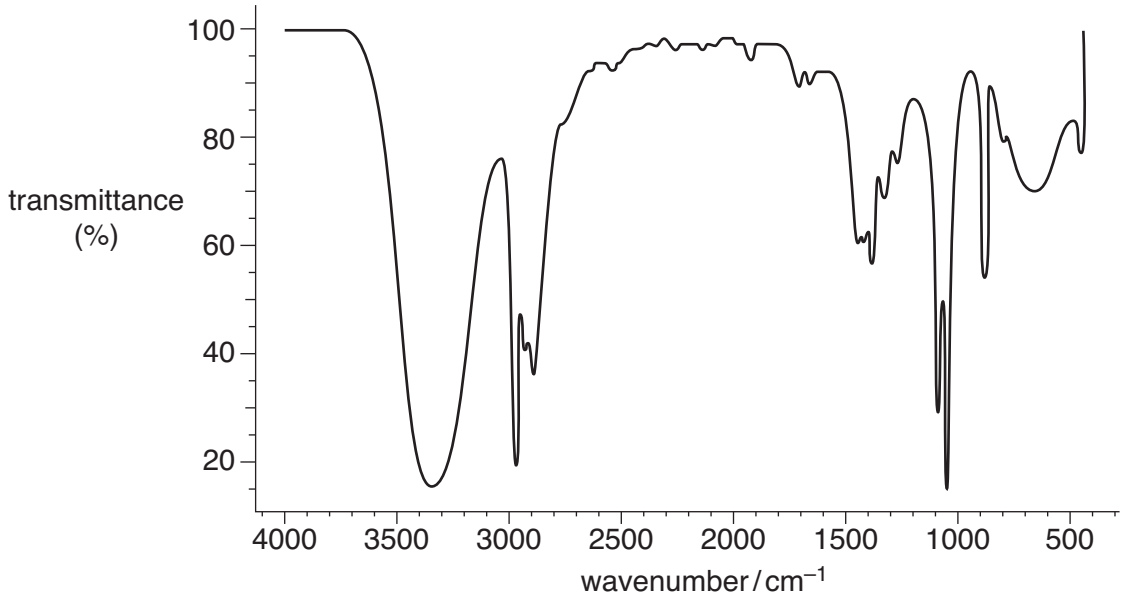
7 Compound **X** and compound **Y** react together to make an ester **Z**. Samples of **X** and **Y** were analysed by a research chemist. A summary of the chemist's results are shown below.

Analysis of compound X

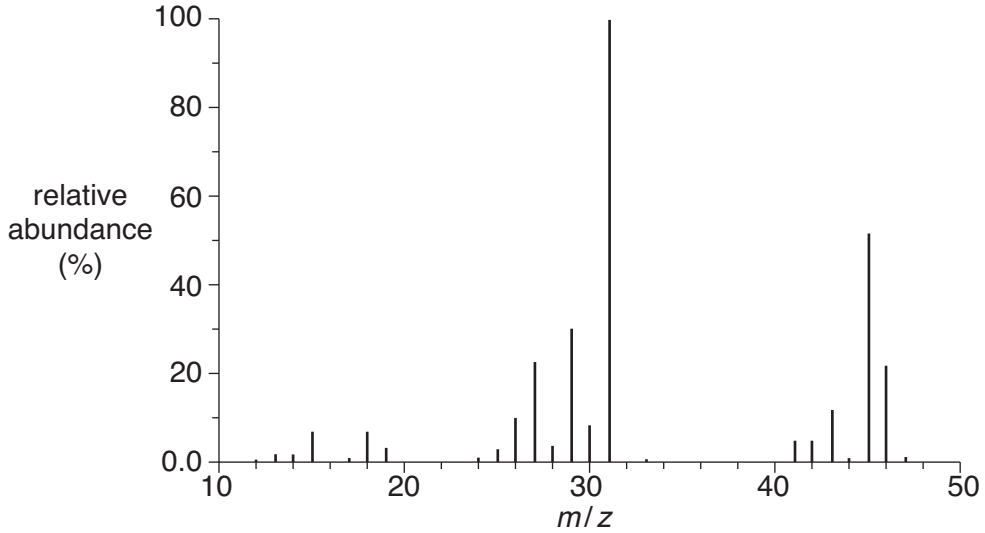
type of analysis	evidence
infrared spectroscopy	absorption at 1720 cm^{-1} and a very broad absorption between 2500 and 3300 cm^{-1}
percentage composition by mass	C, 48.65%; H, 8.11%; O, 43.24%
mass spectrometry	molecular ion peak at $m/z = 74.0$

Analysis of compound Y

infrared spectrum of **Y**



mass spectrum of **Y**



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Use this information to suggest the identity of compound **X**, compound **Y** and ester **Z**.

In your answer you should make clear how your explanation is linked to the evidence.

[10]

[Total:10]

END OF QUESTION PAPER

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ADDITIONAL PAGE

If additional space is required, you should use the lined pages below. The question number(s) must be clearly shown.

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ADDITIONAL PAGE

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ADDITIONAL PAGE

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GCE

Chemistry A

Advanced Subsidiary GCE

Unit **F322:** Chains, Energy and Resources

Mark Scheme for June 2011

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Question			Answer	Mark	Guidance
1	(a)	(i)	$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ ✓	1	**IGNORE** state symbols
		(ii)	Bond breaking absorbs energy **AND** bond forming releases energy ✓ More energy released than absorbed ✓	2	**ALLOW** bond breaking is endothermic **AND** bond forming is exothermic **DO NOT ALLOW** bond forming requires energy The second marking point is **dependent** on the correct identification of the energy changes during bond breaking and bond making **ALLOW** exothermic change transfers more energy than endothermic change **OR** bond forming transfers more energy than bond breaking **OR** '(the sum of the) bond enthalpies in the products is greater than the (sum of the) bond enthalpies in the reactants' **OR** '(the sum of the) bond enthalpies of the bonds made is greater than (the sum of) the bond enthalpies of the bonds broken' **IGNORE** reference to strong and weak bonds **IGNORE** reference to number of bonds broken or made **IGNORE** enthalpy of products is less than enthalpy of reactants
	(b)	(i)	(Enthalpy change) when one mole of a substance ✓ is completely combusted **OR** burns in excess oxygen ✓	2	**ALLOW** energy released **DO NOT ALLOW** energy required **ALLOW** element **OR** compound **OR** molecule **DO NOT ALLOW** one mole of atoms **ALLOW** reacts fully with oxygen
		(ii)	Would make carbon dioxide and water instead **OR** activation energy (too) high **OR** rate is (too) slow **OR** do not react together ✓	1	**ALLOW** will make other compounds (containing carbon and hydrogen or carbon, oxygen and hydrogen) **ALLOW** reaction cannot be carried out experimentally **IGNORE** heat is lost to the surroundings

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Question			Answer	Mark	Guidance
1	(b)	(iii)	(+)2801 ✓ + (−)394 × 6 + (−)286 × 6 **OR** (–)4080 ✓ −1279 ✓	3	**IGNORE** sign **IGNORE** sign **ALLOW** full marks for −1279 with no working out ✓✓✓ Unit **not** needed **ALLOW** ECF enthalpy change of combustion of carbon dioxide and water – enthalpy of combustion of glucose **ALLOW for 2 marks:** +1279 cycle wrong way around **OR** +151 **OR** +691 one value not × 6 **OR** –6881 **OR** +6881 wrong sign for 2801 or 4080 **OR** +2121 ✓✓ correct cycle but not × 6 **ALLOW for 1 mark:** –151 **OR** –691 cycle wrong way around and one value not × 6 **OR** –2121 cycle wrong way around and not × 6 **OR** –3481 **OR** +3481 ✓ wrong sign and not × 6 **Note:** There may be other possibilities
			Total	**9**	

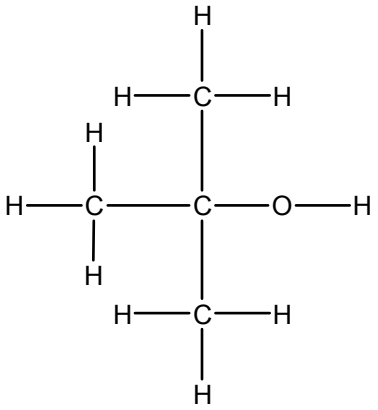
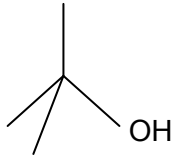
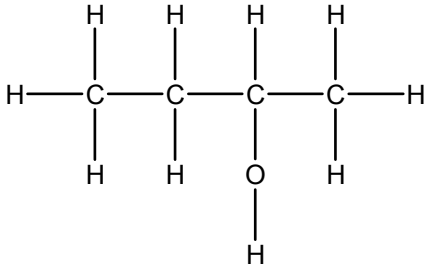
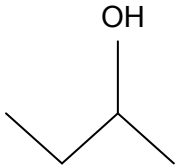
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Question			Answer	Mark	Guidance
2	(a)	(i)	$C_nH_{2n+1}OH$ ✓	1	**ALLOW** $C_nH_{2n+2}O$
		(ii)	$C_{13}H_{28}O$ ✓	1	**ALLOW** $C_{13}H_{27}OH$
	(b)		group of atoms **OR** part of a molecule ✓ that give a compound its (characteristic set of) reactions ✓	2	**ALLOW** part of an alcohol **IGNORE** part of a compound **ALLOW** that determines its **chemical** properties **OR** that gives the compound its reaction **ALLOW** that determines its homologous series
	(c)	(i)	Alkanes have van der Waals' intermolecular forces ✓ Alcohols have hydrogen bonds (and van der Waals' forces) ✓ Hydrogen bonds are stronger (than van der Waals' forces) **OR** ORA ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** reference to specific compounds e.g. comparing methane and methanol vdW force is **not** sufficient here Third marking point is dependent on the correct intermolecular forces being described **BUT ALLOW** hydrogen bonds are stronger than intermolecular forces in alkanes
		(ii)	Methylpropan-1-ol has weaker van der Waals' forces (than butan-1-ol) **OR** ORA ✓ Methylpropan-1-ol has less surface contact (than butan-1-ol) **OR** ORA **OR** Methylpropan-1-ol has more branching (than butan-1-ol) **OR** ORA ✓	2	**ALLOW** methylpropan-1-ol has fewer van der Waals' forces (than butan-1-ol) **IGNORE** reference to more surface area / molecules are closer **ALLOW** methylpropan-1-ol is branched and butan-1-ol is not **IGNORE** 'methylpropan-1-ol is branched' with no comparison

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Question			Answer	Mark	Guidance
2	(d)	(i)	$CH_3OH + 1½O_2 \rightarrow CO_2 + 2H_2O$ ✓ $CH_3OH + O_2 \rightarrow CO + 2H_2O$ ✓	2	**ALLOW** CH_4O for incomplete combustion **ALLOW** $CH_3OH + ½O_2 \rightarrow C + 2H_2O$ **ALLOW** $2CH_3OH + 1½O_2 \rightarrow C + CO + 4H_2O$ **ALLOW** correct multiples of these equations **IGNORE** state symbols
		(ii)	insufficient supply of oxygen **OR** limited amount of air **OR** poorly ventilated ✓	1	
		(iii)	Feedstock (in manufacture of organic compounds) **OR** manufacture of biodiesel **OR** manufacture of esters. ✓	1	**ALLOW** manufacture of a named organic compound that can be made from methanol **ALLOW** antifreeze, screenwash
	(e)		$CH_3CH_2CH_2COOH$ ✓ **BUT** $C_4H_9OH + 2[O] \rightarrow CH_3CH_2CH_2COOH + H_2O$ ✓✓	2	One mark is for the correct structure of the product One mark is for the equation **ALLOW** $CH_3CH_2CH_2CO_2H$ **DO NOT ALLOW** $C_4H_8O_2$, C_3H_7COOH, C_4H_7OOH for the structure mark but **ALLOW** for the equation mark Give credit for the correct structure in the equation e.g. $C_4H_9OH + 2[O] \rightarrow CH_3CH_2CH_2COOH + H_2O$ scores two marks **but** $C_4H_9OH + [O] \rightarrow CH_3CH_2CH_2COOH + H_2$ scores one mark $C_4H_{10}O + 2[O] \rightarrow C_4H_8O_2 + H_2O$ scores one mark **ALLOW** one mark for: $C_4H_9OH + [O] \rightarrow CH_3CH_2CH_2CHO + H_2O$

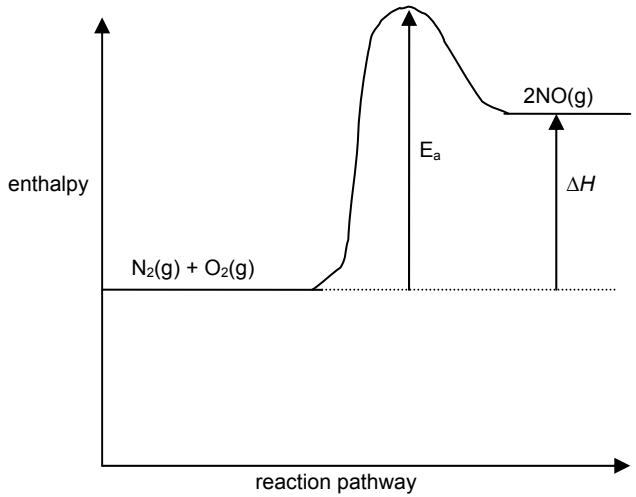
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Question			Answer	Mark	Guidance
2	(f)	(i)	methylpropan-2-ol **OR** 2-methylpropan-2-ol ✓  ✓	2	**DO NOT ALLOW** methylprop-2-ol **ALLOW** $(CH_3)_3COH$ **ALLOW** vertical 'bond' to any part of the OH group **DO NOT ALLOW** horizontal –HO in the formula **ALLOW** 
		(ii)	 ✓	1	**ALLOW** $CH_3CHOHCH_2CH_3$ **ALLOW**  **ALLOW** vertical 'bond' to any part of the OH group **DO NOT ALLOW** horizontal –HO in the formula **IGNORE** an incorrect name
			Total	18	

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Question			Answer	Mark	Guidance
3	(a)	(i)	Reaction in which energy enters the system (from the surroundings) ✓	1	**ALLOW** reaction that absorbs energy **ALLOW** takes energy in (from the surroundings) **ALLOW** enthalpy of products have higher enthalpy than enthalpy of reactants **ALLOW** heat instead of energy **ALLOW** correct reference in terms of bond breaking and bond making **IGNORE** incorrect reference to bond breaking or bond making
		(ii)	+33 ✓	1	+ sign is **not** required **DO NOT ALLOW** –33

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Question			Answer	Mark	Guidance
3	(b)	(i)	2NO added for product ✓ Δ*H* labelled with product above reactant **AND** arrow upwards ✓ E_a labelled correctly **AND** above products ✓  	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **IGNORE** State symbol **ALLOW** product line above or below reactants line **ALLOW** (+)66 **ALLOW** line that has a small gap at the top and bottom **IGNORE** arrows at both ends of activation energy line The E_a line must go to maximum (or near to the maximum) on the curve **ALLOW** if the line clearly shows an activation energy and is not an enthalpy change **ALLOW** line that has a small gap at the top and bottom
		(ii)	Activation energy is the **minimum** amount of energy needed for the reactants to react ✓	1	**ALLOW** compounds **OR** elements **OR** molecules **OR** chemicals instead of reactants **ALLOW** minimum energy needed to start a reaction

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Question			Answer	Mark	Guidance
3	(c)	(i)	Rate of forward reaction slows down and rate of backward reaction speeds up ✓ (Until) rate of forward reaction is the same as the rate of the backward reaction ✓	2	**ALLOW** at start rate of forward reaction is fast but rate of backward reaction is slow **DO NOT ALLOW** forward reaction is the same as backward reaction
		(ii)	Reaction is faster ✓ Increasing pressure mean more particles per unit volume **OR** increasing pressure gives more crowded particles **OR** increasing pressure gives more concentrated (particles) ✓ So more collisions per second **OR** higher collision frequency **OR** collisions more often ✓ (Changes of pressure) do not change the (position of) equilibrium ✓ Both sides of equation have same number of moles (of gas) ✓	5	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** particles are closer together **DO NOT ALLOW** 'area' instead of 'volume' **ALLOW** increased rate of collision **OR** collisions are more likely **OR** there is a greater chance of collisions 'More collisions' or 'more successful collision' are **not** sufficient **DO NOT ALLOW** composition of equilibrium is the same (in question) **ALLOW** both sides of equation have same number of molecules (of gas)
		(iii)	Not a closed system ✓	1	**ALLOW** gases can escape **OR** gases are continuously entering **OR** it is an open system
	(d)		has an unpaired electron ✓	1	**ALLOW** plural: unpaired electrons has a lone electron is **not** sufficient
	(e)	(i)	$2NO + O_2 \rightarrow 2NO_2$ ✓	1	**ALLOW** any correct multiple including fractions **IGNORE** state symbols

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Question			Answer	Mark	Guidance
3	(e)	(ii)	NO is not consumed **OR** overall reaction is $O_3 + O \rightarrow 2O_2$ ✓ $NO + O_3 \rightarrow NO_2 + O_2$ ✓ $NO_2 + O \rightarrow NO + O_2$ ✓	3	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** $2O_3 \rightarrow 3O_2$ **OR** It is a chain reaction **OR** NO is reformed **OR** mechanism of ozone depletion is changed **OR** NO made can react with more ozone **IGNORE dots** **ALLOW** $NO_2 + O_3 \rightarrow NO + 2O_2$
		(iii)	**ANY TWO FROM:** To identify the functional groups (in pollutants) **OR** to identify the bonds (in pollutants) ✓ Match spectrum to known pollutants **OR** each pollutant will have a different spectrum ✓ Idea that you can measure the concentration or abundance of pollutant ✓	2	 **ALLOW** a named bond **IGNORE** any specific wavenumber or range of wavenumbers **ALLOW** match spectrum to database or datasheet
			Total	21	

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Question			Answer	Mark	Guidance
4	(a)		Atom economy = $\frac{\text{sum of (all) } M_r \text{ of desired product(s)}}{\text{sum of (all) } M_r \text{ of (all) products}}$ ✓	1	**ALLOW** Atom economy = $\frac{\text{sum of (all) } M_r \text{ of desired product(s)}}{\text{sum of (all) } M_r \text{ of (all) reactants}}$ **ALLOW** for the numerator: 'sum of' to be crossed out and replaced by 'molecular mass of the desired product(s)' **ALLOW** for the denominator: 'sum of molecular masses of all products'
	(b)	(i)	Process **5** ✓	1	**ALLOW** $C_8H_{18} \rightarrow C_2H_4 + C_6H_{14}$
		(ii)	Process **1** ✓	1	**ALLOW** $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3 \rightarrow (CH_3)_2CHCH_2CH_2CH(CH_3)_2$
		(iii)	Process **2** ✓ water is a waste product ✓	2	**ALLOW** $CH_3CH_2OH + CH_3COOH \rightarrow CH_3COOCH_2CH_3 + H_2O$ **ALLOW** it is a condensation reaction **ALLOW** water is a by-product / water is a non-desirable product **ALLOW** process 2 has an 83% atom economy **IGNORE** it forms more than one product / it forms a waste product
	(c)	(i)	Less waste products **OR** better sustainability **OR** get 100% atom economy ✓ (Stops) greenhouse gas emitted **OR** (stops) gas that (may) cause global warming ✓	2	**ALLOW** no waste products / there is no longer a waste product **ALLOW** increase atom economy

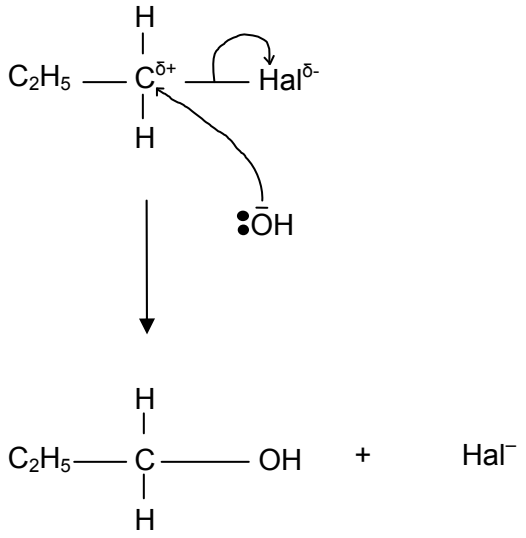
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Question			Answer	Mark	Guidance
4	(c)	(ii)	High percentage yield with a simple reason e.g. because the aim is to manufacture ethanol; to reduce waste; increases sustainability ✓ **BUT** High percentage yield because there is very efficient conversion from **reactant** to product **OR** to reduce the waste of **starting** materials ✓✓ **OR** High atom economy with a simple reason e.g. because it is cheaper or makes less harmful products; to reduces waste; increases sustainability ✓ **BUT** High atom economy to reduce the amount of waste **products** **OR** less **by products** **OR** more desired **product** ✓✓	**2**	No marks for just percentage yield or for atom economy. Marks are for the quality of the explanation Marks are awarded as follows **One** mark – a simple reason that is not fully correct whether a choice has been made or not **Two** marks – a choice must be made and the reason must be correct
			Total	**9**	

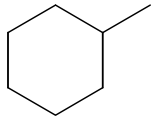
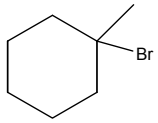
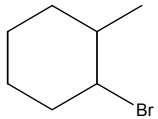
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Question			Answer	Mark	Guidance
5	(a)		Compound of hydrogen and carbon only ✓	1	**ALLOW** contains hydrogen and carbon only **DO NOT ALLOW** 'it contains hydrogen and carbon' **DO NOT ALLOW** a mixture of hydrogen and carbon only
	(b)		**F** ✓	1	**ALLOW** cyclobutane
	(c)		$C_5H_{10}O$ ✓	1	**ALLOW** any order **IGNORE** structural or displayed formula
	(d)		**D** and **E** **OR** **F** and **G** ✓	1	**ALLOW** pentanal and pentan(-3-)one **ALLOW** cyclobutane and but(-2-)ene Award mark if both pairs are given
	(e)	(i)	Tetrahedral ✓ Four (single) bonds (around carbon atom) **OR** four (single) bond pairs (around carbon atom) **OR** (carbon) bonded to four groups ✓	2	**IGNORE** incorrect bond angle If shape is not given, explanation mark **can** be credited If shape is incorrect, explanation mark **cannot** be credited
		(ii)	Trigonal planar ✓	1	**ALLOW** planar triangle **IGNORE** if incorrect bond angle is stated
	(f)	(i)	**G** ✓	1	**ALLOW** but-2-ene
		(ii)	Non rotating (carbon–carbon) double bond ✓ Each carbon atom of the double bond attached to (two) different groups/atoms ✓	2	

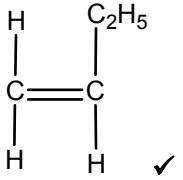
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Question	Answer	Mark	Guidance
5 (g)	**Equation** $C_3H_7X + KOH \rightarrow C_3H_7OH + KX$ **OR** $C_3H_7X + OH^- \rightarrow C_3H_7OH + X^-$ ✓ **Structure of product** $CH_3CH_2CH_2OH$ ✓ **Reaction mechanism** QWC - nucleophilic substitution ✓ dipole shown on C–Hal bond, $C^{\delta+}$ and $Hal^{\delta-}$ ✓ curly arrow from HO^- to carbon atom of C–Hal bond ✓ curly arrow from C–Hal bond to the halogen atom ✓	10	**ANNOTATE ANSWER WITH TICKS AND CROSSES** X = Br or C*l* **ALLOW** molecular, structural, displayed or skeletal formula in equation **ALLOW** $C_3H_7X + H_2O \rightarrow C_3H_7OH + HX$ **ALLOW** equation from the mechanism **IGNORE** incorrect equations **ALLOW** structural, displayed or skeletal formula of product if seen **ONCE** in equation, mechanism or drawn out **If two mechanism shown award marks from the mechanism that gives the higher mark**  The curly arrow must start from the oxygen lone pair or the negative charge on the oxygen of ^-OH ion No need to show lone pair on the oxygen atom

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Question			Answer	Mark	Guidance
5	(g)		**Type of bond fission** QWC - heterolytic ✓ **Reasons for the difference in rate of hydrolysis** 1-bromopropane reacts faster (than 1-chloropropane) **OR B** reacts faster (than **C**) **OR** C–Br reacts faster ✓ Because the C–Br bond is weaker **OR** C–Br has a lower bond enthalpy **OR** C–Br bond is longer ✓ C–Br is more easy to break ✓		**ALLOW S_N1 mechanism** dipole shown on C–Hal bond, $C^{\delta+}$ and $Hal^{\delta-}$ ✓ curly arrow from C–Hal bond to the halogen atom ✓ curly arrow from OH^- to correct carbocation ✓ **IGNORE** bromine reacts faster than chlorine **ALLOW** ora **ALLOW** less energy to break C–Br **ALLOW** ora **ALLOW** ora
	(h)		With H_2  ✓ With HBr  ✓  ✓	**3**	**ALLOW** methylcyclohexane **ALLOW** 1-bromo-1-methylcyclohexane **ALLOW** 1-bromo-2-methylcyclohexane **ALLOW** 2-bromo-1-methylcyclohexane
			Total	**23**	

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Question			Answer	Mark	Guidance
6	(a)	(i)	But-1-ene ✓  ✓	2	**ALLOW** displayed formula **ALLOW** $C_2H_5CH=CH_2$
		(ii)	Poly(ethenol) has (many) O–H group(s) ✓ Poly(ethenol) forms hydrogen bonds with water ✓	2	**ALLOW** poly(ethenol) has hydroxyl group **OR** hydroxy group **OR** is an alcohol **DO NOT ALLOW** hydroxide **DO NOT ALLOW** 'it forms hydrogen bonds'
	(b)		CO is a poisonous gas ✓ HC*l* is acidic/forms acid rain **OR** corrosive **OR** HC*l* will react with metalwork **OR** HC*l* will react with marble/limestone buildings ✓ **ANY TWO METHODS FROM:** **Method 1** Remove HC*l* by reacting with a base **OR** remove HC*l* by use of a gas scrubber ✓ **Method 2** Develop ways of ensuring all CO is oxidised to CO_2 **OR** ensure complete combustion to avoid making CO ✓ **Method 3** Remove CO_2 by CCS ✓ **Method 4** (Use methods to remove the need for incineration such as) separation **AND** recycling of the plastics/polymers ✓ **Method 5** (Use methods to remove the need for incineration such as) developing biodegradable/compostable plastics/polymers ✓	4	**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW** CO reduces amount of oxygen transported in blood Forming carboxyhaemoglobin/binds with haemoglobin is **not** sufficient **IGNORE** HC*l* is toxic **IGNORE** references to ozone layer and greenhouse effect **Methods 1 to 3 must be linked to a gas** **IGNORE** reference to catalytic converter **ALLOW** specific examples of CCS e.g. CO_2 stored as a metal carbonate / CO_2 stored deep under sea / CO_2 stored in rock **ALLOW** (Use methods to remove the need for incineration such as) use of plastics/polymers as a feedstock for making other chemicals

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Question			Answer	Mark	Guidance
6	(c)		**ANY TWO FROM:** Idea that all countries contribute towards pollution ✓ Idea that atmospheric pollution (from incineration travels) across borders **OR** waste plastics travel across borders / waste plastics travel across the sea ✓ Cooperation means that scientists can share ideas **OR** scientists can warn governments of risk **OR** world-wide legislation can be introduced **OR** allows monitoring of pollution in different countries **OR** richer countries can help poorer countries introduce pollution controls ✓ One country cannot control pollution unless all countries do ✓	2	**ALLOW** some countries produce more pollution than others. **ALLOW** reference to protocols
			Total	10	

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Question	Answer	Mark	Guidance
7	**ANY SEVEN FROM:** **Compound X** QWC: **X** contains C=O because of absorption at 1720 cm^{-1} **AND** contains O–H because of (broad) absorption between 2500 to 3300 cm^{-1} ✓ So **X** is a carboxylic acid ✓ Molar ratio (C:H:O) of **X** is 4.05 : 8.1 : 2.7 **OR** $\frac{48.65}{12.0} : \frac{8.11}{1.0} : \frac{43.24}{16.0}$ ✓ (Empirical formula) is $C_3H_6O_2$ ✓ M_r is 74.0 so **X** is $C_3H_6O_2$ ✓	7	**ANNOTATE ANSWER WITH TICKS AND CROSSES** PLEASE ENSURE YOU LOOK AT THE DATA AND SPECTRA ON PAGE 20 IN CASE THEY INCLUDE COMMENTS THAT ARE WORTHY OF CREDIT. MARK THIS PAGE WITH AN OMISSION MARK, ^ , IF BLANK QWC: mark is integrated into the chemistry marks. These marks need to link evidence with an explanation **ALLOW X** contains C=O and O–H because of absorptions at 1720 cm^{-1} and 2500 to 3300 cm^{-1} **ALLOW X** contains carboxylic acid/COOH because of absorption at 1720 cm^{-1} and (broad) absorption between 2500 to 3300 cm^{-1} ✓✓ **ALLOW** alternative approach to molecular formula M_r is 74.0 ✓ $74 \times \frac{48.65}{100} : 74 \times \frac{8.11}{100} : 74 \times \frac{43.24}{100}$ = 36 : 6 : 32 ✓ $C_3H_6O_2$ ✓ This mark is for some evidence of using M_r to deduce the molecular or structural formula **ALLOW** M_r is 74.0 so **X** is CH_3CH_2COOH ✓ **DO NOT ALLOW** ECF from the empirical formula with the wrong molar ratio

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Question			Answer	Mark	Guidance
7			**Compound Y** QWC **Y** contains O–H because of absorption between 3100 and 3500 cm^{-1} ✓ QWC Mass spec of **Y** has molecular ion, *m*/*z* = 46 so M_r is 46 ✓ Correct identification of one fragment from a *m*/*z* value e.g. *m*/*z* = 31 is CH_2OH^+; *m*/*z* = 29 is $C_2H_5^+$; *m*/*z* = 15 is CH_3^+ ✓		**ANNOTATE ANSWER WITH TICKS AND CROSSES** **ALLOW Y** is an alcohol (or phenol) because of absorption between 3200 and 3550 cm^{-1} **ALLOW Y** contains C–O, C–H and O–H bonds because of absorptions at approximately 1030, 2950 and 3350 cm^{-1} **ALLOW** *m*/*z* = 46 so M_r is 46 **OR** mass spectrum has a peak at 46 which is the M_r **OR** M_r is 46 because of *m*/*z* peak shown on the actual spectra M_r = 46 on its own is **not** sufficient *m*/*z* = 46 on its own is not sufficient **ALLOW** *m*/*z* = 31 shows CH_2OH (fragment); *m*/*z* = 29 shows C_2H_5 (fragment); *m*/*z* = 15 is CH_3 (fragment)
			Identification of compounds So **X** must be CH_3CH_2COOH **OR** propanoic acid ✓ So **Y** is ethanol **OR** C_2H_5OH **OR** CH_3CH_2OH ✓ **Z** is $CH_3CH_2COOC_2H_5$ **OR** ethyl propanoate ✓	**3**	**Note**: an incorrect name CONs a correct structure **ALLOW** skeletal **OR** displayed formula throughout **DO NOT ALLOW** propanoic acid with wrong structure or incorrect molecular formula **DO NOT ALLOW** ethanol with wrong structure or incorrect molecular formula **DO NOT ALLOW** ethyl propanoate with wrong structure or incorrect molecular formula **ALLOW** ECF for identification of **Z** from incorrect **X** and **Y**. **DO NOT ALLOW** this ECF if name and structures of **X** or **Y** do **not** match
			Total	**10**	

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OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE

CHEMISTRY A

Chains, Energy and Resources

F322

Candidates answer on the question paper.

OCR Supplied Materials:
- *Data Sheet for Chemistry A* (inserted)

Other Materials Required:
- Scientific calculator

Thursday 20 January 2011
Afternoon

Duration: 1 hour 45 minutes

OCE/23212

F3222

Candidate forename		Candidate surname	

Centre number						Candidate number				

INSTRUCTIONS TO CANDIDATES

- The insert will be found in the centre of this document.
- Write your name, centre number and candidate number in the boxes above. Please write clearly and in capital letters.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully. Make sure you know what you have to do before starting your answer.
- Write your answer to each question in the space provided. If additional space is required, you should use the lined pages at the end of this booklet. The question number(s) must be clearly shown.
- Answer **all** the questions.
- Do **not** write in the bar codes.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **24** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 Crude oil is a source of alkanes.

(a) Fractional distillation is used to separate useful hydrocarbons found in crude oil.

Explain, in terms of intermolecular forces, how fractional distillation works.

.....

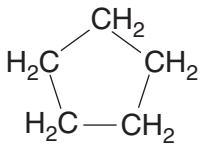
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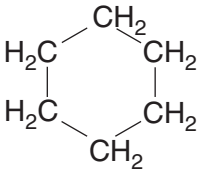
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..... **[2]**

(b) The petroleum industry processes straight-chained alkanes into cycloalkanes such as cyclopentane and cyclohexane.



cyclopentane



cyclohexane

(i) Deduce the general formula of a **cycloalkane**.

..... **[1]**

(ii) Construct the equation to show the formation of cyclohexane from hexane.

[1]

(iii) Suggest why the petroleum industry processes hexane into cyclohexane.

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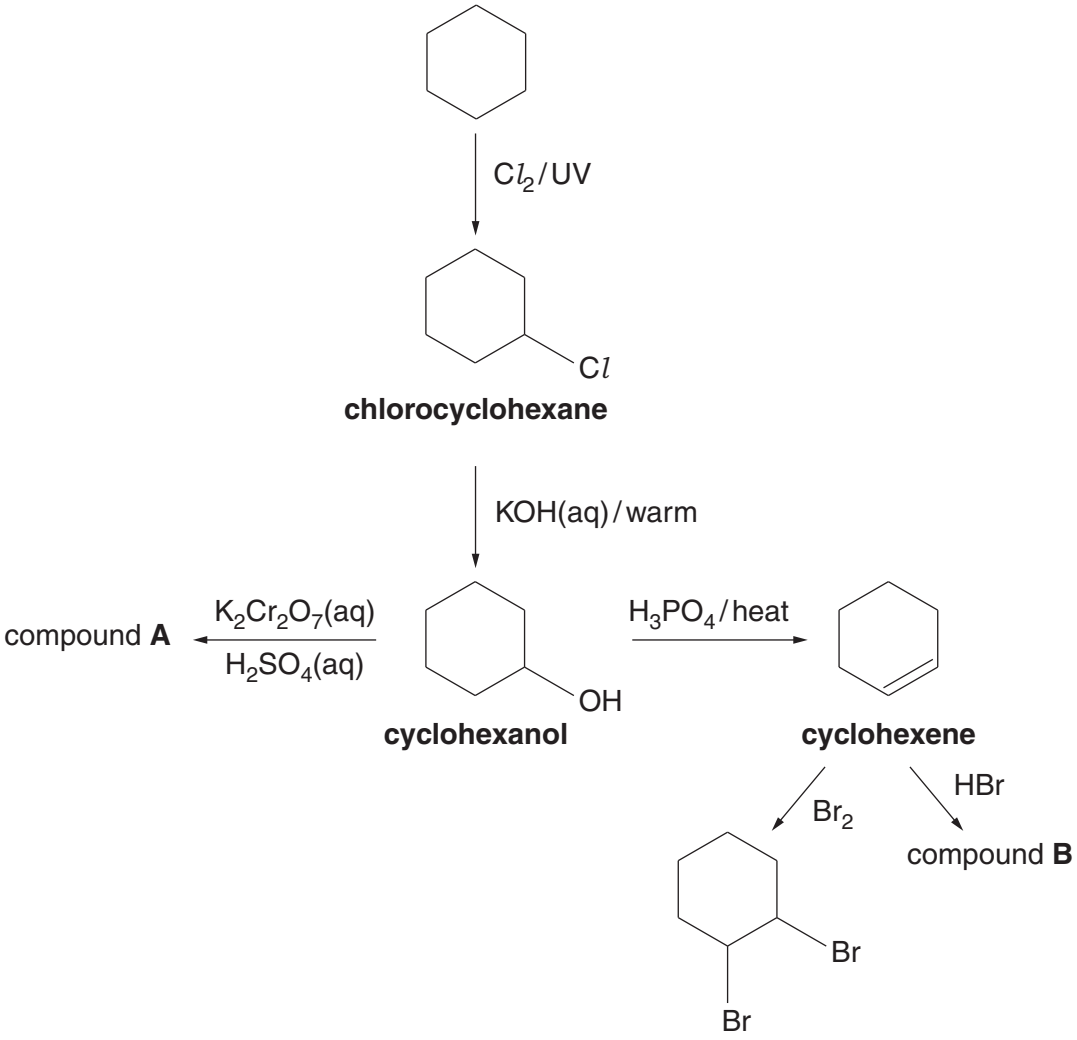
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..... **[1]**

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(c) The flowchart below shows some of the organic compounds that could be made starting from cyclohexane.



(i) Explain why cyclohexene is described as *unsaturated* and as a *hydrocarbon*.

.....

.....

.....

.....

..... **[2]**

(ii) The reaction between chlorine and cyclohexane is an example of radical substitution.

State **one** problem of using this reaction to prepare a sample of chlorocyclohexane.

.....

..... **[1]**

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(iii) The formation of cyclohexanol from chlorocyclohexane involves the reaction of a nucleophile, the hydroxide ion.

Suggest what feature of the hydroxide ion makes it able to act as a nucleophile.

.....

..... **[1]**

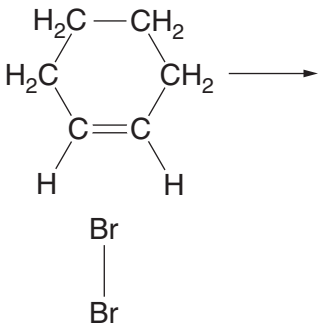
(iv) Using the flowchart, draw the structures of compound **A** and compound **B**.

compound **A**	compound **B**

[2]

(v) Describe, using the 'curly arrow model', the mechanism for the reaction between Br_2 and cyclohexene.

Show relevant dipoles and charges.



[4]

[Total: 15]

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2 Butyl ethanoate is an ester used as a flavouring.
This ester can be synthesised from butan-1-ol by two different processes.

Process 1 is a one-step process that involves a reversible reaction.

$$CH_3CH_2CH_2CH_2OH + CH_3COOH \rightleftharpoons CH_3COOCH_2CH_2CH_2CH_3 + H_2O$$

The percentage yield for **process 1** is 67.1%.
The atom economy for **process 1** is 86.6%.

Process 2 is a two-step process.

$$CH_3COOH + SOCl_2 \longrightarrow CH_3COCl + SO_2 + HCl$$

$$CH_3CH_2CH_2CH_2OH + CH_3COCl \longrightarrow CH_3COOCH_2CH_2CH_2CH_3 + HCl$$

The overall percentage yield for **process 2** is 93.3%.
The overall atom economy for **process 2** is 45.8%.

(a) Draw the skeletal formula for the ester butyl ethanoate.

[1]

(b) Show that the atom economy for **process 1** is 86.6%.

[2]

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(c) A research chemist investigates **process 1**.
She finds that 6.25 g of butan-1-ol forms 6.57 g of butyl ethanoate.

(i) Suggest the conditions needed for this reaction.

.....

.....

..... **[2]**

(ii) Show that the percentage yield of **process 1** is 67.1%.

[2]

(d) Explain why **process 2** has a high percentage yield but a low atom economy.

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..... **[2]**

(e) Suggest **two** reasons why butyl ethanoate is manufactured by **process 1** rather than by **process 2**.

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..... **[2]**

[Total: 11]

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3 Enthalpy changes of reaction can be determined by experiment or by using bond enthalpies.

(a) What is meant by the term *enthalpy change of reaction*?

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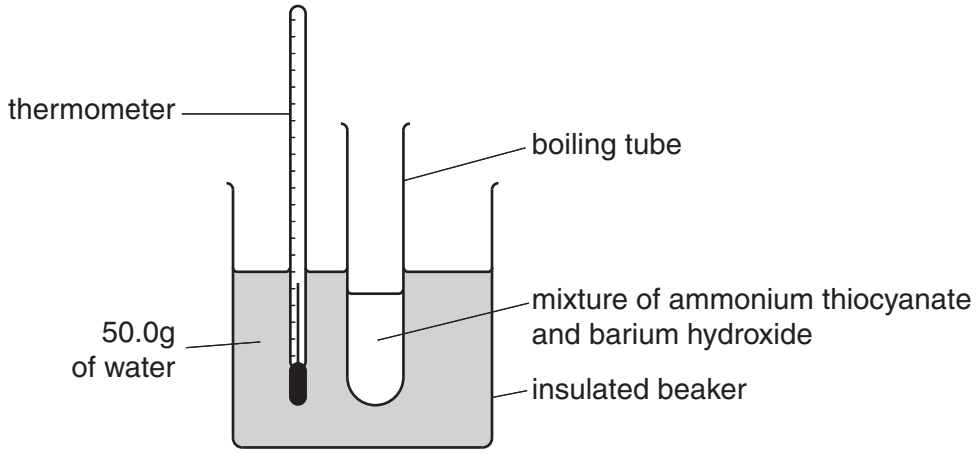
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..... **[2]**

(b) Solid ammonium thiocyanate, NH_4SCN, reacts with solid barium hydroxide, $Ba(OH)_2$, as shown in the equation below.

$$2NH_4SCN(s) + Ba(OH)_2(s) \longrightarrow Ba(SCN)_2(s) + 2H_2O(l) + 2NH_3(g)$$

A research chemist carries out an experiment to determine the enthalpy change of this reaction.



In the experiment, 15.22 g of NH_4SCN is reacted with a slight excess of $Ba(OH)_2$. The reaction absorbs energy, cooling the 50.0 g of water from 21.9 °C to 10.9 °C.

(i) Calculate the energy absorbed, in kJ, during this reaction.

The specific heat capacity of water = $4.2\,J\,g^{-1}\,K^{-1}$.

energy = ...kJ **[2]**

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(ii) Calculate the amount, in moles, of NH_4SCN used by the research chemist.

amount = ... mol **[1]**

(iii) Calculate the enthalpy change of reaction.

Include the sign in your answer.

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

ΔH_r = ...kJ mol^{-1} **[3]**

PART (c) CONTINUES ON PAGE 10

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(c) Standard enthalpy changes of reaction can also be determined using average bond enthalpies.

(i) What is meant by the term *average bond enthalpy*?

.....

.....

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..... **[2]**

Table 3.1 below shows some average bond enthalpies.

bond	average bond enthalpy / kJ mol^{-1}
C–H	+415
C–C	+345
C=C	+611

Table 3.1

(ii) Explain the bonding in a C=C double bond. Use the orbital overlap model.

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..... **[2]**

(iii) Suggest why the average bond enthalpy of a C=C bond is **not** twice the bond enthalpy of a C–C bond.

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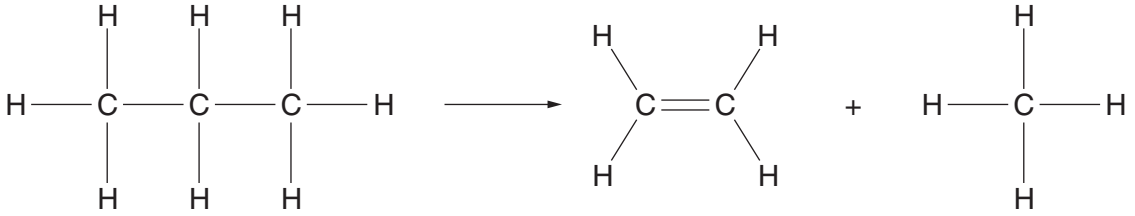
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..... **[1]**

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(iv) Propane can be cracked to make ethene.



Using the average bond enthalpies in **Table 3.1**, calculate the enthalpy change of this reaction.

ΔH_r = ...kJ mol^{-1} **[2]**

(v) The actual value for the enthalpy change of this reaction is +81 kJ mol^{-1}.

Suggest a reason why the actual value for the enthalpy change of this reaction is different from the calculated value.

.....

.....

..... **[1]**

[Total: 16]

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4 Catalysts speed up the rate of a reaction without being consumed by the overall reaction.

(a) Chlorine radicals in the stratosphere act as a catalyst for ozone depletion.

(i) Research chemists have proposed possible reaction mechanisms for ozone depletion. The equations below represent part of such a mechanism.

Complete the equations.

$Cl + O_3 \longrightarrow$ ..... + ...

ClO + ... $\longrightarrow$ ..... + O_2 **[2]**

(ii) Write an equation for the overall reaction in **(i)**.

..... **[1]**

(b) One of the catalysed reactions that takes place in a catalytic converter is shown below.

$$2CO(g) + 2NO(g) \longrightarrow N_2(g) + 2CO_2(g)$$

The catalyst used is platinum/rhodium attached to a ceramic surface.

Outline the stages that take place in a catalytic converter to allow CO to react with NO.

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..... **[4]**

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(c) Explain, using an enthalpy profile diagram and a Boltzmann distribution, how the presence of a catalyst increases the rate of reaction.

In your answer you should organise your answer and use the correct technical terms.

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.... **[7]**

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(d) Explain why many industrial manufacturing processes use catalysts.

Include in your answer ideas about sustainability, economics and pollution control.

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..... **[4]**

[Total: 18]

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5 This question is about halogenated hydrocarbons.

(a) Halogenoalkanes undergo nucleophilic substitution reactions with ammonia to form amines. Amines contain the $-NH_2$ functional group.

For example, 1-bromopropane reacts with ammonia to form propylamine, $CH_3CH_2CH_2NH_2$.

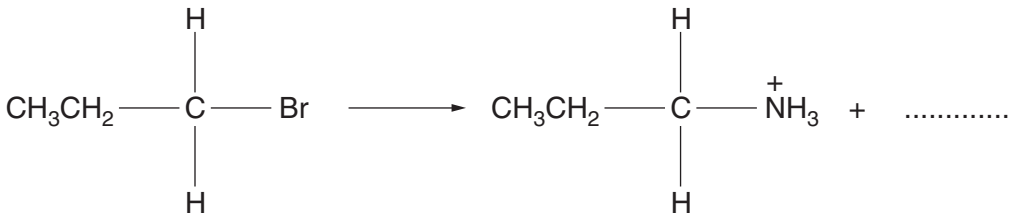
$$CH_3CH_2CH_2Br + 2NH_3 \longrightarrow CH_3CH_2CH_2NH_2 + NH_4Br$$

(i) Iodoethane is reacted with ammonia.

Write an equation for this reaction.

..... **[2]**

(ii) The first step in the mechanism of the reaction between $CH_3CH_2CH_2Br$ and NH_3 is shown below. It is incomplete.



Complete the mechanism.

Include relevant dipoles, lone pairs, curly arrows and the missing product. **[3]**

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(b) A student investigates the rate of hydrolysis of six halogenoalkanes.

The student mixes 5 cm^3 of ethanol with five drops of halogenoalkane. This mixture is warmed to 50 °C in a water bath. The student adds 5 cm^3 of aqueous silver nitrate, also heated to 50 °C, to the halogenoalkane. The time taken for a precipitate to form is recorded in a results table.

The student repeats the whole experiment at 60 °C instead of 50 °C.

halogenoalkane	**time taken for a precipitate to form / s**	
	at 50 °C	**at 60 °C**
$CH_3CH_2CH_2CH_2Cl$	243	121
$CH_3CH_2CH_2CH_2Br$	121	63
$CH_3CH_2CH_2CH_2I$	40	19
$CH_3CH_2CHBrCH_3$	89	42
$(CH_3)_2CHCH_2Br$	110	55
$(CH_3)_3CBr$	44	21

Describe and explain the factors that affect the rate of hydrolysis of halogenoalkanes.

Include ideas about
- the halogen in the halogenoalkanes
- the groups attached to the carbon of the carbon–halogen bond (the type of halogenoalkane)
- the temperature of the hydrolysis.

In your answer you should link the evidence with your explanation.

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..... **[7]**

(c) Poly(tetrafluoroethene), PTFE, and poly(chloroethene), PVC, are halogenated plastics.

(i) Write an equation, using displayed formulae, for the reaction to form PTFE from its monomer.

[3]

(ii) The combustion of waste polymers can be used for energy production.

What problem is caused by disposing of PTFE and PVC in this way?

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..... **[1]**

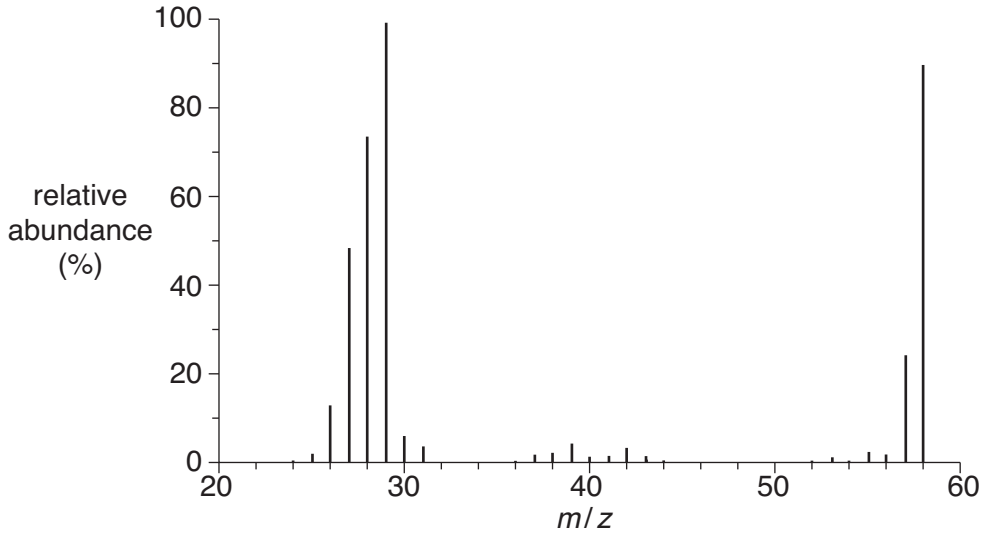
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6 Mass spectrometry and infrared spectroscopy are used in analysis.

(a) The mass spectrum of compound **Z** is shown below.



Compound **Z** has the molecular formula $C_3H_6O_x$.

(i) Using the mass spectrum, deduce the value of x in $C_3H_6O_x$.

Explain your answer.

.....

.....

.....

..... **[2]**

(ii) Suggest a possible structure for **Z**.

[1]

(iii) Suggest the formula of an ion that gives rise to the peak at $m/z = 29$ in this spectrum.

..... **[1]**

(b) A space probe has detected the presence of the element iron on the surface of the planet Mars.

Outline how a mass spectrum would show the presence of iron.

.....

.....

..... **[1]**

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(c) The space probe also detected different isotopes of sulfur on Mars.

(i) Outline how the mass spectrum would show how many different isotopes of sulfur were present on Mars.

.....

.....

..... **[1]**

(ii) The relative atomic mass of the sulfur found by the space probe was different from the relative atomic mass of sulfur on Earth.

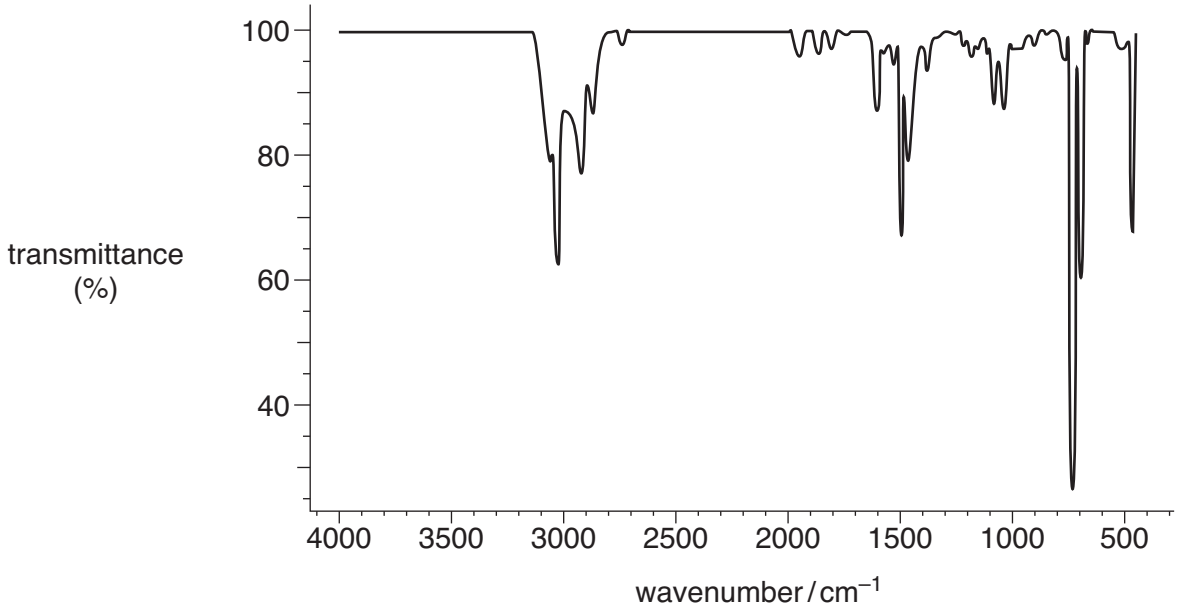
Suggest why.

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..... **[1]**

(d) An environmental chemist used infrared spectroscopy to monitor air pollution outside a petrol station. The infrared spectrum below was obtained from one of these pollutants.



What evidence is there in the spectrum that the pollutant may be a hydrocarbon rather than an alcohol or a carbonyl compound?

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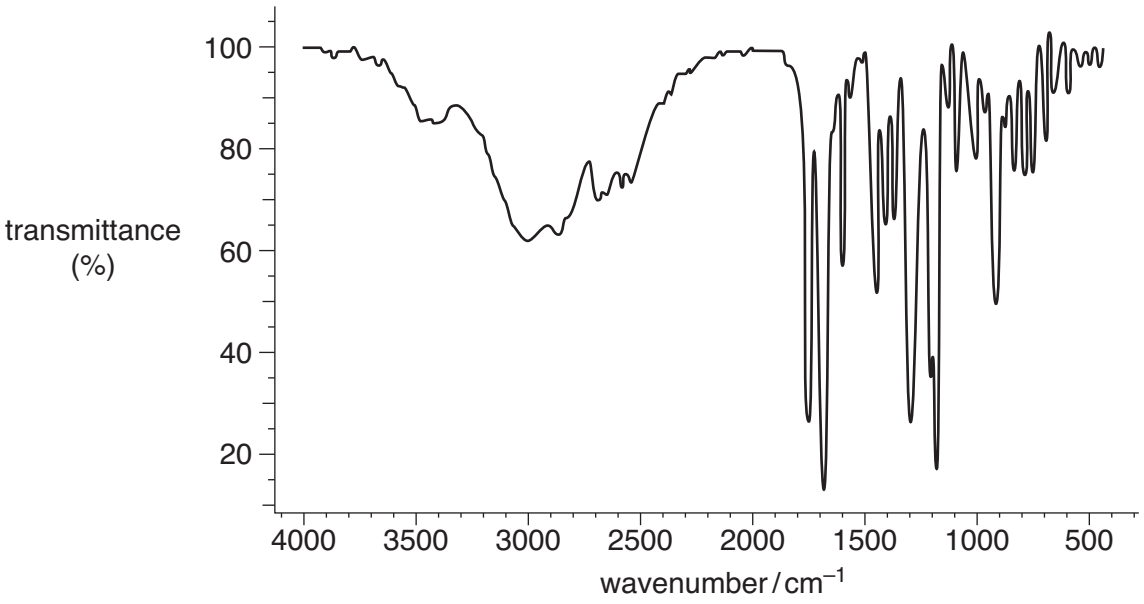
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..... **[1]**

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(e) The infrared spectrum of a drug is shown below.



Suggest, with reasons, possible functional group(s) present in the drug.

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..... **[2]**

[Total: 10]

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7 Biofuels such as bioethanol and biodiesel are increasingly being used as an alternative to fossil fuels to provide energy.

(a) Describe, with the aid of an equation, how bioethanol is manufactured by fermentation.

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..... **[3]**

(b) Biodiesel is obtained from plant oils. The manufacture involves several stages, all of which have a high energy requirement.

Biodiesel is often described as being 'carbon-neutral' because:

- plants convert atmospheric carbon dioxide into carbon compounds
- on burning biodiesel this carbon dioxide is returned to the atmosphere.

(i) Construct an equation to show the complete combustion of biodiesel.

Assume that the molecular formula of the biodiesel is $C_{15}H_{30}O_2$.

..... **[2]**

(ii) Suggest why biodiesel is **not** completely carbon-neutral.

.....

.....

..... **[1]**

(c) Many scientists suggest that society should use more biofuels rather than fossil fuels to provide energy. Other scientists are worried that biofuels will need large areas of land to grow suitable crops.

Suggest **disadvantages** or **advantages**, other than being carbon-neutral, of using more biofuels.

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..... **[3]**

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(d) Unsaturated compounds in plant oils can also be used to make margarine.

Describe how.

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..... **[2]**

(e) Part of the structure of an unsaturated compound in plant oils is shown below:

$$-CH_2CH_2CH=CHCH_2CH_2-$$

(i) Draw the displayed formula of the *Z* isomer of this part of the structure.

[1]

(ii) Explain why this part of the structure can have an *E* and a *Z* isomer.

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..... **[2]**

[Total: 14]

END OF QUESTION PAPER

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ADDITIONAL PAGE

If additional space is required, you should use the lined pages below. The question number(s) must be clearly shown.

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ADDITIONAL PAGE

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Unit **F322:** Chains, Energy and Resources

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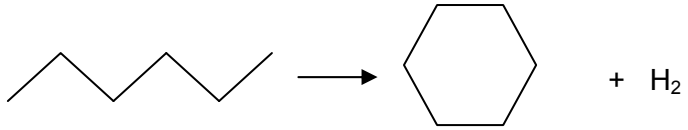
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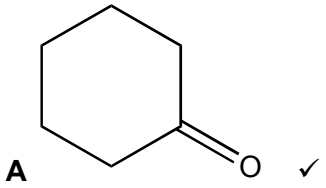
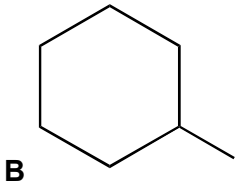
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Question			Answer	Mark	Guidance
1	(a)		(The hydrocarbons have) different boiling points ✓ The larger the molecules the stronger the van der Waals' forces ✓	2	**PLEASE READ COMMENT ON PAGE 3** **ALLOW** longer chains have higher boiling points **OR** separation based on boiling point **OR** condense at different temperatures **ALLOW** the larger molecular size more van der Waals' forces **OR** longer chains have stronger van der Waals' force **OR** the more electrons, the stronger the van der Waals' forces **OR** the more surface contact the more van der Waals' forces **IGNORE** surface area **ALLOW ORA** van der Waals must be seen at least once in correct context **ALLOW** any 'recognisable' spelling of van der Waals', use of VDW is **not** sufficient **DO NOT ALLOW** intermolecular force unless qualified as van der Waals' somewhere
	(b)	(i)	C_nH_{2n} ✓	1	
		(ii)	$C_6H_{14} \rightarrow C_6H_{12} + H_2$ ✓	1	**ALLOW** displayed, skeletal or structural formulae or combination in the equation  + H_2

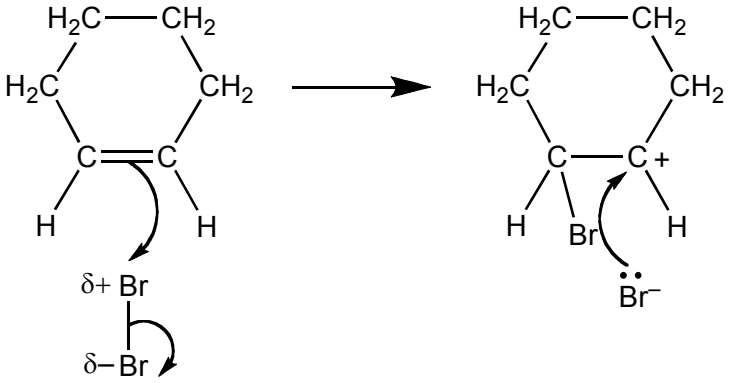
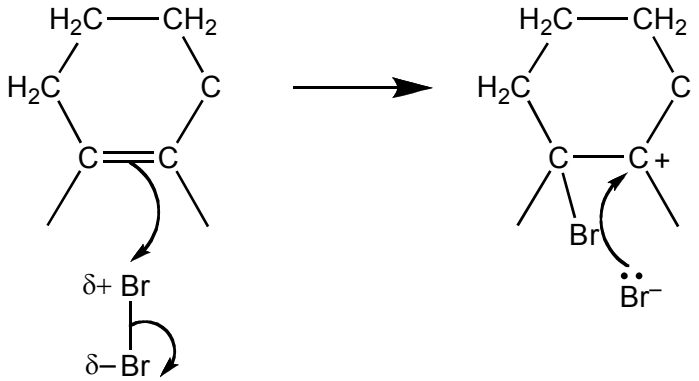
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Question			Answer	Mark	Guidance
1	(b)	(iii)	cyclohexane has more efficient combustion ✓	1	Assume comments refer to cyclohexane unless specified otherwise **ALLOW** cyclohexane allows smoother burning **OR** cyclohexane increases octane number **OR** cyclohexane reduces knocking **OR** cyclohexane is less likely to produce pre-ignition **OR** cyclohexane is a more efficient fuel **OR** cyclohexane burns better **OR** easier to burn **OR** cyclohexane combusts more easily **OR** improves combustion **DO NOT ALLOW** cyclohexane ignites more easily **ALLOW** ORA for hexane **IGNORE** cyclohexane increases volatility of fuel **IGNORE** cyclohexane has a lower boiling point cyclohexane is a better fuel on its own is **NOT** sufficient cyclohexane burns more cleanly on its own is **NOT** sufficient
	(c)	(i)	*Unsaturated:* Contains (at least one) **carbon–carbon** double bond **OR** C=C **OR** multiple carbon–carbon bond ✓ *hydrocarbon*: Contains hydrogen and carbon **only** ✓	2	**DO NOT ALLOW** just 'contains a double bond' **DO NOT ALLOW** 'a mixture of carbon and hydrogen' **OR** 'contains carbon and hydrogen' **OR** carbon and hydrogen molecules only
		(ii)	More than one hydrogen atom is substituted **OR** 'multisubstitution' (by chlorine) **OR** further substitution occurs ✓	1	**ALLOW** can get dichloro-compounds (**IGNORE** numbering) **ALLOW** reaction forms more than one **organic** product **DO NOT ALLOW** 'forms termination products' on its own Reaction is not specific **OR** reaction is difficult to control is **NOT** sufficient

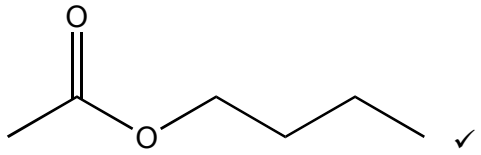
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Question			Answer	Mark	Guidance
1	(c)	(iii)	Contains a lone pair that can be donated ✓	1	**ALLOW** it can donate an electron pair 'lone pair' on its own is **NOT** sufficient
		(iv)	**A**  ✓ **B**  ✓	2	**ALLOW** skeletal, displayed or structural formulae for **A** and **B** **ALLOW** combination of types of formulae as long as it is unambiguous **DO NOT ALLOW** molecular formula For **A**, **ALLOW** carbonyl group on any carbon atom as it is still cyclohexanone For **B**, **ALLOW** bromine atom on any carbon atom as it is still bromocyclohexane

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Question			Answer	Mark	Guidance
1	(c)	(v)	Correct dipole on Br_2 / correct partial charges on Br_2 ✓ Correct curly arrow from double bond to attack bromine atom and correct curly arrow to show heterolytic fission of Br–Br ✓ Correct carbocation / carbonium ion drawn with the **full** positive charge shown: C^+ ✓ Correct curly arrow from lone pair of Br^- to correct carbon atom **OR** correct curly arrow from negative charge of Br^- to correct carbon atom ✓  	4	**ANNOTATE WITH TICKS AND CROSSES** Curly arrow must come from covalent bonds and not atoms **DO NOT ALLOW** $C^{\delta+}$ for charge on carbonium ion Curly arrow from bromide ion can come from the negative charge or the lone pair **DO NOT ALLOW** $Br^{\delta-}$ instead of Br^- Lone pair does not need to be shown on Br^- or used in mechanism Treat missing hydrogens on the CH_2 as a slip Treat missing hydrogens on the double bond or carbonium ion as a slip providing a bond is shown ie  **ALLOW** use of skeletal formulae in mechanism
			Total	**15**	

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Question			Answer	Mark	Guidance
2	(a)		 ✓	1	**IGNORE** any structural or displayed formula shown even if wrong (ie treat as rough working)
	(b)		(M_r of all reactants **or** M_r of all products) is 134.0 **OR** 134 **OR** (M_r of desired product) is 116.0 **OR** 116 ✓ Atom economy = 100 × $\frac{116.0}{134.0}$ ✓	2	Remember the marks are for the working out and not for the answer **IGNORE** lack of decimal place in answer **ALLOW** correct expressions to calculate the M_r or the atom economy eg Atom economy = 100 × $\frac{(6\times12)+(12\times1)+(2\times16)}{116+18}$ Award 2 marks for this expression: 100 × $\frac{116.0}{134.0}$ or similar expressions such as that above (subsumes 1st marking point)
	(c)	(i)	**acid** (catalyst) ✓ heat **OR** reflux ✓	2	**ALLOW** any acid, concentrated or dilute **ALLOW** 'high temperature' **OR** any temperature from 70 ºC to 120 ºC Warm is **not** sufficient **but ALLOW** warm to 80 ºC **IGNORE** pressure

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Question			Answer	Mark	Guidance
2	(c)	(ii)	maximum mass of ester than can be made is 9.7972973 (g) ✓ % yield = $\frac{6.57}{9.80} \times 100$ ✓ **ALLOW** 2 or more sig figs up to calculated value but rounded up correctly, ie **ALLOW** $\frac{6.57}{9.797} \times 100$ **OR** $\frac{6.57}{9.8} \times 100$	2	**ALLOW** moles of butan-1-ol = 0.08445946 **AND** moles of ester = 0.05663791 **OR** moles of butan-1-ol = $\frac{6.25}{74}$ **AND** moles of ester = $\frac{6.57}{116}$ for one mark **ALLOW** % yield = $\frac{0.05664}{0.08446} \times 100$ for one mark **ALLOW** 2 or more sig figs up to calculated value but rounded up correctly, ie $\frac{0.057}{0.084} \times 100$ **OR** $\frac{0.0566}{0.0845} \times 100$ Remember the marks are for the working out
	(d)		Link between yield **AND** explanation required: (high percentage) yield shows a high % conversion (of reactants into products) ✓ Link between atom economy **AND** explanation required: (low) atom economy shows a **lot** of waste (product) **OR** (low) atom economy shows not much desired product ✓	2	**ALLOW** percentage yield takes into account the practical difficulties of the process **OR** high % yield very little experimental loss of product **OR** high % yield because the process is not reversible **OR** most of reactants react to form products **DO NOT ALLOW** 'a lot of product made' There are waste products is **NOT** sufficient Reaction forms many products is **NOT** sufficient **ALLOW** undesired product(s) as alternative for waste **IGNORE** a lot of by-products but …….. **ALLOW** a lot of **waste** by-products **ALLOW** (low) atom economy shows a **lot** of HCl **OR** a lot of SO_2 is made **ALLOW** (low) atom economy shows not much ester / butyl ethanoate made

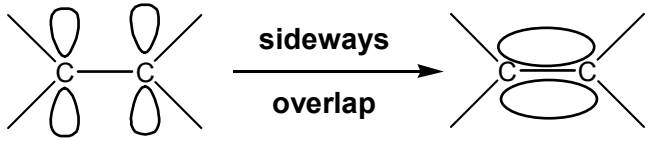
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Question			Answer	Mark	Guidance
2	(e)		**NOTE**: **Comparison** essential throughout, ie **higher**, **less**, etc. **ANY TWO FROM** Less waste (products) **OR** higher atom economy ✓ Less toxic reactants **OR** less toxic (waste) products **OR** less corrosive reactants **OR** less corrosive (waste) products **OR** less harmful reactants **OR** less harmful (waste) products **OR** less hazardous reactants **OR** less hazardous (waste) products ✓ Cheaper starting materials **OR** more readily available starting materials ✓ Fewer steps **OR** one step rather than two steps ✓	2	**ALLOW** more sustainable **ALLOW** poisonous for toxic **IGNORE** 'dangerous' 'Water is produced' is **not** sufficient Cheaper is **not** sufficient on its own **IGNORE** less energy **OR** easier to carry out **OR** reversible
			Total	**11**	

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Question			Answer	Mark	Guidance
3	(a)		(enthalpy change when) the number of moles of reactants ✓ as specified in the (balanced) equation react together ✓	 2	**ALLOW** (enthalpy change when) the number of moles of products **ALLOW** molar quantities / amounts Enthalpy change that occurs during a reaction is **not** sufficient
	(b)	(i)	$Q = 50 \times 4.2 \times 11.0$ ✓ 2.3 ✓	 2	**ALLOW** 2310 J ✓ 2300j **ALLOW** use 4.18 for *c* which gives 2.299 J **ALLOW** two marks for 2.31 / 2.310 with no working out **ALLOW ECF** ie *Q* divided by 1000 **IGNORE** any sign quoted
		(ii)	moles = 0.200 ✓	1	**ALLOW** 0.2 / 0.20
		(iii)	$\Delta H_r = 2 \times (2.3 \div 0.200)$ ✓ 23 ✓ + sign ✓	 3	**ALLOW ECF** from answer from 2 × [**(i)** ÷ answer to **(ii)**] Answer from 2 × [**(i)** ÷ answer to **(ii)**] must have only **2 sig figs** **+** sign **must** be written for 'sign mark' **+** sign is **independent** of answer **ALLOW** answers per mole of NH_4SCN $\Delta H_r = 2.3 \div 0.200$ for one mark 12 for the second mark + sign for the third mark **NOTE** If *c* = 4.18 has been used in **b(i)**, ΔH_r = +11 by **ECF** for calculation per mole of NH_4SCN

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Question			Answer	Mark	Guidance
3	(c)	(i)	(Enthalpy change) when one mole of bonds ✓ of (gaseous covalent) bonds is broken ✓	2	**ALLOW** energy required rather than enthalpy change **DO NOT ALLOW** energy released **DO NOT ALLOW** bonds formed
		(ii)	(Sideways) overlap of p orbitals ✓ Forming a π/pi bond ✓	2	**IGNORE** reference to σ bonds **IGNORE** incorrect diagram This diagram would score one mark – the π bond needs to be labelled for second mark  **2p orbitals**
		(iii)	π bond is weaker (than the σ bond) **OR** σ bond is stronger (than the π bond) ✓	1	There are two types of bonds is **not** sufficient **DO NOT ALLOW** π bond is stronger than the σ bond **ALLOW** the two bonds in double bond are not the same strength
		(iv)	bonds broken = (+)4010 **AND** bonds formed = (–)3931 Overall enthalpy change = +79 ✓	2	**ALLOW** Bonds broken = (+)690 **AND** bonds formed = (–)611✓ **ALLOW** 79 without a sign **ALLOW** –79 for one mark overall **ALLOW ECF** from incorrect enthalpy changes calculated for bonds broken and made

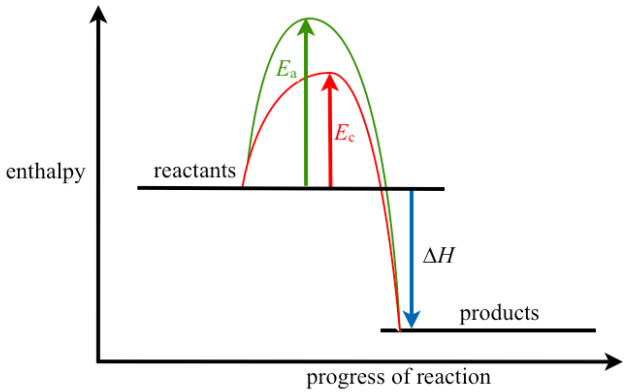
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Question			Answer	Mark	Guidance
3	(c)	(v)	Bond enthalpies may not be the same as the average bond enthalpy **OR** The idea that bonds have different strengths in different environments ✓	1	**DO NOT ALLOW** answers involving heat loss **OR** the use of non standard conditions Average bond enthalpies are used is **NOT** sufficient
			Total	**16**	

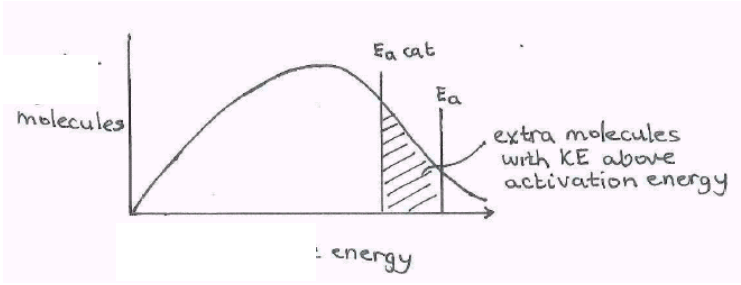
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Question			Answer	Mark	Guidance
4	(a)	(i)	$Cl + O_3 \rightarrow ClO + O_2$ ✓ $ClO + O \rightarrow Cl + O_2$ ✓	2	**ALLOW** any correct multiples **ALLOW** $ClO + O_3 \rightarrow 2O_2 + Cl$ **IGNORE** state symbols and dots
		(ii)	$O_3 + O \rightarrow 2O_2$ ✓	1	**ALLOW** any correct multiple **ALLOW** $2O_3 \rightarrow 3O_2$ **IGNORE** state symbols and dots
	(b)		Adsorption of reactants **OR** NO and CO attached to surface ✓ Bonds weaken in reactants ✓ Chemical reaction **OR** rearrangement of electrons ✓ Desorption ✓	4	**ANNOTATE WITH TICKS AND CROSSES** **ALLOW** CO and NO (weakly) bonded to surface **OR** reactants bond to surface **OR** CO and NO form temporary bonds with the catalyst **DO NOT ALLOW** absorption **ALLOW** bonds weaken in NO **OR** bonds weaken in CO **OR** activation energy is lowered **ALLOW** bonds break and new bonds made in product **OR** N_2 and CO_2 made **ALLOW** products leave the surface **OR** N_2 and CO_2 no longer bonded to surface **ALLOW** deadsorption **ALLOW** deabsorption if absorption given at start of answer

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Question			Answer	Mark	Guidance
4	(c)		one activation energy labelled on enthalpy profile diagram ✓ idea that activation energy is lowered ✓ catalyst has a different reaction pathway **OR** different reaction mechanism **OR** two curves drawn on profile ✓ **QWC** – correct diagram of reaction profile for endothermic or exothermic reaction with products and reactants at different heights – y axis labelled as energy or enthalpy ✓		**ANNOTATE WITH TICKS AND CROSSES** **ALLOW** double headed arrows on the activation energy label **ALLOW** vertical line with no arrows **DO NOT ALLOW** arrow just pointing downwards Be generous with respect to the position of the line and the maximum of the curve marks can be awarded via, reaction profile, in words or from Boltzmann **IGNORE** any enthalpy change label drawn  **IGNORE** missing progress of reaction

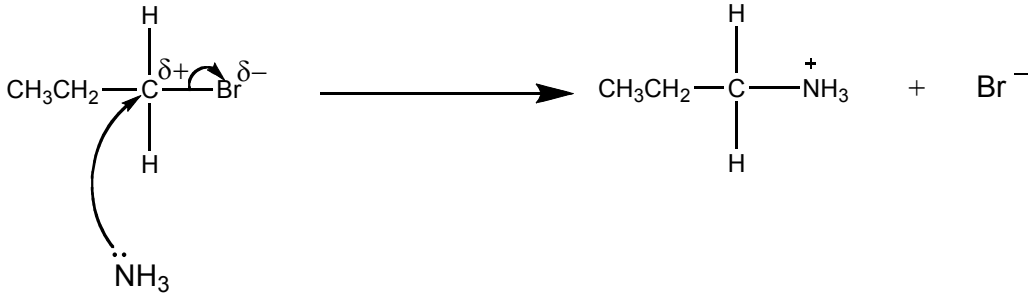
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Question			Answer	Mark	Guidance
4	(c)		Drawing of Boltzmann distribution **AND** axes labelled (number of) molecules and energy ✓		Boltzmann distribution - must start at origin and must not end up at 0 on *y*-axis ie must not touch *x*-axis. **DO NOT ALLOW** Boltzmann mark if two distributions are drawn one for non-catalysed and one for catalysed **ALLOW** particles instead of molecules **DO NOT ALLOW** atoms instead of particles 
			More molecules with energy above activation energy with a catalyst **OR** More molecules that overcome the activation energy ✓		**DO NOT ALLOW** more molecules have sufficient energy to react
			More effective collisions **OR** more successful collisions ✓	7	

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Question			Answer	Mark	Guidance
4	(d)		**ANY FOUR FROM** Enable reactions to occur with less waste **OR** enable reactions to take place with higher atom economy **OR** fewer undesired products ✓ Enable reactions to happen with less toxic solvents/reactants **OR** enable reactions to produce less toxic waste/side products ✓ Reactions can happen at room temperature **OR** reactions can happen at atmospheric pressure **OR** reactions can happen at a lower pressure **OR** reactions can happen at a lower temperature ✓ Saves energy (costs) ✓ Reduce carbon dioxide emissions **OR** reduces amount of fuel burnt **OR** reduces greenhouse gas emissions ✓ Enable reactions to occur with more specificity **OR** enable reactions to produce correct stereoisomer ✓	4	**ANNOTATE WITH TICKS AND CROSSES** **ALLOW** make less hazardous waste **ALLOW** corrosive, poisonous, harmful, hazardous as alternative to toxic **DO NOT ALLOW** does not harm the environment **IGNORE** dangerous **IGNORE** less expensive **IGNORE** reduces activation energy **IGNORE** less pollution
			Total	**18**	

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Question			Answer	Mark	Guidance
5	(a)	(i)	$CH_3CH_2I + 2NH_3 \rightarrow CH_3CH_2NH_2 + NH_4I$ correct reactants ✓ correct products and balanced ✓	2	**ALLOW** $CH_3CH_2I + NH_3 \rightarrow CH_3CH_2NH_2 + HI$ **ALLOW** $CH_3CH_2I + NH_3 \rightarrow CH_3CH_2NH_3I$
		(ii)	 Correct curly arrow from the lone pair of ammonia to the carbon atom of C–Br ✓ Correct dipole on $C^{\delta+}$–$Br^{\delta-}$ bond **and** curly arrow showing the heterolytic fission of the C–Br bond ✓ Correct missing product: Br^- ✓	3	Curly arrow **must** start from the lone pair on nitrogen and go to the carbon atom **DO NOT ALLOW** NH_3^- **OR** $^-NH_3$ **ALLOW** δ– on the N atom of NH_3 Curly arrow must start from the bond and go to the Br

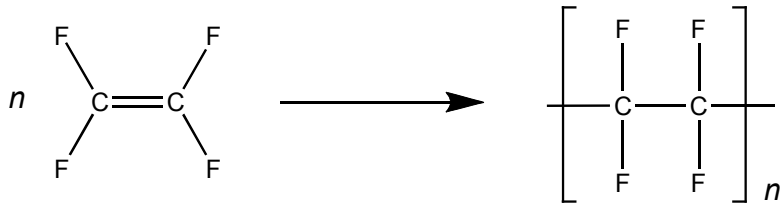
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Question			Answer	Mark	Guidance
5	(b)		***Effect of halogen in RX (3 marks)*** Any correct comparison of rate **OR** reaction time between at least **TWO** of chloroalkane, bromoalkane and iodoalkane ✓		**ANNOTATE WITH TICKS AND CROSSES** ***Examples*** chloroalkane reacts the slowest iodo compound reacts the fastest C–I bond is hydrolysed faster than C–Br C–Br has shorter reaction time than C–Cl **DO NOT ALLOW** references to halogens as elements: *ie* chlorine is less reactive than bromine than iodine **DO NOT ALLOW** chloride, bromide and iodide
			Bond strength **OR** bond enthalpy/bond energy mentioned anywhere as a factor (even if reasoning is incorrect) ✓		**ALLOW** this mark if mentioned within effect of halogen, branching **OR** temperature
			Any correct comparison of bond strength **OR** bond enthalpy/energy **OR** bond length **OR** ease of breaking of at least **TWO** of C–Cl, C–Br and C–I ✓		***Examples*** C–I bond is weaker than C–Br bond C–I bond is the weakest C–Cl bond is shorter than C–I bond C–Cl is strongest bond C–Br is broken more easily than C–Cl

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Question			Answer	Mark	Guidance
5	(b)		***Effect of branching (2 marks)*** Any correct comparison of rate or reaction time between at least **TWO** of the bromoalkanes ✓ A sensible comparison of bond strength **OR** bond enthalpy/energy **OR** bond length **OR** ease of breaking of the C–Br bond in at least **TWO** of the bromoalkanes ✓ ***Effect of temperature (2 marks)*** **QWC** – Use of 50 ºC and 60 ºC using information in the table to show that rate increases with temperature ✓ At higher temperature, particles have more energy **OR** At higher temperature, particles move faster ✓	7	Tertiary hydrolyses faster than secondary **OR** reaction time is less with tertiary than primary **OR** secondary hydrolyses faster than primary **OR** branched hydrolyses faster than straight chains **OR** primary hydrolyses the slowest **OR** tertiary hydrolyses the fastest **OR** when halogen on carbon 1 is hydrolysed slower than when halogen is on carbon 2 ✓ **DO NOT ALLOW** short chains hydrolyse faster than long chains ***Examples*** C—Hal is weaker in tertiary halogenoalkane **OR** C—Br bond is stronger when it is bonded to carbon 1 rather than carbon 2 **ALLOW** an explanation based on relative stabilities of tertiary, secondary and/or primary carbocations Answer must **quote evidence** from the table to get this mark Rate increases with temperature is **NOT** sufficient **ALLOW** more energy available to break the C–Hal bond **OR** more energy vibrates the C–Hal more so bond can break more easily **ALLOW** more successful collisions at higher temperature **ALLOW** more molecules exceed activation energy **ALLOW ORA**

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Question			Answer	Mark	Guidance
5	(c)	(i)			
			Correct monomer ✓		
			Correct polymer ✓		Polymer must have **side** links (do not have to cut through bracket) **ALLOW a correct section of the polymer with side links** **ALLOW ECF** from wrong monomer, including use of Fl for F
			Balanced equation – correct use of *n* in the equation ✓	3	*n* on LHS can be at any height to the left of formula **AND** *n* on the RHS must be a subscript (essentially below the side link) On the LHS, **DO NOT ALLOW** $(C_2F_4)_n$ (the *n* must be in front of the monomer) nC_2F_4 → $–(–C_2F_4–)_n–$ scores 1 mark for the correct use of *n*
		(ii)	(PVC) produces hydrogen chloride **OR** produces acidic gases **OR** (PVC) produces phosgene **OR** produces toxic gases **OR** (PVC) produces dioxins ✓	1	**ALLOW** produces poisonous gases **OR** produces gases that can kill **IGNORE** HF, Cl_2 and F_2 Makes a dangerous or harmful gas is **NOT** sufficient **IGNORE** CO and CO_2 are greenhouse gases **IGNORE** chlorine radicals and ozone depletion **IGNORE** causes pollution
			Total	**16**	

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Question			Answer	Mark	Guidance
6	(a)	(i)	molecular ion is 58 **OR** *m*/*z* is 58 ✓ (58 – (36 + 6) = 16) so *x* = 1 ✓	 2	**ALLOW** peak on the right is 58 **OR** parent ion is 58 **ALLOW** 58 shown on the spectrum eg the peak is labelled with a number **OR** there is a ring around the peak The M_r **OR** molecular mass is 58 with no evidence is **not** sufficient **ALLOW** ***x*** = 1 **ALLOW Z** is C_3H_6O
		(ii)	CH_3CH_2CHO **OR** CH_3COCH_3 ✓	1	**ALLOW** displayed or skeletal formulae **ALLOW** combination of types of formulae as long as it is unambiguous **ALLOW** other correct structures, eg enols, ethers and cyclic structures eg CH_2=$CHCH_2OH$ **OR** CH_2=$CHOCH_3$ **OR** structure of cyclopropanol **DO NOT ALLOW** a structure showing H with 2 bonds, ie OH—C
		(iii)	$C_2H_5^+$ ✓	1	**ALLOW** $CH_3CH_2^+$ **OR** COH^+ **OR** HCO^+ The positive sign **must** be included
	(b)		*m*/*z* values/peaks around 56 ✓	1	**ALLOW** peaks around 56 **OR** peak at 56 **OR** peaks around 55.8 **DO NOT ALLOW** peak at 55.8 **DO NOT ALLOW** peaks show the iron isotopes
	(c)	(i)	The **number** of *m*/*z* values (around 32) ✓	1	**ALLOW** the **number** of peaks **IGNORE** any reference to molecular ion peak
		(ii)	Different isotopic abundance ✓	1	**ALLOW** different percentage of each isotope **OR** different isotopes present **ALLOW** sulfur atoms have different number of neutrons **OR** different mass numbers

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Question			Answer	Mark	Guidance
6	(d)		No absorption between 1640 and 1750 cm^{-1} **AND** no (broad) absorption between 3200 and 3550 cm^{-1} ✓	1	**ALLOW** the only significant absorption is at around 2850 to 3100 cm^{-1} due to C–H bond **OR** There is an absorption around 2850 to 3100 cm^{-1} due to C–H bond **AND no** absorptions by C=O and O–H bonds **IGNORE** comments about C—O **ALLOW** any values within the wavenumber range
	(e)		C=O because of absorption between 1640 and 1750 cm^{-1} **AND** O–H (broad) absorption between 2500 to 3300 cm^{-1} ✓ Carboxyl group **OR** carboxylic acid ✓	2	**ALLOW** any values within the wavenumber range **ALLOW** O–H (broad) absorption between 2500 to 3500 cm^{-1} (from spectrum) **IGNORE** C–O **ALLOW** carboxylic acid if linked with O–H absorption **IGNORE** alcohol, ester, aldehyde, ketone or amide
			Total	**10**	

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Question			Answer	Mark	Guidance
7	(a)		**ANY THREE FROM** $C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$ ✓ Use of yeast/zymase at 25–45 ºC **OR** warm with yeast/zymase ✓ Anaerobic **OR** lack of oxygen ✓ (Separate bioethanol) by (fractional) distillation ✓	3	**IGNORE** state symbols **ALLOW** correct multiples **DO NOT ALLOW** yeast/zymase and heat **DO NOT ALLOW** yeast/zymase and reflux
	(b)	(i)	$C_{15}H_{30}O_2 + 21½O_2 \rightarrow 15CO_2 + 15H_2O$ ✓✓	2	**ALLOW** $\frac{43}{2}$ for 21½ **DO NOT ALLOW** [O] **ALLOW** one mark for correct products if equation is wrong
		(ii)	(Energy needed) for processing biofuel makes carbon dioxide ✓	1	**ALLOW** (energy needed) for transport makes carbon dioxide
	(c)		**ANY THREE FROM** Fossil fuels are finite resources **OR** biofuels are renewable ✓ Allows fossil fuels to be used as a feedstock for organic compounds ✓ Less food crops may be grown **OR** Land not used to grow food crops ✓ (rain) forests have to be cut down to provide land **OR** deforestation ✓ Shortage of fertile soils **OR** reduces fertility of soils ✓ No risk of large scale pollution from exploitation of fossil fuels ✓	3	**ANNOTATE WITH TICKS AND CROSSES** **ALLOW** fossil fuels are non-renewable **OR** plants are a renewable resource **OR** bio-fuels is (more) sustainable **OR** fossil fuels are not sustainable **ALLOW** decrease the need for fossil fuels Destroys habitats is **NOT** sufficient **IGNORE** comments about availability / fertilisers / pesticides

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Question			Answer	Mark	Guidance
7	(d)		React with hydrogen **OR** hydrogenation ✓ Nickel catalyst ✓	2	**IGNORE** reference to pressure and temperature
	(e)	(i)	Drawing of the *Z* isomer with the double bond shown in full ✓	1	Diagram must show a minimum of four carbon atoms and two hydrogen atoms and the correct orientation of the C=C double bond **ALLOW** minor slips with rest of structure eg missing atoms, bonds and subscripts
		(ii)	Double bond does not rotate **OR** restricted rotation of the double bond ✓ Each carbon atom of double bond is bonded to (two) different groups ✓	2	**ALLOW** π/pi bond does not rotate **IGNORE** 'bond does not move' **ALLOW** each carbon atom of double bond is bonded to (two) different atoms **OR** each carbon atom of double bond is bonded to a hydrogen and a carbon/different group **OR** each end of the π/pi-bond is bonded to different groups or atoms
			Total	**12**	

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THIS IS A NEW SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE
CHEMISTRY A
Chains, Energy and Resources

F322

Candidates answer on the Question Paper

OCR Supplied Materials:
- *Data Sheet for Chemistry A* (inserted)

Other Materials Required:
- Scientific calculator

Monday 7 June 2010
Morning

Duration: 1 hour 45 minutes

OCE/22979

F322

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided. Additional paper may be used if necessary but you must clearly show your Candidate Number, Centre Number and question number(s).

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **24** pages. Any blank pages are indicated.

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Answer **all** the questions.

1 The alkanes are an homologous series of hydrocarbons.
The table shows information about some straight chain alkanes.

alkane	molecular formula	boiling point / °C
methane	CH_4	–164
ethane	C_2H_6	–89
propane	C_3H_8	–42
butane	C_4H_{10}	–1

(a) (i) What is meant by an *homologous series*?

.....

.....

..... **[1]**

(ii) Explain why the boiling points increase down the alkane homologous series.

.....

.....

.....

.....

..... **[2]**

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(b) Alkynes are another homologous series of hydrocarbons.
The table gives the molecular formulae of the first five straight chain alkynes.

alkyne	molecular formula
ethyne	C_2H_2
propyne	C_3H_4
but-1-yne	C_4H_6
	C_5H_8
hex-1-yne	C_6H_{10}

(i) Suggest the name of a straight chain alkyne with the molecular formula C_5H_8.

..... **[1]**

(ii) Deduce the general formula for an alkyne.

..... **[1]**

(iii) The alkynes contain the C≡C functional group.

Suggest the displayed formula for propyne.

[1]

(iv) Hex-1-yne has many cyclic structural isomers.

Draw the skeletal structure of one of these cyclic structural isomers.

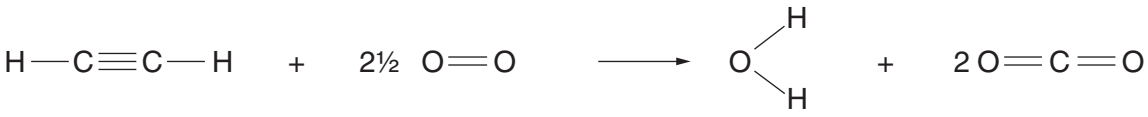
[1]

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(c) Ethyne is commonly called acetylene.
It is used in an oxy-acetylene flame which is hot enough to cut through steel.

Ethyne completely combusts as shown in the equation below.



Calculate the enthalpy change of combustion of ethyne using the average bond enthalpies in the table below.

bond	average bond enthalpy / kJ mol^{-1}
C–H	+415
C≡C	+837
O=O	+498
C=O	+805
O–H	+464

enthalpy change of combustion = ... kJ mol^{-1} **[3]**

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(d) Ethyne is formed when water reacts with calcium carbide, CaC_2.

$$CaC_2(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(s) + C_2H_2(g)$$

The standard enthalpy change of this reaction can be determined indirectly using standard enthalpy changes of formation.

(i) What is meant by the term *standard enthalpy change of formation*, $\Delta H_f^{\ominus}$?
You should state the standard conditions in your answer.

.....

.....

.....

..... **[3]**

(ii) Standard enthalpy changes of formation are shown in the table below.

substance	**standard enthalpy change of formation, $\Delta H_f^{\ominus}$ / kJ mol^{-1}**
$CaC_2(s)$	−60
$H_2O(l)$	–286
$Ca(OH)_2(s)$	–987
$C_2H_2(g)$	+227

Calculate the standard enthalpy change of the reaction:

$$CaC_2(s) + 2H_2O(l) \longrightarrow Ca(OH)_2(s) + C_2H_2(g)$$

standard enthalpy change of reaction = ... kJ mol^{-1} **[3]**

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(e) A factory makes ethyne gas from calcium carbide, CaC_2.
One of the waste products is calcium hydroxide.

$$CaC_2 + 2H_2O \longrightarrow Ca(OH)_2 + C_2H_2$$

Each day 1.00×10^6 grams of calcium carbide are used and 3.60×10^5 dm^3 of ethyne gas, measured at room temperature and pressure, is manufactured.

(i) Calculate the atom economy for this process using the relative formula masses in the table below.

compound	relative formula mass
CaC_2	64.1
H_2O	18.0
$Ca(OH)_2$	74.1
C_2H_2	26.0

atom economy = ... % **[2]**

(ii) Calculate the amount, in moles, of CaC_2 used each day.

amount of CaC_2 = ...mol **[1]**

(iii) Calculate the amount, in moles, of C_2H_2 made each day.

amount of C_2H_2 = ...mol **[1]**

(iv) Calculate the percentage yield of C_2H_2.

percentage yield = ... % **[1]**

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(v) Comment on the percentage yield and the atom economy of this process in terms of sustainability.

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..... **[2]**

[Total: 23]

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2 Petrol and diesel are both complex mixtures of hydrocarbons used as fuels in transport.

(a) Petrol contains some branched chain alkanes.
The number of carbon atoms per molecule varies between five and nine.

Name one branched chain alkane with between five and nine carbon atoms.

..... **[1]**

(b) When petrol burns in an internal combustion engine the exhaust gases contain CO_2, CO, NO, N_2, O_2, H_2O and unburnt hydrocarbons.

(i) What effect does the absorption of infrared radiation have on the bonds in CO_2 molecules in the atmosphere?

..... **[1]**

(ii) Why is CO present in the exhaust gases?

.....

..... **[1]**

(iii) Both NO and CO are atmospheric pollutants.

For each pollutant, describe one environmental problem.

NO .....

.....

CO .....

..... **[2]**

(c) Most cars are fitted with a catalytic converter which catalyses the exothermic reaction between NO and CO to form two less harmful gases.

(i) Name the two gases formed and write an equation for this reaction.

.....

.....

..... **[2]**

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(ii) NO and CO react very slowly without a catalyst.
The catalyst in a catalytic converter increases the rate of reaction.

Explain, using an enthalpy profile diagram and the Boltzmann distribution model, how the use of a catalyst increases the rate of reaction.

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..... **[7]**

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(d) Many lorries and some cars use diesel powered engines.
Biodiesel is being developed as a substitute for diesel from crude oil.

Biodiesel is a methyl ester of a long chain carboxylic acid.
The flow chart shows how it is produced.

plants → plant oil → long chain carboxylic acids → biodiesel

Describe the benefits and disadvantages of changing from diesel to biodiesel.

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..... **[3]**

[Total: 17]

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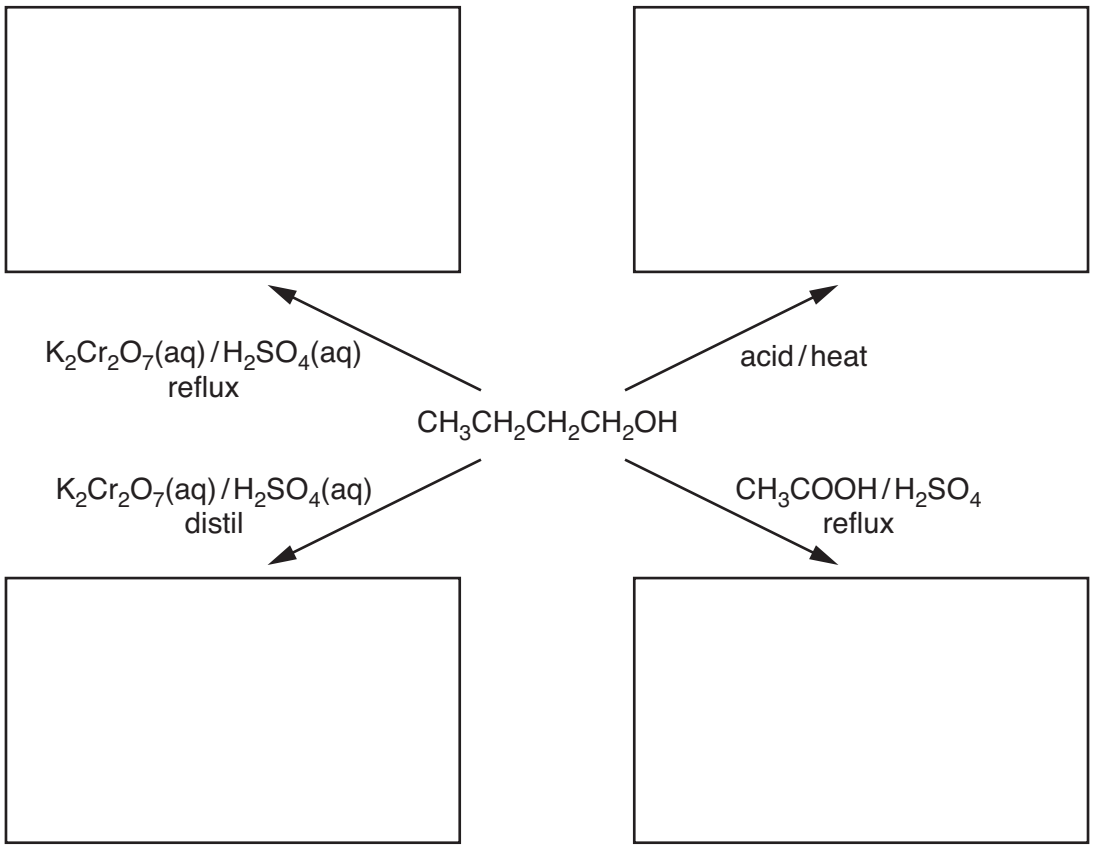
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3 Alcohols are used in the industrial production of many organic compounds.

(a) Complete the flowchart below to show the organic product formed in each of the reactions of butan-1-ol.



[4]

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(b) Butan-1-ol can be prepared by the alkaline hydrolysis of 1-iodobutane.

$$CH_3CH_2CH_2CH_2I + OH^- \longrightarrow CH_3CH_2CH_2CH_2OH + I^-$$

The reaction mixture is gently heated for 20 minutes.

(i) The curly arrow model is used in reaction mechanisms to show the movement of electron pairs.

Use the curly arrow model to outline the mechanism for the alkaline hydrolysis of 1-iodobutane.

In your answer, include the name of the mechanism, the type of bond fission and relevant dipoles.

name of mechanism .....

type of bond fission ..... **[5]**

(ii) A student decides to prepare butan-1-ol by the alkaline hydrolysis of 1-chlorobutane.

Suggest, with reasons, any change in the conditions from those used in the alkaline hydrolysis of 1-iodobutane.

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..... **[2]**

[Total: 11]

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4 Infrared spectroscopy and mass spectrometry are used to identify substances.

(a) Police use breathalysers to detect ethanol in the breath of drivers.

(i) Some modern breathalysers use infrared spectroscopy.

Suggest **two** characteristic infrared absorptions that could be used to identify the presence of ethanol vapour.

1 ..... cm^{-1}

2 ..... cm^{-1} **[2]**

(ii) Some older breathalysers used the redox reaction between acidified dichromate(VI) ions and ethanol. A colour change was seen which indicated the presence of ethanol in the breath.

What is the colour change that would be seen in this breathalyser if ethanol was present in the breath?

..... to ..... **[1]**

(iii) Give an equation to show the reaction between acidified dichromate(VI) ions and ethanol.

Use [O] to represent the acidified dichromate(VI) ions, the oxidising agent.

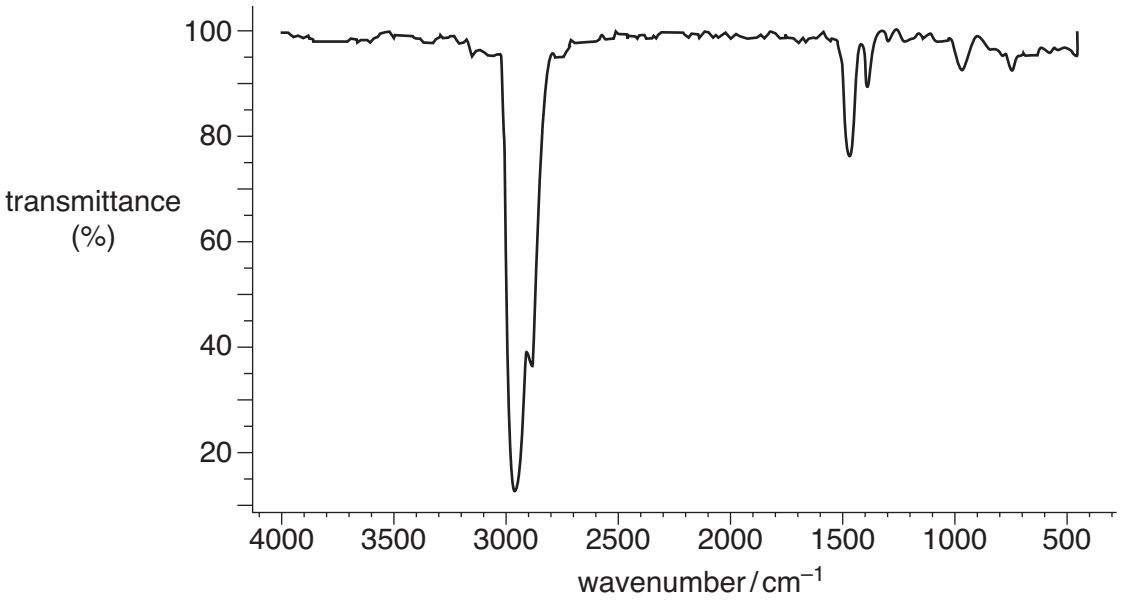
..... **[2]**

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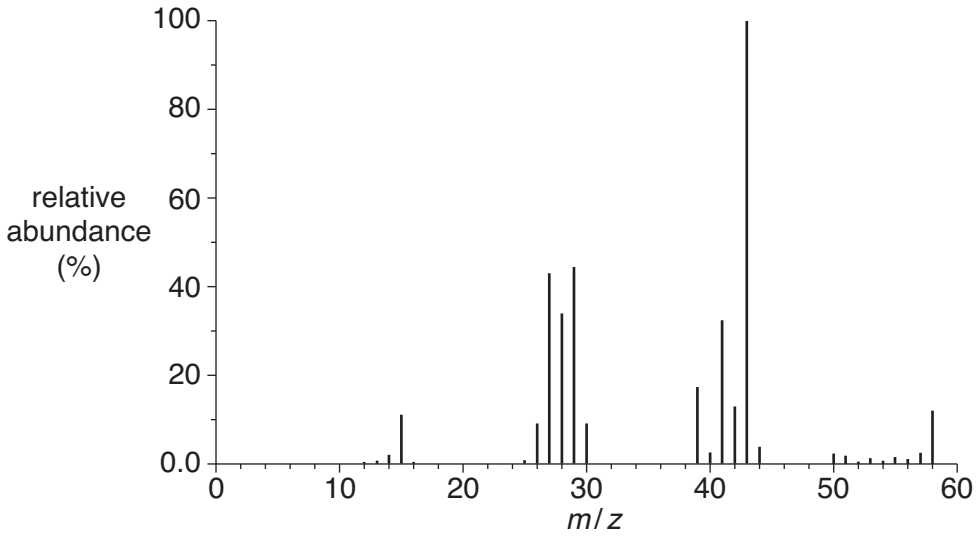
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(b) Infrared spectroscopy and mass spectrometry are used in the search for organic molecules in outer space.

Compound **A** has been analysed by infrared spectroscopy.



The mass spectrum of compound **A** is shown below.



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(i) A research chemist concludes that compound **A** is a hydrocarbon.

What evidence is there to support this conclusion?

.....

.....

.....

..... **[2]**

(ii) How does the mass spectrum confirm that compound **A** has a molecular formula of C_4H_{10}?

..... **[1]**

(iii) Draw the structural isomers of C_4H_{10}.

[1]

(iv) Identify the fragment ions that give rise to the following peaks in the mass spectrum.

m/z 15 is …….

m/z 29 is …….

m/z 43 is ……. **[3]**

(v) Use your answer to part **(iv)** to identify which of the isomers in part **(iii)** is compound **A**. Explain your reasoning.

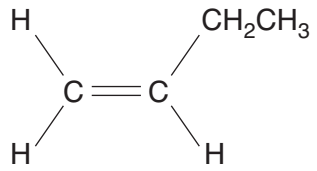
[1]

[Total: 13]

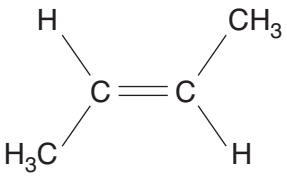
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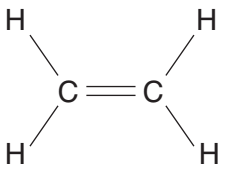
5 Alkenes **B**, **C**, **D**, **E** and **F** are shown below.



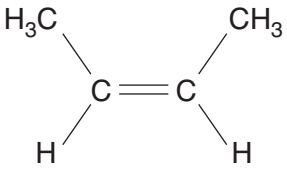
B



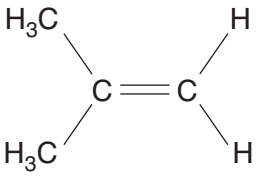
C



D



E



F

You will have to refer to these alkenes throughout the question.

(a) Describe, using the orbital overlap model, how the π-bond in alkene **D** is formed.

[2]

(b) Many alkenes show *E*/*Z* isomerism.

(i) Explain why *E*/*Z* isomerism is shown in some alkenes.

.....

.....

.....

..... **[2]**

(ii) Which **two** alkenes are a pair of *E*/*Z* isomers?

Choose from **B**, **C**, **D**, **E** and **F**.

…… and ……. **[1]**

(c) What is the main organic product of the reaction between alkene **D** and steam in the presence of a phosphoric acid catalyst?

..... **[1]**

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(d) Describe and explain the reaction of hydrogen bromide, HBr, with alkene **B** and with alkene **D**.

Include in your answer

- equations and structures of the products,
- why one of these alkenes gives just one product but the other gives more than one product,
- the reaction mechanism for the reaction with alkene **D** using the curly arrow model showing any relevant dipoles.



*Your answer needs to be clear and well organised using appropriate examples from the chemistry of alkenes **B** and **D**.*

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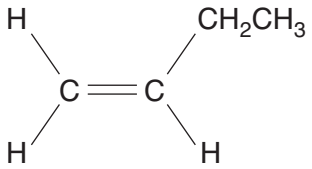
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..... **[9]**

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(e) Alkenes are a major source of polymers.
Alkene **B** can be polymerised.



B

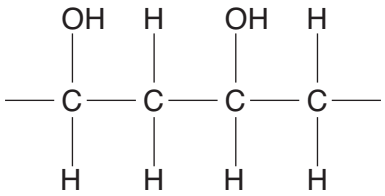
(i) Draw a section of the resultant polymer showing **two** repeat units.

[1]

(ii) Give the name of this polymer.

..... **[1]**

(f) Poly(ethenol) is a very unusual polymer because it can dissolve in water under certain conditions.



(i) Suggest why poly(ethenol) can dissolve in water.

.....

.....

..... **[2]**

(ii) Waste poly(ethenol) does not cause many environmental problems.
Other polymers such as poly(ethene), PVC or PTFE cause significant environmental problems.

Outline **two** ways in which waste polymers can be processed to reduce their environmental impact.

.....

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..... **[2]**

[Total: 21]

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6 An important reaction in the manufacture of nitric acid is the catalytic oxidation of ammonia.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -909 \text{ kJ mol}^{-1}$$

(a) Low pressures and low temperatures would give the maximum equilibrium yield of NO.

Explain why.

.....

.....

.....

..... **[2]**

(b) The actual conditions used in the catalytic oxidation of ammonia include 900 °C and an increase in pressure.

Suggest why these conditions are a compromise.

.....

.....

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.....

.....

..... **[3]**

(c) A factory makes 2.50×10^5 mol of NO a day.

(i) How much energy is released every day?

energy released = ... kJ **[1]**

(ii) Suggest how this energy can be used to reduce the cost of making NO.

.....

..... **[1]**

[Total: 7]

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7 Compound **G** was extracted from the leaves of a plant. A sample of **G** was analysed by a research chemist. A summary of the chemist's results is shown in the table.

type of analysis	**evidence**
infrared spectroscopy	absorptions at 1080, 1720 and a very broad absorption at 2900 cm^{-1}
percentage composition by mass	C, 26.7%; H, 2.22%; O, 71.1%
volumetric analysis	0.00105 mol of **G** has a mass of 0.0945 g

Use this information to suggest a possible structure for compound **G**.

In your answer, you should make clear how your explanation is linked to the evidence.

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..... **[8]**

[Total: 8]

END OF QUESTION PAPER

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GCE

Chemistry A

Advanced Subsidiary GCE **F322**

Chains, Energy and Resources

Mark Scheme for June 2010

Oxford Cambridge and RSA Examinations

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General advice to Assistant Examiners on the procedures to be used

YOU WILL BE REQUIRED TO UNDERTAKE 10 PRACTICE AND 10 STANDARDISATION SCRIPTS BEFORE STARTING TO MARK LIVE SCRIPTS.

1 The schedule of dates for the marking of this paper is very important. It is vital that you meet these requirements. If you experience problems then you must contact your Team Leader (Supervisor) without delay.

2 An element of professional judgement is required in the marking of any written paper. Candidates often do not use the exact words which appear in the detailed sheets which follow. If the science is correct and also answers the question then the mark(s) should normally be credited. If you are in doubt about the validity of any answer then consult your Team Leader (Supervisor) by phone, the messaging system within SCORIS or e-mail.

3 Correct answers to calculations always gain full credit even if no working is shown. (The 'Show your working' is to help candidates, who may then gain partial credit even if their final answer is not correct.)

4 Some questions may have a 'Level of Response' mark scheme. Any details about these will be in the Additional Guidance.

5 If an answer has been crossed out and no alternative answer has been written then mark the answer crossed out.

6 In addition to the award of 0 marks, there is a NR (No Response) option on SCORIS.

Award 0 marks

- if there is any attempt that earns no credit (including copying out the question or some crossed out working)

Award NR (No Response)

- if there is nothing written at all in the answer space
  OR
- if there is any comment which does not in any way relate to the question being asked (e.g. 'can't do', 'don't know')
  OR
- if there is any sort of mark which is not an attempt at the question (e.g. a dash, a question mark)

7 Abbreviations, annotations and conventions used in the detailed Mark Scheme.

/ = alternative and acceptable answers for the same marking point
not = answers which are not worthy of credit
reject = answers which are not worthy of credit
ignore = statements which are irrelevant
allow = answers that can be accepted
( ) = words which are not essential to gain credit
__ = underlined words must be present in answer to score a mark
ECF = error carried forward
AW = alternative wording
ora = or reverse argument

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8 Annotations: the following annotations are available on SCORIS.

✓	=	correct response
✗	=	incorrect response
bod	=	benefit of the doubt
nbod	=	benefit of the doubt **not** given
ECF	=	error carried forward
^	=	information omitted
I	=	ignore
R	=	reject

Highlighting is also available to highlight any particular points on the script.

The following questions should be annotated with ticks to show where marks have been awarded in the body of the text:
2(c)(ii), 3(b)(i), 5(d), 6(b) and **7**

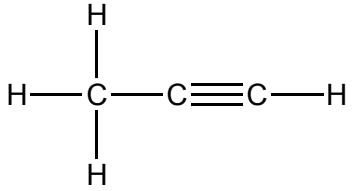
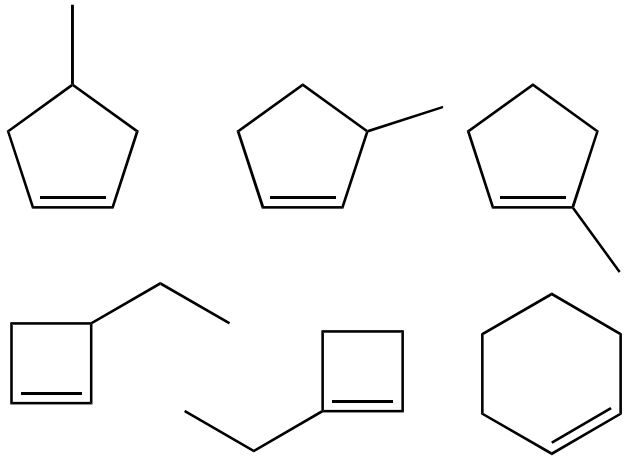
9 The Comments box
The comments box will be used by your PE to explain their marking of the practice scripts for your information. Please refer to these comments when checking your practice scripts. You should only type in the comments box yourself when you have an additional object of the type described in Appendix B of the Handbook for Assistant Examiners and Subject Markers.
Please do not use the comments box for any other reason.
Any questions or comments you have for your Team Leader should be communicated by phone, SCORIS messaging system or e-mail.

10 Please send a brief report on the performance of the candidates to your Team Leader (Supervisor) by the end of the marking period. The Assistant Examiner's Report Form (AERF) can be found on the Cambridge Assessment Support Portal. This should contain notes on particular strengths displayed, as well as common errors or weaknesses. Constructive criticisms of the question paper/mark scheme are also appreciated.

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Question			Expected Answers	Marks	Additional Guidance
1	a	i	Series having same functional group and a general formula ✓	1	**ALLOW** same functional group and members vary by CH_2 **ALLOW** organic compounds with the same functional group that differ in length of their hydrocarbon chain
		ii	More surface contact **OR** bigger molecules ✓ More van der Waals' forces ✓	2	**BOTH answers need to be comparisons** **ALLOW** higher relative formula mass **OR** has more electrons **OR** longer chain length **OR** more carbon atoms **IGNORE** surface area / bigger compounds **ALLOW** stronger van der Waals' forces / stronger induced dipoles VDW forces is not sufficient More intermolecular forces is **not** sufficient **DO NOT ALLOW** breaking bonds within the chain / breaking covalent bonds **IGNORE** reference to bonds if not linked to covalent bonds
	b	i	Pent-1-yne **OR** pent-2-yne ✓	1	**ALLOW** pentyne Look for answer in the table if not on answer line but answer line takes precedence
		ii	C_nH_{2n-2} ✓	1	**ALLOW** $C_nH_{2(n-1)}$

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Question			Expected Answers	Marks	Additional Guidance
1	b	iii	Correct displayed formula ✓	1	
		iv	Correct skeletal formula of cyclic hydrocarbon with formula C_6H_{10} ✓	1	Examples of correct skeletal formulae include 
	c		Energy required to break bonds = (+) 2912 ✓ Energy released to make bonds = (–)4148 ✓ Enthalpy of combustion = –1236 ✓	3	**ALLOW** full marks for correct answer with no working out **ALLOW** (2 × 415) + (837) + (2.5 × 498) **ALLOW** (4 × –805) + (2 × –464) **OR** (4 × 805) + (2 × 464) **ALLOW** ECF for calculation of enthalpy of combustion **ALLOW** 2 marks for +1236 with no working out

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Question			Expected Answers	Marks	Additional Guidance
1	d	i	(Enthalpy change) when one mole of a compound ✓ is made from its elements (in their standard states) ✓ (Standard conditions are) 298 K and 100 kPa ✓	3	**IGNORE** energy required / energy released **ALLOW** (energy change) when one mole of a substance **DO NOT ALLOW** enthalpy change for one mole of products **ALLOW** 1 atmosphere pressure / 101 kPa / 10^5 Pa / 1.01×10^5 Nm^{-2} / 1000 millibars / 25 °C / any stated temperature in words **IGNORE** 1 mol dm^{-3} for solutions
		ii	From energy cycle Enthalpy change to get elements = −(−60) – (2 −286) / (+) 632 ✓ Enthalpy change from elements = −987 + (+227) / (−)760 ✓ Enthalpy change = −128 ✓	3	**ALLOW** full marks for −128 with no working out **ALLOW** ECF from errors in calculation **ALLOW two** marks for answer of −414 / +128 / –1392 / +1392 **ALLOW one** mark for answer of +414
	e	i	$\frac{26.0}{\mathbf{100.1}} \times 100$ ✓ 26.0% ✓	2	First mark for 100.1 **OR** (64.1 + 36.0) **OR** (74.1 + 26.0) at **bottom** of fraction with or without × 100 **ALLOW full** marks for 26.0 or 26% with no working out **ALLOW** from two significant figures up to calculator value **ALLOW** 25.97 / 26% **NO ECF** for this part from incorrect numbers in first expression

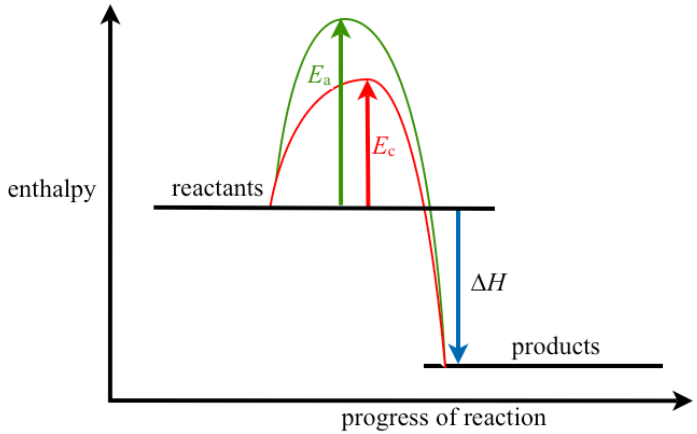
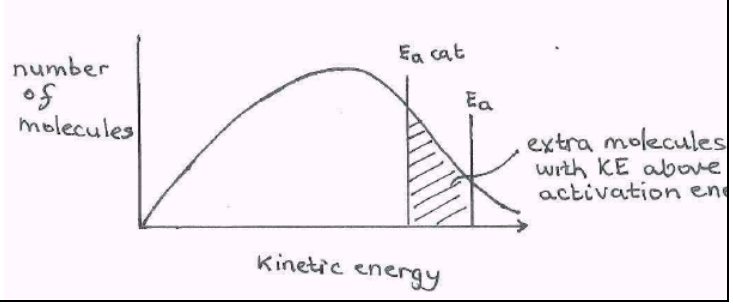
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Question			Expected Answers	Marks	Additional Guidance
1	e	ii	1.56×10^4 **OR** 15600 **OR** 15601 ✓	1	**ALLOW** calculator value of 15600.62402 and any rounded value to a minimum of three significant figures
		iii	1.5×10^4 **OR** 15000 ✓	1	**ALLOW** 1.50×10^4 etc.
		iv	96.2 ✓	1	**ALLOW** ECF from **(iii)** ÷ **(ii)** **ALLOW** calculator value 96.1538461 and any rounded value to a minimum of two significant figures **ALLOW** 96.14768284 if 15601 is used **ALLOW** any value between 88 to 89 if answer to **(iii)** was calculated by dividing by 26
		v	**Any two from:** Low atom economy gives a poor sustainability **OR** low atom economy means lots of waste ✓ A use for the aqueous calcium hydroxide needs to be developed to increase atom economy ✓ Alternative process needs to be developed with high atom economy ✓	2	**ANNOTATE WITH TICKS AND CROSSES** **IGNORE** comments about percentage yield **ALLOW** ECF from **(i)** e.g. high atom economy will have good sustainability **ALLOW** find a use for the waste to increase atom economy
			Total	**23**	

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Question			Expected Answers	Marks	Additional Guidance
2	a	i	Branched chain alkane of formula C_5H_{12} to C_9H_{20} e.g. 2-methylpentane, 3-methyloctane ✓	1	Must have position number **but ALLOW** methylbutane **DO NOT ALLOW** 1-methylpentane or 2-ethylpentane etc **DO NOT ALLOW** incorrect nomenclature e.g. 2-**methy**pentane etc
	b	i	Vibrate (more) ✓	1	**ALLOW** bend / stretch / oscillate **IGNORE** rotate **NOT** break / molecules vibrate
		ii	Incomplete combustion ✓	1	**ALLOW** not enough oxygen
		iii	NO for photochemical smog **OR low level** ozone ✓ CO is toxic ✓	2	**ALLOW** NO can (eventually) cause acid rain **OR** can result in respiratory irritation **OR** can (eventually) depletes high level ozone **OR** depletes ozone layer **IGNORE** greenhouse gas **ALLOW** poisonous **OR** kills **OR** lethal **ALLOW** CO reduces the capacity of blood to carry oxygen Oxygen combines with haemoglobin is insufficient **IGNORE** CO is harmful / suffocates / greenhouse gas
	c	i	Makes nitrogen **AND** carbon dioxide ✓ $2CO + 2NO \rightarrow N_2 + 2CO_2$ ✓	2	 **ALLOW** any correct multiples **IGNORE** state symbols

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Question			Expected Answers	Marks	Additional Guidance
2	c	ii	One activation energy correctly labelled on enthalpy profile diagram ✓ Idea that activation energy is lowered ✓ Catalyst has a different reaction pathway **OR** different reaction mechanism **OR** two curves drawn on profile ✓ Correct diagram of reaction profile for exothermic reaction with product below reactants with y axis as enthalpy or energy and ΔH label – arrow should go down. Ignore a small gap between at either end of ΔH line ✓ Drawing of Boltzmann distribution – axes labelled number of molecules and energy ✓ More molecules with energy above activation energy with a catalyst ✓ More effective collisions **OR** more successful collisions ✓	7	**ANNOTATE WITH TICKS AND CROSSES** With the line/arrow no more than 1 mm from top of curve or reactant line – arrow can be double headed for activation energy **ALLOW** vertical line with no arrows **DO NOT ALLOW** arrow just pointing downwards Marks can be awarded via, reaction profile, in words or from Boltzmann  Boltzmann distribution – must start at origin and must not end up at 0 on *y*-axis i.e. must not touch *x*-axis 

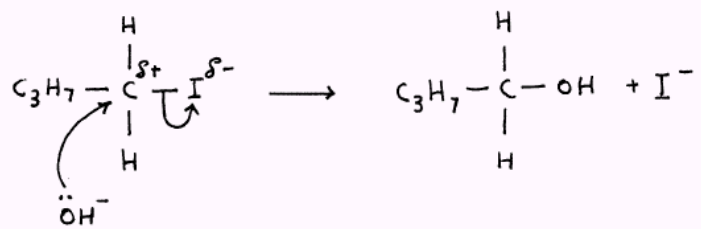
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Question			Expected Answers	Marks	Additional Guidance
2	d		**Any two benefits from**:	3	**ANNOTATE WITH TICKS AND CROSSES**
			Save crude oil **OR** no risk of large scale pollution from exploitation of crude oil ✓		**ALLOW** decrease the need for fossil fuels
			Biodiesel is renewable **OR** diesel is non-renewable ✓		**ALLOW** plants are a renewable resource / crude oil non-renewable resource / biodiesel is more sustainable / diesel is not sustainable
			Use of biodiesel is (more) carbon-neutral **OR** plants take up the carbon dioxide released during combustion ✓		**ALLOW** lower carbon footprint **IGNORE** can be used by diesel powered cars with or without any conversion
			and one disadvantage		
			Land not used to grow food crops **OR** (rain)forests have to be cut down to provide land **OR** food prices may rise because less is grown ✓		**IGNORE** comments about availability / fertilisers / pesticides Destroys habitats is not sufficient
			Total	**17**	

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Question			Expected Answers	Marks	Additional Guidance
3	a		Answers clockwise from top left $CH_3CH_2CH_2COOH$ ✓ $CH_3CH_2CHCH_2$ ✓ $CH_3COOCH_2CH_2CH_2CH_3$ ✓ $CH_3CH_2CH_2CHO$ ✓	4	**ALLOW** skeletal formula **ALLOW** butanoic acid **ALLOW** but-1-ene **ALLOW** butyl ethanoate **ALLOW** butanal If name and structure given both must be correct If C_3H_7 used instead of $CH_3CH_2CH_2$ penalise once and then apply ECF If wrong carbon skeleton used then penalise once then apply ECF If a hydrogen is missing then penalise once

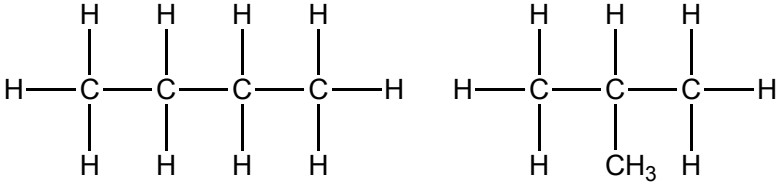
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Question			Expected Answers	Marks	Additional Guidance
3	b	i	Nucleophilic substitution ✓ Heterolytic ✓ Dipole shown on C–I bond, $C^{\delta+}$ and $I^{\delta-}$ ✓ Curly arrow from OH^- to carbon atom of C–I bond ✓ Curly arrow from C–I bond to the iodine atom ✓	5	**ANNOTATE WITH TICKS AND CROSSES** **DO NOT ALLOW** fish hooks No need to show lone pair on OH^- or I^- Curly arrow must come from the negative sign or lone pair on the oxygen of the hydroxide ion  **ALLOW S_N1 mechanism** dipole shown on C–I bond, $C^{\delta+}$ and $I^{\delta-}$ ✓ curly arrow from C–I bond to the iodine atom ✓ curly arrow from OH^- to correct carbonium ion ✓
		ii	Use reflux **OR** heat for more than 20 minutes ✓ C–C*l* stronger bond (than C–I bond) **OR** C–C*l* shorter bond (than C–I bond) **OR** C–C*l* bond is harder to break **OR** needs more energy to break C–C*l* bond **OR** ora ✓	2	**ALLOW** heat stronger **OR** heat for longer **OR** heat at a higher temperature **OR** more heat Answer must refer to the C–C*l* bond or C–I bonds
			Total	**11**	

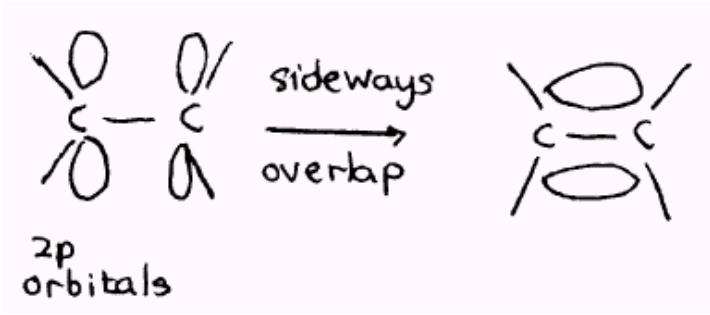
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Question			Expected Answers	Marks	Additional Guidance
4	a	i	**Any two from:** Any value between 1000–1300 ✓ Any value between 2850–3100 ✓ Any value between 3200–3550 ✓	2	
		ii	Orange to green or blue ✓	1	
		iii	$CH_3CH_2OH + [O] \rightarrow CH_3CHO + H_2O$ **OR** $CH_3CH_2OH + 2[O] \rightarrow CH_3COOH + H_2O$ Correct organic product ✓ Balanced equation ✓	2	**IGNORE** any state symbols **ALLOW** CH_3COH in equation but not for the structure **ALLOW** equations with molecular formulae but not the product mark
	b	i	Absorption around 2850–3100 (cm^{-1}) so contains C—H bonds ✓ No other **important** absorptions present / no other **characteristic** absorptions ✓	2	Answer must have a reference to infrared spectrum i.e. use of cm^{-1} or data from the infrared spectrum 'Has no other peaks so no functional groups present' is **not** sufficient **BUT** There are no peaks due to functional groups is sufficient **ALLOW** peaks instead of absorption **ALLOW** no absorption due to C=O and O–H / no absorption due to carbonyl and hydroxyl
		ii	Peak furthest to right hand side is 58 / molecular ion peak is 58 / peak at highest mass ✓	1	**ALLOW** peak at *m*/*z* 58 marked on the mass spectrum / M peak is 58 / peak at 58 linked to the molecular mass **DO NOT ALLOW** highest peak but **ALLOW** 58 is the highest peak

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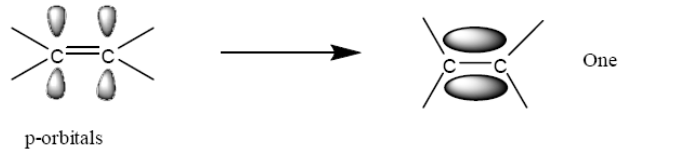
Question			Expected Answers	Marks	Additional Guidance
4	b	iii	 **BOTH** isomers correct ✓	1	If three structures are drawn then do not award mark **ALLOW** skeletal formulae / structural formulae **IGNORE** incorrect names
		iv	CH_3^+ ✓ $C_2H_5^+$ ✓ $C_3H_7^+$ / $CH_3CH_2CH_2^+$ / $(CH_3)_2CH^+$ ✓	3	Essentially marks are allocated as positive ions ✓ Formula of two fragments correct (ignore charge) ✓ **BUT** formulae of all three fragments correct (ignore charge) ✓✓
		v	$CH_3CH_2CH_2CH_3$ because there is a peak at m/z = 29 ✓	1	**ALLOW** name, displayed or skeletal structure **ALLOW** butane because there is a C_2H_5 fragment **ALLOW** butane because it gives all three fragments listed in **(iv)**
			Total	**13**	

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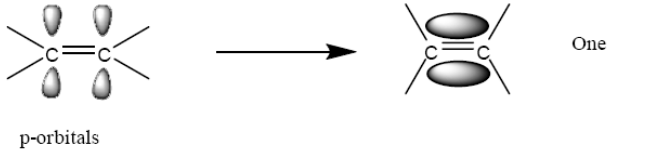
Question			Expected Answers	Marks	Additional Guidance
5	a		**Sideways** overlap of two p orbitals on each carbon atom ✓ forms π-orbital or π-bond above and below plane of molecule ✓	2	Answers can be awarded from a labelled diagram see additional page with typical diagrams you might see  Drawings with a double bond drawn can score a maximum of one mark Drawing above with no labels scores one mark

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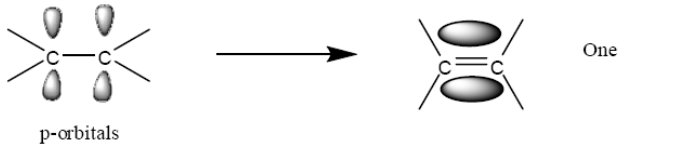
Each of the following diagrams is worth one mark. The words p-orbitals must be present to score the mark



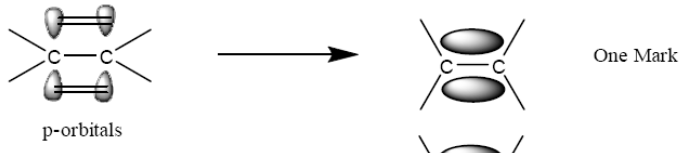
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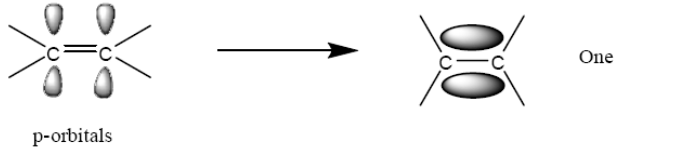


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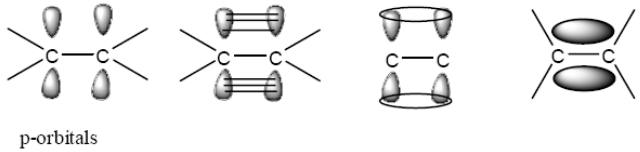
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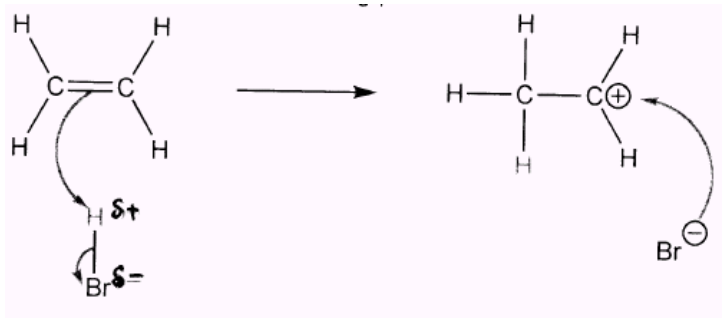
Each of the diagrams on its own scores no mark



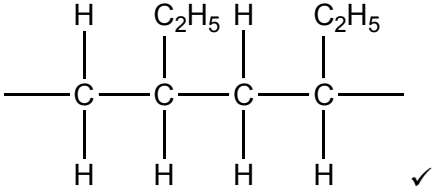
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Question			Expected Answers	Marks	Additional Guidance
5	b	i	Double bond does not rotate / restricted rotation of the double bond ✓ Each carbon atom of double bond is bonded to (two) different groups ✓	2	**ALLOW** π bond does not rotate **ALLOW** each carbon atom of double bond is bonded to (two) different atoms / each end of the π-bond is bonded to different groups or atoms ✓
		ii	**C** and **E** ✓	1	

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Question			Expected Answers	Marks	Additional Guidance
5	c		CH_3CH_2OH / ethanol ✓	1	**IGNORE** alcohol
	d			9	**ANNOTATE WITH TICKS AND CROSSES** **QWC** mark and **8 other** marking points
			C_4H_8 + HBr → C_4H_9Br ✓ C_2H_4 + HBr → C_2H_5Br ✓		The equation must be the overall equation not a series of steps as in a mechanism
			B makes $CH_3CH_2CH_2CH_2Br$ ✓ $CH_3CHBrCH_2CH_3$ ✓		**ALLOW** skeletal or displayed formulae **ALLOW B** makes 1-bromobutane and 2-bromo butane ✓ if marks for the structures not awarded
			QWC – number of products is linked to structure of alkene e.g. because **D** is symmetrical **OR B** is not symmetrical ✓		
			Movement of electron pair from double bond to attack hydrogen of H–Br and breaking of H–Br bond ✓ Correct dipole shown on H–Br ✓ Correct carbonium ion drawn ✓ Curly arrow from Br^- to the carbonium ion ✓		 **ALLOW** curly arrow from lone pair or minus sign of bromide ion **ALLOW** marks for the mechanism even if the wrong alkene is used e.g. for alkene **B** If two mechanisms are drawn mark the one for alkene **D**

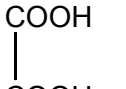
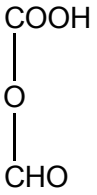
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Question			Expected Answers	Marks	Additional Guidance
5	e	i	 ✓	1	Must have at least two repeat units and the free bonds at the end All carbon–carbon bonds in the polymer chain must be shown **ALLOW** bond to ethyl group to any part of ethyl group **IGNORE** any brackets drawn
		ii	Poly(but-1-ene) ✓	1	**ALLOW** polybut-1-ene n.b. the bracket is part of the answer **DO NOT ALLOW** polybutene
	f	i	(Lots of) OH group present ✓ Can form hydrogen bonds with water ✓	2	**ALLOW** hydroxyl group present / hydroxy group Alcohol group is not sufficient
		ii	**Any two from:** Incineration to produce energy **OR** combustion to produce energy ✓ Sorting and recycling **OR** sorting and remoulding ✓ Cracked (to give monomers) **OR** as an organic feedstock ✓	2	Used as a fuel is not sufficient **IGNORE** use photodegradable or biodegradable polymers
			Total	**21**	

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Question			Expected Answers	Marks	Additional Guidance
6	a		Low pressure because more (gas) molecules on right hand side of equation **OR** low pressure because ΔV = positive ✓ Low temperature because the (forward) reaction is exothermic ✓	2	**ALLOW** low pressure because more (gas) moles on right hand side of equation
	b		Increased pressure speeds up reaction / ora ✓ 900 ^{o}C increases the rate **OR** increased temperature speeds up reaction / ora ✓ Idea that high enough temperature without compromising yield **OR** idea that high enough pressure without compromising yield ✓	3	**ANNOTATE WITH TICKS AND CROSSES** **ALLOW** 'pushes gases through system'
	c	i	5.68×10^7 / 5.7×10^7 ✓	1	**ALLOW** two or more significant figures Calculator answer is 5.6812500×10^7
		ii	Used to heat the incoming gases ✓	1	**ALLOW** used to heat rest of factory **OR** sold to the national grid Provide energy to create conditions is not sufficient because one condition is pressure
			Total	**7**	

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Question	Expected Answers	Marks	Additional Guidance
7	**Infrared** QWC – 1720 cm^{-1} indicates carbonyl group ✓ QWC – broad 2900 cm^{-1} indicates O–H bond in **carboxylic acid** ✓ QWC – 1080 cm^{-1} indicates C–O bond ✓ **Percentage composition** Mole ratio C : H : O = 2.23 : 2.22 : 4.44 ✓ Empirical formula is CHO_2 ✓ (mass of one mole is 90 g) so M_r is 90 ✓ QWC – molecular formula is $C_2H_2O_4$ with working out from M_r ✓ Structure is  ✓	8	**ANNOTATE WITH TICKS AND CROSSES** ✎ **QWC** –Structure linked to information at least once **ALLOW** 1720 indicates presence of aldehydes, ketones, esters, carboxylic acid, amides **ALLOW** 2900 indicates carboxylic acid **ALLOW** 1080 indicates alcohol, esters, carboxylic acids **ALLOW** 26.7/12.0. 2.22/1.0 and 71.1/16.0 **ALLOW** COOH **ALLOW two** marks for correct empirical formula with no working out **ALLOW** 0.0945/0.00105 = 90 **ALLOW** 
	Total	**8**	

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THIS IS A NEW SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE
CHEMISTRY A
Chains, Energy and Resources

F322

Candidates answer on the Question Paper

OCR Supplied Materials:
- *Data Sheet for Chemistry A* (inserted)

Other Materials Required:
- Scientific calculator

Thursday 14 January 2010
Morning

Duration: 1 hour 45 minutes

OCE/19234

F322

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **20** pages. Any blank pages are indicated.

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Turn over

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Answer **all** the questions.

1 Kerosene is used as a fuel for aeroplane engines.

(a) Kerosene is obtained from crude oil.

Name the process used to obtain kerosene from crude oil **and** explain why the process works.

.....

.....

..... **[2]**

(b) Some of the hydrocarbons in kerosene have the formula $C_{10}H_{22}$.

(i) What is the name of the straight chain hydrocarbon with the formula $C_{10}H_{22}$?

..... **[1]**

(ii) Draw the skeletal formula of one branched chain isomer with the formula $C_{10}H_{22}$.

[1]

(iii) Explain why the straight chain isomer of $C_{10}H_{22}$ has a higher boiling point than any of its branched chain structural isomers.

.....

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.....

.....

..... **[2]**

(iv) Explain why the straight chain isomer of $C_{10}H_{22}$ is converted by the petroleum industry into its branched chain isomers.

.....

..... **[1]**

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(c) When kerosene burns in an aeroplane engine very little carbon monoxide, CO, is formed but a significant amount of nitrogen monoxide, NO, is formed.

(i) Construct the equation to show the **complete** combustion of $C_{10}H_{22}$.

..... **[2]**

(ii) Suggest, with the aid of an equation, how NO is formed within an aeroplane engine.

.....

.....

..... **[1]**

(d) NO is a radical and contributes towards ozone depletion in the stratosphere.

(i) What is a *radical*?

.....

..... **[1]**

(ii) One of the processes leading to the breakdown of ozone in the stratosphere can be represented by the following two equations.

$$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g)$$

$$NO_2(g) + O(g) \rightarrow NO(g) + O_2(g)$$

What is the role of the NO in this process?

..... **[1]**

(iii) Ozone in the stratosphere is broken down to make O_2 and O.

Describe and explain how the concentration of ozone in the stratosphere is maintained.

.....

.....

..... **[2]**

(iv) Why is it important to life on the Earth's surface that the concentration of ozone in the stratosphere is maintained?

.....

..... **[1]**

[Total: 15]

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2 Dilute aqueous hydrogen peroxide, $H_2O_2(aq)$, is used to sterilise contact lenses.

(a) Dilute $H_2O_2(aq)$ slowly decomposes at room temperature to produce oxygen and water.

The decomposition of $H_2O_2(aq)$ can be made faster by:

- increasing the concentration of the $H_2O_2(aq)$,
- adding a small amount of manganese(IV) oxide catalyst,
- heating the solution to 60 °C.

(i) Construct the equation for the decomposition of H_2O_2.

..... **[1]**

(ii) Explain why increasing the concentration of $H_2O_2(aq)$ increases the rate of decomposition.

.....

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..... **[2]**

(iii) Explain how the catalyst can increase the rate of decomposition of $H_2O_2(aq)$.

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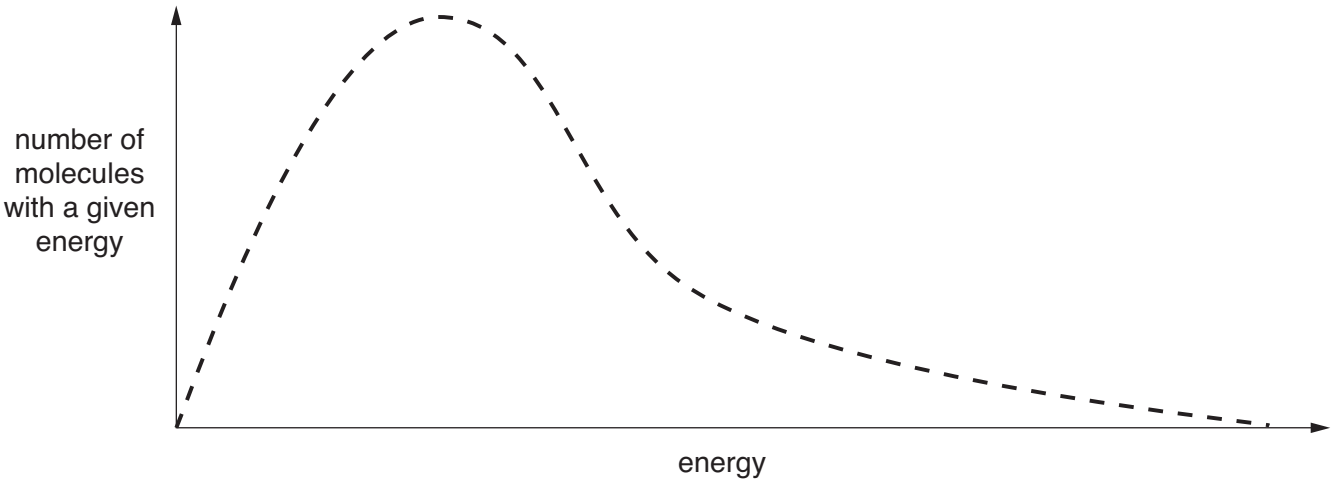
..... **[2]**

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(iv) Explain why increasing the temperature of $H_2O_2(aq)$ increases the rate of decomposition.

As part of your answer, you should add a second curve and any necessary labels to the Boltzmann distribution of molecular kinetic energies shown below.



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..... **[3]**

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(b) (i) In the past, hydrogen peroxide was manufactured by reacting barium peroxide, BaO_2, with ice-cold dilute sulfuric acid.

$$BaO_2(s) + H_2SO_4(aq) \longrightarrow BaSO_4(s) + H_2O_2(aq)$$

This method required the disposal of poisonous barium compounds.

Calculate the atom economy for this manufacture of hydrogen peroxide from BaO_2. Use the table of relative formula masses given below.

compound	relative formula mass
BaO_2	169.3
H_2SO_4	98.1
$BaSO_4$	233.4
H_2O_2	34.0

atom economy = ... % **[2]**

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(ii) Nowadays, hydrogen peroxide is manufactured using hydrogen gas, oxygen from the air and a substance called anthraquinone.

stage 1 H_2 + anthraquinone $\longrightarrow$ anthraquinol

stage 2 O_2 + anthraquinol $\longrightarrow$ H_2O_2 + anthraquinone

Compare the manufacture of H_2O_2 from hydrogen and oxygen with the manufacture from barium peroxide described in **b(i)**.

Explain the advantages of the manufacture of H_2O_2 from hydrogen and oxygen.

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..... **[3]**

(c) Some reactions of H_2O_2 are exothermic.

Use ideas about the enthalpy changes that take place during bond breaking and bond making to explain why some reactions are exothermic.

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..... **[2]**

[Total: 15]

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3 Glucose, $C_6H_{12}O_6$, can be completely combusted to give carbon dioxide and water.

$$C_6H_{12}O_6(s) + 6O_2(g) \rightarrow 6CO_2(g) + 6H_2O(l)$$

(a) In the body, the conversion of glucose into carbon dioxide and water takes place in a number of stages catalysed by enzymes.

What name is given to this oxidation process in the body?

..... **[1]**

(b) A student carries out an experiment to determine the enthalpy change of combustion of glucose.

In the experiment, 0.831 g of glucose is burned. The energy released is used to heat 100 cm^3 of water from 23.7 °C to 41.0 °C.

(i) Calculate the energy released, in kJ, during combustion of 0.831 g glucose.

The specific heat capacity of water = 4.18 $J\,g^{-1}\,K^{-1}$.
Density of water = 1.00 $g\,cm^{-3}$.

energy = ... kJ **[2]**

(ii) Calculate the amount, in moles, of glucose that is burned.

amount = ... mol **[2]**

(iii) Calculate the enthalpy change of combustion of glucose.
Give your answer to **three** significant figures.

ΔH_c = ... kJ mol^{-1} **[2]**

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(c) The standard enthalpy change of combustion of glucose can also be determined indirectly.

Calculate the standard enthalpy change of combustion of glucose using the standard enthalpy changes of formation below.

substance	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$C_6H_{12}O_6(s)$	–1250
$CO_2(g)$	–394
$H_2O(l)$	–286

$$C_6H_{12}O_6(s) + 6O_2(g) \longrightarrow 6CO_2(g) + 6H_2O(l)$$

–1

answer = ... kJ mol^{-1} **[3]**

(d) Suggest **two** reasons why standard enthalpy changes of combustion determined experimentally are less exothermic than the calculated theoretical values.

.....

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..... **[2]**

[Total: 12]

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4 A reaction mechanism shows the individual steps that take place during a reaction.

(a) Methane reacts with bromine in the presence of ultraviolet radiation to form several products. Two of these products are bromomethane and hydrogen bromide.

(i) Write an equation for the reaction between methane and bromine to make bromomethane and hydrogen bromide.

..... **[1]**

(ii) Name one other bromine-containing organic product which is formed when methane reacts with bromine.

..... **[1]**

(iii) The mechanism for this reaction is called radical substitution.

Describe the mechanism for the radical substitution of methane by bromine to make bromomethane.

Use the mechanism to suggest why a small amount of ethane is also formed.

In your answer, you should organise your answer and use the correct technical terms.

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..... **[7]**

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(b) The 'curly arrows' model is used in reaction mechanisms to show the movement of electron pairs during chemical reactions.

Choose a reaction mechanism that you have studied involving the curly arrow model.

Name and describe your chosen reaction mechanism.

In your answer, include:

- an example of the reaction with the chosen mechanism,
- the type of bond fission that occurs,
- relevant dipoles.

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[6]

[Total: 15]

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5 Alkenes are a very useful series of hydrocarbons used widely in synthesis. Alkenes are more reactive than alkanes.

(a) What is the name of the process used to convert long chain alkanes into more useful shorter chain alkenes?

..... **[1]**

(b) Ethene and steam can be converted into ethanol.
The equilibrium is shown below.

$$C_2H_4(g) + H_2O(g) \rightleftharpoons C_2H_5OH(g) \qquad \Delta H = -46 \text{ kJ mol}^{-1}$$

le Chatelier's principle can be used to predict the effect of changing conditions on the position of equilibrium.

(i) Name the catalyst used in this reaction.

..... **[1]**

(ii) State le Chatelier's principle.

.....

.....

..... **[1]**

(iii) Using le Chatelier's principle, predict and explain the conditions that would give the maximum equilibrium yield of ethanol from ethene and steam.

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.....

.....

..... **[3]**

(iv) The actual conditions used are 60 atmospheres pressure at 300 °C in the presence of a catalyst. Compare these conditions with your answer to **(iii)** and comment on why these conditions are used.

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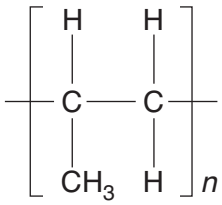
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..... **[3]**

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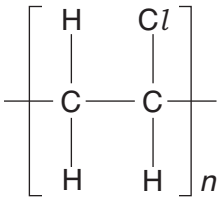
(c) Alkenes are used to make addition polymers.
The repeat unit for an addition polymer is shown below.



What is the name of the monomer used to make this polymer?

..... **[1]**

(d) Poly(chloroethene) has the repeat unit below.



This repeat unit can be written as —CH_2CHCl— .

One way to dispose of poly(chloroethene) is to react it with oxygen at high temperature. This is called incineration.

(i) Complete the following equation that shows the reaction taking place during incineration.

—CH_2CHCl— + ... O_2 → ..... CO_2 + ... H_2O + ... HCl **[1]**

(ii) Research chemists have reduced the environmental impact of incineration by removing the HCl formed from the waste gases.

Suggest a type of reactant that could be used to remove the HCl.

..... **[1]**

(e) The disposal of polymers causes environmental damage.
Research chemists are developing polymers that will reduce this environmental damage and increase sustainability.

Describe **two** ways in which chemists can reduce this environmental damage.

.....

.....

..... **[2]**

[Total: 14]

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6 This question is about the six alcohols below.

butan-2-ol	**ethane-1,2-diol**
2-methylpentan-3-ol	**2-methylpropan-2-ol**
propan-1-ol	**propan-2-ol**

(a) Which alcohol is an example of a tertiary alcohol?

..... **[1]**

(b) Draw the skeletal formula for 2-methylpentan-3-ol.

[1]

(c) Butan-2-ol and 2-methylpropan-2-ol are structural isomers.

(i) What is meant by the term *structural isomer*?

.....

.....

..... **[1]**

(ii) Draw another structural isomer of these two alcohols.

[1]

(d) Ethane-1,2-diol can be dissolved in water to act as an anti-freeze in car radiators.

Explain why ethane-1,2-diol is very soluble in water.

.....

.....

.....

..... **[2]**

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(e) Ethane-1,2-diol is heated under reflux with ethanoic acid and a small amount of H_2SO_4 catalyst. Compound **A** is formed with molecular formula $C_6H_{10}O_4$.

Draw the structure of compound **A**.

[2]

(f) Butan-2-ol is heated with H_2SO_4 catalyst.

- A mixture of **three** alkenes forms, **B**, **C** and **D**.
- The alkenes **B** and **C** are stereoisomers.

(i) Draw the structures of the two stereoisomers **B** and **C**.

[2]

(ii) What type of stereoisomerism is shown by **B** and **C**?

..... **[1]**

(iii) Draw the structure of the other alkene, **D**, that is formed in this reaction.

[1]

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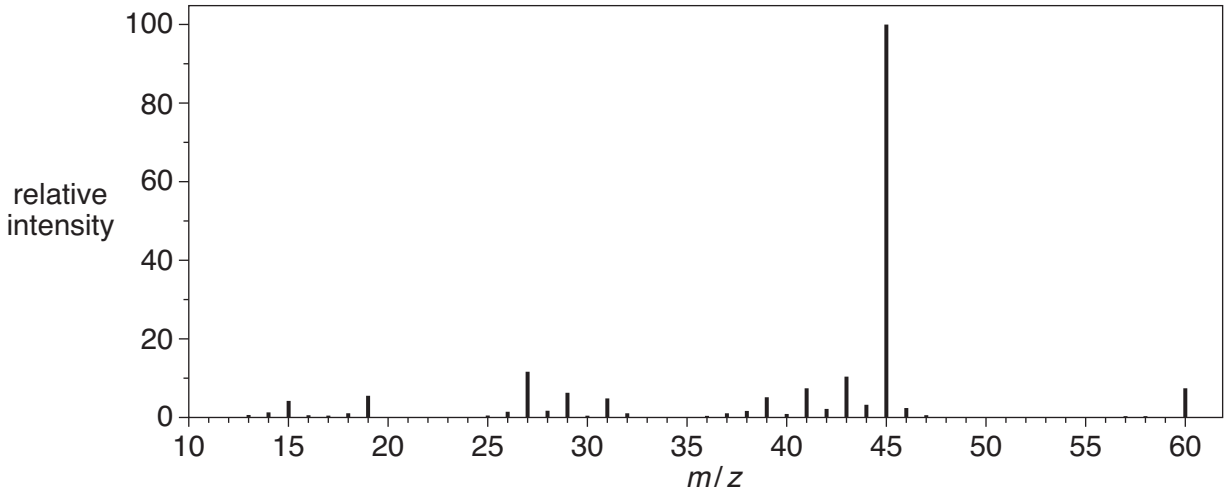
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(g) Alcohol **E** is one of the following alcohols.

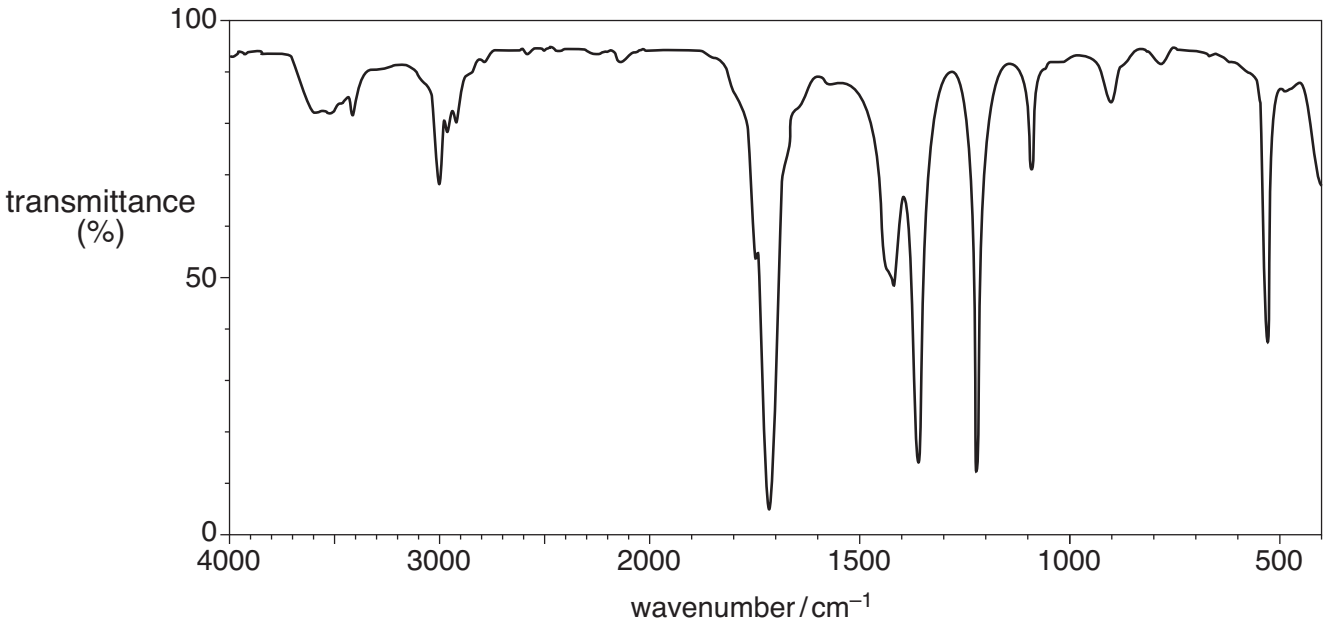
butan-2-ol	**ethane-1,2-diol**
2-methylpentan-3-ol	**2-methylpropan-2-ol**
propan-1-ol	**propan-2-ol**

A student oxidises alcohol **E** by heating under reflux with excess acidified potassium dichromate(VI). An organic product **F** is isolated.

The mass spectrum of the alcohol **E** is shown below.



The infrared spectrum of the organic product **F** is shown below.



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- Name **or** draw the structures of the alcohol **E** and the organic product **F**.
- Write an equation for the reaction of alcohol **E** with acidified potassium dichromate(VI).

Use [O] to represent the oxidising agent, acidified potassium dichromate(VI).



In your answer, you should make clear how each structure fits with the information given above.

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..... **[7]**

[Total: 19]

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7 There is much international concern that an increase in atmospheric concentrations of carbon dioxide and methane may lead to global warming and climate change.

(a) Carbon dioxide and methane are both greenhouse gases.

(i) What type of radiation is absorbed by methane molecules and what effect does this radiation have on these molecules?

.....

.....

..... **[2]**

(ii) Some scientists are more concerned about carbon dioxide as a greenhouse gas than methane.

Suggest why.

.....

..... **[1]**

(b) Describe ways that research chemists are trying to minimise climate change resulting from global warming caused by the release of greenhouse gases.

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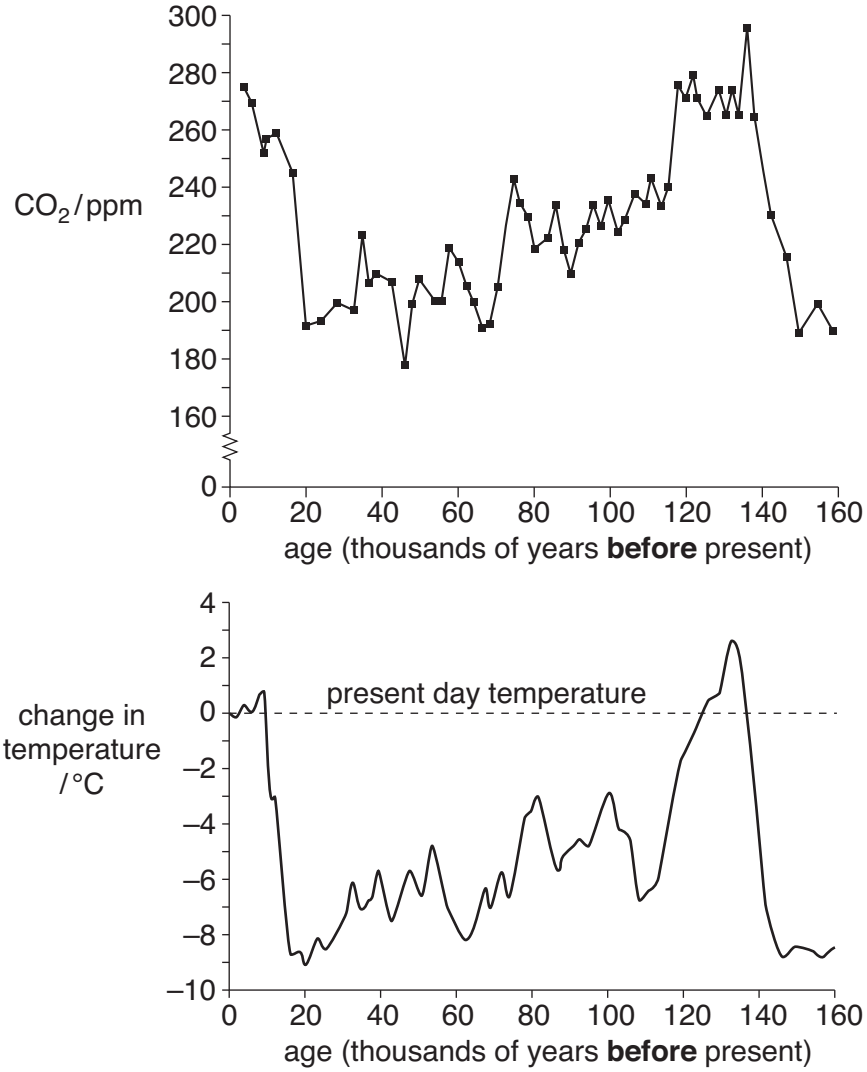
..... **[5]**

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(c) Research scientists working in the Antarctic have measured the concentration of carbon dioxide in the ice. This study has allowed the scientists to estimate the atmospheric concentration of carbon dioxide over many thousands of years.

The graphs below show these atmospheric concentrations and the corresponding average surface temperature.



Do the graphs provide reliable evidence that an increase in atmospheric carbon dioxide concentration will result in global warming?

Explain your answer.

.....

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..... **[2]**

[Total: 10]

END OF QUESTION PAPER

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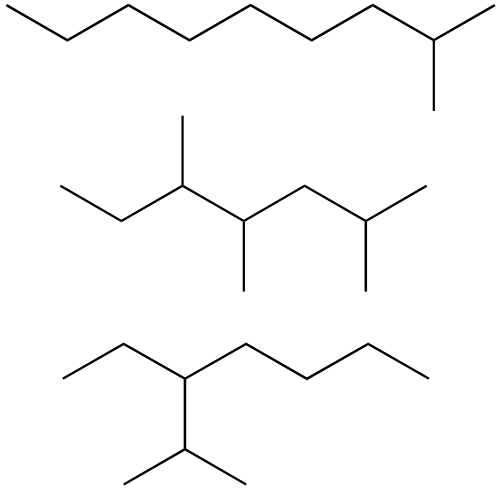
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F322 Chains, Energy and Resources

Question			Expected Answers	Marks	Additional Guidance
1	(a)		Fractional distillation ✓ Because fractions have different boiling points ✓	2	**DO NOT ALLOW** just 'distillation' For fractions, **ALLOW** components **OR** hydrocarbons **OR** compounds **ALLOW** condense at different temperatures **ALLOW** because van der Waals' forces differ between molecules **IGNORE** reference to melting points **IGNORE** 'crude oil' **OR** 'mixture' has different boiling points' …… **but ALLOW** 'separates crude oil by boiling points
	(b)	(i)	Decane ✓	1	**DO NOT ALLOW** deceane
		(ii)	Skeletal formula of branched $C_{10}H_{22}$ ✓	1	Formula **must** be skeletal **AND** must not include any symbol, e.g. CH_3 Any possible skeletal formulae e.g.

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Question			Expected Answers	Marks	Additional Guidance
					
		(iii)	Decane has more surface contact **OR** branched chains have less surface contact ✓ Decane has more van der Waals' forces **OR** branched chains have fewer van der Waals' forces ✓	2	**Both answers need to be comparisons** Assume 'it' refers to decane **IGNORE** surface area **ALLOW** straight chains can get closer together **OR** branched chains cannot get as close to one another **IGNORE** branched chain are more compact **ALLOW** Decane has stronger van der Waals' forces **OR** branched chains have weaker van der Waals' forces More intermolecular forces is **not** sufficient
		(iv)	Branched chains have more efficient combustion **OR** decane has less efficient combustion ✓	1	**ALLOW** branched chains are easier to burn **OR** easier to combust **OR** burn better **OR** more efficient fuel **OR** less likely to produce pre-ignition or knocking **OR** increases octane rating **ALLOW** ORA for decane

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Question			Expected Answers	Marks	Additional Guidance
					Better fuel is **NOT** sufficient Burns more cleanly is **NOT** sufficient
	(c)	**(i)**	$C_{10}H_{22} + 15½O_2 \longrightarrow 10CO_2 + 11H_2O$ All **four** species correct ✓ balancing of four correct species ✓	**2**	**ALLOW** any correct multiple **IGNORE** state symbols
		(ii)	$N_2 + O_2 \longrightarrow 2NO$ ✓	**1**	**ALLOW** any correct multiple including fractions **IGNORE** state symbols The mark is for the equation **IGNORE** writing

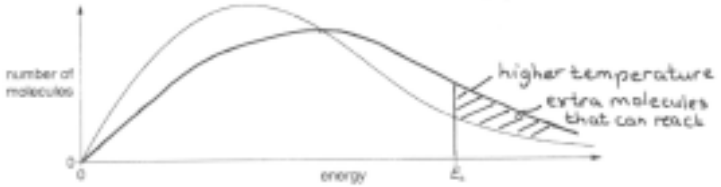
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Question			Expected Answers	Marks	Additional Guidance
	(d)	(i)	Species with an unpaired electron ✓	1	**ALLOW** atom, molecule or particle with an unpaired electron **ALLOW** 'has an unpaired electron' **ALLOW** particle formed by homolytic fission **DO NOT ALLOW** particle with a single electron **OR** particle with a free electron
		(ii)	catalyst ✓	1	
		(iii)	$O + O_2 \longrightarrow O_3$ **OR** O reacts with O_2 to make ozone **OR** the reaction is reversible ✓ Rate of formation of ozone is the same as rate of decomposition ✓	2	**ALLOW** $O_2 + O \rightleftharpoons O_3$ **OR** $O_3 \rightleftharpoons O_2 + O$ ✓✓ **ALLOW** is in equilibrium **OR** $\rightleftharpoons$ in **correct** equation **OR** has steady state condition ✓ **IGNORE** other equations involving ozone
		(iv)	absorbs (harmful) UV ✓	1	**ALLOW** 'keeps out UV' **OR** 'filters UV' **ALLOW** increased UV could cause skin cancer **OR** increased UV could cause cataracts **OR** increased UV could cause mutation of crops ✓ **IGNORE** gamma
			Total	15	

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Question			Expected Answers	Marks	Additional Guidance
2	(a)	(i)	$2H_2O_2 \longrightarrow 2H_2O + O_2$ ✓	1	**ALLOW** any correct multiple including fractions **IGNORE** state symbols
		(ii)	More crowded particles **OR** more particles per (unit) volume ✓ more collisions per second **OR** more frequent collisions ✓	2	**ALLOW** particles are closer together **DO NOT ALLOW** 'area' instead of 'volume' **IGNORE** 'more concentrated particles' **ALLOW** collisions more often **OR** increased rate of collision **OR** collisions are more likely **OR** there is a greater chance of collisions 'More collisions' is **not** sufficient
		(iii)	**Any two from the following:** Reaction takes alternative route ✓ Activation energy is lowered ✓ More molecules have energy above activation energy **OR** more molecules have enough energy to react ✓	2	 **ALLOW** catalyst changes reaction mechanism **ALLOW** an alternative approach using adsorption particles **adsorbed** onto surface ✓ so bonds weakened as a result of the adsorption ✓

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Question			Expected Answers	Marks	Additional Guidance
		(iv)	Correct curve for higher temperature ✓ Activation energy does not change **OR** clearly labelled on diagram, e.g. E_a **OR** E ✓ More molecules have energy above activation energy **OR** more molecules have enough energy to react ✓	**3**	maximum of curve to right **AND** lower than maximum of original curve **AND** above dotted line at higher energy as shown in diagram below **IGNORE** minor point of inflexion of curve  Note that the diagram above would score all 3 marks More successful collisions is **not** sufficient
	(b)	**(i)**	$\frac{34.0}{}$ × 100 **267.4** ✓ 12.7% ✓	**2**	First mark for 267.4 **OR** (34.0 + 233.4) **OR** (169.3 + 98.1) at **bottom** of fraction with or without × 100 **ALLOW** from 2 sig figs up to calculator value **ALLOW** full marks for 13 **OR** 12.7 **OR** 12.72 **OR** 12.715 up to calculator value with no working out 12.71 scores one mark only **NO ECF** for this part from incorrect numbers in first expression

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Question			Expected Answers	Marks	Additional Guidance
		(ii)	**Any three from the following**: Oxygen comes from air ✓ No poisonous materials formed **OR** no poisonous materials involved ✓ No waste products formed **OR** atom economy is 100% ✓ Anthraquinone is regenerated **OR** recycled **OR** used again **OR** Anthraquinone acts as a catalyst ✓	3	 **IGNORE** hydrogen comes from the air **IGNORE** harmful **ALLOW** higher atom economy
	(c)		Bond breaking absorbs energy **AND** bond making releases energy ✓ More energy released than absorbed ✓	2	**ALLOW** bond breaking is endothermic **AND** bond making is exothermic **ALLOW** exothermic change transfers more energy than endothermic change **OR** bond making transfers more energy than bond breaking **OR** '(the sum of the) bond enthalpies in the products is greater than the (sum of the) bond enthalpies in the reactants' **OR** '(the sum of the) bond enthalpies of the bonds made is greater than (the sum of) the bond enthalpies of the bonds broken' **IGNORE** reference to strong and weak bonds **IGNORE** enthalpy of products is less than enthalpy of reactants
			Total	15	

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Question			Expected Answers	Marks	Additional Guidance
3	(a)		Respiration ✓	1	**IGNORE** anaerobic
	(b)	(i)	100 × 4.18 × 17.3 ✓ 7.23 (kJ) ✓	2	**ALLOW** 7231 J ✓ **ALLOW** 7.23 with no working out **ALLOW** from 7.2 up to calculator value of 7.2314 **ALLOW** from 0.060 up to calculator value for 1 mark (i.e. ECF from use of m = 0.831 in first stage) **IGNORE** sign
		(ii)	M_r = 180 ✓ amount = 4.62 × 10^{-3} (mol) ✓	2	 **ALLOW** 4.6 × 10^{-3} **OR** 4.62 × 10^{-3} **OR** 4.617 × 10^{-3} up to calculator value **DO NOT ALLOW** 0.005 **ALLOW** ECF from wrong M_r
		(iii)	ΔH_c = 1560 (kJ) **OR** 1570 (kJ) but answer must be to 3 sig fig ✓ minus sign ✓	2	**ALLOW** ECF from 'answer to **(i)** ÷ answer to **(ii)**' but answer must be to 3 sig fig minus mark is an independent mark

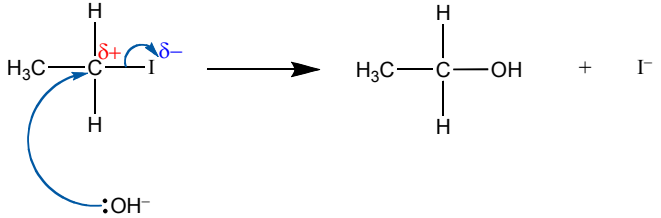
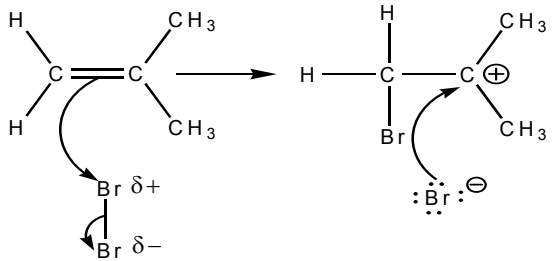
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Question	Expected Answers	Marks	Additional Guidance
(c)	+1250 ✓ +(−394 × 6) + (−286 × 6) **OR** –4080 ✓ −2830 ✓	3	**ALLOW** full marks for −2830 with no working out ✓✓✓ **ALLOW for 2 marks:** +2830 cycle wrong way around **OR** 1400 **OR** 860 one value not × 6 **OR** –5330 **OR** +5330 wrong sign for 1250 or 4080 **OR** +570 ✓✓ correct cycle but not × 6 **ALLOW for 1 mark:** –1400 **OR** –860 cycle wrong way around and one value not × 6 **OR** –570 cycle wrong way around and not × 6 **OR** –1930 **OR** +1930 ✓ wrong sign and not × 6 **Note:** There may be other possibilities.
(d)	**Any two from the following:** Heat released to the surroundings ✓ Incomplete combustion **OR** incomplete reaction **OR** not everything burns ✓ Non-standard conditions ✓	2	 **ALLOW** heat loss **IGNORE** reference to evaporation
	Total	12	

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Question			Expected Answers	Marks	Additional Guidance
4	(a)	(i)	$CH_4 + Br_2 \longrightarrow CH_3Br + HBr$ ✓	1	**ALLOW** any correct multiple **IGNORE** state symbols
		(ii)	Dibromomethane **OR** tribromomethane **OR** tetrabromomethane ✓	1	**ALLOW** 1,1-dibromomethane **OR** 1,1,1-tribromomethane etc **ALLOW** 1-dibromomethane **DO NOT ALLOW** 2,2-dibromomethane etc **ALLOW** correct formulae e.g. CH_2Br_2
		(iii)	$Br_2 \longrightarrow 2Br$ **OR** homolytic fission of bromine ✓ $Br + CH_4 \longrightarrow HBr + CH_3$ ✓ $CH_3 + Br_2 \longrightarrow CH_3Br + Br$ ✓ $Br + CH_3 \longrightarrow CH_3Br$ **OR** $Br + Br \longrightarrow Br_2$ ✓ Ethane made when two methyl radicals react **OR** $CH_3 + CH_3 \longrightarrow C_2H_6$ ✓ **Quality of Written Communication** – Consists of initiation step linked to correct equation propagation step linked to one equation in which there is a radical on the left and a radical on the right termination step linked to correct equation: 2 names of steps linked to correct equations ✓ **BUT** 3 names of steps linked to correct equations ✓✓	7	**All equations can be described in words** Radicals do **NOT** need a single dot **IGNORE** any state symbols **ALLOW** any other suitable termination If no equations are given to link the names of the step then award one mark for mention of all three steps

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Question	Expected Answers	Marks	Additional Guidance
(b)	**EITHER** Nucleophilic substitution ✓ Example of nucleophilic substitution ✓ Heterolytic fission ✓ C–I curly arrow ✓ Correct dipole on C— I bond ✓ OH^- curly arrow from one lone pair on O of OH^- ion **OR** from minus sign on OH^- ion ✓ **OR** Electrophilic addition ✓ Example of electrophilic addition ✓ Heterolytic fission ✓ Curly arrow from C=C bond to Br—Br bond and Dipole and curly arrow associated with Br_2 ✓ Correct carbocation ion ✓ Curly arrow from one lone pair on Br^- ion **OR** from minus sign on Br^- ion ✓	6	The example mark can be awarded as an example of the name of the mechanism given or if the name is wrong can be given as an example of a reasonably correct drawn mechanism *If **curly half arrows** drawn do not give a mark the first time used and then apply ECF*  **ALLOW** mechanisms for other halogenoalkaes  **ALLOW** mechanisms for other halogens and hydrogen halides
	ALLOW Electrophilic substitution ✓ Example of electrophilic substitution ✓ Heterolytic fission ✓ Curly arrow from benzene ring to the electrophile (i.e. NO_2^+ OR Br^+) ✓ Correct intermediate ✓ Curly arrow to show loss of hydrogen ion ✓		**ALLOW** Nucleophilic addition ✓ Example of nucleophilic addition ✓ Heterolytic fission ✓ Correct dipole on carbonyl group ✓ Curly arrow from lone pair on H^- ion **OR** from minus sign on H^- to C=O carbon and breaking of C=O bond ✓ Curly arrow from carbonyl oxygen to either H^+ or H_2O ✓
	Total	**15**	

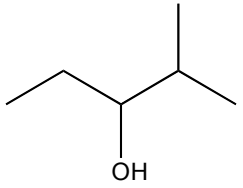
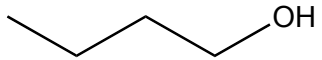
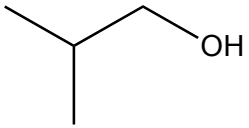
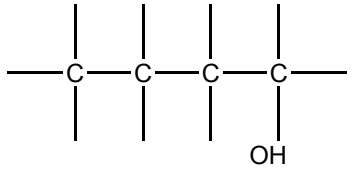
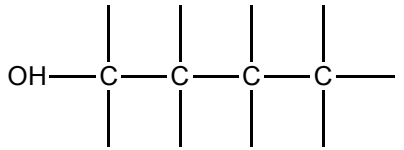
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Question			Expected Answers	Marks	Additional Guidance
5	(a)		Cracking ✓	1	**ALLOW** catalytic or thermal cracking ✓
	(b)	(i)	Acid ✓	1	**ALLOW** correct formula if no name given: e.g. H_3PO_4 **OR** H_2SO_4 **OR** H^+ ✓ **ALLOW** correct name of acid even if an incorrect formula is used **IGNORE** heterogeneous **OR** homogeneous
		(ii)	The position of equilibrium will shift so as to minimise the effect of any change in conditions ✓	1	**DO NOT ALLOW** 'reaction shifts' The idea of a shift in equilibrium is essential
		(iii)	Low temperature **AND** high pressure ✓ Low temperature because the (forward) reaction is exothermic ✓ High pressure because there are fewer moles (of gas) on the right hand side ✓	3	One mark for conditions. This mark is independent of the reasons for conditions One mark for reason for the chosen temperature One mark for reason for the chosen pressure **ALLOW** fewer moles of products
		(iv)	(60 atmosphere pressure is a) high pressure may be too expensive **OR** may cause safety problems ✓ (300 ºC is sufficiently high) to give a fast rate of reaction ✓ without shifting equilibrium to the left **OR** compromising equilibrium yield ✓	3	
	(c)		Propene ✓	1	**ALLOW** prop-1-ene ✓ **DO NOT ALLOW** prop-2-ene
	(d)	(i)	—CH_2CHCl— + $2\frac{1}{2}O_2 \longrightarrow 2CO_2 + H_2O + HCl$ ✓	1	
		(ii)	Alkali **OR** base **OR** carbonate ✓	1	**ALLOW** correct formula of or named carbonate **OR** alkali **OR** base Correct name and wrong formula does **not** score

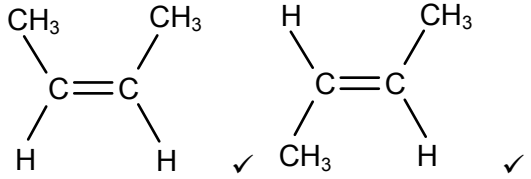
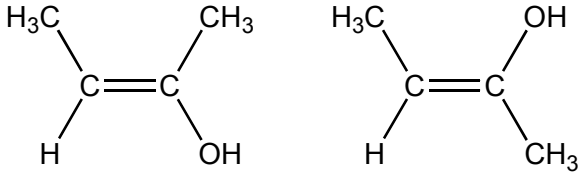
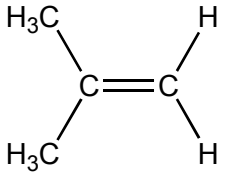
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Question			Expected Answers	Marks	Additional Guidance
	(e)		**Any two marks from the following**: Develop photodegradable polymers ✓ Develop biodegradable polymers **OR** develop compostable polymers ✓ Develop techniques for cracking polymers **OR** develop use as a chemical feedstock ✓ Develop ways of making polymers from plant-based substances **OR** reduce the need to use finite raw materials such as crude oil ✓ Designing processes with high atom economy **OR** reduce waste products during manufacture ✓ Develop ways of sorting **AND** recycling polymers ✓	**2**	
			Total	**14**	

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Question			Expected Answers	Marks	Additional Guidance
6	(a)	(i)	2-Methylpropan-2-ol ✓	1	**ALLOW** methylpropan-2-ol
	(b)		 ✓	1	Formula **must** be skeletal **AND** not include any symbol except for OH
	(c)	(i)	Same **molecular** formula but different structural formulae ✓	1	**ALLOW** Same molecular formula but different arrangement of atoms **OR** Same molecular formula but different structures **OR** Same molecular formula but different displayed formulae **DO NOT ALLOW** Same molecular formula but different spatial arrangement of atoms
		(ii)	$CH_3CH_2CH_2CH_2OH$ **OR** $(CH_3)_2CHCH_2OH$ ✓ **ALLOW**  **OR** 	1	**ALLOW** displayed formula **ALLOW** sticks (i.e. no H shown bonded to C) **ALLOW**  *sticks OK and –OH is OK* **DO NOT ALLOW** OH shown as below  *sticks OK but OH– is not OK* **ALLOW** correct ethers

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Question			Expected Answers	Marks	Additional Guidance
	(d)		Has O–H (bonds) **OR** has hydroxyl (groups) **OR** has hydroxy (groups) ✓ Forms hydrogen bonds with water (molecules) ✓	2	**ALLOW** marks from a diagram of hydrogen bonding **IGNORE** reference to alcohol functional group **DO NOT ALLOW** 'forms hydrogen bonds'
	(e)		$CH_3COOCH_2CH_2OOCCH_3$ 1 mark for each ester end of molecule ✓✓	2	**ALLOW** displayed formula **OR** skeletal formula **ALLOW** sticks $CH_3COOCH_2CH_2OH$ shows one of the two ester groups and scores one mark
	(f)	(i)	 ✓ ✓	2	**DO NOT ALLOW**  i.e. no ECF
		(ii)	*E/Z* ✓	1	**ALLOW** *cis-trans* **IGNORE** geometric
		(iii)	$CH_3CH_2CH=CH_2$ **OR** but-1-ene ✓	1	If but-1-ene given in part **(i)**, **ALLOW** but-2-ene **OR** $CH_3CH=CHCH_3$ i.e. ECF from **f(i)** **DO NOT ALLOW** methylpropene: 

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Question	Expected Answers	Marks	Additional Guidance
From the evidence, candidates may have identified compound **F** as propanone, propanal or propanoic acid • The mark scheme for **F** = propanone and propanal is shown in the 'Expected Answers' column. • The mark scheme for **F** = propanoic acid is shown in the 'Additional Guidance' column. If **F** is propanone or propanoic acid, then maximum score = 7; **but** if **F** is propanal then maximum score = 6			
(g)	**Mark scheme for F = propanone and propanal**	**7**	**Mark scheme for F = propanoic acid**
	mass spec of E– Remember to check the spectrum **Quality of Written Communication –** mass spec gives M^+ or molecular ion of 60 **OR** mass spec gives parent ion of 60 **OR** highest *m*/*z* (**ALLOW** *m*/*e*) value is 60 ✓ *m*/*z* = 45 indicates loss of CH_3 **OR** *m*/*z* = 45 indicates presence of CH_3CHOH **OR** CH_2CH_2OH **OR** C_2H_5O ✓		**mass spec of E– Remember to check the spectrum** **QWC –** mass spec gives M^+ or molecular ion of 60 **OR** mass spec gives parent ion of 60 **OR** highest *m*/*z* (**OR** *m*/*e*) value is 60 ✓ *m*/*z* = 45 indicates loss of CH_3 **OR** *m*/*z* = 45 indicates presence of CH_3CHOH **OR** CH_2CH_2OH **OR** C_2H_5O ✓
	IR of F – Remember to check the spectrum IR shows no broad absorption between 2500 to 3300 cm^{-1} so no O—H bond **OR** no broad absorption between 2500 to 3300 cm^{-1} so not a carboxylic acid ✓ IR shows absorption at 1700 cm^{-1} due to a C=O bond **OR** absorption at 1700 cm^{-1} indicates a ketone **OR** aldehyde present ✓		**IR of F– Remember to check the spectrum** IR shows (broad) absorption somewhere between 3500 and 2500 cm^{-1} suggests carboxylic acid **OR** O–H bond ✓ IR shows absorption at 1700 cm^{-1} due to C=O **OR** absorption at 1700 cm^{-1} indicates a carboxylic acid ✓
	Identification and equation **F** is CH_3COCH_3 **OR** propanone ✓ **E** is $CH_3CHOHCH_3$ **OR** propan-2-ol ✓ $CH_3CHOHCH_3 + [O] \longrightarrow CH_3COCH_3 + H_2O$ ✓		**Identification and equation** **F** is CH_3CH_2COOH **OR** propanoic acid ✓ **E** is $CH_3CH_2CH_2OH$ **OR** propan-1-ol ✓ $CH_3CH_2CH_2OH + 2[O] \longrightarrow CH_3CH_2COOH + H_2O$ ✓
	If **F** has been incorrectly identified as propanal, mark identification and equation as ECF, so max = 2 **ALLOW E** is $CH_3CH_2CH_2OH$ ✓ **ALLOW**: $CH_3CH_2CH_2OH + [O] \rightarrow CH_3CH_2CHO + H_2O$ ✓		
	Total	**19**	

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Extra guidance for marking of Q6(g)

If **E** has **not** been identified **OR** if **F** has been identified as a **ketone or aldehyde**,
use the **left-hand** mark scheme

If **F** has been identified as a **carboxylic acid**,
use the **right-hand** mark scheme

Mass spec

These two marking points stand as **independent** marks whichever compounds have been identified.

The positive sign for fragment ions is not required. **IGNORE** negative charge.
The mass spec may well be on the actual spectrum.

IR mark

These stand as **independent** marks whichever compounds have been identified.
The IR analysis may well be on the actual spectrum.

Identification marks

If both structure and name are given they must **both** be correct
but allow 'propanol' drawn with the correct structure because the position number of the –OH has been clearly identified

ALLOW ECF for identification of **F** e.g. if **E** is pentan-2-ol × then an answer of pentan-2-one for **F** will be given a mark ✓ as ECF

ALLOW identification marks for **E** and **F** from equation

Equation mark

ALLOW ECF for any correct equation showing the oxidation of **any** alcohol to the appropriate product.
ALLOW molecular formulae in equations,
i.e. $C_3H_7OH + [O] \rightarrow C_2H_5CHO + H_2O$ ✓ ; $C_3H_8O + [O] \rightarrow C_3H_6O + H_2O$ ✓ ; $C_3H_7OH + [O] \rightarrow C_2H_5COH + H_2O$ ✓

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Question			Expected Answers	Marks	Additional Guidance
7	(a)	(i)	Infrared (radiation absorbed) ✓ by (C–H) bond vibration ✓	2	**ALLOW** bond stretching **OR** bond bending **DO NOT ALLOW** molecules vibrating
		(ii)	Greater concentration of carbon dioxide **OR** more carbon dioxide is being made ✓	1	**ALLOW** carbon dioxide is the main contributor to global warming **DO NOT ALLOW** any response that states that CO_2 causes ozone depletion **ALLOW** C=O bonds absorb IR more readily than C–H bonds **ALLOW** carbon dioxide has a greater greenhouse effect

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Question			Expected Answers	Marks	Additional Guidance
7	(b)		**Any five from the following:** Developing carbon capture **AND** storage ✓ One example of CCS ✓ Second example of CCS ✓ Provide evidence to governments **OR** international conferences (e.g. Kyoto) **OR** reports to United Nations etc ✓ Educating society **OR** writing in journals **OR** producing documentaries **OR** writing books **OR** making posters ✓ Monitoring atmospheric changes ✓ Develop alternative energy sources ✓ One example of an alternative energy source e.g. develop fuel cells **OR** developing solar power **OR** fuels that do not produce CO_2 ✓ (Develop) more efficient engines for transport **OR** lean burn engines **OR** hybrid engines **OR** electric cars ✓ Find uses for carbon dioxide **OR** named use: e.g. dry cleaning **OR** making decaffeinated coffee **OR** blowing agent **OR** fizzy drinks, etc ✓	5	carbon, capture **AND** storage required **ALLOW** CCS **Examples of CCS** **deep** in the oceans **OR** on the **sea-bed** ✓ **DO NOT ALLOW** dissolve CO_2 in the sea **OR** stored in ocean storage in geological formations **OR** piped into disused or partially filled oil wells or porous rocks **OR** under the sea-bed ✓ by reaction with metal oxides **OR** reaction to form (solid) carbonates **OR** stored as a carbonate **OR** equation to show formation of metal carbonate ✓ **IGNORE** mineral storage **ALLOW** idea of biofuels only if linked to carbon-neutrality **IGNORE** reforestation **IGNORE** reference to CFCs **DO NOT ALLOW** use less carbon dioxide

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Question			Expected Answers	Marks	Additional Guidance
	(c)		**Any two from the following:** There are times when CO_2 has a **high** concentration and the temperature is also **high** **OR** There are times when CO_2 has a **low** concentration and the temperature is **low** ✓ It is impossible to measure with certainty the average temperature years ago ✓ There are other gases that may cause a greenhouse effect **OR** There are other factors that may cause a greenhouse effect ✓ There are very few anomalous results ✓	**2**	**ALLOW** a (positive) correlation between temperature and carbon dioxide concentration but **DO NOT ALLOW** just 'a correlation' **IGNORE** 'graphs are the same shape' **IGNORE** 'graphs are similar'
			Total	**10**	

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THIS IS A NEW SPECIFICATION

OCR
RECOGNISING ACHIEVEMENT

ADVANCED SUBSIDIARY GCE
CHEMISTRY A
Chains, Energy and Resources

F322

OCE/T73768

Candidates answer on the question paper

OCR Supplied Materials:
- *Data Sheet for Chemistry A* (Inserted)

Other Materials Required:
- Scientific calculator

Wednesday 3 June 2009
Morning

Duration: 1 hour 45 minutes

F322

Candidate Forename		Candidate Surname	

Centre Number						Candidate Number				

INSTRUCTIONS TO CANDIDATES

- Write your name clearly in capital letters, your Centre Number and Candidate Number in the boxes above.
- Use black ink. Pencil may be used for graphs and diagrams only.
- Read each question carefully and make sure that you know what you have to do before starting your answer.
- Answer **all** the questions.
- Do **not** write in the bar codes.
- Write your answer to each question in the space provided, however additional paper may be used if necessary.

INFORMATION FOR CANDIDATES

- The number of marks is given in brackets **[ ]** at the end of each question or part question.
- Where you see this icon you will be awarded marks for the quality of written communication in your answer.

  This means for example you should:
  - ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear;
  - organise information clearly and coherently, using specialist vocabulary when appropriate.
- You may use a scientific calculator.
- A copy of the *Data Sheet for Chemistry A* 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**.
- This document consists of **16** pages. Any blank pages are indicated.

FOR EXAMINER'S USE		
Qu.	**Max.**	**Mark**
1	13	
2	14	
3	15	
4	14	
5	13	
6	12	
7	19	
TOTAL	**100**	

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Answer **all** the questions.

1 Crude oil is a source of hydrocarbons which can be used as fuels or for processing into petrochemicals.

Octane, C_8H_{18}, is one of the alkanes present in petrol.

Carbon dioxide is formed during the complete combustion of octane.

$$C_8H_{18} + 12\frac{1}{2}O_2 \rightarrow 8CO_2 + 9H_2O$$

(a) What is the general formula for an alkane?

..... **[1]**

(b) Carbon monoxide, CO, is formed during the incomplete combustion of octane.

(i) Write an equation for the incomplete combustion of octane, forming carbon monoxide and water.

..... **[1]**

(ii) Why does incomplete combustion sometimes take place?

.....

..... **[1]**

(c) In cars fitted with a catalytic converter, two toxic gases, CO and NO, react together to form two non-toxic gases.

(i) Write an equation for the reaction between CO and NO in a catalytic converter.

..... **[1]**

(ii) Outline the stages that take place in a catalytic converter to allow CO to react with NO.

.....

.....

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.....

..... **[3]**

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(d) Oil companies process hydrocarbons, such as octane, into branched and cyclic hydrocarbons that promote efficient combustion in petrol.

Draw the skeletal formulae of a branched hydrocarbon and a cyclic hydrocarbon, each containing eight carbon atoms.

[2]

(e) Some scientists believe that increased CO_2 levels arising from the combustion of hydrocarbons lead to global warming because CO_2 is a greenhouse gas. Carbon capture and storage, CCS, is being developed as a method for removing CO_2 produced by combustion.

(i) Different gases have different contributions to global warming.

State **two** factors that affect the contribution of a greenhouse gas to global warming.

.....

.....

.....

..... **[2]**

(ii) Outline **two** methods that could be developed to achieve carbon capture and storage, CCS.

.....

.....

.....

.....

..... **[2]**

[Total: 13]

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2 Enthalpy changes of combustion, ΔH_c, are amongst the easiest enthalpy changes to determine directly.

(a) Define the term *enthalpy change of combustion*.

.....

.....

.....

..... **[2]**

(b) A student carried out an experiment to determine the enthalpy change of combustion of pentan-1-ol, $CH_3(CH_2)_4OH$.

In the experiment, 1.76 g of pentan-1-ol was burnt. The energy was used to heat 250 cm^3 of water from 24.0 °C to 78.0 °C.

(i) Calculate the energy released, in kJ, during combustion of 1.76 g pentan-1-ol.

The specific heat capacity of water = 4.18 $J\,g^{-1}\,K^{-1}$.

Density of water = 1.00 $g\,cm^{-3}$.

energy = ... kJ **[1]**

(ii) Calculate the amount, in moles, of pentan-1-ol that was burnt.

amount = ... mol **[2]**

(iii) Calculate the enthalpy change of combustion of pentan-1-ol.

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

ΔH_c = ... $kJ\,mol^{-1}$ **[3]**

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(c) The standard enthalpy change of formation of hexane can be defined as:

The enthalpy change when 1 mol of hexane is formed from its constituent elements in their standard states under standard conditions.

Hexane melts at –95 °C and boils at 69 °C.

(i) What are *standard conditions*?

..... **[1]**

(ii) An incomplete equation is shown below for the chemical change that takes place to produce the standard enthalpy change of formation of hexane.

Add state symbols to the equation to show each species in its standard state.

$$6C(\ldots\ldots) + 7H_2(\ldots\ldots) \longrightarrow C_6H_{14}(\ldots\ldots)$$ **[1]**

(iii) It is very difficult to determine the standard enthalpy change of formation of hexane directly. Suggest a reason why.

.....

..... **[1]**

(iv) The standard enthalpy change of formation of hexane can be determined indirectly.

Calculate the standard enthalpy change of formation of hexane using the standard enthalpy changes of combustion below.

substance	$\Delta H_c^{\ominus}$ / kJ mol^{-1}
C	–394
H_2	–286
C_6H_{14}	–4163

answer = ... kJ mol^{-1} **[3]**

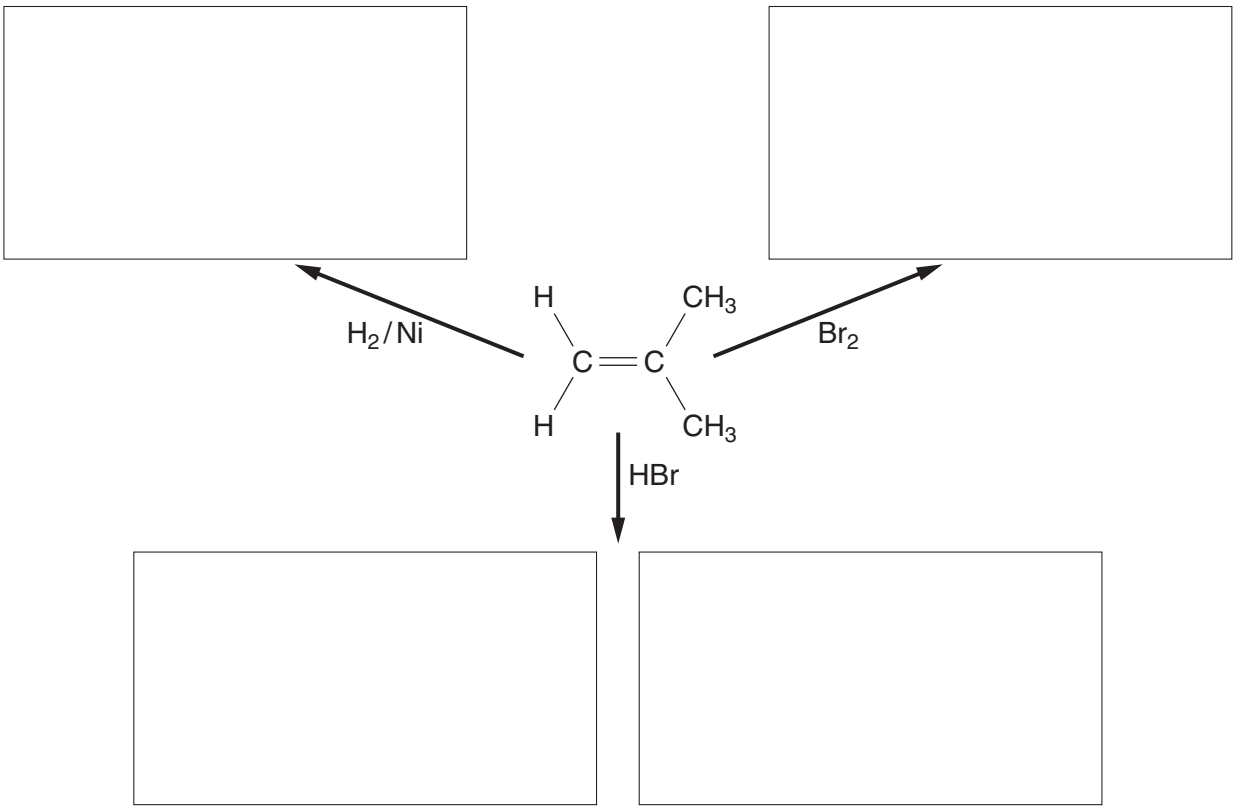
[Total: 14]

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3 Alkenes are unsaturated hydrocarbons used in the industrial production of many organic compounds.

(a) Complete the flowchart below to show the organic product formed in each addition reaction of methylpropene.



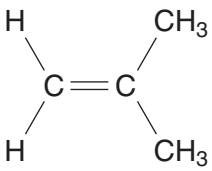
mixture of isomers

[4]

(b) Curly arrows are used in reaction mechanisms to show the movement of electron pairs during chemical reactions.

Use curly arrows to outline the mechanism for the addition reaction of methylpropene with bromine. The structure of methylpropene has been drawn for you.

Include relevant dipoles in your answer.

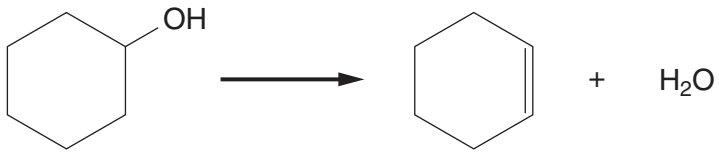


[4]

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(c) Alkenes can be prepared by the dehydration of alcohols with an acid catalyst. Cyclohexene can be prepared by the dehydration of cyclohexanol, shown below.



A student reacted 7.65 g of cyclohexanol, $C_6H_{12}O$, and obtained 0.0268 mol of cyclohexene.

(i) What is the molecular formula of cyclohexene?

..... **[1]**

(ii) Calculate the percentage yield of cyclohexene.

answer = ... % **[3]**

(d) Percentage yield has been used for many years to measure the 'success' of a reaction. Recently, chemists have turned their thoughts also to the atom economy of a reaction.

(i) Explain the term *atom economy*.

.....

..... **[1]**

(ii) Cyclohexene can also be prepared by the reaction below.



Explain why the atom economy of this cyclohexene preparation is higher than that from cyclohexanol in **(c)**.

.....

.....

.....

..... **[2]**

[Total: 15]

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4 In the chemical industry methanol, CH_3OH, is synthesised by reacting together carbon monoxide and hydrogen in the presence of copper, zinc oxide and alumina which act as a catalyst. This is a reversible reaction.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -91\,kJ\,mol^{-1}$$

(a) High pressures and low temperatures would give the maximum equilibrium yield of methanol. Explain why.

.....

.....

.....

.....

..... **[2]**

(b) Explain why the actual conditions used in the chemical industry might be different from those in **(a)** above.

.....

.....

.....

.....

..... **[2]**

(c) Catalysts are increasingly being used in chemical processes.

A catalyst speeds up a reaction without being consumed by the overall reaction.
A catalyst provides an alternative reaction route with a lower activation energy.

(i) Chlorine radicals, $Cl^{\bullet}$, catalyse some reactions.

Choose a reaction that you have studied that is catalysed by chlorine radicals.

Write down an equation for the overall reaction and show how chlorine radicals are **not** consumed by the overall reaction.

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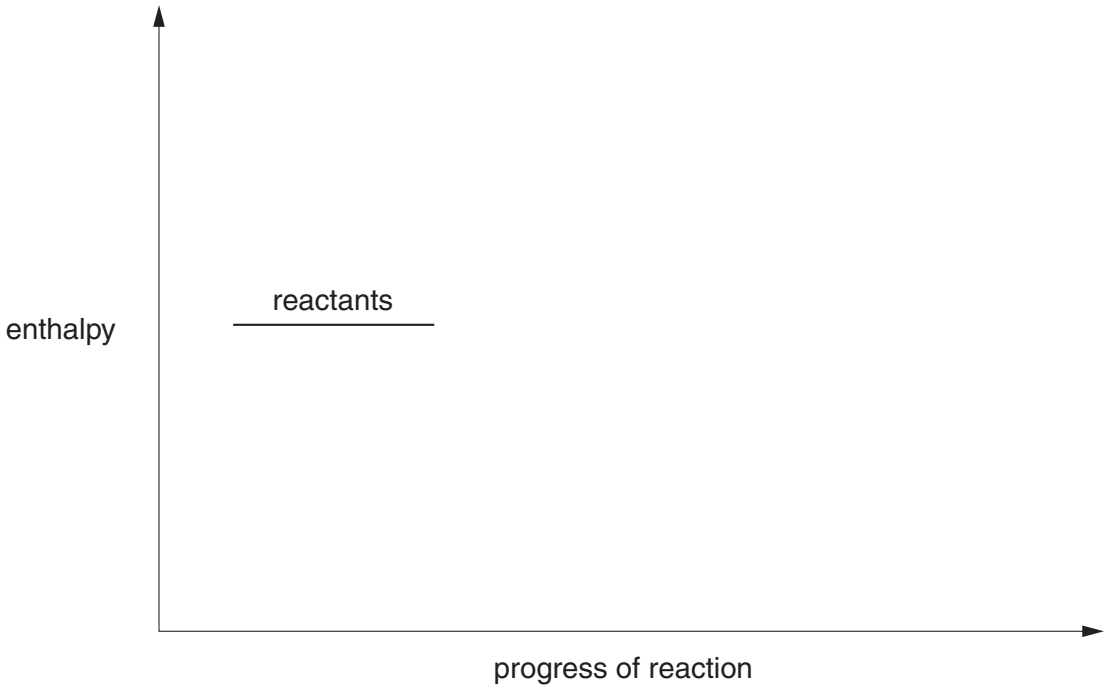
..... **[3]**

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(ii) Using the axes below, sketch an enthalpy profile diagram for an exothermic reaction to show how a catalyst provides an alternative reaction route with a lower activation energy. Include on your diagram labels for:

- enthalpy change, ΔH;
- activation energy for the catalysed route, E_c;
- activation energy for the uncatalysed route, E_a.



[3]

(d) Chemical companies are using catalysts to develop processes that are more sustainable. These processes reduce costs and are less harmful to the environment.

Suggest **two** ways in which the use of catalysts helps chemical companies to make their processes more sustainable.

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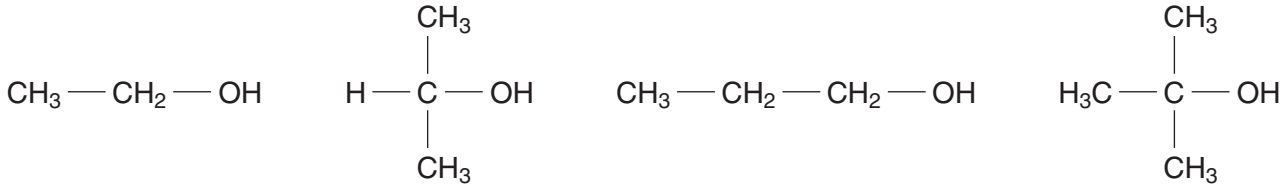
..... **[4]**

[Total: 14]

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5 Alcohols **A**, **B**, **C** and **D** are shown below.



A **B** **C** **D**

(a) Compound **A** is ethanol, a very useful alcohol.

Identify the two main methods used in the industrial production of ethanol.
Write an equation for each method.

method 1 .....

.....

equation .....

method 2 .....

.....

equation ..... **[4]**

(b) A student heated each alcohol, **A**–**D**, with acidified potassium dichromate(VI) as the oxidising agent. With alcohols **A**, **B** and **C**, the colour turned from orange to green.

(i) Identify the organic product and write a balanced equation for the reaction of alcohol **B** with acidified potassium dichromate(VI).

Use [O] to represent the oxidising agent, acidified potassium dichromate(VI).

organic product:

balanced equation:

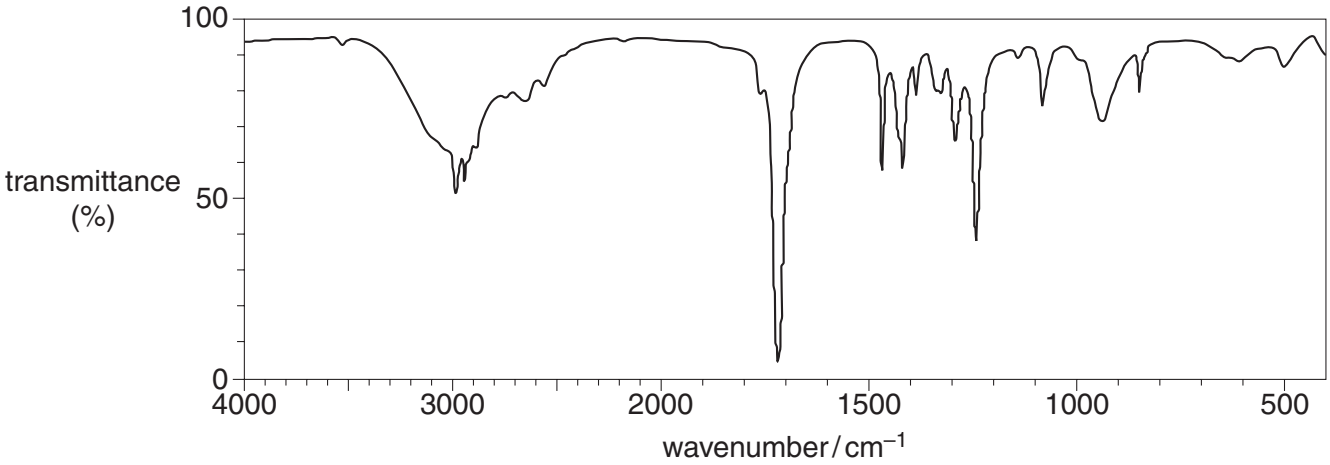
[2]

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(ii) The organic product obtained from **C** was analysed by infrared (IR) spectroscopy.

The IR spectrum of the product is shown below.



Use your *Data Sheet* to identify the organic product. Explain your reasoning.

organic product:

reasoning .....

.....

..... **[3]**

(c) The student heated alcohol **D** with ethanoic acid in the presence of an acid catalyst. An organic product **E** was formed with a fruity smell.

(i) Name alcohol **D**.

..... **[1]**

(ii) Name the functional group in the organic product **E**.

..... **[1]**

(iii) Draw the structure of the organic product **E**.

[2]

[Total: 13]

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6 A student carried out an investigation to compare the rates of hydrolysis of 1-iodopropane and 1-bromopropane. The student heated hot aqueous sodium hydroxide with each halogenoalkane and found that 1-iodopropane was hydrolysed faster.

The equation for the reaction with 1-iodopropane is shown below.

$$CH_3CH_2CH_2I + OH^- \longrightarrow CH_3CH_2CH_2OH + I^-$$

(a) (i) Outline the mechanism for this hydrolysis of 1-iodopropane.

Show curly arrows and relevant dipoles.

[3]

(ii) State the name of this type of mechanism.

..... **[1]**

(b) Explain why 1-iodopropane is hydrolysed faster than 1-bromopropane.

.....

.....

.....

..... **[2]**

(c) Chlorofluoroalkanes, CFCs, were developed from fluoroalkanes and were used in aerosols and as refrigerants. Under the Montreal Protocol, CFCs are now largely banned because of their ozone-depleting properties. CFCs have now been replaced in many applications.

Suggest **two** reasons why there is still concern about ozone depletion.

.....

.....

.....

.....

..... **[2]**

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(d) Fluoroalkenes are used to make polymers. For example, PVF, $(CH_2CHF)_n$, is used to make non-flammable interiors of aircraft.

(i) Draw **two** repeat units of the polymer PVF showing all bonds.

[1]

(ii) Draw the structure of the monomer of PVF.

[1]

(e) Once polymers have been used, they become waste.

Outline **two** ways that waste polymers are processed usefully, rather than just dumped in landfill sites.

.....

.....

.....

.....

..... **[2]**

[Total: 12]

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7 In this question, you are asked to suggest structures for several organic compounds.

(a) Compounds **F**, **G** and **H** are **unbranched** alkenes that are isomers, each with a relative molecular mass of 70.0.

Compounds **F** and **G** are *E*/*Z* stereoisomers.

Compound **H** is a structural isomer of compounds **F** and **G**.

- Explain what is meant by the terms *structural isomer* and *stereoisomer*.
- Explain why some alkenes have *E*/*Z* isomerism.
- Analyse this information to suggest possible structures for compounds **F**, **G** and **H**.



In your answer you should make clear how each structure fits with the information given above.

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..... **[11]**

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(b) An analytical chemist was provided with a compound **J** which has an unbranched carbon skeleton. After analysis, the chemist obtained the following results.

type of analysis	**evidence**
infrared spectroscopy	broad absorption at 3350 cm^{-1}
percentage composition by mass	C, 70.59%; H, 13.72%; O, 15.69%
mass spectrometry	molecular ion peak at m/z = 102.0

Use this information to suggest all the possible structures for the **unbranched** compound **J**.

In your answer you should make clear how your explanation is linked to the evidence.

[8]

[Total: 19]

END OF QUESTION PAPER

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F322 Chains, Energy and Resources

Question			Expected Answers	Marks	Additional Guidance
1	(a)		C_nH_{2n+2} ✓	1	**ALLOW** $C_nH_{2(n+1)}$ ✓ **IGNORE** size of subscripts
	(b)	(i)	$C_8H_{18} + 8½O_2 \rightarrow 8CO + 9H_2O$ ✓	1	**ALLOW** any correct multiples **IGNORE** state symbols
		(ii)	limited supply of air **OR** not enough O_2 ✓	1	**ALLOW** use of air or oxygen **IGNORE** it is not completely oxidised
	(c)	(i)	$2CO + 2NO \rightarrow 2CO_2 + N_2$ ✓	1	**ALLOW** any correct multiples including fractions **IGNORE** state symbols
	(c)	(ii)	CO and NO are adsorbed (onto surface) **OR** reactants are adsorbed (onto surface) ✓ weakening of bonds **OR** lowers activation energy ✓ CO_2 and N_2 desorbs (from the surface) **OR** products desorbs (from the surface) ✓	3	**ALLOW** CO and NO stick onto surface **OR** CO and NO form weak attractions to the surface **OR** gases are adsorbed onto surface **NOT** absorb but **allow** ecf for deabsorb later on **IGNORE** alternative pathway Requires less energy is not sufficient **ALLOW** products leave the surface **OR** products diffuse away from surface **OR** weak attraction to surface is broken **ALLOW** deadsorb
	(d)		skeletal formula of a branched isomer of C_8H_{18} ✓ skeletal formula of a cyclic hydrocarbon **OR** skeletal formula of substituted arene of C_8H_{10}✓	2	**ALLOW** any ring between C_3 and C_8 with 8 carbon atoms per molecule **IGNORE** wrong names If two correct structural or displayed formulae drawn award one mark

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Question			Expected Answers	Marks	Additional Guidance
	(e)		**Any TWO from:** atmospheric concentration ✓ ability to absorb infrared radiation ✓ residence time ✓	2	 **ALLOW** the amount of the gas **OR** abundance of gas **ALLOW** how much IR it absorbs **OR** ability to absorb heat **IGNORE** global warming potential / heat reflected / how much is produced **ALLOW** how long it stays in the atmosphere
			Any TWO from: deep in the oceans **OR** on the sea-bed ✓ storage in geological formations **OR** under the sea-bed ✓ by reaction (with metal oxides) to form carbonates ✓	2	 **ALLOW** piped into disused or partially filled oil wells **ALLOW** stored as a carbonate **OR** equation to show formation of suitable carbonate from an oxide **IGNORE** mineral storage **IGNORE** reforestation
			Total	13	

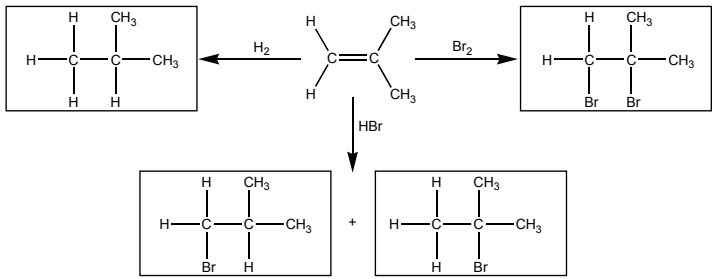
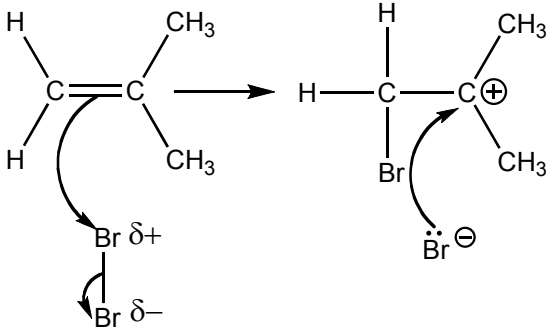
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Question			Expected Answers	Marks	Additional Guidance
2	(a)	(i)	The enthalpy change for the complete combustion ✓ of 1 mol (of a substance) ✓	2	**ALLOW** energy change for combustion in excess oxygen **OR** energy released during complete combustion **OR** energy change for combustion in excess air **NOT** energy required This mark is not stand alone but must relate to statement about an enthalpy change even if the statement was not awarded a mark
	(b)	(i)	56.430 (kJ) ✓	1	**ALLOW** 56.43 (kJ) **OR** 56.4 kJ ✓ **OR** 56 kJ **ALLOW** -56.43 i.e. ignore sign
		(ii)	M_r [$CH_3(CH_2)_4OH$] = 88.0 ✓ n = 0.0200 mol ✓	2	**ALLOW** 88 **ALLOW** 0.02 **OR** ecf from wrong M_r **ALLOW** full marks for 0.02 with no working out
		(iii)	(–)2821.5 ✓ = (–)2820 (3 SF) ✓ correct minus sign ✓	3	**ALLOW correct substitution into formula**(b)(i) ÷ (b)(ii) e.g. 56.4 ÷ 0.02 this is essentially a mark for the working **ALLOW** ecf from i.e. answer from (b)(i) ÷ (b)(ii) The minus mark is stand alone and is independent of the numerical answer
	(c)	(i)	pressure: 100 kPa **OR** 101 kPa **AND** temperature: 298 K **OR** 25 °C ✓	1	**units needed** **ALLOW** 1 bar **OR** 1 atm **OR** 760 mmHg **ALLOW** any stated temperature so for example 100kPa and 40°C would be credited with a mark **IGNORE** any reference to moles or concentration
		(ii)	$6C(s) + 7H_2(g) \rightarrow C_6H_{14}(l)$ ✓	1	**ALLOW** graphite / gr
		(iii)	many different hydrocarbons would form **OR** activation energy too high **OR** reaction too slow **OR** they don't react together ✓	1	**ALLOW** can form different isomers **OR** can form different structures **IGNORE** reaction may be reversible

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Question			Expected Answers	Marks	Additional Guidance
		(iv)	6 × –394 + 7 × –286 shown **OR** calculated as –4366 ✓ –4366 and –4163 added **OR** subtracted ✓ correct answer –4366 – (–4163) = –203 ✓	3	**ALLOW THREE** marks for –203 on its own with no working out or written on the answer line **ALLOW TWO** marks for +203,+3483, +1513, +1767 or -8529 on its own with no working out **ALLOW ONE** mark for or –3483, –1513, –1767 or +8529 on its own with no working out units **NOT** needed Positive sign not needed for endothermic answers
			Total	14	

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Question			Expected Answers	Marks	Rationale
3	(a)		 one mark for each correct structure ✓ ✓ ✓ ✓	4	**ALLOW** skeletal formula OR displayed formulae **IGNORE** molecular formulae **IF** two answers given e.g. name and structure then both must be correct to be given a mark **ALLOW** methylpropane **OR** $(CH_3)_3CH$ ✓ **ALLOW** 1,2-dibromo-methylpropane **OR** $CH_2BrCBr(CH_3)_2$ ✓ **ALLOW** 1-bromo-methylpropane **OR** $CH_2BrCH(CH_3)_2$ ✓ **ALLOW** 2-bromo-methylpropane **OR** $CH_3CBr(CH_3)_2$ ✓ **ALLOW** ecf if wrong carbon skeleton is used in all of the structures mark first structure wrong and then apply ecf for the rest
	(b)		curly arrow from double bond to $Br^{\delta+}$ and curly arrow from Br—Br bond pair to $Br^{\delta-}$ in 1st step ✓ curly arrow in 2nd step from bromide ion ✓ correct dipole shown on Br_2 ✓ correct carbocation shown ✓ 	4	Curly arrow must start from the double bond and not a carbon atom, other curly arrow must start from Br—Br bond **ALLOW** curly arrow from any part of bromide ion The bromide ion does not need to show a lone pair Dipole must be partial charge and not full charge Carbocation needs a full charge and not a partial charge (charges do not need to be surrounded by a circle) **ALLOW** carbocation on carbon 1 where electrophile attacks carbon 2 i.e. $^{+}CH_2CBr(CH_3)_2$

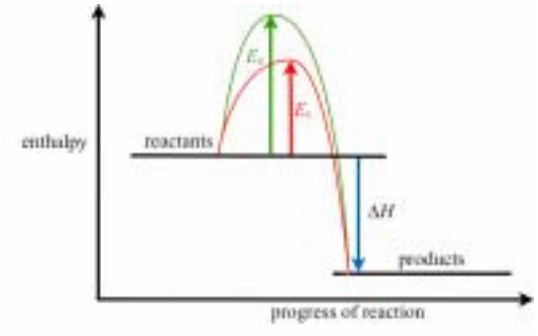
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Question			Expected Answers	Marks	Rationale
	(c)	(i)	C_6H_{10} ✓	1	
		(ii)	M_r(cyclohexanol) = 100 ✓ amount of cyclohexanol = 0.0765 mol ✓ percentage yield = 35.0% ✓	3	**ALLOW** full marks for correct answer with no or limited working out **ALLOW** ecf from wrong molar mass i.e. 7.65 ÷ molar mass **ALLOW** ecf from wrong amount in moles i.e. [0.0268 ÷ moles] × 100 **ALLOW** 35% **ALLOW** two marks for 0.35% If M_r of 82 is used then % yield will be 28.7 or 29 and this is worth two marks
	(d)	(i)	(sum of) the molecular masses of the desired product ÷ sum of molecular masses of all products × 100 ✓	1	**ALLOW** (sum of) the molecular masses of the desired product ÷ sum of molecular masses of all reactants × 100 ✓
		(ii)	this preparation is addition **OR** has 100% atom economy **OR** there is only one product ✓ preparation from cyclohexanol has less than100% atom economy **OR** H_2O is produced as well **OR** calculated atom economy = 82% ✓	2	**ALLOW** no by products formed **ALLOW** other substances formed **OR** cyclohexene is not the only product
			Total	15	

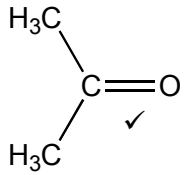
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Question			Expected Answers	Marks	Additional Guidance
4	(a)		high pressure as fewer moles (of gas) on right-hand side OR high pressure as volume of products less than that of reactants ✓ low temperature as (forward) reaction is exothermic ✓	2	**ALLOW** ora **ALLOW** fewer particles **OR** fewer molecules **ALLOW** ora
	(b)		Too expensive to use a high pressure ✓ Too slow to use a low temperature ✓	2	**ALLOW** high pressures provide a safety risk **OR** high pressure is too dangerous **ALLOW** with low temperature molecules cannot overcome activation barrier
	(c)	(i)	$Cl + O_3 \rightarrow ClO + O_2$ ✓ $ClO + O \rightarrow Cl + O_2$ ✓ overall: $O_3 + O \rightarrow 2O_2$ ✓ **OR** $Cl + CH_4 \rightarrow CH_3 + HCl$ ✓ $CH_3 + Cl_2 \rightarrow CH_3Cl + Cl$ ✓ overall: $CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$ ✓	3	Marks must come from one or other of the radical process and not from both of them. If two processes are described then an incorrect step in one process will contradict a correct step in the other process. **ALLOW** overall equation mark even if the steps are wrong the radicals do **NOT** need a single dot **IGNORE** any state symbols **ALLOW** $Cl + O_3 \rightarrow ClO + O_2$ ✓ $ClO + O_3 \rightarrow Cl + 2O_2$ ✓ overall: $2O_3 \rightarrow 3O_2$ ✓ **ALLOW** any saturated hydrocarbon including cyclic **ALLOW** ecf for second step and overall reaction if wrong hydrocarbon used e.g. C_2H_4 is used in first step

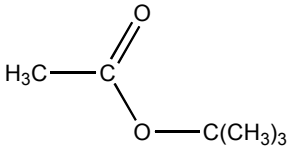
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Question			Expected Answers	Marks	Additional Guidance
		(ii)	ΔH shown **and** products below reactants ✓ E_a shown ✓ E_c shown < E_a ✓  	3	**NOT** double headed arrows but apply ecf for more than one double headed arrow **ALLOW** one mark if two correctly labelled curves are drawn but the arrows are not shown or are incorrectly drawn The arrows must be positioned as closely as possible to the maximum height of the curves but allow some degree of bod
	(d)		**Any FOUR from:** catalyst not used up in reaction ✓ reactions take place at lower temperatures ✓ with lower energy demand **OR** lower activation energy **OR** use less fuel ✓ so less carbon dioxide emitted into atmosphere **OR** so fossil fuels last longer ✓ different reactions can be used ✓ with better atom economy **OR** less waste ✓ less hazardous chemicals ✓ catalysts or enzymes can generate specific products ✓	4	 **ALLOW** catalysts can work at room temperature **OR** enzymes work at room temperature **IGNORE** cheaper
			Total	**14**	

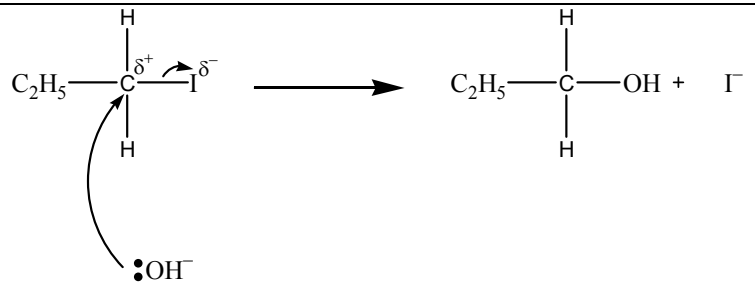
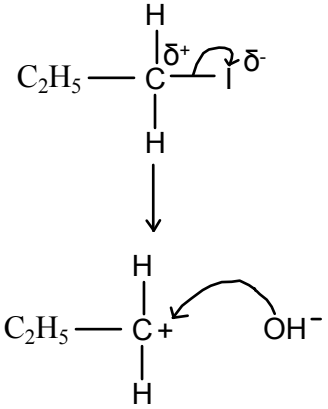
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Question			Expected Answers	Marks	Additional Guidance
5	(a)		**method 1:** fermentation of sugars or carbohydrates **OR** reaction with yeast with sugar or carbohydrates ✓ $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$ ✓ **method 2:** hydration of ethene OR reaction of ethene with water **OR** reaction of steam with ethene ✓ $C_2H_4 + H_2O \rightarrow C_2H_5OH$ ✓	**4**	**ALLOW** sugar from equation **ALLOW** C_2H_6O in equation **ALLOW** correct multiples **IGNORE** state symbols **ALLOW** ethene from the equation **IGNORE** mention of any catalyst **ALLOW** C_2H_6O in equation **OR** H_2O over the arrow **ALLOW** correct multiples **IGNORE** state symbols
	(b)	(i)	$(CH_3)_2CO$ **OR**  ✓ $(CH_3)_2CHOH + [O] \longrightarrow (CH_3)_2CO + H_2O$ ✓	**2**	If name and formula given both need to be correct **ALLOW** propanone **OR** acetone **IGNORE** propone **NOT** incorrect named compound **ALLOW** $C_3H_8O + [O] \rightarrow C_3H_6O + H_2O$ **ALLOW** O instead of [O] **ALLOW** correct multiples **IGNORE** state symbols
		(ii)	CH_3CH_2COOH **OR** propanoic acid ✓ Any number or range of numbers between 1750–1640 (cm^{-1}) for C=O ✓ Any number or range of numbers between 2500–3300 (cm^{-1}) for O–H ✓	**3**	 **ALLOW** C=O and O—H marks independent of compound identified **i.e. stand alone marks** **ALLOW** correct bonds shown by the appropriate absorption on the IR spectrum **IGNORE** reference to C—O bond
	(c)	(i)	2-methylpropan-2-ol ✓	**1**	**ALLOW** methylpropan-2-ol **OR** tertiarybutanol

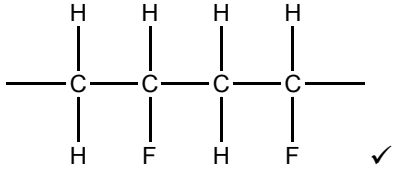
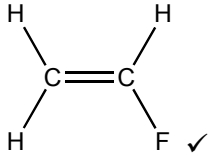
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Question			Expected Answers	Marks	Additional Guidance
		(ii)	ester ✓	1	
		(iii)	$CH_3CO_2C(CH_3)_3$ **OR** $CH_3COOC(CH_3)_3$ **OR**  ester group shown ✓ rest of molecule ✓	2	**ALLOW** skeletal formula **OR** displayed formula **ALLOW** ester linkage even if rest of structure is wrong
			Total	13	

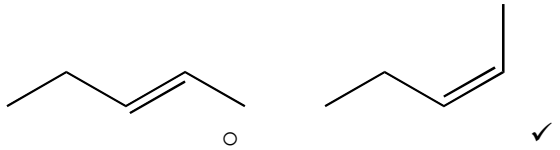
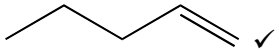
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Question			Expected Answers	Marks	Additional Guidance
6	(a)	(i)	 C–I curly arrow from the bond not from carbon atom ✓ curly arrow from the OH^- ✓ correct partial charges on C—I ✓	3	no need to show any lone pairs on oxygen but must have a clear negative sign rather than partial negative charge **IGNORE** lone pairs **IGNORE** products of this reaction **ALLOW** curly arrow from a negative charge or from any part of hydroxide ion If S_N1 mechanism is given then use the mark scheme below correct partial charges on C—I ✓ C–I curly arrow from the bond not from carbon atom ✓ curly arrow from the OH^- to the **correct** carbocation ✓ 
		(ii)	nucleophilic substitution ✓	1	
	(b)		C–I bonds broken more easily ✓ C–I bonds are weaker **OR** have less bond enthalpy **OR** C–I bonds are longer ✓	2	**ALLOW** ora e.g. C—Br bonds are stronger **OR** broken less easily

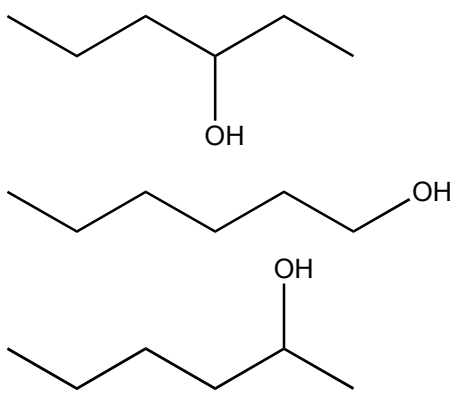
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Question			Expected Answers	Marks	Additional Guidance
	(c)		**Any TWO from:** CFCs take many years to reach the ozone layer **OR** long residence time ✓ CFCs are still being used ✓ there are other ozone depleting substances ✓	2	 **IGNORE** because chlorine radicals stay in the stratosphere **ALLOW** other named ozone depleting substances e.g. NO and HFCs
	(d)	(i)	 ✓	1	Free bonds at bond ends must be present **ALLOW** minor slip e.g. missing one hydrogen and left as a stick **ALLOW** more than two repeat units but must be a whole number of repeat units **IGNORE** brackets, use of numbers and n in the drawn structure
		(ii)	 ✓	1	**ALLOW** skeletal formula **ALLOW** CH_2CHF
	(e)		**Any two from:** separation into types and recycling **OR** sort plastics, melt and remould ✓ combustion for energy generation ✓ used for cracking **OR** feedstock for plastics or chemicals ✓	2	**IGNORE** biodegradable used as a fuel is insufficient releases energy is insufficient **ALLOW** burning plastics to release energy **ALLOW** organic feedstock / raw materials to make organic compounds
			Total	12	

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Question			Expected Answers	Marks	Additional Guidance
7	(a)		**Structural isomer** compounds with the same molecular formula ✓ but with different structural formulae ✓ **Stereoisomer** compounds with the same structural formula ✓ but with different arrangements in space ✓ **Evidence** of using M_r of 70 to **calculate** molecular formula of C_5H_{10} ✓ **F** and **G** are  ○ ✓ Correct identification of the *E* and *Z* isomers ✓ **H is**  ✓ ***E/Z* happens because** double bonds restricts rotation ✓ different groups on each carbon of the double bond ✓	11	**ALLOW** same molecular formula ✓ but different structures✓ Second marking point is **DEPENDENT** on first mark **ALLOW** compounds with the same structure Second marking point is **DEPENDENT** on first mark This is the QWC mark **IGNORE** wrong names of **F**, **G** and **H** **ALLOW** structural or displayed formulae for **F**, **G** and **H** e.g. **H is** $CH_3CH_2CH_2CHCH_2$ **ALLOW** identification using *trans* and *cis* and **ALLOW** this marking point as identification of another example of identifying *E/Z* or *cis* and *trans* if not done for **F** and **G** **ALLOW** one mark if no structures drawn but correct names given for **F**, **G** and **H** i.e *E*-pent-2-ene, *Z*-pent-2-ene and pent-1-ene **ALLOW** ecf on structures if wrong molecular formula used or consistent error or slip such as having just sticks

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Question	Expected Answers	Marks	Additional Guidance
(b)	from IR absorption, **J** contains O–H **OR** from IR **J** is an alcohol✓ C : H : O = $\frac{70.59}{12.0}$: $\frac{13.72}{1.0}$: $\frac{15.69}{16.0}$ **OR** 5.8825 : 13.72 : 0.9806 ✓ empirical formula = $C_6H_{14}O$ ✓ (from mass spectrum), M_r = 102 ✓ evidence that it has been shown that the empirical formula is the molecular formulae e.g. M_r of $C_6H_{14}O$ = 102 so empirical formula is molecular formula ✓  One mark for each correct structure ✓ ✓ ✓	8	This is a QWC mark **ALLOW two** marks for correct empirical formula with no working out This is a QWC mark **ALLOW** structural or displayed formulae **IGNORE** incorrect names **ALLOW** one minor slip in drawing structures e.g. one missing hydrogen but **ALLOW** ecf for bigger slips such as showing just sticks and no hydrogen atoms **ALLOW** bond to H in OH **ALLOW one** mark for three isomers of $C_6H_{13}OH$ whether branched or unbranched as a catch mark if no other mark has been awarded for the structures If more than three isomers of $C_6H_{13}OH$ drawn • 1 branched and 3 unbranched award **two** marks • any other combination award **one** mark **ALLOW** one mark for hexan-1-ol, hexan-2-ol and hexan-3-ol if structures not drawn
	Total	**19**	

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