AQA A-LEVEL CHEMISTRY

CHEMISTRY



EXAM QUESTION PACK

UNIT 2 OLD SPECIFICATION PAPERS

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AQA

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Centre number | | | | | | Candidate number | | | | |

Surname _____

Forename(s) _____

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AS CHEMISTRY

Unit 2 Chemistry in Action

Friday 10 June 2016 Afternoon Time allowed: 1 hour 45 minutes

Materials

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator.

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use scientific terminology accurately.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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Section A

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

1 This question is about the Group 2 metals and their compounds.

1 (a) Explain why the first ionisation energy of barium is less than the first ionisation energy of calcium.

[2 marks]

1 (b) Magnesium reacts readily with steam.

State **two** observations you would make when magnesium reacts with steam. Write an equation for the reaction.

[3 marks]

Observation 1 _____

Observation 2 _____

Equation _____

Do not write outside the box

1 (c) Explain why different observations are made when aqueous barium chloride is added separately to aqueous magnesium sulfate and to aqueous magnesium nitrate.

Write the simplest ionic equation, including state symbols, for any reaction that occurs.

[2 marks]

Explanation _____

_____

_____

_____

_____

Equation _____

7

Turn over for the next question

Do not write outside the box

2 Standard enthalpy of combustion data can be used to calculate enthalpies of formation.

2 (a) State the meaning of the term standard enthalpy of combustion.

[3 marks]

2 (b) The equation corresponding to the enthalpy of formation of propan-1-ol is shown.

$$3C(s) + 4H_2(g) + \frac{1}{2}O_2(g) \longrightarrow CH_3CH_2CH_2OH(l)$$

Table 1 contains some standard enthalpy of combustion data.

Table 1

	C(s)	**H_2(g)**	**$CH_3CH_2CH_2OH$(l)**
$\Delta H_c^{\ominus}$ / kJ mol^{-1}	–394	–286	–2010

Use data from **Table 1** to calculate a value for the standard enthalpy of formation of propan-1-ol. Show your working.

[3 marks]

Do not write outside the box

2 (c) An equation for the complete combustion of gaseous propan-1-ol is shown.

$$CH_3CH_2CH_2OH(g) + 4\tfrac{1}{2}O_2(g) \longrightarrow 3CO_2(g) + 4H_2O(g) \quad \Delta H = -1893 \text{ kJ mol}^{-1}$$

Table 2 shows some bond enthalpy data.

Table 2

	C–H	**C–O**	**O–H**	**C=O**	**O=O**
Bond enthalpy / kJ mol^{-1}	412	360	463	805	496

Use data from **Table 2** and the enthalpy change for this reaction to calculate a value for the bond enthalpy of a C–C bond in propan-1-ol.

[3 marks]

9

Turn over for the next question

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3 Haloalkanes are used as refrigerants, solvents and anaesthetics.

3 (a) Trichloromethane ($CHCl_3$) is a haloalkane that can be formed by heating a mixture of chloromethane (CH_3Cl) and chlorine.

3 (a) (i) Write an overall equation for the formation of trichloromethane by the reaction of chloromethane with chlorine.

[1 mark]

3 (a) (ii) Name the mechanism for this formation of trichloromethane.

[1 mark]

3 (a) (iii) Dichloromethane (CH_2Cl_2) is an intermediate in this formation of trichloromethane.

Write an equation for each of the following steps in the mechanism for the reaction of dichloromethane with chlorine.

[4 marks]

Initiation step

First propagation step

Second propagation step

A termination step leading to the formation of a compound with formula $C_2H_2Cl_4$

Do not write outside the box

3 (b) Chlorotrifluoromethane ($CClF_3$) is used as a refrigerant, but is being phased out due to concerns about ozone depletion in the upper atmosphere.
In the upper atmosphere, $CClF_3$ decomposes in the presence of UV light forming a reactive intermediate that catalyses the decomposition of ozone.

3 (b) (i) Write an equation to show how $CClF_3$ decomposes to form the reactive intermediate.

[1 mark]

_____

3 (b) (ii) Write two equations to show how this reactive intermediate is involved in catalysing the decomposition of ozone.

[2 marks]

1 _____

2 _____

9

Turn over for the next question

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4 Compounds **A**, **B**, **C** and **D** are isomers with the molecular formula $C_4H_{10}O$
They all have a broad absorption in their infrared spectra in the range 3230–3550 cm^{-1}.

4 (a) Use **Table A on the data sheet** to identify the bond and the functional group present responsible for this absorption.

[1 mark]

_____

4 (b) Compounds **A** and **B** are both straight-chain compounds.
A can be oxidised to form **P**.
B can be oxidised to form **Q**.
P and **Q** are isomers with molecular formula C_4H_8O

Tollens' reagent and Fehling's solution can be used to distinguish between isomers **P** and **Q**. The results shown in **Table 3** are obtained.

Table 3

Compound	Observation with Tollens' reagent	Observation with Fehling's solution
P	No visible change	No visible change
Q	Silver mirror formed	Brick-red precipitate formed

Use the information about compounds **P** and **Q** to identify compounds **A** and **B**.
Explain your answer with reference to the functional groups in **P** and **Q**.

[3 marks]

Identity of **A** _____

Identity of **B** _____

Explanation _____

_____

_____

_____

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4 (c) Isomer **C** is resistant to oxidation.
Isomer **C** reacts to form compound **R** that has an absorption in its infrared spectrum in the range 1620–1680 cm^{-1}.

State the bond that causes the absorption in the range 1620–1680 cm^{-1}.

Give the displayed formula of isomer **C**.

Identify the reagent and give **one** reaction condition needed to convert **C** into **R**.

[4 marks]

Bond _____

Displayed formula of **C**

Reagent _____

Condition _____

Question 4 continues on the next page

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4 (d) Compound **D** is a branched-chain isomer that can be oxidised to form compounds **S** and **T**.

4 (d) (i) Compound **S** is obtained by distilling it off as it forms during the oxidation. Compound **T** is formed when the oxidation takes place under reflux.

Identify the functional groups in **S** and **T**.

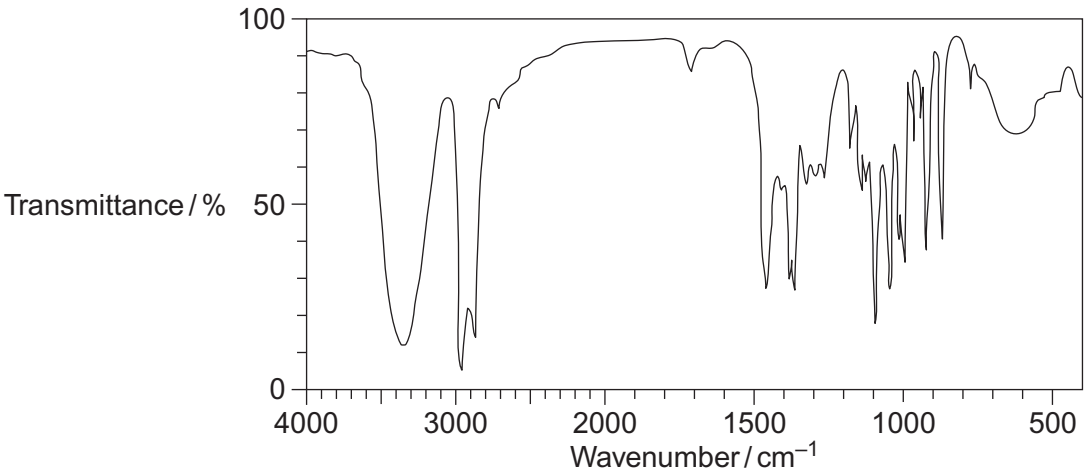
Explain, with reference to intermolecular forces, why it is possible to obtain compound **S** but not **T** from the reaction mixture by distilling off **S** as soon as it forms.

[3 marks]

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4 (d) (ii) A student claims to have oxidised compound **D**.
Figure 1 shows the infrared spectrum of the product obtained by the student.

Figure 1



Suggest two ways in which the spectrum shows that compound **D** has **not** been oxidised.

[2 marks]

13

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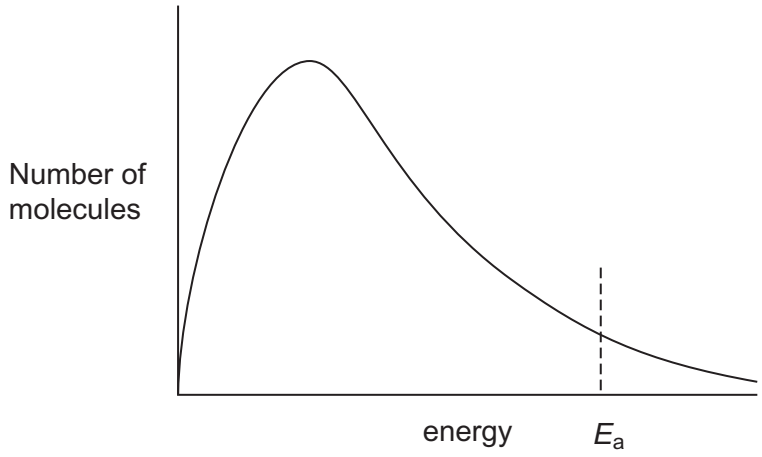
5 Methanol, for use as a fuel, can be produced by the reaction of carbon monoxide with hydrogen.

$$CO(g) + 2H_2(g) \rightleftharpoons CH_3OH(g) \qquad \Delta H = -90 \text{ kJ mol}^{-1}$$

The reaction is typically carried out at 300 ºC and 3×10^7 Pa, in the presence of a catalyst.

5 (a) **Figure 2** shows the Maxwell–Boltzmann distribution for a mixture of carbon monoxide and hydrogen at 300 ºC.

Figure 2



5 (a) (i) Sketch a second curve on **Figure 2** to show the distribution of molecular energies in this mixture at a higher temperature.

[1 mark]

5 (a) (ii) Explain with reference to both curves in **Figure 2** how a small change in temperature leads to a large change in the rate of reaction.

[2 marks]

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5 (b) Both the rate of production and equilibrium yield of methanol are considered when choosing the most appropriate conditions for the operation of this process on an industrial scale.

5 (b) (i) State and explain the effect of a higher pressure on the equilibrium yield of methanol.

[3 marks]

5 (b) (ii) By considering both rate and yield, state why the reaction is carried out at a temperature of 300 ºC rather than at a higher temperature.

[2 marks]

8

Turn over for the next question

Do not write outside the box

6 The halogens are the elements in Group 7.

6 (a) The electronegativities of the halogens are shown in **Table 4**.

Table 4

Halogen	**Fluorine**	**Chlorine**	**Bromine**	**Iodine**
Electronegativity	4.0	3.0	2.8	2.5

Explain the trend in electronegativities shown by the halogens.

[2 marks]

6 (b) The halogens can all behave as oxidising agents in reactions.

6 (b) (i) Explain, in terms of electron transfer, the meaning of the term oxidising agent.

[1 mark]

6 (b) (ii) An equation for the reaction that takes place when chlorine gas is bubbled through aqueous potassium bromide is shown.

$$Cl_2(g) + 2KBr(aq) \longrightarrow Br_2(aq) + 2KCl(aq)$$

Explain, with reference to the oxidation states, why this is a redox reaction.

[1 mark]

Do not write outside the box

6 (c) Solid sodium halides react with concentrated sulfuric acid.

6 (c) (i) A sample of solid sodium iodide is reacted with concentrated sulfuric acid.
A black solid forms and hydrogen sulfide gas is produced.

Write a half-equation for the reaction of sulfuric acid to form hydrogen sulfide.

[1 mark]

---

6 (c) (ii) Write a half-equation for the formation of the black solid.

[1 mark]

---

6 (c) (iii) Use your answers to parts **(c) (i)** and **(c) (ii)** to write an overall equation for the reaction of sodium iodide with concentrated sulfuric acid.

[1 mark]

---

6 (c) (iv) Give the role of sulfuric acid in its reaction with sodium iodide.
Tick (✓) **one** box.

[1 mark]

Acid ☐

Oxidising agent ☐

Reducing agent ☐

Electrophile ☐

6 (c) (v) Write an equation for the reaction of concentrated sulfuric acid with solid sodium fluoride.

[1 mark]

---

6 (c) (vi) Suggest **one** reason why the reaction of sodium fluoride with concentrated sulfuric acid is different from the reaction with sodium iodide.

[1 mark]

Turn over ▶

Do not write outside the box

6 (d) Chlorine reacts with water to form an equilibrium mixture containing hydrochloric acid and chloric(I) acid.

6 (d) (i) Write an equation for the formation of this equilibrium mixture.

[1 mark]

6 (d) (ii) Household bleach contains sodium chlorate(I) and sodium chloride.
State and explain, with reference to your equation in part **(d)(i)**, why it is dangerous to acidify an aqueous mixture of sodium chlorate(I) and sodium chloride.

[2 marks]

13

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7 The ores used for the extraction of many metals contain metal sulfides or metal oxides. Various methods are used to extract metals from these ores.

7 (a) Sulfide ores such as zinc blende (ZnS) are crushed and then roasted in a stream of air to convert them into the metal oxide.

7 (a) (i) Write an equation for the reaction that takes place when ZnS is roasted in air.

[1 mark]

_____

7 (a) (ii) State a useful substance that can be manufactured from the gaseous product of this reaction.

[1 mark]

_____

7 (b) Zinc oxide is reduced by carbon monoxide in the extraction of zinc. The carbon monoxide is produced by the incomplete combustion of methane.

7 (b) (i) Write an equation for the production of carbon monoxide by the incomplete combustion of methane.

[1 mark]

_____

7 (b) (ii) Write an equation for the reaction between zinc oxide and carbon monoxide.

[1 mark]

_____

7 (c) Most copper is produced by reduction of copper(II) oxide with carbon. The copper(II) oxide is produced by roasting chalcopyrite ($CuFeS_2$) in air.

Copper can also be obtained from other low-grade ores. When these low-grade ores are processed, aqueous solutions containing low concentrations of Cu^{2+} ions are produced. Scrap iron is used to recover copper from these solutions.

7 (c) (i) Give the ionic equation for the reaction involved in the recovery of solid copper from an aqueous solution using scrap iron. Include state symbols.

[1 mark]

_____

Do not write outside the box

7 (c) (ii) Suggest two environmental reasons and one economic reason why the extraction of copper from solutions containing Cu^{2+} ions, using iron, is preferable to the reduction of copper(II) oxide made by roasting chalcopyrite.

[3 marks]

Environmental reason 1 _____

_____

_____

Environmental reason 2 _____

_____

_____

Economic reason _____

_____

_____

7 (d) Titanium can be extracted from its ore, rutile (TiO_2), in a two-step process using carbon, chlorine and magnesium. Extraction of titanium is not possible by direct reduction of TiO_2 with carbon.

7 (d) (i) Give equations for the two-step process using carbon, chlorine and magnesium.

[2 marks]

Step 1 _____

Step 2 _____

7 (d) (ii) State why direct reduction of TiO_2 with carbon cannot be used.

[1 mark]

_____

_____

11

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Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

Do not write outside the box

Section B

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

8 Two reactions of 2-bromopentane, ($CH_3CH_2CH_2CHBrCH_3$) are shown.

$$C_5H_{10} \xleftarrow{\text{reaction } \mathbf{1}} CH_3CH_2CH_2CHBrCH_3 \xrightarrow{\text{reaction } \mathbf{2}} C_5H_{11}OH$$

The C_5H_{10} formed in reaction **1** exists as a mixture of three isomers, one of which is pent-1-ene. Two of the isomers are a pair of stereoisomers. All three isomers decolourise bromine.

8 (a) The same reagent is used in both reactions. The product is determined by the choice of conditions.

State the reagent and the conditions for each of reaction **1** and reaction **2**.

State the role of the reagent in each reaction.

Name and outline the mechanism of reaction **1** for the formation of pent-1-ene.

[8 marks]

Do not write outside the box

8 (b) All three isomers of C_5H_{10} contain the same functional group.

Draw the displayed formula of pent-1-ene.

Draw the structures of the pair of stereoisomers and give their full IUPAC names.

Explain the origin of the stereoisomerism shown.

[5 marks]

Do not write outside the box

8 (c) The rates of hydrolysis of two chloroalkanes can be investigated by adding aqueous silver nitrate to the chloroalkanes. During the hydrolysis reactions, chloride ions are liberated slowly. Precipitates of silver chloride are formed.

Outline a method to compare the rate of hydrolysis of 1-chlorobutane with that of 2-chlorobutane. State how the method would ensure a fair test.

[4 marks]

17

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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9 Alcohols can be prepared from alkenes in various ways.

9 (a) On a laboratory scale, a mixture of propan-1-ol and propan-2-ol can be prepared from propene in two steps.

In step 1, propene reacts with cold, concentrated sulfuric acid to form intermediate compounds.

In step 2, the intermediate compounds react with water to form the mixture of alcohols.

Name and outline the mechanism for the reaction between propene and concentrated sulfuric acid to form the intermediate compound which gives propan-2-ol in step 2.

Explain why propan-2-ol is the major product of this preparation.

[7 marks]

Do not write outside the box

9 (b) On an industrial scale ethanol can be produced from ethene by direct hydration or from glucose by fermentation.

State the conditions for the direct hydration reaction.

State two advantages and two disadvantages of the fermentation method compared with the direct hydration method.

[6 marks]

13

END OF QUESTIONS

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AQA Qualifications

A-LEVEL

Chemistry

CHEM2 Chemistry in Action

Mark scheme

2420
June 2016

Version: 1.0 Final

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Question	Answers	Mark	Additional Comments/Guidance
1a)	more (electron) shells / (outer) electrons further from the nucleus / larger atoms / more shielding so weaker <u>attraction</u> of nucleus/protons for (outer) electrons	1 1	If 'molecules' mentioned CE = 0 It = Ba Mark independently **ALLOW** energy levels for shells Both ideas must be comparative **NOT** hold/pull/bonded for 'attraction' idea of nucleus or protons must be clear **ALLOW** M2 if electrons implied from mention in M1 **ALLOW** converse if it is clear that answer refers to Ca
1b)	<u>White</u> solid / <u>white</u> ash Bright light / white light $Mg + H_2O \rightarrow MgO + H_2$	1 1 1	**ALLOW** 'white smoke/powder' **IGNORE** 'product' **NOT** ppt **IGNORE** fumes **IGNORE** tube/glass goes black **ALLOW** glow/flame for light **IGNORE** state symbols
1c)	$BaSO_4$ is insoluble but $Ba(NO_3)_2$ is soluble **OR** $BaSO_4$ precipitates but $Ba(NO_3)_2$product(s) of second reaction is soluble/remains in solution **OR** $BaSO_4$ is insoluble but no reaction occurs in second case $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$	1 1	**NOT** just 'no observation' in second case **<u>Comparison</u> of solubilities must be implied** **NOT** Barium is soluble/insoluble **Correct state symbols required**
Total		**7**	

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Question	Answers	Mark	Additional Comments/Guidance
2a)	The <u>enthalpy / heat energy change</u> when <u>1 mol</u> (of a substance)	1	If enthalpy of formation definition given CE=O **NOT** just 'energy' **ALLOW** alternatives for substance e.g. molecule/compound/element
	is <u>burned/reacts completely in oxygen</u>	1	**ALLOW** reacts in excess oxygen
	with all reactants and products in their <u>standard states</u> **OR** With all reactants and products in their normal states at 298K/given temp & 100kPa	1	**ALLOW** 'everything' for 'reactants and products' Penalise incorrect conditions if given **ALLOW** 'normal states under standard conditions'
2b)	$\Delta H = \Sigma\Delta H_c$(reactants) - $\Sigma\Delta H_c$ (products) **OR** correctly and fully balanced cycle	1	Correct answer scores 3
	$\Delta H = [3(-394) + 4(-286)] – (-2010)$ **OR** $\Delta H = -2326 + 2010$	1	M2 also scores M1
	$\Delta H = -316$ (kJ mol^{-1}) +316 scores 1 mark only	1	**IGNORE** units Check for AE in working – can award M3 as ecf (error carried forward) from M2 if M2 not given due to AE

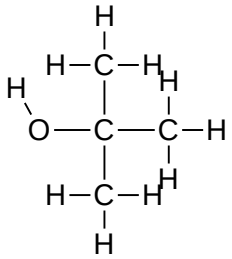
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2c)	ΔH/-1893 = ΣB(reactants) - ΣB(products) **OR** ΔH/-1893 = ΣBonds broken - ΣBonds formed **OR** ΔH/-1893 = 2B(C-C) + 7B(C-H) + B(C-O) + B(O-H) + 4½ B(O=O) – 6B(C=O) – 8B(O-H)	1	Correct answer gains 3 marks
	-1893= 2B(C-C) + 7(412) + 360 + 463 + 4½(496) – 6(805) – 8(463) **OR** -1893= 2B(C-C) +5939 – 8534 **OR** -1893= 2B(C-C) -2595 **OR** 2B(C-C) = 702	1	M2 also scores M1 May see no 463 in bonds broken and 7x463 in made (gives 5476 – 8071)
	B(C-C) = (+)351(kJ mol^{-1})	1	If **NOT** 351 check for AE. This would lose M2, but could gain M1 and M3 (+)234 scores 1 (due to 3(C-C)) **NOT** M3 from incorrect M2 unless incorrect M2 is due to AE **IGNORE** Units If no other mark awarded then **ALLOW** 1 if 5939 or 5476 or 8534 or 8071 seen
Total		**9**	

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Question	Answers	Mark	Additional Comments/Guidance
3a) i.	$CH_3Cl + 2Cl_2 \rightarrow CHCl_3 + 2HCl$	1	**IGNORE** state symbols **ALLOW** multiples
3a) ii.	(Free-)radical substitution	1	This answer only
3a) iii.	Initiation: $Cl_2 \rightarrow 2Cl\bullet$ 1st Propagation step $Cl\bullet + CH_2Cl_2 \rightarrow \bullet CHCl_2 + HCl$ 2nd Propagation step $\bullet CHCl_2 + Cl_2 \rightarrow CHCl_3 + Cl\bullet$ Termination $2 \bullet CHCl_2 \rightarrow C_2H_2Cl_4$	1 1 1 1	Penalise absence of dot once only Penalise + and/or – charges every time **ALLOW** • anywhere on $\bullet CHCl_2$ but, if drawn out as a structure, then • must be on C Mark independently **ALLOW** $\bullet CH_2Cl + \bullet CCl_3 \rightarrow C_2H_2Cl_4$ **IGNORE** state symbols throughout
3b) i.	$CClF_3 \rightarrow \bullet CF_3 + Cl\bullet$	1	**ALLOW** • anywhere on $\bullet CF_3$ unless displayed
3b) ii.	$Cl\bullet + O_3 \rightarrow ClO\bullet + O_2$ $ClO\bullet + O_3 \rightarrow 2O_2 + Cl\bullet$	1 1	Equations can be in either order Penalise absence of • once only **ALLOW** • anywhere on $\bullet ClO$ **NOT** $\bullet O_3$
Total		**9**	

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Question	Answers	Mark	Additional Comments/Guidance
4a)	OH AND alcohol	1	**IGNORE** hydroxy(l)
4b)	**A** = butan-2-ol / $CH_3CH(OH)CH_2CH_3$ **B** = butan-1-ol / $CH_3CH_2CH_2CH_2OH$ product from **A** / **P** is a ketone **AND** product from **B** / **Q** is an aldehyde	1 1 1	If formulae given then must be unambiguous If both formula and name given then formula must match name for mark to be awarded Penalise reference to incorrect class of alcohol
4c)	Type of Bond: C=C  Reagent: conc. H_2SO_4 / conc. H_3PO_4 Conditions: 180 °C / High temp / Hot / Reflux /	1 1 1 1	 Must show all bonds in Isomer **C** including O–H bond If incorrect attempt at correct reagent, mark on Apply list principle for reagents and conditions marks conc required - may appear on conditions line **NOT** (aq) For M3 even if seen on conditions line **ALLOW** Reagent = Al_2O_3 Condition = 'passing vapour over hot solid' owtte **ALLOW** stated temp in range 100-300 °C/373-573 K **IGNORE** 'heat' M4 dependent on correct reagent in M3

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4d) i)	S = aldehyde/CHO **AND** T = carboxylic/COOH/CO_2H T forms hydrogen bonds (which are) stronger than / need more energy to break than forces between molecules/IMFs in S ora (or reverse argument)	1 1 1	 If implication of breaking covalent bonds max M1 only
4d) ii	(No oxidation has occurred as..) (Still) contains peak at 3230−3550 cm-1 due to O−H/alcohol Does not contain peak at 2500−3000 cm-1 due to O−H/carboxylic acid Does not contain peak at 1680−1750 cm-1 due to C=O	Any 2	Must have wavenumber range (or value within range) and bond or functional group to score each mark.
Total		**13**	

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Question	Answers	Mark	Additional Comments/Guidance
5(a)(i)	curve drawn from origin with peak clearly lower and to right.	1	new curve crosses original once only, finishes above original and does **not** clearly curve up **IGNORE** relative areas
5(a)(ii)	(Relative areas under curves indicate) <u>many</u> (owtte) more molecules with E greater than or equal to Ea (at higher T) or reverse argument (large) increase in (number of) <u>successful</u> (owtte) <u>collisions per unit time</u>	1 1	**ALLOW** 'particles' **IGNORE** 'atoms' OR '<u>frequency</u> of successful <u>collisions</u>'
5(b)(i)	Yield increases more moles/molecules (of gas) on left/fewer on right/3 on left 1 on right <u>equilibrium shifts/moves</u> (to right) to reduce pressure/oppose higher pressure	1 1 1	Yield decreases/stays the same CE = 0 If not answered mark on No M3 if 'more moles on right' in M2 **IGNORE** 'favours' **NOT** just 'oppose the change' QoL means that M3 is only awarded if these ideas are clearly linked in one statement
5(b)(ii)	Higher T would increase rate but decrease yield/make less methanol **OR** Lower T decreases rate but increases yield; Chosen T is a compromise/balance (between rate and yield) owtte	1 1	If no mention of both rate **AND** (idea of) yield max 1
Total		**8**	

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Question	Answers	Mark	Additional Comments/Guidance
6(a)	increasing atomic radius / shielding / number of shells / size (down group) or reverse argument decreasing attraction of nucleus/protons for shared (electron) pair / bond electrons	1 1	**NOT** 'molecules' **NOT** if attraction for single electron implied
6(b)(i)	electron acceptor / species that accepts electrons / species that gains electrons	1	**NOT** electron pair **NOT** just 'gain of electrons'
6(b)(ii)	chlorine 0 to –1 / oxidation state/number of chlorine decreases **AND** bromine –1 to 0 / oxidation state/number of bromine increases	1	penalise if oxidised for chlorine and/or reduced for bromine credit oxidation states if labelled on equation
6(c)(i)	$H_2SO_4 + 8H^+ + 8e^{(-)} \rightarrow H_2S + 4H_2O$	1	**ALLOW** $SO_4^{2-} + 10H^+ + 8e^{(-)} \rightarrow H_2S + 4H_2O$ **ALLOW** fractions/multiples **IGNORE** state symbols
6(c)(ii)	$2I^- \rightarrow I_2 + 2e^{(-)}$	1	**ALLOW** fractions/multiples **IGNORE** state symbols **ALLOW** $2I^- - 2e^{(-)} \rightarrow I_2$

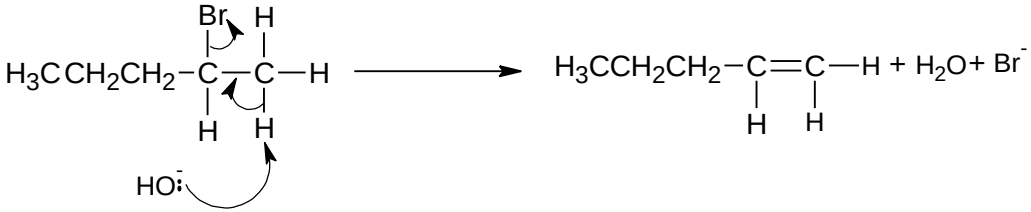
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6(c)(iii)	$H_2SO_4 + 8H^+ + 8I^- \rightarrow H_2S + 4H_2O + 4I_2$	1	**ALLOW** $H_2SO_4 + 8HI \rightarrow H_2S + 4H_2O + 4I_2$ $SO_4^{2-} + 2H^+ + 8HI \rightarrow H_2S + 4H_2O + 4I_2$ $SO_4^{2-} + 10H^+ + 8I^- \rightarrow H_2S + 4H_2O + 4I_2$ $9H_2SO_4 + 8I^- \rightarrow H_2S + 4H_2O + 4I_2 + 8HSO_4^-$ $9H_2SO_4 + 8NaI \rightarrow H_2S + 4H_2O + 4I_2 + 8NaHSO_4$ $H_2SO_4 + 8H^+ + 8NaI \rightarrow H_2S + 4H_2O + 4I_2 + 8Na^+$ $5H_2SO_4 + 8I^- \rightarrow H_2S + 4H_2O + 4I_2 + 4SO_4^{2-}$ $5H_2SO_4 + 8NaI \rightarrow H_2S + 4H_2O + 4I_2 + 4Na_2SO_4$
6(c)(iv)	'oxidising agent' box ticked	1	
6(c)(v)	$H_2SO_4 + 2NaF \rightarrow Na_2SO_4 + 2HF$ **OR** $H_2SO_4 + NaF \rightarrow NaHSO_4 + HF$	1	
6(c)(vi)	fluoride less powerful reducing agent (than iodide) OR fluoride less easily oxidised than iodide or reverse argument in either case	1	NOT general group VII trend statement NOT fluorine/F or iodine/I Must be comparative
6(d)(i)	$Cl_2 + H_2O \rightleftharpoons 2H^+ + Cl^- + ClO^-/HCl + HOCl$	1	**ALLOW** → for ⇌
6(d)(ii)	equilibrium <u>shifts/moves</u> left (producing) chlorine (which) is toxic/poisonous	1 1	Mark independently
Total		**13**	

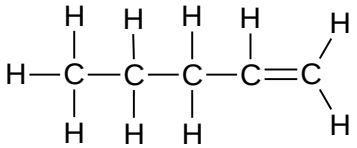
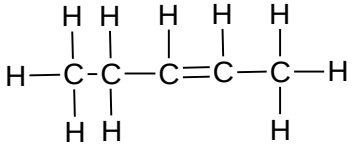
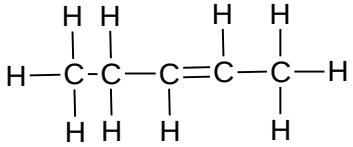
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Question	Answers	Mark	Additional Comments/Guidance
7(a)(i)	$2ZnS + 3O_2 \rightarrow 2ZnO + 2SO_2$	1	**ALLOW** multiples/fractions
7(a)(ii)	sulfuric acid/H_2SO_4	1	**ALLOW** $CaSO_4$ **ALLOW** SO_3 **IGNORE** gypsum/plaster/$CaSO_3$
7(b)(i)	$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$	1	**ALLOW** multiples/fractions **ALLOW** $2CH_4 + 3½O_2 \rightarrow CO + CO_2 + 4H_2O$
7(b)(ii)	$ZnO + CO \rightarrow Zn + CO_2$	1	**ALLOW** multiples/fractions **IGNORE** state symbols
7(c)(i)	$Cu^{2+}(aq) + Fe(s) \rightarrow Cu(s) + Fe^{2+}(aq)$	1	state symbols required
7(c)(ii)	***environmental* (2 from)** no/less CO_2/greenhouse gases produced/reduced effect on global warming conserves resources/fossil fuels no/less SO_2/acid rain produced no/less global dimming/particulates no/less land scarring/mining/habitat damage/noise pollution ***economic* (1 from)** less energy/lower temp hence cheaper less labour hence cheaper	 1 1 1	**IGNORE** CO **IGNORE** scrap iron is cheap 'cheaper' must be qualified **NOT** just less energy/labour
7(d)(i)	$TiO_2 + C + 2Cl_2 \rightarrow TiCl_4 + CO_2$ **OR** $TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$ $TiCl_4 + 2Mg \rightarrow 2MgCl_2 + Ti$	1 1	**ALLOW** multiples/fractions
7(d)(ii)	forms (titanium) carbide		**ALLOW** makes product/Ti brittle
Total		**11**	

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Question	Answers	Mark	Additional Comments/Guidance
8(a)	NaOH/KOH	1	**IGNORE** OH^- **NOT** M1 if any mention of acidified/H^+ in reagents or conditions
	reaction 1 = ethanolic/alcoholic **AND** *reaction 2* = aqueous	1	**IGNORE** temp **NOT** ethanoic
	rxn 1 = base/proton acceptor	1	
	rxn 2 = nucleophile/lone pair donor/electron pair donor	1	
	(Base) Elimination	1	**NOT** nucleophilic
		1 1 1	
	M6 must show an arrow from the lone pair on the oxygen of a negatively charged hydroxide ion to a correct H atom **M7** must show an arrow from a correct C–H bond on C adjacent to the C of the C–Br bond to a correct C–C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C–H bond in **M6** **M8** is independent provided it is from their original molecule and shows curly arrow from C-Br to Br		**ALLOW** correct E1 mechanism **IGNORE** incorrect inorganic products If forming pent-2-ene can award M8 only even if arrows in mechanism correct If C chain length or halogen wrong in reactant or product max 2/3

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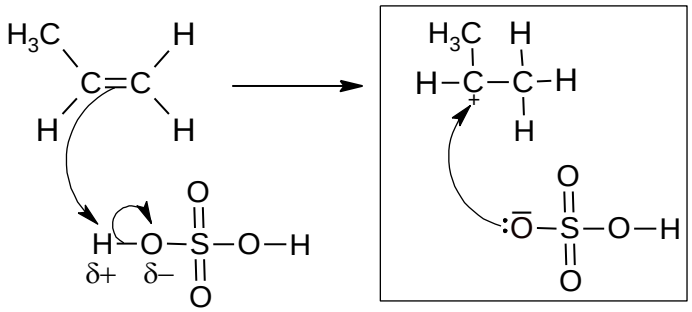
8(b)		1	
		1	
	Z-pent-2-ene		If no M2 and M3 **ALLOW** 1 mark if both structures **OR** both names correct **NOT** cis and trans
		1	
	E-pent-2-ene		
	no free rotation around C=C	1	**ALLOW** no rotation of C=C
	2 different atoms/groups on each of the C=C Cs owtte	1	**IGNORE** 'functional'

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8(c)	Same volume/amount of $AgNO_3$(aq) added to same volume/amount/no. of drops of haloalkane (in beaker/flask) in each experiment	1	both volume references needed **IGNORE** inappropriate volumes
	same temp **OR** same [$AgNO_3$] each time	1	
	record time to measure sensible observation about the amount of AgCl ppt	1	e.g. first appearance of ppt / ppt obscures mark / reading on a colorimeter **IGNORE** colour of ppt **ALLOW** silver mirror **NOT** reference to same time if describing method based on timing how long (for ppt to form) **ALLOW** gravimetric method based on same time for each experiment
	Rate = amount/time **OR** proportional to 1/time **OR** reference to shorter time = higher rate/longer time = lower rate	1	**ALLOW** greater mass = higher rate if gravimetric method

Total		**17**	

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Question	Answers	Mark	Additional Comments/Guidance
9(a)	electrophilic addition  Major product/propan-2-ol formed via most stable <u>carbocation/carbonium ion</u> <u>secondary</u> <u>carbocation/carbonium ion</u> more stable (than primary) or reverse argument	1 1 1 1 1 1 1	 M2 = curly arrow from C=C towards H of H−O on 'their' sulfuric acid M3 = curly arrow to break H−O Penalise incorrect dipole/full charges M4 = intermediate M5 = correct anion, lone pair on correct O and curly arrow from that lone pair to C+ on their carbocation **IGNORE** position of minus sign unless displayed structure **IGNORE** product M6 for idea of carbocation stability This statement gets M6 and M7 **NOT** stability of alcohols
9(b)	Hot/High T (and High P) (SiO_2 coated in) <u>phosphoric</u> acid (catalyst) *advantages of fermentation* • Low(er) T and P / lower energy use • less use of non-renewable fossil fuels/renewable/sustainable (resources) • low(er) equipment/plant/capital costs *disadvantages of fermentation* • slow(er) reaction • low atom economy • impure product/extra purification/distillation required • Batch process/labour intensive/difficult to automate • Land used for sugar crops (so not available for food crops)	1 1 1 1 1 1	**ALLOW** 200-450 C/473-723 K (Quoted **NOT** (aq) **IGNORE** carbon neutral max 2 **IGNORE** low yield max 2
Total		**13**	

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General principles applied to marking CHEM2 papers by CMI+ (June 2016)

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are <u>required information</u> to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**

A. <u>The "List principle" and the use of "ignore" in the mark scheme</u>

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. <u>Incorrect case for element symbol</u>

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. <u>Spelling</u>

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

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D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

E. Reagents

The command word "Identify", allows the candidate to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.
For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a candidate provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

F. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

G. Marking calculations, such as those involving enthalpy changes

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In general

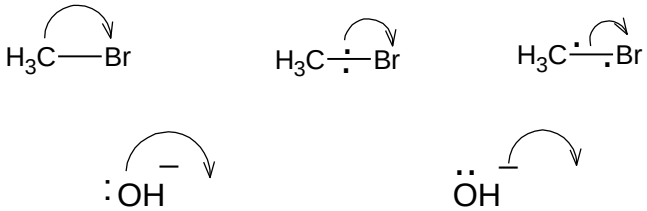
- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will usually score **only one mark**.

All other values **gain no credit** except

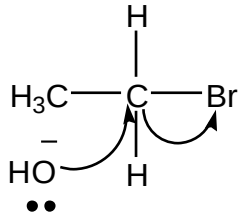
- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

H. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.
The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.
In free-radical substitution

- The absence of a radical dot should be penalised **once only** within a clip.

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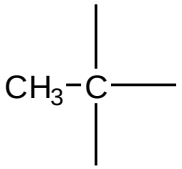
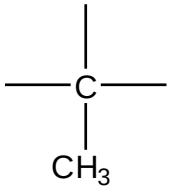
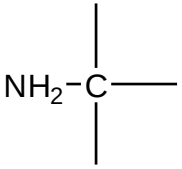
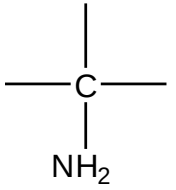
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

I. Organic structures

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if candidates show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in structures, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or C ─ NH_2 bonds should **not** be penalised. For the other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.
  By way of illustration, the following would apply

(a)  allowed	(b)  allowed
(c)  allowed	(d)  allowed

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- In most cases, the use of "sticks" to represent C ─ H bonds in a structure should **not** be penalised. The exceptions will include structures in mechanisms when the C ─ H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.
- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

N.B. Exceptions <u>may</u> be made in the context of balancing equations

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

J. <u>Organic names</u>

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.
Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**

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ethan-1,2-diol	should be **ethane-1,2-diol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**
3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

K. <u>Additional sheets and blank clips</u>

- Markers should **mark all that is seen** and carry on marking as normal. Clips which refer to the use of additional sheets should **not** be referred to the senior team. Clips which refer to other parts of the script must be referred to the senior team.
- When considering crossed out work, **mark it** as if it were not crossed out **unless** it has been replaced by a later version; this later version then takes priority.
- Mark a blank section with a dash (—) and **not with a score of zero**.

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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8	
9	
TOTAL	

AQA

General Certificate of Education
Advanced Subsidiary Examination
June 2015

Chemistry CHEM2

Unit 2 Chemistry in Action

Tuesday 2 June 2015 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use scientific terminology accurately.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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Do not write outside the box

Section A

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

1 Chlorine is an important industrial chemical.

1 (a) Chlorine is formed when $KMnO_4$ reacts with hydrochloric acid.
The ionic equation for this redox reaction is

$$16H^+ + 2MnO_4^- + 10Cl^- \longrightarrow 2Mn^{2+} + 8H_2O + 5Cl_2$$

1 (a) (i) Deduce the half-equation for the oxidation of chloride ions to chlorine.

[1 mark]

.....

1 (a) (ii) Give the oxidation state of manganese in the MnO_4^- ion.

[1 mark]

.....

1 (a) (iii) Deduce the half-equation for the reduction of the MnO_4^- ions in acidified solution to manganese(II) ions and water.

[1 mark]

.....

1 (b) Chlorine behaves as an oxidising agent in the extraction of bromine from seawater.
In this process, chlorine gas is bubbled through a solution containing bromide ions.

1 (b) (i) Write the **simplest ionic** equation for the reaction of chlorine with bromide ions.

[1 mark]

.....

1 (b) (ii) Give **one** observation that would be made during this reaction.

[1 mark]

.....

.....

Do not write outside the box

1 (b) (iii) In terms of electrons, state the meaning of the term **oxidising agent**.

[1 mark]

.....

.....

1 (c) In sunlight, chlorine can also oxidise water slowly to form oxygen.

Write an equation for this reaction.
Give the oxidation state of chlorine in the chlorine-containing species that is formed.

[2 marks]

Equation

.....

Oxidation state of chlorine in the species formed .....

1 (d) Explain why chlorine has a lower boiling point than bromine.

[2 marks]

.....

.....

.....

.....

.....

.....

.....

10

Turn over ▶

Do not write outside the box

2 The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair of compounds, give a reagent (or combination of reagents) that, when added separately to each compound, could be used to distinguish between them. State what is observed in each case.

2 (a) Butan-2-ol and 2-methylpropan-2-ol

[3 marks]

Reagent .....

Observation with butan-2-ol

.....

.....

Observation with 2-methylpropan-2-ol

.....

.....

2 (b) Propane and propene

[3 marks]

Reagent .....

Observation with propane

.....

.....

Observation with propene

.....

.....

Do not write outside the box

2 (c) Aqueous silver nitrate and aqueous sodium nitrate

[3 marks]

Reagent .....

Observation with aqueous silver nitrate

.....

.....

Observation with aqueous sodium nitrate

.....

.....

2 (d) Aqueous magnesium chloride and aqueous barium chloride

[3 marks]

Reagent .....

Observation with aqueous magnesium chloride

.....

.....

Observation with aqueous barium chloride

.....

.....

12

Turn over for the next question

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

3 The elements in Group 2 from Mg to Ba can be used to show the trends in properties down a group in the Periodic Table.

3 (a) State the trend in atomic radius for atoms of the elements down Group 2 from Mg to Ba Give a reason for this trend.

[2 marks]

Trend .....

Reason .....

.....

.....

.....

.....

3 (b) The Group 2 elements react with water.

3 (b) (i) State the trend in reactivity with water of the elements down Group 2 from Mg to Ba

[1 mark]

.....

3 (b) (ii) Write an equation for the reaction of strontium with water.

[1 mark]

.....

3 (c) Give the **formula** of the hydroxide of the element in Group 2 from Mg to Ba that is most soluble in water.

[1 mark]

.....

5

Do not write outside the box

4 Hydrogen is produced in industry from methane and steam in a two-stage process.

4 (a) In the first stage, carbon monoxide and hydrogen are formed.
The equation for this reaction is

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206 \text{ kJ mol}^{-1}$$

4 (a) (i) Use Le Chatelier's principle to state whether a high or low temperature should be used to obtain the highest possible equilibrium yield of hydrogen from this first stage.
Explain your answer.

[3 marks]

Temperature .....

Explanation .....

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4 (a) (ii) Le Chatelier's principle suggests that a high pressure will produce a low yield of hydrogen in this first stage.

Explain, in terms of the behaviour of particles, why a high operating pressure is used in industry.

[2 marks]

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Do not write outside the box

4 (a) (iii) A nickel catalyst is used in the first stage.

Explain why the catalyst is more effective when coated onto an unreactive honeycomb.

[2 marks]

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4 (b) The second stage is carried out in a separate reactor. Carbon monoxide is converted into carbon dioxide and more hydrogen is formed.

The equation for this reaction is

$$CO(g) + H_2O(g) \rightleftharpoons CO_2(g) + H_2(g) \qquad \Delta H = -41 \text{ kJ mol}^{-1}$$

Use Le Chatelier's principle to state the effect, if any, of a **decrease** in the total pressure on the yield of hydrogen in this second stage. Explain your answer.

[2 marks]

Effect .....

Explanation .....

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.....

9

Turn over for the next question

Do not write outside the box

5 There are many uses of halogenated organic compounds despite environmental concerns.

5 (a) Bromotrifluoromethane is used in fire extinguishers in aircraft.
Bromotrifluoromethane is formed when trifluoromethane reacts with bromine.

$$CHF_3 + Br_2 \longrightarrow CBrF_3 + HBr$$

The reaction is a free-radical substitution reaction similar to the reaction of methane with chlorine.

5 (a) (i) Write an equation for each of the following steps in the mechanism for the reaction of CHF_3 with Br_2

[4 marks]

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step

.....

5 (a) (ii) State **one** condition necessary for the initiation of this reaction.

[1 mark]

.....

Do not write outside the box

5 (b) Bromine-containing and chlorine-containing organic compounds may have a role in the decomposition of ozone in the upper atmosphere.

5 (b) (i) Draw an appropriate **displayed formula** in the space provided to complete the following equation to show how $CBrF_3$ may produce bromine atoms in the upper atmosphere.

[1 mark]

$CBrF_3 \longrightarrow$ ..... + $Br\bullet$

5 (b) (ii) In the upper atmosphere, it is more likely for $CBrF_3$ to produce bromine atoms than it is for $CClF_3$ to produce chlorine atoms.

Suggest **one** reason for this.

[1 mark]

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Question 5 continues on the next page

Do not write outside the box

5 (b) (iii) Bromine atoms have a similar role to chlorine atoms in the decomposition of ozone. The overall equation for the decomposition of ozone is

$$2O_3 \longrightarrow 3O_2$$

Write **two** equations to show how bromine atoms (Br•) act as a catalyst in the decomposition of ozone.

Explain how these two decomposition equations show that bromine atoms behave as a catalyst.

[3 marks]

Equation 1

.....

Equation 2

.....

Explanation .....

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10

Do not write outside the box

6 Butane and propanal are compounds with M_r = 58.0, calculated using data from your Periodic Table.

6 (a) A mass spectrometer can be used to distinguish between samples of butane and propanal.

Table 1 shows some precise relative atomic mass values.

Table 1

Atom	Precise relative atomic mass
^{1}H	1.00794
^{12}C	12.00000

6 (a) (i) Use data from **Table 1** to show that, to 3 significant figures, a more accurate value for the M_r of butane is 58.1

[1 mark]

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6 (a) (ii) State why the precise relative atomic mass quoted in **Table 1** for the ^{12}C isotope is exactly 12.00000

[1 mark]

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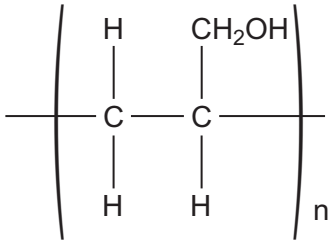
Question 6 continues on the next page

Do not write outside the box

6 (b) Draw a **displayed formula** for the organic product that is formed when propanal is oxidised by warm Tollens' reagent.

[1 mark]

6 (c) Prop-2-en-1-ol is an isomer of propanal and can be polymerised to form a polymer represented by the following structure.



6 (c) (i) Draw the structure of prop-2-en-1-ol.

[1 mark]

6 (c) (ii) Deduce the type of polymerisation that results in the formation of this polymer from prop-2-en-1-ol.

[1 mark]

.....

Do not write outside the box

6 (c) (iii) There are two functional groups in prop-2-en-1-ol. Each of these functional groups contains a bond with a characteristic absorption range in the infrared spectrum.

Use **Table A** on the Data Sheet to suggest a bond and its absorption range for each of the two functional groups.

[2 marks]

Bond 1 ..... Absorption range .....

Bond 2 ..... Absorption range .....

6 (d) Compound **X** is another isomer of propanal. The infrared spectrum of **X** shows an absorption in the range 1680–1750 cm^{-1}.

6 (d) (i) Draw the structure of **X**.

[1 mark]

6 (d) (ii) Which of the following, **A**, **B**, **C** or **D**, represents the type of isomerism shown by **X** and propanal?

Write the correct letter, **A**, **B**, **C** or **D**, in the box.

[1 mark]

A chain isomerism
B E–Z isomerism
C functional group isomerism
D position isomerism

9

Do not write outside the box

7 (a) Propanone can be formed when glucose comes into contact with bacteria in the absence of air.

7 (a) (i) Balance the following equation for this reaction of glucose to form propanone, carbon dioxide and water.

[1 mark]

.....$C_6H_{12}O_6$ $\longrightarrow$ .....CH_3COCH_3 + ...CO_2 + ...H_2O

7 (a) (ii) Deduce the role of the bacteria in this reaction.

[1 mark]

.....

7 (b) Propanone is also formed by the oxidation of propan-2-ol.

7 (b) (i) Write an equation for this reaction using [O] to represent the oxidising agent.

[1 mark]

.....

7 (b) (ii) State the class of alcohols to which propan-2-ol belongs.

[1 mark]

.....

Do not write outside the box

7 (c) A student determined a value for the enthalpy change when a sample of propanone was burned. The heat produced was used to warm some water in a copper calorimeter. The student found that the temperature of 150 g of water increased by 8.0 °C when 4.50×10^{-3} mol of pure propanone was burned in air.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of propanone is burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

[3 marks]

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Question 7 continues on the next page

Do not write outside the box

7 (d) Define the term **standard enthalpy of combustion**.

[3 marks]

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7 (e) Use the mean bond enthalpy data in **Table 2** and the equation given below **Table 2** to calculate a value for the standard enthalpy change when gaseous propanone is burned.

[3 marks]

Table 2

	C—H	C—C	C—O	O—H	C=O	O=O
Mean bond enthalpy / kJ mol^{-1}	412	348	360	463	805	496

$$CH_3COCH_3(g) + 4O_2(g) \longrightarrow 3CO_2(g) + 3H_2O(g)$$

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Do not write outside the box

7 (f) Suggest **two** reasons why the value obtained by the student in Question **7 (c)** is different from the value calculated in Question **7 (e)**.

[2 marks]

Reason 1 .....

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Reason 2 .....

.....

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15

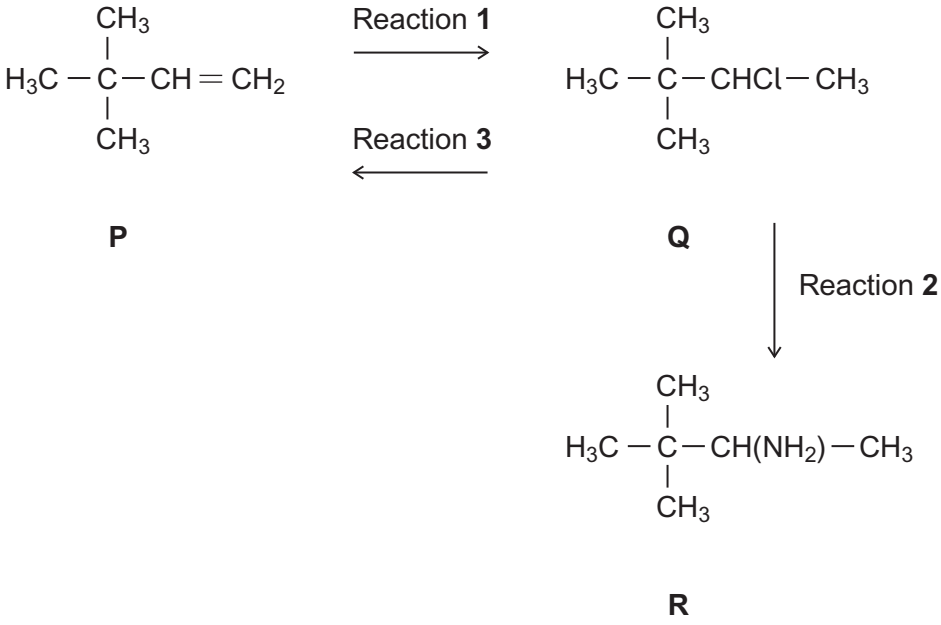
Turn over for the next question

Do not write outside the box

Section B

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

8 Consider the following scheme of reactions.



8 (a) Give the IUPAC name for compound **P** and that for compound **Q**.

[2 marks]

P .....

Q .....

Do not write outside the box

8 (b) The conversion of **P** into **Q** in Reaction **1** uses HCl

Name and outline a mechanism for this reaction.

[5 marks]

.....

8 (c) The conversion of **Q** into **R** in Reaction **2** uses NH_3

Name and outline a mechanism for this reaction.

[5 marks]

.....

Question 8 continues on the next page

Do not write outside the box

8 (d) State the type of reaction shown by Reaction **3**.

Identify a reagent for this reaction.

Give **one** condition necessary for a high yield of product when **Q** is converted into **P**.

[3 marks]

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8 (e) Hydrogen bromide (HBr) could be used in the overall conversion of **P** into **R**, instead of using HCl

Hydrogen bromide is made by the reaction of NaBr with concentrated phosphoric acid.

Concentrated sulfuric acid is **not** used to make HBr from NaBr

Write an equation for the reaction of NaBr with H_3PO_4 to produce HBr and Na_3PO_4 only.

Identify **two** toxic gases that are formed, together with HBr, when NaBr reacts with concentrated H_2SO_4

State the role of H_2SO_4 in the formation of these two toxic gases.

[4 marks]

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19

Do not write outside the box

9 Vanadium is an important metal. Ferrovanadium, an alloy of iron and vanadium, is used to make a strong type of vanadium-steel. Pure vanadium is used in nuclear reactors.

9 (a) **Table 3** shows some standard enthalpy of formation data.

Table 3

	$V_2O_5(s)$	CaO(s)
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–1560	–635

In the oldest method of extraction of vanadium, V_2O_5 is reacted with calcium at a high temperature.

$$5Ca(s) + V_2O_5(s) \longrightarrow 2V(s) + 5CaO(s)$$

Use data from **Table 3** and the equation to calculate the standard enthalpy change for this reaction.

State the type of reaction that V_2O_5 has undergone.

Suggest **one** major reason why this method of extracting vanadium is expensive, other than the cost of heating the reaction mixture.

[5 marks]

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Question 9 continues on the next page

Do not write outside the box

9 (b) Ferrovanadium is produced by the reaction of aluminium with a mixture of V_2O_5 and iron(III) oxide.

Write an equation for the reaction of aluminium with iron(III) oxide.

State the change in oxidation state of aluminium in this reaction.

[2 marks]

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9 (c) Pure vanadium, for nuclear reactors, is formed by the reaction of hydrogen with purified VCl_2

Write an equation for this reaction in which the only other product is HCl gas.

Identify **two** hazards in this process, other than the fact that it operates at a high temperature.

Deduce why this process produces **pure** vanadium, other than the fact that purified VCl_2 is used.

[4 marks]

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11

END OF QUESTIONS

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AQA Qualifications

A-LEVEL

Chemistry

CHEM2 Chemistry in Action

Mark scheme

2420
June 2015

Version 0.3 – Post Standardisation

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Mark schemes are prepared by the Lead Assessment Writer and considered, together with the relevant questions, by a panel of subject teachers. This mark scheme includes any amendments made at the standardisation events which all associates participate in and is the scheme which was used by them in this examination. The standardisation process ensures that the mark scheme covers the students' responses to questions and that every associate understands and applies it in the same correct way. As preparation for standardisation each associate analyses a number of students' scripts: alternative answers not already covered by the mark scheme are discussed and legislated for. If, after the standardisation process, associates encounter unusual answers which have not been raised they are required to refer these to the Lead Assessment Writer.

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Question	Marking Guidance	Mark	Comments
1(a)(i)	**2**Cl^- ⟶ Cl_2 + **2**e^-	1	Ignore state symbols Credit loss of electrons from LHS Credit multiples Do not penalise absence of charge on electron
1(a)(ii)	+7 ***OR*** 7 ***OR*** VII ***OR*** +VII	1	Allow Mn^{+7} and 7+
1(a)(iii)	MnO_4^- + $8H^+$ + 5**e**$^-$ ⟶ Mn^{2+} + $4H_2O$	1	Ignore state symbols Credit loss of electrons from RHS Credit multiples Do not penalise absence of charge on electron
1(b)(i)	Cl_2 + **2**Br^- ⟶ **2**Cl^- + Br_2 ***OR*** $\frac{1}{2}Cl_2$ + Br^- ⟶ Cl^- + $\frac{1}{2}Br_2$	1	One of these two equations <u>only</u> Ignore state symbols
1(b)(ii)	(Turns to) <u>yellow / orange / brown</u> (solution)	1	Penalise "red / reddish" as the only colour Accept "red-brown" and "red-orange" Ignore "liquid" Penalise reference to a product that is a gas or

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			a precipitate
1(b)(iii)	(Chlorine) gains electron(s) / takes electron(s) / accepts electron(s) (from the bromide ions) *OR* (Chlorine) causes another species (Br^-) to lose electron(s)	1	Penalise "electron pair acceptor" Not simply "causes loss of electrons"

1(c)	**M1** $\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$ ($\mathbf{4}H^+ + \mathbf{4}Cl^-$) **M2** Oxidation state **–1**	2	Ignore state symbols Credit multiples **M2** consequential on HCl or Cl^- which **must** be the only chlorine-containing product in the (un)balanced equation. For **M2** allow Cl^{-1} or Cl^{1-} but **not** Cl^-

1(d)	**M1 The relative size (of the molecules/atoms)** Chlorine is smaller than bromine ***OR*** has fewer electrons/electron shells ***OR*** It is smaller / It has a smaller atomic radius / it is a smaller molecule / atom (or converse) **M2 How size of the intermolecular force affects energy needed** The forces between chlorine / Cl_2 molecules are weaker (than the forces between bromine / Br_2 molecules) (or converse for bromine) ***OR*** chlorine / Cl_2 has weaker / fewer/ less (VdW) intermolecular forces / forces between molecules	2	For **M1** ignore whether it refers to molecules or atoms. **CE=0** for the clip for reference to (halide) ions or incorrect statements about relative size Ignore molecular mass and M_r Ignore shielding **QoL in M2** for clear reference to the difference in size of the force between molecules. Reference to Van der Waals forces alone is not enough.

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	(or converse for bromine)		Penalise **M2** if (covalent) bonds are broken

Question	Marking Guidance	Mark	Comments
2(a)	**M1** acidified potassium dichromate or $K_2Cr_2O_7/H_2SO_4$ ***OR*** $K_2Cr_2O_7/H^+$ ***OR*** acidified $K_2Cr_2O_7$ **M2** (orange to) green solution ***OR*** goes green **M3** (solution) remains orange or no reaction or no (observed) change Alternative using $KMnO_4/H_2SO_4$ **M1** acidified potassium manganate(VII) / potassium permanganate or $KMnO_4/H_2SO_4$ ***OR*** $KMnO_4/H^+$ ***OR*** acidified $KMnO_4$ **M2** colourless solution ***OR*** goes colourless **M3** (solution) remains purple or no reaction or no (observed) change	3	If no reagent or incorrect reagent in **M1**, **CE= 0** and no marks for **M1**, **M2** or **M3** If incomplete / inaccurate attempt at reagent e.g. "dichromate" or "dichromate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on** For **M2** ignore dichromate described as "yellow" or "red" For **M3** ignore "nothing (happens)" or "no observation" For **M1** If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on** Credit alkaline $KMnO_4$ for possible full marks but **M2** gives brown precipitate or solution goes green

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2(b)	**M1** (Shake with) Br_2 ***OR*** bromine (water) ***OR*** bromine (in CCl_4 / organic solvent) **M2** (stays) orange / red / yellow / brown / the same ***OR*** no reaction ***OR*** no (observed) change **M3** decolourised / goes colourless / loses its colour / orange to colourless ***OR* as alternatives** **Use $KMnO_4/H_2SO_4$** **M1** acidified potassium manganate(VII) / potassium permanganate ***OR*** $KMnO_4/H_2SO_4$ ***OR*** $KMnO_4/H^+$ ***OR*** acidified $KMnO_4$ **M2** (stays) <u>purple</u> or no reaction or no (observed) change **M3** decolourised / goes colourless / loses its colour **Use iodine** **M1** **iodine** or I_2 / KI or iodine solution **M2** no change **M3** decolourised / goes colourless / loses its colour **Use concentrated sulfuric acid** **M1** <u>concentrated</u> H_2SO_4 **M2** no change	3	If no reagent or incorrect reagent in **M1**, **CE= 0** and no marks for **M1**, **M2** or **M3** If incomplete /inaccurate attempt at reagent (e.g. Br), **penalise M1 only and mark on** No credit for combustion observations; **CE=0** For **M2 in every case** Ignore "nothing (happens)" Ignore "no observation" Ignore "clear" **For M1**, it must be a whole reagent and/or correct formula **For M1** penalise incorrect attempt at correct formula, but mark **M2** and **M3** **With potassium manganate(VII)** If incomplete / inaccurate attempt at reagent e.g. "manganate" or "manganate(IV)" or incorrect formula or no acid, **penalise M1 only and mark on** Credit alkaline/neutral $KMnO_4$ for possible full marks but **M3** gives <u>brown precipitate</u> or solution goes <u>green</u> Apply similar guidance for errors in the formula of iodine or concentrated sulfuric acid reagent

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	M3 brown		as those used for other reagents.

2(c)	**M1** Any soluble chloride including hydrochloric acid (ignore concentration) **M2** white precipitate or white solid / white suspension **M3** remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear ***OR* as an alternative** **M1** Any soluble iodide including HI **M2** yellow precipitate or yellow solid / yellow suspension **M3** remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear ***OR* as an alternative** **M1** Any soluble bromide including HBr **M2** cream precipitate or cream solid / cream suspension **M3** remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear ***OR* as an alternative** **M1** NaOH or KOH or any soluble carbonate **M2** brown precipitate or brown solid / brown suspension with NaOH / KOH (white precipitate/ solid/ suspension with carbonate) **M3** remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear	3	If no reagent or incorrect reagent or insoluble chloride in **M1**, **CE= 0** and no marks for **M1**, **M2** or **M3** Allow chlorine water If incomplete reagent (e.g. chloride ions) or inaccurate attempt at formula of chosen chloride, or chlorine, **penalise M1 only and mark on** For **M2** require the word "white" and some reference to a solid. Ignore "cloudy solution" OR "suspension" (similarly for the alternatives) For **M3** Ignore "nothing (happens)" Ignore "no observation" Ignore "clear" on its own Ignore "dissolves"

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2(d)	**M1** Any <u>soluble</u> <u>sulfate</u> including (dilute or aqueous) sulfuric acid **M2** remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear **M3** <u>white precipitate</u> or <u>white solid / white suspension</u> ***OR* as an alternative** **M1** NaOH or KOH **M2** <u>white precipitate</u> or <u>white solid / white suspension</u> **M3** remains colourless or no reaction or no (observed) change or no precipitate or clear solution or it remains clear	3	If no reagent or incorrect reagent or insoluble sulfate in **M1**, **CE= 0** and no marks for **M1**, **M2** or **M3** Accept $MgSO_4$ and $CaSO_4$ but not barium, lead or silver sulfates If concentrated sulfuric acid or incomplete reagent (eg sulfate ions) or inaccurate attempt at formula of chosen sulfate, **penalise M1 only and mark on** For **M3 (or M2 in the alternative)** require the word "white" and some reference to a solid. Ignore "cloudy solution" OR "suspension" For **M2 (or M3 in the alternative)** Ignore "nothing (happens)" Ignore "no observation" Ignore "clear" <u>on its own</u> Ignore "dissolves" If incomplete reagent (e.g. hydroxide ions) or inaccurate attempt at formula of chosen hydroxide, **penalise M1 only and mark on** If **M1** uses NH_3 (dilute or concentrated) **penalise M1 only and mark on**

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Question	Marking Guidance	Mark	Comments
3(a)	**M1** Increases / gets bigger **M2 requires a correct M1** More shells or sub-shells or (main) levels or sub-levels or orbitals (of electrons)	2	If **M1** is incorrect **CE=0** for the clip If **M1** is blank, mark on and seek to **credit the correct information in the text** **M2** requires correct **M1** If "molecules" penalise **M2** Not simply "more electrons" Not "more outer shells" Ignore reference to nuclear charge and shielding
3(b)(i)	Increases / gets more reactive / reacts more vigorously / violently (down the Group)	1	
3(b)(ii)	$Sr + 2H_2O \longrightarrow Sr(OH)_2 + H_2$	1	Credit multiples and correct ionic equations Ignore state symbols
3(c)	$Ba(OH)_2$	1	This MUST be a formula so ignore the name Credit Ba^{2+} $2OH^-$ Ignore state symbols

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Question	Marking Guidance	Mark	Comments
4(a)(i)	**M1** High (temperature) OR Increase (the temperature) **M2** The (forward) reaction / to the right is endothermic or takes in / absorbs heat ***OR*** The reverse reaction / to the left is exothermic or gives out / releases heat **M3 depends on correct M2 and must refer to temperature/heat** At high temperature, the (position of) equilibrium shifts / moves left to right to oppose the increase in temperature	3	If **M1** is incorrect **CE=0** for the clip If **M1** is blank, mark on and seek to **credit the correct information in the text** **M3** depends on a correct statement for **M2** For **M3**, the position of equilibrium shifts/moves to absorb heat OR to lower the temperature OR to cool down the reaction

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4(a)(ii)	**M1** The reaction gets to equilibrium faster / in less time ***OR*** Produces a small yield faster / in less time ***OR*** Increases the rate (of reaction / of attainment of equilibrium) **M2** High pressure leads to **one** of the following • more particles / molecules in a given volume • particles / they are closer together • higher concentration of particles /molecules ***AND*** • more collisions in a given time / increased collision frequency	2	Mark independently Penalise **M2** for reference to increased energy of the particles

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4(a)(iii)	**M1** Increase in / more / large(r) / big(ger) surface area / surface sites **M2** increase in / more successful / productive / effective collisions (in a given time) (on the surface of the catalyst / with the nickel)	2	Mark independently For **M1** accept "an increase in surface" For **M2** not simply "more collisions" Ignore "the chance or likelihood" of collisions

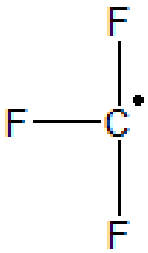
4(b)	**M1** No effect / None **M2 requires a correct M1** Equal / same number / amount of moles / molecules / particles on either side of the equation ***OR*** 2 moles / molecules / particles on the left and 2 moles / molecules / particles on the right	2	If **M1** is incorrect **CE=0** for the clip If **M1** is blank, mark on and seek to **credit the correct information in the text** **M2** depends on a correct statement for **M1** In **M2 not** "atoms"

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Question	Marking Guidance	Mark	Comments
5(a)(i)	**Initiation** $Br_2 \longrightarrow 2Br\bullet$ **First propagation** $Br\bullet + CHF_3 \longrightarrow \bullet CF_3 + HBr$ **Second propagation** $Br_2 + \bullet CF_3 \longrightarrow CBrF_3 + Br\bullet$ **Termination** $2\bullet CF_3 \longrightarrow C_2F_6$ ***OR*** CF_3CF_3 ***OR*** $2Br\bullet \longrightarrow Br_2$ ***OR*** $Br\bullet + \bullet CF_3 \longrightarrow CBrF_3$	4	Penalise absence of dot once only Credit the dot anywhere on the radical

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5(a)(ii)	Ultra-violet / uv / sunlight ***OR*** T > 100°C OR <u>high</u> temperature	1	

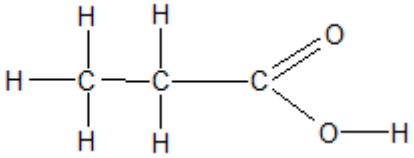
5(b)(i)		1	Displayed formula required with the radical dot on carbon

5(b)(ii)	(The) <u>C—Br</u> (bond) breaks more readily / is weaker than (the) <u>C—Cl</u> (bond) (or converse) ***OR*** The <u>C—Br</u> <u>bond enthalpy / bond strength</u> is less than that for <u>C—Cl</u> (or converse)	1	Requires **a comparison** between the two bonds Give credit for an answer that suggests that the UV frequency / energy may favour <u>C—Br</u> bond breakage rather than <u>C—Cl</u> bond breakage Ignore correct references either to size, polarity or electronegativity Credit correct answers that refer to, for example "the bond between carbon and bromine requires less energy to break than the bond between carbon and chlorine"

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5(b)(iii)	**M1** $Br\bullet + O_3 \longrightarrow BrO\bullet + O_2$ **M2** $BrO\bullet + O_3 \longrightarrow Br\bullet + 2O_2$ **M3 One of the following** They / it / the bromine (atom) • does not appear in the overall equation • is regenerated • is unchanged <u>at the end</u> • has <u>not been used up</u> • provides an alternative route / mechanism	3	**M1** and **M2** could be in either order Credit the dot anywhere on the radical Penalise absence of dot once only Penalise the use of multiples once only

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Question	Marking Guidance	Mark	Comments
6(a)(i)	C_4H_{10} M_r = 4(12.00000) + 10(1.00794) = <u>58.07940</u> or <u>58.0794</u> or <u>58.079</u> or <u>58.08</u> **<u>and</u>** **<u>58.1</u>	1	Working is essential, leading to the final value of 58.1 which must be stated in addition to one of the four numbers underlined
6(a)(ii)	<u>By definition</u> ***OR*** The <u>standard</u> / <u>reference</u> (value / isotope)	1	Reference to ^{12}C alone is not enough
6(b)		1	All bonds and atoms must be drawn Give credit for the displayed formula for the anion
6(c)(i)	$H_2C{=}CHCH_2OH$	1	Any correct representation including correct use of “sticks”. Require the double bond to be shown

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6(c)(ii)	Addition (polymerisation)	1	ONLY this answer

6(c)(iii)	**M1** **C=C** (in range) **1620 to 1680** (cm^{-1}) **M2** **O—H** (in range) **3230 to 3550** (cm^{-1})	2	Award one mark for two correct ranges but a failure to draw out the C=C or O—H bonds

6(d)(i)	CH_3COCH_3	1	Any correct representation including correct use of "sticks"

6(d)(ii)	C	1	

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Question	Marking Guidance	Mark	Comments
7(a)(i)	**2**$C_6H_{12}O_6$ ⟶ **3**CH_3COCH_3 + **3**CO_2 + **3**H_2O	1	Or multiples
7(a)(ii)	to speed up the reaction ***OR*** (provide a) catalyst or catalyses the reaction or biological catalyst ***OR*** release / contain / provides an enzyme	1	Ignore "fermentation" Ignore "to break down the glucose" Not simply "enzyme" on its own
7(b)(i)	$CH_3CH(OH)CH_3$ + [O] ⟶ CH_3COCH_3 + H_2O	1	Any correct representation for the two organic structures. Brackets not essential. Not "sticks" for the structures in this case
7(b)(ii)	Secondary (alcohol) OR 2° (alcohol)	1	

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7(c)	**M1** q = m c ΔT ***OR*** q =150 × 4.18 × 8.0 **M2** = (±) 5016 (J) ***OR*** 5.016 (kJ) ***OR*** 5.02 (kJ) (also scores M1) **M3** This mark is for dividing correctly the number of kJ by the number of moles and arriving at a final answer in the range shown. Using 0.00450 mol therefore ΔH = **– 1115** (kJ mol^{-1}) ***OR*** **– 1114.6 to – 1120** (kJ mol^{-1}) **Range (+)1114.6 to (+)1120 gains 2 marks** **BUT – 1110 gains 3 marks and +1110 gains 2 marks** **AND – 1100 gains 3 marks and +1100 gains 2 marks**	3	Award full marks for correct answer In **M1**, do not penalise incorrect cases in the formula Penalise **M3** ONLY if correct numerical answer but sign is incorrect; **(+)1114.6 to (+)1120 gains 2 marks** Penalise **M2** for arithmetic error and mark on If ΔT = 281; score q = m c ΔT only If c = 4.81 (leads to 5772) penalise **M2** ONLY and mark on for **M3** = – 1283 Ignore incorrect units in **M2** If units are given in **M3** they must be either kJ or kJ mol^{-1} in this case

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7(d)	**M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element **M2** is burned / combusts / reacts completely in oxygen ***OR*** burned / combusted / reacted in excess oxygen **M3** with (all) reactants and products / (all) substances in standard / specified states ***OR*** (all) reactants and products / (all) substances in normal states under standard conditions / 100 kPa / 1 bar and specified T / 298 K	3	If standard enthalpy of formation **CE=0** For **M3** Ignore reference to 1 atmosphere

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7(e)	**M1** $\sum$ B(**reactants**) – $\sum$ B(**products**) = ΔH ***OR*** Sum of bonds broken – Sum of bonds formed = ΔH ***OR*** 2B(C-C) + B(C=O) + 6B(C-H) + 4B(O=O) (LHS) – 6B(C=O) – 6B(O–H) (RHS) = ΔH **M2** (also scores **M1**) 2(348)+805+6(412)+4(496) [LHS = **5957**] (696) (2472) (1984) – 6(805) – 6(463) [RHS = (–)**7608**] = ΔH (4830) (2778) ***OR*** using only bonds broken and formed (**5152 – 6803**) **M3** ΔH = **– 1651** (kJ mol^{-1}) **Candidates may use a cycle and gain full marks.**	3	Correct answer gains full marks Credit 1 mark for (+) 1651 (kJ mol^{-1}) For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication / addition error; this would score 2 marks (**M1** and **M2**) • If no AE, check for a correct method; this requires either a correct cycle with $4O_2$, $3CO_2$ and $3H_2O$ OR a clear statement of **M1** which could be in words and scores **only M1** Allow a maximum of one mark if the only scoring point is LHS = 5957 (or 5152) OR RHS = 7608 (or 6803) Award 1 mark for +1651

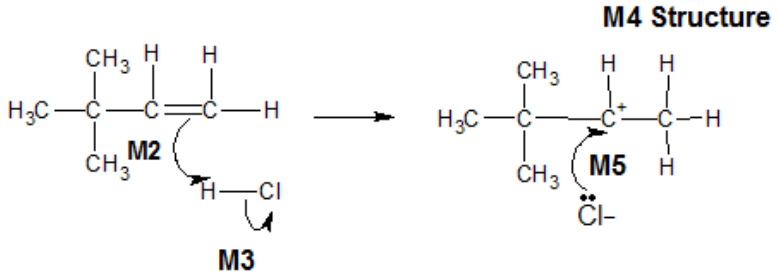
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7(f)	**For the two marks M1 and M2, <u>any two</u> from** • <u>heat</u> loss or not all <u>heat</u> transferred to the apparatus or <u>heat</u> absorbed by the apparatus or (specific) heat capacity of the apparatus not considered • incomplete combustion / not completely burned / reaction is not complete • The idea that the water may end up in the gaseous state (rather than liquid) • reactants and/or products may not be in standard states. • MBE data refers to gaseous species but the enthalpy of combustion refers to liquids in their standard states / liquid propanone and liquid water in standard states • MBE <u>do not refer to specific compounds</u> OR MBE <u>values vary with different compounds / molecules</u> OR are average / mean values taken <u>from a range of compounds / molecules</u>	2	Apply the list principle but ignore incomplete reasons that contain correct chemistry Ignore “evaporation” Ignore “faulty equipment” Ignore ”human error” Not enough simply to state that “MBE are mean / average values”

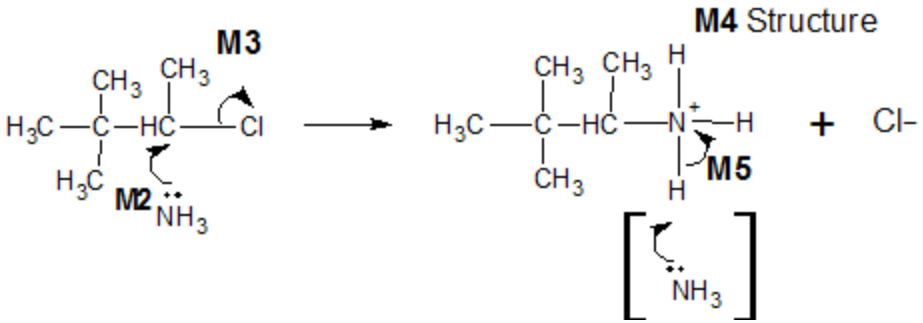
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Question	Marking Guidance	Mark	Comments
8(a)	**P** 3,3-dimethylbut-1-ene ***OR*** accept 3,3-dimethylbutene **Q** 3-chloro-2,2-dimethylbutane ***OR*** accept 2-chloro-3,3-dimethylbutane	2	Ignore absence of commas, hyphens and gaps Require correct spelling In Q, “chloro” must come before “dimethyl”

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8(b)	**M1 <u>Electrophilic addition</u>**  **M2** must show an arrow from the double bond towards the H atom of HCl **M3** must show the breaking of the H–Cl bond **M4** is for the structure of the carbocation **M5** must show an arrow from the lone pair of electrons on the negatively charged chloride ion towards the positively charged carbon atom on <u>their</u> carbocation. **NB The arrows here are double-headed**	5	**M1** both words required **For the mechanism** **M3** Penalise incorrect partial charge on H–Cl bond and penalise formal charges Ignore partial negative charge on the double bond. **<u>Maximum 3 of 4 marks</u> <u>for a correct mechanism</u>** using HBr or the wrong organic reactant or wrong organic product (if shown) or a primary carbocation Penalise once only in any part of the mechanism for a line and two dots to show a bond Credit the correct use of “sticks” For **M5**, credit attack on a partially positively charged carbocation structure, but penalise **M4**

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8(c)	**M1** **<u>Nucleophilic substitution</u>**  **M2** must show an arrow from the lone pair of electrons **on the nitrogen atom** of an ammonia molecule to the correct C atom **M3** must show the movement of a pair of electrons from the C– Cl bond to the Cl atom. Mark **M3** independently provided it is from <u>their original molecule</u> **M4** is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge **must** be shown on, or close to, the N atom. **M5** is for an arrow from the N–H bond to the N atom Award full marks for an S_N1 mechanism in which **M2** is the attack of the ammonia on the intermediate carbocation **NB These are double-headed arrows**	5	For **M1**, both words required. Accept phonetic spelling **For the mechanism** Penalise **M2** if NH_3 is negatively charged. Penalise **M3** for formal charge on C of the C–Cl or incorrect partial charges on C–Cl Penalise **M3** for an additional arrow from the Cl to something else The second mole of ammonia is not essential for **M5**; therefore ignore any species here Penalise once only for a line and two dots to show a bond **<u>Maximum 3 of 4 marks</u>** **<u>for the mechanism</u>** for wrong organic reactant ***OR*** wrong organic product if shown Accept the correct use of “sticks”

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8(d)	**M1** (base) elimination **M2** KOH ***OR*** NaOH **M3** Must be consequential on a correct reagent in **M2**, but if incomplete or inaccurate attempt at reagent (e.g. hydroxide ion), **penalise M2 only and mark on** Any **one** from • high temperature OR hot OR heat / boil under reflux • concentrated • alcohol / ethanol (as a solvent) / (ethanolic conditions)	3	**M1** Dehydrohalogenation **M3** not "reflux" alone **M3** if a temperature is stated it must be in the range 78°C to 200 °C Ignore "pressure"

8(e)	**M1** $3NaBr + H_3PO_4 \longrightarrow 3HBr + Na_3PO_4$ **M2 and M3** SO_2 **and** Br_2 identified **M4** Concentrated sulfuric acid • is an oxidising agent • oxidises the bromide (ion) or Br^- or NaBr or HBr • is an electron acceptor	4	**M1** Credit correct ionic species in the equation In **M2** and **M3** the two gases need to be identified. If equations are used using sulfuric acid and the toxic gases are not identified clearly, allow one mark for the formulas of SO_2 and Br_2 • apply the list principle as appropriate but ignore any reference to HBr • the marks are for identifying the two gases either by name or formula

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Question	Marking Guidance	Mark	Comments
9(a)	**M1 (could be scored by a correct mathematical expression)** **M1** $\Delta H = \sum\Delta H_f$(**products**) - $\sum\Delta H_f$(**reactants**) ***OR*** a correct cycle of balanced equations **M2** = 5(–635) – (– 1560) = – 3175 + 1560 (This also scores M1) **M3** = **– 1615** (kJ mol^{-1}) **Award 1 mark ONLY for (+) 1615** **M4 Type of reaction is** • reduction • redox • (or accept) V_2O_5 / it / V(V) has been reduced	5	Correct answer to the calculation gains all of **M1**, **M2** and **M3** Credit 1 mark for(+) 1615 (kJ mol^{-1}) For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**) • If no AE, check for a correct method; this requires either a correct cycle with V_2O_5 and 5CaO OR a clear statement of **M1** which could be in words and scores **only M1** In **M4** not "vanadium / V is reduced"

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9(a) cont.	**M5 Major reason for expense of extraction – the answer must be about calcium** Calcium is produced / extracted by electrolysis ***OR*** calcium is expensive to extract ***OR*** calcium extraction uses electricity ***OR*** calcium extraction uses large amount of energy ***OR*** calcium is a (very) reactive metal / reacts with water or air ***OR*** calcium needs to be extracted / does not occur native		**QoL** Accept calcium is expensive "to produce" but not "to source, to get, to obtain, to buy" etc. In **M5** it is neither enough to say that calcium is "expensive" nor that calcium "must be purified"
9(b)	**M1** $2Al + Fe_2O_3 \longrightarrow 2Fe + Al_2O_3$ **M2** (Change in oxidation state) **0** to (+)**3** ***OR*** (changed by) **+3**	2	Ignore state symbols Credit multiples of the equation In **M2** if an explanation is given it must be correct and unambiguous

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9(c)	**M1** $VCl_2 + H_2 \longrightarrow V + 2HCl$ **M2** and **M3** Two hazards in either order • HCl / hydrogen chloride / hydrochloric acid is acidic / corrosive / toxic / poisonous • Explosion risk with hydrogen (gas) OR H_2 is flammable **M4** The only other product / the HCl is easily / readily removed / lost / separated because it is a gas *OR* will escape (or this idea strongly implied) as a gas ***OR*** vanadium / it is the only solid product (and is easily separated) ***OR*** vanadium / it is a solid and the other product / HCl is a gas	4	In **M1** credit multiples of the equation For **M2/M3** there must be reference to hydrogen; it is not enough to refer simply to an explosion risk For **M2/M3** with HCl hazard, require reference to acid(ic) / corrosive / toxic only In **M4** it is not enough to state simply that HCl is a gas, since this is in the question.

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General principles applied to marking CHEM2 papers by CMI+ (June 2015)

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are <u>required information</u> to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**

A. <u>The "List principle" and the use of "ignore" in the mark scheme</u>

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. <u>Incorrect case for element symbol</u>

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. <u>Spelling</u>

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

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D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

E. Reagents

The command word "Identify", allows the candidate to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.
For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a candidate provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

F. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

G. Marking calculations, such as those involving enthalpy changes

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In general

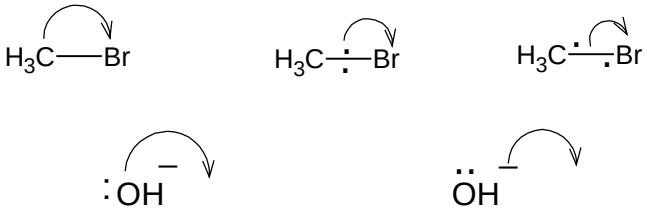
- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will usually score **only one mark**.

All other values **gain no credit** except

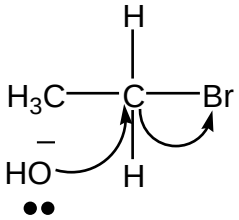
- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

H. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.
The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.
In free-radical substitution

- The absence of a radical dot should be penalised **once only** within a clip.

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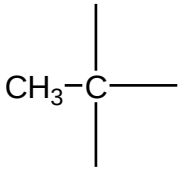
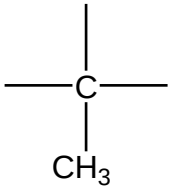
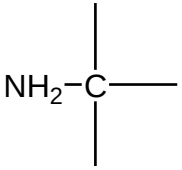
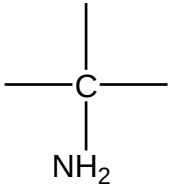
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

I. Organic structures

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if candidates show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in structures, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or C ─ NH_2 bonds should **not** be penalised. For the other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.
  By way of illustration, the following would apply

(a)  allowed	(b)  allowed
(c)  allowed	(d)  allowed

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- In most cases, the use of "sticks" to represent C ─ H bonds in a structure should **not** be penalised. The exceptions will include structures in mechanisms when the C ─ H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.
- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

N.B. Exceptions <u>may</u> be made in the context of balancing equations

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

J. <u>Organic names</u>

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.
Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**

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ethan-1,2-diol	should be **ethane-1,2-diol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**
3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

K. <u>Additional sheets and blank clips</u>

- Markers should **mark all that is seen** and carry on marking as normal. Clips which refer to the use of additional sheets should **not** be referred to the senior team. Clips which refer to other parts of the script must be referred to the senior team.
- When considering crossed out work, **mark it** as if it were not crossed out **unless** it has been replaced by a later version; this later version then takes priority.
- Mark a blank section with a dash (—) and **not with a score of zero**.

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
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TOTAL	

AQA

General Certificate of Education
Advanced Subsidiary Examination
June 2014

Chemistry CHEM2

Unit 2 Chemistry in Action

Tuesday 3 June 2014 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a ruler with millimetre measurements
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use scientific terminology accurately.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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Do not write outside the box

Section A

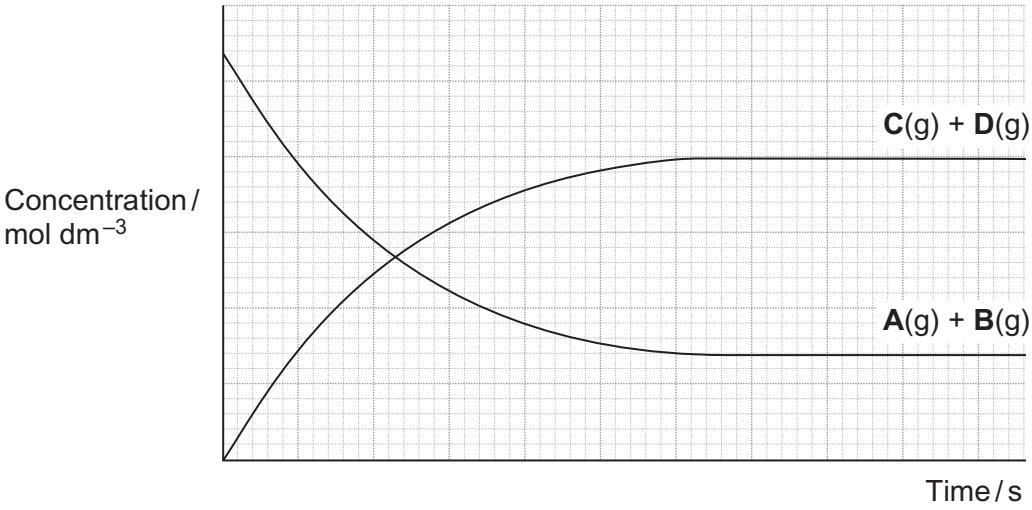
Answer **all** questions in the spaces provided.

1 A dynamic equilibrium is established when gas **A** is mixed with gas **B** at a given temperature.

$$\mathbf{A}(g) + \mathbf{B}(g) \rightleftharpoons \mathbf{C}(g) + \mathbf{D}(g)$$

Figure 1 shows how the concentrations of reactants and products change with time.

Figure 1



1 (a) (i) On the appropriate axis of **Figure 1**, place an **X** to show the time when equilibrium is first established.

[1 mark]

1 (a) (ii) State how the rate of the forward reaction and the rate of the reverse reaction are related to each other at equilibrium.

[1 mark]

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1 (b) Give the meaning of the term **dynamic** in the context of a dynamic equilibrium.

[1 mark]

.....

.....

.....

1 (c) The total pressure on the system is increased at constant temperature.

1 (c) (i) State and explain the effect, if any, of this change on the position of this equilibrium.

[2 marks]

Effect .....

Explanation .....

.....

.....

.....

1 (c) (ii) State and explain the effect, if any, of this change on the time taken to reach this equilibrium.

[3 marks]

Effect .....

Explanation .....

.....

.....

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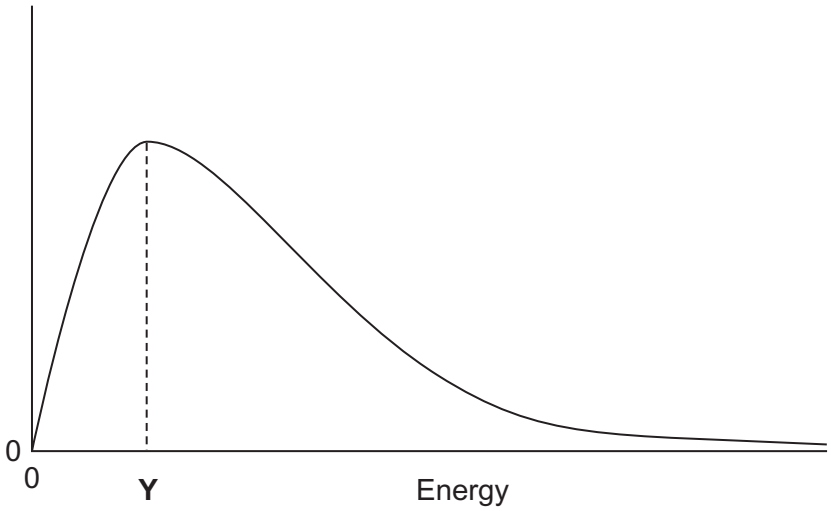
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2 **Figure 2** shows the Maxwell–Boltzmann distribution of molecular energies in a sample of gas at temperature *T*.

Figure 2



2 (a) One of the axes is labelled.
Label the other axis.

[1 mark]

2 (b) State why the curve starts at the origin.

[1 mark]

.....

.....

.....

2 (c) Which of the following, **A**, **B** or **C**, describes what the value of **Y** represents in **Figure 2**?
Write the correct letter, **A**, **B** or **C**, in the box.

[1 mark]

A The energy needed for a successful collision
B The minimum energy needed for a reaction to occur
C The most probable energy

Do not write outside the box

2 (d) On **Figure 2**, draw a distribution of molecular energies in this sample of gas at a **higher** temperature.

[2 marks]

2 (e) The pressure of the original sample of gas is doubled at temperature *T*.

State the effect, if any, of this change on the value of **Y**.

[1 mark]

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6

Turn over for the next question

Do not write outside the box

3 Antimony is a solid element that is used in industry. The method used for the extraction of antimony depends on the grade of the ore.

3 (a) Antimony can be extracted by reacting scrap iron with low-grade ores that contain antimony sulfide (Sb_2S_3).

3 (a) (i) Write an equation for the reaction of iron with antimony sulfide to form antimony and iron(II) sulfide.

[1 mark]

.....

3 (a) (ii) Write a half-equation to show what happens to the iron atoms in this reaction.

[1 mark]

.....

3 (b) In the first stage of the extraction of antimony from a high-grade ore, antimony sulfide is roasted in air to convert it into antimony(III) oxide (Sb_2O_3) and sulfur dioxide.

3 (b) (i) Write an equation for this reaction.

[1 mark]

.....

3 (b) (ii) Identify **one** substance that is manufactured directly from the sulfur dioxide formed in this reaction.

[1 mark]

.....

Do not write outside the box

3 (c) In the second stage of the extraction of antimony from a high-grade ore, antimony(III) oxide is reacted with carbon monoxide at high temperature.

3 (c) (i) Use the standard enthalpies of formation in **Table 1** and the equation given below **Table 1** to calculate a value for the standard enthalpy change for this reaction.

Table 1

	$Sb_2O_3(s)$	$CO(g)$	$Sb(l)$	$CO_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	−705	−111	+20	−394

$$Sb_2O_3(s) + 3CO(g) \longrightarrow 2Sb(l) + 3CO_2(g)$$

[3 marks]

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3 (c) (ii) Suggest why the value for the standard enthalpy of formation of liquid antimony, given in **Table 1**, is **not** zero.

[1 mark]

.....

.....

3 (c) (iii) State the type of reaction that antimony(III) oxide has undergone in this reaction.

[1 mark]

.....

3 (d) Deduce **one** reason why the method of extraction of antimony from a low-grade ore, described in part **3 (a)**, is a low-cost process. Do **not** include the cost of the ore.

[1 mark]

.....

.....

10

Turn over ▶

Do not write outside the box

4 There are many uses for Group 2 metals and their compounds.

4 (a) State a medical use of barium sulfate.
State why this use of barium sulfate is safe, given that solutions containing barium ions are poisonous.

[2 marks]

Use .....

Why this use is safe .....

.....

.....

4 (b) Magnesium hydroxide is used in antacid preparations to neutralise excess stomach acid.

Write an equation for the reaction of magnesium hydroxide with hydrochloric acid.

[1 mark]

.....

4 (c) Solutions of barium hydroxide are used in the titration of weak acids.

State why magnesium hydroxide solution could **not** be used for this purpose.

[1 mark]

.....

.....

4 (d) Magnesium metal is used to make titanium from titanium(IV) chloride.

Write an equation for this reaction of magnesium with titanium(IV) chloride.

[1 mark]

.....

Do not write outside the box

4 (e) Magnesium burns with a bright white light and is used in flares and fireworks.

Use your knowledge of the reactions of Group 2 metals with water to explain why water should **not** be used to put out a fire in which magnesium metal is burning.

[2 marks]

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[Extra space] .....

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7

Turn over for the next question

Do not write outside the box

5 Trifluoromethane (CHF_3) can be used to make the refrigerant chlorotrifluoromethane ($CClF_3$).

5 (a) Chlorotrifluoromethane is formed when trifluoromethane reacts with chlorine.

$$CHF_3 + Cl_2 \longrightarrow CClF_3 + HCl$$

The reaction is a free-radical substitution reaction similar to the reaction of methane with chlorine.

5 (a) (i) Write an equation for each of the following steps in the mechanism for the reaction of CHF_3 with Cl_2

[4 marks]

Initiation step

.....

First propagation step

.....

Second propagation step

.....

Termination step to form hexafluoroethane

.....

5 (a) (ii) Give **one** essential condition for this reaction.

[1 mark]

.....

Do not write outside the box

5 (b) In some refrigeration systems, CHF_3 has replaced $CClF_3$ because of concerns about ozone depletion.

5 (b) (i) Identify the species formed from $CClF_3$ that is responsible for the catalytic decomposition of ozone in the upper atmosphere.

[1 mark]

.....

5 (b) (ii) Write an overall equation to represent the decomposition of ozone into oxygen.

[1 mark]

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7

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6 This question is about Group 7 chemistry.

6 (a) Sea water is a major source of iodine.
The iodine extracted from sea water is impure. It is purified in a two-stage process.

Stage **1** $I_2 + 2H_2O + SO_2 \longrightarrow 2HI + H_2SO_4$

Stage **2** $2HI + Cl_2 \longrightarrow I_2 + 2HCl$

6 (a) (i) State the initial oxidation state and the final oxidation state of sulfur in Stage **1**.
[2 marks]

Oxidation state of S in SO_2 .....

Oxidation state of S in H_2SO_4 .....

6 (a) (ii) State, in terms of electrons, what has happened to chlorine in Stage **2**.
[1 mark]

.....

.....

6 (b) When concentrated sulfuric acid is added to potassium iodide, iodine is formed in the following redox equations.

$$.....KI + ...H_2SO_4 \longrightarrow .....KHSO_4 + ...I_2 + S + ...H_2O$$

$$8KI + 9H_2SO_4 \longrightarrow 8KHSO_4 + 4I_2 + H_2S + 4H_2O$$

6 (b) (i) Balance the equation for the reaction that forms sulfur.
[1 mark]

6 (b) (ii) Deduce the half-equation for the formation of iodine from iodide ions.
[1 mark]

.....

6 (b) (iii) Deduce the half-equation for the formation of hydrogen sulfide from concentrated sulfuric acid.
[1 mark]

.....

Question 6 continues on the next page

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6 (c) A yellow precipitate is formed when silver nitrate solution, acidified with dilute nitric acid, is added to an aqueous solution containing iodide ions.

6 (c) (i) Write the **simplest ionic** equation for the formation of the yellow precipitate.

[1 mark]

.....

6 (c) (ii) State what is observed when concentrated ammonia solution is added to this yellow precipitate.

[1 mark]

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6 (c) (iii) State why the silver nitrate solution is acidified when testing for iodide ions.

[1 mark]

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6 (c) (iv) Explain why dilute hydrochloric acid is **not** used to acidify the silver nitrate solution in this test for iodide ions.

[1 mark]

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Do not write outside the box

6 (d) Chlorine is toxic to humans. This toxicity does not prevent the large-scale use of chlorine in water treatment.

6 (d) (i) Give **one** reason why water is treated with chlorine.

[1 mark]

.....

.....

6 (d) (ii) Explain why the toxicity of chlorine does **not** prevent this use.

[1 mark]

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6 (d) (iii) Write an equation for the reaction of chlorine with cold water.

[1 mark]

.....

6 (e) Give the formulas of the **two** different chlorine-containing compounds that are formed when chlorine reacts with cold, dilute, aqueous sodium hydroxide.

[1 mark]

Formula 1 .....

Formula 2 .....

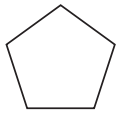
14

Turn over for the next question

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7 **Table 2** gives the names and structures of some structural isomers with the molecular formula C_5H_{10}

Table 2

	Name of isomer	Structure
Isomer **1**	pent-2-ene	$CH_3CH=CHCH_2CH_3$
Isomer **2**	cyclopentane	
Isomer **3**	3-methylbut-1-ene	$(CH_3)_2CHCH=CH_2$
Isomer **4**	2-methylbut-2-ene	$(CH_3)_2C=CHCH_3$
Isomer **5**	2-methylbut-1-ene	$H_2C=C(CH_3)CH_2CH_3$

7 (a) Isomer **1** exists as E and Z stereoisomers.

7 (a) (i) State the meaning of the term **stereoisomers.**

[2 marks]

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7 (a) (ii) Draw the structure of the E stereoisomer of Isomer **1**.

[1 mark]

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7 (b) A chemical test can be used to distinguish between separate samples of Isomer **1** and Isomer **2**.

Identify a suitable reagent for the test.
State what you would observe with Isomer **1** and with Isomer **2**.

[3 marks]

Reagent.....

Observation with Isomer **1**.....

.....

Observation with Isomer **2**.....

.....

7 (c) Use **Table A** on the Data Sheet when answering this question.
Isomer **3** and Isomer **4** have similar structures.

7 (c) (i) State the infrared absorption range that shows that Isomer **3** and Isomer **4** contain the same functional group.

[1 mark]

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7 (c) (ii) State **one** way that the infrared spectrum of Isomer **3** is different from the infrared spectrum of Isomer **4**.

[1 mark]

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Question 7 continues on the next page

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7 (d) Two alcohols are formed by the hydration of Isomer **4**.

Draw the **displayed formula** for the alcohol formed that is oxidised readily by acidified potassium dichromate(VI).

[1 mark]

7 (e) Isomer **4** reacts with hydrogen bromide to give two structurally isomeric bromoalkanes.

7 (e) (i) Name and outline a mechanism for the reaction of Isomer **4** with hydrogen bromide to give 2-bromo-2-methylbutane as the major product.

[5 marks]

$$(CH_3)_2C{=}CHCH_3 \quad + \quad HBr \quad \longrightarrow \quad (CH_3)_2CBrCH_2CH_3$$

Name of mechanism.....

Mechanism

Do not write outside the box

7 (e) (ii) The minor product in this reaction mixture is 2-bromo-3-methylbutane.

Explain why this bromoalkane is formed as a minor product.

[2 marks]

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7 (f) Name and outline a mechanism for the following reaction to form Isomer **5**.
State the role of the hydroxide ion in this reaction.

[5 marks]

$(CH_3)_2CBrCH_2CH_3 + KOH \longrightarrow H_2C=C(CH_3)CH_2CH_3 + KBr + H_2O$

Name of mechanism .....

Mechanism

Role of hydroxide ion .....

21

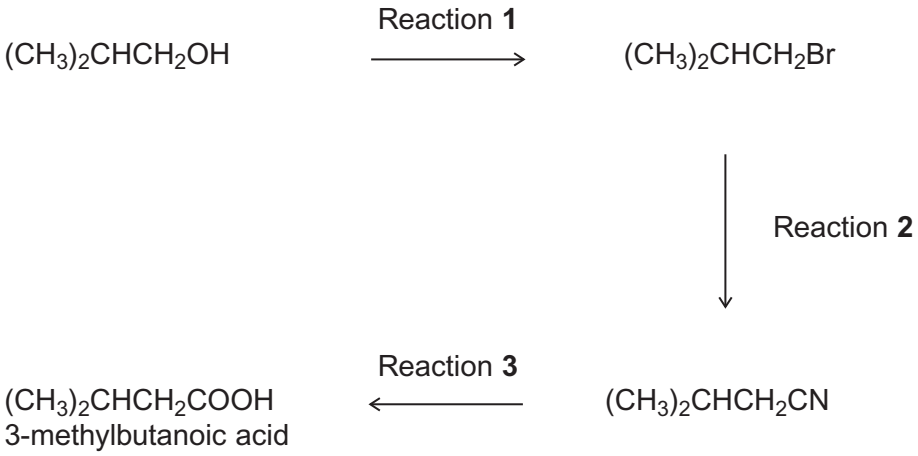
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Section B

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

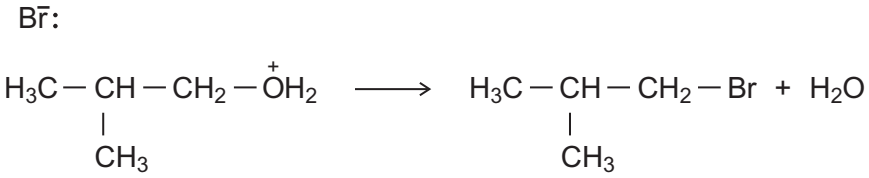
8 The carboxylic acid 3-methylbutanoic acid is used to make esters for perfumes. The following scheme shows some of the reactions in the manufacture of this carboxylic acid.



8 (a) One of the steps in the mechanism for Reaction **1** involves the replacement of the functional group by bromine.

8 (a) (i) Use your knowledge of organic reaction mechanisms to complete the mechanism for this step by drawing **two** curly arrows on the following equation.

[2 marks]



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8 (a) (ii) Deduce the name of the mechanism in Question **8 (a) (i)**.

Give the IUPAC name of $(CH_3)_2CHCH_2Br$

[2 marks]

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8 (b) Reaction **3** is an acid-catalysed reaction in which water is used to break chemical bonds when the CN functional group is converted into the COOH functional group. Infrared spectroscopy can be used to distinguish between the compounds in this reaction.

Deduce the name of the type of reaction that occurs in Reaction **3**.

Identify **one** bond in $(CH_3)_2CHCH_2CN$ and a **different** bond in $(CH_3)_2CHCH_2COOH$ that can be used with infrared spectroscopy to distinguish between each compound. For each of these bonds, give the range of wavenumbers at which the bond absorbs. Use **Table A** on the Data Sheet when answering this question.

[3 marks]

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Question 8 continues on the next page

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8 (c) When 3-methylbutanoic acid reacts with ethanol in the presence of an acid catalyst, an equilibrium is established. The organic product is a pleasant-smelling ester.

$$(CH_3)_2CHCH_2COOH + CH_3CH_2OH \rightleftharpoons \underset{\text{an ester}}{(CH_3)_2CHCH_2COOCH_2CH_3} + H_2O$$

The carboxylic acid is very expensive and ethanol is inexpensive. In the manufacture of this ester, the mole ratio of carboxylic acid to ethanol used is 1 to 10 rather than 1 to 1.

8 (c) (i) Use Le Chatelier's principle to explain why a 1 to 10 mole ratio is used. In your explanation, you should **not** refer to cost.

[3 marks]

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[Extra space] .....

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8 (c) (ii) Explain how a catalyst increases the rate of a reaction.

[2 marks]

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[Extra space] .....

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12

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9 Ethanol is an important fuel.

9 (a) A dilute aqueous solution of ethanol can be produced by the fermentation of an aqueous solution of glucose.
It is claimed that the ethanol obtained from this solution is a carbon-neutral biofuel.

Write an equation for this fermentation reaction.

Give **two** other essential conditions for this reaction to produce a good yield of ethanol.

Name a process used to produce a much more concentrated solution of ethanol from a dilute aqueous solution.

State the meaning of the term **carbon-neutral** in the context of this biofuel.

[5 marks]

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[Extra space] .....

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Question 9 continues on the next page

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9 (b) A student carried out a laboratory experiment to determine the enthalpy change when a sample of ethanol was burned. The heat produced was used to warm some water in a copper calorimeter. The student found that the temperature of 75.0 g of water increased by 5.50 ºC when 2.40×10^{-3} mol of pure ethanol was burned in air.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of ethanol is burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

Deduce **two** reasons why the student's value for the standard enthalpy of combustion of ethanol is different from a Data Book value of –1279 kJ mol^{-1}.

[5 marks]

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[Extra space].....

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9 (c) Mean bond enthalpies can be used to calculate enthalpies of reaction.

9 (c) (i) Give the meaning of the term **mean bond enthalpy**.

[2 marks]

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9 (c) (ii) Consider the mean bond enthalpy data in **Table 3**.

Table 3

	C—H	**C—C**	**C—O**	**O=O**	**C=O**	**O—H**
Mean bond enthalpy / kJ mol^{-1}	412	348	360	to be calculated	805	463

Use the data in **Table 3** and the equation shown to calculate a value for the bond enthalpy for the O=O double bond in an oxygen molecule.

[3 marks]

$$CH_3CH_2OH(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g) \quad \Delta H = -1279 \text{ kJ mol}^{-1}$$

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END OF QUESTIONS

15

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AQA Qualifications

A-LEVEL
CHEMISTRY

CHEM2 Chemistry in Action
Mark scheme

2420
June 2014

Version: 1.2 Final

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Question	Marking Guidance	Mark	Comments
1(a)(i)	Award mark for **X on the time axis** at the point where the lines just become **horizontal**	1	Allow this mark If **X** is above the letters “sh” in the word “show’ in Question 1(a)(ii) - in the range of lines 31 to 33
1(a)(ii)	They are equal / the same **OR** Forward (rate) = Reverse / backward (rate)	1	Allow the word ‘speed’ in this context. Ignore reference to concentration.
1(b)	Both **OR** forward and reverse reactions occur at the same time **OR** both are occurring at once **OR** both occur all of the time **OR** both are ongoing **OR** both never stop	1	Ignore ‘at equal rates’. Ignore reference to concentration or equilibrium. The idea that both reactions occur simultaneously is essential. The simple idea of ‘both reactions occurring’ is insufficient for the mark.
1(c)(i)	**M1** No effect / no change / none / stays the same **M2** requires correct **M1** **M2** Equal (number of) moles / molecules on both sides	2	In **M2**, ignore reference to particles or atoms.

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1(c)(ii)	**M1** Less time or it decreases or (equilibrium) reached faster (ie **M1** is a reference to time taken) **M2** More particles / molecules in a given volume / space **OR** the particles / molecules are closer together **M3** More successful / productive collisions in a given time **OR** more collisions with $E>E_{Act}$ in a given time **OR** more frequent successful / productive collisions **OR** increased / greater successful / productive collision frequency / rate	3	If **M1** is 'more time / it increases' or 'no effect', then **CE=0** for the clip. Reference to faster / increased rate / increased speed alone penalises **M1**, but mark on **M2** and **M3** If **M1** is blank, then look for all three marks in the text. Ignore reference to reactants / products. Penalise **M3** if an increase / decrease in the value of E_{Act} is stated.

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Question	Marking Guidance	Mark	Comments
2(a)	Amount / number / proportion / percentage / fraction / moles of molecules / particles	1	Penalise an incorrect qualification of the number eg NOT number of molecules with E greater than Ea Not 'atoms'.
2(b)	There are no molecules / particles with zero energy **OR** All of the molecules / particles are moving / have some energy	1	Not 'atoms'. The answer should relate the energy to the molecules.
2(c)	**C** (The most probable energy)	1	

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2(d)	**M1** The peak of the new curve is <u>displaced to the right</u> and <u>lower</u> than the original **M2** All of the following needed • The new curve starts at the origin and should begin to separate from the original almost immediately • <u>and</u> the new curve only crosses the original curve once • <u>and</u> the total area under the new curve is <u>approximately</u> the same as the original • <u>and</u> an attempt has been made to draw the new curve correctly towards the axis <u>above the original curve</u> but not to touch the original curve	2	

2(e)	None / no effect / stays the same	1	

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Question	Marking Guidance	Mark	Comments
3(a)(i)	**3**Fe + Sb_2S_3 ⟶ **3**FeS + **2**Sb	1	Or multiples. Ignore state symbols.
3(a)(ii)	Fe ⟶ Fe^{2+} + $2e^-$	1	Ignore charge on the electron unless incorrect. Or multiples. Credit the electrons being subtracted on the LHS. Ignore state symbols.
3(b)(i)	Sb_2S_3 + **4.5**O_2 ⟶ Sb_2O_3 + **3**SO_2	1	Or multiples. Ignore state symbols.
3(b)(ii)	SO_3 or sulfur trioxide / sulfur (VI) oxide	1	Credit also the following ONLY H_2SO_4 or sulfuric acid ***OR*** gypsum / $CaSO_4$ or plaster of Paris

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3(c)(i)	**M1 (could be scored by a correct mathematical expression)** **M1** $\underline{\Delta H_r = \sum \Delta H_f(\textbf{products}) - \sum \Delta H_f(\textbf{reactants})}$ **OR** a <u>correct cycle of balanced equations / correct numbers of moles</u> **M2** = 2(+20) + 3(– 394) – (– 705) – 3(–111) = 40 –1182 + 705 + 333 = –1142 – (–1038) (This also scores M1) **M3** = **<u>–104</u>** (kJ mol^{-1}) **(Award 1 mark ONLY for + 104)**	3	Correct answer gains full marks. Credit 1 mark for +104 (kJ mol^{-1}). For other incorrect or incomplete answers, proceed as follows: • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks. • If no AE, check for a correct method; this requires either a correct cycle with 3CO, 2Sb and $3CO_2$ OR a clear statement of **M1** which could be in words and scores **<u>only M1</u>**.
3(c)(ii)	It / Sb is <u>not in its standard state</u> **OR** <u>Standard state</u> (for Sb) <u>is solid / (s)</u> **OR** <u>(Sb) liquid is not its standard state</u>	1	Credit a correct definition of standard state as an alternative to the words 'standard state'. **QoL**
3(c)(iii)	Reduction **OR** reduced **OR** redox	1	

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3(d)	Low-grade ore extraction / it • uses (cheap) <u>scrap / waste</u> <u>iron / steel</u> • is a single-step process • uses / requires <u>less / low(er) energy</u>	1	Ignore references to temperature / heat or labour or technology.

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Question	Marking Guidance	Mark	Comments
4(a)	**M1** Used in a barium meal / barium swallow / barium enema **OR** (used to absorb) X-rays **M2** $\underline{BaSO_4}$ / barium sulfate / it is insoluble	2	Credit a correct reference to **M1** written in the explanation in **M2** unless contradictory. For **M2** penalise obvious reference to barium or to barium ions being insoluble.
4(b)	$Mg(OH)_2 + \mathbf{2}HCl \longrightarrow MgCl_2 + 2H_2O$	1	Or multiples. Ignore state symbols.
4(c)	It / magnesium hydroxide is insoluble / insufficiently soluble / sparingly soluble / less soluble than barium hydroxide / forms low concentration solutions	1	Weak alkali alone is insufficient. Formation of a precipitate needs explanation.
4(d)	$TiCl_4 + \mathbf{2}Mg \longrightarrow \mathbf{2}MgCl_2 + Ti$	1	Or multiples. Ignore state symbols.

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4(e)	**M1** Hydrogen / H_2 produced **OR** an equation to produce <u>hydrogen / H_2</u> (eg $Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2$) (eg $Mg + H_2O \longrightarrow MgO + H_2$) **M2** requires correct **M1** risk of explosion **OR** forms explosive mixture (with air) **OR** (highly) flammable	2	For **M1** Do not penalise an incorrect equation; the mark is for H_2 or hydrogen. Award one mark only for '<u>exothermic reaction</u> with steam / H_2O' for a student who has not scored **M1** Ignore 'violent' reaction.

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Question	Marking Guidance	Mark	Comments
5(a)(i)	**M1 Initiation** $Cl_2 \longrightarrow 2Cl\bullet$ **M2 First propagation** $Cl\bullet + CHF_3 \longrightarrow CF_3\bullet + HCl$ **M3 Second propagation** $Cl_2 + CF_3\bullet \longrightarrow CClF_3 + Cl\bullet$ **M4 Termination (must make C_2F_6)** $2\ CF_3\bullet \longrightarrow C_2F_6$ or CF_3CF_3	4	Penalise absence of dot once only. Penalise + or – charges <u>every time</u> Credit $CF_3\bullet$ with the radical dot above / below / to either side. Mark independently.
5(a)(ii)	ultra-violet / uv / sun light **OR** (very) high temperature **OR** 500 $^oC \leq T \leq 1000\ ^oC$ **OR** 773 K $\leq T \leq$ 1273 K	1	

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5(b)(i)	Cl• **OR** chlorine atom / chlorine (free-) radical / Cl (atom)	1	Not 'chlorine' alone. Credit 'Cl' alone on this occasion.

5(b)(ii)	**2**O_3 $\longrightarrow$ **3**O_2	1	Or multiples. Ignore state symbols. If the correct answer is on the line OR clearly identified below some working, then ignore any working.

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Question	Marking Guidance	Mark	Comments
6(a)(i)	**M1** (+) 4 **OR** IV **M2** (+) 6 **OR** VI	2	
6(a)(ii)	It / Chlorine has gained / accepted electron(s) **OR** Correctly balanced half-equation eg $Cl_2 + \mathbf{2}e^- \longrightarrow \mathbf{2}Cl^-$	1	Credit 1 or 2 electrons but not lone pair. The idea of 'reduction' alone is not enough.
6(b)(i)	$\mathbf{6}KI + \mathbf{7}H_2SO_4 \longrightarrow \mathbf{6}KHSO_4 + \mathbf{3}I_2 + S + \mathbf{4}H_2O$	1	
6(b)(ii)	$\mathbf{2}I^- \longrightarrow I_2 + \mathbf{2}e^-$ **OR** $8I^- \longrightarrow 4\mathbf{I_2} + 8e^-$	1	Ignore charge on the electron unless incorrect. Or multiples. Credit the electrons being subtracted on the LHS. Ignore state symbols.
6(b)(iii)	$H_2SO_4 + \mathbf{8}H^+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$ **OR** $SO_4^{2-} + \mathbf{10}H^+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$	1	Ignore charge on the electron unless incorrect. Or multiples. Credit the electrons being subtracted on the RHS. Ignore state symbols.

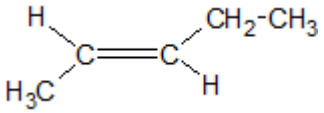
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6(c)(i)	$Ag^+ + I^- \longrightarrow AgI$ ONLY	1	Ignore state symbols. Not multiples.
6(c)(ii)	The precipitate / solid / it does not dissolve / is insoluble / remains **OR** a white / cream / yellow solid / precipitate **OR** stays the same **OR** no (visible / observable) change **OR** no effect / no reaction	1	Ignore 'nothing (happens)'. Ignore 'no observation'.
6(c)(iii)	The silver nitrate is acidified to • react with / remove (an)ions that would interfere with the test • prevent the formation of other silver precipitates / insoluble silver compounds that would interfere with the test • remove (other) ions that react with the silver nitrate • react with / remove carbonate / hydroxide / sulfite (ions)	1	Credit a correct reference to ions that give a 'false positive'. Do not penalise an incorrect formula for an ion that is written in addition to the name. If only the formula of the ion is given, it must be correct. Ignore 'sulfate'.
6(c)(iv)	HCl would form a (white) precipitate / (white) solid (with silver nitrate and this would interfere with the test)	1	It is not sufficient simply to state either that it will interfere **or** simply that the ions / compounds react to form AgCl

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6(d)(i)	Any **one** from • to sterilise / disinfect water • to destroy / kill microorganisms / bacteria / microbes / pathogens	1	Ignore 'to clean water'. Ignore 'water purification' and 'germs'. Credit 'remove bacteria etc' / prevent algae.
6(d)(ii)	The (health) benefit outweighs the risk **OR** a clear statement that once it has done its job, little of it remains **OR** used in (very) dilute concentrations / small amounts / low doses	1	
6(d)(iii)	$Cl_2 + H_2O \longrightarrow HClO + HCl$ **OR** $Cl_2 + H_2O \longrightarrow \mathbf{2}H^+ + ClO^- + Cl^-$ **OR** $\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$	1	Credit HOCl or ClOH Or multiples. Credit other ionic or mixed representations. Ignore state symbols.
6(e)	**In either order - Both required for one mark only** NaClO (OR NaOCl) **and** NaCl	1	Credit correct ionic formulae. Give credit for answers in equations unless contradicted.

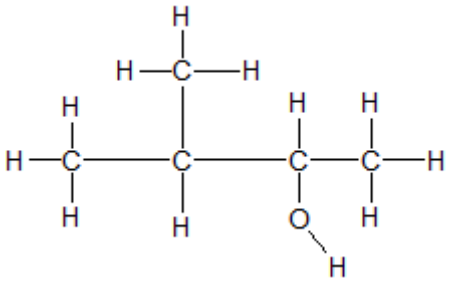
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Question	Marking Guidance	Mark	Comments
7(a)(i)	**M1** (Compounds / molecules with) the same structural formula **M2** with atoms / bonds / groups arranged differently in space **OR** atoms / bonds / groups with different spatial arrangements / different orientation	2	Penalise **M1** if 'same structure' or 'different structural / displayed formula'. Ignore references to 'same molecular formula' or 'same empirical formula'. Mark independently.
7(a)(ii)		1	Credit C–H_3C Credit C_2H_5 Penalise C–CH_3CH_2

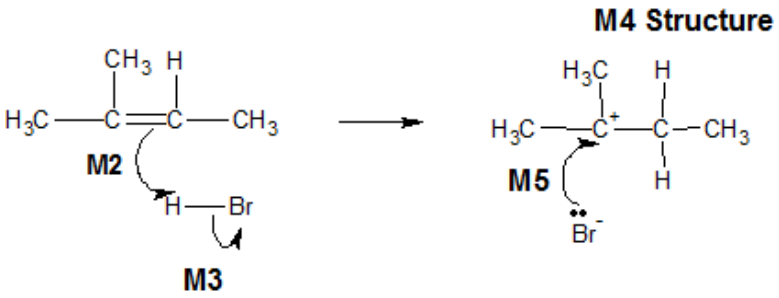
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7(b)	**M1** Br_2 OR bromine (water) OR bromine (in CCl_4 / organic solvent) **M2** Isomer 1: decolourised / goes colourless / loses its colour **M3** Isomer 2: remains orange / red / yellow / brown / the same **OR** no reaction / no (observable) change **OR** reference to colour going to the cyclopentane layer **Alternatives** : **potassium manganate(VII)** **M1** $KMnO_4$ in acid **M2** colourless **M3** purple **M1** $KMnO_4$ in alkali / neutral **M2** brown solid **M3** purple Credit for the use of **iodine** **M1** iodine (solution / in KI) **M2** colourless **M3** (brown) to purple (credit no change) Credit for the use of **<u>concentrated</u> H_2SO_4** **M1** <u>concentrated</u> H_2SO_4 **M2** brown **M3** no change / colourless	3	If **M1**, has no reagent or an incorrect reagent, **CE=0** Ignore 'acidified'. For **M1** penalise Br (or incorrect formula of other correct reagent), but mark on. For **M1**, it must be a whole reagent and/or correct formula. If oxidation state given in name, it must be correct. If 'manganate' OR 'manganate(IV)' or incorrect formula, penalise **M1**, but mark on. Ignore 'goes clear'. Ignore 'nothing (happens)'. Ignore 'no observation'. No credit for combustion observations.

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7(c)(i)	(Both infrared spectra show an absorption in range) **1620 to 1680** (cm^{-1})	1	Ignore reference to other ranges (eg for C–H or C–C).
7(c)(ii)	The fingerprint (region) / below 1500 cm^{-1} will be different **or** its fingerprinting will be different **OR** different absorptions / peaks are seen (in the region) below 1500 cm^{-1} (or a specified region within the fingerprint range)	1	Allow the words 'dip' **OR** 'spike' **OR** 'low transmittance' as alternatives for absorption. **QoL**
7(d)		1	All bonds must be drawn. Ignore bond angles.

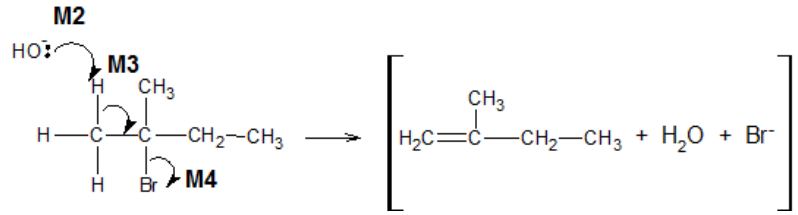
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7(e)(i)	**M1 Electrophilic addition**  **M2** must show an arrow from the double bond towards the H atom of the H–Br molecule **M3** must show the breaking of the H—Br bond **M4** is for the structure of the tertiary carbocation **M5** must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged carbon atom of either a secondary or a tertiary carbocation **NB The arrows here are double-headed**	5	**M1** both words needed. Penalise one mark from <u>their</u> total if half-headed arrows are used. **M2** Ignore partial negative charge on the double bond. **M3** Penalise incorrect partial charges on H–Br bond and penalise formal charges. Penalise **M4** if there is a bond drawn to the positive charge. Penalise once only in any part of the mechanism for a line and two dots to show a bond. **<u>Max 3 of any 4 marks in the mechanism</u>** for wrong organic reactant or wrong organic product (if shown) or secondary carbocation. **<u>Max 2 of any 4 marks in the mechanism</u>** for use of bromine. Do not penalise the correct use of 'sticks". For **M5**, credit attack on a partially positively charged carbocation structure but penalise **M4**

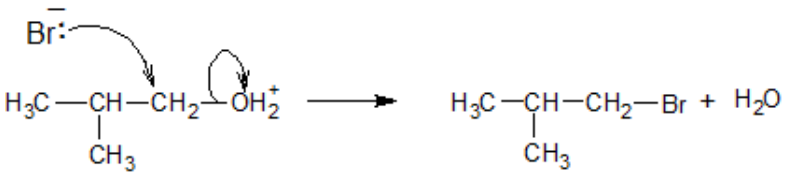
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7(e)(ii)	**M1** Reaction goes via intermediate carbocations / carbonium ions **M2 (scores both marks and depends on M1)** Tertiary carbocation / carbonium ion is more stable (than the secondary carbocation / carbonium ion) **OR** Secondary carbocation / carbonium ion is less stable (than the tertiary carbocation / carbonium ion)	2	**M1** is a lower demand mark for knowledge that carbocations are involved. **M2** is of higher demand and requires the idea that the secondary carbocation is less stable or the tertiary carbocation is more stable. Reference to incorrect chemistry is penalised. A carbocation may be defined in terms of alkyl groups / number of carbon atoms, rather than formally stated.

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7(f)	**M1 Elimination**  **M2** must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to a correct H atom **M3** must show an arrow from a correct C–H bond adjacent to the C–Br bond to a correct C–C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C–H bond (in **M2**) **M4** is independent provided it is from their original molecule **BUT penalise M2, M3 and M4 if nucleophilic substitution** shown Award full marks for an E1 mechanism in which **M2** is on the correct carbocation **NB The arrows here are double-headed** **M5** hydroxide ion behaves as a base / proton acceptor / electron pair donor / lone pair donor	5	**M1** credit 'base elimination' but no other qualifying prefix. Penalise one mark from their total if half-headed arrows are used. Penalise **M2** if covalent KOH Penalise **M4** for formal charge on C or Br of the C–Br bond or incorrect partial charges on C–Br Penalise **M4** if an additional arrow is drawn from the Br of the C–Br bond to, for example, K^+ Ignore other partial charges. Penalise **once only** in any part of the mechanism for a line and two dots to show a bond. **Max 2 of any 3 marks in the mechanism** for wrong reactant or wrong organic product (if shown) or a correct mechanism that leads to the alkene 2-methylbut-2-ene Credit the correct use of "sticks" for the molecule except for the C–H being attacked. Penalise **M5** if 'nucleophile'.

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Question	Marking Guidance	Mark	Comments
8(a)(i)	**M1** double-headed curly arrow from the lone pair of the bromide ion to the C atom of the CH_2 **M2** double-headed arrow from the bond to the O atom As follows 	2	Penalise additional arrows.
8(a)(ii)	**M1** <u>nucleophilic substitution</u> **M2** 1-bromo(-2-)methylpropane	2	**M1** both words needed (allow phonetic spelling). **M2** Require correct spelling in the name but ignore any hyphens or commas.

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8(b)	**M1** hydrolysis **M2** C≡N with absorption range 2220–2260 (cm^{-1}) **M3** O–H(acids) with absorption range 2500–3000 (cm^{-1}) **OR** C=O with absorption range 1680–1750 (cm^{-1}) **OR** C–O with absorption range 1000–1300 (cm^{-1})	3	For **M1** give credit for 'hydration' on this occasion only. Credit 1 mark from **M2** and **M3** for identifying C≡N **and** either O–H(acids) **or** C=O **or** C–O without reference to wavenumbers or with incorrect wavenumbers. Apply the list principle to **M3**
8(c)(i)	**M1** Yield / product **OR** ester increases / goes up / gets more **M2** (By Le Chatelier's principle) the position of equilibrium is driven / shifts / moves to the right / L to R / in the forward direction / to the product(s) **M3 – requires a correct statement in M2** (The position of equilibrium moves) to oppose the increased concentration of ethanol to oppose the increased moles of ethanol to lower the concentration of ethanol to oppose the change and decrease the ethanol	3	If no reference to **M1**, marks **M2** and **M3** can still score BUT if **M1** is incorrect CE=0 If there is reference to 'pressure' award **M1** ONLY.

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8(c)(ii)	**M1** Catalysts provide an alternative route / pathway / mechanism **OR** surface adsorption / surface reaction occurs **M2** that has a lower / reduced activation energy **OR** lowers / reduces the activation energy	2	For **M1**, not simply 'provides a surface' as the only statement. **M1** may be scored by reference to a specific example. Penalise **M2** for reference to an increase in the energy of the molecules. For **M2**, the student may use a definition of activation energy without referring to the term. Reference to an increase in successful collisions in unit time alone is not sufficient for **M2** since it does not explain why this has occurred.

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Question	Marking Guidance	Mark	Comments
9(a)	**M1** $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH + **2**CO_2 ($2C_2H_5OH$) **M2** and **M3** Any **two** conditions **<u>in any order</u>** for **M2** and **M3** from • (enzymes from) yeast or zymase • 25 °C ≤ T ≤ 42 °C OR 298 K ≤ T ≤ 315 K • <u>anaerobic / no oxygen / no air</u> OR neutral pH **M4** (fractional) distillation or GLC **M5** Carbon-neutral **in this context** means There is no <u>net / overall</u> (annual) <u>carbon dioxide / CO_2 emission</u> <u>to the atmosphere</u> **OR** There is no change in the <u>total amount / level</u> of <u>carbon dioxide / CO_2</u> present <u>in the atmosphere</u>	5	Penalise C_2H_6O for ethanol in **M1** Mark **M2** and **M3** independently. A lack of oxygen can mean either without oxygen or not having enough oxygen and does not ensure <u>no oxygen,</u> therefore only credit "lack of oxygen" if it is qualified. Penalise 'bacteria', 'phosphoric acid', 'high pressure' using the list principle. Ignore reference to 'aqueous' or 'water' (ie not part of the list principle). For **M5** – must be about CO_2 <u>and</u> the atmosphere. The idea that the <u>carbon dioxide / CO_2</u> given out equals the <u>carbon dioxide / CO_2</u> that was taken in from <u>the atmosphere.</u>

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9(b)	**M1** q = m c ΔT (this mark for correct mathematical formula) **M2** = (75 × 4.18 × 5.5) 1724 (J) **OR** 1.724 (kJ) **OR** 1.72 (kJ) **OR** 1.7 (kJ) (also scores **M1**) **M3** Using 0.0024 mol therefore ΔH = **– 718** (kJ mol^{-1}) (Accept a range from –708 to –719 but do not penalise more than 3 significant figures) **M4** and **M5** in any order Any **two** from • incomplete combustion • heat loss • heat capacity of Cu not included • some ethanol lost by evaporation • not all of the (2.40×10^{-3} mol) ethanol is burned / reaction is incomplete	5	Full marks for **M1**, **M2** and **M3** for the correct answer. In **M1**, do not penalise incorrect cases in the formula. Ignore incorrect units in **M2** Penalise **M3** ONLY if correct numerical answer but sign is incorrect. Therefore **+718 gains two marks.** If units are quoted in **M3** they must be correct If ΔT = 278.5, CE for the calculation and penalise **M2** and **M3** If c = 4.81 (leads to 1984) penalise **M2** ONLY and mark on for **M3** = – 827

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9(c)(i)	**M1** enthalpy / heat / energy change (at constant pressure) or enthalpy / heat / energy needed in <u>breaking / dissociating (a) covalent bond(s)</u> **M2** <u>averaged</u> for that type of bond over <u>different / a range of molecules / compounds</u>	2	Ignore bond making. Ignore reference to moles.

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9(c)(ii)	**M1** $\sum$ B(**reactants**) – $\sum$ B(**products**) = ΔH **OR** Sum of bonds broken – Sum of bonds formed = ΔH **OR** B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O) – 4B(C=O) – 6B(O–H) = ΔH = –1279 **M2** (also scores **M1**) 348+360+463+5(412)+ 3B(O=O) (**3231**) (or **2768** if O–H cancelled) – 4(805) – 6(463) = ΔH = – 1279 (**5998**) (or **5535** if O–H cancelled) 3B(O=O) = **1488** (kJ mol^{-1}) **M3** B(O=O) = **496** (kJ mol^{-1}) Award 1 mark for –496 **Students may use a cycle and gain full marks**	3	Correct answer gains full marks. Credit **1 mark for – 496** (kJ mol^{-1}) For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**). If no AE, check for a correct method; this requires either a correct cycle with $2CO_2$ and $3H_2O$ OR a clear statement of **M1** which could be in words and scores **only M1**. Credit a maximum of one mark if the only scoring point is bonds formed adds up to **5998 (or 5535) OR** bonds broken includes the calculated value of **3231 (or 2768)**.

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General principles applied to marking CHEM2 papers by CMI+ (June 2014)

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are <u>required information</u> to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**

1. The "List principle" and the use of "ignore" in the mark scheme

If a question requires **one** answer and a student gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

NB Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

2. Incorrect case for element symbol

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

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3. Spelling

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

NB Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

4. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

5. Reagents

The command word "Identify", allows the student to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.
For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a student provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

6. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

7. Marking calculations

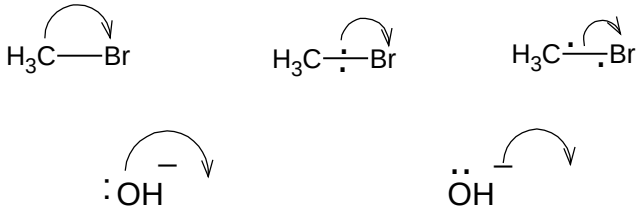
In general

- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- An arithmetic or transposition error will result in a one mark penalty if further working is correct.
- A chemical error will usually result in at least a two mark penalty; often no marks are awarded.

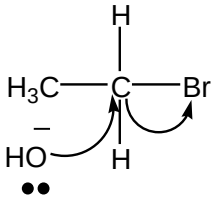
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8. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.
The following representations should not gain credit **and will be penalised each time** within a clip.

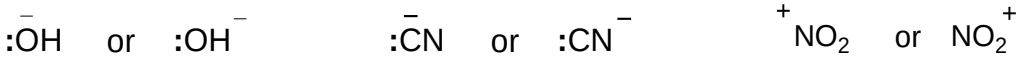


For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

The following are acceptable representations of ions, both in equations and in mechanisms:



In free-radical substitution

- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

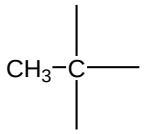
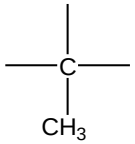
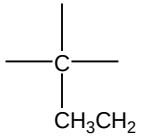
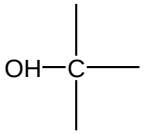
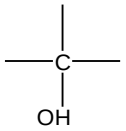
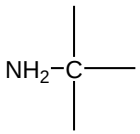
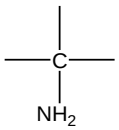
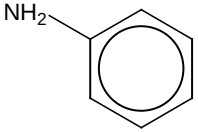
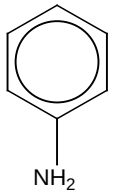
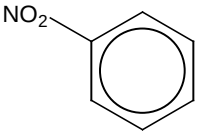
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9. Organic structures

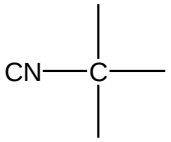
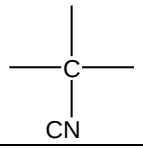
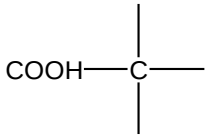
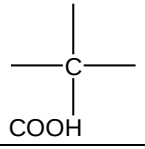
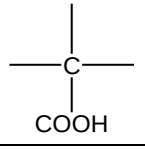
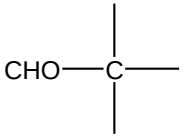
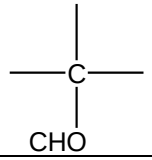
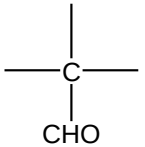
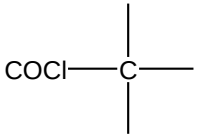
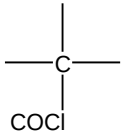
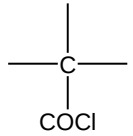
In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms. This principle applies in all cases where the attached functional group contains a carbon atom, e.g nitrile, carboxylic acid, aldehyde and acid chloride. The carbon-carbon bond should be clearly shown. Wrongly bonded atoms will be penalised **on every occasion**. (see the examples below)
- The same principle should also be applied to the structure of alcohols. For example, if students show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in alkyl groups, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Similar latitude should be given to the representation of amines where NH_2─ C will be allowed, although H_2N─ C would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or vertical C ─ NH_2 bonds should **not** be penalised. For other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.

By way of illustration, the following would apply.

				
allowed	**allowed**	not allowed	not allowed	not allowed
				
allowed	**allowed**	**allowed**	**allowed**	not allowed

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not allowed	not allowed	not allowed	not allowed	not allowed	
					
not allowed	not allowed	not allowed	not allowed	not allowed	not allowed

- In most cases, the use of "sticks" to represent C ─ H bonds in a structure should **not** be penalised. The exceptions will include structures in mechanisms when the C ─ H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.

- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethane

NB Exceptions may be made in the context of balancing equations

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- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

10. Organic names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.

Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**
ethan-1,2-diol	should be **ethane-1,2-diol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**
3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
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TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
June 2013

Chemistry CHEM2

Unit 2 Chemistry in Action

Tuesday 4 June 2013 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use scientific terminology accurately.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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ANSWER IN THE SPACES PROVIDED

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Section A

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

1 Sulfuric acid is manufactured by the Contact Process.

1 (a) In this process, sulfur dioxide reacts with oxygen.
The equation for the equilibrium that is established is

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad \Delta H = -98\ kJ\ mol^{-1}$$

1 (a) (i) State and explain the effect of a **decrease** in temperature on the equilibrium yield of SO_3

Effect of a decrease in temperature on yield .....

Explanation .....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

1 (a) (ii) Give **two** features of a reaction at equilibrium.

Feature 1 .....

.....

.....

.....

Feature 2 .....

.....

.....

.....

(2 marks)

Question 1 continues on the next page

Turn over ▶

Do not write outside the box

1 (b) Write an equation for the reaction of concentrated sulfuric acid with potassium bromide to form potassium hydrogensulfate and hydrogen bromide.

.....

(1 mark)

1 (c) Bromine is one of the products formed when concentrated sulfuric acid reacts with hydrogen bromide.

Write an equation for this reaction.
State the role of sulfuric acid in this reaction.

Equation

.....

Role of sulfuric acid .....

(3 marks)

1 (d) Concentrated sulfuric acid is used in a two-stage process to convert 2-methylpropene into 2-methylpropan-2-ol.

Stage **1** $(CH_3)_2C{=}CH_2 + H_2SO_4 \longrightarrow (CH_3)_2C(OSO_2OH)CH_3$

Stage **2** $(CH_3)_2C(OSO_2OH)CH_3 + H_2O \longrightarrow (CH_3)_2C(OH)CH_3 + H_2SO_4$

1 (d) (i) Name and outline a mechanism for Stage **1** of this conversion.

Name of mechanism .....

Mechanism

(5 marks)

Do not write outside the box

1 (d) (ii) Deduce the type of reaction in Stage **2** of this conversion.

.....

(1 mark)

1 (d) (iii) State the overall role of sulfuric acid in this conversion.

.....

(1 mark)

16

Turn over for the next question

Do not write outside the box

2 The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair, give a suitable reagent that could be added separately to each compound to distinguish between them.
Describe what you would observe in each case.

2 (a) AgBr(s) and AgI(s)

Reagent .....

Observation with AgBr(s) .....

.....

Observation with AgI(s) .....

.....

(3 marks)

2 (b) HCl(aq) and HNO_3(aq)

Reagent .....

Observation with HCl(aq) .....

.....

Observation with HNO_3(aq) .....

.....

(3 marks)

2 (c) Cyclohexane and cyclohexene

Reagent .....

Observation with cyclohexane .....

.....

Observation with cyclohexene .....

.....

(3 marks)

Do not write outside the box

2 (d) Butanal and butanone

Reagent .....

Observation with butanal .....

.....

Observation with butanone .....

.....

(3 marks)

12

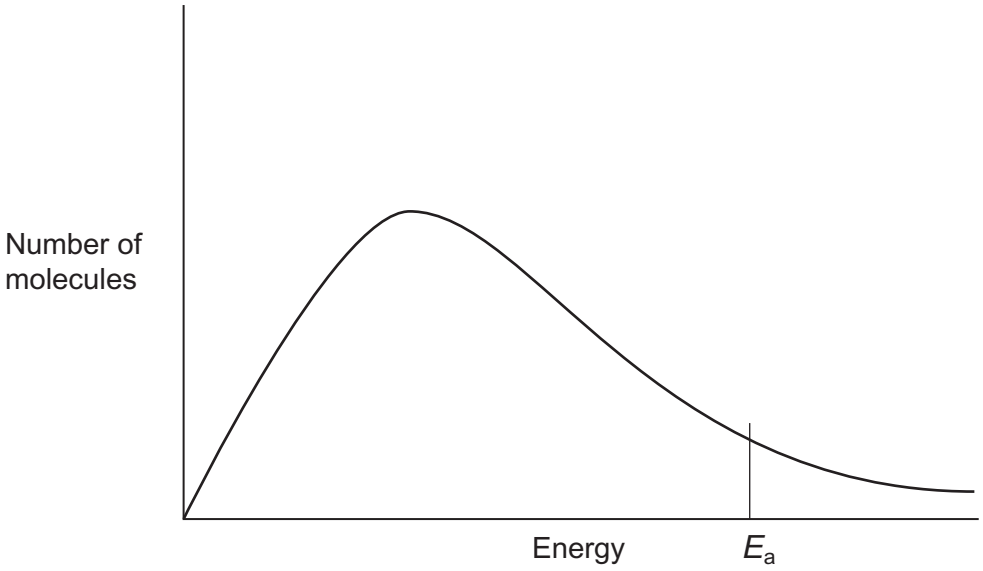
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ANSWER IN THE SPACES PROVIDED

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3 The diagram shows the Maxwell–Boltzmann distribution for a sample of gas at a fixed temperature.
E_a is the activation energy for the decomposition of this gas.



E_{mp} is the most probable value for the energy of the molecules.

3 (a) On the appropriate axis of this diagram, mark the value of E_{mp} for **this** distribution.

On this diagram, sketch a new distribution for the same sample of gas at a **lower** temperature.

(3 marks)

3 (b) With reference to the Maxwell–Boltzmann distribution, explain why a decrease in temperature decreases the rate of decomposition of this gas.

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(2 marks)

5

Turn over ▶

Do not write outside the box

4 The price of copper is increasing as supplies of high-grade ores start to run out. The mineral covellite (CuS), found in low-grade ores, is a possible future source of copper.

4 (a) When copper is extracted from covellite, a reaction occurs between copper(II) sulfide and nitric acid to form a dilute solution of copper(II) sulfate.

4 (a) (i) Balance the equation for this reaction.

$$3CuS(s) + \ldots\ldots HNO_3(aq) \longrightarrow \ldots\ldots CuSO_4(aq) + \ldots\ldots NO(g) + \ldots\ldots H_2O(l)$$

(1 mark)

4 (a) (ii) Give the oxidation state of nitrogen in each of the following.

HNO_3 .....

NO .....

(2 marks)

4 (a) (iii) Deduce the redox half-equation for the reduction of the nitrate ion in acidified solution to form nitrogen monoxide and water.

.....

(1 mark)

4 (a) (iv) Deduce the redox half-equation for the oxidation of the sulfide ion in aqueous solution to form the sulfate ion and $H^+(aq)$ ions.

.....

(1 mark)

Do not write outside the box

4 (b) Use your knowledge of metal reactivity to state and explain a low-cost method for the extraction of copper from a dilute aqueous solution of copper(II) sulfate.
Write the **simplest ionic** equation for the reaction that occurs during this extraction process.

.....

.....

.....

.....

.....

.....

Simplest ionic equation

.....

(4 marks)

9

Turn over for the next question

Do not write outside the box

5 Haloalkanes are used in the synthesis of other organic compounds.

5 (a) Hot concentrated ethanolic potassium hydroxide reacts with 2-bromo-3-methylbutane to form two alkenes that are structural isomers of each other. The major product is 2-methylbut-2-ene.

5 (a) (i) Name and outline a mechanism for the conversion of 2-bromo-3-methylbutane into 2-methylbut-2-ene according to the equation.

$$(CH_3)_2CHCHBrCH_3 + KOH \longrightarrow (CH_3)_2C{=}CHCH_3 + KBr + H_2O$$

Name of mechanism .....

Mechanism

(4 marks)

5 (a) (ii) Draw the **displayed formula** for the other isomer that is formed.

(1 mark)

5 (a) (iii) State the type of structural isomerism shown by these two alkenes.

.....

(1 mark)

Do not write outside the box

5 (b) A small amount of another organic compound, **X**, can be detected in the reaction mixture formed when hot concentrated ethanolic potassium hydroxide reacts with 2-bromo-3-methylbutane.
Compound **X** has the molecular formula $C_5H_{12}O$ and is a secondary alcohol.

5 (b) (i) Draw the **displayed formula** for **X**.

(1 mark)

5 (b) (ii) Suggest **one** change to the reaction conditions that would increase the yield of **X**.

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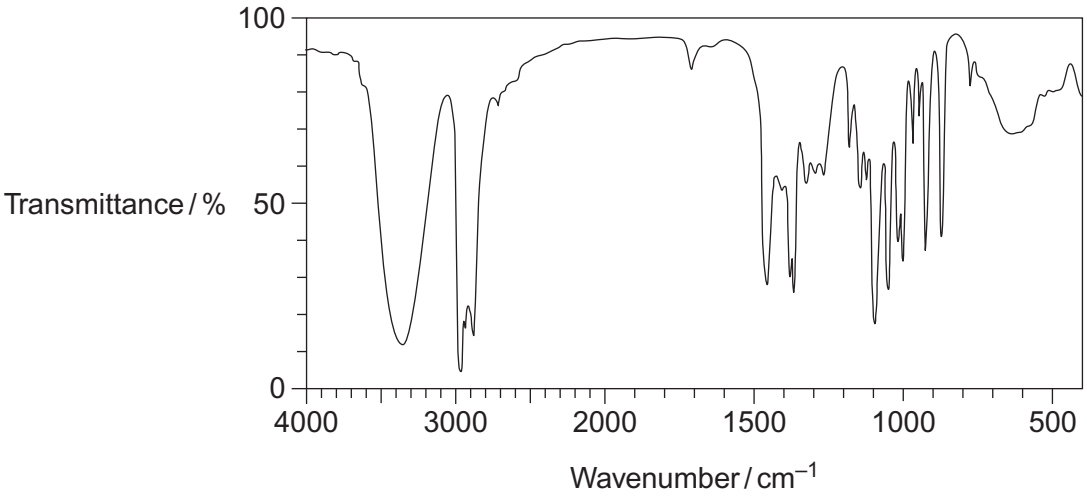
(1 mark)

5 (b) (iii) State the type of mechanism for the conversion of 2-bromo-3-methylbutane into **X**.

.....

(1 mark)

5 (b) (iv) Identify **one** feature of this infrared spectrum of a pure sample of **X** that may be used to confirm that **X** is an alcohol.
You may find it helpful to refer to **Table 1** on the Data Sheet.



Feature .....

.....

(1 mark)

10

Turn over ▶

Do not write outside the box

6 (a) Chlorine displaces iodine from aqueous potassium iodide.

6 (a) (i) Write the **simplest ionic** equation for this reaction.

.....

(1 mark)

6 (a) (ii) Give **one** observation that you would make when this reaction occurs.

.....

.....

(1 mark)

6 (b) In bright sunlight, chlorine reacts with water to form oxygen as one of the products. Write an equation for this reaction.

.....

(1 mark)

6 (c) Explain why chlorine has a lower boiling point than bromine.

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(2 marks)

(Extra space) .....

.....

.....

5

Do not write outside the box

7 Chlorine can be used to make chlorinated alkanes such as dichloromethane.

7 (a) Write an equation for each of the following steps in the mechanism for the reaction of chloromethane (CH_3Cl) with chlorine to form dichloromethane (CH_2Cl_2).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

The termination step that forms a compound with empirical formula CH_2Cl

.....

(4 marks)

7 (b) When chlorinated alkanes enter the upper atmosphere, carbon–chlorine bonds are broken. This process produces a reactive intermediate that catalyses the decomposition of ozone. The overall equation for this decomposition is

$$2O_3 \rightleftharpoons 3O_2$$

7 (b) (i) Name the type of reactive intermediate that acts as a catalyst in this reaction.

.....

(1 mark)

7 (b) (ii) Write **two** equations to show how this intermediate is involved as a catalyst in the decomposition of ozone.

Equation 1 .....

Equation 2 .....

(2 marks)

7

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ANSWER IN THE SPACES PROVIDED

Do not write outside the box

8 In each of the following questions, you should draw the structure of the compound in the space provided.

8 (a) Draw the structure of the alkene that would form 1,2-dibromo-3-methylbutane when reacted with bromine.

(1 mark)

8 (b) Draw the structure of the alcohol with molecular formula $C_4H_{10}O$ that is resistant to oxidation by acidified potassium dichromate(VI).

(1 mark)

8 (c) Draw the structure of the alkene that has a peak, due to its molecular ion, at $m/z = 42$ in its mass spectrum.

(1 mark)

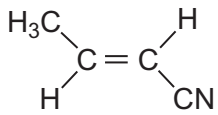
8 (d) Draw the structure of the organic product with $M_r = 73$, made from the reaction between 2-bromobutane and ammonia.

(1 mark)

4

Do not write outside the box

9 The alkene (*E*)-but-2-enenitrile is used to make acrylic plastics.
The structure of (*E*)-but-2-enenitrile is



9 (a) (i) Draw the structure of (*Z*)-but-2-enenitrile.

(1 mark)

9 (a) (ii) Identify the feature of the double bond in the E and Z isomers that causes them to be stereoisomers.

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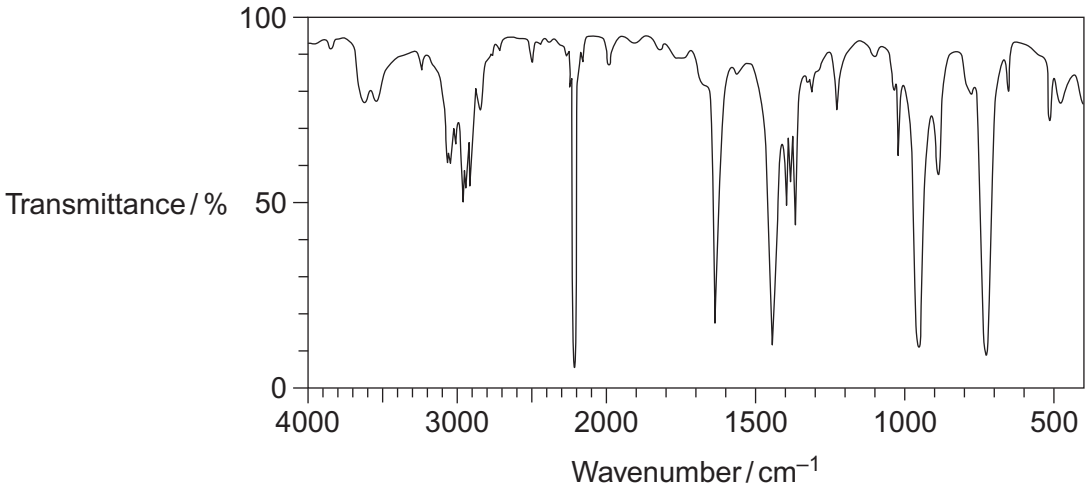
(1 mark)

9 (b) Draw the repeating unit of the polyalkene formed by addition polymerisation of (*E*)-but-2-enenitrile.

(1 mark)

Do not write outside the box

9 (c) Consider the infrared spectrum of (*E*)-but-2-enenitrile.



Identify **two** features of the infrared spectrum that support the fact that this is the infrared spectrum for but-2-enenitrile.
You may find it helpful to refer to **Table 1** on the Data Sheet.

Feature 1 .....

.....

.....

Feature 2 .....

.....

.....

(2 marks)

5

Turn over for the next question

Do not write outside the box

Section B

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

10 Ethanol is an important industrial compound.

10 (a) Ethanol can be produced by the hydration of ethene.
The equation for the equilibrium that is established is

$$H_2C{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \qquad \Delta H = -42\,kJ\,mol^{-1}$$

The operating conditions for the process are a temperature of 300 °C and a pressure of 7 MPa.
Under these conditions, the conversion of ethene into ethanol is 5%.

10 (a) (i) Identify the catalyst used in this process.
Deduce how an overall yield of 95% is achieved in this process without changing the operating conditions.

.....

.....

.....

.....

(2 marks)

10 (a) (ii) Use your knowledge of equilibrium reactions to explain why a manufacturer might consider using an excess of steam in this process, under the same operating conditions.

.....

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(3 marks)

Do not write outside the box

10 (a) (iii) At pressures higher than 7 MPa, some of the ethene reacts to form a solid with a relative molecular mass greater than 5000

Deduce the identity of this solid.

Give **one** other reason for **not** operating this process at pressures higher than 7 MPa. Do **not** include safety reasons.

.....

.....

.....

(2 marks)

10 (b) Write an equation for the reaction that has an enthalpy change that is the standard enthalpy of formation of ethanol.

.....

(2 marks)

10 (c) When ethanol is used as a fuel, it undergoes combustion.

10 (c) (i) Define the term *standard enthalpy of combustion*.

.....

.....

.....

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.....

.....

.....

(3 marks)

Question 10 continues on the next page

Do not write outside the box

10 (c) (ii) Consider these bond enthalpy data.

	C—H	C—C	C—O	O=O	C=O	O—H
Bond enthalpy / kJ mol^{-1}	412	348	360	496	805	463

Use these data and the equation to calculate a value for the enthalpy of combustion of gaseous ethanol.

$$CH_3CH_2OH(g) + 3O_2(g) \longrightarrow 2CO_2(g) + 3H_2O(g)$$

.....

.....

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.....

.....

.....

(3 marks)

10 (d) Gaseous ethanol can be used to convert hot copper(II) oxide into copper.

10 (d) (i) Deduce the role of ethanol in this reaction.

.....

(1 mark)

10 (d) (ii) Draw the structure of the organic compound with M_r = 60 that is produced in this reaction.

(1 mark)

17

Do not write outside the box

11 Group 2 metals and their compounds are used commercially in a variety of processes.

11 (a) Strontium is extracted from strontium oxide (SrO) by heating a mixture of powdered strontium oxide and powdered aluminium.

Consider these standard enthalpies of formation.

	SrO(s)	$Al_2O_3(s)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 590	– 1669

$$3SrO(s) + 2Al(s) \longrightarrow 3Sr(s) + Al_2O_3(s)$$

Use these data and the equation to calculate the standard enthalpy change for this extraction of strontium.

The use of powdered strontium oxide and powdered aluminium increases the surface area of the reactants.
Suggest **one** reason why this increases the reaction rate.

Suggest **one** major reason why this method of extracting strontium is expensive.

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(5 marks)

Question 11 continues on the next page

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11 (b) Explain why calcium has a higher melting point than strontium.

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(2 marks)

11 (c) Magnesium is used in fireworks. It reacts rapidly with oxygen, burning with a bright white light. Magnesium reacts slowly with cold water.

Write an equation for the reaction of magnesium with oxygen.

Write an equation for the reaction of magnesium with cold water.

Give a medical use for the magnesium compound formed in the reaction of magnesium with cold water.

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(3 marks)

10

END OF QUESTIONS

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Version 1.0



General Certificate of Education (A-level)
June 2013

Chemistry CHEM2

(Specification 2420)

Unit 2: Chemistry In Action

Final

Mark Scheme

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It must be stressed that a mark scheme is a working document, in many cases further developed and expanded on the basis of candidates' reactions to a particular paper. Assumptions about future mark schemes on the basis of one year's document should be avoided; whilst the guiding principles of assessment remain constant, details will change, depending on the content of a particular examination paper.

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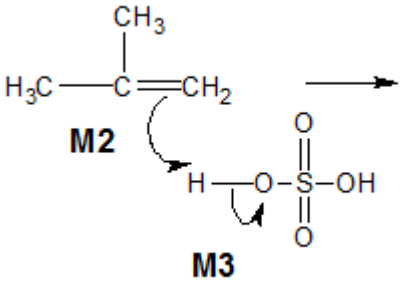
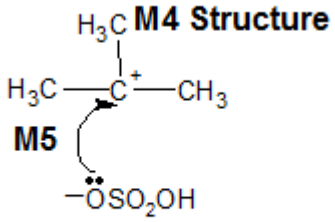
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Question	Marking Guidance	Mark	Comments
1(a)(i)	**M1 (**Yield) increases / goes up / gets more **M2** The (forward) reaction / to the right is <u>exothermic</u> or <u>gives out / releases heat</u> ***OR*** The reverse reaction / to the left is <u>endothermic</u> or <u>takes in / absorbs heat</u> **M3 depends on correct M2 and must refer to temperature/heat** The (position of) <u>equilibrium shifts / moves</u> left to right to <u>oppose the decrease in temperature</u>	3	If **M1** is blank, mark on and seek to **credit the correct information in the explanation.** If **M1** is incorrect **CE=0** for the clip. **M3** depends on a correct statement for **M2** For **M3**, the <u>equilibrium shifts/moves</u> to <u>release heat</u> ***OR*** to <u>raise the temperature</u> ***OR*** to <u>heat up the reaction.</u>
1(a)(ii)	**M1** <u>Concentration(s)</u> (of reactants and products) remain or stay constant / the same **M2** <u>Forward rate</u> = <u>reverse / backward rate</u>	2	For **M1** credit [ ] for concentration. Not “equal concentrations”. Not “concentrations <u>is / are the same</u>”. Not “amount”. Ignore “dynamic” and ignore “speed”. Ignore “closed system”. It is possible to score both marks under the heading of a single feature.

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1(b)	$KBr + H_2SO_4 \longrightarrow KHSO_4 + HBr$	1	Credit this equation in its ionic form. Ignore state symbols. Credit multiples.
1(c)	**M1** SO_2 identified **M2 correctly balanced equation (would also gain M1)** $\mathbf{2}HBr + H_2SO_4 \longrightarrow Br_2 + SO_2 + \mathbf{2}H_2O$ **Mark M3 independently** **M3** Oxidising agent ***OR*** electron acceptor ***OR*** oxidant ***OR*** to oxidise the bromide (ion) / HBr	3	Credit **M2** equation in its ionic form. Ignore state symbols. Credit multiples. Not H_2SO_3 on the right-hand side. **M3** Not “electron pair acceptor”.

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1(d)(i)	**M1 Electrophilic addition**   **M2** must show an arrow from the double bond towards the H atom of the H – O bond / HO on a compound with molecular formula for H_2SO_4 **M2** could be to an H+ ion and **M3** an independent O – H bond break on a compound with molecular formula for H_2SO_4 **M3** must show the breaking of the O ─ H bond on H_2SO_4 **M4** is for the structure of the carbocation **M5** must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards the positively charged carbon atom on <u>their</u> carbocation **NB The arrows here are double-headed**	5	**M1** both words required. **For the mechanism** **M3** Penalise incorrect partial charges on O – H bond and penalise formal charges Ignore partial negative charge on the double bond. **M5** Not HSO_4^- For **M5**, credit <u>as shown</u> or <u>$^-OSO_3H$</u> ONLY with the negative charge anywhere on this ion ***OR*** <u>correctly</u> drawn out with the negative charge placed correctly on oxygen. <u>Max any 3 of 4 marks</u> **<u>for a correct mechanism</u>** using the wrong organic reactant or wrong organic product (if shown) or a primary carbocation. Penalise once only in any part of the mechanism for a line and two dots to show a bond. Credit the correct use of “sticks”. For **M5**, credit attack on a partially positively charged carbocation structure, but penalise **M4**
1(d)(ii)	Hydrolysis	1	Credit “(nucleophilic) substitution” but do not accept any other prefix. Credit phonetic spelling.
1(d)(iii)	Catalyst	1	

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Question	Marking Guidance	Mark	Comments
2(a)	**M1** concentrated sulfuric acid OR c(onc) H_2SO_4 **M2** (cream solid) turns orange ***OR*** orange / red / brown fumes / gas / vapour **M3** (yellow solid) turns black ***OR*** purple fumes / gas / vapour ***OR*** correct reference to H_2S observation (eg bad egg smell) ***OR*** **as an alternative** **M1** concentrated ammonia ***OR*** c(onc) NH_3 **M2** (cream solid) dissolves / solution formed **M3** precipitate remains / does not dissolve / insoluble ***OR*** no reaction / no change / (yellow solid) turns to white solid	3	If no reagent or incorrect reagent in **M1**, **CE= 0** and no marks for **M2** or **M3** If dilute sulfuric acid OR "aq" (alone) **CE=0** If H_2SO_4 / sulfuric acid given but not stated whether dilute or concentrated, penalise **M1** and mark on for **M2** and **M3** If incorrect formula for the acid, penalise **M1** but mark **M2** and **M3** If NH_3 / ammonia / aq ammonia given, but not stated as concentrated ***OR*** if dilute ammonia given, penalise **M1** but mark on for **M2** and **M3** Ignore "partially" and ignore "clear" in **M2** If incorrect formula for ammonia, penalise **M1** but mark **M2** and **M3** In **M3** for ammonia. Ignore "nothing (happens)". Ignore "no observation".

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2(b)	**M1** $AgNO_3$ ***OR*** silver nitrate ***OR*** any <u>soluble</u> silver salt **M2** <u>white precipitate</u> or <u>white solid / white suspension</u> **M3** remains colourless ***OR*** no reaction ***OR*** no (observed) change ***OR*** no precipitate Credit alternative test for nitrate ions	3	If no reagent or incorrect reagent in **M1**, **CE= 0** and no marks for **M2** or **M3** An insoluble silver salt OR Tollens' ***OR*** Ag ***OR*** ammoniacal silver nitrate or HCl / $AgNO_3$ **CE= 0** for the clip. For **M1** Credit acidified (or HNO_3) silver nitrate for **M1** and mark on. If silver ions or incorrect formula for silver nitrate, penalise **M1** but mark **M2** and **M3** For **M2** Ignore "cloudy solution" ***OR*** "suspension". For **M3** Ignore "nothing (happens)". Ignore "no observation". Ignore "clear". Ignore "dissolves".

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2(c)	**M1** Br_2 ***OR*** bromine (water) ***OR*** bromine (in CCl_4 / organic solvent) **Either order** **M2** (stays) orange / red / yellow / brown / the same ***OR*** no reaction ***OR*** no (observed) change ***OR*** reference to colour going to cyclohexane layer **M3** decolourised / goes colourless / loses its colour ***OR* as an alternative** **Use $KMnO_4/H_2SO_4$** **M1** acidified potassium manganate(VII) or $KMnO_4/H_2SO_4$ ***OR*** $KMnO_4/H^+$ ***OR*** acidified $KMnO_4$ **M2** (stays) <u>purple</u> or no reaction or no (observed) change **M3** <u>purple to colourless</u> solution ***OR*** goes <u>colourless</u> Credit alternative test using **iodine** (for **M1**) **M2** (brown) to purple or accept no change, **M3** colourless Credit alternative test using <u>concentrated</u> H_2SO_4 **M2** no change, **M3** brown	3	If no reagent or incorrect reagent in **M1**, **CE= 0** and no marks for **M2** or **M3** No credit for combustion observations; **CE=0** For **M2 in every case.** Ignore "nothing (happens)". Ignore "no observation". Ignore "clear". **With bromine (water)** **For M1**, it must be a whole reagent and/or correct formula. If oxidation state given in name, it must be correct. **For M1** penalise incorrect formula, but mark **M2** and **M3** **With potassium manganate(VII)** **For M1** If "manganate" or "manganate(IV)" or incorrect formula or no acid, penalise **M1** but mark **M2** and **M3** Credit alkaline/neutral $KMnO_4$ for possible full marks but **M3** gives <u>brown precipitate</u> or solution goes <u>green.</u>

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2(d)	**M1** Tollens' (reagent) OR ammoniacal silver nitrate OR a description of making Tollens' (Ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark **M2** and **M3**) **M2** silver mirror ***OR*** black solid/precipitate (ignore silver precipitate) **M3 (**stays) colourless or no reaction or no (observed) change Alternative using Fehling's (solution) **M1** Fehling's (solution) or Benedict's solution (Ignore $Cu^{2+}(aq)$ or $CuSO_4$ on their own, but mark **M2** and **M3**) **M2** Red solid/precipitate (Credit orange or brown solid) **M3 (**stays) blue or no reaction or no (observed) change Alternative using $K_2Cr_2O_7/H_2SO_4$ **M1** acidified potassium dichromate or $K_2Cr_2O_7/H_2SO_4$ ***OR*** $K_2Cr_2O_7/H^+$ ***OR*** acidified $K_2Cr_2O_7$ **M2** (orange to) green solution OR goes green **M3** (stays) orange or no reaction or no (observed) change Alternative using $KMnO_4/H_2SO_4$ **M1** acidified potassium manganate(VII) or $KMnO_4/H_2SO_4$ ***OR*** $KMnO_4/H^+$ ***OR*** acidified $KMnO_4$ **M2** purple to colourless solution OR goes colourless **M3** (stays) purple or no reaction or no (observed) change	3	If no reagent or incorrect reagent in **M1**, **CE= 0** and no marks for **M2** or **M3** For **M3 in every case** Ignore "nothing (happens)". Ignore "no observation". **With potassium dichromate(VI)** **For M1** If "dichromate" or "(potassium) dichromate(IV)" or incorrect formula or no acid, penalise **M1** but mark **M2** and **M3** **For M3** Ignore dichromate described as "yellow" or "red". **With potassium manganate(VII)** **For M1** If "manganate" or "(potassium manganate(IV)" or incorrect formula or no acid, penalise **M1** but mark **M2** and **M3** Credit alkaline/neutral $KMnO_4$ for possible full marks but **M2** gives brown precipitate or solution goes green.

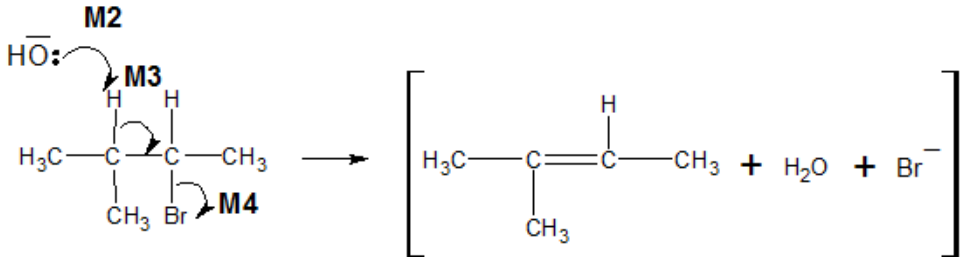
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Question	Marking Guidance	Mark	Comments
3(a)	**M1** On the energy axis E_{mp} at the maximum of the original peak **M2** The peak of their new curve is displaced to the left and higher than the original **M3** **All of the following** are required • The new curve starts at the origin and should begin to separate from the original almost immediately • and the new curve crosses the original curve once • and an attempt has been made to draw the new curve correctly towards the energy axis below the original curve but not to touch the original curve or the axis	3	**M1** The limits for the horizontal position of E_{mp} are defined as above the word "the" in the sentence below the graph.
3(b)	**The rate of reaction decreases as the temperature decreases because** **M1** A decrease in the number / proportion of molecules with $E \geq E_a$ ***OR*** fewer molecules have $E \geq E_a$ ***OR*** fewer molecules have sufficient / enough energy to react / decompose **M2** Fewer effective / productive / successful collisions in a given time / given period ***OR*** fewer frequent effective / productive / successful collisions ***OR*** lower rate of effective / productive / successful collisions	2	**In M1** Ignore "molecules have less energy". Ignore "less energetic collisions". Ignore "molecules do not gain activation energy". Ignore "fewer collisions". Credit "particles" for "molecules" but NOT "atoms". Ignore "chance of collision"; this alone does not gain **M2**

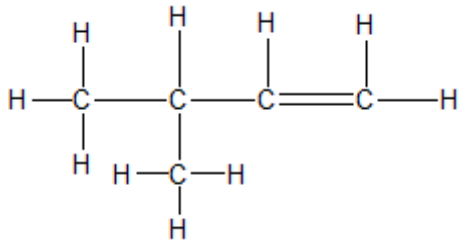
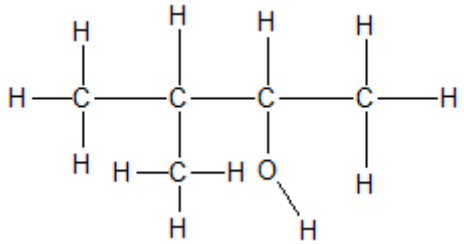
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Question	Marking Guidance	Mark	Comments
4(a)(i)	$3CuS(s) + \mathbf{8}HNO_3(aq) \longrightarrow \mathbf{3}CuSO_4(aq) + \mathbf{8}NO(g) + \mathbf{4}H_2O(l)$	1	
4(a)(ii)	**(+) 5** **(+) 2**	2	
4(a)(iii)	$\mathbf{4}H^+ + NO_3^- + \mathbf{3}e^- \longrightarrow \mathbf{2}H_2O + NO$	1	Ignore state symbols. Credit multiples of **this equation only.** Ignore absence of charge on the electron.
4(a)(iv)	$S^{2-} + \mathbf{4}H_2O \longrightarrow SO_4^{2-} + \mathbf{8}e^- + \mathbf{8}H^+$	1	Ignore state symbols. Credit multiples of **this equation only.** Ignore absence of charge on the electron.
4(b)	**M1** add <u>scrap / recycled / waste iron (or steel)</u> to the aqueous solution **M2** the iron is a <u>more reactive</u> metal ***OR*** <u>Fe is a better reducing agent</u> **M3** <u>Cu^{2+} /copper ions</u> are <u>reduced</u> / <u>gain electrons</u> ***OR*** $Cu^{2+} + 2e^- \longrightarrow Cu$ ***OR*** <u>copper / Cu is displaced by Fe</u> **M4** $Fe + Cu^{2+} \longrightarrow Fe^{2+} + Cu$ ONLY	4	If **M1** refers to iron / steel, but does not make it clear in the text that it is "scrap" / "waste" / "recycled", penalise **M1** but mark on. Credit zinc or magnesium as an alternative to iron for **M2**, **M3** and **M4** only, penalising **M1** Ignore absence of charge on the electron. For **M4**, ignore state symbols.

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Question	Marking Guidance	Mark	Comments
5(a)(i)	**M1 Elimination**  **M2** must show an arrow from the <u>lone pair on the oxygen</u> of a negatively charged hydroxide ion <u>to a correct</u> H atom **M3** must show an arrow from a correct C–H bond adjacent to the C–Br bond to a correct C–C bond. Only award if an arrow is shown attacking the H atom of a correct adjacent C–H bond in **M2** **M4** is independent provided it is from their <u>original molecule</u>, **BUT CE=0 <u>for the mechanism (penalise M2, M3 and M4 only)</u> if nucleophilic substitution mechanism is shown** Award full marks for an E1 mechanism in which **M4** is on the correct carbocation **NB These are double-headed arrows**	4	**M1** Credit "base elimination" but no other prefix. Penalise **M2** if covalent KOH Penalise **M4** for formal charge on C or Br of C–Br or incorrect partial charges on C–Br Ignore other partial charges. Penalise **once only** in any part of the mechanism for a line and two dots to show a bond. **<u>Maximum any 2 of 3 marks for the mechanism</u>** for wrong organic reactant or wrong organic product (if shown). Credit the correct use of "sticks" for the molecule except for the C–H being attacked. Penalise **M4**, if an additional arrow is drawn from Br eg to K+

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5(a)(ii)	Displayed formula for 3-methylbut-1-ene 	1	All bonds and atoms must be drawn out, but ignore bond angles.
5(a)(iii)	Position(al) (isomerism or isomer)	1	Penalise any other words that are written in addition to these.
5(b)(i)	Displayed formula for 3-methylbutan-2-ol 	1	All bonds and atoms must be drawn out, but ignore bond angles.
5(b)(ii)	Any **one** from • Lower / decreased temperature ***OR*** cold • Less concentrated (comparative) ***OR*** dilute KOH • Water (as a solvent) / (aqueous conditions)	1	Ignore “pressure”.
5(b)(iii)	Nucleophilic substitution	1	Both words needed – credit phonetic spelling.

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5(b)(iv)	(Strong / broad) absorption / peak in the range **3230 to 3550** cm^{-1} or specified value in this range or marked correctly on spectrum	1	Allow the words "dip" ***OR*** "spike" ***OR*** "trough" ***OR*** "low transmittance" as alternatives for absorption.

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Question	Marking Guidance	Mark	Comments
6(a)(i)	$\frac{1}{2}Cl_2 + I^- \longrightarrow \frac{1}{2} I_2 + Cl^-$ OR $Cl_2 + \mathbf{2}I^- \longrightarrow I_2 + \mathbf{2}Cl^-$	1	**Only** these two equations.
6(a)(ii)	(Solution turns from colourless to) <u>brown / red-brown solution</u>	1	Allow <u>grey / black solid.</u> Ignore "purple".
6(b)	$\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$ $(\mathbf{4}H^+ + \mathbf{4}Cl^-)$	1	Credit multiples.
6(c)	**M1 The relative size (of the molecules/atoms)** Chlorine is smaller than bromine OR has fewer electrons/electron shells ***OR*** It is smaller / It has a smaller atomic radius / it is a smaller molecule / or has smaller M_r (or converse for bromine) **M2 How size of the <u>intermolecular force</u> affects energy needed** The forces <u>between</u> chlorine / Cl_2 <u>molecules</u> are weaker (than the forces <u>between</u> bromine / Br_2 <u>molecules</u> leading to less energy needed to separate the <u>molecules</u>) (or converse for bromine) ***OR*** chlorine / Cl_2 has <u>weaker / less / fewer forces between molecules</u> ***OR*** chlorine / Cl_2 has <u>weaker / less / fewer intermolecular forces</u> (or converse for bromine)	2	Ignore general Group 7 statements. For **M1** ignore whether it refers to molecules or atoms. **CE=0** for reference to (halide) ions. QoL for clear reference to the difference in size <u>of the force between molecules.</u> Penalise **M2** if (covalent) <u>bonds</u> are broken.

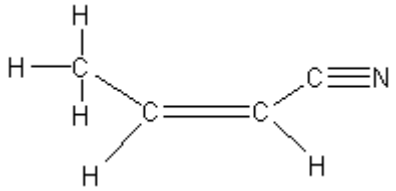
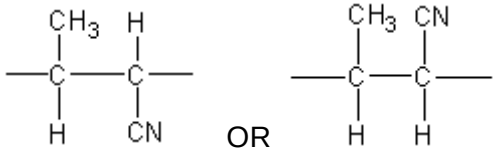
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Question	Marking Guidance	Mark	Comments
7(a)	**Initiation** $Cl_2 \longrightarrow 2Cl\bullet$ **First propagation** $Cl\bullet + CH_3Cl \longrightarrow \bullet CH_2Cl + HCl$ **Second propagation** $Cl_2 + \bullet CH_2Cl \longrightarrow CH_2Cl_2 + Cl\bullet$ **Termination (must make 1,2-dichloroethane)** $2 \bullet CH_2Cl \longrightarrow CH_2ClCH_2Cl$	4	Penalise absence of dot once only. Credit the dot anywhere on the radical. Penalise $C_2H_4Cl_2$
7(b)(i)	(chlorine free) radical	1	Ignore formula.
7(b)(ii)	**M1** $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$ **M2** $ClO\bullet + O_3 \longrightarrow Cl\bullet + 2O_2$	2	**M1** and **M2** could be in either order. Credit the dot anywhere on the radical. Penalise absence of dot once only. Individual multiples acceptable but both need to be doubled if two marks are to be awarded.

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Question	Marking Guidance	Mark	Comments
8(a)	Structure for 3-methylbut-1-ene $H_2C=CHCH(CH_3)_2$	1	Any correct structural representation. Credit "sticks" and require the double bond.
8(b)	Structure for 2-methylpropan-2-ol $(CH_3)_3COH$	1	Any correct structural representation. Credit "sticks".
8(c)	Structure for propene $H_2C=CHCH_3$	1	Any correct structural representation. Credit "sticks" and require the double bond.
8(d)	Structure for 2-aminobutane $CH_3CH_2CH(NH_2)CH_3$	1	Any correct structural representation. Credit "sticks".

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Question	Marking Guidance	Mark	Comments
9(a)(i)	Structure of (Z)-but-2-enenitrile with or without either or both of the CH_3 and the CN groups displayed 	1	Penalise C–NC Do <u>not</u> penalise C–H_3C Ignore bond angles.
9(a)(ii)	Restricted <u>rotation</u> / no (free) <u>rotation</u> about the double bond / about the C=C ***OR*** does not <u>rotate</u> (about the double bond)	1	Must use the word <u>rotate / rotation.</u>
9(b)	Repeating unit of polyalkene  OR	1	All the bonds relevant to the unit must be drawn out including those on either side of the unit. There is no need to expand either the CH_3 or the CN Penalise C–NC Penalise “sticks”. Ignore brackets. Penalise “n”

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9(c)	**Feature 1** Absorption / peak in the range **2220 to 2260** cm^{-1} or specified value in this range or marked correctly on spectrum **and** (characteristic absorption / peak for) **C≡N / CN** group / **nitrile / cyanide** group **Feature 2** Absorption / peak in the range **1620 to 1680** cm^{-1} or specified value in this range or marked correctly on spectrum **and** (characteristic absorption / peak for) **C=C** group / **alkene** / **carbon-carbon double bond**	2	Allow the words "dip" ***OR*** "spike" ***OR*** "trough" ***OR*** "low transmittance" as alternatives for absorption. Allow a peak at 2200 cm^{-1} to 2220 cm^{-1} **in this case.** Ignore reference to other absorptions eg C-H Either order.

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Question	Marking Guidance	Mark	Comments
10(a)(i)	**M1** c(oncentrated) phosphoric acid / c(onc.) H_3PO_4 ***OR*** c(oncentrated) sulfuric acid / c(onc.) H_2SO_4 **M2** Re-circulate / re-cycle the (unreacted) ethene (and steam) / the reactants ***OR*** pass the gases over the catalyst several / many times	2	In **M1**, the acid must be concentrated. Ignore an incorrect attempt at the correct formula that is written in addition to the correct name. In **M2**, ignore "remove the ethanol". Credit "re-use".
10(a)(ii)	**M1** (By Le Chatelier's principle) the equilibrium is driven / shifts / moves to the right / L to R / forwards / in the forward direction **M2 depends on a correct statement of M1** The equilibrium moves / shifts to • oppose the addition of / increased concentration of / increased moles/ increased amount of water / steam • to decrease the amount of steam / water **Mark M3 independently** **M3** Yield of product / conversion increase ***OR*** ethanol increases / goes up / gets more	3	

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10(a)(iii)	**M1** Poly(ethene) / polyethene / polythene / HDPE / LDPE **M2 At higher pressures** More / higher cost of electrical energy to pump / pumping cost ***OR*** Cost of higher pressure equipment / valves / gaskets / piping etc. ***OR*** expensive equipment	2	Credit all converse arguments for **M2**

10(b)	**M1** for balanced equation **M2** for state symbols in a correctly balanced equation $2C(s / graphite) + 3H_2(g) + \frac{1}{2}O_2(g) \longrightarrow CH_3CH_2OH(l)$ (C_2H_5OH)	2	Not multiples but credit correct state symbols in a correctly balanced equation. Penalise C_2H_6O but credit correct state symbols in a correctly balanced equation.

10(c)(i)	**M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element **M2** is burned / combusts / reacts completely in oxygen ***OR*** burned / combusted / reacted in excess oxygen **M3** with (all) reactants and products / (all) substances in standard / specified states ***OR*** (all) reactants and products / (all) substances in normal states under standard conditions / 100 kPa / 1 bar and specified T / 298 K	3	If standard enthalpy of formation **CE=0** For **M3** Ignore reference to 1 atmosphere.

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10(c)(ii)	**M1** $\sum$ B(**reactants**) – $\sum$ B(**products**) = ΔH OR Sum of bonds broken – Sum of bonds formed = ΔH OR B(C-C) + B(C-O) + B(O-H) + 5B(C-H) + 3B(O=O) (LHS) – 4B(C=O) – 6B(O–H) (RHS) = ΔH **M2** (also scores **M1**) 348+360+463+5(412)+3(496) [LHS = **4719**] (2060) (1488) – 4(805) – 6(463) [RHS = – **5998**] = ΔH (3220) (2778) OR using only bonds broken and formed (**4256 – 5535**) **M3** ΔH = **– 1279** (kJ mol^{-1}) Award 1 mark for +1279 **Candidates may use a cycle and gain full marks**	3	Correct answer gains full marks Credit 1 mark for (+) 1279 (kJ mol^{-1}) For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**) • If no AE, check for a correct method; this requires either a correct cycle with 2C and 6H and 7O OR a clear statement of **M1** which could be in words and scores **only M1** Allow a maximum of one mark if the only scoring point is LHS = 4719 ***OR*** RHS = 5998

10(d)(i)	Reducing agent ***OR*** reductant ***OR*** electron donor ***OR*** to reduce the copper oxide	1	Not “reduction”. Not “oxidation”. Not “electron pair donor”.

10(d)(ii)	CH_3COOH	1	

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Question	Marking Guidance	Mark	Comments
11(a)	**M1 (could be scored by a correct mathematical expression)** **M1** $\Delta H = \sum\Delta H_f$ (**products**) - $\sum\Delta H_f$ (**reactants**) ***OR*** a correct cycle of balanced equations **M2** = – 1669 – 3(– 590) = –1669 + 1770 (This also scores M1) **M3** = **+ 101** (kJ mol^{-1}) **Award 1 mark ONLY for – 101** **M4 – Using powders** Any **one** from • To increase collision frequency / collisions in a given time / rate of collisions • To increase the surface contact / contact between the solids / contact between (exposed) particles **M5 Major reason for expense of extraction** Any **one** from • Aluminium is extracted by electrolysis OR aluminium extraction uses(large amounts of) electricity • Reaction / process / It /the mixture requires heat • It is endothermic	5	Correct answer to the calculation gains all of **M1**, **M2** and **M3** Credit 1 mark for – 101 (kJ mol^{-1}) For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**) • If no AE, check for a correct method; this requires either a correct cycle with 3Sr and 2Al OR a clear statement of **M1** which could be in words and scores **only M1** Ignore dividing final answer by 3 Penalise **M4** for reference to molecules.

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11(b)	Calcium has a higher melting point than strontium, because **Correct reference to size of cations/proximity of electrons** **M1** (For Ca) delocalised <u>electrons closer to cations / positive ions / atoms / nucleus</u> ***OR*** <u>cations / positive ions / atoms are smaller</u> ***OR*** <u>cation / positive ion / atom or it has fewer (electron) shells / levels</u> **Relative strength of metallic bonding** **M2** (Ca) has <u>stronger</u> attraction between the <u>cations / positive ions / atoms / nucleus</u> and the <u>delocalised electrons</u> ***OR*** <u>stronger metallic</u> bonding (assume argument refers to Ca but credit converse argument for Sr)	2	Ignore general Group 2 statements. Penalise **M1** if either of Ca or Sr is said to have <u>more or less</u> delocalised electrons OR the same nuclear charge. Ignore reference to shielding. **CE= 0** for reference to molecules or Van der Waals forces or intermolecular forces or covalent bonds.

11(c)	**M1** $\mathbf{2}Mg + O_2 \longrightarrow \mathbf{2}MgO$ **M2** $Mg + \mathbf{2}H_2O \longrightarrow Mg(OH)_2 + H_2$ **M3** Magnesium hydroxide is used as an antacid / relieve indigestion (heartburn) / neutralise (stomach) acidity / laxative	3	Credit multiples of the equations. Not simply “milk of magnesia” in **M3**

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General principles applied to marking CHEM2 papers by CMI+ June 2013

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are required information to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**

A. The "List principle" and the use of "ignore" in the mark scheme

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. Incorrect case for element symbol

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. Spelling

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

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D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

E. Reagents

The command word "Identify", allows the candidate to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.
For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a candidate provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

F. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

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G. Marking calculations, such as those involving enthalpy changes

In general

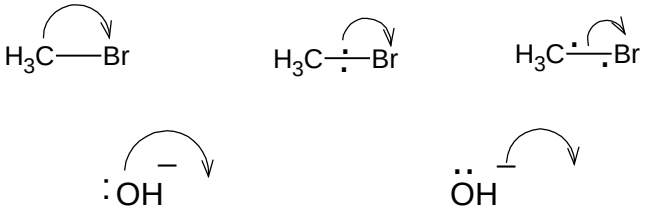
- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will usually score **only one mark**.

All other values **gain no credit** except

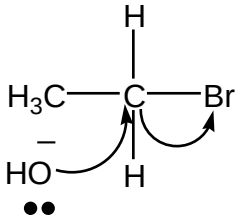
- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

H. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.
The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

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In free-radical substitution

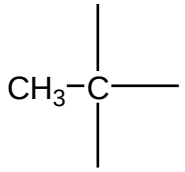
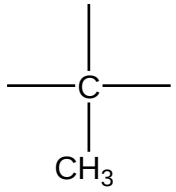
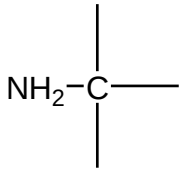
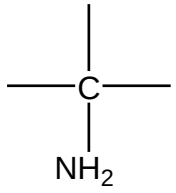
- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

I. Organic structures

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if candidates show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in structures, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or C ─ NH_2 bonds should **not** be penalised. For the other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.
  By way of illustration, the following would apply

(a)  allowed	(b)  allowed
(c)  allowed	(d)  allowed

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- In most cases, the use of "sticks" to represent C ─ H bonds in a structure should **not** be penalised. The exceptions will include structures in mechanisms when the C ─ H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.
- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

N.B. Exceptions <u>may</u> be made in the context of balancing equations

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

J. <u>Organic names</u>

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.
Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**
ethan-1,2-diol	should be **ethane-1,2-diol**

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2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**
3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
January 2013

Chemistry CHEM2

Unit 2 Chemistry in Action

Wednesday 16 January 2013 9.00 am to 10.45 am

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use scientific terminology accurately.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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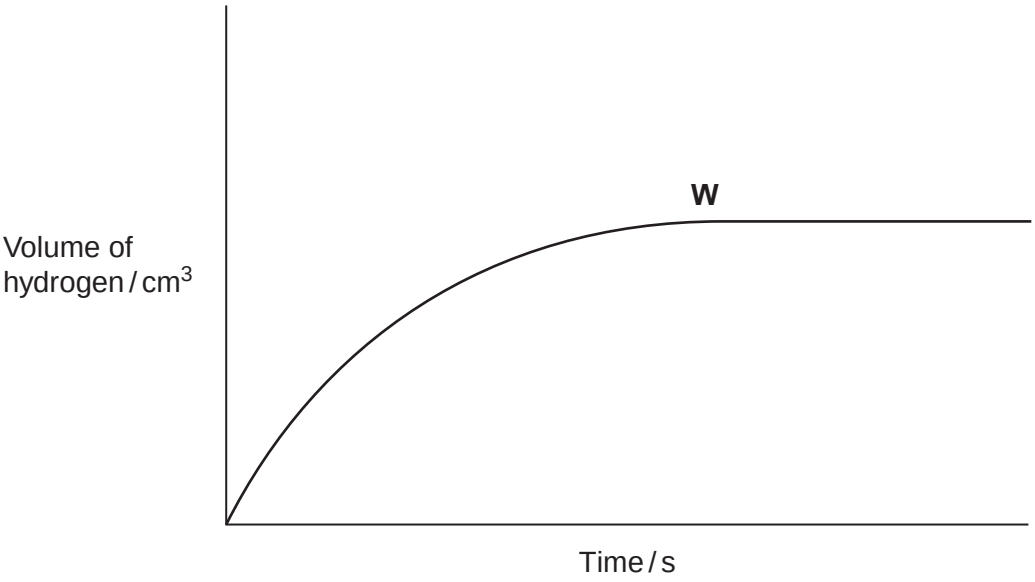
Section A

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

1 (a) **Figure 1** shows the volume of hydrogen gas collected when a sample of magnesium reacted with an excess of dilute hydrochloric acid.

The rate of this reaction can be studied by measuring the time it takes for a given volume of hydrogen to be collected.

Figure 1



1 (a) (i) State the meaning of the term *rate of reaction*.

.....

.....

.....

(1 mark)

1 (a) (ii) State and explain what has happened to the rate of this reaction at point **W** in **Figure 1**.

.....

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.....

(2 marks)

Do not write outside the box

1 (a) (iii) In terms of collision theory explain why, at a fixed temperature, the rate of this reaction doubles when the concentration of the hydrochloric acid doubles.

.....

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(2 marks)

1 (b) In a study of the reaction in part **(a)**, a student referred to activation energy.

1 (b) (i) State the meaning of the term *activation energy*.

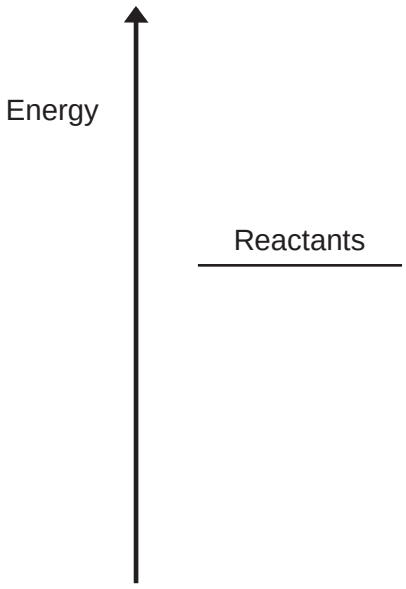
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(1 mark)

1 (b) (ii) Complete **Figure 2** by drawing the shape of the reaction profile from reactants to products for an exothermic reaction.
Show the position of the products. Show and label the activation energy.

Figure 2



(2 marks)

Question 1 continues on the next page

Turn over ▶

Do not write outside the box

1 (c) Barium metal reacts very quickly with dilute hydrochloric acid, but it reacts more slowly with water.

1 (c) (i) Write an equation for the reaction of barium with water.

.....

(1 mark)

1 (c) (ii) A solution containing barium ions can be used to show the presence of sulfate ions in an aqueous solution of sodium sulfate.

Write the **simplest ionic** equation for the reaction that occurs and state what is observed.

Simplest ionic equation

.....

Observation

.....

(2 marks)

1 (c) (iii) State **one** use of barium sulfate in medicine.
Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .....

.....

Explanation .....

.....

.....

(2 marks)

13

Turn over for the next question

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ANSWER IN THE SPACES PROVIDED

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2 A study of equilibrium is important for understanding chemical reactions.

2 (a) State Le Chatelier's principle.

.....

.....

.....

.....

(1 mark)

(Extra space) .....

.....

2 (b) Catalysts play an important role in many reactions.

2 (b) (i) State the meaning of the term *catalyst*.
Explain, in general terms, how catalysts work.

Meaning of the term *catalyst* .....

.....

.....

How catalysts work .....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

2 (b) (ii) State the effect, if any, of a catalyst on the time taken to reach equilibrium.

.....

(1 mark)

2 (b) (iii) State the effect, if any, of a catalyst on the position of an equilibrium.

.....

(1 mark)

Do not write outside the box

2 (c) Consider the following equilibrium reactions.

		$\Delta H^{\ominus}$ / kJ mol^{-1}
P	$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$	–10
Q	$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$	–49
R	$N_2O_4(g) \rightleftharpoons 2NO_2(g)$	+58
S	$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$	–92
T	$C_2H_4(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g)$	–42

In each of parts **(c) (i)** to **(c) (v)**, you should record in the box **one** of the letters, **P**, **Q**, **R**, **S** or **T**, that corresponds to the equilibrium that best fits the information provided. You may use each letter once, more than once or not at all.

2 (c) (i) A decrease in temperature at constant pressure shifts the position of this equilibrium from right to left.

(1 mark)

2 (c) (ii) This equilibrium uses concentrated phosphoric acid as a catalyst in a hydration reaction.

(1 mark)

2 (c) (iii) A decrease in pressure at constant temperature shifts the position of this equilibrium from left to right.

(1 mark)

2 (c) (iv) There is no change in the position of this equilibrium when the pressure is increased at constant temperature.

(1 mark)

2 (c) (v) An increase in the concentration of steam at constant temperature and constant pressure shifts the position of this equilibrium from right to left.

(1 mark)

11

Turn over ▶

Do not write outside the box

3 This question is about the extraction of metals.

3 (a) Manganese can be extracted from Mn_2O_3 by reduction with carbon monoxide at high temperature.

3 (a) (i) Use the standard enthalpy of formation data from the table and the equation for the extraction of manganese to calculate a value for the standard enthalpy change of this extraction.

	$Mn_2O_3(s)$	$CO(g)$	$Mn(s)$	$CO_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 971	– 111	0	– 394

$$Mn_2O_3(s) + 3CO(g) \longrightarrow 2Mn(s) + 3CO_2(g)$$

.....

.....

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(3 marks)

3 (a) (ii) State why the value for the standard enthalpy of formation of Mn(s) is zero.

.....

(1 mark)

Do not write outside the box

3 (b) Titanium is extracted in industry from titanium(IV) oxide in a two-stage process.

3 (b) (i) Write an equation for the first stage of this extraction in which titanium(IV) oxide is converted into titanium(IV) chloride.

.....

(2 marks)

3 (b) (ii) Write an equation for the second stage of this extraction in which titanium(IV) chloride is converted into titanium.

.....

(2 marks)

3 (c) Chromium is extracted in industry from chromite ($FeCr_2O_4$).

3 (c) (i) In the first stage of this extraction, the $FeCr_2O_4$ is converted into Na_2CrO_4

Balance the equation for this reaction.

..... $FeCr_2O_4$ + ... Na_2CO_3 + ... O_2 $\longrightarrow$ ..... Na_2CrO_4 + $2Fe_2O_3$ + $8CO_2$

(1 mark)

3 (c) (ii) In the final stage, chromium is extracted from Cr_2O_3 by reduction with aluminium.

Write an equation for this reaction.

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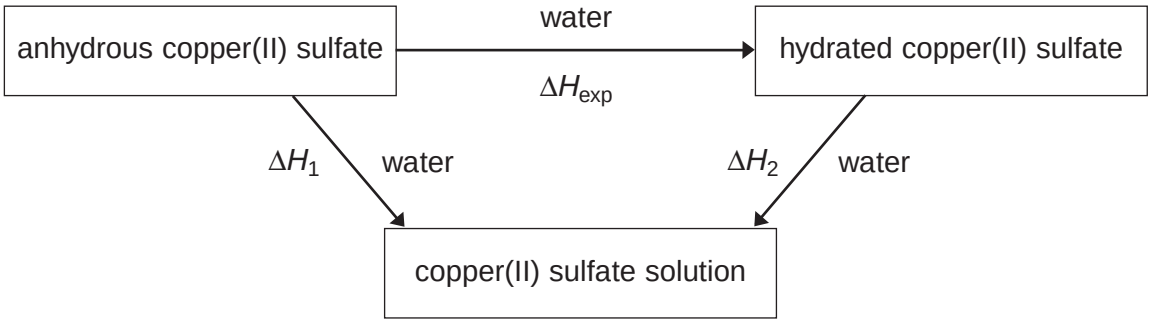
(1 mark)

10

Turn over for the next question

Do not write outside the box

4 A student used Hess's Law to determine a value for the enthalpy change that occurs when anhydrous copper(II) sulfate is hydrated.
This enthalpy change was labelled ΔH_{exp} by the student in a scheme of reactions.



4 (a) State Hess's Law.

.....

.....

.....

.....

(1 mark)

4 (b) Write a mathematical expression to show how ΔH_{exp}, ΔH_1 and ΔH_2 are related to each other by Hess's Law.

.....

(1 mark)

4 (c) Use the mathematical expression that you have written in part **(b)**, and the data book values for the two enthalpy changes ΔH_1 and ΔH_2 shown, to calculate a value for ΔH_{exp}

$\Delta H_1 = -156\,kJ\,mol^{-1}$
$\Delta H_2 = +12\,kJ\,mol^{-1}$

.....

.....

.....

.....

(1 mark)

Do not write outside the box

4 (d) The student added 0.0210 mol of pure anhydrous copper(II) sulfate to 25.0 cm^3 of deionised water in an open polystyrene cup. An exothermic reaction occurred and the temperature of the water increased by 14.0 °C.

4 (d) (i) Use these data to calculate the enthalpy change, in $kJ\,mol^{-1}$, for this reaction of copper(II) sulfate. This is the student value for ΔH_1

In this experiment, you should assume that all of the heat released is used to raise the temperature of the 25.0 g of water. The specific heat capacity of water is $4.18\,J\,K^{-1}\,g^{-1}$.

.....

.....

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.....

.....

(3 marks)

4 (d) (ii) Suggest **one** reason why the student value for ΔH_1 calculated in part **(d) (i)** is less accurate than the data book value given in part **(c)**.

.....

.....

(1 mark)

4 (e) Suggest **one** reason why the value for ΔH_{exp} **cannot** be measured directly.

.....

.....

(1 mark)

(Extra space) .....

.....

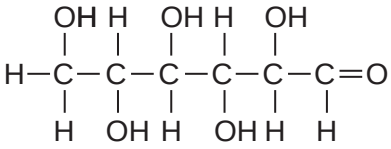
8

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5 Glucose is an organic molecule. Glucose can exist in different forms in aqueous solution.

5 (a) In aqueous solution, some glucose molecules have the following structure.

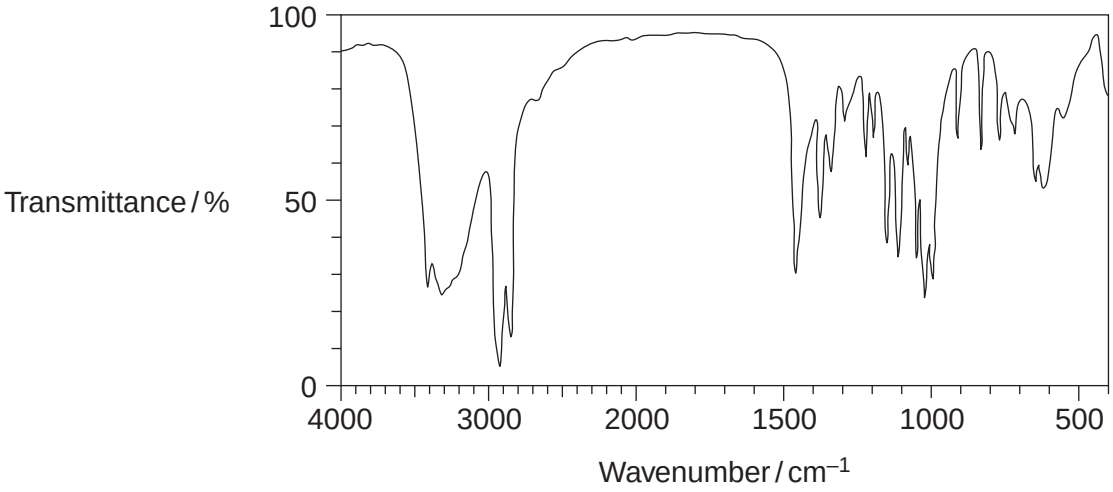


5 (a) (i) Deduce the empirical formula of glucose.

.....

(1 mark)

5 (a) (ii) Consider the infrared spectrum of solid glucose.



State why it is possible to suggest that in the solid state very few molecules have the structure shown.
You may find it helpful to refer to **Table 1** on the Data Sheet.

.....

.....

(1 mark)

Do not write outside the box

5 (b) In the absence of oxygen, an aqueous solution of glucose can be fermented to produce ethanol for use in alcoholic drinks.

Write an equation for this fermentation reaction.
Give **two** other essential conditions for the production of ethanol in this fermentation.

Equation

.....

Condition 1 .....

Condition 2 .....

(3 marks)

5 (c) Any ethanol present in the breath of a drinker can be detected by using a breathalyser. The ethanol is converted into ethanoic acid. The breathalyser has negative and positive electrodes. A current is measured and displayed in terms of alcohol content.

The overall redox equation is as follows

$$CH_3CH_2OH(l) + O_2(g) \longrightarrow CH_3COOH(l) + H_2O(l)$$

5 (c) (i) Draw the displayed formula for ethanoic acid.

(1 mark)

5 (c) (ii) Deduce a half-equation for the reduction of atmospheric oxygen to water in acidic solution at one electrode of the breathalyser.

.....

(1 mark)

5 (c) (iii) Deduce a half-equation for the oxidation of ethanol in water to ethanoic acid at the other electrode of the breathalyser.

.....

(1 mark)

Question 5 continues on the next page

Turn over ▶

Do not write outside the box

5 (c) (iv) The earliest breathalysers used laboratory chemicals to oxidise the ethanol to ethanoic acid. Detection was by a colour change.

Identify a reagent or combination of reagents that you would use in the laboratory to oxidise ethanol to ethanoic acid.
State the colour **change** that you would expect to see.

Reagent or combination of reagents .....

Colour change .....

(2 marks)

5 (d) The fermentation of glucose from crops is the main method for the production of ethanol. The product is called bioethanol. The European Union has declared that bioethanol is carbon-neutral.

5 (d) (i) State the meaning of the term *carbon-neutral*.

.....

.....

.....

(1 mark)

(Extra space) .....

.....

5 (d) (ii) Other than carbon-neutrality, state the **main** advantage of the use of glucose from crops as the raw material for the production of ethanol.

.....

.....

(1 mark)

5 (d) (iii) Give **one** disadvantage of the use of crops for the production of ethanol.

.....

.....

(1 mark)

13

Do not write outside the box

6 Hydrazine (N_2H_4) decomposes in an exothermic reaction. Hydrazine also reacts exothermically with hydrogen peroxide when used as a rocket fuel.

6 (a) Write an equation for the decomposition of hydrazine into ammonia and nitrogen only.

.....

(1 mark)

6 (b) State the meaning of the term *mean bond enthalpy*.

.....

.....

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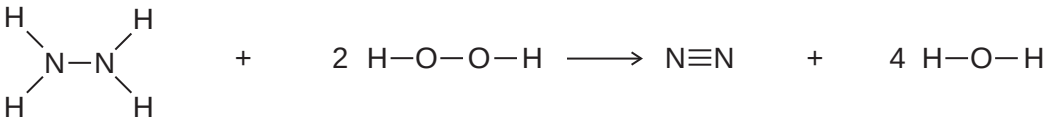
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(2 marks)

6 (c) Some mean bond enthalpies are given in the table.

	N—H	N—N	N≡N	O—H	O—O
Mean bond enthalpy / kJ mol^{-1}	388	163	944	463	146

Use these data to calculate the enthalpy change for the gas-phase reaction between hydrazine and hydrogen peroxide.



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(3 marks)

6

Turn over ▶

Do not write outside the box

7 The refrigerant R410A, used in air conditioners, is a mixture of two fluoroalkanes, pentafluoroethane and difluoromethane.

7 (a) (i) The mechanism for the reaction of fluorine with either an alkane or a fluoroalkane is similar to that for the reaction of chlorine with methane.

Name the type of mechanism for the reaction of chlorine with methane.

.....

(1 mark)

7 (a) (ii) Write equations for the following steps in the mechanism for the reaction of fluorine with fluoromethane (CH_3F) to form difluoromethane (CH_2F_2).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step leading to the formation of 1,2-difluoroethane.

.....

(4 marks)

7 (a) (iii) Write an overall equation for the reaction of fluorine with ethane to form pentafluoroethane (CF_3CHF_2) by this mechanism.

.....

(1 mark)

Do not write outside the box

7 (b) The refrigerant R112A (CCl_3CF_2Cl) has been banned because of concerns about ozone depletion.

Give the IUPAC name for CCl_3CF_2Cl

.....

(1 mark)

7 (c) Nitrogen monoxide (NO) catalyses the decomposition of ozone into oxygen.

7 (c) (i) Write the overall equation for this decomposition.

.....

(1 mark)

7 (c) (ii) Use the overall equation to deduce Step **3** in the following mechanism that shows how nitrogen monoxide catalyses this decomposition.

Step **1** $O_3 \longrightarrow O + O_2$

Step **2** $NO + O_3 \longrightarrow NO_2 + O_2$

Step **3** .....

(1 mark)

9

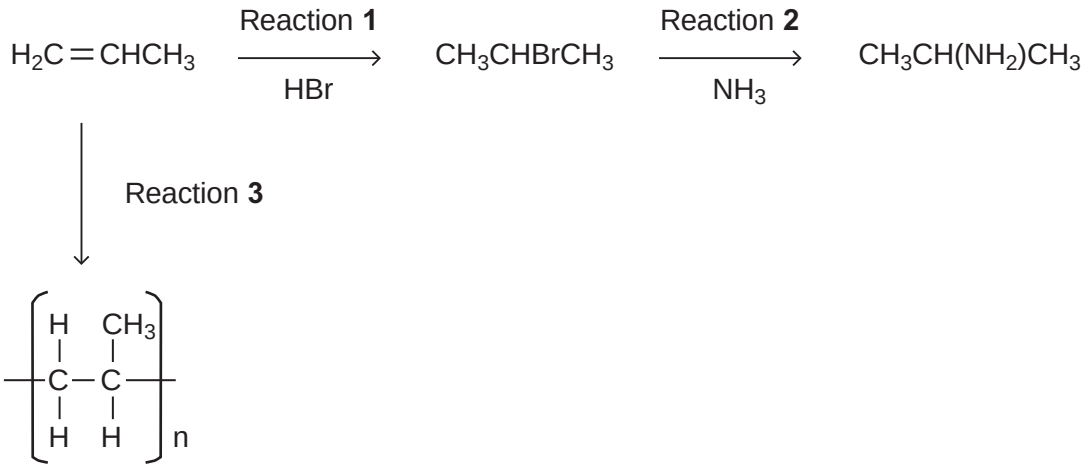
Turn over for the next question

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Section B

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

8 Consider the following reactions.



substance **X**

8 (a) Name and outline a mechanism for Reaction **1**.

Name of mechanism .....

Mechanism

(5 marks)

Do not write outside the box

8 (b) Name and outline a mechanism for Reaction **2**.

Name of mechanism .....

Mechanism

(5 marks)

8 (c) State the type of reaction in Reaction **3**.
Give the name of substance **X**.

.....

.....

.....

(2 marks)

Question 8 continues on the next page

Do not write outside the box

8 (d) The haloalkane produced in Reaction **1** can be converted back into propene in an elimination reaction using ethanolic potassium hydroxide.

$$CH_3CHBrCH_3 \xrightarrow{KOH} H_2C{=}CHCH_3$$

Outline a mechanism for this conversion.

(3 marks)

15

Do not write outside the box

9 Concentrated sulfuric acid reacts with solid potassium iodide as shown in the equation.

$$8KI + 9H_2SO_4 \longrightarrow 4I_2 + 8KHSO_4 + H_2S + 4H_2O$$

Give **two** observations that you would make when this reaction occurs.

In terms of electrons, state what happens to the iodide ions in this reaction.

State the **change** in oxidation state of sulfur that occurs during this formation of H_2S and deduce the half-equation for the conversion of H_2SO_4 into H_2S

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(5 marks)

5

Turn over for the next question

Do not write outside the box

10 Chlorine is a powerful oxidising agent.

10 (a) Write the **simplest ionic** equation for the reaction between chlorine and aqueous potassium bromide.

State what is observed when this reaction occurs.

.....

.....

.....

.....

(2 marks)

(Extra space) .....

.....

10 (b) Write an equation for the reaction between chlorine and cold, dilute, aqueous sodium hydroxide.

Give a major use for the solution that is formed by this reaction.

Give the IUPAC name of the chlorine-containing compound formed in this reaction in which chlorine has an oxidation state of +1.

.....

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(3 marks)

(Extra space) .....

.....

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Do not write outside the box

10 (c) Write an equation for the equilibrium reaction that occurs when chlorine gas reacts with cold water.

Give **one** reason why chlorine is used for the treatment of drinking water even though the gas is very toxic.

.....

.....

.....

.....

(2 marks)

(Extra space) .....

.....

10 (d) State how you could test a sample of water to show that it contains chloride ions.

In your answer, give a reagent, **one** observation and the **simplest ionic** equation for the reaction with the reagent.

.....

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(3 marks)

(Extra space) .....

.....

.....

10

END OF QUESTIONS

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General Certificate of Education (A-level)
January 2013

Chemistry CHEM2

(Specification 2420)

Unit 2: Chemistry In Action

Final

Mark Scheme

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Question	Marking Guidance	Mark	Comments
1(a)(i)	Change in concentration (of a substance / reactant / product) in unit time / given time / per (specified) unit of time ***OR*** Amount of substance formed / used up in unit time / given time / per (specified) unit of time	1	This may be written mathematically ***OR*** may refer to the gradient of a graph of concentration / volume against time Ignore additional information including reference to collisions
1(a)(ii)	At **W** **M1 (QoL)** The rate / it is zero **M2** The magnesium has all reacted / has been used up ***OR*** No more collisions possible between acid and Mg ***OR*** Reaction is complete / it has stopped ***OR*** No more hydrogen / product is produced	2	Ignore reference to the acid being used up

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1(a)(iii)	**M1** Twice / double as many particles / hydrogen ions (in a given volume) ***OR*** Twice / double as much hydrochloric acid **M2** Twice / double as many effective / successful collisions (in a given time) ***OR*** Twice / double as many collisions with either sufficient energy to react ***OR*** with E ≥ Ea ***OR*** double the successful / effective collision frequency	2	Penalise reference to (hydrochloric acid) molecules in **M1** Penalise reference to "HCl particles" in **M1**
1(b)(i)	The activation energy is the minimum energy for a reaction to go / start ***OR*** Minimum energy for a successful/ effective collision	1	
1(b)(ii)	**M1** Products lower than reactants on the profile **M2** Activation energy (E_a) shown and labelled correctly from reactants to peak of curve	2	Mark independently

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1(c)(i)	$Ba + \mathbf{2}H_2O \longrightarrow Ba(OH)_2 + H_2$	1	$Ba + 2H_2O \longrightarrow Ba^{2+} + 2OH^- + H_2$ Allow multiples Ignore state symbols
1(c)(ii)	**M1** $Ba^{2+} + SO_4^{2-} \longrightarrow BaSO_4$ **M2** White precipitate / solid	2	Ignore state symbols in **M1** Not multiples in **M1** Extra ions must be cancelled Penalise contradictory observations in **M2**
1(c)(iii)	**M1** Barium meal / barium swallow / barium enema ***OR*** used in X-rays ***OR*** to block X-rays ***OR*** X-ray contrast medium ***OR*** CT scans **M2** $BaSO_4$ / barium sulfate is insoluble (and therefore not toxic)	2	Accept a correct reference to **M1** written in the explanation in **M2**, unless contradictory For **M2** NOT barium ions NOT barium NOT barium meal and NOT "It" Ignore radio-tracing

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Question	Marking Guidance	Mark	Comments
2(a)	(If any factor is changed which affects an equilibrium), the (position of) equilibrium will shift / move so as to oppose / counteract the change. ***OR*** (When a system / reaction in equilibrium is disturbed), the (position of) equilibrium shifts / moves in a direction which tends to reduce the disturbance	1	Must refer to equilibrium Ignore reference to "system" alone A variety of wording will be seen here and the key part is the last phrase An alternative to shift / move would be the idea of changing / altering the position of equilibrium
2(b)(i)	**M1** A substance that speeds up the reaction / alters the rate but is chemically unchanged at the end / not used up **M2** Catalysts provide an alternative route / alternative pathway / different mechanism **M3** that has a lower activation energy / E_a ***OR*** lowers the activation energy / E_a	3	Both ideas needed for **M1** Credit can score for **M1**, **M2** and **M3** from anywhere within the answer
2(b)(ii)	(Time is) less / shorter / decreases / reduces	1	Credit "faster", "speeds up", "quicker" or words to this effect
2(b)(iii)	None	1	

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2(c)(i)	R	1	
2(c)(ii)	T	1	
2(c)(iii)	R	1	
2(c)(iv)	P	1	
2(c)(v)	Q	1	

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Question	Marking Guidance	Mark	Comments
3(a)(i)	**M1 (could be scored by a correct mathematical expression which must have all Δ*H* symbols and the ∑ or SUM)** **M1** $\Delta H = \sum \Delta H_f$ **(products)** - $\sum \Delta H_f$ **(reactants)** ***OR*** a correct cycle of balanced equations **M2** ΔH = 3(–394) – 3(–111) – (–971) (This also scores M1) **M3** = **(+) 122** (kJ mol^{-1}) **Award 1 mark ONLY for –122**	3	Correct answer gains full marks Credit 1 mark ONLY if **–122** (kJ mol^{-1}) For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**) • If no AE, check for correct method; this requires either a correct cycle of balanced equations OR a clear statement of **M1** which could be in words and scores **M1 only**
3(a)(ii)	By definition ***OR*** Because it is an element / elemental	1	Ignore reference to "standard state"
3(b)(i)	$TiO_2 + \mathbf{2}Cl_2 + \mathbf{2}C \longrightarrow TiCl_4 + \mathbf{2}CO$ ***OR*** $TiO_2 + \mathbf{2}Cl_2 + C \longrightarrow TiCl_4 + CO_2$ **M1** use of Cl_2 and C **M2** a correct balanced equation	2	Allow multiples Ignore state symbols

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3(b)(ii)	$TiCl_4$ + **4**Na ⟶ Ti + **4**NaCl ***OR*** $TiCl_4$ + **2**Mg ⟶ Ti + **2**$MgCl_2$ **M1** use of Na ***OR*** Mg **M2** a correct balanced equation	2	Allow multiples Ignore state symbols
3(c)(i)	**4**$FeCr_2O_4$ + **8**Na_2CO_3 + **7**O_2 ⟶ **8**Na_2CrO_4 + 2Fe_2O_3 + 8CO_2	1	Allow multiples Ignore state symbols
3(c)(ii)	Cr_2O_3 + **2**Al ⟶ Al_2O_3 + **2**Cr	1	Allow multiples Ignore state symbols

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Question	Marking Guidance	Mark	Comments
4(a)	The <u>enthalpy change</u> / <u>heat (energy) change</u> (at constant pressure) in a reaction is independent of the route / path taken (and depends only on the initial and final states)	1	Ignore the use of ΔH for enthalpy
4(b)	$\Delta H_{exp} + \Delta H_2 - \Delta H_1 = 0$ ***OR*** $\Delta H_{exp} + \Delta H_2 = \Delta H_1$ ***OR*** $\Delta H_1 = \Delta H_{exp} + \Delta H_2$ ***OR*** $\Delta H_{exp} = \Delta H_1 - \Delta H_2$ ***OR*** $\Delta H_{exp} = \Delta H_1 + (-\Delta H_2)$	1	Any correct mathematical statement that uses <u>all three terms</u>
4(c)	$\Delta H_{exp} = \Delta H_1 - \Delta H_2$ $\Delta H_{exp} = -156 - 12 =$ **–168** (kJ mol^{-1}) Award the mark for the correct answer without any working	1	Ignore units

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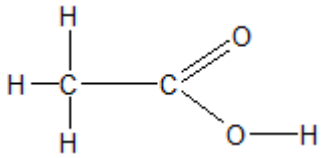
4(d)(i)	**M1** q = m c ΔT OR calculation (25.0 x 4.18 x 14.0) **M2** = **1463** J OR **1.46** kJ (This also scores **M1**) **M3** must have both the correct value within the range specified **and** the minus sign For 0.0210 mol, therefore ΔH_1 = **– 69.67** to **– 69.52** (kJ mol^{-1}) **OR** ΔH_1 = **– 69.7** to **– 69.5** (kJ mol^{-1}) Accept answers to 3sf or 4sf in the range – 69.7 to – 69.5 Ignore -70 after correct answer	3	Award full marks for correct answer In **M1**, do not penalise incorrect cases in the formula Penalise **M3** ONLY if correct numerical value but sign is incorrect; e.g. **+69.5 to +69.7 gains 2 marks** (ignore +70 after correct answer) Penalise **M2** for arithmetic error but mark on ΔT = 287, score q = m c ΔT only If c = 4.81 (leads to 1684 J) penalise **M2** ONLY and mark on for **M3** = – 80.17 (range – 80.0 to – 80.2) Ignore incorrect units

4(d)(ii)	The idea of heat loss ***OR*** Incomplete reaction (of the copper sulfate) ***OR*** Not all the copper sulfate has dissolved	1	NOT impurity NOT incompetence NOT incomplete combustion

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4(e)	Impossible to add / react the <u>exact / precise amount</u> of water ***OR*** Very difficult to measure the temperature rise <u>of a solid</u> ***OR*** Difficult to prevent solid dissolving ***OR*** (Copper sulfate) solution will form	1	Not just “the reaction is incomplete”

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Question	Marking Guidance	Mark	Comments
5(a)(i)	CH_2O	1	Atoms in any order Accept a clear indication that $C_6H_{12}O_6$ yields CH_2O as the answer
5(a)(ii)	No peak / no absorption / no C=O in the **range 1680 to 1750** (cm^{-1}) (suggesting no evidence of C=O)	1	Allow the words "dip", "spike", "low transmittance" and "trough" as alternatives for absorption Ignore references to other wavenumbers
5(b)	**M1** $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH (C_2H_5OH) + **2**CO_2 Either order **M2** (enzymes from) yeast or zymase **M3** 25 $^oC \leq T \leq 42\ ^oC$ OR $298\ K \leq T \leq 315\ K$	3	Penalise C_2H_6O Allow multiples of the equation in **M1** For **M2** and **M3** Ignore "aqueous" Ignore "anaerobic/absence of oxygen" Ignore "controlled pH" Ignore "warm"
5(c)(i)	Displayed formula for CH_3COOH 	1	All bonds must be drawn out, but ignore bond angles

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5(c)(ii)	$O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$	1	Ignore state symbols Negative charge on electron not essential Accept multiples Accept electrons subtracted from RHS
5(c)(iii)	$CH_3CH_2OH + H_2O \longrightarrow CH_3COOH + 4H^+ + 4e^-$ (C_2H_6O or C_2H_5OH)	1	Ignore state symbols Negative charge on electron not essential Accept multiples Accept electrons subtracted from LHS
5(c)(iv)	**M1** Acidified potassium or sodium dichromate ***OR*** H_2SO_4 / $K_2Cr_2O_7$ OR H^+ / $K_2Cr_2O_7$ etc. ***OR*** correct combination of formula and name **M2 (requires an attempt at M1)** orange to green Possible alternative **M1** (acidified) potassium manganate(VII) ***OR*** $KMnO_4$ / H_2SO_4 **M2** purple to colourless	2	For **M1**, it must be a whole reagent and/or correct formulae Do not penalise incorrect attempt at formula if name is correct or vice versa If oxidation state given in name, it must be correct, but mark on from an incorrect attempt at a correct reagent. Credit **acidified** potassium chromate(VI) / $H_2SO_4 + K_2CrO_4$ Other alternatives will be accepted but **M2** is dependent on **M1** in every case **M2** requires an attempt at a correct reagent for **M1** Ignore reference to states

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5(d)(i)	An activity which has no net / overall (annual) carbon emissions to the atmosphere / air ***OR*** An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere / air. ***OR*** There is no change in the total amount of carbon dioxide / carbon /greenhouse gas present in the atmosphere / air	1	The idea that the carbon / CO_2 given out equals the carbon / CO_2 that was taken in from the atmosphere / air Answer must refer to the atmosphere or air
5(d)(ii)	Renewable / sustainable ONLY	1	Ignore references to global warming or greenhouse gases

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5(d)(iii)	**Any one statement <u>about this process</u> from** Subject to weather / climate ***OR*** Depletes <u>food</u> supply OR the land use <u>for</u> (specified) <u>food</u> ***OR*** Requires use of / uses more fossil fuels ***OR*** Not carbon-neutral OR CO_2 produced during a named process (eg harvest, transport etc.) ***OR*** Slow process / slow rate of reaction / takes a long time (to grow crops) ***OR*** This route leads to the production of a mixture of water and ethanol / impure ethanol <u>that requires separation / further processing</u>	1	Ignore “batch”

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Question	Marking Guidance	Mark	Comments
6(a)	$3N_2H_4 \longrightarrow 4NH_3 + N_2$	1	Or multiples Ignore state symbols
6(b)	**M1** <u>enthalpy</u> / <u>heat (energy)</u> <u>change / required / needed</u> to <u>break</u> / <u>dissociate</u> a <u>covalent bond (or a specified covalent bond)</u> **M2** <u>average / mean</u> over <u>different molecules / compounds / substances</u>	2	Ignore bond making Ignore standard conditions **M2** requires an attempt at **M1**
6(c)	**M1** $\sum$ (bonds broken) – $\sum$ (bonds formed) = ΔH ***OR*** <u>Sum</u> of bonds broken – <u>Sum</u> of bonds formed = ΔH **M2** (also scores **M1**) 4(+388) + 163 + 2(146) + 4(463) – 944 – 8(463) = ΔH OR broken +3859 (2007) formed – 4648 (2796) **M3** ΔH = **<u>– 789</u>** (kJ mol^{-1}) Award 1 mark for + 789 Students may use a cycle and gain full marks	3	**M1** could stand alone <u>Award full marks for correct answer</u> Ignore units Two marks can score with an arithmetic error in the working Credit **one mark only** for calculating <u>either</u> the sum of the bonds broken <u>or</u> the sum of the bonds formed provided this is <u>the only mark that is to be awarded</u>

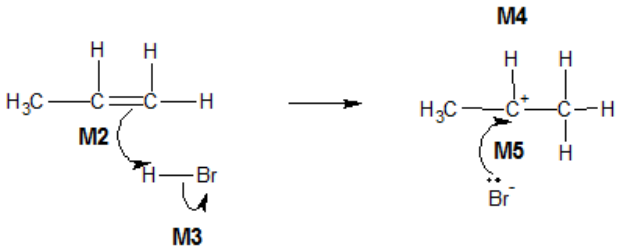
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Question	Marking Guidance	Mark	Comments
7(a)(i)	(Free-) radical substitution	1	Both underlined words are required Penalise a correct answer if contradicted by an additional answer
7(a)(ii)	**Initiation** $F_2 \longrightarrow 2F\bullet$ **First propagation** $F\bullet + CH_3F \longrightarrow \bullet CH_2F + HF$ **Second propagation** $F_2 + \bullet CH_2F \longrightarrow CH_2F_2 + F\bullet$ **Termination (must make 1,2-difluoroethane)** $2\ \bullet CH_2F \longrightarrow \underline{CH_2FCH_2F}$	4	Penalise absence of dot once only Penalise + or – charges every time Accept dot anywhere on CH_2F radical Mark independently Use of half-headed arrows must be correct to score, but if not correct then penalise once only in this clip
7(a)(iii)	$CH_3CH_3 + \mathbf{5}F_2 \longrightarrow CF_3CHF_2 + \mathbf{5}HF$ (C_2H_6) (C_2HF_5)	1	
7(b)	1,1,1,2-tetrachloro-2,2-difluoroethane ***OR*** 1,2,2,2-tetrachloro-1,1-difluoroethane	1	Accept phonetic spelling eg “fluro, cloro” Penalise “flouro” and “floro”, since **QoL** Ignore commas and hyphens

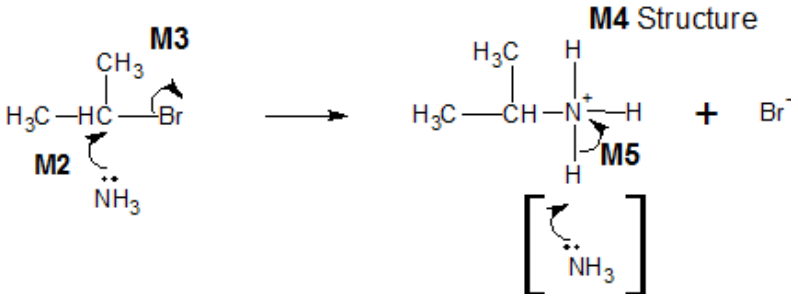
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7(c)(i)	**2**O_3 ⟶ **3**O_2	1	ONLY this equation or a multiple Ignore NO over the arrow Other species must be cancelled
7(c)(ii)	O + NO_2 ⟶ NO + O_2	1	ONLY this answer and NOT multiples Ignore any radical dot on the O atom

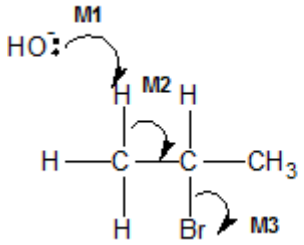
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Question	Marking Guidance	Mark	Comments
8(a)	**M1** **<u>electrophilic addition</u>**  **M2** must show an arrow from the double bond towards the H atom of the H–Br molecule **M3** must show the breaking of the H–Br bond **M4** is for the structure of the secondary carbocation **M5** must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the correct (positively charged) carbon atom **NB These are double-headed arrows**	5	For **M1**, both words required Accept phonetic spelling **For the mechanism** **M2** Ignore partial negative charge on the double bond **M3** Penalise partial charges on H–Br bond if wrong way and penalise formal charges Penalise once only in any part of the mechanism for a line and two dots to show a bond **<u>Maximum any 3 of 4 marks</u>** **<u>for the mechanism</u>** for wrong (organic) reactant ***OR*** wrong organic product (if shown) ***OR*** primary carbocation Accept the correct use of sticks

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Question	Marking Guidance	Mark	Comments
8(b)	**M1** **<u>Nucleophilic substitution</u>**  **M2** must show an arrow from the lone pair of electrons **on the nitrogen atom** of an ammonia molecule to the correct C atom **M3** must show the movement of a pair of electrons from the C–Br bond to the Br atom. Mark **M3** independently provided it is from <u>their original molecule</u> **M4** is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge **must** be shown on/or close to, the N atom **M5** is for an arrow from the N–H bond to the N atom Award full marks for an S_N1 mechanism in which **M2** is the attack of the ammonia on the intermediate carbocation **NB These are double-headed arrows**	5	For **M1**, both words required Accept phonetic spelling **For the mechanism** Penalise **M2** if NH_3 is negatively charged Penalise **M3** for formal charge on C of the C-Br or incorrect partial charges on C-Br Penalise **M3** for an additional arrow from the Br to something else The second mole of ammonia is not essential for **M5**; therefore ignore any species here Penalise once only for a line and two dots to show a bond **<u>Maximum any 3 of 4 marks</u>** **<u>for the mechanism</u>** for wrong organic reactant ***OR*** wrong organic product if shown Accept the correct use of “sticks”

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Question	Marking Guidance	Mark	Comments
8(c)	**M1** (addition) polymerisation OR poly-addition **M2** poly(propene) / polypropene	2	Ignore "additional" Credit polyprop-1-ene and polypropylene Penalise "condensation polymerisation"
8(d)	 **M1** must show an arrow from the <u>lone pair on the oxygen</u> of a negatively charged hydroxide ion <u>to a correct</u> H atom **M2** must show an arrow from a correct C–H bond adjacent to the C–Br bond to the appropriate C–C bond. Only award if an arrow is shown <u>attacking</u> the H atom of a correct C-H bond in **M1** **M3** is independent provided it is from their <u>original molecule</u>, but **CE=0 if nucleophilic substitution** Award full marks for an E1 mechanism in which **M3** is on the correct carbocation. **NB These are double-headed arrows**	3	Penalise **M1** if covalent KOH Penalise **M3** for formal charge on C of C–Br or incorrect partial charges on C-Br. Ignore other partial charges Penalise once only in any part of the mechanism for a line and two dots to show a bond **<u>Maximum any 2 of 3 marks</u>** for wrong organic reactant Accept the correct use of "sticks" for the molecule except for the C–H being attacked

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Question	Marking Guidance	Mark	Comments
9	**M1 and M2 (either order)** **Any two from** • purple <u>vapour/gas</u> • (white solid goes to) black or black/grey or black/purple <u>solid</u> • bad <u>egg smell</u> or words to this effect **M3** The <u>iodide ion(s) / they lose (an) electron(s)</u> ***OR*** $2I^- \longrightarrow I_2 + 2e^-$ **M4** Oxidation state of S changes from **<u>+6 to –2</u>** or **<u>changes by 8</u>** **M5** $H_2SO_4 + \mathbf{8}H^+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$ ***OR*** $SO_4^{2-} + \mathbf{10}H^+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$	5	Ignore misty white fumes Ignore yellow solid Ignore purple solid Ignore “goes (dark) brown” Or multiples for possible equation in **M3** Accept “changes by – 8”

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Question	Marking Guidance	Mark	Comments
10(a)	**M1** $Cl_2 + \mathbf{2}Br^- \longrightarrow \mathbf{2}Cl^- + Br_2$ **M2** solution goes <u>orange / yellow</u> (from colourless)	2	Accept a correct equation using ½ Cl_2 but no other multiples Ignore reference to brown colour Penalise incorrect observations eg fumes, precipitates
10(b)	**M1** $Cl_2 + 2NaOH \longrightarrow NaClO + NaCl + H_2O$ (NaOCl) **M2** bleach or kills bacteria / bacteriacide / micro-organisms / microbes **M3** <u>sodium chlorate(I)</u> ONLY	3	Or a correct ionic equation Ignore reference to “swimming pools” and to “disinfectant”
10(c)	**M1** $Cl_2 + H_2O \rightleftharpoons HClO + HCl$ (HOCl) **M2** The (health) benefit outweighs the risk or wtte ***OR*** a clear statement that once it has done its job, little of it remains ***OR*** used in (very) dilute concentrations / small amounts / low doses	2	Equilibrium symbol **<u>required</u>** in **M1** Accept ionic RHS

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10(d)	**M1** Silver nitrate OR $AgNO_3$ (with or without nitric acid) **M2** **(depends on M1)** white precipitate / white solid **M3** $Ag^+ + Cl^- \longrightarrow AgCl$	3	For **M1** If only the formula is written then it must be correct If both the formula and the name are written then ignore incorrect attempt at the formula, but penalise an incorrect name If the reagent is incomplete eg Ag+ ions, penalise **M1** and mark on Penalise both **M1** and **M2** for alkaline $AgNO_3$ ***OR*** for the use of HCl to acidify the silver nitrate ***OR*** for Tollens' reagent

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General principles applied to marking CHEM2 papers by CMI+ January 2013

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are required information to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**

A. The "List principle" and the use of "ignore" in the mark scheme

If a question requires **one** answer and a student gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. Incorrect case for element symbol

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. Spelling

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

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E. Reagents

The command word "Identify", allows the student to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.
For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a student provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

F. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

G. Marking calculations, such as those involving enthalpy changes

In general

- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will usually score **only one mark**.

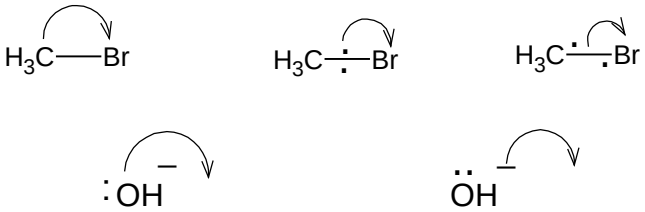
All other values **gain no credit** except

- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

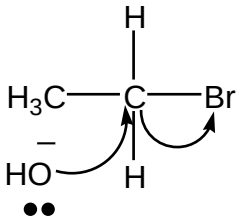
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H. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.
The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

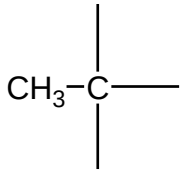
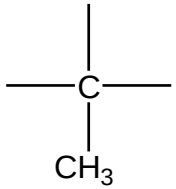
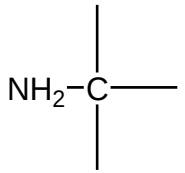
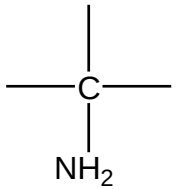
In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

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I. Organic structures

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if students show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in structures, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or C ─ NH_2 bonds should **not** be penalised. For the other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.
  By way of illustration, the following would apply

(a)  allowed	(b)  allowed
(c)  allowed	(d)  allowed

- In most cases, the use of "sticks" to represent C ─ H bonds in a structure should **not** be penalised. The exceptions will include structures in mechanisms when the C ─ H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.

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- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

N.B. Exceptions may be made in the context of balancing equations

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

J. Organic names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit. Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**

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3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
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TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
June 2012

Chemistry CHEM2

Unit 2 Chemistry in Action

Wednesday 23 May 2012 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- You are expected to use a calculator, where appropriate.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use accurate scientific terminology.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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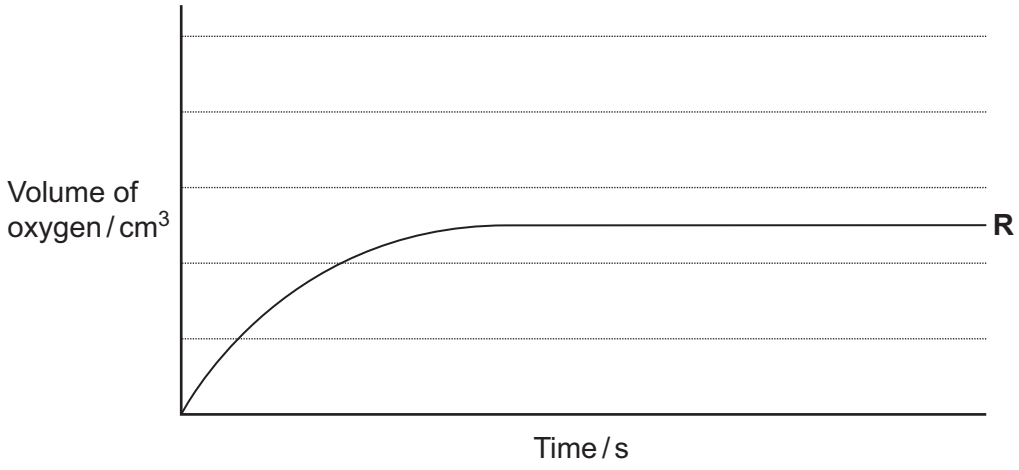
Section A

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

1 A student carried out an experiment to determine the rate of decomposition of hydrogen peroxide into water and oxygen gas.
The student used 100 cm^3 of a 1.0 mol dm^{-3} solution of hydrogen peroxide at 298 K and measured the volume of oxygen collected.
Curve **R**, in each of **Figures 1**, **2** and **3**, shows how the total volume of oxygen collected changed with time under these conditions.

1 (a) Draw a curve on **Figure 1** to show how the total volume of oxygen collected will change with time if the experiment is repeated at 298 K using 100 cm^3 of a 2.0 mol dm^{-3} solution of hydrogen peroxide.

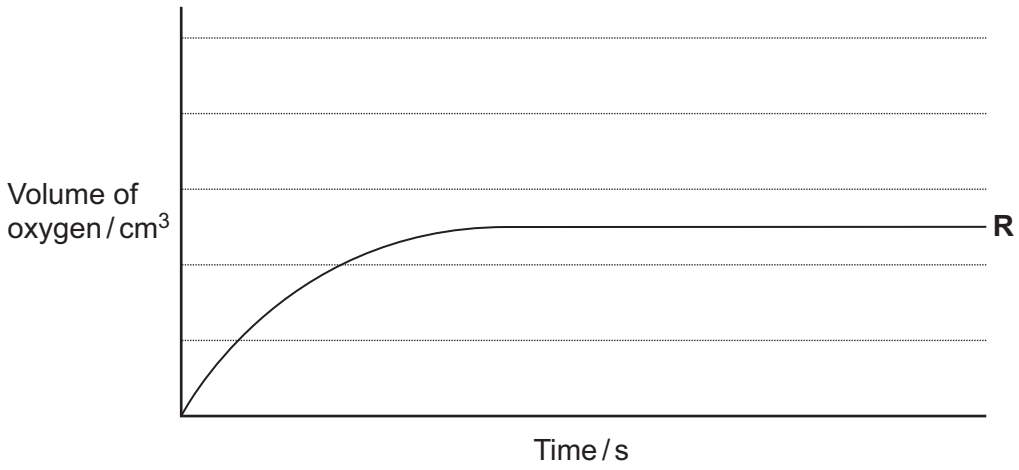
Figure 1



(2 marks)

1 (b) Draw a curve on **Figure 2** to show how the total volume of oxygen collected will change with time if the experiment is repeated at 298 K using 100 cm^3 of a 0.4 mol dm^{-3} solution of hydrogen peroxide.

Figure 2

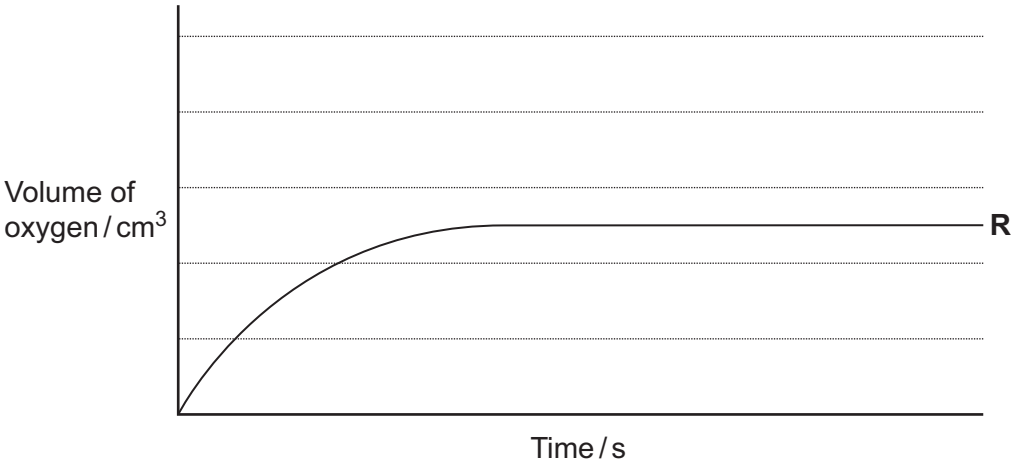


(2 marks)

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1 (c) Draw a curve on **Figure 3** to show how the total volume of oxygen collected will change with time if the **original** experiment is repeated at a temperature higher than 298 K.
You should assume that the gas is collected at a temperature of 298 K.

Figure 3



(2 marks)

1 (d) Explain why the slope (gradient) of curve **R** decreases as time increases.

.....

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(2 marks)

(Extra space) .....

.....

Question 1 continues on the next page

Do not write outside the box

1 (e) The student discovered that hydrogen peroxide decomposes at a faster rate when a few drops of aqueous hydrogen bromide are added to the solution.
The student found on the Internet that this decomposition is thought to proceed in two steps as shown by the following equations.

Step **1** $H_2O_2 + HBr \longrightarrow HBrO + H_2O$

Step **2** $HBrO + H_2O_2 \longrightarrow H_2O + O_2 + HBr$

1 (e) (i) Write an equation for the overall reaction.

.....

(1 mark)

1 (e) (ii) Give **one** reason, other than the increase in rate of reaction, why the student was able to deduce that hydrogen bromide behaves as a catalyst in this two-step reaction.

.....

.....

.....

(1 mark)

10

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

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2 Methanol (CH_3OH) is an important fuel that can be synthesised from carbon dioxide.

2 (a) The table shows some standard enthalpies of formation.

	$CO_2(g)$	$H_2(g)$	$CH_3OH(g)$	$H_2O(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 394	0	– 201	– 242

2 (a) (i) Use these standard enthalpies of formation to calculate a value for the standard enthalpy change of this synthesis.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

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(3 marks)

(Extra space) .....

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2 (a) (ii) State why the standard enthalpy of formation for hydrogen gas is zero.

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(1 mark)

Do not write outside the box

2 (b) State and explain what happens to the yield of methanol when the total pressure is increased in this synthesis.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Effect on yield .....

Explanation .....

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

2 (c) The hydrogen required for this synthesis is formed from methane and steam in a reversible reaction. The equation for this reaction is shown below.

$$CH_4(g) + H_2O(g) \rightleftharpoons CO(g) + 3H_2(g) \qquad \Delta H = +206\ kJ\ mol^{-1}$$

State and explain what happens to the yield of hydrogen in this reaction when the temperature is increased.

Effect on yield .....

Explanation .....

.....

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(3 marks)

(Extra space) .....

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Question 2 continues on the next page

Do not write outside the box

2 (d) The methanol produced by this synthesis has been described as a carbon-neutral fuel.

2 (d) (i) State the meaning of the term *carbon-neutral*.

.....

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.....

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(1 mark)

(Extra space) .....

.....

2 (d) (ii) Write an equation for the complete combustion of methanol.

.....

(1 mark)

2 (d) (iii) The equation for the synthesis of methanol is shown below.

$$CO_2(g) + 3H_2(g) \rightleftharpoons CH_3OH(g) + H_2O(g)$$

Use this equation and your answer to part **(d) (ii)** to deduce an equation to represent the overall chemical change that occurs when methanol behaves as a carbon-neutral fuel.

Equation .....

(1 mark)

Do not write outside the box

2 (e) A student carried out an experiment to determine the enthalpy change when a sample of methanol was burned.

The student found that the temperature of 140 g of water increased by 7.5 °C when 0.011 mol of methanol was burned in air and the heat produced was used to warm the water.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of methanol was burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1}).

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(3 marks)

(Extra space) .....

.....

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16

Turn over for the next question

Do not write outside the box

3 The manufacture of food grade phosphoric acid for use in cola drinks begins with the production of pure white phosphorus from the mineral fluoroapatite, $Ca_5F(PO_4)_3$

3 (a) Complete the following equation for the manufacture of phosphorus.

.....$Ca_5F(PO_4)_3$ + $9SiO_2$ + ...C ⟶ $9CaSiO_3$ + CaF_2 + ...CO + ...P

(1 mark)

3 (b) As the phosphorus cools, it forms white phosphorus, P_4

Give the oxidation state of phosphorus in each of the following.

P_4 .....

H_3PO_4 .....

(2 marks)

3 (c) Fertiliser grade phosphoric acid is manufactured from sulfuric acid and calcium phosphate.
Use the following precise relative atomic mass data to show how mass spectrometry can be used to distinguish between pure sulfuric acid (H_2SO_4) and pure phosphoric acid (H_3PO_4) which both have M_r = 98 to two significant figures.

Atom	Precise relative atomic mass
^{1}H	1.00794
^{16}O	15.99491
^{31}P	30.97376
^{32}S	32.06550

.....

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(1 mark)

Do not write outside the box

3 (d) Concentrated phosphoric acid is used as a catalyst in the hydration of propene to form the alcohol $CH_3CH(OH)CH_3$ as the main organic product.
The industrial name for this alcohol is isopropyl alcohol.

3 (d) (i) State the meaning of the term *catalyst*.

.....

.....

.....

(1 mark)

(Extra space) .....

.....

3 (d) (ii) State the meaning of the term *hydration*.

.....

.....

.....

(1 mark)

(Extra space) .....

.....

3 (d) (iii) Write an equation for the hydration of propene to form isopropyl alcohol.
Give the IUPAC name for isopropyl alcohol.

Equation .....

IUPAC name .....

(2 marks)

8

Turn over ▶

Do not write outside the box

4 Metals can be extracted by different methods.

4 (a) Give **one** reason why titanium cannot be extracted directly from titanium(IV) oxide using carbon.

.....

.....

(1 mark)

4 (b) Titanium steel is an alloy of titanium and iron. Titanium steel is extracted from the mineral ilmenite ($FeTiO_3$) in a two-stage process.
Purified $FeTiO_3$ is first converted into a mixture of two metal chlorides. These two metal chlorides are then reduced simultaneously using sodium.

4 (b) (i) Write an equation for the reaction of $FeTiO_3$ with chlorine and carbon to produce iron(III) chloride ($FeCl_3$), titanium(IV) chloride and carbon monoxide.

.....

(1 mark)

4 (b) (ii) Write an equation for the simultaneous reduction of the mixture of iron(III) chloride and titanium(IV) chloride to iron and titanium using sodium.

.....

(1 mark)

Do not write outside the box

4 (c) Scrap iron is used to extract copper from dilute aqueous solutions containing copper(II) ions.
Explain, in terms of redox, what happens to the copper(II) ions in this extraction.

.....

.....

.....

.....

(2 marks)

4 (d) Aluminium is an expensive metal because it is extracted from molten aluminium oxide using electrolysis.
Write the half-equation for the reaction that occurs at the positive electrode during this extraction.

.....

(1 mark)

6

Turn over for the next question

Do not write outside the box

5 There are many uses for compounds of barium.

5 (a) (i) Write an equation for the reaction of barium with water.

.....

(1 mark)

5 (a) (ii) State the trend in reactivity with water of the Group 2 metals from Mg to Ba

.....

(1 mark)

5 (b) Give the formula of the **least** soluble hydroxide of the Group 2 metals from Mg to Ba

.....

(1 mark)

5 (c) State how barium sulfate is used in medicine.
Explain why this use is possible, given that solutions containing barium ions are poisonous.

Use .....

.....

Explanation .....

.....

(2 marks)

(Extra space) .....

.....

5

Do not write outside the box

6 Chloromethanes, such as dichloromethane and trichloromethane, are produced in industry as they have many uses.
Trichloromethane has been used in the manufacture of the refrigerant chlorodifluoromethane.

6 (a) Chlorine can react with dichloromethane (CH_2Cl_2) to form trichloromethane ($CHCl_3$).

6 (a) (i) Write an equation for each of the following steps in the mechanism for this reaction.

Initiation step

.....

First propagation step

.....

Second propagation step

.....

(3 marks)

6 (a) (ii) Give **one** essential condition for this reaction and name the type of mechanism.

Essential condition .....

Type of mechanism .....

(2 marks)

Question 6 continues on the next page

Turn over ▶

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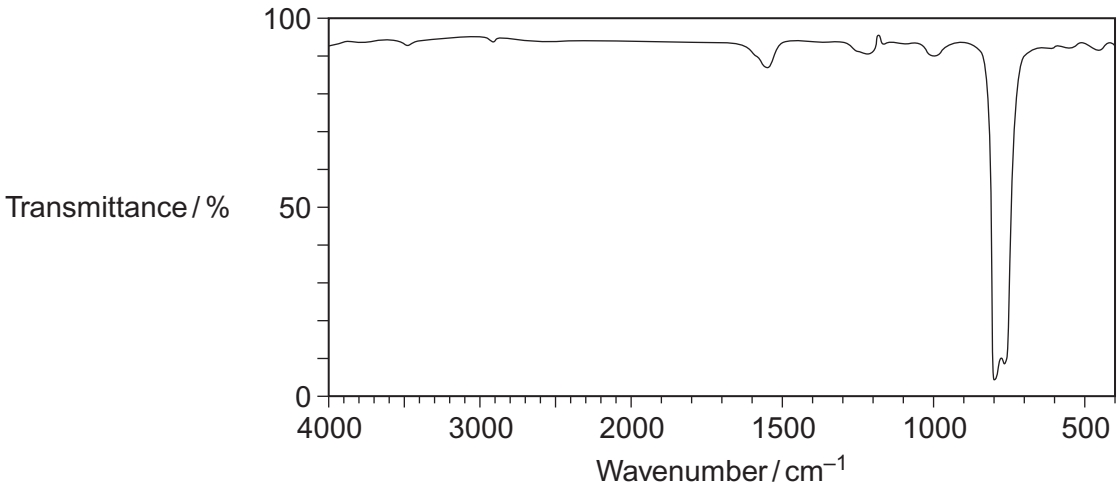
6 (b) An organic product, **X**, with M_r = 154.0 is obtained when chlorine reacts with trichloromethane.

6 (b) (i) Write an equation for the overall reaction of chlorine with trichloromethane to form **X**, by the same mechanism as that outlined in part **(a) (i)**.

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(1 mark)

6 (b) (ii) The following infrared spectrum was obtained for a sample of **X** produced in this reaction.



Use this infrared spectrum to explain why it is possible to deduce that this sample of **X** contains no trichloromethane.
You may find it helpful to refer to **Table 1** on the Data Sheet.

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(2 marks)

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6 (c) Explain, with the aid of equations and the intermediates that form in the ozone layer, why the European Union has banned the use of chlorodifluoromethane ($CHClF_2$) as a refrigerant.

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(4 marks)

(Extra space) .....

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6 (d) The compound 2,3,3,3-tetrafluoropropene is the refrigerant used in all new car air conditioners.

6 (d) (i) Draw the displayed formula for 2,3,3,3-tetrafluoropropene.

(1 mark)

6 (d) (ii) Give **one** reason why 2,3,3,3-tetrafluoropropene is a more **environmentally** acceptable refrigerant than chlorodifluoromethane.

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(1 mark)

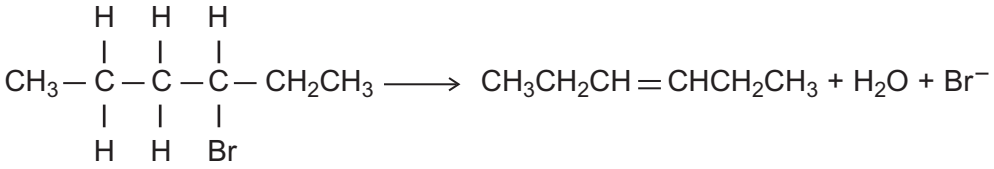
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7 Alkenes are useful intermediates in the synthesis of organic compounds.

7 (a) (i) Complete the elimination mechanism by drawing appropriate curly arrows.

$H\bar{O}$**:**



3-bromohexane hex-3-ene

(3 marks)

7 (a) (ii) Draw structures for the E and Z stereoisomers of hex-3-ene.

E isomer of hex-3-ene Z isomer of hex-3-ene

(2 marks)

7 (a) (iii) State the meaning of the term *stereoisomers*.

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(2 marks)

(Extra space) .....

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7 (b) The equation for the first reaction in the conversion of hex-3-ene into hexan-3-ol is shown below.

$CH_3CH_2CH=CHCH_2CH_3 + H_2SO_4 \longrightarrow CH_3CH_2CH_2CH(OSO_2OH)CH_2CH_3$

Outline a mechanism for this reaction.

(4 marks)

11

Turn over for the next question

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Section B

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

8 The reaction of butane-1,4-diol with butanedioic acid produces the polymer PBS used in biodegradable packaging and disposable cutlery.
Butanedioic acid is produced by two different processes.

Process 1
- Aqueous sodium hydroxide reacts with 1,4-dibromobutane to make butane-1,4-diol.
- Butane-1,4-diol is oxidised to butanedioic acid.

Process 2
- Glucose reacts with carbon dioxide in the presence of microorganisms to produce butanedioic acid directly.
- The carbon dioxide used in this process is obtained from a local factory that produces bioethanol.

8 (a) Deduce **one** safety reason and **one** environmental reason why **Process 2** is preferred to **Process 1**.

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(2 marks)

(Extra space) .....

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Do not write outside the box

8 (b) (i) Name and outline a mechanism for the following reaction that occurs in **Process 1**.

$$BrCH_2CH_2CH_2CH_2Br + NaOH \longrightarrow BrCH_2CH_2CH_2CH_2OH + NaBr$$

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(3 marks)

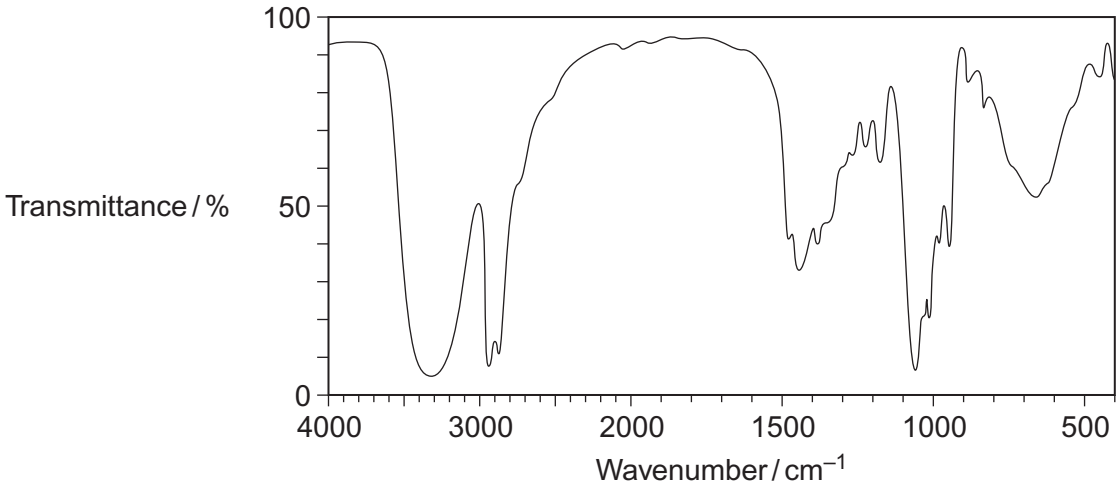
Question 8 continues on the next page

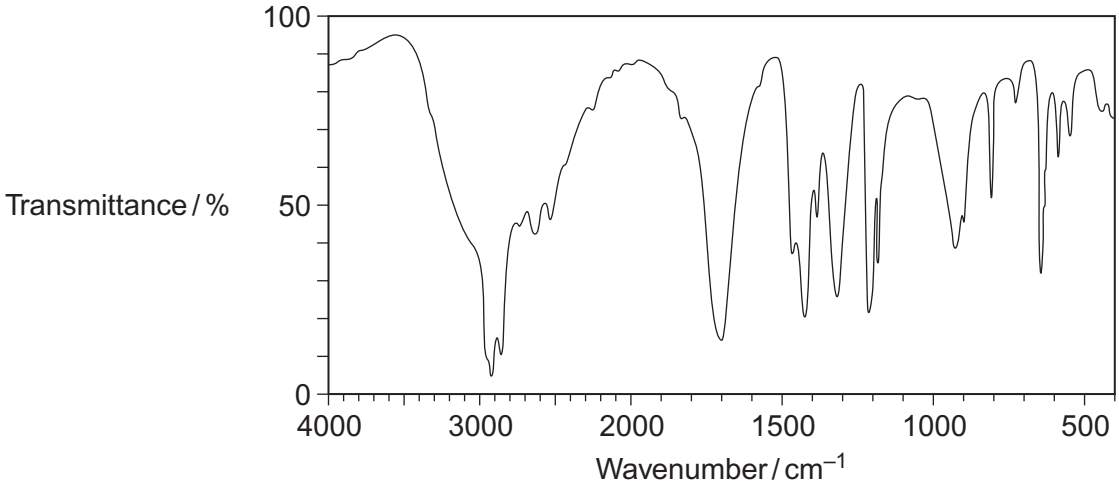
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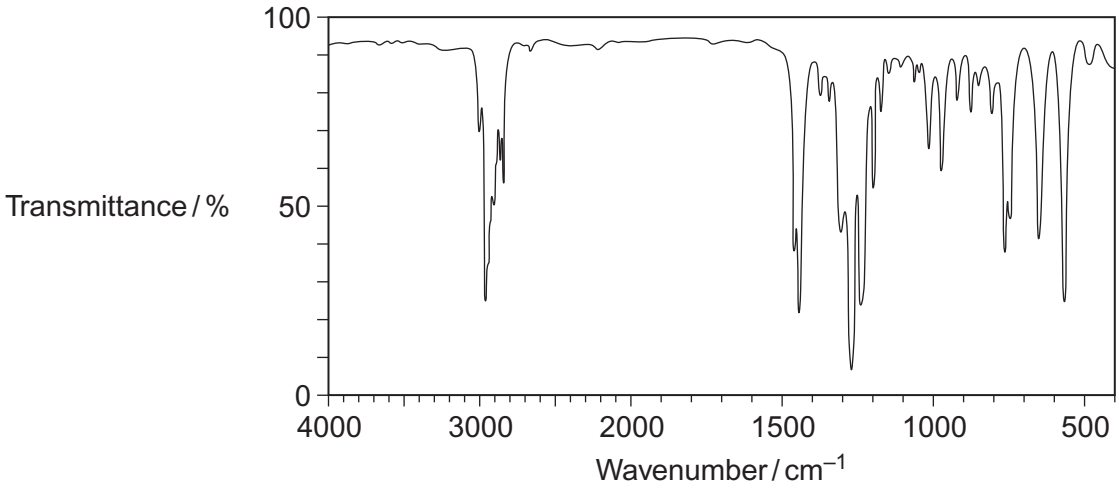
8 (b) (ii) The infrared spectra shown are those of three compounds.

Compound **A** 1,4-dibromobutane
Compound **B** butane-1,4-diol
Compound **C** butanedioic acid

Identify the compound responsible for each spectrum by writing the correct letter, **A**, **B** or **C**, in the box next to each spectrum.
You may find it helpful to refer to **Table 1** on the Data Sheet.







(3 marks)

Do not write outside the box

8 (c) In the production of bioethanol, glucose ($C_6H_{12}O_6$) is converted into a dilute aqueous solution of ethanol and carbon dioxide.

Give the name of this process and state **three** essential conditions necessary to produce a good yield of ethanol.

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(4 marks)

(Extra space) .....

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8 (d) State the class of alcohols to which the diol butane-1,4-diol belongs.

Identify a suitable reagent or combination of reagents for the conversion of butane-1,4-diol into butanedioic acid ($HOOCCH_2CH_2COOH$).

Write an equation for this oxidation reaction using [O] to represent the oxidising agent.

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(3 marks)

(Extra space) .....

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9 A student investigated the chemistry of the halogens and the halide ions.

9 (a) In the first two tests, the student made the following observations.

Test	Observation
1. Add chlorine water to aqueous potassium iodide solution.	The colourless solution turned a brown colour.
2. Add silver nitrate solution to aqueous potassium chloride solution.	The colourless solution produced a white precipitate.

9 (a) (i) Identify the species responsible for the brown colour in Test **1**.

Write the **simplest ionic** equation for the reaction that has taken place in Test **1**.

State the type of reaction that has taken place in Test **1**.

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(3 marks)

(Extra space) .....

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9 (a) (ii) Name the species responsible for the white precipitate in Test **2**.

Write the **simplest ionic** equation for the reaction that has taken place in Test **2**.

State what would be observed when an excess of dilute ammonia solution is added to the white precipitate obtained in Test **2**.

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(3 marks)

(Extra space) .....

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9 (b) In two further tests, the student made the following observations.

Test	Observation
3. Add concentrated sulfuric acid to solid potassium chloride.	The white solid produced misty white fumes which turned blue litmus paper to red.
4. Add concentrated sulfuric acid to solid potassium iodide.	The white solid turned black. A gas was released that smelled of rotten eggs. A yellow solid was formed.

9 (b) (i) Write the **simplest ionic** equation for the reaction that has taken place in Test **3**.

Identify the species responsible for the misty white fumes produced in Test **3**.

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(2 marks)

(Extra space) .....

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9 (b) (ii) The student had read in a textbook that the equation for one of the reactions in Test **4** is as follows.

$$8H^+ + 8I^- + H_2SO_4 \longrightarrow 4I_2 + H_2S + 4H_2O$$

Write the **two** half-equations for this reaction.

State the role of the sulfuric acid and identify the yellow solid that is also observed in Test **4**.

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(4 marks)

(Extra space) .....

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Question 9 continues on the next page

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9 (b) (iii) The student knew that bromine can be used for killing microorganisms in swimming pool water.
The following equilibrium is established when bromine is added to cold water.

$$Br_2(l) + H_2O(l) \rightleftharpoons HBrO(aq) + H^+(aq) + Br^-(aq)$$

Use Le Chatelier's principle to explain why this equilibrium moves to the right when sodium hydroxide solution is added to a solution containing dissolved bromine.

Deduce why bromine can be used for killing microorganisms in swimming pool water, even though bromine is toxic.

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(3 marks)

(Extra space) .....

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END OF QUESTIONS

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Version 1.2



General Certificate of Education (A-level)
June 2012

Chemistry CHEM2

(Specification 2420)

Unit 2: Chemistry In Action

Final

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Question	Marking Guidance	Mark	Comments
1(a)	**Award in either order for curve** **M1** curve is steeper than original and starts at the origin **M2** curve levels at the top line on the graph	2	"Steeper" requires line to be on the left of the original line, starting from the origin
1(b)	**Award in either order for curve** **M1** curve is shallower than original and starts at the origin **M2** curve levels at the first line on the graph	2	"Shallower" requires line to be on the right of the original line, starting from the origin
1(c)	**M1** curve would be steeper than original **M2** curve levels at the same original volume of O_2	2	"Steeper" requires line to be on the left of the original line, starting from the origin
1(d)	**M1** The (concentration / amount of) H_2O_2 or reactant falls / decreases / used up ***OR*** The number of H_2O_2 or reactant molecules/ particles falls / decreases **M2** The rate of reaction / rate of decomposition / rate of formation of oxygen / frequency of collisions / (effective) collisions in a given time decreases / is slower	2	Mark independently

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1(e)(i)	**2**H_2O_2 ⟶ **2**H_2O + O_2	1	Ignore state symbols Accept only this equation or its multiples Extra species must be crossed through
1(e)(ii)	hydrogen bromide / it does not appear in the overall equation ***OR*** hydrogen bromide / it is not <u>used up</u> in the reaction / <u>unchanged at the end</u> of the reaction ***OR*** hydrogen bromide / it is regenerated / re-formed (in Step 2)	1	

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Question	Marking Guidance	Mark	Comments
2(a)(i)	**M1 (could be scored by a correct mathematical expression which must have all ΔH symbols and the $\sum$ or SUM)** **M1** $\Delta H_r = \sum\Delta H_f$ (**products**) - $\sum\Delta H_f$ (**reactants**) ***OR*** a correct cycle of balanced equations with 1C, $3H_2$ and $1O_2$ **M2** $\Delta H_r = -201 + (-242) - (-394)$ $\Delta H_r = -201 - 242 + 394$ $\Delta H_r = -443 + 394$ (This also scores M1) **M3** = **– 49** (kJ mol^{-1}) **(Award 1 mark ONLY for + 49)**	3	Correct answer gains full marks Credit 1 mark ONLY for + 49 (kJ mol^{-1}) For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**) • If no AE, check for a correct method; this requires either correct cycle of balanced equations with 1C, $3H_2$ and $1O_2$ OR a clear statement of **M1** which could be in words and scores only **M1**
2(a)(ii)	It is an element / elemental ***OR*** By definition	1	Ignore reference to “standard state”

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2(b)	**M1** (The yield) increases / goes up / gets more **M2** There are <u>more moles / molecules</u> (of gas) on the left / of reactants ***OR*** <u>fewer moles / molecules</u> (of gas) on the right / products ***OR*** there are <u>4 moles / molecules</u> (of gas) on the left <u>and 2 moles / molecules</u> on the right. ***OR*** (equilibrium) shifts / moves <u>to the side with less moles / molecules</u> **M3: Can only score M3 <u>if M2 is correct</u>** The (position of) <u>equilibrium shifts / moves</u> (from left to right) to <u>oppose the increase in pressure</u>	3	If M1 is given as “decreases” / “no effect” / ”no change” then CE= 0 for clip, but mark on only **M2** and **M3** from a blank M1 Ignore ”volumes”, “particles” “atoms” and “species” for **M2** For **M3**, <u>not</u> simply “to oppose the change” For **M3** credit the <u>equilibrium</u> <u>shifts / moves</u> (to right) to <u>lower / decrease the pressure</u> (There must be a <u>specific</u> reference to the change that is opposed)

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2(c)	**M1** Yield increases / goes up **M2** The (forward) reaction / to the right is endothermic OR takes in / absorbs heat ***OR*** The reverse reaction / to the left is exothermic OR gives out / releases heat **Can only score M3 if M2 is correct** **M3** The (position of) equilibrium shifts / moves (from left to right) to oppose the increase in temperature **(QoL)**	3	If M1 is given as "decrease" / "no effect" / "no change" then CE= 0 for clip, but mark on only **M2** and **M3** from a blank **M1** For **M3**, not simply "to oppose the change" For **M3**, credit the (position of) equilibrium shifts / moves **(QoL)** to absorb the heat ***OR*** to cool the reaction ***OR*** to lower the temperature (There must be a specific reference to the change that is opposed)
2(d)(i)	An activity which has no net / overall (annual) carbon emissions to the atmosphere ***OR*** An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere. ***OR*** There is no change in the total amount / level of carbon dioxide / CO_2 carbon /greenhouse gas present in the atmosphere.	1	The idea that the carbon / CO_2 given out equals the carbon / CO_2 that was taken in from the atmosphere
2(d)(ii)	$CH_3OH + \mathbf{1}\frac{1}{2}O_2 \longrightarrow CO_2 + \mathbf{2}H_2O$	1	Ignore state symbols Accept multiples

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2(d)(iii)	**3**H_2 + **1½**O_2 ⟶ **3**H_2O ***OR*** **2**H_2 + O_2 ⟶ **2**H_2O	1	Ignore state symbols Accept multiples Extra species must be crossed through

2(e)	**M1** q = m c ΔT ***OR*** q =140 x 4.18 x 7.5 **M2** = 4389 (J) OR 4.389 (kJ) OR 4.39 (kJ) OR 4.4 (kJ) (also scores M1) **M3** Using 0.0110 mol therefore ΔH = **– 399** ($kJmol^{-1}$) OR **– 400** **+399 or +400 gains 2 marks**	3	Award full marks for correct answer Ignore the case for each letter Penalise **M3** ONLY if correct numerical answer but sign is incorrect; **+399 gains 2 marks** Penalise **M2** for arithmetic error and mark on In **M1**, do not penalise incorrect cases in the formula If ΔT = 280.5; score q = m c ΔT only If c = 4.81 (leads to 5050.5) penalise **M2** ONLY and mark on for **M3** = – 459 Ignore incorrect units

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Question	Marking Guidance	Mark	Comments
3(a)	**2**$Ca_5F(PO_4)_3$ + 9SiO_2 + **15**C ⟶ 9$CaSiO_3$ + CaF_2 + **15**CO + **6**P	1	
3(b)	**M1** (P_4 =) **0** **M2** (H_3PO_4 =) **(+) 5**	2	Accept Roman numeral V for **M2**
3(c)	H_2SO_4 M_r = 2(1.00794) + 32.06550 + 4(15.99491) = **98.06102 or 98.0610 or 98.061 or 98.06 or 98.1** **and** H_3PO_4 M_r = 3(1.00794) + 30.97376 + 4(15.99491) = **97.97722 or 97.9772 or 97.977 or 97.98 or 98.0**	1	**Both numbers** required Calculations not required
3(d)(i)	A substance that speeds up a reaction OR alters / increases the rate of a reaction **AND** is chemically unchanged at the end / not used up.	1	**Both ideas** needed Ignore reference to activation energy or alternative route.
3(d)(ii)	The addition of water (**QoL**) to a molecule / compound	1	**QoL- for the underlined words**

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3(d)(iii)	**M1** $CH_3CH=CH_2$ + H_2O ⟶ $CH_3CH(OH)CH_3$ (C_3H_6) **M2** propan-2-ol	2	For **M1** insist on correct structure for the alcohol but credit correct equations using either C_3H_6 or double bond not given.

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Question		Mark	Comments
4(a)	Ti is not produced ***OR*** TiC / <u>carbide</u> is produced OR titanium reacts with carbon ***OR*** Product is brittle ***OR*** Product is a poor engineering material	1	Penalise "titanium carbonate" Ignore "impure titanium" Credit "it / titanium is brittle"
4(b)(i)	$FeTiO_3 + \mathbf{3}½Cl_2 + \mathbf{3}C \longrightarrow FeCl_3 + TiCl_4 + \mathbf{3}CO$	1	Ignore state symbols Credit multiples
4(b)(ii)	$FeCl_3 + TiCl_4 + \mathbf{7}Na \longrightarrow \mathbf{7}NaCl + Fe + Ti$ **OR** (for example) $2FeCl_3 + TiCl_4 + \mathbf{10}Na \longrightarrow \mathbf{10}NaCl + 2Fe + Ti$	1	Ignore state symbols Credit multiples including ratios other than 1:1 Ignore working

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4(c)	Either order **M1** The Cu^{2+} / copper(II) ions / they have gained (two) electrons ***OR*** $Cu^{2+} + 2e^- \longrightarrow Cu$ ***OR*** oxidation state / number decreases (or specified from 2 to 0) **M2** The Cu^{2+} / copper(II) ions / they have been reduced	2	Penalise reference to incorrect number of electrons in **M1** For **M1**, accept "copper" if supported by correct half-equation or simplest ionic equation Ignore charge on the electron For **M2** do **not** accept "copper" alone
4(d)	$\mathbf{2}O^{2-} \longrightarrow O_2 + \mathbf{4}e^-$	1	Or multiples including $\mathbf{3}O^{2-} \longrightarrow \mathbf{1.5}\ O_2 + \mathbf{6}e^-$ Ignore state symbols Ignore charge on the electron Credit the electrons being subtracted on the LHS

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Question	Marking Guidance	Mark	Comments
5(a)(i)	$Ba + \mathbf{2}H_2O \longrightarrow Ba(OH)_2 + H_2$	1	Ignore state symbols Credit multiples and correct ionic equations
5(a)(ii)	(Reactivity with water) increase(s) / increasing / increased (down the Group / from Mg to Ba)	1	Accept "greater" or "gets more" or similar words to that effect. Ignore reference to "increase in solubility / gets more soluble"
5(b)	$Mg(OH)_2$	1	Accept $Mg^{2+}(OH^-)_2$ / $Mg(HO)_2$ Insist on brackets and correct case
5(c)	**M1** Barium meal / barium swallow / barium enema or (internal) X-ray or to block X-rays **M2** $\underline{BaSO_4}$ / barium sulfate is insoluble (and therefore not toxic)	2	Accept a correct reference to **M1** written in the explanation in **M2**, unless contradictory For **M2** NOT barium ions NOT barium NOT barium meal and NOT "It" Ignore radio-tracing

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Question	Marking Guidance	Mark	Comments
6(a)(i)	**M1 Initiation** $Cl_2 \longrightarrow 2Cl\bullet$ **M2 First propagation** $Cl\bullet + CH_2Cl_2 \longrightarrow \bullet CHCl_2 + HCl$ **M3 Second propagation** $Cl_2 + \bullet CHCl_2 \longrightarrow CHCl_3 + Cl\bullet$	3	Penalise absence of dot once only. Penalise + or – charges every time Accept dot anywhere on $CHCl_2$ radical but if the structure is drawn out, the dot must be on the carbon atom. Penalise this error once only Penalise once only for a line and two dots to show a bond. Penalise once only for double headed curly arrows Mark independently
6(a)(ii)	**M1 Condition** ultra-violet / uv / sun light ***OR*** high temperature ***OR*** $400^oC \leq T \leq 900\ ^oC$ **M2 Type of mechanism** (free-) radical substitution (mechanism)	2	
6(b)(i)	$CHCl_3 + Cl_2 \longrightarrow CCl_4 + HCl$	1	Allow X as alternative to CCl_4 only if X is clearly identified as CCl_4

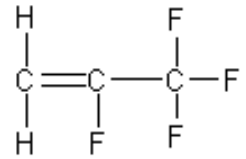
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6(b)(ii)	**M1** <u>Trichloromethane / $CHCl_3$ has a C–H bond</u> ***OR*** <u>X / CCl_4 / it has no C-H bond</u> **M2** The infrared spectrum shows (absorption / peak for C–H in range) <u>**2850 to 3300** **(** cm^{-1}) is missing</u>	2	**M1** must refer to presence or absence of the <u>C–H bond in a compound</u> **M2** answer must refer to / imply the spectrum Allow the words "dip" OR "spike" OR "low transmittance" as alternatives for absorption. Ignore references to other absorptions.

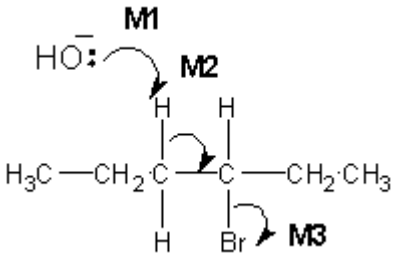
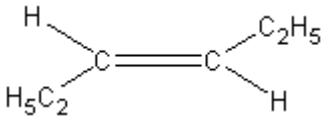
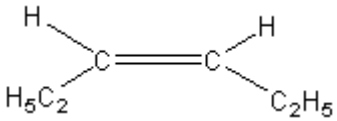
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6(c)	**M1 a statement about bond breakage / formation of Cl•** C-Cl / carbon-chlorine bond breakage occurs ***OR*** Cl• ***/*** chlorine (free) radical forms ***OR*** correct equation $CHClF_2 \longrightarrow Cl\bullet + \bullet CHF_2$ **M2** $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$ **M3** $ClO\bullet + O_3 \longrightarrow Cl\bullet + 2O_2$ **M4** $CHClF_2$ / chlorine-containing compounds/ CFCs damage / react with / decrease the ozone layer ***OR*** this overall decomposition occurs; $2O_3 \longrightarrow 3O_2$ ***OR*** without an ozone layer or with a decreased ozone layer, uv radiation is not being "filtered" / prevented from passing through the atmosphere or there is a concern about an increase in skin cancer etc. ***OR*** Cl• catalyses the decomposition of ozone / a single Cl• causes (chain) reaction / decomposition of many ozone molecules / ozone layer	4	Penalise **M1**, if Cl• is formed from Cl_2 as the only reaction or an additional reaction Do not penalise an incorrect equation using $CHClF_2$ if correct reference is made to Cl• formation or C-Cl / carbon-chlorine bond breakage **M2** and **M3** either order Penalise absence of dot once only. Accept dot anywhere on ClO radical Award **M4** for the general idea behind the EU justification for banning the use of CFCs as refrigerants Penalise **M4** if overall ozone decomposition equation is incorrect Ignore "greenhouse effect", "global warming" etc.

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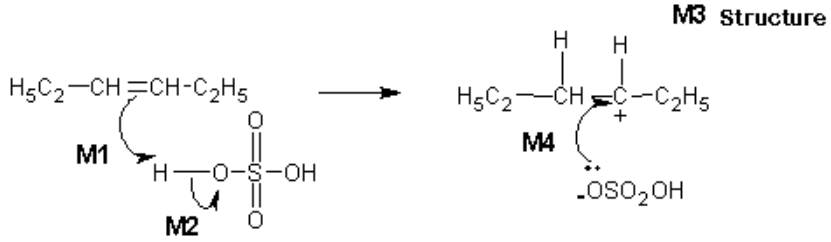
6(d)(i)		1	All bonds must be drawn out
6(d)(ii)	2,3,3,3-tetrafluoropropene / it does not contain chlorine (atoms) / C-Cl (bonds) ***OR*** It does not produce Cl• / does not produce chlorine (free) radical(s) ***OR*** chlorodifluoromethane does contain chlorine / does produce Cl• / does produce chlorine (free) radical(s) ***OR*** C–F is too strong and does not break / create radicals ***OR*** C–F is stronger than C–Cl	1	Ignore “chlorine molecules”

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Question	Marking Guidance	Mark	Comments
7(a)(i)	 **M1** must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion <u>to the correct</u> H atom **M2** must show an arrow from the correct C-H bond to the correct C-C bond. Only award if an arrow is shown <u>attacking</u> the H atom of the correct C-H bond in **M1** **M3** is independent but **CE=0 if nucleophilic substitution** **N.B these are double- headed arrows**	3	Penalise one mark from <u>their</u> total if half-headed arrows are used Penalise **M3** for formal charge on C of the C-Br or incorrect partial charges on C-Br Ignore other partial charges Penalise once only in any part of the mechanism for a line and two dots to show a bond.
7(a)(ii)	**M1** E isomer  **M2** Z isomer 	2	Award 1 mark if both correct stereoisomers but in the wrong places Accept no other alkenes. Be reasonably lenient on the bonds to ethyl (or to CH_2CH_3) since the question is about E and Z positions but penalise once only if connection is clearly to the CH_3 of CH_2CH_3 Accept linear structures

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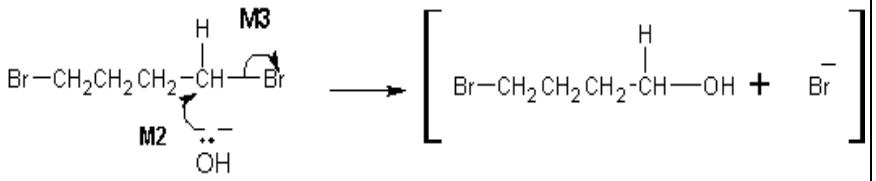
7(a)(iii)	**M1** (Compounds / molecules with) the <u>same structural formula</u> **M2** with <u>atoms/bonds/groups</u> arranged <u>differently in space</u> ***OR*** <u>atoms/bonds/groups</u> that have <u>different spatial arrangements / different orientation</u>.	2	Penalise **M1** if "same structure" Ignore references to " same molecular formula" or "same empirical formula" or any reference to "displayed formula" Mark independently

7(b)	 **M1**must show an arrow from the double bond towards the H atom of the H – O bond OR HO on a compound with molecular formula for H_2SO_4 M1 could be to an H+ ion and M2 an independent O – H bond break on a compound with molecular formula for H_2SO_4 **M2** must show the breaking of the O ─ H bond. **M3** is for the structure of the carbocation. **M4** must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards a correct (positively charged) carbon atom. **NB The arrows here are double-headed**	4	**M1** Ignore partial negative charge on the double bond. **M2** Penalise partial charges on O – H bond if wrong way and penalise formal charges In M2 do not penalise incorrect structures for H_2SO_4 **M4** NOT HSO_4^- For **M4**, credit <u>as shown</u> or <u>$^-OSO_3H$</u> ONLY with the negative charge anywhere on this ion OR <u>correctly</u> drawn out with the negative charge placed correctly on oxygen Penalise once only in any part of the mechanism for a line and two dots to show a bond <u>Max 3 of any 4 marks</u> for wrong organic reactant or wrong organic product (if shown) Accept the correct use of "sticks"

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Question	Marking Guidance	Mark	Comments
8(a)	**M1 Safety (in Process 1)** Sodium hydroxide / alkali is corrosive / harmful / caustic or sodium hydroxide is alkali(ne) ***OR*** Bromine compounds are toxic / poisonous **M2 Environmental** Process 2 could be used as a carbon sink / for carbon capture ***OR*** uses waste / recycled CO_2 / CO_2 from the factory / CO_2 from the bioethanol (or biofuel) production ***OR*** reduces or limits the amount of CO_2 released / given out (into the atmosphere) ***OR*** Process 2 uses renewable glucose ***/*** renewable resource(s)	2	Ignore references to chromium compounds "Carbon-neutral" alone is insufficient for **M2** Ignore references to greenhouse gases

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8(b)(i)	**M1** <u>nucleophilic substitution</u>  **M2** must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the C atom. **M3** must show the movement of a pair of electrons from the C─ Br bond to the Br atom. Mark **M3** independently provided it is from the <u>original molecule</u> For **M2** and **M3** award full marks for an S_N1 mechanism **NB The arrows here are double-headed**	3	For **M1**, **both words** required Penalise **M2** if covalent NaOH / KOH is used Penalise one mark from **M2** or **M3** if half-headed arrows are used Penalise **M3** for formal charge on C of the C-Br or incorrect partial charges on C-Br Penalise once only for a line and two dots to show a bond. For **M2** and **M3**, maximum 1 of 2 marks for the mechanism if wrong reactant is used. Penalise **M3** if an extra arrow is drawn from the Br of the C-Br bond to, for example, K^+ Accept the correct use of "sticks

8(b)(ii)	**M1** B **M2** C **M3** A	3	

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8(c)	**M1** <u>fermentation</u> **Three conditions <u>in any order</u> for M2 to M4** **M2** (enzymes from) yeast or zymase **M3** 25°C ≤ T ≤ 42°C OR 298 K ≤ T ≤ 315 K **M4** anaerobic / no oxygen / no air OR neutral pH	4	Mark **M2** to **M4** independently Penalise "bacteria" and "phosphoric acid" using the list principle Ignore reference to "aqueous" or "water", "closed container", "pressure, "lack of oxygen", "concentration of ethanol" and "batch process" (i.e. not part of the list principle)
8(d)	**M1** primary OR 1° (alcohol) **M2** <u>acidified potassium or sodium dichromate</u> ***OR*** H_2SO_4 / $K_2Cr_2O_7$ OR H^+ / $K_2Cr_2O_7$ ***OR*** correct combination of formula and name **M3** $HOCH_2CH_2CH_2CH_2OH + \mathbf{4}[O] \longrightarrow HOOCCH_2CH_2COOH + \mathbf{2}H_2O$	3	Mark independently For **M2,** it must be a whole reagent and/or correct formulae Do not penalise incorrect attempt at formula if name is correct or *vice versa* Accept phonetic spelling If oxidation state given in name, it must be correct. For **M2** accept acidified potassium manganate(VII) For **M3** structures must be correct and not molecular formula

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Question	Marking Guidance	Mark	Comments
9(a)(i)	**M1** iodine ***OR*** I_2 ***OR*** I_3^- **M2** $Cl_2 + 2I^- \longrightarrow 2Cl^- + I_2$ ***OR*** $\frac{1}{2} Cl_2 + I^- \longrightarrow Cl^- + \frac{1}{2} I_2$ **M3** redox or reduction-oxidation or displacement	3	Ignore state symbols Credit **M1** for "iodine solution" Penalise multiples in M2 except those shown **M2** accept correct use of I_3^-
9(a)(ii)	**M1** **(**the white precipitate is) <u>silver chloride</u> **M2** $Ag^+ + Cl^- \longrightarrow AgCl$ **M3** (white) precipitate / it <u>dissolves</u> ***OR*** <u>colourless solution</u>	3	**M1** <u>must be named</u> and for <u>this mark</u> ignore incorrect formula For **M2** ignore state symbols Penalise multiples Ignore references to "clear" alone
9(b)(i)	**M1** $H_2SO_4 + 2Cl^- \longrightarrow 2HCl + SO_4^{2-}$ ***OR*** $H_2SO_4 + Cl^- \longrightarrow HCl + HSO_4^-$ ***OR*** $H^+ + Cl^- \longrightarrow HCl$ **M2** hydrogen chloride ***OR*** HCl ***OR*** hydrochloric acid	2	For **M1** ignore state symbols Penalise multiples for equations and apply the list principle

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9(b)(ii)	**M1 and M2 in either order** **M1** $2I^- \longrightarrow I_2 + 2e^-$ ***OR*** $8I^- \longrightarrow 4I_2 + 8e^-$ **M2** $H_2SO_4 + 8H^+ + 8e^- \longrightarrow H_2S + 4H_2O$ **OR** $SO_4^{2-} + 10H^+ + 8e^- \longrightarrow H_2S + 4H_2O$ **M3** <u>oxidising agent</u> / <u>oxidises the iodide</u> (ions) ***OR*** <u>electron acceptor</u> **M4** sulfur ***OR*** S ***OR*** S_2 ***OR*** S_8 ***OR*** sulphur	4	For **M1** and **M2**, ignore state symbols and credit multiples Do not penalise absence of charge on the electron Credit electrons shown correctly on the other side of each equation Additional equations should not contradict

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9(b)(iii)	**M1** The NaOH / OH^- / (sodium) hydroxide reacts with / neutralises the H^+ / acid / HBr (lowering its concentration) ***OR*** a correct neutralisation equation for H^+ or HBr with NaOH or with hydroxide ion **M2** **Requires a correct statement for M1** The (position of) equilibrium moves / shifts (from L to R) • to replace the H^+ / acid / HBr that has been removed / lost • ***OR*** to increase the H^+ / acid / HBr concentration • ***OR*** to make more H^+ / acid / HBr / product(s) • ***OR*** to oppose the loss of H^+ / loss of product(s) • ***OR*** to oppose the decrease in concentration of product(s) **M3** The (health) benefit outweighs the risk or wtte ***OR*** a clear statement that once it has done its job, little of it remains ***OR*** used in (very) dilute concentrations / small amounts / low doses	3	Ignore reference to NaOH reacting with bromide ions Ignore reference to NaOH reacting with HBrO alone In **M2**, answers must refer to the (position of) equilibrium shifts / moves and is not enough to state simply that it / the system / the reaction shifts to oppose the change.

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General principles applied to marking CHEM2 papers by CMI+ June 2012

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are required information to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**

A. The "List principle" and the use of "ignore" in the mark scheme

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. Incorrect case for element symbol

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.

For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. Spelling

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

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D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

E. Reagents

The command word "Identify", allows the candidate to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.

For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a candidate provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

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F. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

G. Marking calculations, such as those involving enthalpy changes

In general

- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will usually score **only one mark**.

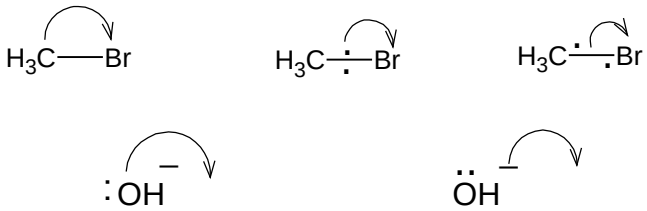
All other values **gain no credit** except

- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

H. Organic reaction mechanisms

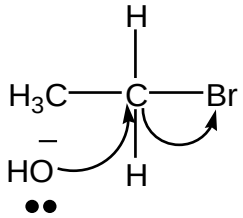
Curly arrows should originate either from a lone pair of electrons or from a bond.

The following representations should not gain credit **and will be penalised each time** within a clip.



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For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

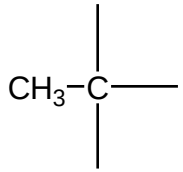
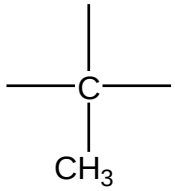
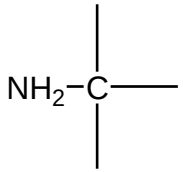
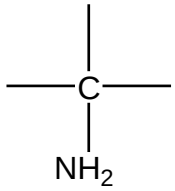
I. Organic structures

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if candidates show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in structures, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or C ─ NH_2 bonds should **not** be penalised. For the other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.

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By way of illustration, the following would apply

(a)  allowed	(b)  allowed
(c)  allowed	(d)  allowed

- In most cases, the use of "sticks" to represent C ─ H bonds in a structure should **not** be penalised. The exceptions will include structures in mechanisms when the C ─ H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.
- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH for ethanal

CH_3CH_2HO for ethanol

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$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

N.B. Exceptions may be made in the context of balancing equations

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

J. Organic names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.

Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**

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2-butanol	should be **butan-2-ol**
ethan-1,2-diol	should be **ethane-1,2-diol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**
3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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10	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
January 2012

Chemistry CHEM2

Unit 2 Chemistry in Action

Thursday 19 January 2012 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use accurate scientific terminology.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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Do not write outside the box

Section A

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

1 The silicon chip industry requires the production of pure silicon. Silicon is extracted from its ore, silicon dioxide (SiO_2), by a process similar to that used in the extraction of titanium.

1 (a) (i) Write an equation for the formation of $SiCl_4$ from SiO_2 using chlorine and carbon.

.....

(1 mark)

1 (a) (ii) Suggest how the liquid $SiCl_4$ is purified.

.....

.....

(1 mark)

1 (b) The final stage in the extraction of silicon involves the use of hydrogen gas to convert the $SiCl_4$ into silicon and hydrogen chloride.

1 (b) (i) Write an equation for this reaction.

.....

(1 mark)

1 (b) (ii) State the role of hydrogen in this reaction.

.....

(1 mark)

1 (b) (iii) Give **one** risk associated with the use of hydrogen gas.

.....

(1 mark)

1 (c) The magnesium used to make magnesium ferrosilicon alloys is extracted from magnesium oxide using silicon.
Write an equation for this reaction to produce magnesium and silicon dioxide.

.....

(1 mark)

6

Do not write outside the box

2 Ammonia is manufactured by the Haber process in which the following equilibrium is established.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

2 (a) Give **two** features of a reaction at equilibrium.

Feature 1 .....

.....

.....

.....

Feature 2 .....

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.....

.....

(2 marks)

2 (b) Explain why a catalyst has no effect on the position of an equilibrium.

.....

.....

.....

.....

(2 marks)

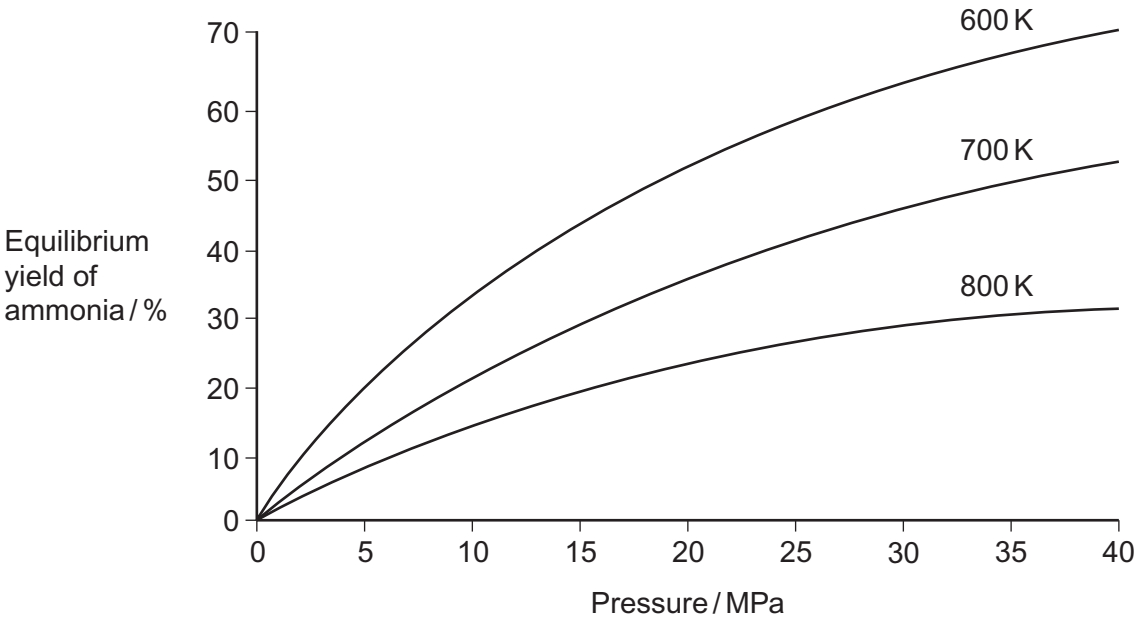
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Question 2 continues on the next page

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2 (c) The diagram shows how the equilibrium yield of ammonia varies with changes in pressure and temperature.



2 (c) (i) Use the diagram to state the effect of an **increase** in pressure at constant temperature on the yield of ammonia. Use Le Chatelier's principle to explain this effect.

Effect on yield .....

Explanation .....

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

Do not write outside the box

2 (c) (ii) Use the diagram to state the effect of an **increase** in temperature at constant pressure on the yield of ammonia. Use Le Chatelier's principle to explain this effect.

Effect on yield .....

Explanation .....

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

2 (d) At equilibrium, with a pressure of 35 MPa and a temperature of 600 K, the yield of ammonia is 65%.

2 (d) (i) State why industry uses a temperature higher than 600 K.

.....

.....

(1 mark)

2 (d) (ii) State why industry uses a pressure lower than 35 MPa.
Do **not** include references to safety.

.....

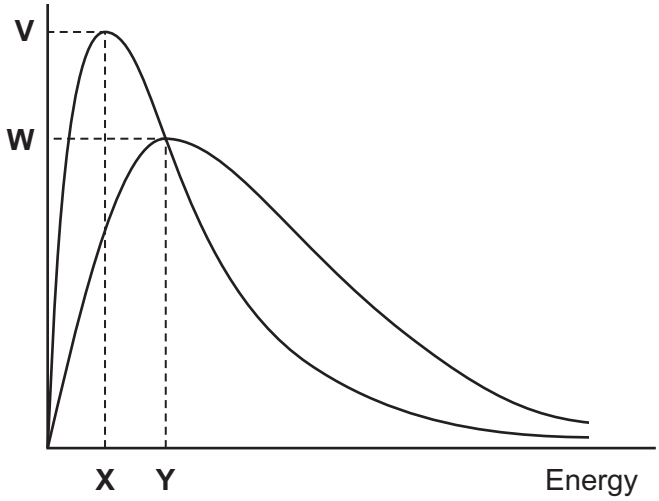
.....

(1 mark)

12

Do not write outside the box

3 The diagram shows the Maxwell–Boltzmann distribution of molecular energies in a gas at two different temperatures.



3 (a) One of the axes is labelled. Complete the diagram by labelling the other axis.

(1 mark)

3 (b) State the effect, if any, of a solid catalyst on the shape of either of these distributions.

.....

.....

(1 mark)

3 (c) In the box, write the letter, **V**, **W**, **X** or **Y**, that represents the most probable energy of the molecules at the lower temperature.

(1 mark)

3 (d) Explain what must happen for a reaction to occur between molecules of two different gases.

.....

.....

.....

.....

(2 marks)

Do not write outside the box

3 (e) Explain why a small increase in temperature has a large effect on the initial rate of a reaction.

.....

.....

.....

.....

(1 mark)

6

Turn over for the next question

Do not write outside the box

4 (a) Iron is extracted from iron(III) oxide using carbon at a high temperature.

4 (a) (i) State the type of reaction that iron(III) oxide undergoes in this extraction.

.....

(1 mark)

4 (a) (ii) Write a half-equation for the reaction of the iron(III) ions in this extraction.

.....

(1 mark)

4 (b) At a high temperature, carbon undergoes combustion when it reacts with oxygen.

4 (b) (i) Suggest why it is **not** possible to measure the enthalpy change directly for the following combustion reaction.

$$C(s,graphite) + \tfrac{1}{2}O_2(g) \longrightarrow CO(g)$$

.....

.....

(1 mark)

4 (b) (ii) State Hess's Law.

.....

.....

.....

(1 mark)

4 (b) (iii) State the meaning of the term *standard enthalpy of combustion*.

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

Do not write outside the box

4 (c) Use the standard enthalpies of formation in the table below and the equation to calculate a value for the standard enthalpy change for the extraction of iron using carbon monoxide.

	$Fe_2O_3(s)$	$CO(g)$	$Fe(l)$	$CO_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 822	– 111	+14	– 394

$$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(l) + 3CO_2(g)$$

.....

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

4 (d) (i) Write an equation for the reaction that represents the standard enthalpy of formation of carbon dioxide.

.....

(1 mark)

4 (d) (ii) State why the value quoted in part **(c)** for the standard enthalpy of formation of $CO_2(g)$ is the same as the value for the standard enthalpy of combustion of carbon.

.....

.....

(1 mark)

12

Do not write outside the box

5 Iodine reacts with concentrated nitric acid to produce nitrogen dioxide (NO_2).

5 (a) (i) Give the oxidation state of iodine in each of the following.

I_2 .....

HIO_3 .....

(2 marks)

5 (a) (ii) Complete the balancing of the following equation.

$$I_2 + 10HNO_3 \longrightarrow \text{.....}HIO_3 + \text{.....}NO_2 + \text{.....}H_2O$$

(1 mark)

5 (b) In industry, iodine is produced from the $NaIO_3$ that remains after sodium nitrate has been crystallised from the mineral Chile saltpetre.
The final stage involves the reaction between $NaIO_3$ and NaI in acidic solution.
Half-equations for the redox processes are given below.

$$IO_3^- + 5e^- + 6H^+ \longrightarrow 3H_2O + \tfrac{1}{2}I_2$$

$$I^- \longrightarrow \tfrac{1}{2}I_2 + e^-$$

Use these half-equations to deduce an overall ionic equation for the production of iodine by this process. Identify the oxidising agent.

Overall ionic equation

The oxidising agent .....

(2 marks)

Do not write outside the box

5 (c) When concentrated sulfuric acid is added to potassium iodide, solid sulfur and a black solid are formed.

5 (c) (i) Identify the black solid.

.....

(1 mark)

5 (c) (ii) Deduce the half-equation for the formation of sulfur from concentrated sulfuric acid.

.....

(1 mark)

5 (d) When iodide ions react with concentrated sulfuric acid in a different redox reaction, the oxidation state of sulfur changes from +6 to –2. The reduction product of this reaction is a poisonous gas that has an unpleasant smell.
Identify this gas.

.....

(1 mark)

5 (e) A yellow precipitate is formed when silver nitrate solution, acidified with dilute nitric acid, is added to an aqueous solution containing iodide ions.

5 (e) (i) Write the **simplest ionic** equation for the formation of the yellow precipitate.

.....

(1 mark)

5 (e) (ii) State what is observed when concentrated ammonia solution is added to this precipitate.

.....

.....

(1 mark)

5 (e) (iii) State why the silver nitrate is acidified when testing for iodide ions.

.....

.....

(1 mark)

Question 5 continues on the next page

Turn over ▶

Do not write outside the box

5 (f) Consider the following reaction in which iodide ions behave as reducing agents.

$$Cl_2(aq) + 2I^-(aq) \longrightarrow I_2(aq) + 2Cl^-(aq)$$

5 (f) (i) In terms of electrons, state the meaning of the term *reducing agent*.

.....

.....

(1 mark)

5 (f) (ii) Write a half-equation for the conversion of chlorine into chloride ions.

.....

(1 mark)

5 (f) (iii) Suggest why iodide ions are stronger reducing agents than chloride ions.

.....

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(2 marks)

(Extra space) .....

.....

15

Do not write outside the box

6 The table shows the structures and names of three compounds with M_r = 72.0

Compound	Formula	Name
1	$CH_3CH_2CH_2CHO$	butanal
2	$CH_3CH_2CH_2CH_2CH_3$	pentane
3	$CH_3CH_2COCH_3$	butanone

6 (a) Explain why M_r values, measured to five decimal places, cannot distinguish between compounds **1** and **3** but can distinguish between compounds **1** and **2**.

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(2 marks)

6 (b) A simple chemical test, using either Fehling's solution or Tollens' reagent, can be used to distinguish between compound **1** and compound **3**.
Choose one of these two reagents and state what you would observe with each of compound **1** and compound **3**.

Chosen reagent .....

Observation with compound **1**.....

.....

Observation with compound **3**.....

.....

(2 marks)

4

Turn over ▶

Do not write outside the box

7 Group 2 elements and their compounds have a wide range of uses.

7 (a) For parts **(a)(i)** to **(a)(iii)**, draw a ring around the correct answer to complete each sentence.

7 (a) (i) From $Mg(OH)_2$ to $Ba(OH)_2$, the solubility in water

decreases.

increases.

stays the same.

(1 mark)

7 (a) (ii) From Mg to Ba, the first ionisation energy

decreases.

increases.

stays the same.

(1 mark)

7 (a) (iii) From Mg to Ba, the atomic radius

decreases.

increases.

stays the same.

(1 mark)

7 (b) Explain why calcium has a higher melting point than strontium.

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(2 marks)

(Extra space) .....

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Do not write outside the box

7 (c) Acidified barium chloride solution is used as a reagent to test for sulfate ions.

7 (c) (i) State why sulfuric acid should **not** be used to acidify the barium chloride.

.....

.....

.....

(1 mark)

7 (c) (ii) Write the **simplest ionic** equation for the reaction that occurs when acidified barium chloride solution is added to a solution containing sulfate ions.

.....

(1 mark)

7

Turn over for the next question

Do not write outside the box

8 It is possible to convert but-1-ene into its structural isomer but-2-ene.

8 (a) State the type of structural isomerism shown by but-1-ene and but-2-ene.

.....

(1 mark)

8 (b) The first stage in this conversion involves the reaction of hydrogen bromide with but-1-ene.

$$CH_3CH_2CH{=}CH_2 \quad + \quad HBr \quad \longrightarrow \quad CH_3CH_2CHBrCH_3$$

Outline a mechanism for this reaction.

(4 marks)

8 (c) The second stage is to convert 2-bromobutane into but-2-ene.

$$CH_3CH_2CHBrCH_3 \quad + \quad KOH \quad \longrightarrow \quad CH_3CH{=}CHCH_3 \quad + \quad KBr \quad + \quad H_2O$$

Outline a mechanism for this reaction.

(3 marks)

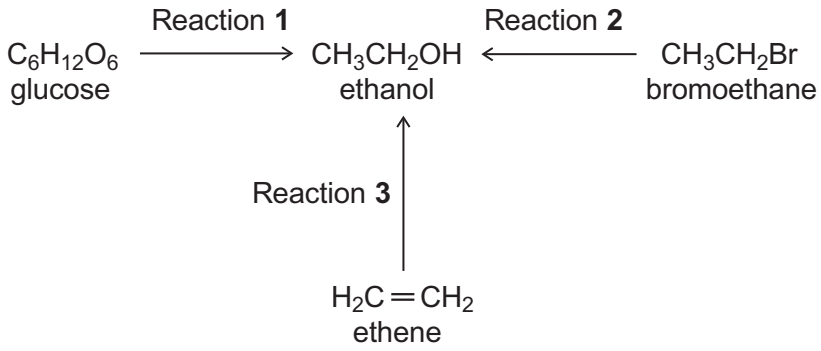
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Section B

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

9 Three different ways of producing ethanol are shown below.



9 (a) Reaction **1** produces a 15% aqueous solution of ethanol.
It is claimed that the ethanol produced in this way is a carbon-neutral biofuel.

Write an equation for Reaction **1** and name the process.

Write an equation for the complete combustion of ethanol.

Explain why the ethanol produced by this process may **not** be a *carbon-neutral* biofuel.

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(5 marks)

(Extra space) .....

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Question 9 continues on the next page

Turn over ▶

Do not write outside the box

9 (b) Give a reagent and conditions for Reaction **2**.

$$CH_3CH_2Br \xrightarrow{\text{Reaction } \mathbf{2}} CH_3CH_2OH$$

Name and outline a mechanism for Reaction **2**.

Suggest **one** reason, other than safety, why this method is **not** used in industry to make ethanol.

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(6 marks)

(Extra space) .....

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Do not write outside the box

9 (c) Reaction **3** is used in industry.

$$H_2C{=}CH_2 \xrightarrow{\text{Reaction 3}} CH_3CH_2OH$$

Identify a suitable catalyst for Reaction **3**.

Identify the type of reaction.

Give **two** conditions, in addition to the presence of a catalyst, necessary for Reaction **3** to produce a high yield of ethanol.

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(4 marks)

(Extra space) .....

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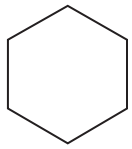
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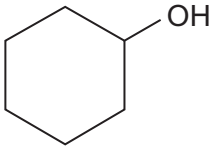
Turn over for the next question

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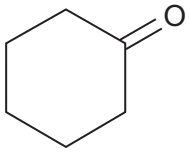
10 Consider the five cyclic compounds, **A**, **B**, **C**, **D** and **E**.



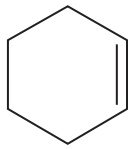
cyclohexane
A



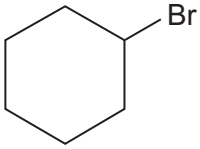
cyclohexanol
B



cyclohexanone
C



cyclohexene
D



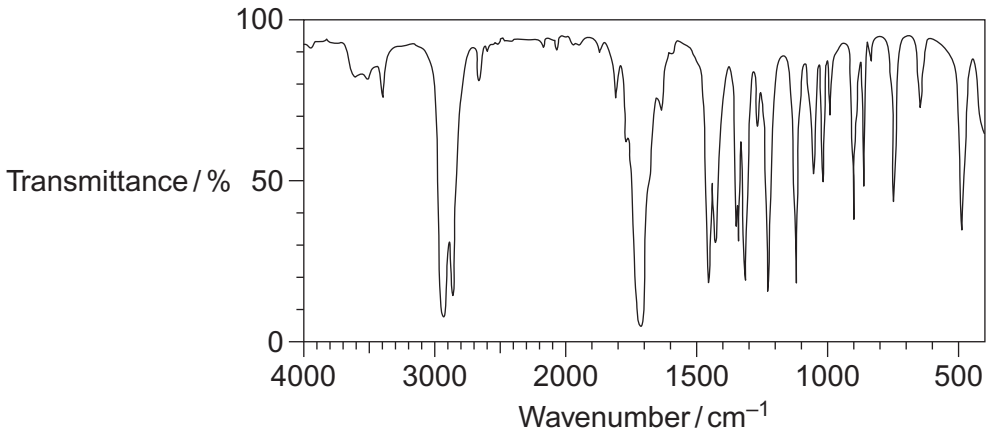
bromocyclohexane
E

10 (a) The infrared spectra of compounds **A**, **B**, **C** and **D** are shown opposite.

Write the correct letter, **A**, **B**, **C** or **D**, in the box next to each spectrum. You may find it helpful to refer to **Table 1** on the Data Sheet.

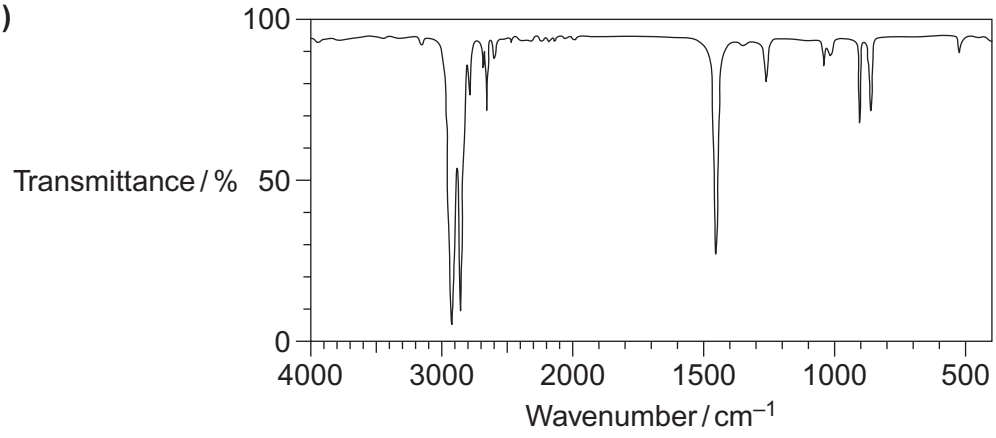
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10 (a) (i)



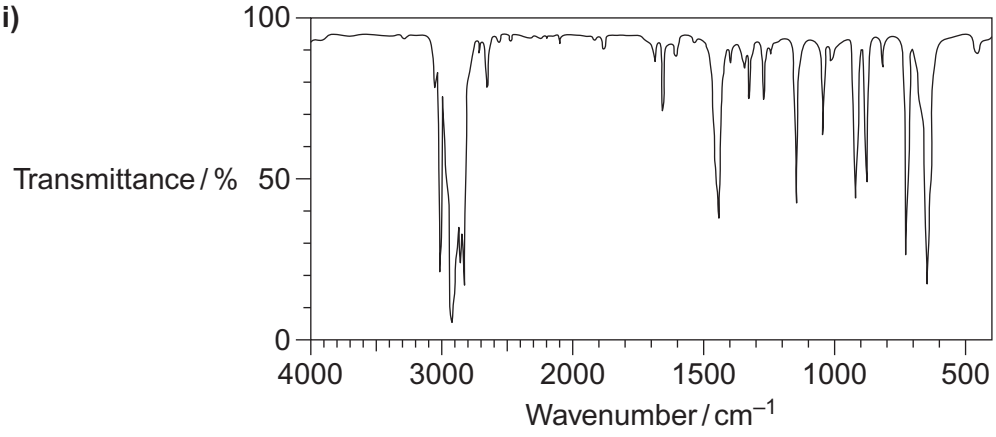
(1 mark)

10 (a) (ii)



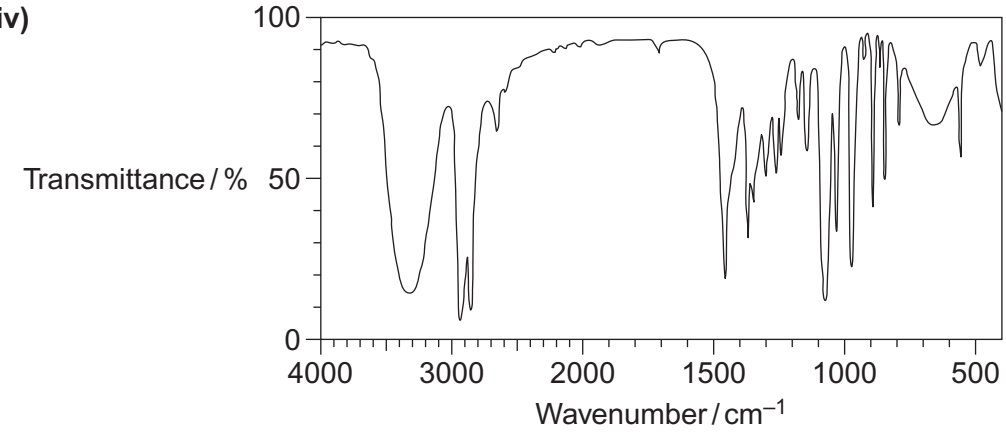
(1 mark)

10 (a) (iii)



(1 mark)

10 (a) (iv)



(1 mark)

Question 10 continues on the next page

Do not write outside the box

10 (b) A simple chemical test can be used to distinguish between cyclohexane (**A**) and cyclohexene (**D**).
Give a reagent for this test and state what you would observe with each compound.

.....

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(3 marks)

(Extra space) .....

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.....

10 (c) Cyclohexanol (**B**) can be converted into cyclohexanone (**C**).

Give a reagent or combination of reagents that can be used for this reaction and state the type of reaction.

State the class of alcohols to which cyclohexanol belongs.

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(3 marks)

(Extra space) .....

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Do not write outside the box

10 (d) Cyclohexane (**A**) can be converted into bromocyclohexane (**E**) by a reaction that is similar to the reaction of methane either with chlorine or with bromine.

Name and outline a mechanism for the reaction of methane (CH_4) with bromine to form bromomethane (CH_3Br). Give **one** condition for this reaction to occur.
Write an equation for each step in your mechanism.

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(5 marks)

(Extra space) .....

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15

END OF QUESTIONS

There are no questions printed on this page

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Version 1.6



General Certificate of Education (A-level)
January 2012

Chemistry CHEM2

(Specification 2420)

Unit 2: Chemistry In Action

Final

Mark Scheme

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Question	Marking Guidance	Mark	Comments
1(a)(i)	SiO_2 + **2**Cl_2 + **2**C ⟶ $SiCl_4$ + **2**CO ***OR*** SiO_2 + **2**Cl_2 + C ⟶ $SiCl_4$ + CO_2	1	Ignore state symbols Credit multiples of either equation
1(a)(ii)	(fractional) distillation ***OR*** G(L)C or gas (-liquid-) chromatography	1	
1(b)(i)	$SiCl_4$ + **2**H_2 ⟶ Si + **4**HCl	1	Ignore state symbols Credit multiples Penalise ionic HCl
1(b)(ii)	Reducing agent **/** reductant **/** reduces $SiCl_4$ **/** reduces (silicon) **/** electron donor	1	
1(b)(iii)	Explosion / explosive ***OR*** (highly) flammable / inflammable ***OR*** readily / easily ignites / burns / combusts	1	
1(c)	**2**MgO + Si ⟶ **2**Mg + SiO_2	1	Ignore state symbols Credit multiples

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Question	Marking Guidance	Mark	Comments
2(a)	**In either order** **M1** Concentrations (of reactants and products) remain or stay constant / the same **M2** Forward rate = Reverse / backward rate	2	For M1 accept [ ] for concentration NOT "equal concentrations" and NOT "concentration(s) is/are the same" NOT "amount" Ignore "dynamic" and ignore "speed" Ignore "closed system" It is possible to score both marks under the heading of a single feature
2(b)	**M1** Catalysts increase rate of / speed up both forward and reverse / backward reactions **M2** increase in rate / affect on rate / speed is equal / the same	2	If M1 is given as "no effect" / "no change" then CE= 0 for clip Ignore references to "decrease in rate"
2(c)(i)	**M1** (The yield) increases / goes up / gets more **M2** There are more moles / molecules (of gas) on the left / of reactants ***OR*** fewer moles / molecules (of gas) on the right / products ***OR*** there are 4 moles / molecules (of gas) on the left and 2 moles / molecules on the right. ***OR*** (equilibrium) shifts / moves to the side with less moles / molecules **M3 Can only score M3 if M2 is correct** The equilibrium shifts / moves (from left to right) to oppose the increase in pressure	3	If M1 is given as "decreases" / "no effect" / "no change" then CE= 0 for clip, but mark on from a blank. Ignore "volumes", "particles" "atoms" and "species" for M2 For M3, not simply "to oppose the change" For M3 credit the equilibrium shifts / moves to lower / decrease the pressure (There must be a specific reference to the change that is opposed)

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2(c)(ii)	**M1** The yield decreases / goes down / gets less **M2** (Forward) reaction is <u>exothermic</u> ***OR*** <u>gives out / releases heat</u> ***OR*** reverse reaction is <u>endothermic</u> ***OR*** <u>takes in / absorbs heat</u> **Can only score M3 <u>if M2 is correct</u>** The <u>equilibrium shifts / moves</u> (from right to left) to <u>oppose the increase in temperature</u>	3	If M1 is given as “increase” / “no effect” / ”no change” then CE= 0 for clip, but mark on from a blank. For M3, <u>not</u> simply “to oppose the change” For M3 credit the <u>equilibrium shifts / moves</u> to <u>absorb the heat</u> OR to <u>cool the reaction</u> OR to <u>lower the temperature</u> (There must be a <u>specific</u> reference to the change that is opposed)

2(d)(i)	Must be comparative <u>Higher rate</u> of reaction ***OR*** <u>increase / speed up the rate</u> (of reaction) ***OR*** Gets to equilibrium <u>faster/ quicker</u> ***OR*** <u>faster or quicker rate / speed</u> of attainment of equilibrium	1	Credit correct reference to rate being <u>too (s)low / (s)lower</u> at temperatures less than 600 K Ignore statements about the “yield of ammonia”

2(d)(ii)	<u>Less</u> electrical <u>pumping cost</u> ***OR*** Use lower pressure <u>equipment / valves / gaskets / piping</u> etc. ***OR*** Uses less expensive <u>equipment</u>	1	Not just “less expensive” alone Not just “less energy or saves energy” alone Credit correct <u>qualified</u> references to higher pressures Ignore references to safety

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Question	Marking Guidance	Mark	Comments
3(a)	Number / proportion / percentage / fraction of molecules	1	Ignore "particles"
3(b)	None ***OR*** no effect ***OR*** no change	1	
3(c)	**X**	1	
3(d)	**Answers in either order** **M1** collision ***OR*** collide **M2** collision / molecules / particles with the activation energy ***OR*** with $E \geq E_{act}$ ***OR*** with sufficient /enough energy ***OR*** with the minimum energy ***OR*** with the correct orientation	2	Mark independently Ignore "correct" amount of energy
3(e)	A small increase in temperature results in many more / much higher proportion of / a lot more / significantly more molecules / particles / collisions with $E \geq E_{act}$ / energy greater than the activation energy / sufficient energy / enough energy / minimum energy to react (compared with a small increase in concentration)	1	Not just "more molecules with $E \geq E_{act}$" The answer must convey that the increase is **significant** Accept reference to "atoms", molecules", "particles" Ignore "species"

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Question	Marking Guidance	Mark	Comments
4(a)(i)	reduction ***OR*** reduced ***OR*** redox ***OR*** reduction-oxidation	1	Not "oxidation" alone
4(a)(ii)	Fe^{3+} + **3**e^- ⟶ Fe	1	Ignore state symbols Do not penalise absence of charge on electron Credit Fe^{3+} ⟶ Fe – **3**e^- Credit multiples
4(b)(i)	**Because (one of the following)** CO is not the only product ***OR*** (Some) complete combustion (also)occurs ***OR*** CO_2 is (also) formed Further oxidation occurs	1	Reference to "incomplete combustion to form CO" does not answer the question
4(b)(ii)	The <u>enthalpy change</u> / <u>heat (energy) change at constant pressure</u> in a reaction is <u>independent of the route / path taken</u> (and depends only on the initial and final states)	1	

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4(b)(iii)	**M1** The <u>enthalpy change</u> / <u>heat change at constant pressure</u> when <u>1 mol</u> of a compound / substance / element **M2** is <u>burned completely</u> / <u>undergoes complete combustion</u> in (excess) <u>oxygen</u> **M3** with <u>all reactants and products / all substances in standard states</u> ***OR*** <u>all reactants and products / all substances in normal / specified states under standard conditions</u> / 100 kPa / 1 bar <u>and</u> specified T / 298 K	3	For M1, credit correct reference to molecule/s or atom/s For M3 Ignore reference to 1 atmosphere
4(c)	**M1 (could be scored by a correct mathematical expression which <u>must</u> have <u>all</u> ΔH symbols and the $\sum$)** **M1** $\Delta H_r = \sum \Delta H_f$ (**products**) - $\sum \Delta H_f$ (**reactants**) ***OR*** <u>correct cycle of balanced equations with 2Fe, 3C and $3O_2$</u> **M2** $\Delta H_r = 2(+14) + 3(-394) - (-822) - 3(-111)$ $= 28 - 1182 + 822 + 333$ (This also scores M1) **M3** = **(+) 1** (kJ mol^{-1}) **(Award 1 mark ONLY for – 1)** **(Award 1 mark ONLY for – 27)**	3	Correct answer gains full marks Credit 1 mark ONLY for –1 (kJ mol^{-1}) Credit 1 mark ONLY for – 27 (kJ mol^{-1}) i.e. assuming value for Fe(l) = 0 For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2) • If no AE, check for a correct method; this requires either a correct cycle with 2Fe, 3C and $3O_2$ OR a clear statement of M1 which could be in words and scores <u>only M1</u>
4(d)(i)	$C(s) + O_2(g) \longrightarrow CO_2(g)$	1	State symbols essential Possible to include C(s, graphite)

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4(d)(ii)	These two enthalpy changes are for <u>the same reaction / same equation / same reactants and products</u> ***OR*** They <u>both make one mole of carbon dioxide only from carbon and oxygen</u> (or this idea clearly implied) ***OR*** The <u>same number and same type of bonds are broken and formed</u>	1	Penalise reference to CO_2 being produced by a different route "both form CO_2" is not sufficient (since other products might occur e.g.CO)

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Question	Marking Guidance	Mark	Comments
5(a)(i)	**M1** **0** **M2** **(+) 5**	2	Accept Roman V for M2
5(a)(ii)	I_2 + 10HNO_3 ⟶ **2**HIO_3 + **10**NO_2 + **4**H_2O	1	Accept multiples
5(b)	**M1** IO_3^- + **6**H^+ + **5**I^- ⟶ **3**I_2 + **3**H_2O **M2** $NaIO_3$ ***OR*** IO_3^- ***OR*** iodate ions ***OR*** iodate(V) ions etc. Accept "the iodine in iodate ions" but NOT "iodine" alone	2	For M1, ignore state symbols Credit multiples Accept 2½I_2 + ½I_2 as alternative to 3I_2 Electrons must be cancelled For M2 Do not penalise an incorrect name for the correct oxidising agent that is written in addition to the formula. Accept "the iodine / I in iodate ions" but NOT "iodine" alone
5(c)(i)	Iodine ***OR*** I_2	1	Insist on correct name or formula
5(c)(ii)	H_2SO_4 + **6**H+ + **6**e^- ⟶ S + **4**H_2O SO_4^{2-} + **8**H+ + **6**e^- ⟶ S + **4**H_2O	1	Ignore state symbols Credit multiples Do not penalise absence of charge on the electron
5(d)	hydrogen sulfide ***OR*** H_2S ***OR*** hydrogen sulphide	1	

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5(e)(i)	$Ag^+ + I^- \longrightarrow AgI$ ONLY	1	Ignore state symbols No multiples
5(e)(ii)	The (yellow) precipitate / solid / it does not dissolve / is insoluble ***OR*** turns to a white solid ***OR*** stays the same ***OR*** no (visible/ observable) change ***OR*** no effect / no reaction	1	ignore "nothing (happens)" ignore "no observation"
5(e)(iii)	The silver nitrate is acidified to • react with / remove (an)ions that would interfere with the test • prevent the formation of other silver precipitates / insoluble silver compounds that would interfere with the test • remove (other) ions that react with the silver nitrate • react with / remove carbonate / hydroxide / sulfite (ions)	1	Ignore reference to "false positive" Do not penalise an incorrect formula for an ion that is written in addition to the name. If only the formula of the ion is given, it must be correct
5(f)(i)	An electron donor ***OR*** (readily) donates / loses / releases / gives (away) electron(s)	1	Penalise "electron pair donor" Penalise "loss of electrons" alone Accept "electron donator"
5(f)(ii)	$Cl_2 + \mathbf{2}e^- \longrightarrow \mathbf{2}Cl^-$	1	Ignore state symbols Do not penalise absence of charge on electron Credit $Cl_2 \longrightarrow \mathbf{2}Cl^- - \mathbf{2}e^-$ Credit multiples

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5(f)(iii)	For M1 and M2, iodide ions are stronger reducing agents than chloride ions, because **M1 Relative size of ions** Iodide ions / they are larger /have more electron levels(shells) (than chloride ions) / larger atomic / ionic radius ***OR*** electron to be lost/outer shell/level (of the iodide ion) is further the nucleus ***OR*** iodide ion(s) / they have greater / more shielding ***OR*** converse for chloride ion **M2 Strength of attraction for electron(s)** The electron(s) lost /outer shell/level electron from (an) iodide ion(s) less strongly held by the nucleus compared with that lost from a chloride ion ***OR*** converse for a chloride ion	2	Ignore general statements about Group VII trends or about halogen molecules or atoms. Answers must be specific CE=0 for the clip if "iodine ions / chlorine ions **QoL** CE=0 for the clip if "iodide ions are bigger molecules / atoms" **QoL** Insist on iodide ions in M1 and M2 or the use of it / they / them, in the correct context (or chloride ions in the converse argument) Must be comparative in both M1 and M2

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Question	Marking Guidance	Mark	Comments
6(a)	**For 2 marks at least <u>one correct reference either to M_r</u> or <u>value to 5 decimal places</u> required** **M1** Compounds <u>1 and 3</u> (butanal and butanone) have the same M_r (to 5dp) <u>because</u> **either** • they contain the <u>same</u> number of atoms of the same / each element • are <u>both</u> C_4H_8O • have the <u>same molecular formula</u> • contain the <u>same number</u> of C,H and O atoms **M2** Compound <u>2</u> (pentane) has a different M_r (to 5dp) <u>because</u> **either** • it has d<u>ifferent</u> numbers of atoms of different elements • is C_5H_{12} / <u>only contains</u> C and H • <u>different molecular formula</u> • does not contain oxygen (atom) / C=O	2	**QoL** (associated with the bold statement here) It may be possible to award 2 marks if there is a clear statement about oxygen having a different precise A_r in the context of the comparison NB The word “similar” does not mean “the same”

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6(b)		**WithTollens' (reagent)** **M1** silver mirror ***OR*** black solid/precipitate (NOT silver (mirror) precipitate) **M2 (**stays) colourless ***OR*** no change / no reaction ***OR*** no silver mirror	**With Fehling's (solution)** **M1** Red solid/precipitate (Credit orange or brown solid) **M2 (**stays) blue ***OR*** no change / no reaction ***OR*** no red solid ***OR*** no (red) precipitate	2	**N.B No mark is awarded for the reagent** If no reagent given allow 1 mark for a consistent statement of M1 and M2 For M2, ignore "nothing (happens)" And ignore "no observation"

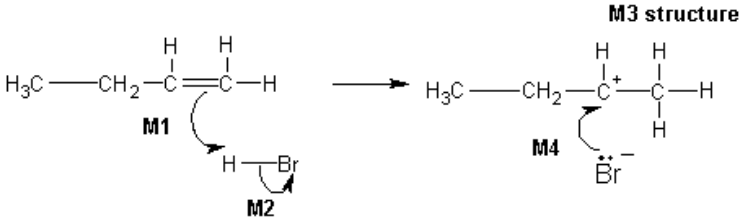
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Question	Marking Guidance	Mark	Comments
7(a)(i)	Increases	1	
7(a)(ii)	Decreases	1	
7(a)(iii)	Increases	1	
7(b)	Calcium has a higher melting point than strontium, because **Correct reference to size of cations/proximity of electrons** **M1** (For Ca) delocalised <u>electron(s) closer to cations / positive ions / nucleus</u> ***OR*** <u>cations / positive ions / atoms are smaller</u> ***OR*** <u>cation / positive ion / atom or it has fewer (electron) shells / levels</u> **Relative strength of metallic bonding** **M2** (For Ca) has <u>stronger</u> attraction between the <u>cations / positive ions / nucleus</u> and the <u>delocalised electron(s)</u> ***OR*** <u>stronger metallic bonding</u> (assume argument refers to Ca but accept converse argument for Sr)	2	CE = 0 for reference to molecules or intermolecular forces or covalent bonds Ignore "Van der Waals forces (between atoms)" but penalise if between "molecules Ignore general Group 2 statements Answers must be specific Penalise M1 if Ca or Sr is said to have <u>more or less</u> delocalised electrons Ignore reference to shielding

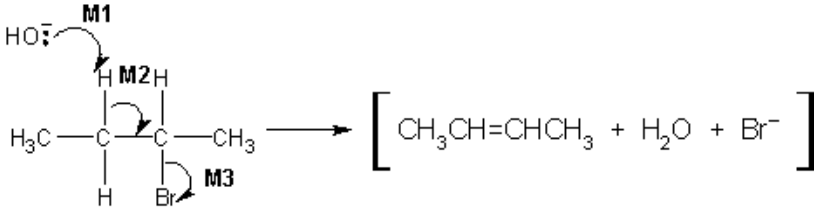
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7(c)(i)	Sulfuric acid / it contains <u>sulfate ions / SO_4^{2-}</u> ***OR*** <u>Sulfuric acid</u> would form a (white) <u>precipitate</u>	1	Do not penalise an <u>additional</u> but incorrect formula for sulfate ion. If only the formula of the sulfate ion is given, it must be correct
7(c)(ii)	Ba^{2+} + SO_4^{2-} ⟶ $BaSO_4$ ONLY	1	Ignore state symbols No multiples

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Question	Marking Guidance	Mark	Comments
8(a)	Position(al) (isomerism)	1	
8(b)	 **M1** must show an arrow from the double bond towards the H atom of the H–Br molecule **M2** must show the breaking of the H–Br bond. **M3** is for the structure of the secondary carbocation. **M4** must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged carbon atom of either a primary or secondary carbocation. **NB The arrows here are double-headed**	4	Penalise one mark from <u>their</u> total if half-headed arrows are used M1 Ignore partial negative charge on the double bond. M2 Penalise partial charges on H–Br bond if wrong way and penalise formal charges Penalise M3 if there is a bond drawn to the positive charge Penalise once only in any part of the mechanism for a line and two dots to show a bond <u>Maximum any 3 of 4 marks</u> for wrong reactant or primary carbocation. If Br_2 is used, <u>maximum 2 marks</u> for their mechanism Do not penalise the use of “sticks”

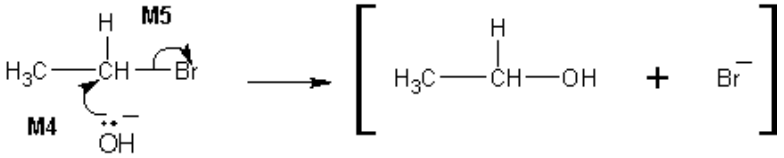
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8(c)	 **M1** must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion <u>to a correct</u> H atom **M2** must show an arrow from a C-H bond adjacent to the C-Br bond towards the appropriate C-C bond. Only award if an arrow is shown attacking the H atom of an adjacent C-H (in M1) **M3** is independent provided it is from their <u>original molecule</u>. Award full marks for an E1 mechanism in which M2 is on the correct carbocation. **NB The arrows here are double-headed**	3	Penalise one mark from <u>their</u> total if half-headed arrows are used Penalise M1 if covalent KOH Penalise M3 for formal charge on C of the C-Br or incorrect partial charges on C-Br Penalise M3 if an extra arrow is drawn from the Br of the C-Br bond to, for example, K^+ Ignore other partial charges Penalise once only in any part of the mechanism for a line and two dots to show a bond. <u>Maximum any 2 of 3 marks</u> for wrong reactant <u>or</u> wrong product (if shown) <u>or</u> a mechanism that leads to but-1-ene Accept the correct use of “sticks” for the molecule except for the C-H being attacked

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Question	Marking Guidance	Mark	Comments
9(a)	**M1** $C_6H_{12}O_6 \longrightarrow$ **2**CH_3CH_2OH + **2**CO_2 ($2C_2H_5OH$) **M2** fermentation **M3** CH_3CH_2OH + **3**$O_2 \longrightarrow$ **2**CO_2 + **3**H_2O (C_2H_5OH) **M4** <u>A specified process</u> e.g. planting / harvesting / transport / extracting sugar / distilling ethanol solution / fertiliser production etc. **M5** The specified process <u>uses / burns</u> (fossil) <u>fuel that releases CO_2</u>	5	Mark independently For M1 and M3 ignore state symbols and credit multiples For M1 and M3 penalise C_2H_6O once only For M5, "releases / increases carbon emissions" is insufficient as an alternative to <u>releases CO_2</u>

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9(b)	**M1** sodium or potassium hydroxide / NaOH / KOH **M2 depends on correct M1** warm / heat / reflux <u>and</u> aqueous or (aq) or water **M3** <u>nucleophilic substitution</u>  **NB The arrows here are double-headed** **M4** must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the C atom. **M5** must show the movement of a pair of electrons from the C─ Br bond to the Br atom. Mark M5 independently provided it is from their <u>original molecule</u>. For M4 and M5, award full marks for an S_N1 mechanism **M6** One statement from • The yield is (very) low / not a high yield OR elimination occurs / ethene formed • The rate of reaction slow • <u>Bromoethane</u> has to be manufactured / made first • <u>Bromoethane</u> is expensive	6	Mark on to M2 from hydroxide ion Ignore OH^- if KOH/ OH^- For M2 ignore “dilute” For M2 penalise T > 100 ^oC Acidified KOH/NaOH or H_2SO_4 with KOH/NaOH loses M1 and M2 For M3, both words required Penalise M4 if covalent NaOH / KOH is used Penalise one mark from M4 or M5 if half-headed arrows are used Penalise M5 for formal charge on C of the C-Br or incorrect partial charges on C-Br Penalise once only for a line and two dots to show a bond. For M4 and M5, maximum 1 of 2 marks if wrong reactant is used. Penalise M5 if an extra arrow is drawn from the Br of the C-Br bond to, for example, K^+ Do not penalise the use of “sticks” For M6 ignore references to other costs and expenses

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9(c)	**M1** concentrated phosphoric acid / conc. H_3PO_4 ***OR*** concentrated sulfuric acid / conc. H_2SO_4 **M2** hydration or (electrophilic) addition **For M3 and M4 any two from** • Excess ethene ***OR*** Excess steam / water / H_2O ***OR*** remove the ethanol as it forms ***OR*** recycle the ethene • Specified Pressure 50 atm $\leq P \leq$ 100 atm ***OR*** 5000 kPa $\leq P \leq$ 10000 kPa ***OR*** 5 MPa $\leq P \leq$ 10 MPa • HighTemperature unless they give a value that is not in the ranges given here; ***OR*** 300 ^{o}C $\leq$ T $\leq$ 600 ^{o}C ***OR*** 570 K $\leq T \leq$ 870 K	4	Answers in any order Ignore reference to support medium in M1 Do not apply the list principle to these three chosen criteria in M3 and M4 Accept a reference to “low temperature” if they specify a correct temperature range or a correct temperature in the range

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Question	Marking Guidance	Mark	Comments
10(a)(i)	C	1	
10(a)(ii)	A	1	
10(a)(iii)	D	1	
10(a)(iv)	B	1	
10(b)	**M1** Br_2 ***OR*** bromine (water) ***OR*** bromine (in CCl_4 / organic solvent) **Either order** **M2** cyclohexane ***OR*** **A** or the alkane: remains orange / red / yellow / brown / the same ***OR*** no reaction ***OR*** reference to colour going to cyclohexane layer **M3** cyclohexene ***OR*** **D** or the alkene: decolourised / goes colourless / loses its colour **Alternatives** : potassium manganate(VII) **M1** $KMnO_4$ in acid **M2** purple **M3** colourless **M1** $KMnO_4$ in alkali / neutral **M2** purple **M3** brown solid Give appropriate credit for the use of iodine and observations	3	If M1, has no reagent or an incorrect reagent, CE=0 Ignore “acidified” For M1 penalise Br (or incorrect formula of other correct reagent), but mark on For M1, it must be a whole reagent and/or correct formulae If oxidation state given in name, it must be correct. For M2 credit “no change” Ignore “nothing” Ignore “nothing happens” Ignore “no observation” For M3, ignore “goes clear” No credit for combustion observations

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10(c)	**M1** acidified potassium or sodium dichromate ***OR*** eg H_2SO_4 / $K_2Cr_2O_7$ ***OR*** H^+/ $K_2Cr_2O_7$ ***OR*** correct combination of formula and name **M2** oxidation ***OR*** oxidised ***OR*** redox **M3** secondary / 2° (alcohol)	3	For M1, it must be a whole reagent and/or correct formulae If oxidation state given in name, it must be correct. Do not penalise incorrect attempt at formula if name is correct or *vice versa* Credit acidified potassium chromate(VI) / H_2SO_4 + K_2CrO_4
10(d)	**M1** **(**free-) radical substitution (mechanism) **M2** $Br_2 \longrightarrow 2Br\bullet$ **M3** $Br\bullet + CH_4 \longrightarrow \bullet CH_3 + HBr$ **M4** $Br_2 + \bullet CH_3 \longrightarrow CH_3Br + Br\bullet$ **M5 Condition** ultra-violet / uv / sun light ***OR*** high temperature ***OR*** 125 ^{o}C ≤ T ≤ 600 ^{o}C ***OR*** 400 K ≤ T ≤ 870 K	5	M1 both words required Penalise absence of dot once only. Penalise + or – charges every time Accept dot anywhere on methyl radical Accept a correct termination step for 1 mark if neither M3 nor M4 are scored; otherwise ignore termination steps Mark independently NB If Cl_2 is used, penalise every time (this may be for M2,M3 and M4) If cyclohexane is used, penalise every time (this may be for M3 and M4) For M5 ignore “heat”

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General principles applied to marking CHEM2 papers by CMI+ January 2012

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are required information to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**

A. The "List principle" and the use of "ignore" in the mark scheme

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. Incorrect case for element symbol

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. Spelling

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

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E. Reagents

The command word "Identify", allows the candidate to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.
For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a candidate provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

F. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

G. Marking calculations, such as those involving enthalpy changes

In general

- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will usually score **only one mark**.

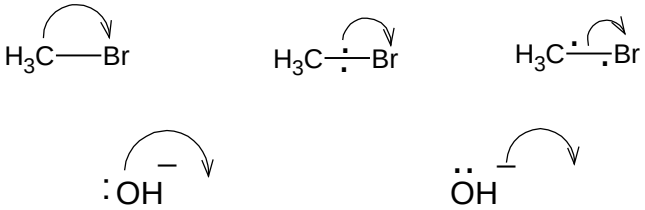
All other values **gain no credit** except

- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

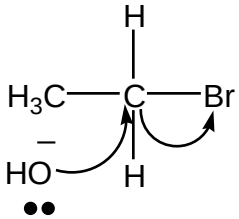
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H. <u>Organic reaction mechanisms</u>

Curly arrows should originate either from a lone pair of electrons or from a bond.
The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

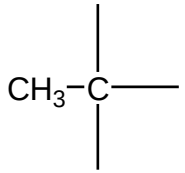
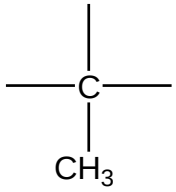
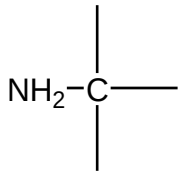
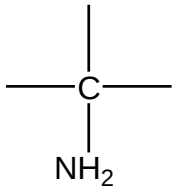
In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

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I. Organic structures

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if candidates show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in structures, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or C ─ NH_2 bonds should **not** be penalised. For the other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.
  By way of illustration, the following would apply

(a)  allowed	(b)  allowed
(c)  allowed	(d)  allowed

- In most cases, the use of "sticks" to represent C ─ H bonds in a structure should **not** be penalised. The exceptions will include structures in mechanisms when the C ─ H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.

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- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

N.B. Exceptions may be made in the context of balancing equations

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

J. Organic names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit. Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**

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3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
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TOTAL	



General Certificate of Education
Advanced Subsidiary Examination
June 2011

Chemistry CHEM2

Unit 2 Chemistry in Action

Friday 27 May 2011 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use accurate scientific terminology.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.



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Do not write outside the box

Section A

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

1 The rate of a chemical reaction is influenced by the size of the activation energy. Catalysts are used to increase the rates of chemical reactions but are not used up in the reactions.

1 (a) Give the meaning of the term *activation energy*.

.....

.....

.....

.....

(2 marks)

1 (b) Explain how a catalyst increases the rate of a reaction.

.....

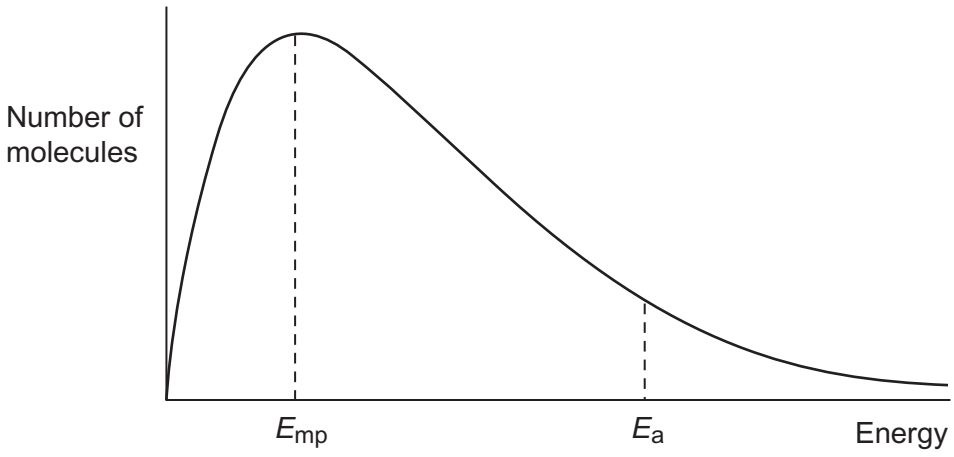
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(2 marks)

1 (c) The diagram below shows the Maxwell–Boltzmann distribution of molecular energies, at a constant temperature, in a gas at the start of a reaction.
On this diagram the most probable molecular energy at this temperature is shown by the symbol E_{mp}
The activation energy is shown by the symbol E_a



Do not write outside the box

To answer the questions **1 (c) (i)** to **1 (c) (iv)**, you should use the words **increases**, **decreases** or **stays the same**. You may use each of these answers once, more than once or not at all.

1 (c) (i) State how, if at all, the value of the most probable energy (E_{mp}) changes as the total number of molecules is increased at constant temperature.

.....

(1 mark)

1 (c) (ii) State how, if at all, the number of molecules with the most probable energy (E_{mp}) changes as the temperature is decreased without changing the total number of molecules.

.....

(1 mark)

1 (c) (iii) State how, if at all, the number of molecules with energy greater than the activation energy (E_a) changes as the temperature is increased without changing the total number of molecules.

.....

(1 mark)

1 (c) (iv) State how, if at all, the area under the molecular energy distribution curve changes as a catalyst is introduced without changing the temperature or the total number of molecules.

.....

(1 mark)

1 (d) For each of the following reactions, identify a catalyst and name the organic product of the reaction.

1 (d) (i) The fermentation of an aqueous solution of glucose.

Catalyst .....

Name of organic product .....

(2 marks)

1 (d) (ii) The hydration of but-2-ene.

Catalyst .....

Name of organic product .....

(2 marks)

12

Turn over ▶

Do not write outside the box

2 This question is about the extraction of titanium from titanium(IV) oxide by a two-stage process.
The first stage in the process produces titanium(IV) chloride. In the second stage, titanium(IV) chloride is converted into titanium.
The enthalpy change for the second stage can be determined using Hess's Law.

2 (a) Give **one** reason why titanium is **not** extracted directly from titanium(IV) oxide using carbon.

.....

.....

(1 mark)

2 (b) Give the meaning of the term *enthalpy change*.

.....

.....

.....

(1 mark)

2 (c) State Hess's Law.

.....

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(1 mark)

2 (d) Define the term *standard enthalpy of formation*.

.....

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(3 marks)

Do not write outside the box

2 (e) The following standard enthalpy of formation data refer to the second stage in the extraction of titanium.

	$TiCl_4(g)$	Na(l)	NaCl(s)	Ti(s)
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–720	+3	–411	0

2 (e) (i) State why the value for the standard enthalpy of formation of Na(l) is **not** zero.

.....

.....

(1 mark)

2 (e) (ii) Use data from the table to calculate a value for the standard enthalpy change of the following reaction.

$$TiCl_4(g) + 4Na(l) \longrightarrow 4NaCl(s) + Ti(s)$$

.....

.....

.....

.....

.....

.....

.....

(3 marks)

2 (e) (iii) State the role of sodium in this reaction.

.....

(1 mark)

11

Turn over ▶

Do not write outside the box

3 (a) Give the **formula** of a Group 2 metal hydroxide used in agriculture.

.....

(1 mark)

3 (b) Identify a sodium halide that does **not** undergo a redox reaction when added as a solid to concentrated sulfuric acid.

.....

(1 mark)

3 (c) Chlorine gas reacts with cold dilute sodium hydroxide solution to form sodium chloride and another chlorine-containing compound, **X**.
Give the **formula** of **X**.

.....

(1 mark)

3 (d) Give the **formula** of the substance responsible for the orange colour when chlorine gas is bubbled through an aqueous solution of sodium bromide.

.....

(1 mark)

3 (e) Solid sodium iodide undergoes a redox reaction with concentrated sulfuric acid.
Give the **formula** for each of the following in this reaction.

Formula of the solid reduction product .....

Formula of the oxidation product .....

(2 marks)

Do not write outside the box

3 (f) Draw the structure of each of the following organic compounds.

3 (f) (i) The hydrocarbon that is a chain isomer of methylpropene, but does **not** exhibit E–Z stereoisomerism.

(1 mark)

3 (f) (ii) The alcohol that is a position isomer of butan-2-ol.

(1 mark)

3 (f) (iii) The hydrocarbon that has a peak, due to its molecular ion, at $m/z = 44$ in its mass spectrum.

(1 mark)

3 (f) (iv) The bromoalkane that reacts with sodium cyanide to produce propanenitrile.

(1 mark)

10

Do not write outside the box

4 Metals are usually extracted from oxides.
Some of these oxides occur naturally. Other oxides are made by roasting sulfide ores in air, producing sulfur dioxide as a by-product.
For the extraction of some metals, the oxide needs to be converted into a chloride.

4 (a) The ore molybdenite contains molybdenum disulfide (MoS_2).
The first stage in the extraction of molybdenum is to roast the ore in air to form molybdenum oxide (MoO_3) and sulfur dioxide.

4 (a) (i) Write an equation for the first stage in this extraction.

.....

(1 mark)

4 (a) (ii) The release of sulfur dioxide into the atmosphere causes environmental problems and wastes a valuable resource. Identify **one** environmental problem and identify **one** use for the sulfur dioxide.

Environmental problem .....

.....

.....

Use for sulfur dioxide .....

.....

.....

(2 marks)

4 (a) (iii) Pure molybdenum is formed in the second stage by the reduction of MoO_3 using hydrogen.
Write an equation for this reaction.

.....

(1 mark)

4 (a) (iv) State **one** risk in using hydrogen gas in metal extractions.

.....

.....

(1 mark)

Do not write outside the box

4 (b) Calcium is an expensive metal. It is extracted by the electrolysis of molten calcium chloride.

4 (b) (i) State why calcium chloride must be molten for electrolysis to occur.

.....

.....

(1 mark)

4 (b) (ii) Write an equation for the reaction that takes place at the negative electrode during this electrolysis.

.....

(1 mark)

4 (b) (iii) Identify the major cost in this extraction of calcium.

.....

.....

(1 mark)

8

Turn over for the next question

Do not write outside the box

5 A sample of nitrogen dioxide gas (NO_2) was prepared by the reaction of copper with concentrated nitric acid.

5 (a) (i) Balance the equation for the reaction of copper with concentrated nitric acid.

$$Cu + \ldots\ldots HNO_3 \longrightarrow Cu(NO_3)_2 + \ldots\ldots NO_2 + \ldots\ldots H_2O$$

(1 mark)

5 (a) (ii) Give the oxidation state of nitrogen in each of the following compounds.

HNO_3 .....

NO_2 .....

(2 marks)

5 (a) (iii) Deduce the half-equation for the conversion of HNO_3 into NO_2 in this reaction.

.....

(1 mark)

5 (b) The following equilibrium is established between colourless dinitrogen tetraoxide gas (N_2O_4) and dark brown nitrogen dioxide gas.

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

5 (b) (i) Give two features of a reaction at equilibrium.

Feature 1 .....

.....

.....

.....

Feature 2 .....

.....

.....

.....

(2 marks)

Do not write outside the box

5 (b) (ii) Use Le Chatelier's principle to explain why the mixture of gases becomes darker in colour when the mixture is heated at constant pressure.

.....

.....

.....

.....

.....

.....

(2 marks)

5 (b) (iii) Use Le Chatelier's principle to explain why the amount of NO_2 decreases when the pressure is increased at constant temperature.

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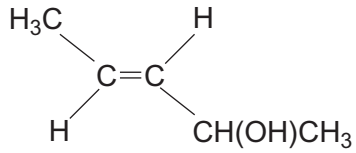
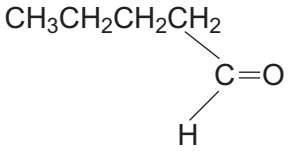
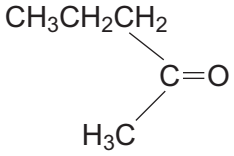
(2 marks)

10

Turn over for the next question

Do not write outside the box

6 The table below shows the structures of three isomers with the molecular formula $C_5H_{10}O$

Isomer **1** 	(*E*)-pent-3-en-2-ol
Isomer **2** 	pentanal
Isomer **3** 	

6 (a) Complete the table by naming Isomer **3**. *(1 mark)*

6 (b) State the type of structural isomerism shown by these three isomers.

.....

(1 mark)

6 (c) The compound (*Z*)-pent-3-en-2-ol is a stereoisomer of (*E*)-pent-3-en-2-ol.

6 (c) (i) Draw the structure of (*Z*)-pent-3-en-2-ol.

(1 mark)

Do not write outside the box

6 (c) (ii) Identify the feature of the double bond in (*E*)-pent-3-en-2-ol and that in (*Z*)-pent-3-en-2-ol that causes these two compounds to be stereoisomers.

.....

(1 mark)

6 (d) A chemical test can be used to distinguish between separate samples of Isomer **2** and Isomer **3**.
Identify a suitable reagent for the test.
State what you would observe with Isomer **2** and with Isomer **3**.

Test reagent .....

Observation with Isomer **2** .....

.....

Observation with Isomer **3** .....

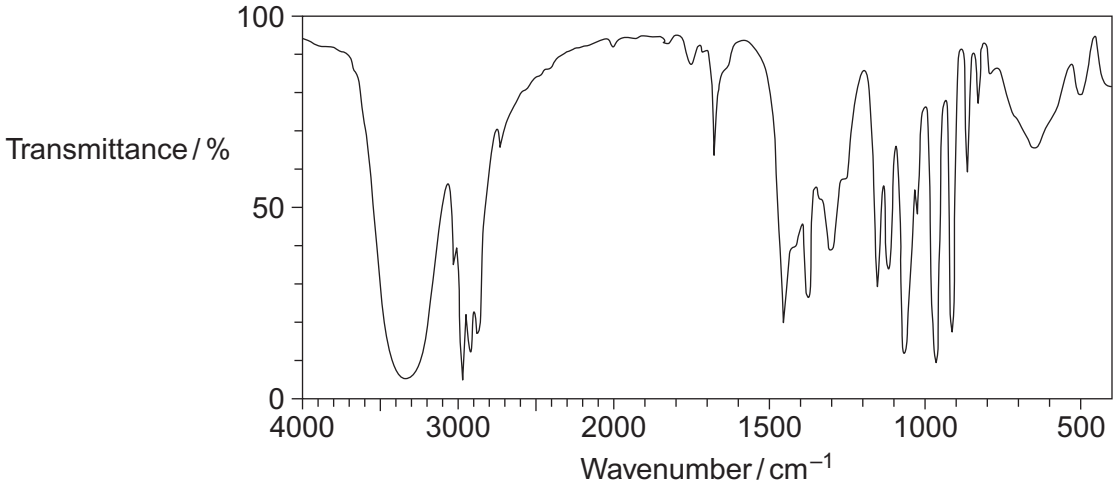
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(3 marks)

Question 6 continues on the next page

Do not write outside the box

6 (e) The following is the infrared spectrum of one of the isomers **1**, **2** or **3**.



6 (e) (i) Deduce which of the isomers (**1**, **2** or **3**) would give this infrared spectrum.
You may find it helpful to refer to **Table 1** on the Data Sheet.

.....

(1 mark)

6 (e) (ii) Identify two features of the infrared spectrum that support your deduction.
In each case, identify the functional group responsible.

Feature 1 and functional group .....

.....

.....

.....

Feature 2 and functional group .....

.....

.....

.....

(2 marks)

10

Turn over for the next question

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

Do not write outside the box

7 Halogens are used to make halogenated organic compounds.

7 (a) The refrigerant used in air conditioners is a mixture of fluorinated alkanes.
These compounds are made by fluorination reactions.
The mechanism for the reaction of fluorine with an alkane or with a fluoroalkane is a free-radical substitution similar to the reaction of chlorine with methane.

7 (a) (i) Write the overall equation for the reaction of fluorine with methane to form trifluoromethane (CHF_3).

.....

(1 mark)

7 (a) (ii) Write equations for the following steps in the mechanism for the reaction of fluorine with trifluoromethane (CHF_3) to form tetrafluoromethane (CF_4).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step leading to the formation of hexafluoroethane.

.....

(4 marks)

Do not write outside the box

7 (b) Chlorofluorocarbons (CFCs) were used as refrigerants.
In the upper atmosphere, ultra-violet radiation breaks bonds in the CFCs to produce a reactive intermediate that catalyses the decomposition of ozone.

7 (b) (i) An example of a CFC is 1,1,1-trichloro-2,2-difluoroethane.
Draw the displayed formula of this CFC.

(1 mark)

7 (b) (ii) Identify a bond in a CFC that is broken by ultra-violet radiation to produce a reactive intermediate.
Give the name of this reactive intermediate that catalyses the decomposition of ozone.
Write an overall equation for this decomposition of ozone.

Bond broken .....

Name of the reactive intermediate .....

Overall equation

.....

(3 marks)

9

Turn over for the next question

Do not write outside the box

Section B

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

8 (a) Some scientists thought that the waste water from a waste disposal factory contained **two** sodium halides.

They tested a sample of the waste water.

They added three reagents, one after the other, to the same test tube containing the waste water.

The table below shows their results.

Reagent added	Observations
1. Silver nitrate solution (acidified with dilute nitric acid)	A cream precipitate formed
2. Dilute ammonia solution	A yellow precipitate remained
3. Concentrated ammonia solution	The yellow precipitate did not dissolve

8 (a) (i) Identify the yellow precipitate that did **not** dissolve in concentrated ammonia solution.
Write the **simplest** ionic equation for the formation of this precipitate from silver ions and the correct halide ion.
Identify the other sodium halide that must be present in this mixture of two sodium halides.

.....

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(3 marks)

8 (a) (ii) Give **one** reason why the silver nitrate solution was acidified before it was used in this test.

.....

.....

.....

(1 mark)

Do not write outside the box

8 (a) (iii) The method that the scientists used could **not** detect one type of halide ion.
Identify this halide ion.
Give **one** reason for your answer.

.....

.....

.....

.....

(2 marks)

8 (b) The scientists thought that the waste water also contained dissolved barium ions.
An aqueous solution of sodium sulfate can be used to test for the presence of dissolved barium ions.

Write the **simplest** ionic equation for the reaction between barium ions and sulfate ions to form barium sulfate.

State what is observed in this reaction.

Give a use for barium sulfate in medicine and explain why this use is possible, given that solutions containing barium ions are poisonous.

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(4 marks)

Question 8 continues on the next page

Do not write outside the box

8 (c) The scientists also analysed the exhaust gases from an incinerator used to destroy waste poly(ethene).
Mass spectrometry showed that there was a trace gas with a precise M_r = 28.03176 in the exhaust gases from the incinerator.

The table below contains some precise relative atomic mass data.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{1}H	1.00794
^{16}O	15.99491

Use the data to show that the trace gas is ethene. Show your working.

Suggest why both ethene and carbon monoxide might have been identified as the trace gas if the scientists had used relative atomic masses to a precision of only one decimal place.

Write an equation for the incomplete combustion of ethene to form carbon monoxide and water only.

Ethene is used to make poly(ethene).
Draw the displayed formula for the repeating unit of poly(ethene).
Name this type of polymer.

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(5 marks)

15

Do not write outside the box

9 Organic reaction mechanisms help chemists to understand how the reactions of organic compounds occur.
The following conversions illustrate a number of different types of reaction mechanism.

9 (a) When 2-bromopentane reacts with ethanolic KOH, two structurally isomeric alkenes are formed.

9 (a) (i) Name and outline a mechanism for the conversion of 2-bromopentane into pent-2-ene as shown below.

$$CH_3CH_2CH_2CHBrCH_3 \xrightarrow{\text{ethanolic KOH}} CH_3CH_2CH{=}CHCH_3$$

(4 marks)

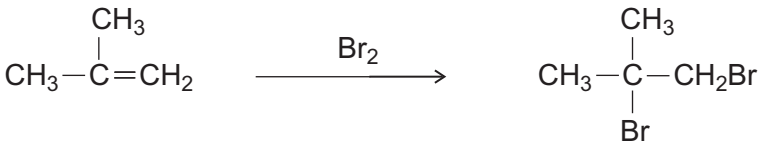
9 (a) (ii) Draw the structure of the other structurally isomeric alkene produced when 2-bromopentane reacts with ethanolic KOH.

(1 mark)

Question 9 continues on the next page

Do not write outside the box

9 (b) Name and outline a mechanism for the following conversion.



(5 marks)

Do not write outside the box

9 (c) Name and outline a mechanism for the following conversion.

$$CH_3CH_2CH_2Br \xrightarrow{NH_3} CH_3CH_2CH_2NH_2$$

(5 marks)

15

END OF QUESTIONS

There are no questions printed on this page

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Version 1.1



General Certificate of Education (A-level)
June 2011

Chemistry CHEM2

(Specification 2420)

Unit 2: Chemistry In Action

Final

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Question	Marking Guidance	Mark	Comments
1(a)	**M1** The activation energy is the minimum / least / lowest energy **M2** (energy) for a reaction to occur / to go / to start OR (energy) for a successful / effective collision	2	Mark independently Ignore "heat" and ignore "enthalpy" Ignore "breaking the bonds"
1(b)	**M1** Catalysts provide an alternative route OR an alternative mechanism OR alternative / different path(way) **M2** Lowers the activation energy	2	Mark independently Ignore reference to "surface"
1(c)(i)	Stay(s) the same	1	
1(c)(ii)	Increases	1	Credit "increase" or "increased"
1(c)(iii)	Increases	1	Credit "increase" or "increased"
1(c)(iv)	Stay(s) the same	1	

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1(d)(i)	**M1** yeast or zymase **M2** <u>ethanol</u>	2	Ignore "enzyme" In M2, ignore "alcohol" and ignore any formula

1(d)(ii)	**M1** (Concentrated) H_3PO_4 OR (Concentrated) H_2SO_4 **M2** <u>butan-2-ol</u>	2	Credit correct names Ignore "hydrogenphosphate or hydrogensulfate" Ignore "dilute" or "aq" Do not penalise absence of hyphens in name. In M2, ignore any formula

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Question	Marking Guidance	Mark	Comments
2(a)	*One from* • Ti is not produced • TiC / carbide is produced OR titanium reacts with carbon • Product is brittle • Product is a poor engineering material	1	Penalise "titanium carbonate" Ignore "impure titanium" Credit "titanium is brittle"
2(b)	Heat (energy) change at constant pressure	1	**QoL**
2(c)	The enthalpy change in a reaction is independent of the route taken (and depends only on the initial and final states)	1	Credit "heat change at constant pressure" as an alternative to "enthalpy change"

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2(d)	**M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / product **M2** is formed from its (constituent) elements **M3** with all reactants and products / all substances in standard states OR all reactants and products / all substances in normal states under standard conditions / 100 kPa / 1 bar and any specified T (usually 298 K)	3	For M1, credit correct reference to molecule/s or atom/s Ignore reference to 1 atmosphere

2(e)(i)	Na / it is not in its standard state / normal state under standard conditions OR Standard state / normal state under standard conditions for Na is solid / (s)	1	**QoL** Ignore "sodium is a liquid or sodium is not a solid"

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2(e)(ii)	**M1** ΔH_r **=** $\sum \Delta H_f$ **(products) - ** $\sum \Delta H_f$ **(reactants)** **M2** ΔH_r = 4(– 411) – (– 720) – 4(+3) = –1644 + 720 – 12 (This also scores M1) **M3** = **– 936** (kJ mol^{-1})	3	Correct answer gains full marks **Credit 1 mark for + 936** (kJ mol^{-1}) **Credit 1 mark for – 924** (kJ mol^{-1}) i.e. assuming value for Na(l) = 0 For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2) • If no AE, check for a correct method; this requires **either** a correct cycle with $2Cl_2$ and 4Na OR a **clear complete statement** of M1 which could be in words and scores only M1

2(e)(iii)	Reducing agent OR reductant OR reduces $TiCl_4$ OR electron donor	1	Ignore “reduces titanium”

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Question	Marking Guidance	Mark	Comments
3(a)	$Ca(OH)_2$ OR $Mg(OH)_2$	1	Ignore name Could be ionic
3(b)	NaF or sodium fluoride OR NaCl or sodium chloride	1	Either formula or name can score Do not penalise the spelling “flouride” When both formula and name are written, • penalise contradictions • if the attempt at the correct formula is incorrect, ignore it and credit **correct name** for the mark unless contradictory • if the attempt at the correct name is incorrect, ignore it and credit **correct formula** for the mark unless contradictory
3(c)	NaClO OR NaOCl	1	Ignore name (even when incorrect) The correct formula must be clearly identified if an equation is written
3(d)	**Br_2** (ONLY)	1	Only the **correct formula** scores; penalise lower case “b”, penalise upper case “R”, penalise superscript Ignore name The correct formula must be clearly identified if an equation is written

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3(e)	**M1** S OR S_8 OR S_2 **M2** I_2 (ONLY)	2	Ignore names penalise lower case "i" for iodine, penalise superscripted numbers Mark independently The correct formula must be clearly identified in each case if an equation is written
3(f)(i)	$CH_3CH_2CH=CH_2$	1	Structure of but-1-ene. Ignore name Credit "sticks" for C-H bonds
3(f)(ii)	$CH_3CH_2CH_2CH_2OH$	1	Structure of butan-1-ol. Ignore name Credit "sticks" for C-H bonds
3(f)(iii)	$CH_3CH_2CH_3$	1	Structure of propane. Ignore name Ignore calculations and molecular formula Credit "sticks" for C-H bonds Ignore the molecular ion
3(f)(iv)	CH_3CH_2Br or C_2H_5Br	1	Structure of bromoethane. Ignore name and structure of nitrile Credit "sticks" for C-H bonds

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Question	Marking Guidance	Mark	Comments
4(a)(i)	**2**MoS_2 + **7**O_2 ⟶ **2**MoO_3 + **4**SO_2 OR MoS_2 + **3½**O_2 ⟶ MoO_3 + **2**SO_2	1	Allow multiples Ignore state symbols
4(a)(ii)	**M1 Environmental problem** Acid rain OR An effect either from acid rain or from an acidic gas in the atmosphere. **M2 Use** SO_2 could be used <u>to make / to form / to produce</u> (or wtte) H_2SO_4 / sulfuric acid OR <u>To make / to form / to produce</u> (or wtte) gypsum / $CaSO_4$ or plaster of Paris / plaster board	2	Ignore references to the greenhouse effect Penalise reference to the ozone layer using the list principle
4(a)(iii)	MoO_3 + **3**H_2 ⟶ Mo + **3**H_2O	1	Allow multiples Ignore state symbols

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4(a)(iv)	*One from* H_2 is • explosive • (in)flammable • <u>easily</u> ignited	1	Ignore "burns"
4(b)(i)	To allow <u>ions</u> to <u>move</u> (when molten) OR <u>Ions cannot move in the solid</u>	1	
4(b)(ii)	$Ca^{2+} + \mathbf{2}e^- \longrightarrow Ca$	1	Or multiples Ignore state symbols Ignore charge on the electron unless incorrect and accept loss of two electrons on the RHS
4(b)(iii)	(High) <u>electricity</u> / <u>electrical energy</u> (cost)	1	Ignore "energy" and ignore "current"

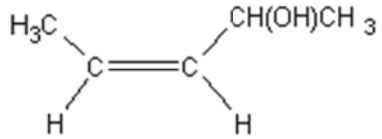
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Question	Marking Guidance	Mark	Comments
5(a)(i)	$Cu + \mathbf{4}HNO_3 \longrightarrow Cu(NO_3)_2 + \mathbf{2}NO_2 + \mathbf{2}H_2O$	1	Or multiples Ignore state symbols
5(a)(ii)	**M1** HNO_3 (+) **5** **M2** NO_2 (+) **4**	2	Ignore working out M1 Credit (V) M2 Credit (IV)
5(a)(iii)	$HNO_3 + H^+ + e^- \longrightarrow NO_2 + H_2O$ OR $NO_3^- + 2H^+ + e^- \longrightarrow NO_2 + H_2O$	1	Or multiples Ignore state symbols Ignore charge on the electron unless incorrect and accept loss of electron on the RHS
5(b)(i)	**In either order** **M1** Concentration(s) (of reactants and products) remain(s) constant / stay(s) the same / remain(s) the same / do(es) not change **M2** Forward rate = Reverse / backward rate	2	For M1 accept [ ] for concentration NOT "equal concentrations" and NOT "concentration(s) is/are the same" NOT "amount" Ignore "dynamic" and ignore "speed" Ignore "closed system" It is possible to score both marks under the heading of a single feature

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5(b)(ii)	**M1** The (forward) reaction / to the right is endothermic or takes in / absorbs heat OR The reverse reaction / to the left is exothermic or gives out / releases heat **M2 depends on correct M1 and must refer to temperature/heat** The equilibrium shifts / moves left to right to oppose the increase in temperature	2	M2 depends on a correct statement for M1 For M2, the equilibrium shifts/moves to absorb the heat OR to lower the temperature OR to cool the reaction
5(b)(iii)	**M1 refers to number of moles** There are fewer moles (of gas) on the left OR more moles (of gas) on the right. OR there is one mole (of gas) on the left and 2 moles on the right. **M2 depends on correct M1 and must refer to pressure** The equilibrium shifts / moves right to left to oppose the increase in pressure	2	M2 depends on a correct statement for M1 For M2, the equilibrium shifts/moves to lower the pressure.

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Question	Marking Guidance	Mark	Comments
6(a)	Pentan-2-one	1	ONLY but ignore absence of hyphens
6(b)	Functional group (isomerism)	1	Both words needed
6(c)(i)		1	Award credit provided it is obvious that the candidate is drawing the Z / cis isomer The group needs to be $CHOHCH_3$ but do not penalise poor C–C bonds or absence of brackets around OH Trigonal planar structure not essential
6(c)(ii)	Restricted rotation (about the C=C) OR No (free) rotation (about the C=C)	1	

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6(d)		3	If M1 is blank CE = 0, for the clip Check the partial reagents listed and if M1 has a <u>totally incorrect</u> reagent, CE = 0 for the clip Allow the following alternatives **M1** (acidified) potassium dichromate(VI) (solution); mark on from incomplete formulae or incorrect oxidation state **M2** (turns) green **M3** (stays) orange / no (observed) change / no reaction OR **M1** (acidified) potassium manganate(VII) (solution); mark on from incomplete formulae or incorrect oxidation state **M2** (turns) colourless **M3** (stays) purple / no (observed) change / no reaction In all cases for **M3** Ignore "nothing (happens)" Ignore "no observation"

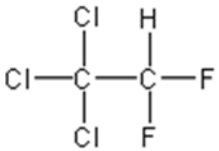
M1 Tollens' (reagent) *(Credit ammoniacal silver nitrate OR a description of making Tollens')* *(Do not credit Ag^+, $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3)*	**M1** Fehling's (solution) / Benedict's *(Penalise $Cu^{2+}(aq)$ or $CuSO_4$ but mark M2 and M3)*
M2 <u>silver mirror</u> OR <u>black solid or black precipitate</u>	**M2** <u>Red solid/precipitate</u> *(Credit <u>orange</u> or <u>brown</u> <u>solid</u>)*
M3 (stays) colourless OR no (observed) change / no reaction	**M3 (**stays) blue OR no (observed) change / no reaction

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6(e)(i)	Spectrum is for **Isomer 1** or named or correctly identified	1	The explanation marks in 6(e)(ii) depend on correctly identifying Isomer 1. The identification should be unambiguous but candidates should not be penalised for an imperfect or incomplete name. They may say "the alcohol" or the "alkene" or the "E isomer"

6(e)(ii)	**If Isomer 1 is correctly identified, award <u>any two</u> from** • (Strong / broad) absorption / peak in the range **<u>3230 to 3550</u>** cm^{-1} or specified value <u>in this range</u> or <u>marked correctly</u> on spectrum **<u>and</u>** (characteristic absorption / peak for) **<u>OH</u>** group /**<u>alcohol</u>** group • No absorption / peak in range **<u>1680 to 1750</u>** cm^{-1} or absence <u>marked correctly</u> on spectrum **<u>and</u>** (No absorption / peak for a) **<u>C=O</u>** group / **<u>carbonyl</u>** group / **<u>carbon-oxygen double bond</u>** • Absorption / peak in the range **<u>1620 to 1680</u>** cm^{-1} or specified value <u>in this range</u> or <u>marked correctly</u> on spectrum **<u>and</u>** (characteristic absorption / peak for) **<u>C=C</u>** group / **<u>alkene</u>** / **<u>carbon-carbon double bond</u>**	2	If 6(e)(i) is incorrect or blank, CE=0 Allow the words "dip" OR "spike" OR "trough" OR "low transmittance" as alternatives for absorption. Ignore reference to other absorptions e.g. C-H, C-O

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Question	Marking Guidance	Mark	Comments
7(a)(i)	$CH_4 + \mathbf{3}F_2 \longrightarrow CHF_3 + \mathbf{3}HF$	1	
7(a)(ii)	**M1 Initiation** $F_2 \longrightarrow \mathbf{2}F\bullet$ **M2 First propagation** $F\bullet + CHF_3 \longrightarrow \bullet CF_3 + HF$ **M3 Second propagation** $F_2 + \bullet CF_3 \longrightarrow CF_4 + F\bullet$ **M4 Termination (must make C_2F_6)** $\mathbf{2}\bullet CF_3 \longrightarrow C_2F_6$ or CF_3CF_3	4	Penalise absence of dot once only. Radical dot on $\bullet CF_3$ can be anywhere but if the structure is drawn out, the dot must be on the carbon atom. Penalise this error once only. Penalise once only for a line and two dots to show a bond. Penalise each of "Fl" and lower case F, once only in this clip
7(b)(i)	<u>Displayed formula</u> e.g. 	1	<u>All bonds</u> must be drawn out. Ignore bond angles. Penalise "sticks"

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7(b)(ii)	**M1** C—Cl bond OR carbon-chlorine bond **M2** chlorine atom OR chlorine (free) radical **M3** $\mathbf{2}O_3 \longrightarrow \mathbf{3}O_2$	3	M1 NOT carbon-halogen Penalise incorrect spelling of chlorine once only in this clip M2 ignore formulae Ignore Cl_2 or Cl• or ClO• balanced on both sides of the equation Ignore other equations leading to the overall equation

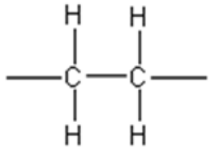
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Question	Marking Guidance	Mark	Comments
8(a)(i)	**M1** (yellow precipitate is) silver iodide OR AgI (which may be awarded from the equation) **M2** $Ag^+ + I^- \longrightarrow AgI$ (Also scores M1 unless contradicted) **M3** sodium chloride OR NaCl	3	For M2 Accept multiples Ignore state symbols Allow crossed out nitrate ions, but penalise if not crossed out
8(a)(ii)	The silver nitrate is acidified to • react with / remove ions that would interfere with the test • prevent the formation of other silver precipitates / insoluble silver compounds that would interfere with the test • remove (other) ions that react with the silver nitrate • react with / remove carbonate / hydroxide / sulfite (ions)	1	Ignore reference to “false positive”
8(a)(iii)	**M1 and M2 in either order** **M1** Fluoride (ion) OR F^- **M2** • Silver fluoride / AgF is soluble / dissolves (in water) • no precipitate would form / no visible /observable change	2	Do not penalise the spelling “flouride”, Penalise “fluride” once only Mark M1 and M2 independently

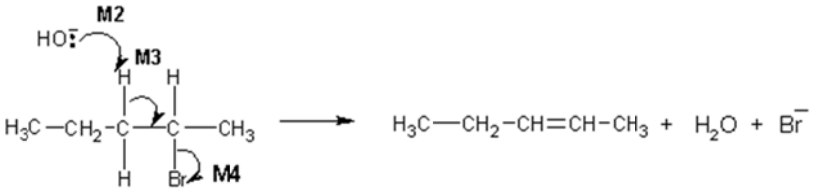
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8(b)	**M1** Ba^{2+} + SO_4^{2-} $\longrightarrow$ $BaSO_4$ (or the ions together) **M2** white precipitate / white solid / white suspension **M3** Barium meal or (internal) X-ray or to block X-rays **M4** $BaSO_4$ / barium sulfate is insoluble (and therefore not toxic)	4	For M1, ignore state symbols Allow crossed out sodium ions, but penalise if not crossed out For M2, ignore "milky" If $BaSO_3$ OR BaS used in M1 and M4, penalise once only For M3 Ignore radio-tracing For M4 NOT barium ions NOT barium NOT barium meal NOT "It" unless clearly $BaSO_4$

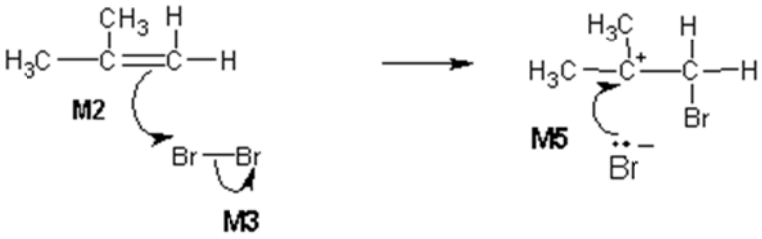
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8(c)	**M1** **2**(12.00000) + **4**(1.00794) = 28.03176 **M2** Ethene and CO or "they" have an imprecise M_r of 28.0 / 28 OR Ethene and CO or "they" have the same M_r to one d.p. OR These may be shown by two clear, simple sums identifying both compounds **M3** C_2H_4 + **2**O_2 → **2**CO + **2**H_2O ($H_2C=CH_2$) **M4** Displayed formula  **M5** Type of polymer = Addition (polymer)	5	M1 must show working using 5 d.p.for hydrogen Penalise "similar" or "close to", if this refers to the imprecise value in M2, since this does not mean "the same" For M3, accept $CH_2=CH_2$ OR CH_2CH_2 For M4, all bonds must be drawn out including those on either side of the unit. Penalise "sticks" Ignore brackets around **correct** repeating unit but penalise "n" Penalise "additional"

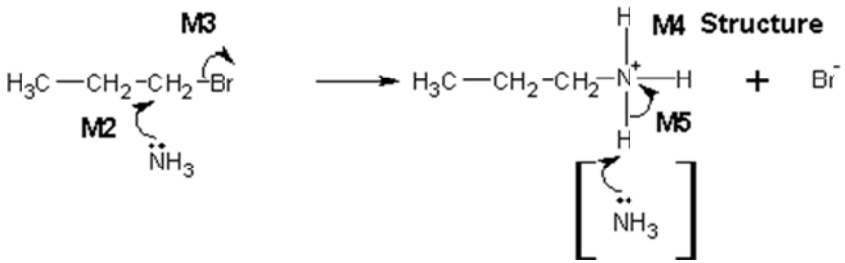
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Question	Marking Guidance	Mark	Comments
9(a)(i)	**M1 <u>Elimination</u>**  **M2** must show an arrow from the <u>lone pair on the oxygen</u> of a negatively charged hydroxide ion <u>to a correct</u> H atom **M3** must show an arrow from a C-H bond adjacent to the C-Br bond towards the appropriate C-C bond. Only award if a reasonable attempt has been made at the attack on the H atom of the appropriate adjacent C-H **M4** is independent provided it is from their <u>original molecule</u> Award full marks for an E1 mechanism in which **M3** is on the correct carbocation. **N.B. These are double-headed arrows**	4	For M1, accept "Base elimination" but <u>no other prefix.</u> Penalise **M2** if covalent KOH Penalise **M4** for formal charge on C of C-Br or incorrect partial charges on C-Br Ignore other partial charges Penalise once only in any part of the mechanism for a line and two dots to show a bond. <u>Max any 2 of 3 marks</u> **<u>for the mechanism</u>** for wrong reactant (or wrong product if shown). Accept the correct use of "sticks" for the molecule except for the C-H being attacked
9(a)(ii)	**Structure for pent-1-ene** $CH_3CH_2CH_2CH=CH_2$	1	Penalise C_3H_7 Accept correct "sticks"

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9 (b)	**M1** **Electrophilic addition** M4 Structure  **M2** must show an arrow from the double bond towards the Br atom of the Br-Br molecule **M3** must show the breaking of the Br-Br bond. **M4** is for the structure of the tertiary carbocation with Br on the correct carbon atom. **M5** must show an arrow from the lone pair of electrons on the negatively charged bromide ion towards the positively charged carbon atom. **N.B. These are double-headed arrows**	5	For M1, both words required. **For the mechanism** **M2** Ignore partial negative charge on the double bond. **M3** Penalise partial charges on Br-Br bond if wrong way and penalise formal charges Penalise once only in any part of the mechanism for a line and two dots to show a bond Max any 3 of 4 marks **for the mechanism** for wrong organic reactant or wrong organic product (if shown) or primary carbocation. If HBr is used, max 2 marks **for their mechanism** Accept the correct use of “sticks”

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9(c)	**M1 <u>Nucleophilic substitution</u>**  **M2** must show an arrow from the lone pair of electrons on the nitrogen atom of an ammonia molecule to the C atom. **M3** must show the movement of a pair of electrons from the C-Br bond to the Br atom. **M3** is independent provided it is from their <u>original molecule</u> **M4** is for the structure of the alkylammonium ion, which could be a condensed formula. A positive charge must be shown on/or close to, the N atom. **M5** is for an arrow from the N-H bond to the N atom. Award full marks for an S_N1 mechanism in which M2 is the attack of the ammonia on the intermediate carbocation. **N.B. These are double-headed arrows**	5	For M1, both words required. Penalise **M2** if NH_3 is negatively charged. Penalise **M3** for formal charge on C or incorrect partial charges The second mole of ammonia is not essential for M5; therefore ignore any species here. Penalise once only for a line and two dots to show a bond. Max any 3 of 4 marks **<u>for the mechanism</u>** for wrong organic reactant (or wrong organic product if shown) Accept the correct use of “sticks”

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General principles applied to marking CHEM2 papers by CMI+ June 2011

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are required information to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**

A. The "List principle" and the use of "ignore" in the mark scheme

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. Incorrect case for element symbol

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. Spelling

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

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E. Reagents

The command word "Identify", allows the candidate to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.
For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a candidate provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

F. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

G. Marking calculations, such as those involving enthalpy changes

In general

- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will usually score **only one mark**.

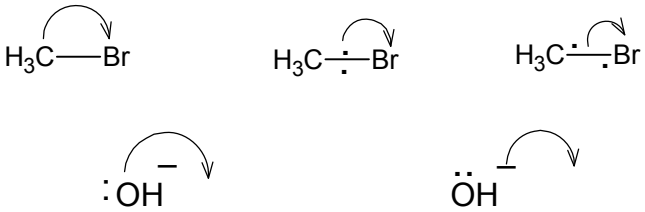
All other values **gain no credit** except

- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

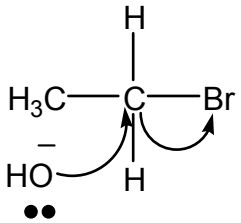
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H. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.
The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

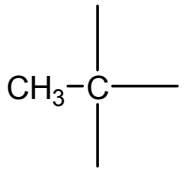
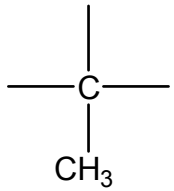
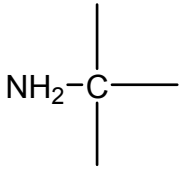
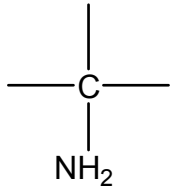
In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

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I. Organic structures

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if candidates show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in structures, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or C ─ NH_2 bonds should **not** be penalised. For the other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group. By way of illustration, the following would apply

(a)  allowed	(b)  allowed
(c)  allowed	(d)  allowed

- In most cases, the use of "sticks" to represent C ─ H bonds in a structure should **not** be penalised. The exceptions will include structures in mechanisms when the C ─ H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.

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- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethane

N.B. Exceptions may be made in the context of balancing equations

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

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J. Organic names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.
Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**
3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

UMS conversion calculator www.aqa.org.uk/umsconversion

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
January 2011

Chemistry CHEM2

Unit 2 Chemistry in Action

Thursday 20 January 2011 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use accurate scientific terminology.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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Do not write outside the box

Section A

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

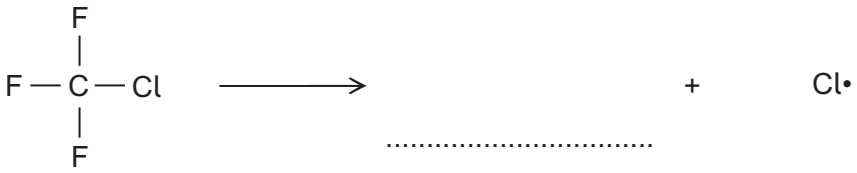
1 Oxygen and ozone (O_3) both occur as gases in the upper atmosphere.
Chlorine atoms catalyse the decomposition of ozone and contribute to the formation of a hole in the ozone layer.
These chlorine atoms are formed from chlorofluorocarbons (CFCs) such as CF_3Cl

1 (a) (i) Give the IUPAC name of CF_3Cl

.....

(1 mark)

1 (a) (ii) Complete the following equation that shows the formation of a chlorine atom from a molecule of CF_3Cl



(1 mark)

1 (a) (iii) State what the • represents in Cl•

.....

(1 mark)

1 (b) Write two equations that show how chlorine atoms catalyse the decomposition of ozone into oxygen.

Equation 1 .....

Equation 2 .....

(2 marks)

Do not write outside the box

1 (c) An equilibrium is established between oxygen and ozone molecules as shown below.

$$3O_2(g) \rightleftharpoons 2O_3(g) \qquad \Delta H = +284\,kJ\ mol^{-1}$$

1 (c) (i) State Le Chatelier's principle.

.....

.....

.....

(1 mark)

(Extra space) .....

.....

1 (c) (ii) Use Le Chatelier's principle to explain how an increase in temperature causes an increase in the equilibrium yield of ozone.

.....

.....

.....

.....

(2 marks)

(Extra space) .....

.....

1 (d) Chemists supported the legislation to ban the use of CFCs. Modern refrigerators use pentane rather than CFCs as refrigerants.
With reference to its formula, state why pentane is a more environmentally acceptable refrigerant.

.....

.....

(1 mark)

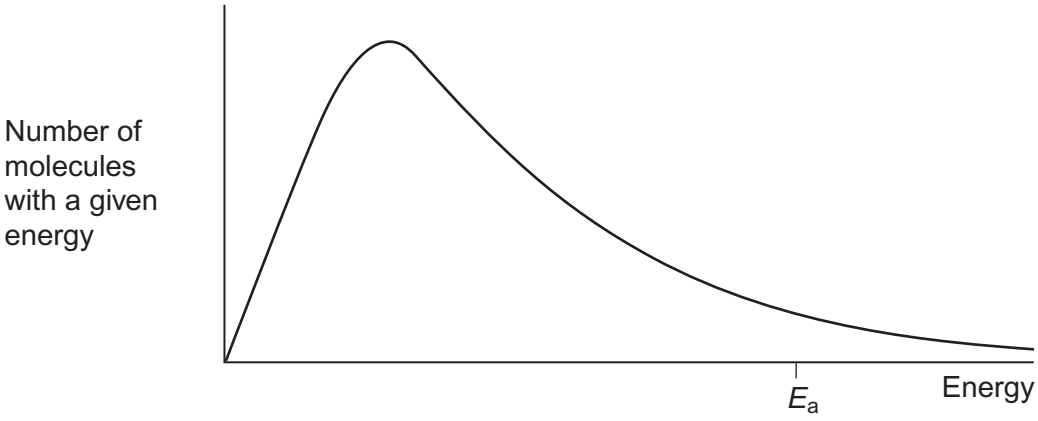
(Extra space) .....

.....

9

Do not write outside the box

2 The diagram below shows a Maxwell–Boltzmann distribution for a sample of gas at a fixed temperature.
E_a is the activation energy for the decomposition of this gas.



2 (a) (i) On this diagram, sketch the distribution for the same sample of gas at a higher temperature. *(2 marks)*

2 (a) (ii) With reference to the Maxwell–Boltzmann distribution, explain why an increase in temperature increases the rate of a chemical reaction.

.....

.....

.....

.....

.....

(2 marks)

(Extra space) .....

.....

Do not write outside the box

2 (b) Dinitrogen oxide (N_2O) is used as a rocket fuel. The data in the table below show how the activation energy for the decomposition of dinitrogen oxide differs with different catalysts.

$$2N_2O(g) \longrightarrow 2N_2(g) + O_2(g)$$

	E_a / kJ mol^{-1}
Without a catalyst	245
With a gold catalyst	121
With an iron catalyst	116
With a platinum catalyst	136

2 (b) (i) Use the data in the table to deduce which is the most effective catalyst for this decomposition.

.....

(1 mark)

2 (b) (ii) Explain how a catalyst increases the rate of a reaction.

.....

.....

.....

.....

(2 marks)

(Extra space) .....

.....

7

Do not write outside the box

3 The following pairs of compounds can be distinguished by observing what happens in test-tube reactions.
For each pair, give a suitable aqueous reagent that could be added separately to each compound.
Describe what you would observe in each case.

3 (a) NaF(aq) and NaCl(aq)

Reagent .....

Observation with NaF(aq) .....

Observation with NaCl(aq) .....

(3 marks)

3 (b) $BaCl_2(aq)$ and $MgCl_2(aq)$

Reagent .....

Observation with $BaCl_2(aq)$.....

Observation with $MgCl_2(aq)$ .....

(3 marks)

3 (c) AgCl(s) and AgI(s)

Reagent .....

Observation with AgCl(s) .....

Observation with AgI(s) .....

(3 marks)

3 (d) Butan-2-ol(l) and 2-methylpropan-2-ol(l)

Reagent .....

Observation with butan-2-ol(l) .....

Observation with 2-methylpropan-2-ol(l) .....

(3 marks)

12

Do not write outside the box

4 (a) Pure manganese is extracted from the ore pyrolusite (MnO_2) by reduction using carbon monoxide.
Write an equation for the reduction of MnO_2 to manganese using carbon monoxide.

.....

(1 mark)

4 (b) Impure manganese is extracted by reduction of Mn_3O_4 using powdered aluminium according to the following equation.

$$3Mn_3O_4 + 8Al \longrightarrow 9Mn + 4Al_2O_3$$

Deduce the redox half-equation for aluminium in this extraction process.

.....

(1 mark)

4 (c) Copper can be extracted by the high-temperature carbon reduction of copper(II) oxide. Write an equation for this reaction.

.....

(1 mark)

4 (d) Scrap iron is used in a low-cost process to extract copper from aqueous solutions containing copper(II) ions.

4 (d) (i) Give **one** reason, other than the cost of scrap iron, why this method is low-cost.

.....

.....

(1 mark)

4 (d) (ii) Write the **simplest ionic** equation for the reaction of iron with copper(II) ions in aqueous solution.

.....

(1 mark)

5

Turn over ▶

Do not write outside the box

5 Sea water contains large amounts of dissolved magnesium compounds. Approximately 1 kg of magnesium can be extracted from 1000 dm^3 of sea water.

5 (a) The first step in the extraction process is to react the magnesium ions in sea water with hydroxide ions to produce a precipitate of magnesium hydroxide. Write the **simplest ionic** equation for this reaction.

.....

(1 mark)

5 (b) The second step in the extraction process is to react magnesium hydroxide with hydrochloric acid to give magnesium chloride. Write an equation for this reaction.

.....

(1 mark)

5 (c) In the final step, molten magnesium chloride is electrolysed to form magnesium and chlorine. This is similar to the method used to extract aluminium. Deduce an equation for the reaction that occurs at the negative electrode in the electrolysis of magnesium chloride.

.....

(1 mark)

5 (d) Magnesium is used in the extraction of titanium.

5 (d) (i) Write an equation for the conversion of titanium(IV) oxide into titanium(IV) chloride.

.....

(2 marks)

5 (d) (ii) Write an equation for the extraction of titanium from titanium(IV) chloride using magnesium.

.....

(1 mark)

5 (d) (iii) State the role of magnesium in this extraction.

.....

(1 mark)

Do not write outside the box

5 (e) Use your knowledge of the reactions of Group 2 metals with water to explain why water should **not** be used to put out a fire in which magnesium metal is burning.

.....

.....

.....

(2 marks)

(Extra space) .....

.....

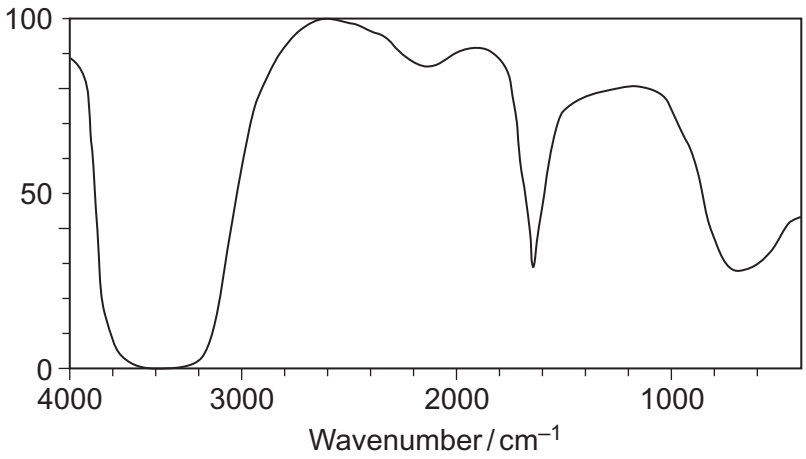
9

Turn over for the next question

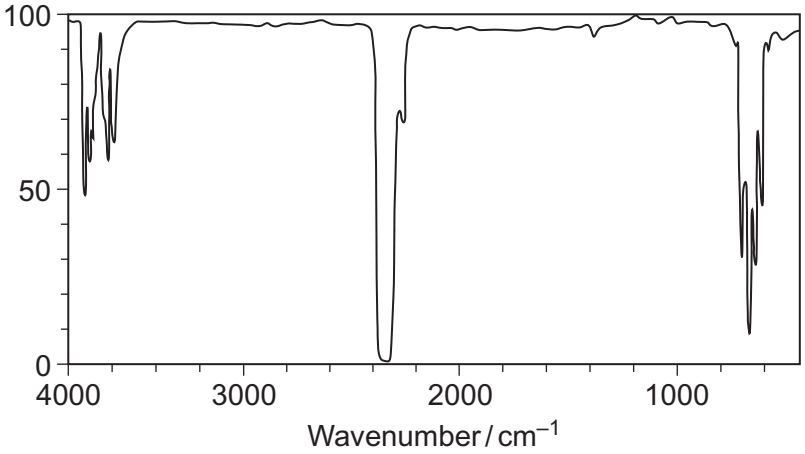
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6 (a) A student used the infrared spectra of water vapour and of carbon dioxide to try to find a link between infrared radiation and global warming.

Infrared spectrum of water vapour



Infrared spectrum of carbon dioxide



6 (a) (i) Use information from the infrared spectra to deduce **one** reason why the student concluded that water vapour is a more effective greenhouse gas than carbon dioxide.

.....

.....

(1 mark)

6 (a) (ii) Use your knowledge of the bonds in CO_2 to state why the infrared spectrum of carbon dioxide is **not** as might be predicted from the data provided in **Table 1** on the Data Sheet.

.....

.....

.....

.....

(2 marks)

Do not write outside the box

6 (b) The initiatives to decrease the carbon dioxide in the atmosphere include the use of carbon-neutral fuels and the development of carbon capture.
The mineral serpentine, $Mg_3Si_2O_5(OH)_4$, has been proposed as a solid for the capture of carbon dioxide gas.

6 (b) (i) Give the meaning of the term *carbon-neutral*, as applied to a fuel.

.....

.....

(1 mark)

(Extra space) .....

.....

6 (b) (ii) Balance the following equation for the reaction of serpentine with carbon dioxide.

$Mg_3Si_2O_5(OH)_4$ + ...CO_2 ⟶ .....$MgCO_3$ + ...SiO_2 + ...H_2O

(1 mark)

5

Turn over for the next question

Do not write outside the box

7 (a) The reaction of bromine with propane is similar to that of chlorine with methane. Three steps in the mechanism for the bromination of propane to form 1-bromopropane are shown below.

Step **1** $Br_2 \longrightarrow 2Br\bullet$

Step **2** $Br\bullet + CH_3CH_2CH_3 \longrightarrow CH_3CH_2CH_2\bullet + HBr$

Step **3** $CH_3CH_2CH_2\bullet + Br_2 \longrightarrow CH_3CH_2CH_2Br + Br\bullet$

7 (a) (i) Name the type of mechanism in this reaction.

.....

(1 mark)

7 (a) (ii) Give an essential condition for Step **1** to occur.

.....

(1 mark)

7 (a) (iii) Name the type of step illustrated by Steps **2** and **3**.

.....

(1 mark)

7 (a) (iv) In this mechanism, a different type of step occurs in which free radicals combine. Name this type of step.
Write an equation to show how hexane could be formed from two free radicals in the mechanism of this reaction.

Type of step .....

Equation .....

(2 marks)

7 (a) (v) Write an overall equation for the reaction between bromine and propane by the same mechanism to produce octabromopropane (C_3Br_8).

.....

(1 mark)

Do not write outside the box

7 (b) Bromine reacts with alkenes, even though bromine is a non-polar molecule.

7 (b) (i) Explain why bromine molecules react with the double bonds in alkenes.

.....

.....

.....

.....

(2 marks)

(Extra space) .....

.....

7 (b) (ii) Name the type of mechanism involved in this reaction.

.....

(1 mark)

7 (b) (iii) Draw the structure of the compound with M_r = 387.6 formed when penta-1,4-diene ($H_2C{=}CHCH_2CH{=}CH_2$) reacts with an excess of bromine.

(1 mark)

7 (c) Two products are formed when propene reacts with hydrogen bromide.
Draw the structure of the intermediate that leads to the formation of the major product in the reaction of propene with hydrogen bromide.
Give the name of this type of intermediate.

Structure of intermediate

Type of intermediate .....

(2 marks)

12

Turn over ▶

There are no questions printed on this page

DO NOT WRITE ON THIS PAGE
ANSWER IN THE SPACES PROVIDED

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8 A student read the following passage on the Internet.

> Haloalkanes contain a polar covalent bond. The carbon atom of the polar covalent bond can be attacked by nucleophiles. Nucleophilic attack enables haloalkanes to undergo substitution reactions.
> A nucleophilic substitution reaction occurs when a haloalkane undergoes hydrolysis; the rate of hydrolysis of the haloalkane is influenced by the carbon–halogen bond enthalpy.

8 (a) Explain the meaning of each of the following terms in the information given above.

8 (a) (i) *nucleophile*

.....

.....

.....

(1 mark)

8 (a) (ii) *substitution,* as applied to nucleophilic substitution in a haloalkane

.....

.....

.....

(1 mark)

8 (a) (iii) *hydrolysis*

.....

.....

.....

(1 mark)

8 (a) (iv) *bond enthalpy,* as applied to a carbon–halogen bond.

.....

.....

.....

(1 mark)

Question 8 continues on the next page

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8 (b) Outline a mechanism for the nucleophilic substitution reaction in which 2-bromopropane ($CH_3CHBrCH_3$) reacts with potassium hydroxide to form propan-2-ol.

(2 marks)

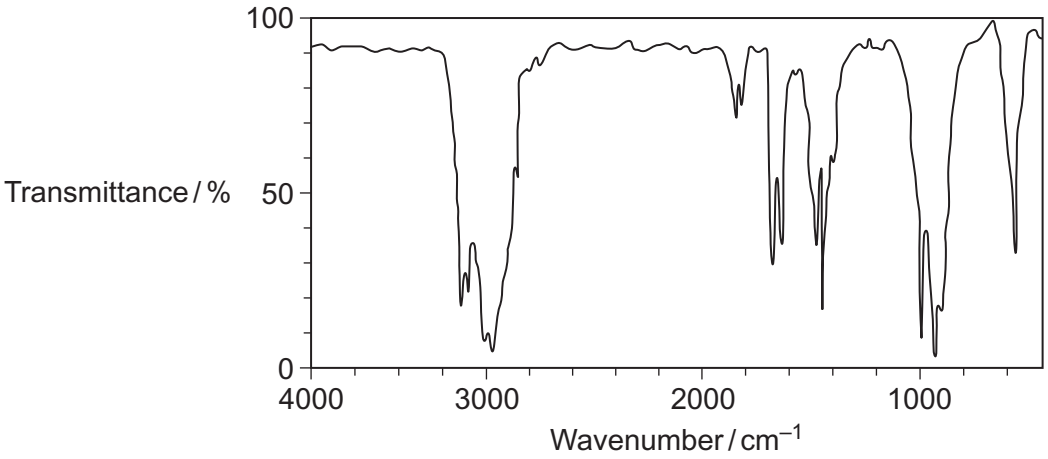
8 (c) Haloalkanes also undergo elimination reactions to produce alkenes.

8 (c) (i) Outline a mechanism for the elimination reaction in which 2-bromopropane reacts with potassium hydroxide to form propene.

(3 marks)

Do not write outside the box

8 (c) (ii) A student obtained the following infrared spectrum for the product from this elimination reaction.



Use information from the infrared spectrum to state and explain how the student deduced that the product was an alkene.
You may find it helpful to refer to **Table 1** on the Data Sheet.

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(2 marks)

(Extra space) .....

.....

11

Turn over for the next question

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Section B

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

9 A student devised an experiment to investigate the enthalpies of combustion of some alcohols. The student chose the following series of primary alcohols.

Name	Formula
Methanol	CH_3OH
Ethanol	CH_3CH_2OH
Propan-1-ol	$CH_3CH_2CH_2OH$
Butan-1-ol	$CH_3CH_2CH_2CH_2OH$
Pentan-1-ol	$CH_3CH_2CH_2CH_2CH_2OH$
Alcohol **X**	$CH_3CH_2CH_2CH_2CH_2CH_2OH$
Heptan-1-ol	$CH_3CH_2CH_2CH_2CH_2CH_2CH_2OH$

9 (a) (i) Name alcohol **X**.

.....

(1 mark)

9 (a) (ii) State the general name of the type of series shown by these primary alcohols.

.....

(1 mark)

9 (a) (iii) Draw the displayed formula of the position isomer of butan-1-ol.

(1 mark)

9 (a) (iv) Using [O] to represent the oxidising agent, write an equation for the oxidation of butan-1-ol to form an aldehyde.

.....

(1 mark)

Do not write outside the box

9 (a) (v) Draw the displayed formula of a functional group isomer of this aldehyde.

(1 mark)

9 (b) The student carried out a laboratory experiment to determine the enthalpy change when a sample of butan-1-ol was burned.
The student found that the temperature of 175 g of water increased by 8.0 °C when 5.00×10^{-3} mol of pure butan-1-ol was burned in air and the heat produced was used to warm the water.

Use the student's results to calculate a value, in kJ mol^{-1}, for the enthalpy change when one mole of butan-1-ol is burned.
(The specific heat capacity of water is 4.18 J K^{-1} g^{-1})

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(3 marks)

(Extra space) .....

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Question 9 continues on the next page

Do not write outside the box

9 (c) (i) Give the meaning of the term *standard enthalpy of combustion*.

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

.....

9 (c) (ii) Use the standard enthalpy of formation data from the table and the equation for the combustion of butan-1-ol to calculate a value for the standard enthalpy of combustion of butan-1-ol.

	$CH_3CH_2CH_2CH_2OH(l)$	$O_2(g)$	$CO_2(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	– 327	0	– 394	– 286

$$CH_3CH_2CH_2CH_2OH(l) + 6O_2(g) \longrightarrow 4CO_2(g) + 5H_2O(l)$$

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.....

(3 marks)

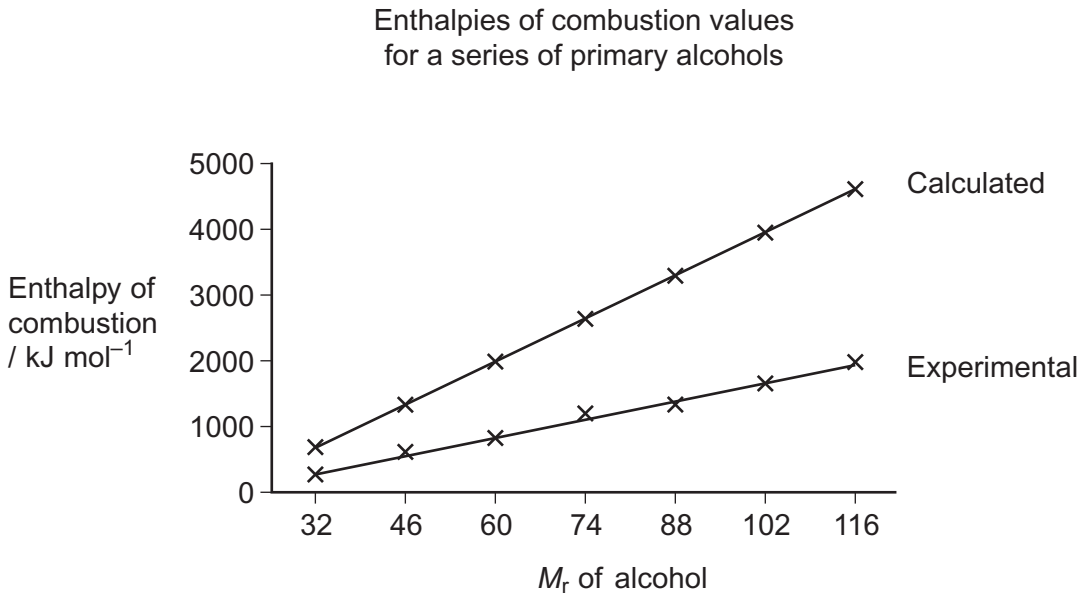
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9 (d) The student repeated the experiment described in part **9 (b)** and obtained an experimental value for the enthalpy of combustion for each alcohol in this series. These experimental values were then compared with calculated values from standard enthalpies of formation, as shown in the graph below.



9 (d) (i) In terms of bonds broken and bonds formed, explain why the calculated values of enthalpies of combustion of these alcohols, when plotted against M_r, follow a straight line.

.....

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.....

.....

(2 marks)

(Extra space) .....

.....

9 (d) (ii) Give **two** reasons why the experimental values obtained by the student are lower than the calculated values using the enthalpy of formation data.

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.....

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.....

(2 marks)

18

Do not write outside the box

10 Reactions that involve oxidation and reduction are used in a number of important industrial processes.

10 (a) Iodine can be extracted from seaweed by the oxidation of iodide ions.
In this extraction, seaweed is heated with MnO_2 and concentrated sulfuric acid.

10 (a) (i) Give the oxidation state of manganese in MnO_2

.....

(1 mark)

10 (a) (ii) Write a half-equation for the reaction of MnO_2 in acid to form Mn^{2+} ions and water as the only products.

.....

(1 mark)

10 (a) (iii) In terms of electrons, state what happens to the iodide ions when they are oxidised.

.....

.....

(1 mark)

10 (b) Chlorine is used in water treatment. When chlorine is added to cold water it reacts to form the acids HCl and HClO
The following equilibrium is established.

$$Cl_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + Cl^-(aq) + HClO(aq)$$

10 (b) (i) Give the oxidation state of chlorine in Cl_2 and in HClO

Cl_2 .....

HClO .....

(2 marks)

Do not write outside the box

10 (b) (ii) Deduce what happens to this equilibrium as the HClO reacts with bacteria in the water supply. Explain your answer.

.....

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.....

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(2 marks)

(Extra space) .....

.....

10 (c) Concentrated sulfuric acid is reduced when it reacts with solid potassium bromide. Concentrated sulfuric acid is **not** reduced when it reacts with solid potassium chloride.

10 (c) (i) Write the two half-equations for the following redox reaction.

$$2H^+ + 2Br^- + H_2SO_4 \longrightarrow Br_2 + SO_2 + 2H_2O$$

Half-equation 1

.....

Half-equation 2

.....

(2 marks)

10 (c) (ii) Write an equation for the reaction of solid potassium chloride with concentrated sulfuric acid.

.....

(1 mark)

Question 10 continues on the next page

Do not write outside the box

10 (c) (iii) Explain why chloride ions are weaker reducing agents than bromide ions.

.....

.....

.....

.....

(2 marks)

(Extra space) .....

.....

.....

12

END OF QUESTIONS

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Version 1



General Certificate of Education (A-level)
January 2011

Chemistry CHEM2

(Specification 2420)

Unit 2: Chemistry in Action

Final

Mark Scheme

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Question	Marking Guidance	Mark	Comments
1(a)(i)	chlorotrifluoromethane	1	Spelling must be correct but do not penalise "flouro" Ignore use of 1-
1(a)(ii)	CF_3•	1	May be drawn out with dot on C OR if as shown dot may be anywhere
1(a)(iii)	An unpaired / non-bonded / unbonded / free / a single / one / lone electron	1	NOT "bonded electron" and NOT "paired electron" NOT "pair of electrons" NOT "electrons" Ignore "(free) radical"
1(b)	**M1** $Cl\bullet + O_3 \longrightarrow ClO\bullet + O_2$ **M2** $ClO\bullet + O_3 \longrightarrow \mathbf{2}O_2 + Cl\bullet$	2	Mark independently Equations could gain credit in either position The dot can be anywhere on either radical Penalise the absence of a dot on the first occasion that it is seen and then mark on. Do not make the same penalty in the next equation, but penalise the absence of a dot on the other radical. Apply the list principle for additional equations

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1(c)(i)	(If any factor is changed which affects an equilibrium), the (position of) equilibrium will shift/move so as to oppose the change. OR (When a system / reaction in equilibrium is disturbed), the equilibrium shifts/moves in a direction which tends to reduce the disturbance	1	Must refer to equilibrium Ignore reference to "system" alone A variety of wording will be seen here and the key part is the last phrase. An alternative to shift/move would be the idea of changing/altering the position of equilibrium
1(c)(ii)	**M1** The (forward) reaction / to the right is endothermic or takes in heat ***OR*** The reverse reaction / to the left is exothermic or gives out heat **M2** The equilibrium moves / shifts to oppose the increase in temperature	2	M2 depends on a correct statement for M1 For M2 accept The equilibrium moves / shifts • to take in heat / lower the temperature • to promote the endothermic reaction and take in heat / lower the temperature • to oppose the change and take in heat / lower the temperature (leading to the formation of more ozone)
1(d)	Any one of • Pentane does not contain chlorine OR C–Cl (bond) • Pentane is chlorine-free • Pentane does not release chlorine (atoms / radicals)	1	Ignore reference to F OR OR C–F OR halogen Ignore "Pentane is not a CFC" Ignore "Pentane is a hydrocarbon" Ignore "Pentane only contains C and H Ignore "Pentane is C_5H_{12}

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Question	Marking Guidance	Mark	Comments
2(a)(i)	**M1** The peak of the new curve is displaced to the right. **M2** **All of the following** are required • The new curve starts at the origin • The peak of the new curve is lower than the original • and the new curve only crosses the original curve once • and an attempt has been made to draw the new curve correctly towards the energy axis but not to touch the original curve • the new curve must not start to diverge from the original curve	2	M1 is low demand M2 is higher demand.
2(a)(ii)	**M1** Increase in the number / proportion of molecules with $E \geq E_a$ OR more molecules have $E \geq E_a$ OR more molecules have sufficient energy to react **M2** More effective / productive / successful collisions	2	Ignore "molecules have more energy" Ignore "more energetic collisions" Ignore "molecules gain activation energy" Ignore "more collisions" Accept "particles" for "molecules" but NOT "atoms" Ignore "chance of collision"; this alone does not gain M2
2(b)(i)	Iron ***OR*** Fe	1	

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2(b)(ii)	**M1** Catalysts provide an alternative route / pathway / mechanism ***OR*** (in this case) surface adsorption / surface reaction occurs. **M2** that has a lower activation energy ***OR*** lowers the activation energy	2	For M1, not simply "provides a surface" alone For M2, the candidate may use a definition of activation energy without referring to the term

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Question	Marking Guidance	Mark	Comments
3(a)	**M1** $AgNO_3$ OR silver nitrate OR any <u>soluble</u> silver salt **M2** remains colourless or no reaction or no (observed) change or no precipitate **M3** <u>white precipitate</u> or <u>white solid / white suspension</u>	3	An insoluble silver salt OR Tollens' OR ammoniacal silver nitrate or HCl / $AgNO_3$ is CE = 0 for the clip For M1 Credit acidified (or HNO_3) silver nitrate for M1 and mark on If silver ions or incorrect formula for silver nitrate, penalise M1 but mark M2 and M3 If no reagent or incorrect reagent in M1, then no marks for M2 or M3 For M2 Ignore "nothing" Ignore "no observation" Ignore "clear" Ignore "dissolves" For M3 Ignore "cloudy solution" OR "suspension"

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3(b)	**M1** any <u>soluble</u> sulfate by name or formula e.g. sodium sulfate or sulfuric acid. **M2** <u>white precipitate</u> or <u>white solid / white suspension</u> **M3** remains colourless or no reaction or no (observed) change or no precipitate ***OR*** as an alternative **M1** NaOH / KOH **M2** remains colourless or no reaction or no (observed) change **M3** <u>white precipitate</u> or <u>white solid / white suspension</u>	3	An insoluble sulfate OR conc H_2SO_4 is CE=0 for the clip If no reagent or incorrect reagent in M1, then no marks for M2 or M3 For the M1 soluble sulfate If sulfate ions or incorrect formula for the chosen sulfate, penalise M1 but mark M2 and M3 For the M1 NaOH/KOH If ammonia, then CE=0 If hydroxide ions or incorrect formula for the chosen hydroxide, penalise M1 but mark M2 and M3 For no (observed) change in both alternatives Ignore “nothing” Ignore “no observation” Ignore “clear” Ignore “dissolves” For the white precipitate in both alternatives Ignore “cloudy solution” OR “suspension”

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3(c)	**M1** ammonia (can be dilute or concentrated) **M2** dissolves OR soluble OR (forms a) colourless solution OR goes colourless **M3** does not dissolve OR not soluble Or remains as a solid OR no (observed) change OR no reaction OR yellow solid remains OR if concentrated ammonia has been used, accept yellow solid turns white. OR as an alternative using conc sulfuric acid **M1** concentrated sulfuric acid OR c(onc) H_2SO_4 **M2** misty / white fumes / gas OR remains white OR no change (in colour) **M3** turns black (solid) OR purple fumes / gas OR correct reference to H_2S observation (e.g. bad egg smell)	3	For M1 If incorrect formula or "ammonium", penalise M1 but mark M2 and M3 If no reagent or incorrect reagent in M1, then no marks for M2 or M3 For M3 Ignore "nothing" Ignore "no observation" For the alternative using sulfuric acid If dilute sulfuric acid or "aq" (alone) or the idea of concentrated not included CE=0 If incorrect formula, penalise M1 but mark M2 and M3 If no reagent or incorrect reagent in M1, then no marks for M2 or M3

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3(d)	**M1** acidified potassium dichromate or $K_2Cr_2O_7/H_2SO_4$ OR $K_2Cr_2O_7/H^+$ OR acidified $K_2Cr_2O_7$ **M2** (orange to) green solution OR goes green **M3** (solution) remains orange or no reaction or no (observed) change Alternative using $KMnO_4/H_2SO_4$ **M1** acidified potassium manganate(VII) or $KMnO_4/H_2SO_4$ OR $KMnO_4/H^+$ OR acidified $KMnO_4$ **M2** colourless solution OR goes colourless **M3** (solution) remains purple or no reaction or no (observed) change	3	If no reagent or incorrect reagent in M1, then no marks for M2 or M3 For M1 If "dichromate" or "dichromate(IV)" or incorrect formula or no acid, penalise M1 but mark M2 and M3 For M2 ignore dichromate described as "yellow" or "red" For M3 Ignore "nothing" Ignore "no observation" For M1 If "manganate" or "manganate(IV)" or incorrect formula or no acid, penalise M1 but mark M2 and M3 Credit alkaline $KMnO_4$ for possible full marks but M2 gives brown precipitate or solution goes green

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Question	Marking Guidance	Mark	Comments
4(a)	$MnO_2 + \mathbf{2}CO \longrightarrow Mn + \mathbf{2}CO_2$	1	Or multiples Ignore state symbols
4(b)	$Al \longrightarrow Al^{3+} + \mathbf{3}e^-$	1	Or multiples Ignore state symbols Credit electrons subtracted from LHS Ignore absence of charge on e
4(c)	$\mathbf{2}CuO + C \longrightarrow \mathbf{2}Cu + CO_2$ OR $CuO + C \longrightarrow Cu + CO$	1	Or multiples Ignore state symbols
4(d)(i)	*Any one from the following three ONLY* • Low(er) energy requirement • Low(er) temperature • Copper is obtained from low grade ore	1	Apply the list principle
4(d)(ii)	$Fe + Cu^{2+} \longrightarrow Fe^{2+} + Cu$	1	Or multiples Ignore state symbols

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Question	Marking Guidance	Mark	Comments
5(a)	$Mg^{2+} + \mathbf{2}OH^- \longrightarrow Mg(OH)_2$	1	NOT multiples Ignore state symbols
5(b)	$Mg(OH)_2 + \mathbf{2}HCl \longrightarrow MgCl_2 + \mathbf{2}H_2O$	1	Or multiples or ionic, with or without the spectator ions Ignore state symbols Accept either of these two equations $OH^- + H^+ \longrightarrow H_2O$ $Mg^{2+} + 2Cl^- \longrightarrow MgCl_2$
5(c)	$Mg^{2+} + \mathbf{2}e^- \longrightarrow Mg$	1	Or multiples Ignore state symbols Credit electrons subtracted from RHS Ignore absence of charge on e
5(d)(i)	**M1** use of Cl_2 and C **M2** balanced equation consequential on correct reactants $TiO_2 + \mathbf{2}Cl_2 + \mathbf{2}C \longrightarrow TiCl_4 + \mathbf{2}CO$ ***OR*** $TiO_2 + \mathbf{2}Cl_2 + C \longrightarrow TiCl_4 + CO_2$	2	Or multiples Ignore state symbols
5(d)(ii)	$TiCl_4 + \mathbf{2}Mg \longrightarrow Ti + \mathbf{2}MgCl_2$	1	Or multiples Ignore state symbols

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5(d)(iii)	Reducing agent ***OR*** reduces $TiCl_4$ ***OR*** Electron donor	1	Credit "reduction" or "reductant" Penalise "electron pair donor"

5(e)	**M1** Hydrogen / H_2 produced ***OR*** an equation to produce <u>hydrogen / H_2</u> (eg $Mg + 2H_2O \longrightarrow Mg(OH)_2 + H_2$) (eg $Mg + H_2O \longrightarrow MgO + H_2$) **M2 requires correct M1** risk of explosion OR forms explosive mixture (with air) ***OR*** (highly) flammable	2	For M1 Do not penalise an incorrect equation; the mark is for H_2 or hydrogen Allow one mark only for "<u>exothermic reaction</u> with steam / H_2O" for a candidate who has not scored M1 Ignore "violent" reaction

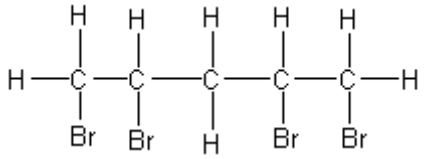
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Question	Marking Guidance	Mark	Comments
6(a)(i)	More absorption / less transmittance of infrared radiation by it / water vapour ***OR*** broader absorption by OH ***OR*** less absorption / more transmittance of infrared radiation by carbon dioxide	1	Must be comparative This may be described and must not be contradictory Credit answers which refer correctly to "transmittance" (more absorption = less transmittance)
6(a)(ii)	**M1** CO_2 contains C=O (stated like this or in words or strongly implied) OR is O=C=O **M2 depends on correct M1** ***OR*** expected absorption / peak (for C=O) is missing ***OR*** expected absorption / peak (for C=O) is shifted to 2300(cm^{-1}) ***OR*** asymmetric stretching is occurring (due to C=O)	2	If M1 and M2 not scored, give one mark for either No absorption / peak at 1700 (cm^{-1}) / 1715 (cm^{-1}) OR no absorption in the range 1680 – 1750 (cm^{-1}) Ignore "carbon-oxygen bonds", "C-O bonds" Ignore reference to other absorptions For M2 Allow "dip" OR "spike" OR "low transmittance" as alternatives for absorption.
6(b)(i)	An activity which has no net / overall (annual) carbon emissions to the atmosphere / air ***OR*** An activity which has no net / overall (annual) greenhouse gas emissions to the atmosphere / air. ***OR*** There is no change in the total amount of carbon dioxide / carbon /greenhouse gas present in the atmosphere / air	1	The idea that the carbon / CO_2 given out equals the carbon / CO_2 that was taken in from the atmosphere / air Answer must refer to the atmosphere or air
6(b)(ii)	$Mg_3Si_2O_5(OH)_4 + \mathbf{3}CO_2 \rightarrow \mathbf{3}MgCO_3 + \mathbf{2}SiO_2 + \mathbf{2}H_2O$	1	Allow multiples

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Question	Marking Guidance	Mark	Comments
7(a)(i)	(Free-) radical substitution	1	Both words needed
7(a)(ii)	UV light / Ultra-violet light / sunlight OR high temperature / $150^{o}C \leq T \leq 500^{o}C$	1	
7(a)(iii)	Propagation (Step)	1	Ignore "first" or "second" Accept phonetic spelling
7(a)(iv)	**M1** Termination (Step) **M2** $\mathbf{2}CH_3CH_2CH_2\bullet \longrightarrow C_6H_{14}$	2	In M2 C_6H_{14} may be drawn out as $CH_3CH_2CH_2CH_2CH_2CH_3$ The dot may be anywhere around the terminal CH_2 on the radical Accept $C_3H_7\bullet$ with dot anywhere Penalise the absence of any radical dot
7(a)(v)	$C_3H_8 + \mathbf{8}Br_2 \longrightarrow C_3Br_8 + \mathbf{8}HBr$	1	Or multiples

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7(b)(i)	**M1** Double bonds are electron-rich OR electon pair donors OR centres of electron density. **M2** Bromine becomes polarised / becomes polar OR forms an induced dipole OR becomes δ+/ δ-	2	M1 **QoL** – require one of these terms Ignore "(very) negative" and "nucleophile" as applied to the double bond. Penalise M2 for ion formation from bromine For M2, do not credit dipole formation solely as a consequence of electronegativity
7(b)(ii)	Electrophilic addition	1	Both words needed Accept phonetic spelling
7(b)(iii)	Structure for 1,2,4,5-tetrabromopentane, for example $BrCH_2CHBrCH_2CHBrCH_2Br$ OR 	1	Must be clear that they have drawn 1,2,4,5-tetrabromopentane and does NOT need to be displayed Credit use of "sticks" for each C-H bond

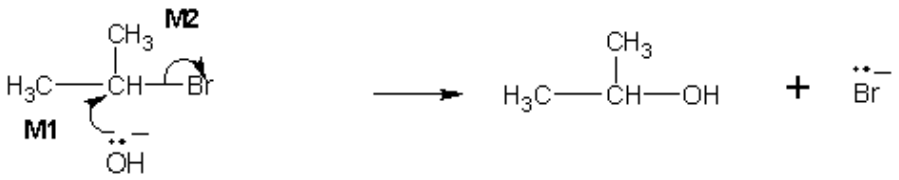
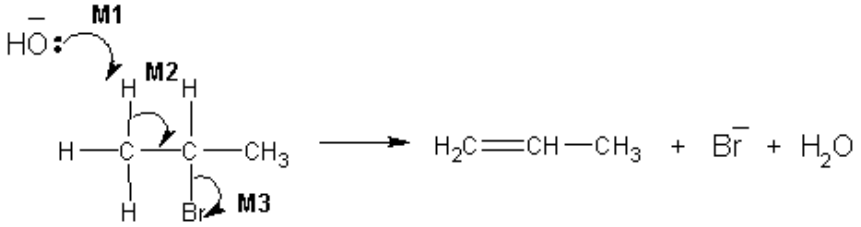
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7(c)	+ **M1** Structure of CH_3CHCH_3 **M2** (Secondary) Carbocation OR (secondary) carbonium ions	2	Mark independently For M1 the positive charge must be on the central carbon atom Penalise bond to positive charge Penalise answers which show more than the correct carbocation e.g. the mechanism, unless the intermediate is clearly identified Credit use of “sticks” for each C-H bond For M2, penalise “primary” or “tertiary”

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Question	Marking Guidance	Mark	Comments
8(a)(i)	Electron pair donor OR Species which uses a pair of electrons to form a co-ordinate / covalent bond.	1	Credit “lone pair” as alternative wording Credit “electron pair donator”
8(a)(ii)	Replacement of the halogen (atom) (by the nucleophile) OR The carbon-halogen bond / C-X breaks and a bond forms with the nucleophile or between the carbon and the nucleophile	1	They must describe the idea of substitution in a haloalkane. Accept the idea that a nucleophile replaces the halogen which becomes a halide ion Penalise reference to “halogen molecule” and penalise the idea that the haloalkane contains a halide
8(a)(iii)	Splitting molecules using / by water OR breaking / splitting / dissociating (C–X) bond(s) / using / by water	1	NOT simply the reaction with water or simply the addition of water. Ignore “compound”
8(a)(iv)	(Heat) energy / enthalpy required / needed / absorbed (at constant pressure) to break / split it / the (carbon-halogen) bond OR (Heat) energy / enthalpy required / needed / absorbed (at constant pressure) for homolysis of the (C—X / the carbon-halogen) bond	1	Ignore bond formation Ignore “average”

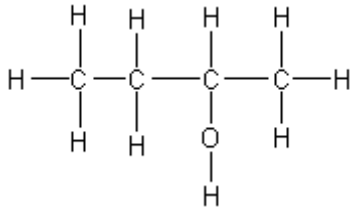
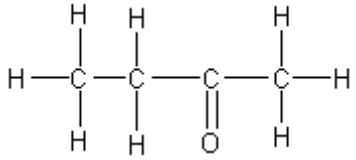
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8(b)	 **M1** must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom. **M2** must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently. Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.	2	Penalise M1 if covalent KOH is used Penalise M2 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 1 mark for the wrong reactant Accept the correct use of "sticks"
8(c)(i)	 **M1** must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion <u>to the correct</u> H atom **M2** must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1 **M3** is independent provided it is from the <u>original molecule</u> Award full marks for an E1 mechanism in which M2 is on the correct carbocation.	3	Penalise M1 if covalent KOH Penalise M3 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 2 marks for wrong reactant Accept the correct use of "sticks" for the molecule except for the C-H being attacked

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8(c)(ii)	**M1** Stated that the spectrum has an absorption / absorbance / peak in the range 1620 cm^{-1} to 1680 (cm^{-1})or specified correctly in this range from the spectrum **M2 depends on correct range or wavenumber being specified** **M2** (Infrared absorption) due to C=C OR carbon-carbon double bond	2	**QoL for correct M1 statement which includes both the word absorption (or alternative) and the correct range or wavenumber** Allow "peak" OR "dip" OR "spike" OR "trough" OR "low transmittance" as alternatives for absorption. For M2 it is not sufficient simply to state that an alkene has C=C M2 could be on the spectrum Ignore reference to other absorptions

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Question	Marking Guidance	Mark	Comments
9(a)(i)	Hexan-1-ol	1	ONLY
9(a)(ii)	Homologous (series)	1	ONLY
9(a)(iii)	Displayed formula for butan-2-ol 	1	All bonds must be drawn out including the O—H bond Ignore bond angles
9(a)(iv)	$CH_3CH_2CH_2CH_2OH + [O] \rightarrow CH_3CH_2CH_2CHO + H_2O$	1	Require this whole equation as written or formulae drawn out Penalise “sticks”
9(a)(v)	Displayed formula for butanone (credit possible enols, ethers and cyclic structures for C_4H_8O) 	1	All bonds must be drawn out Ignore bond angles

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9(b)	**M1** q = m c ΔT OR calculation 175 x 4.18 x 8 **M2** = **5852** (J) OR 5.85 (kJ) OR 5.9 (kJ) (This also scores M1) **M3** 0.005 mol, therefore ΔH = **–1170** ($kJmol^{-1}$) OR ΔH = **–1170.4** ($kJmol^{-1}$) OR ΔH = **–1200** ($kJmol^{-1}$)	3	Award full marks for correct answer In M1, do not penalise incorrect cases in the formula Ignore incorrect units in M2 Penalise M3 ONLY if correct answer but sign is incorrect OR value is in $J\ mol^{-1}$ If m = 5 x 10^{-3} OR if ΔT = 281, CE and only allow one mark for correct mathematical formula for M1 If c = 4.81 (leads to 6734) penalise M2 ONLY and mark on for M3 = – 1350 (– 1347)
9(c)(i)	**M1** The enthalpy change (or heat change at constant pressure) when 1 mol of a compound / substance / alcohol **M2** is burned completely in oxygen OR burned in excess oxygen **M3** with all reactants and products / all substances in standard states OR all reactants and products / all substances in normal states under standard conditions OR 100 kPa / 1 bar and a specified T / 298 K	3	For M3 Ignore reference to 1 atmosphere

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9(c)(ii)	**M1 (could be scored by a correct mathematical expression)** **M1** $\Delta H = \sum\Delta H_f$ (**products**) - $\sum\Delta H_f$ (**reactants**) OR a correct cycle of balanced equations **M2** = 4(–394) + 5(–286) – (–327) (This also scores M1) **M3** = **– 2679** (kJ mol^{-1}) OR **– 2680** (kJ mol^{-1}) **Award 1 mark ONLY for (+) 2679 OR (+) 2680**	3	Correct answer to calculation gains full credit Credit 1 mark if + 2679 (kJ mol^{-1}) For other incorrect or incomplete answers, proceed as follows • check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2) • If no AE, check for correct method; this requires either a correct cycle with $4CO_2$ and $5H_2O$ OR a clear statement of M1 which could be in words and scores only M1
9(d)(i)	**M1 This is about the change in formula up the series** Each alcohol in the series (compared with the previous one) increases by / has an extra CH_2 OR has one more C-C and two more C-H **M2 This is about the reaction and bond breaking/making** Combustion of each alcohol in the series breaks one more C-C and two more C-H compared with the previous one AND forms one more mol CO_2 and one more mol H_2O OR A statement in which there is the idea that the extra OR additional OR difference in number of bonds broken and formed (as the series increases) is the same OR has the same difference in energy	2	N.B. If the first statement here for M2 is given , both marks score

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9(d)(ii)	**For the two marks M1 and M2** heat loss or heat absorbed by the apparatus OR incomplete combustion / not completely burned OR The idea that the water may end up in the gaseous state (rather than liquid) OR reactants and/or products may not be in standard states.	2	

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Question	Marking Guidance	Mark	Comments
10(a)(i)	MnO_2 **(+) 4**	1	
10(a)(ii)	$MnO_2 + \mathbf{4}H^+ + \mathbf{2}e^- \longrightarrow Mn^{2+} + \mathbf{2}H_2O$	1	Or multiples Ignore state symbols Credit electrons subtracted from RHS Ignore absence of charge on e
10(a)(iii)	Iodide ion(s) is/are oxidised because they have lost electron(s)	1	Do not penalise reference to iodine; the mark is for electron loss
10(b)(i)	**M1** Cl_2 **0** **M2** HClO **(+) 1**	2	
10(b)(ii)	**M1** Equilibrium will shift / move to the right OR L to R OR to favour the forward reaction OR to produce more HC*l*O **M2** - **Consequential on correct M1** To oppose the loss of HClO OR replaces the HClO (that has reacted)	2	for M2 NOT just “to oppose the change”

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10(c)(i)	The answers can be in **either order** **M1** $\mathbf{2}Br^- \longrightarrow Br_2 + \mathbf{2}e^-$ **M2** $\mathbf{4}H^+ + SO_4^{2-} + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$ OR $\mathbf{2}H^+ + H_2SO_4 + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$	2	NOT multiples Ignore state symbols Credit electrons subtracted from incorrect side Ignore absence of charge on e
10(c)(ii)	$KCl + H_2SO_4 \longrightarrow KHSO_4 + HCl$ OR $\mathbf{2}KCl + H_2SO_4 \longrightarrow K_2SO_4 + \mathbf{2}HCl$	1	Credit ionic equations
10(c)(iii)	For M1 and M2, chloride ions are weaker reducing agents than bromide ions, because **M1 Relative size of ions** Chloride ions are <u>smaller</u> than bromide ions OR chloride ion electron(s) are <u>closer</u> to the nucleus OR chloride ion has fewer (electron) shells / levels OR chloride ion has less shielding (or converse for bromide ion) **M2 Strength of attraction for electron being lost** <u>Outer shell / level electron(s)</u> OR <u>electron(s) lost</u> from a <u>chloride ion</u> is <u>more strongly held by the nucleus</u> compared with that lost from a <u>bromide ion</u> (or converse for bromide ion)	2	If the forces are described as intermolecular or Van der Waals then CE=0 Ignore general reference to Group 7 trend For M1 accept reference to chlorine/bromine or reference to atoms of these but NOT "chloride/bromide atoms" or "chlorine/bromine molecules" For M2 insist on reference to the correct ions This is the expected answer, but award credit for a candidate who gives a correct explanation in terms of hydration enthalpy, electron affinity and atomisation enthalpy.

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General principles applied to marking CHEM2 papers by CMI+ (January 2011)

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are required information to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**

A. The "List principle" and the use of "ignore" in the mark scheme

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. Incorrect case for element symbol

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. Spelling

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

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D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

E. Reagents

The command word "Identify", allows the candidate to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.
For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a candidate provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

F. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

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G. Marking calculations, such as those involving enthalpy changes

In general

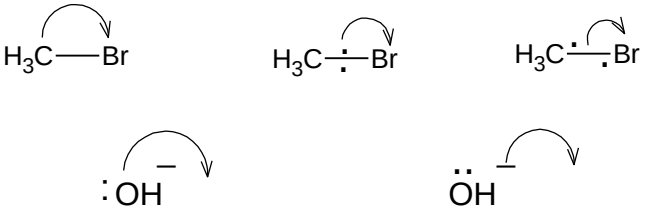
- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will usually score **only one mark**.

All other values **gain no credit** except

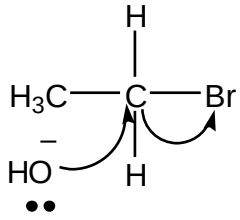
- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

H. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.
The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

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In free-radical substitution

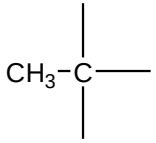
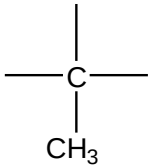
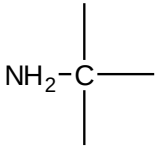
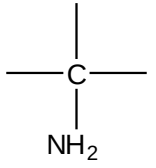
- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

I. Organic structures

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if candidates show the alcohol functional group as C ─ HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C ─ C bonds in structures, given that CH_3─ is considered to be interchangeable with H_3C─ even though the latter would be preferred.
- Poor presentation of vertical C ─ CH_3 bonds or C ─ NH_2 bonds should **not** be penalised. For the other functional groups, such as ─ OH and ─ CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.
  By way of illustration, the following would apply

(a)  allowed	(b)  allowed
(c)  allowed	(d)  allowed

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- In most cases, the use of "sticks" to represent C — H bonds in a structure should **not** be penalised. The exceptions will include structures in mechanisms when the C — H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.
- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

N.B. Exceptions may be made in the context of balancing equations

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

J. Organic names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.
Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**

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2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**
3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

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Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
3	
4	
5	
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7	
8	
9	
TOTAL	



General Certificate of Education
Advanced Subsidiary Examination
June 2010

Chemistry CHEM2

Unit 2 Chemistry in Action

Monday 7 June 2010 9.00 am to 10.45 am

For this paper you must have:
- the Periodic Table/Data Sheet, provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. Do not write outside the box around each page or on blank pages.
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use accurate scientific terminology

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.



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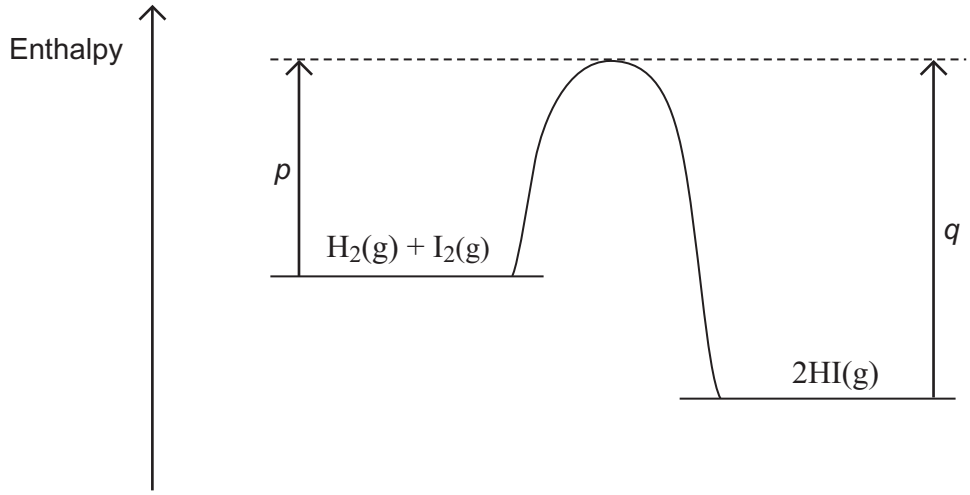
Section A

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

1 An equation for the equilibrium reaction between hydrogen, iodine and hydrogen iodide is shown below.

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

1 (a) The curve in the diagram below illustrates the reaction profile for this equilibrium reaction without a catalyst.



1 (a) (i) Draw on the diagram a curve to illustrate the reaction profile for this equilibrium reaction **with** a catalyst. *(2 marks)*

1 (a) (ii) Use the diagram to deduce whether the formation of hydrogen iodide from hydrogen and iodine is exothermic or endothermic.

.....

(1 mark)

1 (a) (iii) State what the diagram suggests about the sum of the bond enthalpies for the reactant molecules compared with the product molecules.

.....

.....

(1 mark)

Do not write outside the box

1 (a) (iv) In terms of *p* and *q*, identify the following for this equilibrium without a catalyst.

A value for the activation energy for the forward reaction .....

A value for the overall enthalpy change for the forward reaction .....

(2 marks)

1 (b) A mixture of $H_2(g)$ and $I_2(g)$ was allowed to reach equilibrium.

1 (b) (i) State the effect of a catalyst on the rate of attainment of this equilibrium.

.....

(1 mark)

1 (b) (ii) State and explain the effect of an increase in total pressure on the rate of attainment of this equilibrium.

Effect of an increase in pressure on rate .....

Explanation .....

.....

.....

.....

(3 marks)

10

Turn over for the next question

Do not write outside the box

2 A student carried out an experiment to study the rates of hydrolysis of some haloalkanes.

2 (a) In the experiment, two different haloalkanes were placed in separate test tubes containing silver nitrate solution. The haloalkanes reacted with the water in the silver nitrate solution. The student timed how long it took for the first appearance of the silver halide precipitate in each tube at a constant temperature. This time was used to provide a measure of the initial rate of reaction.
The student obtained the following results.

	1-bromobutane	1-iodobutane
Time to form a precipitate / s	480	15

2 (a) (i) State the meaning of the term *hydrolysis.*

.....

.....

(1 mark)

2 (a) (ii) State the colour of the precipitate formed when iodide ions react with silver nitrate and write the **simplest** ionic equation for this reaction.

Colour of precipitate.....

Simplest ionic equation

.....

(2 marks)

2 (a) (iii) Use your knowledge of the reactions of halide ions with silver nitrate to suggest why the student did **not** include 1-fluorobutane in this experiment.

.....

.....

(2 marks)

Do not write outside the box

2 (b) The student used the following enthalpy data to try to account for the different initial rates of hydrolysis of the haloalkanes used in part **(a)**. The student deduced that the rate of hydrolysis of a haloalkane is influenced by the strength of the carbon–halogen bond in the haloalkane.

	C–Br	C–I
Bond enthalpy / kJ mol^{-1}	276	238

State how the experimental evidence enabled the student to make this deduction.

.....

.....

(1 mark)

2 (c) The student had read that the reaction of water with haloalkanes was similar to the reaction of aqueous sodium hydroxide with haloalkanes and was an example of a nucleophilic substitution reaction.

2 (c) (i) State the meaning of the term *nucleophile*.

.....

(1 mark)

2 (c) (ii) When a hydroxide ion collides with a molecule of 1-bromobutane, the following reaction occurs.

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

Outline the nucleophilic substitution mechanism for this reaction.

(2 marks)

Question 2 continues on the next page

Turn over ▶

Do not write outside the box

2 (d) The reaction of hydroxide ions with 2-bromo-2-methylpropane may occur by a different mechanism from the one in part **(c)**. This different mechanism involves the formation of a carbocation.

2 (d) (i) Complete the following equation by drawing the structure of the carbocation formed when the C–Br bond in 2-bromo-2-methylpropane is broken.



.....

(1 mark)

2 (d) (ii) Suggest **one** reason why this reaction occurs by a mechanism involving a carbocation, but the reaction in part **(c) (ii)** does not.

.....

.....

(1 mark)

11

Do not write outside the box

3 Sulfuric acid is made from SO_3 which can be manufactured in a series of stages from iron(II) disulfide (FeS_2), found in the mineral iron pyrites.

3 (a) In the first stage, FeS_2 is roasted in air to form iron(III) oxide and sulfur dioxide.

3 (a) (i) Balance the following equation for this reaction.

$$\ldots\ldots FeS_2 + \ldots\ldots O_2 \longrightarrow \ldots\ldots Fe_2O_3 + \ldots\ldots SO_2$$

(1 mark)

3 (a) (ii) Deduce the oxidation state of sulfur in each of the following compounds.

SO_2 .....

FeS_2 .....

(2 marks)

3 (b) In the second stage of the manufacture of sulfuric acid, sulfur dioxide reacts with oxygen. The equation for the equilibrium that is established is shown below.

$$SO_2(g) + \tfrac{1}{2}O_2(g) \rightleftharpoons SO_3(g) \qquad \Delta H = -98\,kJ\,mol^{-1}$$

State and explain the effect of an increase in temperature on the equilibrium yield of SO_3

Effect of increase in temperature on yield .....

Explanation .....

.....

.....

(3 marks)

(Extra space) .....

.....

3 (c) In the extraction of iron, carbon monoxide reacts with iron(III) oxide. Write an equation for this reaction and state the role of the carbon monoxide.

Equation .....

Role of the carbon monoxide .....

(2 marks)

8

Turn over ▶

Do not write outside the box

4 A scientist used mass spectrometry to analyse a sample of the air near a fertiliser factory. The sample of air included traces of a gas which was shown by its molecular ion to have a precise M_r = 44.00105

4 (a) State the meaning of the term *molecular ion*.

.....

.....

(1 mark)

4 (b) (i) Use the following data to show that the trace gas was dinitrogen oxide (N_2O). Show your working.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{14}N	14.00307
^{16}O	15.99491

.....

.....

(1 mark)

4 (b) (ii) Propane is used as a fuel in the fertiliser factory. State why both propane and its combustion product, carbon dioxide, might have been identified as the trace gas if the scientist had used relative molecular masses calculated to one decimal place.

.....

.....

(1 mark)

4 (b) (iii) State why the precise relative atomic mass for the ^{12}C isotope is exactly 12.00000

.....

(1 mark)

Do not write outside the box

4 (c) Dinitrogen oxide is formed when ammonia is oxidised according to the following equation.

$$2NH_3(g) + 2O_2(g) \longrightarrow N_2O(g) + 3H_2O(l)$$

4 (c) (i) Use the standard enthalpies of formation in the table below to calculate a value for the standard enthalpy change of this reaction.

	$NH_3(g)$	$O_2(g)$	$N_2O(g)$	$H_2O(l)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	–46	0	+82	–286

.....

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

4 (c) (ii) State **one** condition necessary for enthalpies of formation to be quoted as standard values at a specified temperature of 298 K.

.....

(1 mark)

8

Turn over for the next question

Do not write outside the box

5 Sulfuric acid is an important chemical in many industrial and laboratory reactions. Consider the following three reactions involving sulfuric acid.

Reaction **1** $Mg(OH)_2 + H_2SO_4 \longrightarrow MgSO_4 + 2H_2O$

Reaction **2** The reaction of solid sodium bromide with concentrated sulfuric acid

Reaction **3** $H_2C{=}CH_2 + H_2O \xrightarrow{\text{conc. } H_2SO_4} CH_3CH_2OH$

5 (a) Give a use for magnesium hydroxide in medicine.

.....

(1 mark)

5 (b) Sulfuric acid behaves as an oxidising agent in Reaction **2**.

5 (b) (i) In terms of electrons, state the meaning of the term *oxidising agent*.

.....

(1 mark)

5 (b) (ii) Give the formula of the oxidation product that is formed from sodium bromide in Reaction **2**.

.....

(1 mark)

5 (b) (iii) Deduce the half-equation for the reduction of H_2SO_4 to SO_2 in Reaction **2**.

.....

(1 mark)

Do not write outside the box

5 (c) The formation of ethanol in Reaction **3** uses concentrated sulfuric acid and proceeds in two stages according to the following equations.

Stage **1** $H_2C{=}CH_2 + H_2SO_4 \longrightarrow CH_3CH_2OSO_2OH$

Stage **2** $CH_3CH_2OSO_2OH + H_2O \longrightarrow CH_3CH_2OH + H_2SO_4$

5 (c) (i) State the overall role of sulfuric acid in Reaction **3**.

.....

(1 mark)

5 (c) (ii) Outline a mechanism for Stage **1** of this reaction.

(4 marks)

5 (c) (iii) State the class of alcohols to which ethanol belongs.

.....

(1 mark)

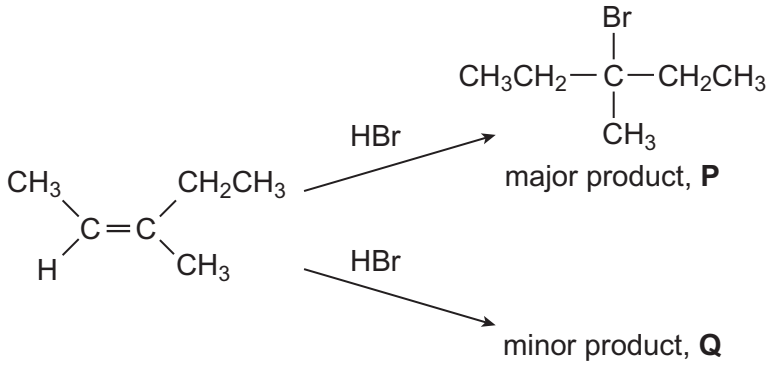
5 (c) (iv) Draw the displayed formula of the carboxylic acid formed when ethanol is oxidised by an excess of acidified potassium dichromate(VI) solution.

(1 mark)

11

Do not write outside the box

6 The alkene (Z)-3-methylpent-2-ene reacts with hydrogen bromide as shown below.



6 (a) (i) Name the major product **P**.

.....

(1 mark)

6 (a) (ii) Name the mechanism for these reactions.

.....

(1 mark)

6 (a) (iii) Draw the displayed formula for the minor product **Q** and state the type of structural isomerism shown by **P** and **Q**.

Displayed formula for **Q**

Type of structural isomerism .....

(2 marks)

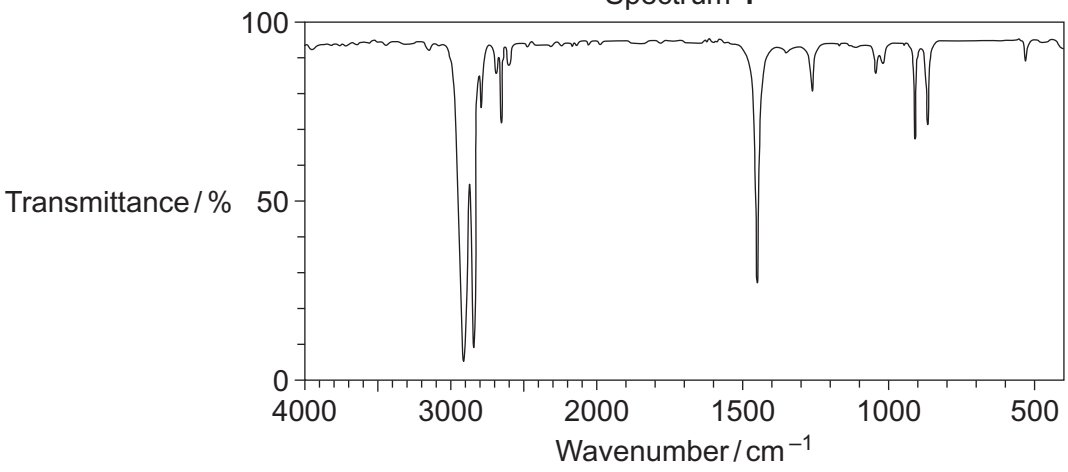
6 (a) (iv) Draw the structure of the (E)-stereoisomer of 3-methylpent-2-ene.

(1 mark)

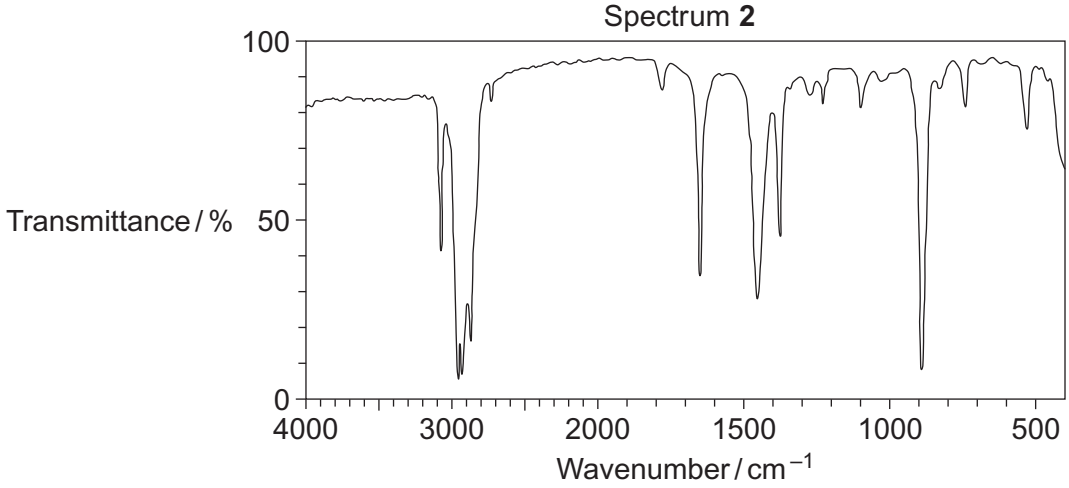
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6 (b) The infrared spectra of two compounds **R** and **S** are shown below. **R** and **S** have the molecular formula C_6H_{12} and are structural isomers of 3-methylpent-2-ene. **R** is an unsaturated hydrocarbon and **S** is a saturated hydrocarbon.

Spectrum **1**



Spectrum **2**



6 (b) (i) Identify the infrared Spectrum **1** or **2** that represents compound **R**.
Use information from the infrared spectra to give **one** reason for your answer.
You may find it helpful to refer to **Table 1** on the Data Sheet.

R is represented by Spectrum .....

Reason .....

.....

(2 marks)

6 (b) (ii) State the type of structural isomerism shown by **R** and **S**.

.....

(1 mark)

6 (b) (iii) Name **one** possible compound which could be **S**.

.....

(1 mark)

9

Turn over ▶

Do not write outside the box

7 Chlorine is a useful industrial chemical.

7 (a) Chlorine gas is used in the manufacture of chlorine-containing organic compounds.

7 (a) (i) Write equations for the following steps in the mechanism for the reaction of chlorine with ethane to form chloroethane (CH_3CH_2Cl).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step producing butane.

.....

(4 marks)

7 (a) (ii) Give **one** essential condition and name the type of mechanism in this reaction of chlorine with ethane.

Essential condition .....

Type of mechanism .....

(2 marks)

Do not write outside the box

7 (b) Chlorine reacts with cold water.

7 (b) (i) Write an equation for this reaction.

.....

(1 mark)

7 (b) (ii) Give **one** large-scale application of the use of chlorine in water. Explain why it is used in this application even though chlorine is very toxic. Do **not** include cost.

Example of application .....

Explanation of use .....

.....

(2 marks)

7 (b) (iii) Two different chlorine-containing compounds are formed when chlorine reacts with cold, dilute sodium hydroxide solution. One of these compounds is sodium chloride. Name the other chlorine-containing compound formed.

.....

(1 mark)

7 (c) Chlorine is used in the extraction of bromine from seawater.

7 (c) (i) Write the **simplest** ionic equation for the reaction of chlorine with bromide ions.

.....

(1 mark)

7 (c) (ii) Explain why bromine has a higher boiling point than chlorine.

.....

.....

.....

(2 marks)

13

Do not write outside the box

Section B

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

8 Glucose, produced during photosynthesis in green plants, is a renewable source from which ethanol can be made. Ethanol is a liquid fuel used as a substitute for petrol. The processes involved can be summarised as follows.

Process **1** Photosynthesis in green plants

$$6CO_2 + 6H_2O \longrightarrow C_6H_{12}O_6 + 6O_2$$

Process **2** Fermentation of glucose to form ethanol

Process **3** Complete combustion of ethanol

$$CH_3CH_2OH + 3O_2 \longrightarrow 2CO_2 + 3H_2O$$

8 (a) State **three** essential conditions for the fermentation of aqueous glucose in Process **2**.

Write an equation for the reaction that takes place during this fermentation.

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(4 marks)

(Extra space) .....

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Do not write outside the box

8 (b) It has been claimed that there is no net carbon (greenhouse gas) emission to the atmosphere when ethanol made by Process **2** is used as a fuel.

State the term that is used to describe fuels of this type.

Use the equations for Processes **1**, **2** and **3** to show why it can be claimed that there is no net emission of carbon-containing greenhouse gases.

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(3 marks)

(Extra space) .....

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Question 8 continues on the next page

Do not write outside the box

8 (c) Use the information from the equation for Process **3** on page 16 and the mean bond enthalpies from the table below to calculate a value for the enthalpy change for this process.

	C–H	C–C	C–O	O–H	C=O	O=O
Mean bond enthalpy / kJ mol^{-1}	+412	+348	+360	+463	+743	+496

Give **one** reason why the value calculated from mean bond enthalpies is different from the value given in a data book.

.....

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(4 marks)

(Extra space) .....

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Do not write outside the box

8 (d) A student carried out a simple laboratory experiment to measure the enthalpy change for Process **3**. The student showed that the temperature of 200 g of water increased by 8.0 °C when 0.46 g of pure ethanol was burned in air and the heat produced was used to warm the water.

Use these results to calculate the value, in $kJ\,mol^{-1}$, obtained by the student for this enthalpy change. (The specific heat capacity of water is $4.18\,J\,K^{-1}\,g^{-1}$)

Give **one** reason, other than heat loss, why the value obtained from the student's results is less exothermic than a data book value.

.....

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(4 marks)

(Extra space) .....

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15

Turn over for the next question

Do not write outside the box

9 The method of extraction of zinc has changed as different ores containing the element have been discovered and as technology has improved.

Extraction process 1
In the earliest process, calamine (impure zinc carbonate) was heated with charcoal in earthenware pots. This two-stage process gave a low yield of zinc.

$$ZnCO_3(s) \longrightarrow ZnO(s) + CO_2(g)$$
$$ZnO(s) + C(s) \longrightarrow Zn(s) + CO(g)$$

Extraction process 2
Deposits of calamine were being used up and a new two-stage process was developed using zinc sulfide ores. All of the waste gases from this process were released into the atmosphere.

$$2ZnS(s) + 3O_2(g) \longrightarrow 2ZnO(s) + 2SO_2(g)$$
$$ZnO(s) + C(s) \longrightarrow Zn(s) + CO(g)$$

Extraction process 3
The modern process uses the electrolysis of aqueous solutions of very pure zinc sulfate. The first step in this process is the same as the first step in Extraction process **2**. The second step uses sulfuric acid made from the SO_2 collected in the first step. The third step involves the electrolysis of zinc sulfate solution to form pure zinc.

$$2ZnS(s) + 3O_2(g) \longrightarrow 2ZnO(s) + 2SO_2(g)$$
$$ZnO(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2O(l)$$
$$ZnSO_4(aq) \xrightarrow{\text{electrolysis}} Zn(s)$$

9 (a) In the first stage of Extraction process **1** the following equilibrium is established when zinc carbonate is heated in a closed container.

$$ZnCO_3(s) \rightleftharpoons ZnO(s) + CO_2(g)$$

Use Le Chatelier's principle to suggest and explain the effect on the yield of zinc oxide of allowing the carbon dioxide to escape from the container.

.....

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(3 marks)

(Extra space) .....

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Do not write outside the box

9 (b) State and explain **one** environmental reason why Extraction process **3** is an improvement over Extraction process **2**.

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(3 marks)

(Extra space) .....

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9 (c) Give **one** reason why Extraction process **3** is an expensive method of making zinc but one which is justified in terms of the product formed.

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(2 marks)

(Extra space) .....

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Question 9 continues on the next page

Do not write outside the box

9 (d) Deduce the half-equation for the formation of zinc from zinc ions during the electrolysis of zinc sulfate solution and identify the electrode at which this reaction occurs.

.....

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.....

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(2 marks)

(Extra space) .....

.....

9 (e) Identify **one** reaction from the three extraction processes that is **not** a redox reaction and state the type of reaction that it is. In terms of redox, state what happens to the carbon in Extraction process **2**.

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(3 marks)

(Extra space) .....

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Do not write outside the box

9 (f) Zinc and magnesium both react with steam in a similar way. Write an equation for the reaction of zinc with steam and name the products of this reaction.

.....

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(2 marks)

(Extra space) .....

.....

15

END OF QUESTIONS

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Version 1.0

General Certificate of Education
June 2010

Chemistry CHEM2

Chemistry in Action

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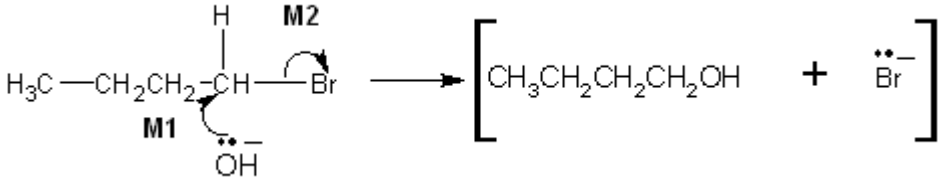
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Q	Part	Sub Part	Marking Guidance	Mark	Comments
1	a	i	**M1** drawn curve <u>starts at reactants</u> and <u>ends at products</u> **M2** curve peak is <u>below</u> the one drawn in the question (and may show one/two humps)	2	Tapered lines into the original curve gain credit for M1 Mark M1 and M2 independently
1	a	ii	Exothermic (reaction)	1	Ignore "ΔH is negative"
1	a	iii	∑ bond (enthalpy) <u>reactants</u> < ∑ bond (enthalpy) <u>products</u> The sum for H_2 and I_2 / reactants is <u>less than / lower than / smaller than</u> the sum for 2HI / products OR The sum for 2HI /products is <u>more than / larger than / bigger than</u> the sum for H_2 and I_2 / reactants	1	Accept "It OR the sum will be <u>smaller</u> or <u>less</u>"
1	a	iv	**M1** p **M2** $-(q-p)$ ***OR*** $p-q$ ***OR*** $-q+p$	2	M2 demands that the sign for an exothermic reaction is part of the outcome mathematically. Ignore case

1	b	i	Increase / speed up / faster (rate of attainment of equilibrium) ***OR*** Increase / speed up / faster rate of <u>both</u> forward <u>and</u> reverse reaction ***OR*** Increase / speed up / faster rate of reaction	1	Credit "It took less time"

1	b	ii	**M1** Increase / speed up / faster (rate of attainment of equilibrium) **M2** <u>More particles / molecules</u> in a <u>given volume / space</u> ***OR*** the <u>particles /</u> <u>molecules</u> are clos<u>er</u> together ***OR*** an increase in concentration. **M3** <u>More / higher chance</u> of <u>successful / effective / productive collisions</u> (between particles) ***OR*** <u>more collisions / higher chance of collisions (of particles) with $E>E_{Act}$</u>	3	If M1 is blank, mark on and credit M1 in the text If M1 is given as "decrease" / "no effect" / "no change" then CE= 0 for clip In M1, if increase <u>both</u> the forward and reverse reaction, but no mention of rate, penalise M1 but mark on. In M1, if increase <u>either</u> forward rate <u>or</u> reverse rate <u>only</u>, then penalise M1 but mark on. Penalise M3 if an increase in the value of E_{Act} / energy of particles is stated. Max 1 for M2 and M3 if reference to "atoms"

Q	Part	Sub Part	Marking Guidance	Mark	Comments
2	a	i	Splitting/ breaking C─X / bond(s) using / by (adding) / with water ***OR*** Splitting/ breaking the molecule / substance / compound using / by (adding) / with water	1	NOT simply the reaction of / with water NOT simply the addition or adding of water. NOT the "splitting of water" Accept any halogen bond, but penalise other specified bonds
2	a	ii	**M1** yellow ONLY **M2** $Ag^+ + I^- \longrightarrow AgI$ $(Ag^+ I^-)$	2	For M1, penalise cream(y) OR white Ignore pale or light or dark (yellow) For M2, ignore state symbols
2	a	iii	**M1** AgF OR silver fluoride is soluble / dissolves (in water) **M2** No result OR no precipitate OR no (visible) change would occur OR colourless solution	2	Accept "silver flouride" Mark independently Ignore reference to C **–** F bond breakage in M1 Ignore "no reaction" and "nothing"

2	b		The bond that takes less energy to break / the lower bond enthalpy (energy) / weaker bond means the precipitate / reaction / hydrolysis occurs faster / quicker /takes less time ***OR*** The bond that takes more energy / the higher bond enthalpy (energy) / stronger bond means the precipitate / reaction / hydrolysis occurs slower/ takes longer / takes more time	1	Insist on comparative on both bond strength and rate of reaction
2	c	i	An electron pair donor ***OR*** Forms a covalent or co-ordinate or dative bond by donating a pair of electrons	1	Answer must refer to an electron pair. Credit "lone pair" "Attracted" does not equal "donated"
2	c	ii	 **M1** must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom. **M2** must show the movement of a pair of electrons from the C─ Br bond to the Br atom. Mark M2 independently. **NB The arrows here are double-headed**	2	Penalise M1 if covalent NaOH is used Penalise M2 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 1 mark for the wrong reactant Award 1 mark only for C-Br bond breakage if **an S_N1 mechanism** is used. Do not penalise the use of "sticks"

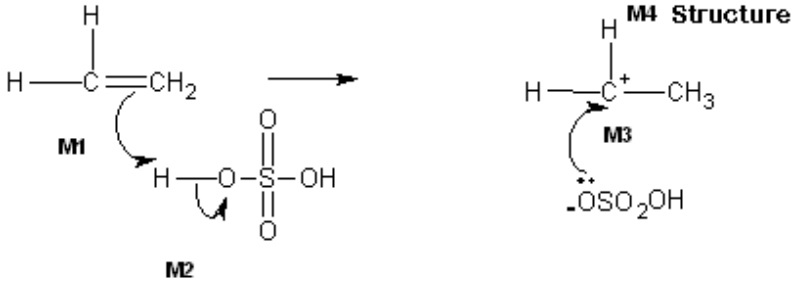
2	d	i	Structure of tertiary carbocation $(CH_3)_3C^+$ or drawn out	1	Insist on a full positive charge on the central C atom. Penalise a bond to the positive charge. Be lenient on vertical C-C bonds
2	d	ii	Tertiary carbocation / carbonium ion (from 2-bromo-2-methylpropane) is more stable (than the primary carbocation / carbonium ion) ***OR*** Primary carbocation / carbonium ion (from 2-bromo-2-methylpropane) is less stable (than the tertiary carbocation / carbonium ion)	1	**QoL** Ignore reference to the alleged relative stability of haloalkanes

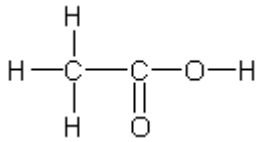
Q	Part	Sub Part	Marking Guidance	Mark	Comments
3	a	i	**4**FeS_2 + **11**O_2 ⟶ **2**Fe_2O_3 + **8**SO_2 **2** **5½** **(1)** **4**	1	Or multiples of this equation
3	a	ii	**M1** **(+) 4** **M2** **– 1**	2	Ignore working M1, credit (+) IV M2, credit – I
3	b		**M1** Lower / smaller / decreases / reduced yield ***OR*** equilibrium shifts (right) to left **M2** **(**Forward) reaction is exothermic OR reverse reaction is endothermic **M3** (By Le Chatelier's principle) equilibrium responds / shifts / moves (R to L) to lower the temperature ***OR*** to absorb the heat ***OR*** to cool the reaction	3	If M1 is blank, mark on and credit M1 in the text. If M1 is incorrect, only credit correct M2 Mark M2 independently – it may be above the arrow in the equation For M3, not simply "to oppose the change / temperature"
3	c		**M1** Fe_2O_3 + **3**CO ⟶ **2**Fe + **3**CO_2 **M2** Reducing agent ***OR*** Reduce(s) (Fe_2O_3 / iron(III) oxide) ***OR*** Electron donor ***OR*** to remove the oxygen (from iron(III) oxide to form CO_2) ***OR*** reductant	2	Or multiples Ignore state symbols For M2, credit "reduction"

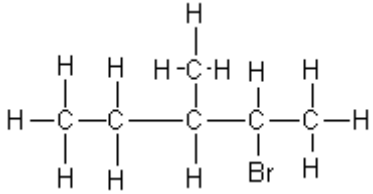
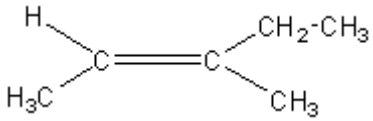
Q	Part	Sub Part	Marking Guidance	Mark	Comments
4	a		The molecular ion is • The molecule with one / an electron knocked off / lost ***OR*** • The molecule with a (single) positive charge ***OR*** • the ion with / it has the largest / highest / biggest m/z (value / ratio) ***OR*** • the ion with / it has an m/z equal to the M_r	1	Ignore the highest or biggest m/z peak Ignore "the peak to the right" Ignore "compound"
4	b	i	2(14.00307) + 15.99491 = 44.00105	1	A sum is needed to show this
4	b	ii	Propane / C_3H_8 and carbon dioxide / CO_2 (and N_2O) or they or both the gases / molecules or all three gases / molecules have an (imprecise) M_r of 44.0 (OR 44) ***OR*** they have the same M_r or molecular mass (to one d.p)	1	This could be shown in a calculation of relative masses for propane and carbon dioxide
4	b	iii	By definition ***OR*** The standard / reference (value / isotope)	1	Ignore "element" Ignore "atom"

4	c	i	**M1 (could be scored by a correct mathematical expression)** $\Delta H = \sum \Delta H_{products} - \sum \Delta H_{reactants}$ OR a correct cycle of balanced equations **M1 and M2 can be scored with correct moles as follows** ΔH + 2(– 46) = +82 +3(– 286) ΔH – 92 = – 776 ΔH = 92 – 776 OR 92 + 82 – 858 **M3** ΔH = **– 684** (kJ mol^{-1}) **(This is worth 3 marks)** **Award 1 mark ONLY for + 684**	3	Full marks for correct answer. Ignore units. Deduct one mark for an arithmetic error.
4	c	ii	The value is quoted at a pressure of 100 kPa OR 1 bar or 10^5 Pa ***OR*** All reactants and products are in their standard states / their normal states at 100 kPa or 1 bar	1	Ignore 1 atmosphere / 101 kPa Ignore "constant pressure"

Q	Part	Sub Part	Marking Guidance	Mark	Comments
5	a		to neutralise stomach acidity ***OR*** as an antacid ***OR*** eases indigestion / heartburn	1	Ignore milk of magnesia Credit suitable reference to indigestion / laxative / relief of constipation
5	b	i	an electron acceptor ***OR*** (readily) gains / accepts / receives electron(s)	1	NOT an electron pair acceptor Ignore removes / takes away / attracts electrons
5	b	ii	Br_2 ONLY	1	Ignore "bromine" Apply the list principle
5	b	iii	$H_2SO_4 + \mathbf{2}H^+ + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$ ***OR*** $SO_4^{2-} + \mathbf{4}H^+ + \mathbf{2}e^- \longrightarrow SO_2 + \mathbf{2}H_2O$	1	Ignore state symbols Ignore absence of negative charge on electron Or multiples of equations

5	c	i	(acid) catalyst ***OR*** catalyses (the reaction) ***OR*** to speed up the reaction / increase the rate (of reaction)	1	Ignore "provides H^+ ions" Accept phonetic spelling
5	c	ii	 **M1** must show an arrow from the double bond towards the H atom of the H – O bond OR HO on a compound with molecular formula for H_2SO_4 (or accept H_2SO_3 here) M1 could be to an H+ ion and M2 an independent O – H bond break on a compound with molecular formula for H_2SO_4 or H_2SO_3 **M2** must show the breaking of the O ─ H bond. **M3** must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards the positively charged carbon atom. **M4** is for the structure of the carbocation. **NB The arrows here are double-headed**	4	M2 Ignore partial charges unless wrong M3 NOT HSO_4^- For M3, credit <u>as shown</u> or <u>$^-$:OSO$_3$H</u> ONLY with the negative charge anywhere on this ion OR <u>correctly</u> drawn out with the negative charge placed correctly on oxygen Max 3 marks for wrong reactant Do not penalise the use of "sticks"

5	c	iii	Primary ***OR*** 1° (alcohol)	1	
5	c	iv	<u>Displayed formula</u> for ethanoic acid, CH_3COOH 	1	All the bonds must be drawn out and this includes the O ─ H bond Ignore bond angles.

Q	Part	Sub Part	Marking Guidance	Mark	Comments
6	a	i	**3**-bromo-**3**-methylpentane ONLY	1	Must be correct spelling but ignore hyphens and commas
6	a	ii	<u>Electrophilic addition</u> (reaction)	1	Both words needed Accept phonetic spelling
6	a	iii	**M1** Displayed formula of 2-bromo-3-methylpentane  **M2** Position(al) (isomerism)	2	All the bonds must be drawn out but ignore bond angles **Do not forget to award this mark**
6	a	iv	Structure of (E)-3-methylpent-2-ene 	1	The arrangement of groups around the double bond must be clear with the ethyl group attached in the correct order. Ignore bond angles. Accept C_2H_5 for ethyl Be lenient on C ─ C bonds. The main issue here is whether they have drawn an (E) isomer. Accept "sticks" for C ─ H bonds and correct skeletal formula

6	b	i	**M1** **R** is represented by **Spectrum 2** **M2** Spectrum 2 shows an infrared absorption / spike / dip / trough / peak with any value(s) / range within the range 1620 to 1680 (cm^{-1}) OR this range quoted / identified and this is due to C=C OR this information could be a correctly labelled absorption on the spectrum OR Spectrum 1 does not have an infrared absorption in range 1620 to 1680 (cm^{-1}) and does not contain C=C.	2	Award M1 if it is obvious that they are referring to the second spectrum (or the bottom one) M2 depends on a correct M1 Ignore other correctly labelled peaks Ignore reference to “double bond” or “alkene”
6	b	ii	Functional group (isomerism)	1	
6	b	iii	Cyclohexane ***OR*** Methylcyclopentane etc.	1	Named correctly Ignore structures and ignore numbers on the methyl group of methylcyclopentane

Q	Part	Sub Part	Marking Guidance	Mark	Comments
7	a	i	**M1 Initiation** $Cl_2 \longrightarrow 2Cl\bullet$ **M2 First propagation** $Cl\bullet + CH_3CH_3 \longrightarrow \bullet CH_2CH_3 + HCl$ C_2H_6 **M3 Second propagation** $Cl_2 + \bullet CH_2CH_3 \longrightarrow CH_3CH_2Cl + Cl\bullet$ C_2H_5Cl **M4 Termination (must make C_4H_{10})** $2 \bullet CH_2CH_3 \longrightarrow C_4H_{10}$ or $CH_3CH_2CH_2CH_3$	4	Penalise absence of dot once only. Penalise + or – charges <u>every time</u> Penalise incorrect position of dot on ethyl radical once only. Penalise $C_2H_5\bullet$ once only Accept $CH_3CH_2\bullet$ with the radical dot above / below / to the side of <u>the CH_2</u> Mark independently
7	a	ii	**M1** ultra-violet / uv / sun light OR (very) high temperature OR 500 $^oC \geq T \leq 1000\ ^oC$ **M2** (free-)<u>radical substitution</u>	2	Ignore “heat” for M1 Both words needed for M2 For M2, ignore the word “mechanism”
7	b	i	$Cl_2 + H_2O \longrightarrow HClO + HCl$ ***OR*** $Cl_2 + H_2O \longrightarrow 2H^+ + ClO^- + Cl^-$	1	Accept HOCl or ClOH Accept other ionic or mixed representations Ignore state symbols

7	b	ii	**M1** Any one from • in swimming pools • in drinking water • to sterilise / disinfect / sanitise water • in water treatment **M2** The (health) benefit outweighs the risk or wtte OR a clear statement that once it has done its job, little of it remains OR used in (very) dilute concentrations / small amounts / low doses	2	Ignore the manufacture of bleach Ignore "to clean water" Ignore "water purification" Mark independently but M1 can score from (M2) explanation
7	b	iii	Sodium chlorate(I) or sodium hypochlorite	1	Must be named Ignore (in)correct formulae Insist on the (I) in the name
7	c	i	$Cl_2 + 2Br^- \longrightarrow Br_2 + 2Cl^-$	1	Or half this equation Ignore state symbols
7	c	ii	**M1** **The relative size (of the molecules/atoms)** Bromine is larger than chlorine OR has more electrons/electron shells ***OR*** It is larger / It has a larger atomic radius / it is a larger molecule / atom **M2** **How size of the intermolecular force affects energy needed** The forces between bromine / Br_2 molecules are stronger (than the forces between chlorine / Cl_2 molecules leading to more energy needed to separate the molecules) (or converse) ***OR*** bromine / Br_2 has stronger / more (VdW) intermolecular forces. (or converse)	2	For M1 ignore whether it refers to molecules or atoms. CE=0 for reference to (halide) ions Ignore molecular mass **QoL** for clear reference to the difference in size of the force between molecules Penalise M2 if covalent bonds are broken

Q	Part	Sub Part	Marking Guidance	Mark	Comments
8	a		**Three conditions <u>in any order</u> for M1 to M3** **M1** yeast or zymase **M2** $30^{o}C \geq T \leq 42\ ^{o}C$ **M3** anaerobic / no oxygen / no air OR neutral pH **M4** $C_6H_{12}O_6 \longrightarrow \mathbf{2}C_2H_5OH + \mathbf{2}CO_2$ OR $\mathbf{2}C_6H_{12}O_6 \longrightarrow \mathbf{4}C_2H_5OH + \mathbf{4}CO_2$	4	Mark independently Penalise “bacteria” and “phosphoric acid” using the list principle Ignore reference to “aqueous” or “water” (i.e. not part of the list principle) Or other multiples
8	b		**M1** Carbon-neutral **M2** <u>6 (mol / molecules) CO_2 / carbon dioxide taken in / used / used up</u> (to form glucose or in photosynthesis) **M3** <u>6 (mol / molecules) CO_2 / carbon dioxide</u> given out <u>due to **2** (mol / molecules) CO_2 / carbon dioxide from fermentation / Process 2 and **4** (mol / molecules) CO_2 / carbon dioxide from combustion / Process 3</u>	1 1 1	Ignore “biofuel” It is NOT sufficient in M2 and M3 for equations alone without commentary or annotation or calculation

8	c		**M1** **(could be scored by a correct mathematical expression)** (Sum of) bonds broken – (Sum of) bonds made / formed = Δ*H* ***OR*** (∑) $B_{reactants}$ – (∑) $B_{products}$ = Δ*H* (where B = bond enthalpy / bond energy) **M2** Reactants = (+) 4719 ***OR*** Products = (–) 5750 **M3** Overall + 4719 –5750 = **–1031** ($kJmol^{-1}$) **(This is worth 3 marks)** **Award 1 mark ONLY for +1031** Candidates may use a cycle and gain full marks. **M4** Mean bond enthalpies are not specific for this reaction ***OR*** they are average values from many different compounds / molecules	3 1	For M1 there must be a correct mathematical expression using ΔH or "enthalpy change" Award full marks for correct answer. Ignore units. M2 is for either value underlined M3 is NOT consequential on M2 **Do not forget to award this mark**

8	d		**M1** q = m c ΔT (this mark for correct mathematical formula) **M2** = 6688 (J) OR 6.688 (kJ) OR 6.69 (kJ) OR 6.7 (kJ) **M3** 0.46g is 0.01 mol therefore ΔH = **– 669** $kJmol^{-1}$ OR **– 670** $kJmol^{-1}$ OR **– 668.8** $kJmol^{-1}$ **M4** Incomplete combustion	4	Award M1, M2 and M3 for correct answer to the calculation Penalise M3 ONLY if correct answer but sign is incorrect In M1, do not penalise incorrect cases in the formula If m = 0.46 or m = 200.46 OR if ΔT = 281, CE and penalise M2 and M3 If c = 4.81 (leads to 7696) penalise M2 ONLY and mark on for M3 = – 769.6 OR – 770 Ignore incorrect units in M2 **Do not forget to award this mark. Mark independently**

Q	Part	Sub Part	Marking Guidance	Mark	Comments
9	a		**M1** The yield of zinc oxide <u>increases / greater</u> **M2** Removal of the carbon dioxide results in the **<u>equilibrium</u>** **Either** Shifting / moving / goes <u>to the right</u> shifting / moving / goes <u>L to R</u> <u>favours the forward reaction / towards the products</u> **M3** (By Le Chatelier's principle) the reaction/equilibrium will respond so as <u>to replace the CO_2 / lost product</u> OR <u>to make more CO_2</u> OR <u>to increase concentration of CO_2</u>	3	If M1 is given as "decrease" OR "no effect" then CE= 0 For M3, not simply "to oppose the change / to oppose the loss of CO_2 / to oppose the removal of carbon dioxide."
9	b		**M1** Process 2 produces / releases SO_2 ***OR*** Process 2 produces / releases CO **M2** It / Process 3 avoids the release of SO_2 OR CO ***OR*** It / Process 3 (captures and) converts SO_2 to H_2SO_4 **M3** SO_2 causes acid rain OR is toxic / poisonous ***OR*** CO is toxic / poisonous	3	Ignore "global warming" and "greenhouse gases" and "the ozone layer" If both CO and SO_2 claimed to form acid rain, treat as contradiction
9	c		**M1** Process 3 (is expensive because it) uses <u>electrolysis</u> OR due to high <u>electricity / electrical</u> consumption **M2** this is justified because the product / zinc is pure	2	Ignore "energy" Penalise "pur<u>er</u>"

9	d		**M1** $Zn^{2+} + 2e^- \longrightarrow Zn$ **M2** the negative electrode OR the cathode	2	Ignore state symbols Ignore absence of negative charge on electron Accept electrons subtracted from RHS
9	e		**M1** The reaction of ZnO with sulfuric acid ***OR*** the second reaction in Extraction process 3 **M2** neutralisation or acid-base OR alternatively **M1** The reaction of zinc carbonate in Extraction process 1 **M2** (thermal) decomposition **M3** It / carbon is <u>oxidised / gains oxygen / changes oxidation state / number from 0 to +2 / increase in oxidation state / number</u> in Process 2	3	M1 could be the equation written out in both cases M2 depends on correct M1 **Do not forget to award this mark** Ignore reference to electron loss but penalise electron gain Ignore “carbon is a reducing agent”

9	f		**M1** $Zn + H_2O \longrightarrow ZnO + H_2$ **M2** <u>Zinc oxide and hydrogen</u> OR as an alternative **M1** $Zn + 2H_2O \longrightarrow Zn(OH)_2 + H_2$ **M2** <u>Zinc hydroxide and hydrogen</u>	2	Mark independently If ZnO_2 is given for zinc oxide in the equation, penalise M1 and mark on If ZnOH is given for zinc hydroxide in the equation, penalise M1 and mark on Ignore state symbols Credit multiples of the equation If M1 is blank, either of the M2 answers could score To gain <u>both</u> marks, the names must match the correct equation given.

General principles applied to marking CHEM2 papers by CMI+ June 2010

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

Basic principles

- **Examiners should note that throughout the mark scheme, items that are underlined are required information to gain credit.**
- **Occasionally an answer involves incorrect chemistry and the mark scheme records CE = 0, which means a chemical error has occurred and no credit is given for that section of the clip or for the whole clip.**

A. The "List principle" and the use of "ignore" in the mark scheme

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. Incorrect case for element symbol

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. Spelling

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly or an idea needs to be articulated with clarity, as part of the "Quality of Language" (**QoL**) marking. These will be identified in the mark scheme and marks are awarded only if the QoL criterion is satisfied.

D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

E. Reagents

The command word "Identify", allows the candidate to choose to use **either** the name or the formula of a reagent in their answer. In some circumstances, the list principle may apply when both the name and the formula are used. Specific details will be given in mark schemes.

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify complete reagents **will be penalised**, but follow-on marks (e.g. for a subsequent equation or observation) can be scored from an incorrect attempt (possibly an incomplete reagent) at the correct reagent. Specific details will be given in mark schemes.
For example, **no credit** would be given for

- the cyanide ion or CN^- when the reagent should be potassium cyanide or KCN;
- the hydroxide ion or OH^- when the reagent should be sodium hydroxide or NaOH;
- the $Ag(NH_3)_2^+$ ion when the reagent should be Tollens' reagent (or ammoniacal silver nitrate). In this example, no credit is given for the ion, but credit could be given for a correct observation following on from the use of the ion. Specific details will be given in mark schemes.

In the event that a candidate provides, for example, **both** KCN and cyanide ion, it would be usual to ignore the reference to the cyanide ion (because this is not contradictory) and credit the KCN. Specific details will be given in mark schemes.

F. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

G. Marking calculations, such as those involving enthalpy changes

In general

- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will usually score **only one mark**.

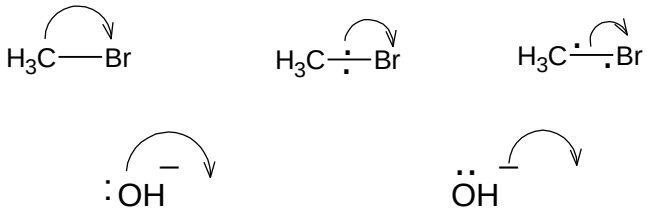
All other values **gain no credit** except

- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

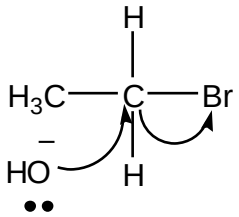
H. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.

The following representations should not gain credit **and will be penalised each time** within a clip.



For example, the following would score zero marks



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

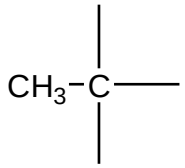
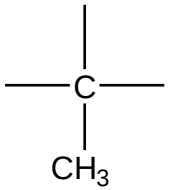
- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

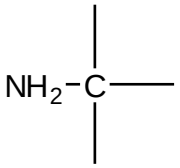
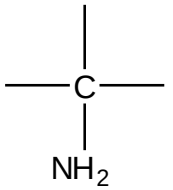
In mass spectrometry fragmentation equations, the absence of a radical dot on the molecular ion and on the free-radical fragment would be considered to be two independent errors and both would be penalised if they occurred within the same clip.

I. Organic structures

In general

- Displayed formulae must show all of the bonds and all of the atoms in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if candidates show the alcohol functional group as C — HO, they should be penalised **on every occasion**.
- Latitude should be given to the representation of C — C bonds in structures, given that CH_3— is considered to be interchangeable with H_3C— even though the latter would be preferred.
- Poor presentation of vertical C — CH_3 bonds or C — NH_2 bonds should **not** be penalised. For the other functional groups, such as — OH and — CN, the limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.
  By way of illustration, the following would apply

(a)  allowed	(b)  allowed

(c)  allowed	(d)  allowed

- In most cases, the use of "sticks" to represent C — H bonds in a structure should not be penalised. The exceptions will include structures in mechanisms when the C — H bond is essential (e.g. elimination reactions in haloalkanes) and when a displayed formula is required.
- Some examples are given here of **structures** for specific compounds that should **not** gain credit

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

N.B. Exceptions <u>may</u> be made in the context of balancing equations

- Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

J. Organic names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.
Some illustrations are given here.

but-2-ol	should be **butan-2-ol**
2-hydroxybutane	should be **butan-2-ol**
butane-2-ol	should be **butan-2-ol**
2-butanol	should be **butan-2-ol**
2-methpropan-2-ol	should be **2-methylpropan-2-ol**
2-methylbutan-3-ol	should be **3-methylbutan-2-ol**
3-methylpentan	should be **3-methylpentane**
3-mythylpentane	should be **3-methylpentane**
3-methypentane	should be **3-methylpentane**
propanitrile	should be **propanenitrile**
aminethane	should be **ethylamine** (although aminoethane can gain credit)
2-methyl-3-bromobutane	should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane	should be **2-bromo-3-methylbutane**
3-methyl-2-bromobutane	should be **2-bromo-3-methylbutane**
2-methylbut-3-ene	should be **3-methylbut-1-ene**
difluorodichloromethane	should be **dichlorodifluoromethane**

Centre Number						Candidate Number				
Surname										
Other Names										
Candidate Signature										

For Examiner's Use	
Examiner's Initials	
Question	Mark
1	
2	
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10	
TOTAL	

General Certificate of Education
Advanced Subsidiary Examination
January 2010

Chemistry CHEM2

Unit 2 Chemistry in Action

Thursday 21 January 2010 1.30 pm to 3.15 pm

For this paper you must have:
- the Periodic Table/Data Sheet provided as an insert (enclosed)
- a calculator.

Time allowed
- 1 hour 45 minutes

Instructions
- Use black ink or black ball-point pen.
- Fill in the boxes at the top of this page.
- Answer **all** questions.
- You must answer the questions in the spaces provided. **Answers written in margins or on blank pages will not be marked.**
- All working must be shown.
- Do all rough work in this book. Cross through any work you do not want to be marked.

Information
- The marks for questions are shown in brackets.
- The maximum mark for this paper is 100.
- The Periodic Table/Data Sheet is provided as an insert.
- Your answers to the questions in **Section B** should be written in continuous prose, where appropriate.
- You will be marked on your ability to:
  – use good English
  – organise information clearly
  – use accurate scientific terminology.

Advice
- You are advised to spend about 1 hour 15 minutes on **Section A** and about 30 minutes on **Section B**.

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Areas outside the box will not be scanned for marking

SECTION A

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

1 Hydrogen gas is used in the chemical industry.

1 (a) Tungsten is extracted by passing hydrogen over heated tungsten oxide (WO_3).

1 (a) (i) State the role of the hydrogen in this reaction.

.....

(1 mark)

1 (a) (ii) Write an equation for this reaction.

.....

(1 mark)

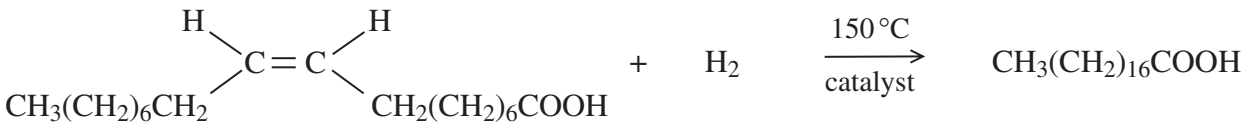
1 (a) (iii) State **one** risk of using hydrogen gas in metal extractions.

.....

.....

(1 mark)

1 (b) Hydrogen is used to convert oleic acid into stearic acid as shown by the following equation.



oleic acid stearic acid

1 (b) (i) Use your knowledge of the chemistry of alkenes to deduce the type of reaction that has occurred in this conversion.

.....

(1 mark)

1 (b) (ii) State the type of stereoisomerism shown by oleic acid.

.....

(1 mark)

Areas outside the box will not be scanned for marking

1 (c) Hydrogen reacts with nitrogen in the Haber Process. The equation for the equilibrium that is established is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

1 (c) (i) State Le Chatelier's principle.

.....

.....

(1 mark)

1 (c) (ii) Use Le Chatelier's principle to explain why an increase in the total pressure of this equilibrium results in an increase in the equilibrium yield of ammonia.

.....

.....

.....

.....

(2 marks)

1 (d) Hydrogen reacts with oxygen in an exothermic reaction as shown by the following equation.

$$H_2(g) + \tfrac{1}{2}O_2(g) \longrightarrow H_2O(g) \qquad \Delta H = -242\,\text{kJ mol}^{-1}$$

Use the information in the equation and the data in the following table to calculate a value for the bond enthalpy of the H–H bond.

	O–H	O=O
Mean bond enthalpy / kJ mol^{-1}	+463	+496

.....

.....

.....

.....

(3 marks)

(Extra space) .....

.....

11

Turn over ▶

Areas outside the box will not be scanned for marking

2 Hess's Law is used to calculate the enthalpy change in reactions for which it is difficult to determine a value experimentally.

2 (a) State the meaning of the term *enthalpy change*.

.....

(1 mark)

2 (b) State Hess's Law.

.....

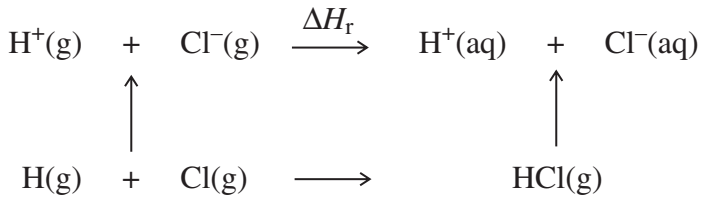
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(1 mark)

2 (c) Consider the following table of data and the scheme of reactions.

Reaction	Enthalpy change / kJ mol^{-1}
$HCl(g) \longrightarrow H^+(aq) + Cl^-(aq)$	–75
$H(g) + Cl(g) \longrightarrow HCl(g)$	–432
$H(g) + Cl(g) \longrightarrow H^+(g) + Cl^-(g)$	+963



Use the data in the table, the scheme of reactions and Hess's Law to calculate a value for ΔH_r

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(3 marks)

5

Areas outside the box will not be scanned for marking

3 For each of the following reactions, select from the list below, the **formula** of a sodium halide that would react as described.

NaF NaCl NaBr NaI

Each **formula** may be selected once, more than once or not at all.

3 (a) This sodium halide is a white solid that reacts with concentrated sulfuric acid to give a brown gas.

Formula of sodium halide .....

(1 mark)

3 (b) When a solution of this sodium halide is mixed with silver nitrate solution, no precipitate is formed.

Formula of sodium halide .....

(1 mark)

3 (c) When this solid sodium halide reacts with concentrated sulfuric acid, the reaction mixture remains white and steamy fumes are given off.

Formula of sodium halide .....

(1 mark)

3 (d) A colourless aqueous solution of this sodium halide reacts with orange bromine water to give a dark brown solution.

Formula of sodium halide .....

(1 mark)

4

Turn over for the next question

Areas outside the box will not be scanned for marking

4 Group 2 metals and their compounds are used commercially in a variety of processes and applications.

4 (a) State a use of magnesium hydroxide in medicine.

.....

(1 mark)

4 (b) Calcium carbonate is an insoluble solid that can be used in a reaction to lower the acidity of the water in a lake.

Explain why the rate of this reaction decreases when the temperature of the water in the lake falls.

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.....

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(3 marks)

(Extra space) .....

.....

.....

4 (c) Strontium metal is used in the manufacture of alloys.

4 (c) (i) Explain why strontium has a higher melting point than barium.

.....

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.....

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(2 marks)

(Extra space) .....

.....

Areas outside the box will not be scanned for marking

4 (c) (ii) Write an equation for the reaction of strontium with water.

.....

(1 mark)

4 (d) Magnesium can be used in the extraction of titanium.

4 (d) (i) Write an equation for the reaction of magnesium with titanium(IV) chloride.

.....

(1 mark)

4 (d) (ii) The excess of magnesium used in this extraction can be removed by reacting it with dilute sulfuric acid to form magnesium sulfate.

Use your knowledge of Group 2 sulfates to explain why the magnesium sulfate formed is easy to separate from the titanium.

.....

.....

.....

(1 mark)

9

Turn over for the next question

Areas outside the box will not be scanned for marking

5 Nitric acid is manufactured from ammonia in a process that involves several stages.

5 (a) In the first stage, ammonia is converted into nitrogen monoxide and the following equilibrium is established.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -905\,kJ\,mol^{-1}$$

The catalyst for this equilibrium reaction is a platinum–rhodium alloy in the form of a gauze. This catalyst gauze is heated initially but then remains hot during the reaction.

5 (a) (i) In terms of redox, state what happens to the ammonia in the forward reaction.

.....

(1 mark)

5 (a) (ii) Suggest a reason why the catalyst must be hot.

.....

(1 mark)

5 (a) (iii) Suggest a reason why the catalyst remains hot during the reaction.

.....

(1 mark)

5 (a) (iv) State how a catalyst increases the rate of a reaction.

.....

.....

.....

.....

(2 marks)

Areas outside the box will not be scanned for marking

5 (b) In the second stage, nitrogen monoxide is converted into nitrogen dioxide. The equation for the equilibrium that is established is shown below.

$$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = -113\,kJ\,mol^{-1}$$

Explain why the equilibrium mixture is cooled during this stage of the process.

.....

.....

.....

.....

(2 marks)

5 (c) In the final stage, nitrogen dioxide reacts with water as shown by the following equation.

$$2NO_2(g) + H_2O(l) \longrightarrow H^+(aq) + NO_3^-(aq) + HNO_2(aq)$$

Give the oxidation state of nitrogen in each of the following.

NO_2 .....

NO_3^- .....

HNO_2 .....

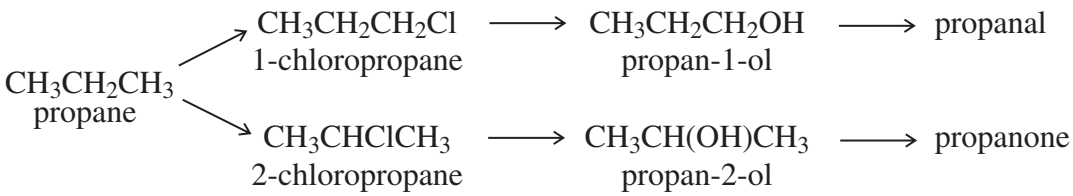
(3 marks)

10

Turn over for the next question

Areas outside the box will not be scanned for marking

6 Consider the following scheme of reactions.



6 (a) State the type of structural isomerism shown by propanal and propanone.

.....

(1 mark)

6 (b) A chemical test can be used to distinguish between separate samples of propanal and propanone.

Identify a suitable reagent for the test.
State what you would observe with propanal and with propanone.

Test reagent .....

Observation with propanal .....

Observation with propanone .....

(3 marks)

6 (c) State the structural feature of propanal and propanone which can be identified from their infrared spectra by absorptions at approximately 1720 cm^{-1}.
You may find it helpful to refer to **Table 1** on the Data Sheet.

.....

(1 mark)

Areas outside the box will not be scanned for marking

6 (d) The reaction of chlorine with propane is similar to the reaction of chlorine with methane.

6 (d) (i) Name the type of mechanism in the reaction of chlorine with methane.

.....

(1 mark)

6 (d) (ii) Write an equation for each of the following steps in the mechanism for the reaction of chlorine with propane to form l-chloropropane ($CH_3CH_2CH_2Cl$).

Initiation step

.....

First propagation step

.....

Second propagation step

.....

A termination step to form a molecule with the empirical formula C_3H_7

.....

(4 marks)

6 (e) High resolution mass spectrometry of a sample of propane indicated that it was contaminated with traces of carbon dioxide.

Use the data in the table to show how precise M_r values can be used to prove that the sample contains both of these gases.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{1}H	1.00794
^{16}O	15.99491

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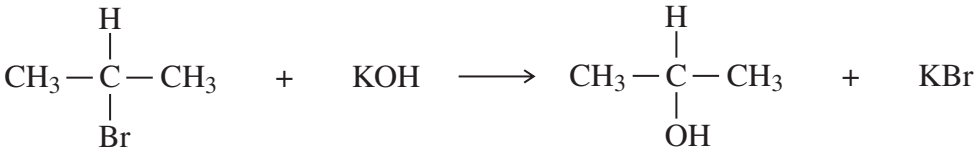
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(2 marks)

12

Areas outside the box will not be scanned for marking

7 (a) Consider the following reaction.



7 (a) (i) Name and outline a mechanism for this reaction.

Name of mechanism .....

Mechanism

(3 marks)

7 (a) (ii) Name the haloalkane in this reaction.

.....

(1 mark)

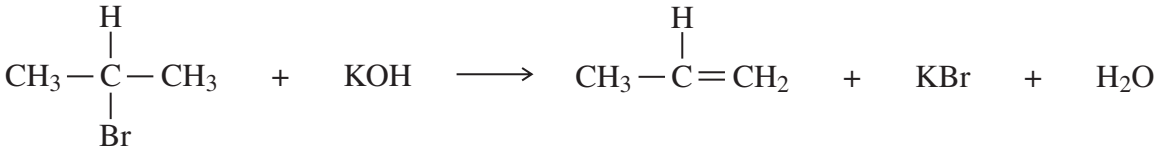
7 (a) (iii) Identify the characteristic of the haloalkane molecule that enables it to undergo this type of reaction.

.....

(1 mark)

Areas outside the box will not be scanned for marking

7 (b) An alternative reaction can occur between this haloalkane and potassium hydroxide as shown by the following equation.



Name and outline a mechanism for this reaction.

Name of mechanism .....

Mechanism

(4 marks)

7 (c) Give **one** condition needed to favour the reaction shown in part (b) rather than that shown in part (a).

.....

(1 mark)

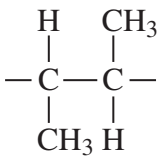
7 (d) Alkenes can be polymerised to produce poly(alkenes).

7 (d) (i) State the type of polymerisation that alkenes undergo.

.....

(1 mark)

7 (d) (ii) Name the alkene that gives a polymer with the repeating unit shown below.



Name of alkene .....

(1 mark)

12

Turn over ▶

Areas outside the box will not be scanned for marking

8 Copper is extracted from the ore chalcopyrite ($CuFeS_2$) in a three-stage process.

8 (a) In the first stage of this extraction, the chalcopyrite is heated with silicon dioxide and oxygen.

8 (a) (i) Balance the following equation for this first stage in which copper(I) sulfide is formed.

……$CuFeS_2$ + ……SiO_2 + ……O_2 ⟶ Cu_2S + ……$FeSiO_3$ + ……SO_2

(1 mark)

8 (a) (ii) Give **one** environmental reason why the SO_2 gas formed in this reaction is not allowed to escape into the atmosphere.

.....

.....

(1 mark)

8 (a) (iii) State **one** use for the sulfur dioxide formed in this reaction.

.....

.....

(1 mark)

8 (b) In the second stage of this extraction, the copper(I) sulfide is converted into copper(II) oxide. This occurs by roasting the sulfide with oxygen at high temperature. Write an equation for this reaction.

.....

(1 mark)

8 (c) In the third stage of this extraction, copper(II) oxide is reduced to copper by its reaction with carbon. Write an equation for this reaction.

.....

(1 mark)

Areas outside the box will not be scanned for marking

8 (d) Scrap iron can be used to extract copper from dilute aqueous solutions containing copper(II) ions.

8 (d) (i) Explain why this is a low-cost method of extracting copper.

.....

.....

(1 mark)

8 (d) (ii) Write the **simplest ionic** equation for the reaction of iron with copper(II) ions in aqueous solution.

.....

(1 mark)

7

Turn over for the next question

Areas outside the box will not be scanned for marking

SECTION B

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

9 There are **four** isomeric alcohols with the molecular formula $C_4H_{10}O$

9 (a) Two of these are butan-l-ol ($CH_3CH_2CH_2CH_2OH$) and butan-2-ol.
The other two isomers are alcohol **X** and alcohol **Y**.

Draw the displayed formula for butan-2-ol.

Alcohol **X** does not react with acidified potassium dichromate(VI) solution.
Give the structure of alcohol **X**.

Name the fourth isomer, alcohol **Y**.

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(3 marks)

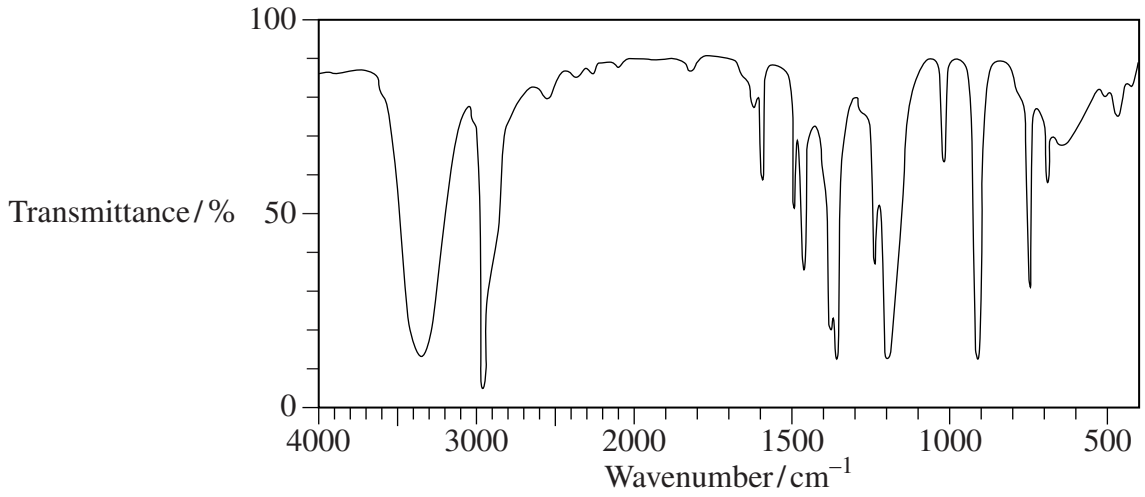
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Areas outside the box will not be scanned for marking

9 (b) The infrared spectrum of one of these isomeric alcohols is given below.



Identify **one** feature of the infrared spectrum which supports the fact that this is an alcohol. You may find it helpful to refer to **Table 1** on the Data Sheet.

Explain how infrared spectroscopy can be used to identify this isomeric alcohol.

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(3 marks)

(Extra space) .....

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Question 9 continues on the next page

Turn over ▶

Areas outside the box will not be scanned for marking

9 (c) British scientists have used bacteria to ferment glucose and produce the biofuel butan-l-ol.

Write an equation for the fermentation of glucose ($C_6H_{12}O_6$) to form butan-l-ol, carbon dioxide and water only.

State **one** condition necessary to ensure the complete combustion of a fuel in air.

Write an equation for the complete combustion of butan-l-ol and state why it can be described as a *biofuel*.

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(4 marks)

(Extra space) .....

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Areas outside the box will not be scanned for marking

9 (d) Butan-l-ol reacts with acidified potassium dichromate(VI) solution to produce two organic compounds.

State the class of alcohols to which butan-l-ol belongs.

Draw the displayed formula for **both** of the organic products.

State the type of reaction that occurs and the change in colour of the potassium dichromate(VI) solution.

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(5 marks)

(Extra space) .....

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15

Turn over for the next question

Areas outside the box will not be scanned for marking

10 (a) When chlorine gas dissolves in cold water, a pale green solution is formed. In this solution, the following equilibrium is established.

$$Cl_2(g) + H_2O(l) \rightleftharpoons H^+(aq) + Cl^-(aq) + HClO(aq)$$

Give the formula of the species responsible for the pale green colour in the solution of chlorine in water.

Use Le Chatelier's principle to explain why the green colour disappears when sodium hydroxide solution is added to this solution.

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(3 marks)

(Extra space) .....

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Areas outside the box will not be scanned for marking

10 (b) Consider the following reaction in which iodide ions behave as reducing agents.

$$Cl_2(aq) + 2I^-(aq) \longrightarrow I_2(aq) + 2Cl^-(aq)$$

In terms of electrons, state the meaning of the term *reducing agent*.

Deduce the half-equation for the conversion of chlorine into chloride ions.

Explain why iodide ions are stronger reducing agents than chloride ions.

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(4 marks)

(Extra space) .....

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Question 10 continues on the next page

Areas outside the box will not be scanned for marking

10 (c) When chlorine reacts with water in bright sunlight, only two products are formed. One of these products is a colourless, odourless gas and the other is an acidic solution that reacts with silver nitrate solution to give a white precipitate.

Write an equation for the reaction of chlorine with water in bright sunlight.

Name the white precipitate and state what you would observe when an excess of aqueous ammonia is added to it.

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(3 marks)

(Extra space) .....

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Areas outside the box will not be scanned for marking

10 (d) The reaction of chlorine with ethene is similar to that of bromine with ethene.

Name and outline a mechanism for the reaction of chlorine with ethene to form 1,2-dichloroethane, as shown by the following equation.

$$H_2C{=}CH_2 + Cl_2 \longrightarrow ClCH_2CH_2Cl$$

(5 marks)

15

END OF QUESTIONS

There are no questions printed on this page

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Version : 1.0 02/2010

General Certificate of Education

Chemistry 1421

CHEM2 Chemistry in Action

Mark Scheme

2010 examination - January series

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
1	a	i	Reducing agent ***OR*** Reduce(s) (WO_3 / tungsten oxide) ***OR*** electron donor ***OR*** to remove <u>oxygen</u> (from WO_3 / tungsten oxide or to form water);	1	
1	a	ii	$WO_3 + \mathbf{3}H_2 \longrightarrow W + \mathbf{3}H_2O$	1	Or multiples
1	a	iii	*One from* H_2 is • explosive • flammable or inflammable • easily ignited	1	Ignore reference to pressure or temperature
1	b	i	Addition ***OR*** (catalytic) hydrogenation ***OR*** Reduction	1	Ignore “electrophilic” Penalise “nucleophilic addition”
1	b	ii	Geometric(al) ***OR*** cis/trans OR E Z OR E/Z	1	
1	c	i	(If any factor is changed which affects an equilibrium), the position of <u>equilibrium</u> will <u>shift / move / change/ respond / act</u> so as <u>to oppose the change</u>. ***OR*** (When a system/reaction in equilibrium is disturbed), the <u>equilibrium</u> <u>shifts / moves</u> in a direction which tends <u>to reduce the disturbance</u>	1	A variety of wording will be seen here and the key part is the last phrase and must refer to <u>movement of the equilibrium</u>. **QoL**

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1	c	ii	**M1 – Statement of number of moles / molecules** There are <u>more moles / molecules</u> (of gas) on the left / of reactants ***OR*** <u>fewer moles / molecules</u> (of gas) on the right./ products ***OR*** there are <u>4 moles / molecules</u> (of gas) on the left <u>and 2 moles / molecules</u> on the right. **M2 – Explanation of response / movement in <u>terms of pressure</u>** <u>Increase in pressure is opposed</u> (or words to that effect) ***OR*** <u>pressure is lowered</u> by a shift in the equilibrium (from left) <u>to right</u> / favours forward reaction.	2	Ignore ”volumes” for M1 Mark independently
1	d		$\sum$ B(reactants) – $\sum$ B(products) = ΔH (**M1**) ***OR*** <u>Sum</u> of bonds broken – <u>Sum</u> of bonds formed = ΔH (**M1**) B(H–H) +½B(O=O) – 2B(O–H) = – 242 (**M1**) B(H–H) = – 242 – ½(+496) + 2(+463) (this scores **M1** and **M2**) B(H–H) = (+)**<u>436</u>** (kJ mol^{-1}) (**M3**) Award 1 mark for – 436 Candidates may use a cycle and gain full marks.	3	M1 could stand alone <u>Award full marks for correct answer</u>. Ignore units. Two marks can score with an arithmetic error in the working.

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
2	a		Heat (energy) change at constant pressure	1	Ignore references to standard conditions, but credit specified pressure.
2	b		The enthalpy change / heat (energy) change (at constant pressure) in a reaction is independent of the route / path taken (and depends only on the initial and final states)	1	
2	c		ΔH + 963 = –75 – 432 OR ΔH + 963 = – 507 (**M1**) ΔH = –75 – 432 – 963 (**M1** and **M2**) ΔH = **–1470** (kJ mol^{-1}) Award 1 mark for + 1470	3	Award full marks for correct answer Ignore units. Ignore numbers on the cycle **M1** and **M2** can score for an arithmetic error

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
3	a		NaBr ONLY	1	Penalise incorrect case or additional formulae. Ignore names
3	b		NaF ONLY	1	Penalise incorrect case or additional formulae. Ignore names
3	c		ONLY one from either NaF ***OR*** NaCl	1	Penalise incorrect case or additional formulae. Ignore names
3	d		NaI ONLY	1	Penalise incorrect case or additional formulae. Ignore names

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
4	a		Antacid ***OR*** to neutralise acidity ***OR*** eases indigestion	1	Credit suitable reference to indigestion or to laxative or to relief of constipation
4	b		**M1** Decrease in T decreases the energy of the particles / ions / H^+ / molecules **M2 (also scores M1)** Decrease in the number of / less particles / ions / H^+ / molecules with $E \geq E_{Act}$ or $E \geq$ minimum energy to react **M3** Few(er) / Less effective / productive / successful collisions	3	In **M1** and **M2,** credit "atoms" but ignore "calcium carbonate", ignore "calcium", ignore any ion formula except H^+ **QoL**
4	c	i	Strontium has a higher melting point than barium, because **Correct reference to size of cations/proximity of electrons** **M1** (For Sr) delocalised electrons closer to cations / positive ions / atoms / nucleus ***OR*** cations / positive ions / atoms are smaller ***OR*** cation / positive ion / atom or it has fewer (electron) shells / levels **Relative strength of metallic bonding** **M2** (Sr) has stronger attraction between the cations / positive ions / atoms / nucleus and the delocalised electrons ***OR*** stronger metallic bonding (assume argument refers to Sr but accept converse argument for Ba)	2	Ignore general Group 2 statements Penalise M1 if Sr or Ba is said to have more or less delocalised electrons Ignore reference to shielding **CE = 0** for reference to molecules or intermolecular forces or covalent bonds Ignore "Van der Waals forces (between atoms)" but penalise if "between molecules"
4	c	ii	$Sr + \mathbf{2}H_2O \longrightarrow Sr(OH)_2 + H_2$	1	Or multiples
4	d	i	$\mathbf{2}Mg + TiCl_4 \longrightarrow \mathbf{2}MgCl_2 + Ti$	1	Or multiples

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4	d	ii	It or $MgSO_4$ is <u>soluble</u> OR forms <u>a solution</u> (and is washed away) OR <u>dissolves</u>	1	Credit reference to $MgSO_4$ being the most soluble Group 2 sulfate. Ignore “disappears”

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Q	Part	Sub Part	Marking Guidance	Mark	*Comments*
5	a	i	Oxidation ***OR*** Oxidised ONLY	1	
5	a	ii	Any one from • to provide / overcome activation energy • to provide the minimum energy to make the reaction go / start	1	NOT simply to increase the (initial) reaction rate.
5	a	iii	The reaction is exothermic OR releases heat (energy)	1	
5	a	iv	**M1** Catalysts provide an alternative route / pathway OR an alternative mechanism ***OR*** (in this case) surface adsorption occurs (or a description of adsorption) **M2** Lowers the activation energy ***OR*** of lower activation energy	2	Ignore reference to “surface” alone
5	b		**M1** The (forward) reaction is exothermic OR the (forward) reaction releases heat ***OR*** The reverse reaction is endothermic or absorbs heat **M2** – Direction of change N.B. **M2** depends on correct **M1** At lower temperatures, • the equilibrium yield of NO2 is greater • more NO2 is formed • equilibrium shifts (left) to right • (equilibrium) favours the forward reaction (***OR*** converse for higher temperatures)	2	

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5	c		NO_2 (+) 4 $NO3^-$ (+) 5 HNO_2 (+) 3	3	

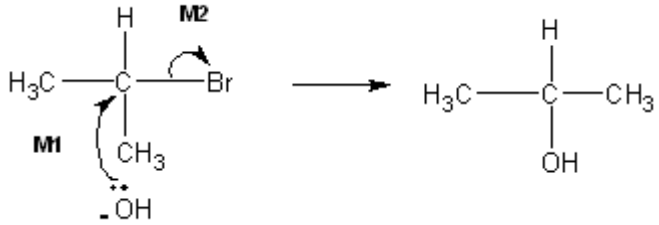
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Q	Part	Sub Part	Marking Guidance	Mark	Comments
6	a		Functional group (isomerism)	1	
6	b		**M1** Tollens' (reagent) *(Credit ammoniacal silver nitrate OR a description of making Tollens')* *(Ignore either $AgNO_3$ or $[Ag(NH_3)_2^+]$ or "the silver mirror test" on their own, but mark M2 and M3)* **M2** silver mirror OR black solid/precipitate *(NOT silver precipitate)* **M3 (**stays) colourless or no change or no reaction **M1** Fehling's (solution) or Benedict's solution *(Ignore $Cu^{2+}(aq)$ or $CuSO_4$ on their own, but mark on to M2 and M3)* **M2** Red solid/precipitate *(Credit orange or brown solid)* **M3 (**stays) blue or no change or no reaction Mark on from an incomplete / incorrect attempt at the correct reagent, penalising M1	3	No reagent, CE=0 Allow the following alternatives **M1** (acidified) potassium dichromate(VI) (solution) **M2** (turns) green **M3** (stays) orange / no change OR **M1** (acidified) potassium manganate(VII) (solution) **M2** (turns) colourless **M3** (stays) purple / no change For M3 Ignore "nothing (happens)" Ignore "no observation"
6	c		(Both have) C=O ***OR*** a carbonyl (group)	1	
6	d	i	(Free-) radical substitution ONLY	1	Penalise "(free) radical mechanism"

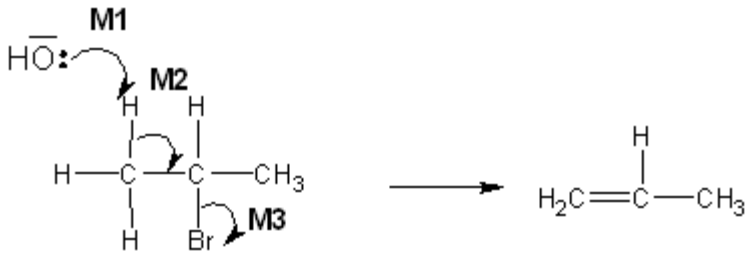
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6	d	ii	**Initiation** $Cl_2 \longrightarrow 2Cl\bullet$ **First propagation** $Cl\bullet + CH_3CH_2CH_3 \longrightarrow \bullet CH_2CH_2CH_3 + HCl$ OR C_3H_8 **Second propagation** $Cl_2 + \bullet CH_2CH_2CH_3 \longrightarrow CH_3CH_2CH_2Cl + Cl\bullet$ ***OR*** C_3H_7Cl **Termination (must make C_6H_{14})** $2 \bullet CH_2CH_2CH_3 \longrightarrow C_6H_{14}$ or $CH_3CH_2CH_2CH_2CH_2CH_3$	4	Penalise absence of dot once only. Penalise incorrect position of dot on propyl radical once only. Penalise $C_3H_7\bullet$ once only Accept $CH_3CH_2CH_2\bullet$ with the radical dot above / below / to the side of the last carbon. Use of the secondary free radical might gain 3 of the four marks
6	e		M_r = 44.06352 (for propane) M_r = 43.98982 (for carbon dioxide) **M1** a correct value for both of these M_r values. **M2** a statement or idea that two peaks appear (in the mass spectrum) ***OR*** two molecular ions are seen (in the mass spectrum).	2	Mark independently

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
7	a	i	Nucleophilic substitution  **M1** must show an arrow from the lone pair of electrons on the oxygen atom of the negatively charged hydroxide ion to the central C atom. **M2** must show the movement of a pair of electrons from the C-Br bond to the Br atom. Mark M2 independently. Award full marks for an S_N1 mechanism in which M1 is the attack of the hydroxide ion on the intermediate carbocation.	1 2	Penalise M1 if covalent KOH is used Penalise M2 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 1 mark **for the mechanism** for the wrong reactant and/or "sticks" Ignore product
7	a	ii	2-bromopropane ONLY	1	
7	a	iii	Polar C–Br ***OR*** polar carbon–bromine bond ***OR*** dipole on C–Br ***OR*** δ+ (δ–) C atom of carbon–bromine bond is δ+ / electron deficient ***OR*** C—Br (Credit carbon–halogen bond as an alternative to carbon–bromine bond)	1	It must be clear that the discussion is about the carbon atom of the C–Br bond. NOT just reference to a polar molecule. Ignore X for halogen

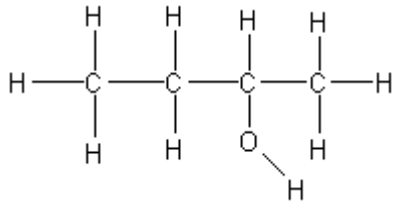
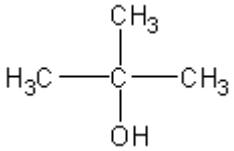
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7	b		Elimination  **M1** must show an arrow from the lone pair on oxygen of a negatively charged hydroxide ion to the correct H atom **M2** must show an arrow from the correct C-H bond to the C-C bond and should only be awarded if an attempt has been made at M1 **M3** is independent. Award full marks for an E1 mechanism in which M2 is on the correct carbocation.	1 3	Credit "base elimination" but NOT "nucleophilic elimination" No other prefix. Mechanism Penalise M1 if covalent KOH Penalise M3 for formal charge on C or incorrect partial charges Penalise once only for a line and two dots to show a bond. Max 2 marks **for the mechanism** for wrong reactant and/or "sticks" Ignore product
7	c		*Any one condition from this list to favour elimination;* • alcohol(ic) / ethanol(ic) (solvent) • high concentration of KOH / alkali / hydroxide OR concentrated KOH / hydroxide • high temperature or hot or heat under reflux or T = 78 to 100°C	1	Apply the list principle Ignore "aqueous" Ignore "excess"
7	d	i	Addition (polymerisation) ONLY	1	Penalise "additional"
7	d	ii	But-2-ene ONLY (hyphens not essential)	1	Ignore references to cis and trans or E/Z Ignore butene

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
8	a	i	**2**$CuFeS_2$ + **2**SiO_2 + **4**O_2 ⟶ Cu_2S + **2**$FeSiO_3$ + **3**SO_2	1	
8	a	ii	Acid rain ***OR*** an effect either from acid rain or from an acidic gas in the atmosphere	1	
8	a	iii	SO_2 could be used to make H_2SO_4 ***OR*** to make gypsum / plaster or $CaSO_4$ (xH_2O)	1	
8	b		Cu_2S + **2**O_2 ⟶ **2**CuO + SO_2	1	Or multiples Ignore state symbols
8	c		**2**CuO + C ⟶ **2**Cu + CO_2 ***OR*** CuO + C ⟶ Cu + CO	1	Or multiples Ignore state symbols
8	d	i	*Any one from the following two ONLY* • (Scrap) iron is cheap • Low energy requirement	1	Apply the list principle Not “less energy”
8	d	ii	Fe + Cu^{2+} ⟶ Fe^{2+} + Cu	1	Or multiples Ignore state symbols

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
9	a		**M1** Displayed formula for butan-2-ol  **M2** Alcohol **X** is  **M3** Alcohol **Y** is named (2)-methylpropan-1-ol ONLY	3	M1 displayed formula must have all bonds drawn out, including the O—H but ignore angles Penalise "sticks" M2 structure must be clearly identifiable as 2-methylpropan-2-ol and may be drawn in a variety of ways. M3 must be correct name, but ignore structures
9	b		**M1** The infrared spectrum shows an absorption / peak in the range 3230 to 3550 (cm^{-1})(which supports the idea that an alcohol is present) **M2** Reference to the 'fingerprint region' or below 1500 (cm^{-1}) **M3** Match with or same as known sample / database spectra ***OR*** alternatively **M2** Run infrared spectra (of the alcohols) **M3** Find which one matches or is the same as this spectrum.	3	In M1, allow the words "dip", "spike", "low transmittance" and "trough" as alternatives for absorption. Check the spectrum to see if alcohol OH is labelled and credit.

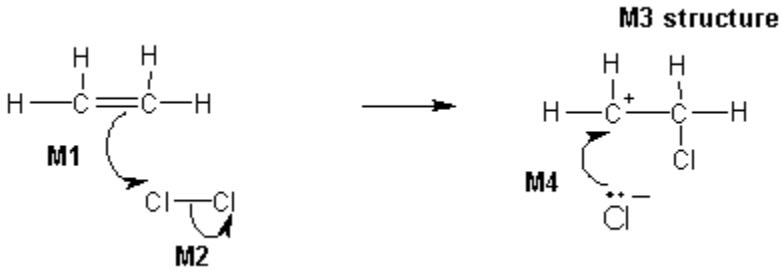
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9	c		**M1** balanced equation $C_6H_{12}O_6 \longrightarrow CH_3CH_2CH_2CH_2OH + \mathbf{2}CO_2 + H_2O$ or C_4H_9OH **M2** *Any one from* • excess/adequate/sufficient/ correct amount of /enough/plenty / a good supply of oxygen or air • good mixing of the fuel and air/oxygen **M3** $CH_3CH_2CH_2CH_2OH + \mathbf{6}O_2 \longrightarrow \mathbf{4}CO_2 + \mathbf{5}H_2O$ or C_4H_9OH **M4** A biofuel is a fuel produced from (renewable) biological (re)source(s) ***OR*** (renewable) (re)source(s) from (a specified) plant(s) /fruit(s) /tree(s)	4	Or multiples for M1 and M3 In M1 and M3 penalise use of $C_4H_{10}O$ or butan-2-ol once only For M2, do not accept simply "oxygen" or "air" alone Ignore reference to "temperature" In M4 Ignore references to "carbon neutral" Ignore "sugar" and "glucose"
9	d		**M1** butan-1-ol is a primary or 1° (alcohol) **M2** Displayed formula (ONLY) for butanal $CH_3CH_2CH_2CHO$ **M3** Displayed formula (ONLY) for butanoic acid $CH_3CH_2CH_2COOH$ **M4** Oxidation (oxidised) OR Redox **M5** orange to green	5	M2 and M3 displayed formula must have all bonds drawn out including the O—H but ignore angles. If butanal and butanoic acid formulae are both correctly given but not displayed, credit one mark out of two. Both colours required for M5 Ignore states

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Q	Part	Sub Part	Marking Guidance	Mark	Comments
10	a		**M1** Cl_2 (provides the pale green colour) **M2** NaOH reacts with the acid(s) / the HCl / the HClO / H^+ **M3** **requires a correct answer in M2** Equilibrium shifts (from left) to right OR wtte	3	M1 requires the formula Ignore "reacts with the products" Ignore "reacts with chloride ion" Ignore "reacts with chlorine"
10	b		**M1** A reducing agent is an electron donor OR (readily) loses / gives away electrons **M2** $Cl_2 + 2e^- \longrightarrow 2Cl^-$ For M3 and M4, **i**odide ions are stronger reducing agents than chloride ions, because **M3** **Relative size of ions / atomic radius / ionic radius** Iodide ions are larger / have more (electron) shells / levels than chloride ions (or converse for chloride ion) OR electron(s) to be lost/outer shell/level is further from the nucleus (or converse for chloride ion) OR greater / more shielding **M4** **Strength of attraction for electron(s) being lost** Electron(s) lost from an iodide ion is less strongly held by the nucleus compared with that lost from a chloride ion (assume argument refers to iodide ions but accept converse argument for chloride ions)	4	Penalise M1 if "electron pair donor" Ignore state symbols in M2 Accept no charge on the electron Credit the electrons being lost on the RHS M3 and M4 must be comparative and should refer to electrons. For M3 insist on "iodide ions"

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10	c		**M1** $\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$ **M2** <u>silver chloride</u> ONLY **M3** The solid / precipitate would dissolve ***OR*** is soluble ***OR*** (It) forms a (colourless) solution	3	Or multiples <u>M2 requires a name</u> Mark M3 independently Ignore "disappears"
10	d		<u>Electrophilic addition</u> *Mechanism:*  **M1**must show an arrow from the double bond towards one of the Cl atoms on a Cl–Cl molecule. **M2** must show the breaking of the Cl–Cl bond. **M3** is for the structure of the carbocation with Cl substituent. **M4** must show an arrow from the lone pair of electrons on a negatively charged chloride ion towards the positively charged carbon atom.	1 4	M2 Penalise partial charges if wrong way around, otherwise ignore Max 3 marks **<u>for the mechanism</u>** for wrong reactant and/or "sticks" (wrong reactant could be HBr or Br_2 or incorrect alkene)

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General principles applied to marking CHEM2 papers by CMI+ for January 2010

It is important to note that the guidance given here is generic and specific variations may be made at individual standardising meetings in the context of particular questions and papers.

A. The "List principle" and the use of "ignore" in the mark scheme

If a question requires **one** answer and a candidate gives two answers, no mark is scored if one answer is correct and one answer is incorrect. There is no penalty if both answers are correct.

N.B. Certain answers are designated in the mark scheme as those which the examiner should "Ignore". These answers are not counted as part of the list and should be ignored and will not be penalised.

B. Incorrect case for element symbol

The use of an incorrect case for the symbol of an element should be penalised **once only** within a clip.
For example, penalise the use of "h" for hydrogen, "CL" for chlorine or "br" for bromine.

C. Spelling

In general

- The names of chemical compounds and functional groups **must be spelled correctly** to gain credit.
- Phonetic spelling may be acceptable for some chemical terminology.

N.B. Some terms may be required to be spelled correctly as part of the "Quality of Language" (QoL) marking.

D. Equations

In general

- Equations **must** be balanced.
- When an equation is worth two marks, one of the marks in the mark scheme will be allocated to one or more of the reactants or products. This is independent of the equation balancing.
- State symbols are generally ignored, unless specifically required in the mark scheme.

E. Reagents

The guiding principle is that a reagent is a chemical which can be taken out of a bottle or container. Failure to identify whole reagents **will be penalised**. The command word "Identify", allows the candidate to choose to use either the name or the formula in their answer. In some circumstances, the list principle may apply when both are used.

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For example

potassium cyanide rather than cyanide ion **or** KCN rather than CN^-

sodium hydroxide rather than hydroxide ion **or** NaOH rather than OH^-

F. Marking calculations, such as those involving enthalpy changes

In general

- The sign for an enthalpy change will be assumed to be positive unless specifically shown to be negative.
- A correct answer alone will score **full marks** unless the necessity to show working is specifically required in the question.
- A correct numerical value with the **wrong sign** will score **only one mark**.

All other values **gain no credit** except

- Two marks can be awarded for correct chemistry with an arithmetic error.
- One mark can be awarded for a correct mathematical statement (or cycle) for the method.

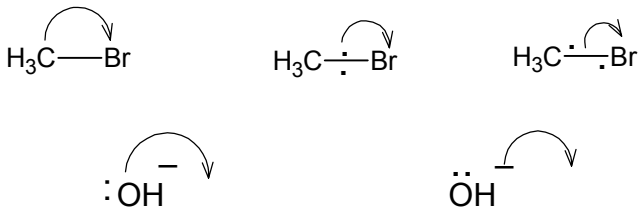
G. Oxidation states

In general, the sign for an oxidation state will be assumed to be positive unless specifically shown to be negative.

H. Organic reaction mechanisms

Curly arrows should originate either from a lone pair of electrons or from a bond.

Each of the following representations **should not gain credit** and will be penalised **once only** within a clip.



When the curly arrow is showing the formation of a bond to an atom, the arrow can go directly to the relevant atom, alongside the relevant atom or **more than half-way** towards the relevant atom.

In free-radical substitution

- The absence of a radical dot should be penalised **once only** within a clip.
- The use of double-headed arrows or the incorrect use of half-headed arrows in free-radical mechanisms should be penalised **once only** within a clip

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I. Organic structures

In general

- Displayed formulae must show all of the bonds in the molecule, but need not show correct bond angles.
- Bonds should be drawn correctly between the relevant atoms.
  For example, if candidates show the alcohol functional group as C-H-O, they should be penalised **on every occasion**.
- Some latitude should be given to the representation of C-C bonds in structures, given that CH_3— is considered to be interchangeable with H_3C— even though the latter would be preferred.
- Poor presentation of vertical C — CH_3 bonds or C — OH bonds or C — NH_2 bonds should **not** gain credit. The limit of tolerance is the half-way position between the vertical bond and the relevant atoms in the attached group.
- The use of 'sticks' in structures should **not** gain credit. The occasions that this applies will be indicated in the mark scheme.

- Some examples of formulae for specific compounds which should **not** gain credit are given here

CH_3COH	for	ethanal
CH_3CH_2HO	for	ethanol
$OHCH_2CH_3$	for	ethanol
C_2H_6O	for	ethanol
CH_2CH_2	for	ethene
$CH_2.CH_2$	for	ethene
$CH_2:CH_2$	for	ethene

N.B. Exceptions may be made in the context of balancing equations

Each of the following **should gain credit** as alternatives to correct representations of the structures.

$CH_2 = CH_2$	for	ethene, $H_2C=CH_2$
$CH_3CHOHCH_3$	for	propan-2-ol, $CH_3CH(OH)CH_3$

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J. Organic names

As a general principle, non-IUPAC names or incorrect spelling or incomplete names should **not** gain credit.
Some illustrations are given here.

but-2-ol
2-hydroxybutane — all should be **butan-2-ol**
butane-2-ol
2-butanol

2-methpropan-2-ol — should be **2-methylpropan-2-ol**

2-methylbutan-3-ol — should be **3-methylbutan-2-ol**

3-methylpentan — all should be **3-methylpentane**
3-mythylpentane
3-methypentane

propanitrile — should be **propanenitrile**

aminethane — should be **ethylamine** (although aminoethane can gain credit)

2-methyl-3-bromobutane — all should be **2-bromo-3-methylbutane**
3-bromo-2-methylbutane
3-methyl-2-bromobutane

2-methylbut-3-ene — should be **3-methylbut-1-ene**

difluorodichloromethane — should be **dichlorodifluoromethane**

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