INSTRUCTIONS
• Use black ink. You may use an HB pencil for graphs and diagrams.
• Complete the boxes above with your name, centre number and candidate number.
• Answer all the questions.
• Where appropriate, your answers should be supported with working. Marks may be given for a correct method even if the answer is incorrect.
• Write your answer to each question in the space provided.
• Additional paper may be used if required but you must clearly show your candidate number, centre number and question number(s).
• Do not write in the bar codes.

INFORMATION
• The total mark for this paper is 70.
• The marks for each question are shown in brackets [ ].
• This document consists of 28 pages.
2

SECTION A

You should spend a maximum of 25 minutes on this section.

Answer all the questions.

1. How many electrons are in a $^{24}_{12}\text{Mg}^{2+}$ ion?
   
   A. 10  
   B. 12  
   C. 14  
   D. 22  

   Your answer [ ]

2. What is the formula of chromium(III) sulfate?
   
   A. $\text{Cr}_3\text{SO}_4$  
   B. $\text{Cr(SO}_4)_3$  
   C. $\text{Cr}_2(\text{SO}_4)_3$  
   D. $\text{Cr}_3\text{SO}_3$  

   Your answer [ ]

3. Which molecule is non-polar?
   
   A. $\text{SF}_6$  
   B. $\text{H}_2\text{S}$  
   C. $\text{PF}_3$  
   D. $\text{NH}_3$  

   Your answer [ ]
4 Which row is correct?

<table>
<thead>
<tr>
<th>Highest pH when added to water</th>
<th>Most reactive halogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>A MgO</td>
<td>F₂</td>
</tr>
<tr>
<td>B MgO</td>
<td>I₂</td>
</tr>
<tr>
<td>C BaO</td>
<td>F₂</td>
</tr>
<tr>
<td>D BaO</td>
<td>I₂</td>
</tr>
</tbody>
</table>

Your answer [ ]

5 Which equation represents a redox reaction?

A Mg + 2HCl → MgCl₂ + H₂
B MgO + 2HCl → H₂O + MgCl₂
C MgCO₃ + 2HCl → CO₂ + H₂O + MgCl₂
D Mg(OH)₂ + 2HCl → MgCl₂ + 2H₂O

Your answer [ ]

6 This question is about trends in the periodic table.

Which trend is correct?

A melting point decreases from lithium to carbon
B boiling point decreases from fluorine to iodine
C first ionisation energy decreases from lithium to caesium
D first ionisation energy increases from nitrogen to oxygen

Your answer [ ]
7 A sample of a compound $\text{M}$ contains 1.46 g of carbon, 0.482 g of hydrogen and 1.69 g of nitrogen.

What is the empirical formula of $\text{M}$?

A $\text{CH}_2\text{N}$  
B $\text{CaHN}_3$  
C $\text{CH}_4\text{N}$  
D $\text{C}_2\text{H}_4\text{N}$

Your answer [1]

8 A student mixes 100 cm$^3$ of 0.200 mol dm$^{-3}$ NaCl(aq) with 100 cm$^3$ of 0.200 mol dm$^{-3}$ $\text{Na}_2\text{CO}_3$(aq).

What is the total concentration of $\text{Na}^+$ ions in the mixture formed?

A 0.100 mol dm$^{-3}$  
B 0.200 mol dm$^{-3}$  
C 0.300 mol dm$^{-3}$  
D 0.400 mol dm$^{-3}$

Your answer [1]

9 Which mass of substance contains the greatest number of atoms?

A 3.00 g of ammonia, $\text{NH}_3$  
B 3.00 g of chloromethane, $\text{CHCl}_3$  
C 4.00 g of hydrogen sulfide, $\text{H}_2\text{S}$  
D 4.00 g of hydrogen chloride, $\text{HCl}$

Your answer [1]
10 Which reagent would exactly neutralise 100 cm$^3$ of 1.00 mol dm$^{-3}$ H$_2$SO$_4$(aq)?

A 0.100 mol Al(OH)$_3$

B 0.100 mol NH$_3$

C 0.100 mol Ba(OH)$_2$

D 0.100 mol NaOH

Your answer

11 The table below shows standard enthalpy changes of formation, $\Delta H$.

<table>
<thead>
<tr>
<th>Compound</th>
<th>NH$_4$NO$_3$(s)</th>
<th>H$_2$O(g)</th>
<th>CO$_2$(g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta H$ / kJ mol$^{-1}$</td>
<td>−366</td>
<td>−242</td>
<td>−394</td>
</tr>
</tbody>
</table>

What is the enthalpy change for the following reaction?

$$2\text{NH}_4\text{NO}_3(s) + C(s) \rightarrow 2\text{N}_2(g) + 4\text{H}_2\text{O}(g) + \text{CO}_2(g)$$

A −630 kJ mol$^{-1}$

B −540 kJ mol$^{-1}$

C +540 kJ mol$^{-1}$

D +630 kJ mol$^{-1}$

Your answer
Carbon monoxide reacts with steam in the following reaction equation:

\[
\text{CO}(g) + \text{H}_2\text{O} (g) \rightleftharpoons \text{CO}_2(g) + \text{H}_2(g) \quad \Delta H = -40 \text{ kJ mol}^{-1}
\]

Which change will shift the position of equilibrium to the right hand side of the equation?

A decrease in pressure  
B increase in pressure  
C decrease in temperature  
D increase in temperature

Your answer [ ]

Which substance contains hydrogen bonding in the liquid state?

A \(\text{CH}_3(\text{CH}_2)_4\text{CH}_3\)  
B \(\text{CH}_3(\text{CH}_2)_3\text{CHFCH}_3\)  
C \(\text{CH}_3(\text{CH}_2)_3\text{COCH}_3\)  
D \(\text{CH}_3(\text{CH}_2)_3\text{CH(OH)CH}_3\)

Your answer [ ]

Which volume of oxygen gas, at room temperature and pressure, is required for complete combustion of \(1.25 \times 10^{-3}\) mol of propan-1-ol?

A \(105 \text{ cm}^3\)  
B \(120 \text{ cm}^3\)  
C \(135 \text{ cm}^3\)  
D \(120 \text{ cm}^3\)

Your answer [ ]
15 Three of the following displayed formulae represent the same isomer of C₃H₄Cl₂ but one structure represents a different isomer, X.

Which displayed formula represents X?

A
\[
\begin{align*}
\text{Cl} & \quad \text{H} \\
\text{H} & \quad \text{C} &= \text{C} \\
\text{H} & \quad \text{Cl} \\
\end{align*}
\]

B
\[
\begin{align*}
\text{H} & \quad \text{C} &= \text{C} \\
\text{Cl} & \quad \text{H} \\
\end{align*}
\]

C
\[
\begin{align*}
\text{Cl} & \quad \text{H} \\
\text{H} & \quad \text{C} &= \text{C} \\
\text{C} & \quad \text{H} \\
\text{H} & \quad \text{Cl} \\
\end{align*}
\]

D
\[
\begin{align*}
\text{H} & \quad \text{C} &= \text{C} \\
\text{Cl} & \quad \text{C} &= \text{Cl} \\
\end{align*}
\]

Your answer [ ]

16 Which alcohol will not react with potassium dichromate(VI) in sulfuric acid?

A \[ \text{CH₃CH₂CH(OH)CH₃} \]

B \[ \text{CH₃CH₂CH(CH₃)CH₂OH} \]

C \[ \text{(CH₃)₂CHCH(CH₂)OH} \]

D \[ \text{(CH₃CH₂)₂C(CH₃)OH} \]

Your answer [ ]
17 A section of a polymer chain is shown below.

Identify the monomer that would give rise to this section of addition polymer.

A  E-But-2-ene
B  Z-But-2-ene
C  Methylpropene
D  Propene

Your answer [ ]
18 (a) A student used the apparatus below in an experiment to determine the enthalpy change of combustion of methanol.

The student measured 100 cm³ and poured it into the beaker.

The student measured a temperature rise of 10.5 °C.

The student calculated the amount of energy transferred to the water.

Which of the following uses the appropriate number of significant figures and correct standard form to represent the result of the calculation?

A  4.389 × 10³ J
B  4.39 × 10³ J
C  43.9 × 10² J
D  44.0 × 10² J

Your answer  [1]
18 (b) The student’s calculated enthalpy change was less exothermic than the value in data books.

Which of the following errors could have contributed to this result?

**Error 1:** After the final temperature was recorded, the student removed the burner from under the beaker. The flame burnt for a further 5 minutes before weighing the spirit burner.

**Error 2:** The student recorded the final temperature 5 minutes after removing the burner.

**Error 3:** The student spilt some water on the bench when pouring the water from the measuring cylinder into the beaker.

A 1, 2 and 3  
B Only 1 and 2  
C Only 2 and 3  
D Only 1

Your answer

19 A student prepares a standard solution and carries out a titration. The standard solution is placed in the burette.

Which of the following would result in a titre that is larger than it should be?

1: Water is added to completely fill the volumetric flask, rather than to the graduation line.

2: The conical flask is washed out with water before carrying out each titration.

3: The pipette is washed out with water before carrying out each titration.

A 1, 2 and 3  
B Only 1 and 2  
C Only 2 and 3  
D Only 1

Your answer
SECTION B

Answer all the questions.

20 Bromine and mercury are the only two naturally occurring elements that are liquids at room temperature and pressure. Some physical properties of these two elements are given below.

<table>
<thead>
<tr>
<th></th>
<th>Appearance at room temperature</th>
<th>Melting point / °C</th>
<th>Boiling point / °C</th>
<th>Electrical conductivity of the liquid</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bromine</td>
<td>dark orange liquid</td>
<td>−7.2</td>
<td>58.8</td>
<td>very low</td>
</tr>
<tr>
<td>Mercury</td>
<td>shiny silver liquid</td>
<td>−38.8</td>
<td>356.7</td>
<td>good</td>
</tr>
</tbody>
</table>

(a) Complete the full electron configuration of a bromine atom.

1s²………………………………………………………………………………………………………………………… [1]

(b) Bromine and mercury react with many elements and compounds.

Predict the formula of the compound formed when bromine reacts with aluminium.

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(c) Explain how the structure and bonding in bromine account for its relatively low melting point.

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(d) Mercury and bromine react together to form mercury(II) bromide, HgBr₂.

Describe and explain how electrical conductivity occurs in mercury(II) bromide and mercury, in both solid and molten states.

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Carbon monoxide can be made in the laboratory by heating a mixture of zinc metal and calcium carbonate. An equation for this reaction is shown below.

\[ \text{Zn}(s) + \text{CaCO}_3(s) \rightarrow \text{ZnO}(s) + \text{CaO}(s) + \text{CO}(g) \]

(a) This reaction is a redox reaction.

Deduce which element has been oxidised and which has been reduced, and state the change in oxidation number in each case.

- Element oxidised ............... Oxidation number change: from ...... to ......
- Element reduced ............... Oxidation number change: from ...... to ......

[2]

(b) Carbon monoxide contains a triple bond, and includes a dative covalent bond.

Construct a ‘dot-and-cross’ diagram to show the outer electron pairs in a molecule of carbon monoxide.

[2]
(c) A student carried out the reaction of zinc (Zn) and calcium carbonate (CaCO₃) in a fume cupboard. The student measured the volume of gas produced.

A mixture containing 0.27 g of powdered zinc and 0.38 g of powdered CaCO₃ was heated strongly for two minutes. The volume of gas collected in the 100 cm³ syringe was then measured. The experiment was then repeated.

(i) Calculate the maximum volume of carbon monoxide, measured at room temperature and pressure, that could be produced by heating this mixture of Zn and CaCO₃.

\[
\text{volume of carbon monoxide} = \ldots \ldots \ldots \ldots \ldots \text{cm}^3
\]

(ii) The student did not obtain the volume of gas predicted in (i) using this procedure.

Apart from further repeats, suggest two improvements to the practical procedure that would allow the student to obtain a more accurate result.
(d) The student repeated the experiment in (c) using different quantities of zinc and calcium carbonate.

The student measured the total volume of gas collected over time.

The student’s results are shown below.

<table>
<thead>
<tr>
<th>Time / s</th>
<th>Total volume of gas collected / cm³</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>20</td>
<td>13</td>
</tr>
<tr>
<td>40</td>
<td>42</td>
</tr>
<tr>
<td>60</td>
<td>56</td>
</tr>
<tr>
<td>80</td>
<td>65</td>
</tr>
<tr>
<td>100</td>
<td>72</td>
</tr>
<tr>
<td>120</td>
<td>72</td>
</tr>
</tbody>
</table>

(i) Plot a graph from the data provided.

Include a line of best fit.
(ii) Using the graph, determine the rate of reaction, in cm$^3$ s$^{-1}$, after 50 s.

Show your working on your graph.

rate after 50 s = .................................. cm$^3$ s$^{-1}$  [2]
22 The organic compounds labelled A to E below are all produced by living organisms.

(a) State the systematic name of compound A.

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

(b) Compound D reacts readily with hydrogen chloride in an addition reaction. Two products are formed in this reaction, but one of the products is formed in much greater amounts than the other.

(i) Draw the structure of both possible addition products of this reaction.

product 1

product 2  [2]
(ii) State and explain which of the two possible products will be formed in greater amounts. Include a diagram of the intermediate in the mechanism of this reaction in your answer.

(iii) 4.125 g of compound D is reacted with an excess of hydrogen chloride. The mixture of products contains 95% by mass of one product and 5% by mass of the other product.

Calculate the mass of each product formed.
(c) Analysis of one of the compounds A to E is shown below.

Percentage composition by mass: C, 78.94%; H, 10.53%; O 10.53%

Infrared spectrum:

Use this information to identify the compound.

Explain your reasoning, referring to all the evidence provided.

........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................
........................................................................................................................................ [3]
A student carries out the following experiment to investigate the reaction between hexane and chlorine.

The chlorine is made by reaction of aqueous sodium chlorate(I) with dilute hydrochloric acid.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 cm³ of hexane is mixed with 1 cm³ dilute aqueous sodium chlorate(I) in a test-tube.</td>
<td>The mixture forms two colourless layers.</td>
</tr>
<tr>
<td>1 cm³ dilute hydrochloric acid is slowly added to the mixture.</td>
<td>The acid mixes with the lower layer, which turns a pale green colour.</td>
</tr>
<tr>
<td>The tube is then stoppered and shaken.</td>
<td>The pale green colour moves to the upper layer, leaving the lower layer colourless.</td>
</tr>
<tr>
<td>The tube is placed under a bright light and shaken at regular intervals for about 10 minutes. The stopper is loosened regularly to release any pressure.</td>
<td>The pale green colour slowly disappears leaving two colourless layers after about 10 minutes.</td>
</tr>
</tbody>
</table>

(a)  
(i) The reaction between aqueous sodium chlorate(I) and dilute hydrochloric acid produces aqueous sodium chloride as well as chlorine.

Suggest an equation for this reaction.

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

(ii) Outline a simple practical test that would confirm the presence of chloride ions in the lower layer, and give the expected result.

test: ....................................................................................................................................................
result: ..................................................................................................................................................
.......................................................................................................................................................... [2]

(iii) Name the apparatus that could be used to separate the two liquid layers present at the end of the experiment.

.......................................................................................................................................................... [1]
(b) The reaction of hexane with chlorine took place when the bright light was switched on.

(i) Give the skeletal formula of one possible organic product of this reaction.

(ii) Explain why this type of mechanism is likely to produce a mixture of organic products.
Every year, two million tonnes of ethanol are produced worldwide by hydration of ethene obtained from crude oil.

\[
\text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{g}) \rightleftharpoons \text{C}_2\text{H}_5\text{OH}(\text{g}) \quad \Delta H = -45 \text{ kJ mol}^{-1}
\]

This reaction is typically carried out using a catalyst at 300 °C and 6000 kPa.

(a) The catalyst allows the reaction to reach equilibrium more quickly at the given temperature and pressure.

(i) State the catalyst used in this reaction.

(ii) Outline how a catalyst increases the rate of a chemical reaction.
(b) An increasing amount of ethanol is made by the fermentation of glucose from plants, rather than by the hydration of ethene. Fermentation is catalysed by enzymes from yeast at a temperature of 40 °C and a pressure of 100 kPa.

\[ \text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \rightarrow 2\text{C}_2\text{H}_5\text{OH}(\text{aq}) + 2\text{CO}_2(\text{g}) \]

Compare the sustainability of each process for the manufacture of ethanol, by considering their:

- atom economies
- raw materials
- reaction conditions.

Suggest which process is the more sustainable.
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Sample Mark Scheme

Maximum Mark: 70

Duration: 1 hour 30 minutes
MARKING INSTRUCTIONS

PREPARATION FOR MARKING

SCORIS

1. Make sure that you have accessed and completed the relevant training packages for on-screen marking: scoris assessor Online Training; OCR Essential Guide to Marking.

2. Make sure that you have read and understood the mark scheme and the question paper for this unit. These are posted on the RM Cambridge Assessment Support Portal http://www.rm.com/support/ca

3. Log-in to scoris and mark the required number of practice responses (“scripts”) and the required number of standardisation responses.

YOU MUST MARK 10 PRACTICE AND 10 STANDARDISATION RESPONSES BEFORE YOU CAN BE APPROVED TO MARK LIVE SCRIPTS.

MARKING

1. Mark strictly to the mark scheme.

2. Marks awarded must relate directly to the marking criteria.

3. The schedule of dates is very important. It is essential that you meet the scoris 50% and 100% (traditional 50% Batch 1 and 100% Batch 2) deadlines. If you experience problems, you must contact your Team Leader (Supervisor) without delay.

4. If you are in any doubt about applying the mark scheme, consult your Team Leader by telephone, email or via the scoris messaging system.
5. Work crossed out:
   a. where a candidate crosses out an answer and provides an alternative response, the crossed out response is not marked and gains no marks
   b. if a candidate crosses out an answer to a whole question and makes no second attempt, and if the inclusion of the answer does not cause a rubric infringement, the assessor should attempt to mark the crossed out answer and award marks appropriately.

6. Always check the pages (and additional objects if present) at the end of the response in case any answers have been continued there. If the candidate has continued an answer there then add a tick to confirm that the work has been seen.

7. There is a NR (No Response) option. Award NR (No Response)
   - if there is nothing written at all in the answer space
   - OR if there is a comment which does not in any way relate to the question (e.g. ‘can’t do’, ‘don’t know’)
   - OR if there is a mark (e.g. a dash, a question mark) which isn’t an attempt at the question.

Note: Award 0 marks – for an attempt that earns no credit (including copying out the question).

8. The scoris comments box is used by your Team Leader to explain the marking of the practice responses. Please refer to these comments when checking your practice responses. **Do not use the comments box for any other reason.**

If you have any questions or comments for your Team Leader, use the phone, the scoris messaging system, or email.

9. Assistant Examiners will send a brief report on the performance of candidates to their Team Leader (Supervisor) via email by the end of the marking period. The report should contain notes on particular strengths displayed as well as common errors or weaknesses. Constructive criticism of the question paper/mark scheme is also appreciated.
10. Annotations

<table>
<thead>
<tr>
<th>Annotation</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DO NOT ALLOW</strong></td>
<td>Answers which are not worthy of credit</td>
</tr>
<tr>
<td><strong>IGNORE</strong></td>
<td>Statements which are irrelevant</td>
</tr>
<tr>
<td><strong>ALLOW</strong></td>
<td>Answers that can be accepted</td>
</tr>
<tr>
<td>()</td>
<td>Words which are not essential to gain credit</td>
</tr>
<tr>
<td>___</td>
<td>Underlined words must be present in answer to score a mark</td>
</tr>
<tr>
<td><strong>ECF</strong></td>
<td>Error carried forward</td>
</tr>
<tr>
<td><strong>AW</strong></td>
<td>Alternative wording</td>
</tr>
<tr>
<td><strong>ORA</strong></td>
<td>Or reverse argument</td>
</tr>
</tbody>
</table>
11. **Subject-specific Marking Instructions**

**INTRODUCTION**

Your first task as an Examiner is to become thoroughly familiar with the material on which the examination depends. This material includes:

- the specification, especially the assessment objectives
- the question paper
- the mark scheme.

You should ensure that you have copies of these materials.

You should ensure also that you are familiar with the administrative procedures related to the marking process. These are set out in the OCR booklet *Instructions for Examiners*. If you are examining for the first time, please read carefully Appendix 5 *Introduction to Script Marking: Notes for New Examiners*.

Please ask for help or guidance whenever you need it. Your first point of contact is your Team Leader.
<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>A</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>A</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>A</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>A</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>D</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>C</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>D</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>D</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>D</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>18a</td>
<td>B</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>18b</td>
<td>B</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>D</td>
<td>1</td>
<td></td>
</tr>
</tbody>
</table>

**Total** 20
## SECTION B

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 (a)</td>
<td>$1s^22s^22p^63s^23p^63d^{10}4s^24p^6$ ✓</td>
<td>1</td>
<td>ALLOW …$4s^23d^{10}$…</td>
</tr>
<tr>
<td>(b)</td>
<td>$\text{AlBr}_3$ ✓</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>(c)</td>
<td>forces between (simple) molecules … ✓</td>
<td>3</td>
<td>IGNORE any reference to covalent bonds&lt;br&gt;ALLOW van der Waals’ forces&lt;br&gt;OR&lt;br&gt;London forces … ✓&lt;br&gt;… are weak, so (relatively easily) overcome by increased thermal motion/kinetic energy ✓</td>
</tr>
<tr>
<td>(d)</td>
<td>$\text{HgBr}_2$ conducts when molten but not when solid ✓</td>
<td>5</td>
<td>Explanations must be included for 2nd and 3rd marks.&lt;br&gt;IGNORE references to aqueous $\text{HgBr}_2$&lt;br&gt;IGNORE ‘delocalised ions’ OR ‘free ions’ for ‘mobile ions’&lt;br&gt;DO NOT ALLOW any mention of electrons moving&lt;br&gt;DO NOT ALLOW any mention of + ions moving&lt;br&gt;Mercury conducts in both the solid and molten states … ✓&lt;br&gt;… because delocalised electrons move (in both solid and liquid state) ✓</td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
<td>Marks</td>
<td>Guidance</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>(e) (i)</td>
<td>((85.00 \times 72.17) + (87.00 \times 27.83)) (\div 2) (\checkmark) (= 85.56) (to 2 d.p.) (\checkmark)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>(ii) Rubidium OR Rb</td>
<td></td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
<td>Marks</td>
<td>Guidance</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>21 (a)</td>
<td>Element oxidised: zinc/Zn 0 to +2 ✓</td>
<td>2</td>
<td>ALLOW 1 mark for all oxidation numbers correct, but oxidised and reduced the wrong way around max 1 mark if missing ‘+’ or ‘if given as charges e.g. ‘2+’</td>
</tr>
<tr>
<td></td>
<td>Element reduced: carbon/C +4 to +2 ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(b)</td>
<td><img src="image" alt="Diagram" /></td>
<td>2</td>
<td>mark can be awarded if either lone pair is missing, but there must be three shared pairs</td>
</tr>
<tr>
<td></td>
<td>three shared electron pairs plus a lone pair on C and O ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>one of the shared pairs shown as dative – i.e. both with the same type of dot/cross as the other electrons around the O ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(c) (i)</td>
<td><em>Determining limiting factor</em></td>
<td>2</td>
<td>evidence of 0.27/65.4 is required (or using the mass ratio to predict 0.116g of CO from 0.27g Zn)</td>
</tr>
<tr>
<td></td>
<td>( n(\text{Zn}) = \frac{0.27}{65.4} = 0.0041 \text{ mol} ) AND</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( n(\text{CaCO}_3) = \frac{0.38}{100.1} = 0.0038 \text{ mol} ) so Zn is in excess ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><em>Determining volume of CO</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ratio 1:1, so ( n(\text{CO}) = 0.0038 \text{ (mol)} ) vol. CO = 0.0038 x 24.0 = 0.091 \text{ dm}^3 = 91 \text{ (cm}^3) ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>ALLOW 2 sig figs up to calculator answer ALLOW second and third marks for correct final answer with no working ALLOW 2 marks for 99 cm(^3) from excess Zn mass</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
<td>Marks</td>
<td>Guidance</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>-------</td>
<td>----------</td>
</tr>
</tbody>
</table>
| (ii)     | heat until syringe stops moving/no further gas produced ✓ | 2 | ALLOW heat for longer than two minutes
|          | wait until the gas has cooled (to room temperature) before measuring the volume owtte ✓ | | ALLOW heat a greater mass |
| (d)      | (i) axes: labels correct, AND units AND scales chosen so that the plotted points occupy at least half the graph grid in both the x and y directions ✓ | 3 | |
|          | All points plotted correctly ✓ | | |
|          | Best curve drawn through points AND ignoring point at 20 s ✓ | | |
| (ii)     | Tangent tangent drawn to curve at $t = 50$ s ✓ | 2 | Annotate tangent on graph
|          | Calculation of rate from the gradient of tangent drawn e.g. rate = $\frac{64}{94} = 0.68$ (cm$^3$ s$^{-1}$) ✓ | | Note: This mark can only be awarded from a tangent
|          | Note: If candidate calculates rate via ln 2 method, consult with TL | | |
|          | | | |
|          | | | TOTAL 13 |

| SPECIMEN |
**Question 22**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
<th>Marks</th>
<th>Guidance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>(a)</strong></td>
<td>4-methylheptan-3-ol ✓</td>
<td>1</td>
<td>ALLOW 4-methyl-3-heptanol</td>
</tr>
<tr>
<td><strong>(b)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(i)</td>
<td><img src="image" alt="Chemical Structures" /></td>
<td>2</td>
<td>ALLOW any unambiguous structure or formula</td>
</tr>
<tr>
<td></td>
<td>ALLOW ECF on the second structure for hydrogen atom errors if candidate tries to convert to a displayed/structural formula, but the carbon skeleton must be correct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(ii)</td>
<td>correct structure of either possible carbocation intermediate shown ✓</td>
<td>2</td>
<td>If both carbocations are drawn, only one needs to be correct to score the mark</td>
</tr>
<tr>
<td></td>
<td>the tertiary halogenoalkane (which will be labelled as either product 1 or product 2) is identified as the one formed in greater amounts … because the carbocation more stable on C3 than C2 owtte ✓</td>
<td></td>
<td>ALLOW ECF from (i) for correct justification of product formed in greater amount based on incorrect structures</td>
</tr>
<tr>
<td>(iii)</td>
<td>Amount of D that reacts</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(M(D: \text{C}<em>7\text{H}</em>{10}\text{O}) = 110 \text{ (g} \text{ mol}^{-1})) AND [\frac{n(\text{C}<em>7\text{H}</em>{10}\text{O})}{110} = 0.0375 \text{ (mol)} ✓]</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Masses of two products formed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(M(\text{product: C}<em>7\text{H}</em>{11}\text{OCl}) = 146.5 \text{ (g} \text{ mol}^{-1})) AND</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mass of 95% product = 0.0375 \times \frac{95}{100} \times 146.5 = 5.22 \text{ g} AND</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
<td>Marks</td>
<td>Guidance</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td></td>
<td>Mass of 5% product $= 0.0375 \times \frac{5}{100} \times 146.5 = 0.27 \text{ g}$ ✓</td>
<td>ALLOW Mass of both products $= 0.0375 \times 146.5 = 5.49 \text{ g}$&lt;br&gt;Mass of 95% product $= \frac{95}{100} \times 5.49 = 5.22 \text{ g}$&lt;br&gt;Mass of 5% product $= \frac{5}{100} \times 5.49 = 0.27 \text{ g}$ ✓</td>
<td>ALLOW 'product 1' and 'product 2' if linked to correct mass given labelling in (i) and reasoning in (ii) (ALLOW ECF from (ii)).</td>
</tr>
<tr>
<td>(c)</td>
<td>(broad) peak at 3300–3600 (cm$^{-1}$) for O–H (therefore A or C) ✓</td>
<td>3</td>
<td>ALLOW 3200–3600 cm$^{-1}$&lt;br&gt;IGNORE references to the peak at ~2900 for C–H&lt;br&gt;ALLOW annotation of the spectrum to identify the bond responsible for the peak instead of quoting the wavenumber&lt;br&gt;Conclusion may also follow from empirical formula followed by IR data.</td>
</tr>
<tr>
<td></td>
<td>molar ratio: C : H : O</td>
<td>OR 6.58 : 10.53 : 0.658 ✓</td>
<td></td>
</tr>
<tr>
<td>Question</td>
<td>Answer</td>
<td>Marks</td>
<td>Guidance</td>
</tr>
<tr>
<td>----------</td>
<td>--------</td>
<td>-------</td>
<td>----------</td>
</tr>
<tr>
<td>23 (a)</td>
<td>(i) NaClO + 2HCl → NaCl + Cl₂ + H₂O</td>
<td>2</td>
<td>ALLOW NaClO₃ + 6HCl → NaCl + 3Cl₂ + 3H₂O for 1 mark</td>
</tr>
<tr>
<td></td>
<td>correct formulae of reactants, NaCl and chlorine ✓ water and balancing ✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(ii) Test: add (a few drops of aqueous) silver nitrate ✓</td>
<td>2</td>
<td>IGNORE addition of dilute nitric acid before the AgNO₃</td>
</tr>
<tr>
<td></td>
<td>Result: white ppt ✓</td>
<td></td>
<td>IGNORE redissolving in excess NH₃ or darkening of the ppt</td>
</tr>
<tr>
<td></td>
<td>(iii) separating funnel ✓</td>
<td>1</td>
<td>ALLOW dropping pipette</td>
</tr>
<tr>
<td>(b)</td>
<td>(i) any mono or multiple substituted chlorohexane – e.g.</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(ii) (because) substitution can replace any H atom / multiple substitution owtte ✓</td>
<td>1</td>
<td>IGNORE vague statements about free radical reactions being random</td>
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<td></td>
<td>ALLOW termination can join alkyl radicals to form larger hydrocarbons owtte</td>
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<td><strong>Total</strong></td>
<td><strong>7</strong></td>
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<tr>
<td>Question</td>
<td>Answer</td>
<td>Marks</td>
<td>Guidance</td>
</tr>
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<tr>
<td>24 (a) (i)</td>
<td>phosphoric acid / $\text{H}_3\text{PO}_4$ ✓</td>
<td>1</td>
<td>if both name and formula are given, the formula must be correct, but ALLOW minor errors in an attempt at the name</td>
</tr>
<tr>
<td>(ii)</td>
<td>(allows the reaction to proceed via a route with) lower activation energy ... ✓</td>
<td>2</td>
<td>ALLOW a sketch of an energy profile diagram as long as the catalysed and uncatalysed $E_a$ are both labelled. ALLOW 'more molecules exceed the activation energy' ALLOW a sketch of a Boltzmann distribution as long as both axes and both $E_a$ values are labelled</td>
</tr>
<tr>
<td>(b)</td>
<td>atom economy suggests hydration is more sustainable ✓</td>
<td>4</td>
<td>IGNORE references to global warming or 'carbon neutral'</td>
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<td></td>
<td>(but ...)</td>
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<td>Any two from:</td>
<td></td>
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<td>There must be a conclusion for this mark</td>
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<tr>
<td>the CO$_2$ given off is taken in by plants as they grow ✓</td>
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<tr>
<td>(ethene from) crude oil is non-renewable/glucose is renewable ✓</td>
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<td>fermentation does not require high temperatures/pressures, so lower energy demand ✓</td>
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<td>so on balance fermentation is more sustainable owtte ✓</td>
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<tr>
<td>Total</td>
<td>7</td>
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</tbody>
</table>
## Summary of updates

<table>
<thead>
<tr>
<th>Date</th>
<th>Version</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>January 2019</td>
<td>2.0</td>
<td>Addition to the rubric clarifying the general rule that working should be shown for any calculation questions</td>
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