



# Mark Scheme (Results)

January 2025

Pearson Edexcel International Advanced  
Subsidiary Level in Chemistry (WCH12)  
Paper 01 Energetics, Group Chemistry,  
Halogenoalkanes and Alcohols

**Section A**

<b>Question Number</b>	<b>Answer</b>	<b>Mark</b>
<b>1</b>	<b>The only correct answer is B</b> (the C–O bond is polar) <i>A is incorrect because this is not the reason for nucleophilic attack</i> <i>C is incorrect because this does not lead to nucleophilic substitution</i> <i>D is incorrect because this is not the reason for nucleophilic attack</i>	<b>(1)</b>

<b>Question Number</b>	<b>Answer</b>	<b>Mark</b>
<b>2</b>	<b>The only correct answer is A</b> (587°C) <i>B is incorrect because the graph value is taken from the relative atomic mass</i> <i>C is incorrect because this value has not been converted to °C from Kelvin</i> <i>D is incorrect because the graph value is taken from the relative atomic mass and has not been converted to °C</i>	<b>(1)</b>

Question Number	Answer	Mark
3	<p><b>The only correct answer is D (50.3)</b></p> <p><i>A is incorrect because this is the mass of crystals precipitated plus the solubility at 20°C</i></p> <p><i>B is incorrect because this is the mass of crystals precipitated times four plus the solubility at 20°C</i></p> <p><i>C is incorrect because this is the value when the solubility at 20°C has been ignored</i></p>	(1)

Question Number	Answer	Mark
4	<p><b>The only correct answer is B (red)</b></p> <p><i>A is incorrect because this is the flame colour of barium</i></p> <p><i>C is incorrect because this is what is seen when magnesium metal is burned</i></p> <p><i>D is incorrect because this is the flame colour of sodium</i></p>	(1)

Question Number	Answer	Mark
5	<p><b>The only correct answer is D (calcium &gt; strontium &gt; barium)</b></p> <p><i>A is incorrect because barium sulfate is the least soluble / magnesium sulfate is the most soluble</i></p> <p><i>B is incorrect because magnesium sulfate is more soluble than calcium and strontium sulfates</i></p> <p><i>C is incorrect because calcium sulfate is more soluble than barium sulfate</i></p>	(1)

Question Number	Answer	Mark
6	<p><b>The only correct answer is A (ethanol)</b></p> <p><i>B is incorrect because halogenoalkanes are not fully soluble in hexane</i></p> <p><i>C is incorrect because halogenoalkanes are not soluble in acid</i></p> <p><i>D is incorrect because halogenoalkanes are not soluble in water alone</i></p>	(1)

Question Number	Answer	Mark
7(a)	<p><b>The only correct answer is C (−67°C)</b></p> <p><i>A is incorrect because this is higher than the value for HF (and is the boiling temperature for bromine)</i></p> <p><i>B is incorrect because this is higher than the value for hydrogen iodide</i></p> <p><i>D is incorrect because this is lower than the value for hydrogen chloride</i></p>	(1)

Question Number	Answer	Mark
7(b)	<p><b>The only correct answer is A (it forms hydrogen bonds)</b></p> <p><i>B is incorrect because this is not the reason for the higher boiling temperature</i></p> <p><i>C is incorrect because this is not the reason for the higher boiling temperature</i></p> <p><i>D is incorrect because this is not the reason for the higher boiling temperature</i></p>	(1)

Question Number	Answer	Mark
8(a)	<p><b>The only correct answer is A</b> (<math>4.5 \times 10^{-5}</math>)</p> <p><i>B is incorrect because this is the rate at 100 seconds</i></p> <p><i>C is incorrect because this is the average rate</i></p> <p><i>D is incorrect because this is the rate at 385 seconds</i></p>	(1)

Question Number	Answer	Mark
8(b)	<p><b>The only correct answer is B</b> (<math>\text{mol dm}^{-3} \text{s}^{-1}</math>)</p> <p><i>A is incorrect because this is not a change in concentration</i></p> <p><i>C is incorrect because the power of the volume should be negative</i></p> <p><i>D is incorrect because all the powers have the incorrect sign</i></p>	(1)

Question Number	Answer	Mark
9	<p><b>The only correct answer is A</b> (oxidising agent)</p> <p><i>B is incorrect because the acid is an oxidising agent</i></p> <p><i>C is incorrect because the acid is not a base</i></p> <p><i>D is incorrect because the acid is not a nucleophile</i></p>	(1)

Question Number	Answer	Mark
10	<p><b>The only correct answer is D</b> (<math>\text{Mg} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2</math>)</p> <p><i>A is incorrect because this reaction is a disproportionation reaction</i></p> <p><i>B is incorrect because this reaction is a disproportionation reaction</i></p> <p><i>C is incorrect because this reaction is a disproportionation reaction</i></p>	(1)

Question Number	Answer	Mark
11	<p><b>The only correct answer is C</b> (<math>2\text{NaI} + \text{Br}_2 \rightarrow 2\text{NaBr} + \text{I}_2</math>)</p> <p><i>A is incorrect because astatine cannot displace chlorine from chloride</i></p> <p><i>B is incorrect because iodine cannot displace bromine from bromide</i></p> <p><i>D is incorrect because chlorine cannot displace fluorine from fluoride</i></p>	(1)

Question Number	Answer	Mark
12(a)	<p><b>The only correct answer is D</b> (<math>0.702 \text{ mol dm}^{-3}</math>)</p> <p><i>A is incorrect because the stoichiometry has been used incorrectly</i></p> <p><i>B is incorrect because volumes have been used the wrong way around</i></p> <p><i>C is incorrect because the stoichiometry has not been used</i></p>	(1)

Question Number	Answer	Mark
12(b)	<p><b>The only correct answer is D (0.68%)</b></p> <p><i>A is incorrect because this is the error of a burette in cm<sup>3</sup> times two</i></p> <p><i>B is incorrect because this is the error if only one reading is taken</i></p> <p><i>C is incorrect because this is the error using the pipette value</i></p>	(1)

Question Number	Answer	Mark
13	<p><b>The only correct answer is B (56.0%)</b></p> <p><i>A is incorrect because this is the atom economy for carbon dioxide</i></p> <p><i>C is incorrect because this is the value of the mass of carbon dioxide divided by the mass of calcium oxide</i></p> <p><i>D is incorrect because the reaction does not have an atom economy of 100%</i></p>	(1)

Question Number	Answer	Mark
14	<p><b>The only correct answer is D (1.012)</b></p> <p><i>A is incorrect because this is the mass divided by the volume</i></p> <p><i>B is incorrect because this is the <math>M_r</math> divided by the volume in cm<sup>3</sup></i></p> <p><i>C is incorrect because this is the number of moles</i></p>	(1)

Question Number	Answer	Mark
15	<p><b>The only correct answer is C</b> (<math>0.683 \text{ mol dm}^{-3}</math>)</p> <p><i>A is incorrect because this is the number of moles in the sample</i></p> <p><i>B is incorrect because this is double the number of moles in the sample</i></p> <p><i>D is incorrect because this is double the value of the concentration</i></p>	(1)

Question Number	Answer	Mark
16(a)	<p><b>The only correct answer is C</b> (<math>0.123 \text{ m}^3</math>)</p> <p><i>A is incorrect because this is the volume of <math>\text{O}_2</math> produced</i></p> <p><i>B is incorrect because this is the volume of <math>\text{NO}_2</math> produced</i></p> <p><i>D is incorrect because this is the volume of gas formed from 2 mols of magnesium nitrate</i></p>	(1)

Question Number	Answer	Mark
16(b)	<p><b>The only correct answer is D</b> (62.0 %)</p> <p><i>A is incorrect because this is 25 divided by the mass of the nitrogen(IV) oxide</i></p> <p><i>B is incorrect because this is 25 divided by the mass of one mole of magnesium nitrate</i></p> <p><i>C is incorrect because this is 25 divided by the mass of <math>2\text{MgO}</math></i></p>	(1)

**TOTAL FOR SECTION A = 20 MARKS**

**Section B**

Question Number	Answer	Additional Guidance	Mark
17(a)(i)	An answer that makes reference to the following points: <ul style="list-style-type: none"> <li>• oxidation numbers of manganese (1)</li> <li>• oxidation numbers of carbon (1)</li> </ul>	(+)7 to (+)2  (+)3 to (+)4 Allow 2+ etc. Allow roman numerals	(2)

Question Number	Answer	Additional Guidance	Mark
17 (a)(ii)	An answer that makes reference to the following points: <ul style="list-style-type: none"> <li>• manganate(VII) reduction</li> </ul>	$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$  Allow multiples  Ignore state symbols	(1)

Question Number	Answer	Additional Guidance	Mark
17 (a)(iii)	An answer that makes reference to the following points: <ul style="list-style-type: none"> <li>• ethanedioic acid oxidation</li> </ul>	$\text{C}_2\text{H}_2\text{O}_4 \rightarrow 2\text{CO}_2 + 2\text{H}^+ + 2\text{e}^-$  Allow multiples  Ignore state symbols	(1)

Question Number	Answer	Additional Guidance	Mark									
17 (b)(i)	<ul style="list-style-type: none"> <li>boxes completed to 3SF</li> </ul>	<table border="1"> <tr> <td>2.07</td> <td>0.00340</td> <td>3.40</td> </tr> <tr> <td>261</td> <td>0.00383</td> <td>3.83</td> </tr> <tr> <td>2.40</td> <td>0.00402</td> <td>4.02</td> </tr> </table>	2.07	0.00340	3.40	261	0.00383	3.83	2.40	0.00402	4.02	(1)
2.07	0.00340	3.40										
261	0.00383	3.83										
2.40	0.00402	4.02										

Question Number	Answer	Additional Guidance	Mark
17 (b)(ii)	<ul style="list-style-type: none"> <li>suitable choice of scale so that the points cover at least 3 large squares (1)</li> <li>correct choice of axes suitably labelled including units (1)</li> <li>all points plotted correctly (within half a small square) (1)</li> <li>curved line of best fit</li> </ul>	<p>An example of a graph:</p> <p>TE on 17(b)(i)  Allow <math>(1 \div t) \times 10^3</math> on the y-axis with units  Ignore spurious 0,0 labels where the curve does not join the origin</p>	(4)

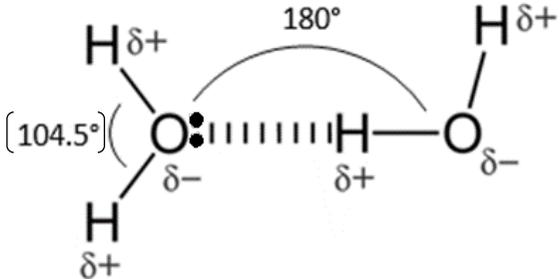
Question Number	Answer	Additional Guidance	Mark
17(b)(iii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li data-bbox="353 309 1216 341">• more particles will be in the same volume <b>(1)</b></li> <li data-bbox="353 496 1216 560">• increasing the number of (successful) collisions per unit time <b>(1)</b></li> </ul>	<p>Allow references to particles being closer together  Allow molecules/ions for particles  Allow space for volume</p> <p>Allow references to frequency of collisions  Ignore chance/probability of collisions</p> <p>More particles so more successful collisions scores 1</p>	<b>(2)</b>

Question Number	Answer	Additional Guidance	Mark
17(c)	<p>An explanation that makes reference to two of the following points:</p> <ul style="list-style-type: none"> <li>• titrate</li> <li>• a known volume of (undiluted) rhubarb juice</li> <li>• with a known concentration of manganate(VII)</li> <li>• until a colour change is seen</li> </ul>	<p>Apply the list principle</p> <p>Allow sample of ethanedioic acid for rhubarb juice  Allow specific volume quoted  Allow fixed/set volume</p> <p>Do not award reference to “known concentration of ethanedioic acid”  Allow fixed/set concentration</p> <p>Allow specific colour changes even if incorrect  Ignore references to indicators</p> <p>Ignore references to calculations  Ignore references to mass  Ignore references to time</p> <p>Allow use of a fixed volume and concentration of manganate(VII) and adding the rhubarb juice dropwise for 2 marks</p> <p>Allow use of known volume of rhubarb juice and excess manganate(VII) and recording the volume of CO<sub>2</sub> gas for 2 marks</p>	(2)

Question Number	Answer	Additional Guidance	Mark
17(d)(i)	<ul style="list-style-type: none"> <li>a line that has a similar shape with peak that is lower and to the right</li> </ul>	<p>Example of a drawing</p> <p>Ignore shading Do not award if the line cut the curve more once Do not award if the line plateaus above the height of the <math>E_a</math> line Do not award if line does not start at the origin Ignore changes to the <math>E_a</math> line</p>	(1)

Question Number	Answer	Additional Guidance	Mark
17(d)(ii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>the molecules/particles have more kinetic energy (1)</li> <li>so more molecules/particles have energy <math>\geq E_a</math> (1)</li> <li>so more successful collisions occur per unit time (1)</li> </ul>	<p>Allow increases the mean energy of the particles</p> <p>Allow reference to correct part of the graph for M2 Allow collisions have more energy than <math>E_a</math></p> <p>Allow more frequent successful collisions</p>	(3)

(Total for Question 17 = 17 marks)

Question Number	Answer	Additional Guidance	Mark
18(a)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• hydrogen bond shown from lone pair on the oxygen on one molecule to the hydrogen on the other (1)</li> <li>• linear O–H–O bond and labelled 180° (1)</li> <li>• <math>\delta+</math> on the hydrogen atom, <math>\delta-</math> on the oxygen atom (in the hydrogen bond) (1)</li> </ul>	<p>Example of a diagram</p>  <p>Ignore other lone pairs</p> <p>Ignore H–O–H bond angles even if incorrect</p> <p>Allow dipole moments (<math>\text{+} \longrightarrow</math>) on bonds</p> <p>Penalise O<sub>2</sub>H once only</p>	(3)

Question Number	Answer	Additional Guidance	Mark
18(b)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• molecules are a similar size / same number of electrons so the London forces are similar (and cannot account for big difference in boiling temperature)</li> <li>• there are more <b>hydrogen bonds</b> between water molecules (than hydrogen bonds between ammonia molecules, resulting in water having a higher boiling temperature than ammonia)</li> <li>• density of ammonia decreases between the two temperatures as it turns (from a liquid) to a gas <b>or</b> density of water increases between the two temperatures as it turns (from a solid) to a liquid</li> </ul>	<p>Ignore comments on permanent dipole-dipole forces</p> <p>Accept for London forces instantaneous dipole-induced dipole/ dispersion forces</p> <p>Allow van der Waals' forces</p> <p>Allow <math>M_r</math> for size</p> <p>Accept converse</p> <p>Allow the hydrogen bonds in water are stronger than the hydrogen bonds in ammonia because oxygen is more electronegative than nitrogen</p> <p>Allow reference to two lone pairs on oxygen compared to one on nitrogen so more hydrogen bonds</p> <p>Allow reference to numbers of hydrogen bonds even if incorrect</p> <p>Allow M3 for a description of the expanded hydrogen bond structure of ice</p>	(3)

(Total for Question 18 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
19(a)	<ul style="list-style-type: none"> <li>2-chloro-3-methylbutane</li> </ul>	Allow 2-chloromethyl-3-butane Ignore additional/omitted brackets, hyphens and commas Ignore 3-methyl-2-chlorobutane	(1)

Question Number	Answer	Additional Guidance	Mark
19(b)(i)	<ul style="list-style-type: none"> <li>elimination</li> </ul>	Do not award addition-elimination	(1)

Question Number	Answer	Additional Guidance	Mark
19(b)(ii)	An answer that makes reference to the following points: <ul style="list-style-type: none"> <li>structure of 3-methylbut-1-ene</li> <li>structure of 2-methylbut-2-ene</li> </ul>	Allow any type of structure, including mixed <div style="display: flex; justify-content: space-around; align-items: center;"> <div style="text-align: center;"> <p>(1)</p> <pre>           H   CH3                           C   C   H                               H   H   C   H                                       H                 </pre> </div> <div style="text-align: center;"> </div> </div> <div style="display: flex; justify-content: space-around; align-items: center; margin-top: 10px;"> <div style="text-align: center;"> <p>(1)</p> <pre>           H   CH3                           C   C   H                               H   C   C   H                                   H   H                 </pre> </div> <div style="text-align: center;"> </div> </div> <p>If multiple structures are given both must be correct            Allow isomers in any order            Ignore connectivity of CH<sub>3</sub>            Ignore names even if incorrect            Penalise missing hydrogen atoms once only</p>	(2)

Question Number	Answer	Additional Guidance	Mark
19(c)(i)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• lone pair on oxygen of OH<sup>-</sup></li> <li>• dipole on C-Cl</li> <li>• curly arrow from oxygen (lone pair) to carbon in C-Cl bond</li> <li>• curly arrow from C-Cl bond to Cl or just beyond</li> <li>• 3-methylbutan-2-ol and Cl<sup>-</sup></li> </ul>	<p>Allow KCl as a product if K<sup>+</sup> is a reactant Ignore OH-C connectivity for P5</p> <p>All 5 points score 3 marks, 3 or 4 points scores 2 marks, 2 points scores 1 mark</p> <p>Allow S<sub>N</sub>1 mechanism for full marks</p> <p>Penalise single headed arrows once only Ignore transition state</p>	(3)

Question Number	Answer	Additional Guidance	Mark
19(c)(ii)	<p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• (the rate will be) faster</li> <li>• the C–I bond is weaker</li> </ul>	<p>Accept converse answers</p> <p>(1) M1 dependent on some attempt at M2 (even if incorrect)</p> <p>(1) Allow bond enthalpy is lower for C–I  Allow C–I bond needs less energy to break  Ignore C – I bond breaks more easily  Ignore breaks faster  Ignore the C – I bond is longer  Ignore reasoning for bond weakness even if incorrect  Ignore comments on polarisation</p>	(2)

Question Number	Answer	Additional Guidance	Mark
19(d)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• role in (b) : base</li> <li>• role in (c) : nucleophile</li> </ul>	<p>(1) Allow proton acceptor  Ignore alkali  Ignore prefixes/suffixes</p> <p>(1) Allow nucleophilic</p>	(2)

(Total for Question 19 = 11 marks)

Question Number	Answer	Additional Guidance	Mark																				
*20	<p>This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.</p> <p>Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.</p> <p>The following table shows how the marks should be awarded for indicative content.</p> <table border="1" data-bbox="309 560 1146 828"> <thead> <tr> <th>Number of indicative marking points seen in answer</th> <th>Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td>6</td> <td>4</td> </tr> <tr> <td>5-4</td> <td>3</td> </tr> <tr> <td>3-2</td> <td>2</td> </tr> <tr> <td>1</td> <td>1</td> </tr> <tr> <td>0</td> <td>0</td> </tr> </tbody> </table> <p>The following table shows how the marks should be awarded for structure and lines of reasoning</p> <table border="1" data-bbox="309 959 1180 1407"> <thead> <tr> <th></th> <th>Number of marks awarded for structure of answer and sustained lines of reasoning</th> </tr> </thead> <tbody> <tr> <td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td> <td>2</td> </tr> <tr> <td>Answer is partially structured with some linkages and lines of reasoning</td> <td>1</td> </tr> <tr> <td>Answer has no linkages between points and is unstructured</td> <td>0</td> </tr> </tbody> </table>	Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points	6	4	5-4	3	3-2	2	1	1	0	0		Number of marks awarded for structure of answer and sustained lines of reasoning	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2	Answer is partially structured with some linkages and lines of reasoning	1	Answer has no linkages between points and is unstructured	0	<p>Guidance on how the mark scheme should be applied.</p> <p>The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).</p> <p>If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</p> <p>In general it would be expected that  5 or 6 indicative points would get 2 reasoning marks  3 or 4 indicative points would get 1 reasoning mark  0, 1 or 2 indicative points would get zero reasoning marks</p> <p>If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).</p>	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points																						
6	4																						
5-4	3																						
3-2	2																						
1	1																						
0	0																						
	Number of marks awarded for structure of answer and sustained lines of reasoning																						
Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2																						
Answer is partially structured with some linkages and lines of reasoning	1																						
Answer has no linkages between points and is unstructured	0																						

	<p><b>Indicative content</b></p> <p><b>IP1</b> O–H bond (broad) absorption at <math>\sim 3400 \text{ (cm}^{-1}\text{)}</math></p> <p><b>IP2</b> C=O absorption at <math>1740\text{-}1700 \text{ (cm}^{-1}\text{)}</math> so cannot be butan-1-ol</p> <p><b>IP3</b> <math>M^+</math> has an m/z value of 74 so could be 1-hydroxypropanone <b>or</b> butan-1-ol (propenoic acid has a <math>M^+</math> value of 72)</p> <p><b>IP4</b> base / most abundant peak has an m/z value of 43 so could be <math>\text{CH}_3\text{CO}^{(+)}</math> / <math>\text{C}_3\text{H}_7^{(+)}</math></p> <p><b>IP5</b> no C=C absorption on IR spectra at <math>1669\text{-}1645 \text{ (cm}^{-1}\text{)}</math></p> <p><b>or</b> O–H peak absorbance too high for acid (so not propenoic acid)</p> <p><b>IP6</b> so the substance is 1-hydroxypropanone, (not propenoic acid or butan-1-ol)</p>	<p><b>Comment:</b> Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning</p> <p>Allow use of molecular formulae throughout Ignore C–H absorptions</p> <p>Allow ranges between <math>3800\text{-}3000 \text{ (cm}^{-1}\text{)}</math> Allow due to hydroxyl/alcohol</p> <p>Accept so can only be 1-hydroxypropanone or propenoic acid Ignore references to aldehydes</p> <p>Allow <math>\text{CCH}_2\text{OH}^{(+)}</math> Ignore other proposed base peaks Do not award negatively charged fragments</p> <p>Allow propenoic acid would have a(n additional) peak at <math>1669\text{-}1645 \text{ (cm}^{-1}\text{)}</math></p> <p>Allow a range from <math>3300\text{-}2500 \text{ (cm}^{-1}\text{)}</math></p> <p>Allow a correct structure</p>	
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(Total for Question 20 = 6 marks)

**TOTAL FOR SECTION B = 40 MARKS**

### Section C

Question Number	Answer	Additional Guidance	Mark
21(a)	<ul style="list-style-type: none"> <li>• calculation of the enthalpy of the broken bonds</li> <li>• calculation of enthalpy of the formed bonds</li> <li>• calculation of the enthalpy change per mole</li> </ul>	<p><u>Example of a calculation:</u></p> <p>(1) <math>(8 \times 413) + 498 = 3802</math></p> <p>(1) <math>(6 \times 413) + (2 \times 336) + (2 \times 464) = 4078</math></p> <p>(1) <math>(3802 - 4078) \div 2 = -276 \div 2</math>  <math>= -138(\text{kJ mol}^{-1})</math>            TE on M1 and M2 if used correctly            Ignore incorrect units</p> <p>Correct answer with some working scores 3 marks</p>	(3)

Question Number	Answer	Additional Guidance	Mark
21(b)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• (it is an) element in its standard state</li> </ul>	<p>Allow no change to element in state or bonding            e.g. <math>\text{O}_2(\text{g}) \rightarrow \text{O}_2(\text{g})</math></p> <p>Ignore references to ground/natural state</p>	(1)

Question Number	Answer	Additional Guidance	Mark
21(c)	An explanation that makes reference to the following points: <ul style="list-style-type: none"> <li>part (a) uses mean bond enthalpies (rather than for specific compounds)</li> <li>bond enthalpies refer to the gaseous state</li> </ul>	(1) Allow average for mean  (1) Allow methanol is not a gas / methanol is a liquid Do not award incorrect states	(2)

Question Number	Answer	Additional Guidance	Mark
21(d)(i)	An answer that makes reference to the following points: <ul style="list-style-type: none"> <li>oxidation</li> </ul>		(1)

Question Number	Answer	Additional Guidance	Mark
21(d)(ii)	An answer that makes reference to the following points: <ul style="list-style-type: none"> <li>sulfuric acid / <math>\text{H}_2\text{SO}_4</math></li> <li>potassium dichromate(VI) / <math>\text{K}_2\text{Cr}_2\text{O}_7</math></li> <li>distillation</li> <li>orange <math>\rightarrow</math> green</li> </ul>	If name and formula are given both must be correct  (1) Ignore concentration Ignore acidified / $\text{H}^+$ Do not award HCl acid  (1) Accept sodium dichromate(VI) / $\text{Na}_2\text{Cr}_2\text{O}_7$ Allow dichromate with no oxidation number Ignore methanol as an extra reagent  (1) Ignore heat Do not award reflux  (1) Allow orange $\rightarrow$ blue  Do not penalise order of responses	(4)

Question Number	Answer	Additional Guidance	Mark
21(e)(i)	<p>An answer that makes reference to two of the following points:</p> <ul style="list-style-type: none"> <li>• (a catalyst) may reduce the operating temperature</li> <li>• a lower pressure may be used which is safer / requires less expensive/specialised equipment</li> <li>• the reaction may not proceed via toxic gas / greenhouse gases</li> <li>• the reaction may go to completion (rather than being in equilibrium)</li> <li>• only one reaction vessel required</li> <li>• may produce fewer by-products produced</li> <li>• may take less time</li> <li>• may require less energy if a lower pressure is used</li> </ul>	<p>Allow definitive answers i.e. “it will” rather than “it may” for all marking points Ignore cost/transport</p> <p>Allow equipment may have thinner walls etc.</p> <p>Ignore pollutants</p> <p>Ignore use less resources</p> <p>Allow less separation steps may be required</p> <p>Allow may increase atom economy</p> <p>Allow reference to faster rate</p>	(2)

Question Number	Answer	Additional Guidance	Mark
21(e)(ii)	<p>An explanation that makes reference to two of the following points:</p> <ul style="list-style-type: none"> <li>• (all contain) d-block elements</li> <li>• (all are) heterogeneous (catalysts)</li> <li>• (all) are solids</li> </ul>	<p>Accept (all contain) transition metals</p> <p>Allow in a different phase/state to reactants</p> <p>If no other mark is scored: Allow reduce activation energy by providing an alternate reaction path scores 1</p>	(2)

Question Number	Answer	Additional Guidance	Mark
21(e)(iii)	<p>An answer that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• the reaction is exothermic (1)</li> <li>• so (by Le Chatelier) the temperature could be decreased (to increase the yield) (1)</li> <li>• but this would decrease the rate (1)</li> <li>• pressure could be increased as fewer moles of gas on the right-hand side (1)</li> <li>• (increasing the pressure would be more expensive because either) increasing the pressure uses more energy (1) or equipment walls need to be thicker/stronger</li> </ul>	<p>All marks are independent</p> <p>Ignore references to removing methanol, increasing concentration and catalysts</p> <p>Allow the catalyst may not work at a lower temperature</p> <p>Allow molecules for moles</p> <p>Allow products side for RHS</p> <p>Do not award incorrect numbers stated for either side</p> <p>Allow fuel for energy</p>	(5)

(Total for Question 17 = 20 marks)  
TOTAL FOR SECTION C = 20 MARKS