



Pearson

# **Mark Scheme (Results)**

Summer 2017

Pearson Edexcel GCE  
in Chemistry (9CH0) Paper 1  
Advanced Inorganic and Physical  
Chemistry

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## General marking guidance

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- All candidates must receive the same treatment. Examiners must mark the first candidate in exactly the same way as they mark the last.
- Mark schemes should be applied positively. Candidates must be rewarded for what they have shown they can do rather than penalised for omissions.
- Examiners should mark according to the mark scheme not according to their perception of where the grade boundaries may lie.
- There is no ceiling on achievement. All marks on the mark scheme should be used appropriately.
- All the marks on the mark scheme are designed to be awarded. Examiners should always award full marks if deserved, i.e. if the answer matches the mark scheme. Examiners should also be prepared to award zero marks if the candidate's response is not worthy of credit according to the mark scheme.
- Where some judgement is required, mark schemes will provide the principles by which marks will be awarded and exemplification may be limited.
- When examiners are in doubt regarding the application of the mark scheme to a candidate's response, the team leader must be consulted.
- Crossed out work should be marked UNLESS the candidate has replaced it with an alternative response.
- Mark schemes will indicate within the table where, and which strands of QWC, are being assessed. The strands are as follows:
  - i) ensure that text is legible and that spelling, punctuation and grammar are accurate so that meaning is clear
  - ii) select and use a form and style of writing appropriate to purpose and to complex subject matter
  - iii) organise information clearly and coherently, using specialist vocabulary when appropriate

## Using the mark scheme

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Examiners should look for qualities to reward rather than faults to penalise. This does NOT mean giving credit for incorrect or inadequate answers, but it does mean allowing candidates to be rewarded for answers showing correct application of principles and knowledge. Examiners should therefore read carefully and consider every response: even if it is not what is expected it may be worthy of credit.

The mark scheme gives examiners:

- an idea of the types of response expected
- how individual marks are to be awarded
- the total mark for each question
- examples of responses that should NOT receive credit.

/ means that the responses are alternatives and either answer should receive full credit.

( ) means that a phrase/word is not essential for the award of the mark, but helps the examiner to get the sense of the expected answer.

Phrases/words in **bold** indicate that the meaning of the phrase or the actual word is **essential** to the answer.

ecf/TE/cq (error carried forward) means that a wrong answer given in an earlier part of a question is used correctly in answer to a later part of the same question.

Candidates must make their meaning clear to the examiner to gain the mark. Make sure that the answer makes sense. Do not give credit for correct words/phrases which are put together in a meaningless manner. Answers must be in the correct context.

### Quality of Written Communication

Questions which involve the writing of continuous prose will expect candidates to:

- write legibly, with accurate use of spelling, grammar and punctuation in order to make the meaning clear
- select and use a form and style of writing appropriate to purpose and to complex subject matter
- organise information clearly and coherently, using specialist vocabulary when appropriate.

Full marks will be awarded if the candidate has demonstrated the above abilities.

Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

| Question Number | Answer   | Mark       |
|-----------------|--|------------|
| 1(a)            | <p><b>The only correct answer is B</b></p> <p><i>A is not correct because incorrect electrons</i></p> <p><i>C is not correct because incorrect protons, neutrons and electrons</i></p> <p><i>D is not correct because incorrect protons and neutrons</i></p> | <b>(1)</b> |

| Question Number | Answer   | Additional Guidance   | Mark       |
|-----------------|--|---|------------|
| 1(b)(i)         | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>(pyramidal / this shape) because there are 4 pairs / 3 bond pairs and one lone pair of electrons (around central / P atom)<br/><b>and</b><br/>these are arranged to minimise repulsion <b>(1)</b></li> <li>(bond angle less than <math>109.5^\circ</math>) as lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion <b>(1)</b></li> </ul> | <p>'ions' scores (0) overall</p> <p>Allow the electron pairs are arranged to minimise repulsion<br/>Allow (4) pairs of electrons with maximum separation / as far apart as possible</p> <p>Ignore reference to 'bonds'<br/>Ignore wrong shape<br/>Ignore repel equally<br/>Ignore repulsion between electrons</p> <p>There must be a comparison in M2<br/>Allow lone pairs have greater repulsion than bond pairs</p> <p>Ignore just 'the lone pairs repel more'<br/>Ignore repetition of the question e.g. 'reduces the bond angle'<br/>Ignore incorrect bond angle stated (Data book value is <math>100.1^\circ</math>)</p> <p>Do not allow bond angle <math>&gt;109.5^\circ</math></p> | <b>(2)</b> |

| Question Number | Answer   | Mark       |
|-----------------|--|------------|
| 1(b)(ii)        | <p><b>The only correct answer is D</b></p> <p><i>A is not correct because both incorrect</i></p> <p><i>B is not correct because non-polar bond is incorrect</i></p> <p><i>C is not correct because non-polar molecule is incorrect</i></p> | <b>(1)</b> |

| Question Number                       | Answer  | Additional Guidance   | Mark |       |                         |     |                                       |     |                                       |     |                         |     |            |
|---------------------------------------|---|---|------|-------|-------------------------|-----|---------------------------------------|-----|---------------------------------------|-----|-------------------------|-----|------------|
| 1(c)                                  | <ul style="list-style-type: none"> <li>• all 4 ion formulae <span style="float: right;"><b>(1)</b></span></li> <li>• all 4 <math>m/z</math> values <span style="float: right;"><b>(1)</b></span></li> </ul> <p><b>or</b></p> <ul style="list-style-type: none"> <li>• any two <math>m/z</math> values with corresponding ion formulae <span style="float: right;"><b>(1)</b></span></li> <li>• the other two <math>m/z</math> values with corresponding ion formulae <span style="float: right;"><b>(1)</b></span></li> </ul> | <p><u>Example of answer:</u></p> <table style="width: 100%; border: none;"> <tr> <td style="width: 70%;">ions</td> <td style="text-align: right;"><math>m/z</math></td> </tr> <tr> <td><math>P(^{35}\text{Cl})_3^+</math></td> <td style="text-align: right;">136</td> </tr> <tr> <td><math>P(^{35}\text{Cl})_2^{37}\text{Cl}^+</math></td> <td style="text-align: right;">138</td> </tr> <tr> <td><math>P^{35}\text{Cl}(^{37}\text{Cl})_2^+</math></td> <td style="text-align: right;">140</td> </tr> <tr> <td><math>P(^{37}\text{Cl})_3^+</math></td> <td style="text-align: right;">142</td> </tr> </table> <p>Allow any other unambiguous way of representing the formulae e.g. with brackets or in words</p> <p>Positive charge only needs to be shown on one of the ions</p> <p>Ignore mass number on P</p> | ions | $m/z$ | $P(^{35}\text{Cl})_3^+$ | 136 | $P(^{35}\text{Cl})_2^{37}\text{Cl}^+$ | 138 | $P^{35}\text{Cl}(^{37}\text{Cl})_2^+$ | 140 | $P(^{37}\text{Cl})_3^+$ | 142 | <b>(2)</b> |
| ions                                  | $m/z$   |   |      |       |                         |     |                                       |     |                                       |     |                         |     |            |
| $P(^{35}\text{Cl})_3^+$               | 136   |   |      |       |                         |     |                                       |     |                                       |     |                         |     |            |
| $P(^{35}\text{Cl})_2^{37}\text{Cl}^+$ | 138   |   |      |       |                         |     |                                       |     |                                       |     |                         |     |            |
| $P^{35}\text{Cl}(^{37}\text{Cl})_2^+$ | 140   |   |      |       |                         |     |                                       |     |                                       |     |                         |     |            |
| $P(^{37}\text{Cl})_3^+$               | 142   |   |      |       |                         |     |                                       |     |                                       |     |                         |     |            |

**(Total for Question 1 = 6 marks)**

| Question Number | Answer   | Additional Guidance  | Mark       |
|-----------------|--|--|------------|
| 2(a)            | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• N changes from (+)5 to (+)4 <b>(1)</b></li> <li>• O changes from -2 to 0 (in O<sub>2</sub>) <b>(1)</b></li> </ul> <p>so nitrogen / N is reduced (as the oxidation number has decreased)<br/> <b>and</b><br/> oxygen / O (in forming O<sub>2</sub>) is oxidised (as the oxidation number has increased) <b>(1)</b></p> | <p>These numbers may be written under the formulae in the equation</p> <p>Allow oxidation numbers written as 5+, 4+, 2-</p> <p>Ignore unchanged oxidation numbers of magnesium and oxygen</p> <p>Allow this mark if incorrect / missing oxidation numbers in M1 and M2</p> <p>Ignore general statement about redox</p> <p>Ignore redox explained in terms of electron gain or loss</p> | <b>(3)</b> |



| Question Number | Answer  | Additional Guidance   | Mark       |
|-----------------|---|---|------------|
| 2(b)            | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• <b>Size</b><br/>calcium ion / <math>\text{Ca}^{2+}</math> has larger (ionic) radius / is larger than magnesium ion<br/><b>or</b><br/>magnesium ion / <math>\text{Mg}^{2+}</math> has smaller (ionic) radius / is smaller than calcium ion <b>(1)</b></li> <li>• <b>Polarising power</b><br/>so calcium ion/ <math>\text{Ca}^{2+}</math> causes less polarisation/ distortion<br/><b>or</b><br/>magnesium ion/ <math>\text{Mg}^{2+}</math> causes more polarisation/ distortion <b>(1)</b></li> <li>• <b>What is polarised</b><br/>of the nitrate (ion / electron cloud) / <math>\text{NO}_3^-</math> / anion / negative ion / N—O bonds / N=O bonds / NO bonds <b>(1)</b></li> </ul> | <p>Penalise omission of 'ion' <b>or</b> just 'calcium / Ca / magnesium / Mg' without charge, <b>or</b> reference to atom or molecule once only</p> <p>Ignore general references to ionic / covalent character</p> <p>Allow ionic radius increases down the group / decreases up the group<br/>Allow magnesium ions have a higher charge density (than calcium ions)<br/>Ignore atomic radius<br/>Ignore effective nuclear charge</p> <p>Allow the cation causes less / more polarisation if it is clear from M1 which cation is involved</p> <p>Do not allow this mark for carbonate / C-O bonds<br/>Do not allow mention of bond <b>between</b> cation and anion<br/><b>Note</b><br/>Nitrate ions are less polarised by <math>\text{Ca}^{2+}</math> / more polarised by <math>\text{Mg}^{2+}</math> scores M2 and M3</p> | <b>(3)</b> |

**(Total for Question 2 = 6 marks)**

| Question Number | Answer   | Additional Guidance   | Mark       |
|-----------------|--|---|------------|
| 3(a)            | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>from chlorine to iodine / down the group, the number of electrons (in the molecule / atom) increases / changes from 34 to 106 / 17 to 53 <b>(1)</b></li> <li>so the strength of the London / instantaneous dipole-(induced) dipole forces increases / there are more London / instantaneous dipole-(induced) dipole forces <b>and</b> more energy is needed to separate the molecules <b>(1)</b></li> </ul> | <p>An answer that states 'covalent bonds break' or 'bonds between atoms break' or refers to 'ions' scores (0) overall</p> <p>Allow reverse argument for M1 and M2</p> <p>Allow iodine has more / most electron shells (than chlorine and/or bromine)</p> <p>Ignore 'the size of the atoms /molecules increases from chlorine to iodine'</p> <p>Do not allow incorrect numbers of electrons</p> <p>Allow iodine has the strongest London force <b>and</b> most energy is needed to separate the molecules</p> <p>Allow more energy is need to overcome / break the London forces / bonds instead of separate the molecules</p> <p>Allow dispersion forces / van der Waals forces for London forces</p> <p>Ignore higher temperature needed to separate the molecules</p> <p>Do not award dipole-dipole forces / just 'intermolecular forces'</p> | <b>(2)</b> |

| Question Number | Answer   | Additional Guidance  | Mark       |
|-----------------|--|--|------------|
| 3(b)            | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• iodide ions are the strongest reducing agent because iodide ions / <math>I^-</math> / (potassium) iodide reduces sulfur (in sulfuric acid) from +6 to 0 in sulfur / -2 in <math>H_2S</math> <b>(1)</b></li> <li>• (whereas) bromide ions / <math>Br^-</math> / (potassium) bromide reduces sulfur (in sulfuric acid) from +6 to +4 <b>(1)</b></li> <li>• (whereas) chloride ions / <math>Cl^-</math> / (potassium) chloride do not reduce sulfuric acid / sulfur / S (as there is no change in oxidation number of Cl or S) <b>(1)</b></li> </ul> | <p>Allow the oxidation numbers written by the species in the table</p> <p>(+)6 only needs to be mentioned once in M1 or M2</p> <p>Allow references to potassium halides / halogens / hydrogen halides instead of halide ions</p> <p>For full marks, the answer must identify iodide as the strongest reducing agent</p> <p>Only 1 oxidation number change is needed. If both are given, both must be correct</p> <p>Allow bromide ions are stronger reducing agents than chloride ions because they are oxidised from -1 to 0</p> <p>Allow just 'it is not a redox reaction'</p> | <b>(3)</b> |

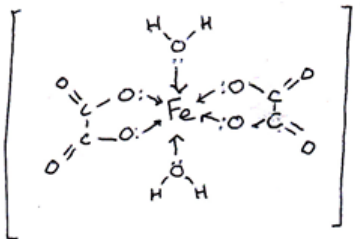
| Question Number | Answer  | Mark |
|-----------------|---|------|
| 3(c)(i)         | <p><b>The only correct answer is A</b></p> <p><i>B is not correct because Cl<sup>-</sup> is not an oxidising agent</i></p> <p><i>C is not correct because I<sub>2</sub> is not a powerful enough oxidising agent</i></p> <p><i>D is not correct because Mn<sup>2+</sup> is not an oxidising agent</i></p> | (1)  |

| Question Number | Answer  | Additional Guidance  | Mark |
|-----------------|---|--|------|
| 3(c)(ii)        | <ul style="list-style-type: none"> <li>all species on correct sides of equation<br/><b>and</b><br/>no electrons / electrons cancelled (1)</li> <li>balancing correct species (1)</li> <li><math>E^{\ominus}_{\text{cell}}</math> value (1)</li> </ul> | <p><u>Example of ionic equation</u><br/> <math>2\text{MnO}_4^- + 16\text{H}^+ + 10\text{Br}^- \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O} + 5\text{Br}_2</math></p> <p>Allow <math>\rightleftharpoons</math></p> <p>Allow correct species if shown in working with half-equations but slip made in final equation e.g. charge missing</p> <p>Ignore state symbols</p> <p>Allow multiples</p> <p>Allow M2 for almost correct species</p> <p><math>E^{\ominus}_{\text{cell}}</math> (= 1.51 - 1.09) = (+)0.42 (V)</p> <p>No TE on incorrect equation</p> | (3)  |

**(Total for Question 3 = 9 marks)**

| Question Number | Answer   | Mark |
|-----------------|--|------|
| 4(a)            | <p><b>The only correct answer is B</b></p> <p><i>A is not correct because 4 of the 3d electrons should be unpaired</i></p> <p><i>C is not correct because there should not be any electrons in the 4s orbital</i></p> <p><i>D is not correct because there should not be any electrons in the 4s orbital</i></p> | (1)  |

| Question Number | Answer   | Additional Guidance  | Mark |
|-----------------|--|--|------|
| 4(b)            | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>(zinc (ions) / Zn<sup>2+</sup>) has / have a full (3)d sub-shell / 3d<sup>10</sup> / all (3)d orbitals are full (1)</li> <li>so d-d transitions cannot take place<br/> <b>or</b><br/>           electrons cannot move between (3)d orbitals<br/> <b>or</b><br/>           electrons cannot be promoted / excited to higher (3)d orbitals (1)</li> </ul> | <p>Allow zinc (ions) / Zn<sup>2+</sup> do not have a partially filled / incomplete (3)d (sub-) shell / no empty (3)d orbitals</p> <p>Do not allow zinc atoms</p> <p>Ignore omission of 'd' in the 'or's, if it is included in M1</p> <p>Do not allow the (3)d orbitals do not split / the (3)d subshell does not split</p> <p>Ignore just 'movement to different energy level'</p> | (2)  |

| Question Number | Answer  | Additional Guidance  | Mark       |
|-----------------|---|--|------------|
| 4(c)(i)         | <ul style="list-style-type: none"> <li>• 2 water ligands joined between O and Fe <b>(1)</b></li> <li>• 2 ethanedioate ligands drawn correctly showing all the bonds<br/><b>and</b><br/>joined between single-bonded O atoms and Fe as shown <b>(1)</b></li> </ul> | <p><u>Example of structure</u></p>  <p>Allow water ligands arranged as <i>cis</i> or <i>trans</i></p> <p>Allow delocalised bonds in ethanedioate ions</p> <p>Allow bonds not shown in H<sub>2</sub>O, provided the ligands are attached to Fe<sup>2+</sup> through oxygen atoms</p> <p>Ignore bond lengths and angles</p> <p>Ignore wedges and dotted lines to show shape</p> <p>Ignore missing lone pairs and arrowheads</p> <p>Ignore missing square brackets and charge / incorrect charge</p> <p>Ignore -ve charges on ethanedioate ions / +ve charge on Fe</p> | <b>(2)</b> |

| Question Number | Answer   | Additional Guidance   | Mark       |
|-----------------|--|---|------------|
| 4(c)(ii)        | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>(there are) more particles / moles / species on the right of the equation (than on the left)<br/><b>or</b><br/>(there is an increase from) 3 particles on the left of the equation to 5 on the right <b>(1)</b></li> <li>so <math>\Delta S_{\text{system}}</math> increases / is positive (and <math>\Delta S_{\text{surroundings}}</math> is unchanged so <math>\Delta S_{\text{total}}</math> increases ) <b>(1)</b></li> </ul> | <p>Do not allow incorrect numbers of particles</p> <p>Do not allow 3 molecules on the left and 5 molecules on the right</p> <p>Allow <math>\Delta S_{\text{total}}</math> is positive / increasing</p> <p>Allow entropy / <math>\Delta S</math> increases</p> <p>Allow there is a positive entropy change</p> <p>Ignore just there is an increase in disorder (from left to right)</p> <p>Ignore <math>\Delta S_{\text{surroundings}}</math> changes</p> <p>Ignore just 'entropy is positive'</p> <p>Ignore references to free energy</p> | <b>(2)</b> |

| Question Number | Answer  | Additional Guidance   | Mark |
|-----------------|---|---|------|
| 4(d)            | <ul style="list-style-type: none"> <li>• Fe<sup>2+</sup> oxidised to Fe<sup>3+</sup> in reaction with S<sub>2</sub>O<sub>8</sub><sup>2-</sup> (1)</li> <li>• Fe<sup>3+</sup> reduced to Fe<sup>2+</sup> in reaction with I<sup>-</sup> (1)</li> </ul> | <p><u>Examples of equations</u></p> $2\text{Fe}^{2+} + \text{S}_2\text{O}_8^{2-} \rightarrow 2\text{Fe}^{3+} + 2\text{SO}_4^{2-}$<br>$2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$ <p>Ignore state symbols</p> <p>Allow equations in either order</p> <p>Allow multiples</p> <p>Penalise uncancelled electrons once only</p> <p><b>Note</b><br/>If no other mark is awarded, allow (1) for all correct species in 2 unbalanced equations</p> | (2)  |

**(Total for Question 4 = 9 marks)**



| Question Number | Answer   | Mark |
|-----------------|--|------|
| 5(a)            | <p><b>The only correct answer is C</b></p> <p><i>A is not correct because standard enthalpy of formation is for making 1 moles of a compound</i></p> <p><i>B is not correct because standard enthalpy of formation is for making 1 moles of a compound</i></p> <p><i>D is not correct because oxygen must be O<sub>2</sub></i></p> | (1)  |


| Question Number | Answer  | Additional Guidance  | Mark |
|-----------------|---|--|------|
| 5(b)            | <ul style="list-style-type: none"> <li>calculation of energy needed to break bonds<br/>(1)</li> <li>calculation of energy released when bonds are made<br/>(1)</li> <li>calculation of mean bond enthalpy of C—O<br/>(1)</li> </ul> | <p><u>Example of calculation</u><br/>           Energy to break bonds: (C—C) + (C—H) + (C—O)<br/>           = 347 + 413 + (C—O)<br/>           = (C—O) + 760 (kJ)</p> <p>Energy released in forming bonds: (C=C) + (O—H)<br/>           = 612 + 464 = (-)1076 (kJ)</p> <p>(C—O) + 760 - 1076 = 42<br/>           (C—O) = (+)358 (kJ mol<sup>-1</sup>)<br/>           TE on M1 and M2</p> <p>If all bonds broken:<br/>           Energy to break bonds = (C—O) + 4049 (kJ)<br/>           Energy released in forming bonds = (-)4365 (kJ)</p> <p>Ignore units</p> <p>Correct answer with no working scores (3)</p> <p>Allow correct working in M1 and M2 if answers not evaluated</p> | (3)  |

| Question Number | Answer  | Mark |
|-----------------|---|------|
| 5(c)            | <p><b>The only correct answer is A</b></p> <p><i>B is not correct because all increase in entropy as disorder increases when gases are formed</i></p> <p><i>C is not correct because all increase in entropy as disorder increases when gases are formed</i></p> <p><i>D is not correct because all increase in entropy as disorder increases when gases are formed</i></p> | (1)  |

| Question Number | Answer   | Mark |
|-----------------|--|------|
| 5(d)            | <p><b>The only correct answer is D</b></p> <p><i>A is not correct because <math>\Delta S_{\text{surroundings}}</math> is incorrect</i></p> <p><i>B is not correct because <math>\Delta S_{\text{surroundings}}</math> is incorrect</i></p> <p><i>C is not correct because sign of <math>\Delta H/T</math> is incorrect</i></p> | (1)  |

| Question Number | Answer   | Additional Guidance   | Mark       |
|-----------------|--|---|------------|
| 5(e)            | <ul style="list-style-type: none"> <li data-bbox="383 491 1032 528">• calculation of <math>\Delta G</math> <span style="float: right;"><b>(1)</b></span></li> <br/> <li data-bbox="383 743 1032 810">• <math>\Delta G</math> is positive / <math>&gt;0</math> so reaction is not feasible <span style="float: right;"><b>(1)</b></span></li> <br/> <li data-bbox="383 959 1032 995">• calculation of <math>T</math> <span style="float: right;"><b>(1)</b></span></li> </ul> | <p data-bbox="1070 316 1749 347">Penalise incorrect units in M1 or M3 once only</p> <p data-bbox="1070 384 1711 416">Working is not required for the calculations</p> <p data-bbox="1070 459 1406 491"><u>Example of calculation</u></p> <p data-bbox="1070 491 1442 560"><math>\Delta G = 178 - \frac{(298 \times 165)}{1000}</math></p> <p data-bbox="1070 560 1514 592"><math>= (+)128.83 / 129 \text{ (kJ mol}^{-1}\text{)}</math></p> <p data-bbox="1070 600 1111 632"><b>or</b></p> <p data-bbox="1070 632 1498 663"><math>\Delta G = 178000 - (298 \times 165)</math></p> <p data-bbox="1070 663 1559 695"><math>= (+)128830 / 129000 \text{ (J mol}^{-1}\text{)}</math></p> <p data-bbox="1070 743 1335 775">Stand alone mark</p> <p data-bbox="1070 775 1890 807">Allow <math>\Delta G</math> must be negative for a reaction to be feasible</p> <p data-bbox="1070 807 1827 839">Ignore 'so reaction is not feasible' without a reason</p> <p data-bbox="1070 839 1621 871">No TE on a calculated negative value</p> <p data-bbox="1070 919 1406 951"><u>Example of calculation</u></p> <p data-bbox="1070 951 1711 983"><math>\Delta G = 0</math>, so <math>\Delta H = T\Delta S_{(sys)}</math> or <math>T = \Delta H/\Delta S_{(sys)}</math></p> <p data-bbox="1070 991 1111 1023"><b>or</b></p> <p data-bbox="1070 1023 1722 1054"><math>\Delta S_{total} = \Delta S_{sys} - \Delta H/T = 0</math>, so <math>T = \Delta H/\Delta S_{(sys)}</math></p> <p data-bbox="1070 1094 1711 1126"><math>T = 178/0.165 = 1078.8 / 1079 / 1080 \text{ (K)}</math></p> <p data-bbox="1070 1134 1111 1166"><b>or</b></p> <p data-bbox="1070 1166 1738 1198"><math>T = 178000/165 = 1078.8 / 1079 / 1080 \text{ (K)}</math></p> <p data-bbox="1070 1206 1111 1238"><b>or</b></p> <p data-bbox="1070 1238 1263 1270"><math>T = 806 \text{ (}^\circ\text{C)}</math></p> <p data-bbox="1070 1302 1402 1334">Ignore SF except 1 SF</p> | <b>(3)</b> |

**(Total for Question 5 = 9 marks)**

| Question Number | Answer   | Additional Guidance   | Mark |
|-----------------|--|---|------|
| 6(a)(i)         | <ul style="list-style-type: none"> <li>dot-and-cross diagram <b>and</b> charges</li> </ul> | <p>Example of diagram</p>  <p>Circles are not needed</p> <p>Allow no electrons or 8 electrons on outer shell of Mg</p> <p>Allow dots or crosses for all electrons</p> <p>Allow diagrams without square brackets, provided charges are shown</p> <p>Allow alternative ways of showing that there are 2 bromide ions</p> <p>Ignore inner shell electrons</p> | (1)  |

| Question Number | Answer  | Additional Guidance  | Mark |
|-----------------|---|--|------|
| 6(a)(ii)        | <ul style="list-style-type: none"> <li>(conducts electricity when) molten / liquid <b>and</b> dissolved in water / (in) aqueous (solution)</li> </ul> | <p>Both needed for the mark</p> <p>Ignore gaseous</p> <p>Allow 'in solution / dissolved'</p> | (1)  |

| Question Number | Answer and Additional Guidance   | Mark       |
|-----------------|--|------------|
| 6(b)(i)         | <p>Box 3: <math>\text{Mg}^{2+}(\text{g}) + 2\text{Br}(\text{g}) + 2\text{e}^{-}</math></p> <p>Box 2: <math>\text{Mg}^{2+}(\text{g}) + \text{Br}_2(\text{l}) + 2\text{e}^{-}</math></p> <p>Box 1: <math>\text{Mg}^+(\text{g}) + \text{Br}_2(\text{l}) + \text{e}^{-}</math></p> <p>Box 4: <math>\text{Mg}^{2+}(\text{g}) + 2\text{Br}^-(\text{g})</math></p> <p>Bottom: <math>\text{MgBr}_2(\text{s})</math></p> <p>Labels for arrows:</p> <ul style="list-style-type: none"> <li><math>2\Delta_{\text{at}}H[\frac{1}{2}\text{Br}_2(\text{l})]/2 \times (+)112/(+)224</math></li> <li><math>2 \times \text{EA}[\text{Br}(\text{g})]</math></li> <li><math>2^{\text{nd}} \text{IE}[\text{Mg}^+(\text{g})]/(+ )1451</math></li> <li><math>1^{\text{st}} \text{IE}[\text{Mg}(\text{g})]/(+ )738</math></li> <li><math>\Delta_{\text{at}}H[\text{Mg}(\text{g})]/(+ )148</math></li> <li><math>\text{LE}[\text{MgBr}_2(\text{s})]/-2440</math></li> <li><math>\Delta_{\text{f}}H[\text{MgBr}_2(\text{s})]/-524</math></li> </ul> <ul style="list-style-type: none"> <li>• Correct arrows with 1<sup>st</sup> <b>and</b> 2<sup>nd</sup> IE of Mg labelled <b>and</b> correct Mg symbols with state symbols in boxes 1 and 2 or 2 and 3 <b>(1)</b></li> <li>• <math>2 \times \Delta_{\text{at}}H^{\ominus}[\frac{1}{2}\text{Br}_2(\text{l})] / 2 \times (+)112 / (+)224</math> <b>and</b> <math>2\text{Br}(\text{g})</math> in box 3 or 1 <b>and</b> <math>2 \times \text{EA}[\text{Br}(\text{g})]</math> labelled <b>and</b> <math>2\text{Br}^-(\text{g})</math> in box 4 <b>and</b> correct arrows <b>(1)</b></li> <li>• <math>\text{LE}[\text{MgBr}_2(\text{s})] / -2440</math> labelled <b>and</b> arrow in correct direction <b>(1)</b></li> </ul> <p>Allow any unambiguous labels for the arrows with words and/or numbers – state symbols not required<br/> Accept enthalpy change of atomisation of bromine before IEs of magnesium<br/> Ignore missing electrons / <math>2\text{e}^{-}</math> in boxes 1, 2 and 3<br/> Allow 1 state symbol missing but penalise 2 missing, or an incorrect state symbol in boxes once only</p> | <b>(3)</b> |

| Question Number | Answer   | Additional Guidance   | Mark       |
|-----------------|--|---|------------|
| 6(b)(ii)        | <ul style="list-style-type: none"> <li data-bbox="383 284 1142 352">• correct expression for 2 x EA(Br) in numbers or symbols <b>(1)</b></li> <li data-bbox="383 427 1142 464">• calculation of EA(Br) <b>(1)</b></li> </ul> | <p data-bbox="1182 252 1518 279"><u>Example of calculation</u></p> <p data-bbox="1182 284 1906 352">2 x EA(Br) = - (2 x +112) - (+1451) - (+738) - (+148) + (-524) - (-2440)</p> <p data-bbox="1182 427 1827 491">EA(Br) = <math>\frac{-645}{2}</math> = -322.5 / -323 (kJ mol<sup>-1</sup>)</p> <p data-bbox="1182 501 1809 528">Correct answer with no working scores (2)</p> <p data-bbox="1182 571 1435 598">Allow for 1 mark:</p> <p data-bbox="1182 608 1664 635">(+ )322.5 / (+ )323 (wrong sign)</p> <p data-bbox="1182 644 1800 671">-266.5 / -267 (2 missing from <math>\Delta_{at}H</math> (Br))</p> <p data-bbox="1182 681 1563 708">-645 (2 missing from EA)</p> <p data-bbox="1182 718 1621 745">-533 (both 2s missing for Br)</p> <p data-bbox="1182 788 1361 815">Ignore units</p> <p data-bbox="1182 858 1693 885">No TE on incorrect arrows in (b)(i)</p> | <b>(2)</b> |

| Question Number | Answer  | Additional Guidance  | Mark       |
|-----------------|---|--|------------|
| 6(c)(i)         | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• <b>Nuclear charge</b><br/>magnesium (atom) / Mg has more protons than sodium (atom) / Na<br/><b>or</b><br/>magnesium / Mg has a greater (effective) nuclear charge (than sodium / Na) <b>(1)</b></li> <li>• <b>Shielding</b><br/>(outer) electron in magnesium (atom) / Mg in the same (quantum) shell / energy level / sub-shell / orbital as in a sodium atom / Na<br/><b>or</b><br/>shielding in magnesium atom / Mg similar to / same as that in sodium atom / Na <b>(1)</b></li> <li>• <b>Attraction</b><br/>so the force of attraction between the nucleus and the (outer) electron is greater in magnesium (atom) / Mg (than in sodium atom / Na) <b>(1)</b></li> </ul> | <p>Penalise reference to ion once only</p> <p>Ignore reference to atomic radius</p> <p>Allow correct E.C of both atoms</p> <p>Allow same number of (quantum) shells / energy levels in Mg and Na</p> <p>Allow the (outer) electron in Mg is held more tightly to the nucleus (than in Na)</p> <p><b>Note</b><br/>An answer that describes the trend across a period, without one reference to either sodium or magnesium, scores maximum (2) marks</p> | <b>(3)</b> |

| Question Number | Answer  | Additional Guidance   | Mark       |
|-----------------|---|---|------------|
| 6(c)(ii)        | <ul style="list-style-type: none"> <li>correct equation with state symbols</li> </ul> | <p><u>Examples of equations</u></p> $\text{Mg}^{2+}(\text{g}) \rightarrow \text{Mg}^{3+}(\text{g}) + \text{e}^{(-)}$ $\text{Mg}^{2+}(\text{g}) - \text{e}^{(-)} \rightarrow \text{Mg}^{3+}(\text{g})$ <p>Ignore state symbol for the electron</p> <p>Do not allow <math>\rightleftharpoons</math></p> | <b>(1)</b> |

**(Total for Question 6 = 11 marks)**



| Question Number | Answer  | Additional Guidance  | Mark       |
|-----------------|---|--|------------|
| 7(a)            | <ul style="list-style-type: none"> <li>• calculation of moles used <b>(1)</b></li> <li>• calculation of energy for that number of moles <b>(1)</b></li> <li>• calculation of temperature change <b>and</b> gives answer to 2 SF (because a school thermometer cannot measure to 3 SF) <b>(1)</b></li> </ul> | <p><u>Example of calculation</u><br/> moles used = <math>25.0 \times 1.00/1000 = 0.0250</math></p> <p>energy released = <math>0.025 \times 53.4 = 1.335</math> (kJ)<br/> / 1335 (J)<br/> TE on moles used<br/> Ignore sign</p> <p>temperature change = <math>1335/(50.0 \times 4.18)</math><br/> = 6.3876<br/> = 6.4 (°C / K)</p> <p>TE on moles and energy</p> <p>Allow final answer to 3 SF 6.39 (°C / K)</p> <p>Ignore units</p> <p>Correct answer with no working scores (3)</p> | <b>(3)</b> |

| Question Number                                    | Answer   | Additional Guidance                                | Mark  |   |   |     |   |     |   |   |   |   |   |  |     |
|--|--|--|---|---|---|-----|---|-----|---|---|---|---|---|--|-----|
| 7(b)*  | <p>This question assesses a 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="360 568 819 970"> <thead> <tr> <th data-bbox="360 568 573 783">Number of indicative marking points seen in answer</th> <th data-bbox="573 568 819 783">Number of marks awarded for indicative marking points</th> </tr> </thead> <tbody> <tr> <td data-bbox="360 783 573 823">6</td> <td data-bbox="573 783 819 823">4</td> </tr> <tr> <td data-bbox="360 823 573 863">5-4</td> <td data-bbox="573 823 819 863">3</td> </tr> <tr> <td data-bbox="360 863 573 903">3-2</td> <td data-bbox="573 863 819 903">2</td> </tr> <tr> <td data-bbox="360 903 573 943">1</td> <td data-bbox="573 903 819 943">1</td> </tr> <tr> <td data-bbox="360 943 573 970">0</td> <td data-bbox="573 943 819 970">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 | <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, an answer 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). If there are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).</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  |  |   |   |   |     |   |     |   |   |   |   |   |  |     |

The following table shows how the marks should be awarded for structure and lines of reasoning.

|   | Number of marks awarded for structure of answer and sustained line of reasoning |
|---|---|
| Answer shows a coherent and 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   |

**Comment:** Look for the indicative marking points first, then consider the mark for the structure of answer and sustained line of reasoning.

In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks. 3 and 4 indicative points would get 1 mark for reasoning and 0, 1 or 2 indicative points would score zero marks for reasoning.

|  |   |   |  |
|--|---|---|--|
|  | <p><b>Indicative content</b></p> <p><b>Hydrochloric acid and nitric acid</b></p> <ul style="list-style-type: none"> <li>(same value for) hydrochloric acid <b>and</b> nitric acid as they are strong / completely dissociated into ions (in solution)</li> <li>reaction taking place is <math>\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}</math> / <math>\text{H}_3\text{O}^+ + \text{OH}^- \rightarrow 2\text{H}_2\text{O}</math></li> </ul> <p><b>Sulfuric acid</b></p> <ul style="list-style-type: none"> <li>sulfuric acid is diprotic / dibasic<br/><b>or</b><br/>(1 mol of) sulfuric acid provides 2 mol <math>\text{H}^+</math> / produces 2 mol <math>\text{H}_2\text{O}</math></li> <li>so value is (almost) twice that of hydrochloric acid / nitric acid <b>or</b> reverse argument</li> </ul> <p><b>Ethanoic acid</b></p> <ul style="list-style-type: none"> <li>ethanoic acid is weak /partially dissociated into ions (in solution) / <math>\text{CH}_3\text{COOH} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}^+</math> / <math>\text{CH}_3\text{COOH} + \text{H}_2\text{O} \rightleftharpoons \text{CH}_3\text{COO}^- + \text{H}_3\text{O}^+</math></li> <li>some energy is needed to break (O-H) bond(s) to release <math>\text{H}^+</math> ions (so enthalpy change of neutralisation is less than for a strong acid)<br/><b>or</b><br/>enthalpy change of neutralisation includes the enthalpy of dissociation of ethanoic acid so it is less exothermic</li> </ul> | <p>Allow correct formulae for names throughout the answer</p> <p>Ignore sulfuric acid as strong(est) acid</p> <p>Allow <math>\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}</math> <b>and</b> <math>\text{HNO}_3 + \text{NaOH} \rightarrow \text{NaNO}_3 + \text{H}_2\text{O}</math></p> <p>Allow hydrochloric acid <b>and</b> nitric acid are both monoprotic / monobasic / provide 1 mol <math>\text{H}^+</math> / produce 1 mol <math>\text{H}_2\text{O}</math></p> <p>Allow<br/><math>\text{H}_2\text{SO}_4 + 2\text{NaOH} \rightarrow \text{Na}_2\text{SO}_4 + 2\text{H}_2\text{O}</math></p> <p>Allow ethanoic acid is the weakest acid</p> <p>Allow some energy is needed to ionise ethanoic acid</p> |  |
|--|---|---|--|

**(Total for Question 7 = 9 marks)**

| Question Number | Answer   | Mark |
|-----------------|--|------|
| 8(a)            | <p><b>The only correct answer is C</b></p> <p><i>A is not correct because this is for a 100-fold increase in concentration</i></p> <p><i>B is not correct because this is for no change in concentration</i></p> <p><i>D is not correct because this is for a 10000-fold decrease in concentration</i></p> | (1)  |

| Question Number | Answer  | Additional Guidance   | Mark |
|-----------------|---|---|------|
| 8(b)            | <ul style="list-style-type: none"> <li>calculation of <math>[H^+]</math> (1)</li> <li>expression relating <math>K_a</math>, <math>[H^+]</math> and <math>[CH_2OHCOOH]</math> (1)</li> <li>calculation of <math>[CH_2OHCOOH]</math> (1)</li> </ul> | <p><u>Example of calculation</u><br/> <math>[H^+] = 10^{-pH} = 0.01 / 1 \times 10^{-2} / 10^{-2} \text{ (mol dm}^{-3}\text{)}</math></p> $K_a = \frac{[H^+]^2}{[CH_2OHCOOH]}$ <p><b>or</b></p> $[CH_2OHCOOH] = \frac{[H^+]^2}{K_a}$ <p>Allow [HA] in M2 and M3</p> $[CH_2OHCOOH] = \frac{0.01^2}{1.5 \times 10^{-4}}$ $= 0.667 / 0.67 \text{ (mol dm}^{-3}\text{)}$ <p>Ignore SF except 1 SF</p> <p>Ignore units</p> <p>Correct answer with no working scores (3)</p> | (3)  |

| Question Number | Answer  | Additional Guidance   | Mark       |
|-----------------|---|---|------------|
| 8(c)(i)         | <ul style="list-style-type: none"> <li>• named indicator <span style="float: right;"><b>(1)</b></span></li> <li>• matching colour <b>change</b> <span style="float: right;"><b>(1)</b></span></li> <br/> <li>• pH range (of indicator) / quoted range lies (completely) in the vertical region (on the titration curve)</li> <li><b>or</b></li> <li>indicator will change colour in the vertical / straight / steep region of the graph</li> <li><b>or</b></li> <li>pH range of indicator and pH range of vertical region of the graph stated, as long as they overlap <span style="float: right;"><b>(1)</b></span></li> </ul> | <p><u>Examples of indicators and colour changes</u><br/> phenol red – red to orange / yellow<br/> phenolphthalein ((in ethanol)) – red / pink to colourless (do not allow purple or clear)<br/> bromothymol blue – blue to yellow</p> <p>M2 is conditional on a correct indicator in M1<br/> Do not allow unsuitable indicators e.g. litmus</p> <p>Stand alone mark<br/> Allow<br/> <math>pK_{in} (\pm 1)</math> is in the vertical jump<br/> <b>or</b><br/> <math>pK_{in}</math> is nearest to the pH at the end / equivalence point<br/> <b>or</b><br/> indicator will change colour at the end / equivalence point<br/> <b>or</b><br/> (because it is a) titration of a weak acid with a strong base</p> | <b>(3)</b> |

| Question Number | Answer   | Mark |
|-----------------|--|------|
| 8(c)(ii)        | <p><b>The only correct answer is C</b></p> <p><i>A is not correct because used the volumes the wrong way round</i></p> <p><i>B is not correct because not used the volume of glycolic acid from the graph</i></p> <p><i>D is not correct because used a 1:2 mole ratio</i></p> | (1)  |

| Question Number | Answer   | Mark |
|-----------------|--|------|
| 8(c)(iii)       | <p><b>The only correct answer is C</b></p> <p><i>A is not correct because this is the pH of glycolic acid</i></p> <p><i>B is not correct because this is the pH at the end of the vertical jump in the curve</i></p> <p><i>D is not correct because this is the pH at the start of the vertical jump</i></p> | (1)  |

| Question Number | Answer  | Additional Guidance  | Mark |
|-----------------|---|--|------|
| 8(d)(i)         | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>the O of the (extra) OH / hydroxyl group (in the 2 / alpha position / CH<sub>2</sub>OH) withdraws / attracts electrons (1)</li> <li>stabilises the anion / CH<sub>2</sub>OHCOO<sup>-</sup> ion<br/>or<br/>weakens O-H bond in acid so hydrogen ion / H<sup>+</sup> lost more easily (1)</li> </ul> | <p>Allow reference to intramolecular hydrogen bonding</p> <p>Allow hydrogen <b>ion</b> / H<sup>+</sup> more easily dissociates</p> | (2)  |

| Question Number | Answer  | Additional Guidance  | Mark       |
|-----------------|---|--|------------|
| <b>8(d)(ii)</b> | $(\text{CH}_2\text{OHCOOH} + \text{CH}_3\text{COOH} \rightarrow )$<br><ul style="list-style-type: none"> <li>• <math>\text{CH}_2\text{OHCOO}^- + \text{CH}_3\text{COOH}_2^+</math></li> </ul> | Both correct for the mark<br><br>Allow formulae in either order<br><br>Allow formulae in brackets with charge outside<br><br>Allow displayed formulae<br><br>Do not allow $\text{CH}_3\text{C}(\text{OH})_2^+$ | <b>(1)</b> |

**(Total for Question 8 = 12 marks)**



| Question Number | Answer  | Additional Guidance  | Mark       |
|-----------------|---|--|------------|
| 9(a)            | <ul style="list-style-type: none"> <li>• <math>\text{HPO}_4^{2-} + \text{H}^+ \rightarrow \text{H}_2\text{PO}_4^-</math></li> <li><b>or</b></li> <li>• <math>\text{HPO}_4^{2-} + \text{H}_3\text{O}^+ \rightarrow \text{H}_2\text{PO}_4^- + \text{H}_2\text{O}</math> <b>(1)</b></li> <li>• <math>\text{H}_2\text{PO}_4^- + \text{OH}^- \rightarrow \text{HPO}_4^{2-} + \text{H}_2\text{O}</math> <b>(1)</b></li> </ul> | <p>Penalise non-ionic equations, e.g. using NaOH or HCl once only</p> <p>Equations must show reaction of ions with <math>\text{H}^+</math> / <math>\text{H}_3\text{O}^+</math> and <math>\text{OH}^-</math></p> <p>Allow <math>\rightleftharpoons</math></p> <p>Ignore state symbols</p> <p>Allow <math>\text{H}_2\text{PO}_4^- \rightarrow \text{HPO}_4^{2-} + \text{H}^+</math> <b>and</b><br/> <math>\text{H}^+ + \text{OH}^- \rightarrow \text{H}_2\text{O}</math></p> | <b>(2)</b> |

| Question Number | Answer  | Additional Guidance   | Mark       |
|-----------------|---|---|------------|
| 9(b)            | <ul style="list-style-type: none"> <li>• calculation of the amount of NaOH / salt <b>(1)</b></li> <li>• calculation of initial amount of acid <b>(1)</b></li> <li>• calculation of the amount of acid left <b>(1)</b></li> <li>• calculation of [H<sup>+</sup>] <b>(1)</b></li> <li>• calculation of pH <b>(1)</b></li> </ul> | <p><u>Example of calculation</u></p> <p>amount of NaOH = amount of salt formed<br/> <math>= 0.100 \times 20.0/1000 = 0.00200</math></p> <p>initial amount of acid = <math>0.150 \times 25.0/1000 = 0.00375</math></p> <p>amount of acid left = <math>0.00375 - 0.00200 = 0.00175</math></p> <p>total volume = <math>20.0 + 25.0 = 45.0 \text{ (cm}^3\text{)}</math><br/> [salt] = <math>0.00200 \times 1000/45.0 = 0.0444 \text{ (mol dm}^{-3}\text{)}</math><br/> [acid] = <math>0.00175 \times 1000/45.0 = 0.0389 \text{ (mol dm}^{-3}\text{)}</math></p> <p><math>K_a = \frac{[\text{H}^+][\text{salt}]}{[\text{acid}]}</math> so <math>[\text{H}^+] = K_a \frac{[\text{acid}]}{[\text{salt}]}</math></p> <p><math>[\text{H}^+] = 1.74 \times 10^{-5} \times 0.0389/0.0444 = 1.52446 \times 10^{-5} \text{ (mol dm}^{-3}\text{)}</math></p> <p>Allow use of moles instead of concentrations</p> <p>pH = <math>-\log[\text{H}^+] = -\log(1.52446 \times 10^{-5}) = 4.817 / 4.82 / 4.8</math></p> <p>Allow TE for each step</p> <p>Ignore SF except 1 SF</p> <p>Correct answer without working score (5)</p> | <b>(5)</b> |

|  |  |  |  |
|--|--|--|--|
|  |  | <p>Allow alternative methods, for example</p> $\text{pH} = \text{p}K_a - \log \frac{[\text{acid}]}{[\text{salt}]}$ $\text{pH} = -\log 1.74 \times 10^{-5} - \log \frac{0.0389}{0.0444}$ <p>pH = 4.817 / 4.82 / 4.8 scores M4 and M5</p> <p><b>or</b></p> $\text{pH} = \text{p}K_a + \log \frac{[\text{salt}]}{[\text{acid}]}$ $\text{pH} = -\log 1.74 \times 10^{-5} + \log \frac{0.0444}{0.0389}$ <p>pH = 4.817 / 4.82 / 4.8 scores M4 and M5</p> |  |
|--|--|--|--|

**(Total for Question 9 = 7 marks)**

| Question Number | Answer  | Additional Guidance   | Mark |
|-----------------|---|---|------|
| 10(a)(i)        | <p>An answer that makes reference to the following point:</p> <ul style="list-style-type: none"> <li>carbon / solid has no (vapour / partial) pressure<br/><b>or</b><br/>(partial) pressure of carbon / solid is constant<br/><b>or</b><br/>carbon does not contribute to the overall pressure (of the system)</li> </ul> | <p>Allow the reaction is heterogeneous <b>and</b> (partial) pressure of a pure solid is not included (in <math>K_p</math> expression)</p> <p>Do not allow just 'because carbon is a solid' or 'carbon is not a gas'</p> | (1)  |

| Question Number | Answer  | Additional Guidance   | Mark |
|-----------------|---|---|------|
| 10(a)(ii)       | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>there are fewer moles / molecules / particles of <b>gas</b> on the left / reactant side<br/><b>(1)</b></li> <li>so equilibrium position/ it moves / shifts to the left / reactant side<br/><b>(1)</b></li> </ul> | <p>Allow 2 moles / molecules of <b>gas</b> on right and 1 mole / molecule on left</p> <p>M2 is conditional on M1 <b>or</b> the idea of fewer particles on the left / decreasing the value of the quotient / Q</p> <p>Do not allow any indication of <math>K_p</math> changing</p> | (2)  |

| Question Number   | Answer  | Additional Guidance  | Mark       |
|-------------------|---|--|------------|
| <b>10(a)(iii)</b> | <p>An explanation that makes reference to the following points:</p> <ul style="list-style-type: none"> <li>• (forward) reaction is endothermic<br/><b>and</b><br/>so equilibrium constant / <math>K_p</math> increases as temperature increases <b>(1)</b></li> <li>• so equilibrium position / it moves / shifts to the right / product side <b>(1)</b></li> </ul> | <p>Ignore references to <math>\Delta G</math> and <math>\Delta S</math></p> <p>M2 is conditional on M1 <b>or</b> endothermic or equilibrium constant increases</p> | <b>(2)</b> |

| Question Number                         | Answer  | Additional Guidance  | Mark                      |                     |                    |       |               |      |   |   |           |                       |      |      |   |  |  |  |               |                        |                       |                       |                       |                              |                            |                           |     |
|---|---|--|---------------------------|---------------------|--------------------|-------|---------------|------|---|---|-----------|-----------------------|------|------|---|--|--|--|---------------|------------------------|-----------------------|-----------------------|-----------------------|------------------------------|----------------------------|---------------------------|-----|
| 10(a)(iv)                               | <ul style="list-style-type: none"> <li>• calculation of moles of each substance at equilibrium <span style="float: right;">(1)</span></li> <br/> <li>• calculation of partial pressure of each substance <span style="float: right;">(1)</span></li> <br/> <li>• calculation of <math>K_p</math> <span style="float: right;">(1)</span></li> <br/> <li>• units (stand alone mark) <span style="float: right;">(1)</span></li> </ul> | <p>Example of calculation:</p> <table border="1" style="width: 100%; border-collapse: collapse; text-align: center;"> <thead> <tr> <th></th> <th>H<sub>2</sub>O(g)</th> <th>H<sub>2</sub>(g)</th> <th>CO(g)</th> </tr> </thead> <tbody> <tr> <td>Initial moles</td> <td>1.00</td> <td>0</td> <td>0</td> </tr> <tr> <td>Eqm moles</td> <td>1.00 – 0.81<br/>= 0.19</td> <td>0.81</td> <td>0.81</td> </tr> <tr> <td colspan="4">Total moles = 0.19 + 0.81 + 0.81 = 1.81</td> </tr> <tr> <td>Mole fraction</td> <td>0.19/1.81<br/>= 0.10497</td> <td>0.81/1.81<br/>= 0.4475</td> <td>0.81/1.81<br/>= 0.4475</td> </tr> <tr> <td>Partial pressure /atm</td> <td>0.10497 x<br/>2.0<br/>=0.20994</td> <td>0.4475 x<br/>2.0<br/>= 0.895</td> <td>0.4475 x<br/>2.0<br/>=0.895</td> </tr> </tbody> </table> <p style="text-align: center;"> <math display="block">K_p = \frac{0.895 \times 0.895}{0.20994}</math> <math display="block">= 3.815 / 3.82 / 3.8 \text{ atm}</math> </p> <p>3.8144 / 3.814 / 3.81 / 3.8 atm from 0.105 and 0.210</p> <p>Correct answer with units but no working scores (4)</p> <p>Allow TE for M2 and M3</p> <p>Ignore SF except 1 SF</p> |                           | H <sub>2</sub> O(g) | H <sub>2</sub> (g) | CO(g) | Initial moles | 1.00 | 0 | 0 | Eqm moles | 1.00 – 0.81<br>= 0.19 | 0.81 | 0.81 | Total moles = 0.19 + 0.81 + 0.81 = 1.81 |  |  |  | Mole fraction | 0.19/1.81<br>= 0.10497 | 0.81/1.81<br>= 0.4475 | 0.81/1.81<br>= 0.4475 | Partial pressure /atm | 0.10497 x<br>2.0<br>=0.20994 | 0.4475 x<br>2.0<br>= 0.895 | 0.4475 x<br>2.0<br>=0.895 | (4) |
|   | H <sub>2</sub> O(g)   | H <sub>2</sub> (g)   | CO(g)                     |                     |                    |       |               |      |   |   |           |                       |      |      |   |  |  |  |               |                        |                       |                       |                       |                              |                            |                           |     |
| Initial moles                           | 1.00  | 0  | 0                         |                     |                    |       |               |      |   |   |           |                       |      |      |   |  |  |  |               |                        |                       |                       |                       |                              |                            |                           |     |
| Eqm moles                               | 1.00 – 0.81<br>= 0.19   | 0.81   | 0.81                      |                     |                    |       |               |      |   |   |           |                       |      |      |   |  |  |  |               |                        |                       |                       |                       |                              |                            |                           |     |
| Total moles = 0.19 + 0.81 + 0.81 = 1.81 |   |  |                           |                     |                    |       |               |      |   |   |           |                       |      |      |   |  |  |  |               |                        |                       |                       |                       |                              |                            |                           |     |
| Mole fraction                           | 0.19/1.81<br>= 0.10497  | 0.81/1.81<br>= 0.4475  | 0.81/1.81<br>= 0.4475     |                     |                    |       |               |      |   |   |           |                       |      |      |   |  |  |  |               |                        |                       |                       |                       |                              |                            |                           |     |
| Partial pressure /atm                   | 0.10497 x<br>2.0<br>=0.20994  | 0.4475 x<br>2.0<br>= 0.895   | 0.4475 x<br>2.0<br>=0.895 |                     |                    |       |               |      |   |   |           |                       |      |      |   |  |  |  |               |                        |                       |                       |                       |                              |                            |                           |     |

| Question Number | Answer  | Additional Guidance  | Mark       |
|-----------------|---|--|------------|
| 10(b)           | <ul style="list-style-type: none"> <li data-bbox="383 355 1288 619">           • the quotient / Q:<br/> <math display="block">\frac{[\text{CO}_2][\text{H}_2]}{[\text{CO}][\text{H}_2\text{O}]} = \frac{2 \times 2}{1 \times 1} = 4</math>, which is larger than <math>K_c</math><br/> <b>or</b><br/>           (since <math>K_c = 1</math>) the concentrations of the products must be equal to the concentrations of the reactants at equilibrium <span style="float: right;"><b>(1)</b></span> </li> <li data-bbox="383 691 1288 831">           • the concentrations of <math>\text{CO}_2</math> and <math>\text{H}_2</math> / products need to decrease<br/> <b>and</b><br/>           those of <math>\text{CO}</math> and <math>\text{H}_2\text{O}</math> / reactants need to increase <span style="float: right;"><b>(1)</b></span> </li> <li data-bbox="383 903 1288 933">           • so reaction shifts to the left <span style="float: right;"><b>(1)</b></span> </li> </ul> | <p data-bbox="1328 248 1816 316">Allow amounts / moles / (partial) pressures for concentrations</p> <p data-bbox="1328 355 1872 422">Allow calculated <math>K_c</math> / the quotient / Q will be greater than 1</p> <p data-bbox="1328 679 1872 746">Allow shift so that there is 1.5 mol of each substance</p> <p data-bbox="1328 895 1854 925">M3 conditional on some explanation</p> | <b>(3)</b> |

**(Total for Question 10 = 12 marks)**

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**TOTAL FOR PAPER = 90 MARKS**

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