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

- 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

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)	**The only correct answer is B** ***A*** *is not correct because incorrect electrons* ***C*** *is not correct because incorrect protons, neutrons and electrons* ***D*** *is not correct because incorrect protons and neutrons*	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(b)(i)	An explanation that makes reference to the following points: • (pyramidal / this shape) because there are 4 pairs / 3 bond pairs and one lone pair of electrons (around central / P atom) **and** these are arranged to minimise repulsion **(1)** • (bond angle less than 109.5^{o}) as lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion **(1)**	‘ions’ scores (0) overall Allow the electron pairs are arranged to minimise repulsion Allow (4) pairs of electrons with maximum separation / as far apart as possible Ignore reference to ‘bonds’ Ignore wrong shape Ignore repel equally Ignore repulsion between electrons There must be a comparison in M2 Allow lone pairs have greater repulsion than bond pairs Ignore just ‘the lone pairs repel more’ Ignore repetition of the question e.g. ‘reduces the bond angle’ Ignore incorrect bond angle stated (Data book value is 100.1^{o}) Do not allow bond angle $>109.5^{o}$	**(2)**

Question Number	Answer	Mark
1(b)(ii)	**The only correct answer is D** ***A*** *is not correct because both incorrect* ***B*** *is not correct because non-polar bond is incorrect* ***C*** *is not correct because non-polar molecule is incorrect*	**(1)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
1(c)	• all 4 ion formulae **(1)** • all 4 m/z values **(1)** **or** • any two m/z values with corresponding ion formulae **(1)** • the other two m/z values with corresponding ion formulae **(1)**	Example of answer: ions m/z $P(^{35}Cl)_3^+$ 136 $P(^{35}Cl)_2{}^{37}Cl^+$ 138 $P^{35}Cl(^{37}Cl)_2^+$ 140 $P(^{37}Cl)_3^+$ 142 Allow any other unambiguous way of representing the formulae e.g. with brackets or in words Positive charge only needs to be shown on one of the ions Ignore mass number on P	**(2)**

(Total for Question 1 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)	An explanation that makes reference to the following points: • N changes from (+)5 to (+)4 **(1)** • O changes from −2 to 0 (in O_2) **(1)** • so nitrogen / N is reduced (as the oxidation number has decreased) **and** oxygen / O (in forming O_2) is oxidised (as the oxidation number has increased) **(1)**	These numbers may be written under the formulae in the equation Allow oxidation numbers written as 5+, 4+, 2− Ignore unchanged oxidation numbers of magnesium and oxygen Allow this mark if incorrect / missing oxidation numbers in M1 and M2 Ignore general statement about redox Ignore redox explained in terms of electron gain or loss	**(3)**

Question Number	Answer	Additional Guidance	Mark
2(b)	An explanation that makes reference to the following points: - **Size** calcium ion / Ca^{2+} has larger (ionic) radius / is larger than magnesium ion **or** magnesium ion / Mg^{2+} has smaller (ionic) radius / is smaller than calcium ion **(1)** - **Polarising power** so calcium ion/ Ca^{2+} causes less polarisation/ distortion **or** magnesium ion/ Mg^{2+}causes more polarisation/ distortion **(1)** - **What is polarised** of the nitrate (ion / electron cloud) / NO_3^- / anion / negative ion / N—O bonds / N=O bonds / NO bonds **(1)**	Penalise omission of 'ion' **or** just 'calcium / Ca / magnesium / Mg' without charge, **or** reference to atom or molecule once only Ignore general references to ionic / covalent character Allow ionic radius increases down the group / decreases up the group Allow magnesium ions have a higher charge density (than calcium ions) Ignore atomic radius Ignore effective nuclear charge Allow the cation causes less / more polarisation if it is clear from M1 which cation is involved Do not allow this mark for carbonate / C-O bonds Do not allow mention of bond **between** cation and anion **Note** Nitrate ions are less polarised by Ca^{2+} / more polarised by Mg^{2+} scores M2 and M3	**(3)**

(Total for Question 2 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
3(a)	An explanation that makes reference to the following points: • from chlorine to iodine / down the group, the number of electrons (in the molecule / atom) increases / changes from 34 to 106 / 17 to 53 **(1)** • so the strength of the London / instantaneous dipole-(induced) dipole forces increases / there are more London / instantaneous dipole-(induced) dipole forces **and** more energy is needed to separate the molecules **(1)**	An answer that states 'covalent bonds break' or 'bonds between atoms break' or refers to 'ions' scores (0) overall Allow reverse argument for M1 and M2 Allow iodine has more / most electron shells (than chlorine and/or bromine) Ignore 'the size of the atoms /molecules increases from chlorine to iodine' Do not allow incorrect numbers of electrons Allow iodine has the strongest London force **and** most energy is needed to separate the molecules Allow more energy is need to overcome / break the London forces / bonds instead of separate the molecules Allow dispersion forces / van der Waals forces for London forces Ignore higher temperature needed to separate the molecules Do not award dipole-dipole forces / just 'intermolecular forces'	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(b)	An explanation that makes reference to the following points:	Allow the oxidation numbers written by the species in the table (+)6 only needs to be mentioned once in M1 or M2 Allow references to potassium halides / halogens / hydrogen halides instead of halide ions For full marks, the answer must identify iodide as the strongest reducing agent	**(3)**
	• iodide ions are the strongest reducing agent because iodide ions / I^- / (potassium) iodide reduces sulfur (in sulfuric acid) from +6 to 0 in sulfur / −2 in H_2S **(1)**	Only 1 oxidation number change is needed. If both are given, both must be correct	
	• (whereas) bromide ions / Br^- / (potassium) bromide reduces sulfur (in sulfuric acid) from +6 to +4 **(1)**	Allow bromide ions are stronger reducing agents than chloride ions because they are oxidised from −1 to 0	
	• (whereas) chloride ions / Cl^- / (potassium) chloride do not reduce sulfuric acid / sulfur / S (as there is no change in oxidation number of Cl or S) **(1)**	Allow just ‘it is not a redox reaction’	

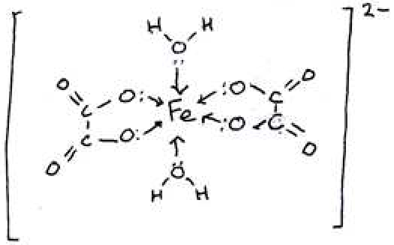
Question Number	**Answer**	**Mark**
3(c)(i)	**The only correct answer is A** ***B*** *is not correct because Cl⁻ is not an oxidising agent* ***C*** *is not correct because I₂ is not a powerful enough oxidising agent* ***D*** *is not correct because* Mn^{2+} is not an oxidising agent	**(1)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
3(c)(ii)	• all species on correct sides of equation **and** no electrons / electrons cancelled **(1)** • balancing correct species **(1)** • $E^{\ominus}_{cell}$ value **(1)**	Example of ionic equation $2MnO_4^- + 16H^+ + 10Br^- \rightarrow 2Mn^{2+} + 8H_2O + 5Br_2$ Allow ⇌ Allow correct species if shown in working with half-equations but slip made in final equation e.g. charge missing Ignore state symbols Allow multiples Allow M2 for almost correct species $E^{\ominus}_{cell}$ (= 1.51 − 1.09) = (+)0.42 (V) No TE on incorrect equation	**(3)**

(Total for Question 3 = 9 marks)

Question Number	Answer	Mark
4(a)	**The only correct answer is B** ***A*** *is not correct because 4 of the 3d electrons should be unpaired* ***C*** *is not correct because there should not be any electrons in the 4s orbital* ***D*** *is not correct because there should not be any electrons in the 4s orbital*	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(b)	An explanation that makes reference to the following points:		**(2)**
	• (zinc (ions) / Zn^{2+}) has / have a full (3)d sub-shell / $3d^{10}$ / all (3)d orbital**s** are full **(1)**	Allow zinc (ions) / Zn^{2+} do not have a partially filled / incomplete (3)d (sub-) shell / no empty (3)d orbitals Do not allow zinc atoms	
	• so d-d transitions cannot take place **or** electrons cannot move between (3)d orbitals **or** electrons cannot be promoted / excited to higher (3)d orbitals **(1)**	Ignore omission of 'd' in the 'or's, if it is included in M1 Do not allow the (3)d orbitals do not split / the (3)d subshell does not split Ignore just 'movement to different energy level'	

Question Number	Answer	Additional Guidance	Mark
4(c)(i)	- 2 water ligands joined between O and Fe **(1)** - 2 ethanedioate ligands drawn correctly showing all the bonds **and** joined between single-bonded O atoms and Fe as shown **(1)**	Example of structure  Allow water ligands arranged as *cis* or *trans* Allow delocalised bonds in ethanedioate ions Allow bonds not shown in H_2O, provided the ligands are attached to Fe^{2+} through oxygen atoms Ignore bond lengths and angles Ignore wedges and dotted lines to show shape Ignore missing lone pairs and arrowheads Ignore missing square brackets and charge / incorrect charge Ignore –ve charges on ethanedioate ions / +ve charge on Fe	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(c)(ii)	An explanation that makes reference to the following points: • (there are) more particles / moles / species on the right of the equation (than on the left) **or** (there is an increase from) 3 particles on the left of the equation to 5 on the right **(1)** • so ΔS_{system} increases / is positive (and $\Delta S_{\text{surroundings}}$ is unchanged so ΔS_{total} increases) **(1)**	Do not allow incorrect numbers of particles Do not allow 3 molecules on the left and 5 molecules on the right Allow ΔS_{total} is positive / increasing Allow entropy / ΔS increases Allow there is a positive entropy change Ignore just there is an increase in disorder (from left to right) Ignore $\Delta S_{\text{surroundings}}$ changes Ignore just 'entropy is positive' Ignore references to free energy	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(d)	• Fe^{2+} oxidised to Fe^{3+} in reaction with $S_2O_8^{2-}$ **(1)** • Fe^{3+} reduced to Fe^{2+} in reaction with I^- **(1)**	Examples of equations $2Fe^{2+} + S_2O_8^{2-} \rightarrow 2Fe^{3+} + 2SO_4^{2-}$ $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$ Ignore state symbols Allow equations in either order Allow multiples Penalise uncancelled electrons once only **Note** If no other mark is awarded, allow (1) for all correct species in 2 unbalanced equations	**(2)**

(Total for Question 4 = 9 marks)

Question Number	Answer	Mark
5(a)	**The only correct answer is C** ***A*** *is not correct because standard enthalpy of formation is for making 1 moles of a compound* ***B*** *is not correct because standard enthalpy of formation is for making 1 moles of a compound* ***D*** *is not correct because* oxygen must be O_2	**(1)**

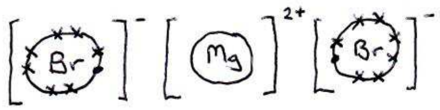
Question Number	Answer	Additional Guidance	Mark
5(b)	• calculation of energy needed to break bonds **(1)**	<u>Example of calculation</u> Energy to break bonds: (C—C) + (C—H) + (C—O) = 347 + 413 + (C—O) = (C—O) + 760 (kJ)	**(3)**
	• calculation of energy released when bonds are made **(1)**	Energy released in forming bonds: (C=C) + (O—H) = 612 + 464 = (−)1076 (kJ)	
	• calculation of mean bond enthalpy of C—O **(1)**	(C—O) + 760 – 1076 = 42 (C—O) = (+)358 (kJ mol^{-1}) TE on M1 and M2 If all bonds broken: Energy to break bonds = (C—O) + 4049 (kJ) Energy released in forming bonds = (−)4365 (kJ) Ignore units Correct answer with no working scores (3) Allow correct working in M1 and M2 if answers not evaluated	

Question Number	Answer	Mark
5(c)	**The only correct answer is A** ***B*** *is not correct because all increase in entropy as disorder increases when gases are formed* ***C*** *is not correct because all increase in entropy as disorder increases when gases are formed* ***D*** *is not correct because all increase in entropy as disorder increases when gases are formed*	**(1)**

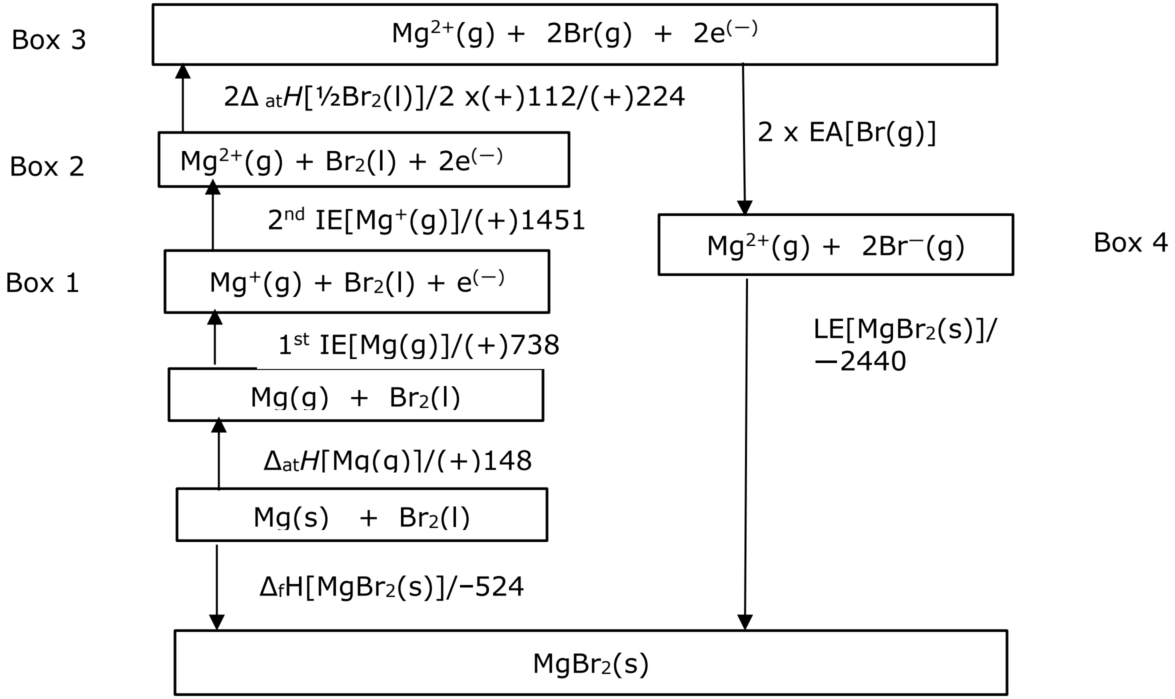
Question Number	Answer	Mark
5(d)	**The only correct answer is D** ***A*** *is not correct because* $\Delta S_{\text{surroundings}}$ *is incorrect* ***B*** *is not correct because* $\Delta S_{\text{surroundings}}$ *is incorrect* ***C*** *is not correct because sign of* $\Delta H/T$ *is incorrect*	**(1)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
5(e)	 • calculation of ΔG **(1)** • ΔG is positive / >0 so reaction is not feasible **(1)** • calculation of T **(1)**	Penalise incorrect units in M1 or M3 once only Working is not required for the calculations Example of calculation $\Delta G = 178 - (298 \times \frac{165}{1000})$ = (+)128.83 / 129 (kJ mol^{-1}) **or** $\Delta G = 178000 - (298 \times 165)$ = (+)128830 / 129000 (J mol^{-1}) Stand alone mark Allow ΔG must be negative for a reaction to be feasible Ignore 'so reaction is not feasible' without a reason No TE on a calculated negative value Example of calculation $\Delta G = 0$, so $\Delta H = T\Delta S_{(sys)}$ or $T = \Delta H/\Delta S_{(sys)}$ **or** $\Delta S_{total} = \Delta S_{sys} - \Delta H/T = 0$, so $T = \Delta H/\Delta S_{(sys)}$ T = 178/0.165 = 1078.8 / 1079 / 1080 (K) **or** T = 178000/165 = 1078.8 / 1079 / 1080 (K) **or** T = 806 (°C) Ignore SF except 1 SF	**(3)**

(Total for Question 5 = 9 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)(i)	• dot-and-cross diagram **and** charges	Example of diagram  Circles are not needed Allow no electrons or 8 electrons on outer shell of Mg Allow dots or crosses for all electrons Allow diagrams without square brackets, provided charges are shown Allow alternative ways of showing that there are 2 bromide ions Ignore inner shell electrons	(1)

Question Number	Answer	Additional Guidance	Mark
6(a)(ii)	• (conducts electricity when) molten / liquid **and** dissolved in water / (in) aqueous (solution)	Both needed for the mark Ignore gaseous Allow 'in solution / dissolved'	(1)

<table>
<tr><th>Question Number</th><th>Answer and Additional Guidance</th><th>Mark</th></tr>
<tr><td>6(b)(i)</td><td>


- Correct arrows with 1st **and** 2nd IE of Mg labelled **and** correct Mg symbols with state symbols in boxes 1 and 2 or 2 and 3 **(1)**
- 2 x $\Delta_{at}H^\ominus[\frac{1}{2}Br_2(l)]$ / 2 x(+)112 / (+)224 **and** 2Br(g) in box 3 or 1 **and** 2 x EA[Br(g)] labelled **and** $2Br^-(g)$ in box 4 **and** correct arrows **(1)**
- LE$[MgBr_2(s)]$ / −2440 labelled **and** arrow in correct direction **(1)**

Allow any unambiguous labels for the arrows with words and/or numbers – state symbols not required
Accept enthalpy change of atomisation of bromine before IEs of magnesium
Ignore missing electrons / $2e^{(-)}$ in boxes 1, 2 and 3
Allow 1 state symbol missing but penalise 2 missing, or an incorrect state symbol in boxes once only
</td><td>(3)</td></tr>
</table>

Question Number	Answer	Additional Guidance	Mark
6(b)(ii)	• correct expression for 2 x EA(Br) in numbers or symbols **(1)** • calculation of EA(Br) **(1)**	Example of calculation 2 x EA(Br) = − (2 x +112) − (+1451) − (+738) − (+148) + (−524) − (−2440) EA(Br) = $-\frac{645}{2}$ = −322.5 /−323 (kJ mol^{-1}) Correct answer with no working scores (2) Allow for 1 mark: (+)322.5 / (+)323 (wrong sign) −266.5 /−267 (2 missing from $\Delta_{at}H$ (Br)) −645 (2 missing from EA) −533 (both 2s missing for Br) Ignore units No TE on incorrect arrows in (b)(i)	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	An explanation that makes reference to the following points: • **Nuclear charge** magnesium (atom) / Mg has more protons than sodium (atom) / Na **or** magnesium / Mg has a greater (effective) nuclear charge (than sodium / Na) **(1)** • **Shielding** (outer) electron in magnesium (atom) / Mg in the same (quantum) shell / energy level / sub-shell / orbital as in a sodium atom / Na **or** shielding in magnesium atom / Mg similar to / same as that in sodium atom / Na **(1)** • **Attraction** so the force of attraction between the nucleus and the (outer) electron is greater in magnesium (atom) / Mg (than in sodium atom / Na) **(1)**	Penalise reference to ion once only Ignore reference to atomic radius Allow correct E.C of both atoms Allow same number of (quantum) shells / energy levels in Mg and Na Allow the (outer) electron in Mg is held more tightly to the nucleus (than in Na) **Note** An answer that describes the trend across a period, without one reference to either sodium or magnesium, scores maximum (2) marks	**(3)**

Question Number	**Answer**	**Additional Guidance**	**Mark**
6(c)(ii)	• correct equation with state symbols	Examples of equations $Mg^{2+}(g) \rightarrow Mg^{3+}(g) + e^{(-)}$ $Mg^{2+}(g) - e^{(-)} \rightarrow Mg^{3+}(g)$ Ignore state symbol for the electron Do not allow ⇌	**(1)**

(Total for Question 6 = 11 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)	• calculation of moles used **(1)** • calculation of energy for that number of moles **(1)** • calculation of temperature change **and** gives answer to 2 SF (because a school thermometer cannot measure to 3 SF) **(1)**	Example of calculation moles used = 25.0 x 1.00/1000 = 0.0250 energy released = 0.025 x 53.4 = 1.335 (kJ) / 1335 (J) TE on moles used Ignore sign temperature change = 1335/(50.0 x 4.18) = 6.3876 = 6.4 (^{o}C / K) TE on moles and energy Allow final answer to 3 SF 6.39 (^{o}C / K) Ignore units Correct answer with no working scores (3)	**(3)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>7(b)*</td><td>This question assesses a student's ability to show a coherent and logically structured answer with linkages and fully-sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr>
<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>
</table></td><td>Guidance on how the mark scheme should be applied:
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).</td><td>(6)</td></tr>
</table>

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.

	Indicative content **Hydrochloric acid and nitric acid** • (same value for) hydrochloric acid **and** nitric acid as they are strong / completely dissociated into ions (in solution) • reaction taking place is $H^+ + OH^- \rightarrow H_2O$ / $H_3O^+ + OH^- \rightarrow 2H_2O$ **Sulfuric acid** • sulfuric acid is diprotic / dibasic **or** (1 mol of) sulfuric acid provides 2 mol H^+ / produces 2 mol H_2O • so value is (almost) twice that of hydrochloric acid / nitric acid **or** reverse argument **Ethanoic acid** • ethanoic acid is weak /partially dissociated into ions (in solution) / $CH_3COOH \rightleftharpoons CH_3COO^- + H^+$ / $CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$ • some energy is needed to break (O-H) bond(s) to release H^+ ions (so enthalpy change of neutralisation is less than for a strong acid) **or** enthalpy change of neutralisation includes the enthalpy of dissociation of ethanoic acid so it is less exothermic	Allow correct formulae for names throughout the answer Ignore sulfuric acid as strong(est) acid Allow $HCl + NaOH \rightarrow NaCl + H_2O$ **and** $HNO_3 + NaOH \rightarrow NaNO_3 + H_2O$ Allow hydrochloric acid **and** nitric acid are both monoprotic / monobasic / provide 1 mol H^+ / produce 1 mol H_2O Allow $H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$ Allow ethanoic acid is the weakest acid Allow some energy is needed to ionise ethanoic acid	

(Total for Question 7 = 9 marks)

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

Question Number	Answer	Additional Guidance	Mark
8(b)	• calculation of $[H^+]$ **(1)** • expression relating K_a, $[H^+]$ and $[CH_2OHCOOH]$ **(1)** • calculation of $[CH_2OHCOOH]$ **(1)**	<u>Example of calculation</u> $[H^+] = 10^{-pH} = 0.01$ / 1×10^{-2} / 10^{-2} (mol dm^{-3}) $K_a = \frac{[H^+]^2}{[CH_2OHCOOH]}$ **or** $[CH_2OHCOOH] = \frac{[H^+]^2}{K_a}$ Allow [HA] in M2 and M3 $[CH_2OHCOOH] = \frac{0.01^2}{1.5 \times 10^{-4}}$ = 0.667 / 0.67 (mol dm^{-3}) Ignore SF except 1 SF Ignore units Correct answer with no working scores (3)	**(3)**

Question Number	Answer	Additional Guidance	Mark
8(c)(i)	• named indicator **(1)** • matching colour **change** **(1)** • pH range (of indicator) / quoted range lies (completely) in the vertical region (on the titration curve) **or** indicator will change colour in the vertical / straight / steep region of the graph **or** pH range of indicator and pH range of vertical region of the graph stated, as long as they overlap **(1)**	<u>Examples of indicators and colour changes</u> phenol red – red to orange / yellow phenolphthalein ((in ethanol)) – red / pink to colourless (do not allow purple or clear) bromothymol blue – blue to yellow M2 is conditional on a correct indicator in M1 Do not allow unsuitable indicators e.g. litmus Stand alone mark Allow pK_{in} (± 1) is in the vertical jump **or** pK_{in} is nearest to the pH at the end / equivalence point **or** indicator will change colour at the end / equivalence point **or** (because it is a) titration of a weak acid with a strong base	**(3)**

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

Question Number	Answer	Mark
8(c)(iii)	**The only correct answer is C** ***A*** *is not correct because this is the pH of glycolic acid* ***B*** *is not correct because this is the pH at the end of the vertical jump in the curve* ***D*** *is not correct because this is the pH at the start of the vertical jump*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(d)(i)	An explanation that makes reference to the following points:		**(2)**
	• the O of the (extra) OH / hydroxyl group (in the 2 / alpha position / CH_2OH) withdraws / attracts electrons **(1)**	Allow reference to intramolecular hydrogen bonding	
	• stabilises the anion / CH_2OHCOO^- ion **or** weakens O-H bond in acid so hydrogen **ion** / H^+ lost more easily **(1)**	Allow hydrogen **ion** / H^+ more easily dissociates	

Question Number	Answer	Additional Guidance	Mark
8(d)(ii)	($CH_2OHCOOH$ + CH_3COOH →) • CH_2OHCOO^- + $CH_3COOH_2^+$	Both correct for the mark Allow formulae in either order Allow formulae in brackets with charge outside Allow displayed formulae Do not allow $CH_3C(OH)_2^+$	**(1)**

(Total for Question 8 = 12 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)	- $HPO_4^{2-} + H^+ \rightarrow H_2PO_4^-$ **or** $HPO_4^{2-} + H_3O^+ \rightarrow H_2PO_4^- + H_2O$ **(1)** - $H_2PO_4^- + OH^- \rightarrow HPO_4^{2-} + H_2O$ **(1)**	Penalise non-ionic equations, e.g. using NaOH or HCl once only Equations must show reaction of ions with H^+ / H_3O^+ and OH^- Allow $\rightleftharpoons$ Ignore state symbols Allow $H_2PO_4^- \rightarrow HPO_4^{2-} + H^+$ **and** $H^+ + OH^- \rightarrow H_2O$	**(2)**

Question Number	Answer	Additional Guidance	Mark
9(b)	• calculation of the amount of NaOH / salt **(1)** • calculation of initial amount of acid **(1)** • calculation of the amount of acid left **(1)** • calculation of $[H^+]$ **(1)** • calculation of pH **(1)**	Example of calculation amount of NaOH = amount of salt formed =0.100 x 20.0/1000 = 0.00200 initial amount of acid = 0.150 x 25.0/1000 = 0.00375 amount of acid left = 0.00375 − 0.00200 = 0.00175 total volume = 20.0 + 25.0 = 45.0 (cm^3) [salt] = 0.00200 x 1000/45.0 = 0.0444 (mol dm^{-3}) [acid] = 0.00175 x 1000/45.0 = 0.0389(mol dm^{-3}) $K_a = \frac{[H^+][salt]}{[acid]}$ so $[H^+] = K_a\frac{[acid]}{[salt]}$ $[H^+]$ = 1.74 x 10^{-5} x 0.0389/0.0444 = 1.52446 x 10^{-5} (mol dm^{-3}) Allow use of moles instead of concentrations pH = −log$[H^+]$ = −log(1.52446 x 10^{-5}) = 4.817 / 4.82 / 4.8 Allow TE for each step Ignore SF except 1 SF Correct answer without working score (5)	**(5)**

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

(Total for Question 9 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
10(a)(i)	An answer that makes reference to the following point: • carbon / solid has no (vapour / partial) pressure **or** (partial) pressure of carbon / solid is constant **or** carbon does not contribute to the overall pressure (of the system)	Allow the reaction is heterogeneous **and** (partial) pressure of a pure solid is not included (in K_p expression) Do not allow just 'because carbon is a solid' or 'carbon is not a gas'	**(1)**

Question Number	Answer	Additional Guidance	Mark
10(a)(ii)	An explanation that makes reference to the following points: • there are fewer moles / molecules / particles of **gas** on the left / reactant side **(1)** • so equilibrium position/ it moves / shifts to the left / reactant side **(1)**	Allow 2 moles / molecules of **gas** on right and 1 mole / molecule on left M2 is conditional on M1 **or** the idea of fewer particles on the left / decreasing the value of the quotient / Q Do not allow any indication of K_p changing	**(2)**

Question Number	Answer	Additional Guidance	Mark
10(a)(iii)	An explanation that makes reference to the following points: • (forward) reaction is endothermic **and** so equilibrium constant / K_p increases as temperature increases **(1)** • so equilibrium position / it moves / shifts to the right / product side **(1)**	Ignore references to ΔG and ΔS M2 is conditional on M1 **or** endothermic or equilibrium constant increases	**(2)**

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>10(a)(iv)</td>
<td>

- calculation of moles of each substance at equilibrium **(1)**
- calculation of partial pressure of each substance **(1)**
- calculation of K_p **(1)**
- units (stand alone mark) **(1)**

</td>
<td>
Example of calculation:
<table>
<tr><th></th><th>H_2O(g)</th><th>H_2(g)</th><th>CO(g)</th></tr>
<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 = 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 = 0.10497</td><td>0.81/1.81 = 0.4475</td><td>0.81/1.81 = 0.4475</td></tr>
<tr><td>Partial pressure /atm</td><td>0.10497 x 2.0 =0.20994</td><td>0.4475 x 2.0 = 0.895</td><td>0.4475 x 2.0 =0.895</td></tr>
</table>

$$K_p = \frac{0.895 \times 0.895}{0.20994}$$
= 3.815 / 3.82 / 3.8 atm

3.8144 / 3.814 / 3.81 / 3.8 atm from 0.105 and 0.210

Correct answer with units but no working scores (4)

Allow TE for M2 and M3

Ignore SF except 1 SF
</td>
<td>(4)</td>
</tr>
</table>

Question Number	Answer	Additional Guidance	Mark
10(b)		Allow amounts / moles / (partial) pressures for concentrations	**(3)**
	• the quotient / Q: $\frac{[CO_2][H_2]}{[CO][H_2O]} = \frac{2 \times 2}{1 \times 1} = 4$, which is larger than K_c **or** (since $K_c = 1$) the concentrations of the products must be equal to the concentrations of the reactants at equilibrium **(1)**	Allow calculated K_c / the quotient / Q will be greater than 1	
	• the concentrations of CO_2 and H_2 / products need to decrease **and** those of CO and H_2O / reactants need to increase **(1)**	Allow shift so that there is 1.5 mol of each substance	
	• so reaction shifts to the left **(1)**	M3 conditional on some explanation	

(Total for Question 10 = 12 marks)

TOTAL FOR PAPER = 90 MARKS

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