Pearson Edexcel

Mark Scheme (Results)

Summer 2022

Pearson Edexcel GCE
In Chemistry (9CH0)
Paper 01 Advanced Inorganic and Physical Chemistry

Summer 2022

Question Paper Log Number P67903

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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.

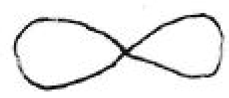
Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>1(a)</td><td>any two or three values correct (1)
all four values correct (1)</td><td><u>Example of table</u>
<table><tr><th>Particle</th><th>Relative charge</th><th>Relative mass</th></tr><tr><td>proton</td><td>(+1)</td><td>(1)</td></tr><tr><td>neutron</td><td>0 / no charge</td><td>1</td></tr><tr><td>electron</td><td>−1</td><td>1/1840</td></tr></table>
Allow negligible / very small or words to that effect / values in a range from 1/1800 to 1/2000 (0.0005) for the relative mass of electron

Do not award 0 / none for mass of electron

Ignore + sign for neutron</td><td>(2)</td></tr>
</table>

Question number	Answer	Mark
1(b)	**The only correct answer is D** (quantum shells) ***A*** *is incorrect because atomic emission spectroscopy does not provide evidence for the existence of atoms* ***B*** *is incorrect because atomic emission spectroscopy does not provide evidence for the existence of electrons* ***C*** *is incorrect because evidence for isotopes is provided by mass spectrometry*	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(c)	• diagram of a p orbital	Example of diagram  Allow any orientation of p orbital Ignore axes	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(d)	An explanation that makes reference to the following points: • silicon – giant atomic / giant covalent / giant molecular / macromolecular **and** contains covalent bonds **(1)** • chlorine - (simple) molecular / molecules / diatomic / Cl_2 **and** contains London forces **(1)** • (covalent) bonds in silicon are stronger than London forces/ intermolecular forces in chlorine **or** covalent bonds take more energy to break than London forces / intermolecular forces **(1)**	Do not allow just 'silicon is a covalent molecule' Do not allow reference to ions or metallic bonding Allow dispersion forces / van der Waals' / attractions between temporary dipole and induced dipole/ attractions between instantaneous dipole (- induced dipole) for London forces Do not award covalent bonds being broken in chlorine Ignore silicone for silicon as correct spelling is given in the paper	(3)

(Total for Question 1 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)	An answer that makes reference to the following points: • (the Universal Indicator changes from green) to blue / purple **(1)** • water level in the test tube drops **or** gas collects at the top of the test tube **(1)**	Allow to dark blue/ blue-green or green-blue Do not award from blue Do not award if the solution is described as 'acidic' or $[H^+]$ increases Do not award any other starting colour Allow water level in the beaker rises Allow hydrogen / H_2 for gas Do not award named incorrect gases (e.g. oxygen/air) Do not award magnesium oxide Do not award magnesium is a white powder Ignore magnesium disappears/dissolves	**(2)**

Question Number	Answer	Additional Guidance	Mark
2(b)	An explanation that makes reference to the following points: • the **outer/ valence** electron is / the **outer electrons** are/ further from the nucleus **(1)** • there is more shielding (from shells of inner electrons) **or** there is an increase in repulsion between the filled inner shells and the electron removed **(1)** • so the (first) ionisation energy decreases (down the group) **and** so the reactivity increases **(1)**	 Allow the outer (s) electron is in a higher (quantum) shell / higher energy level Ignore the atomic / ionic radius increases Allow there is reduced attraction between the nucleus and the outer electrons Do not award any reference to charge or charge density for M2 Allow the outer (s) electron(s) are removed more easily / it takes less energy to remove the (outer) electrons **and** so the reactivity increase	(3)

Question Number	Answer	Additional Guidance	Mark
2(c)	An explanation that makes reference to the following points: • calcium is oxidised as it loses electrons **(1)** • Chlorine / Cl_2 / Cl is reduced as it gains electron(s) **(1)**	Allow $Ca \rightarrow Ca^{2+} + 2e^{-}$ / $Ca - 2e^{-} \rightarrow Ca^{2+}$ **and** oxidation Do not allow calcium loses 1 electron Allow $Cl_2 + 2e^{-} \rightarrow 2Cl^{-}$ **and** reduction	**(2)**

Question Number	Answer	Additional Guidance	Mark
2(d)	• calculation of mol of magnesium **(1)** • calculation of molar volume of H_2 **and** units **(1)**	<u>Example of calculation</u> mol Mg = 0.035 ÷ 24.3 = 1.4403×10^{-3} / 0.0014403 (mol) (mol H_2 = mol Mg) molar volume of H_2 = 32 ÷ 1.4403×10^{-3} = 22 217 / 22 220 / 22 200 /22 000 /2.2217×10^4 / 2.220×10^4 / 2.22×10^4 / 2.2×10^4 **and** cm^3 (mol^{-1}/mol^{-}) Allow value converted to dm^3 e.g. 22.2 **and** dm^3 (mol^{-1}/ mol^{-}) If they have rounded to 1.4×10^{-3} in step 1 then an example of a correct answer would be 22857 **and** cm^3mol^{-1} **or** 23 **and** dm^3mol^{-1} TE on mol Mg Additional guidance Allow 1.4583×10^{-3} and 2.1942×10^4 if 24 used for Mg Correct answer with no working scores (2) Ignore SF except 1 SF	**(2)**

(Total for Question 2 = 9 marks)

Question number	Answer	Mark
3(a)	**The only correct answer is D** (grey/black solid, purple gas) ***A*** *is incorrect because iodine solid is not purple and iodine gas is not brown* ***B*** *is incorrect because iodine solid is not purple* ***C*** *is incorrect because iodine gas is not brown*	**(1)**

Question number	Answer	Mark
3(b)	**The only correct answer is C** ($Cl_2(aq) + 2NaBr(aq) \rightarrow 2NaCl(aq) + Br_2(aq)$) ***A*** *is incorrect because bromine is less reactive than chlorine so no reaction occurs* ***B*** *is incorrect because bromine is less reactive than fluorine so no reaction occurs* ***D*** *is incorrect because chlorine is less reactive than fluorine so no reaction occurs*	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(c)	• electronic configuration of chloride ion	<u>Example of electronic configuration</u> $(1s^2)2s^22p^63s^23p^6$ Allow $2p^6$ / $3p^6$ shown as e.g. $2p_x^22p_y^22p_z^2$ Ignore $1s^2$ repeated Ignore working Do not award correct answer if one or more incorrect answers are given	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(d)(i)	An explanation that makes reference to the following points: • balanced equation **(1)** • calculation of $E^\ominus_{cell}$ value **(1)** • $E^\ominus_{cell}$ / answer is negative / <0 **and** the reaction is not (thermodynamically) feasible **(1)**	<u>Example of equation</u> $Br_2(aq) + H_2O(l) \rightarrow HOBr(aq) + HBr(aq)$ Allow multiples Allow $H^+(aq) + Br^-(aq)$ for HBr(aq) Allow reversible arrows Ignore state symbols even if incorrect $E^\ominus_{cell}$ = 1.09 – 1.57 = −0.48 (V) Allow correct answer without calculation Allow 3 marks for reverse argument $HOBr(aq) + HBr(aq) \rightarrow Br_2(aq) + H_2O(aq)$ (1) $E^\ominus_{cell}$ = 1.57 − 1.09 = (+) 0.48 (V) (1) $E^\ominus_{cell}$ is positive / >0 so the reverse of disproportionation is (thermodynamically) feasible (1)	**(3)**

Question Number	Answer	Additional Guidance	Mark
3(d)(ii)	An answer that makes reference to the following point: • disproportionation is an equilibrium system (and although K is very small, there is still a small concentration of disproportionation products) **or** excess water is used **or** concentration is not 1 mol dm^{-3} **or** HOBr undergoes further disproportionation	Ignore just 'non-standard conditions' Ignore references to activation energy / collision theory Ignore H^+ / ions from the water	**(1)**

Question number	Answer	Mark
3(e)(i)	**The only correct answer is C** (graph C) ***A*** *is incorrect because HF has a much higher boiling temperature than expected due to hydrogen bonding* ***B*** *is incorrect because these is an increase in boiling temperature from HCl to HI as the number of electrons in the molecules increases so the London forces increase in strength* ***D*** *is incorrect because HBr has a higher boiling temperature than HCl as there are more electrons in the molecules*	**(1)**

Question number	Answer	Mark
3(e)(ii)	**The only correct answer is A** (acid-base) ***B*** *is incorrect there is no displacement taking place* ***C*** *is incorrect because neither substance is oxidised or reduced* ***D*** *is incorrect because there is no substitution taking place*	**(1)**

(Total for Question 3 = 9 marks)

Question number	Answer	Mark
4(a)	**The only correct answer is A** (anions and cations) ***B*** *is incorrect because ionic bonding involves positive ions and negative ions* ***C*** *is incorrect because there are no delocalised electrons in ionic bonding* ***D*** *is incorrect because this is a description of covalent bonding*	**(1)**

Question Number	Answer	Additional Guidance	Mark
4(b)	• region **E**: yellow **(1)** • region **F**: blue **(1)**	Ignore additional descriptions of colours e.g. pale, bright Do not award any other colours e.g. blue-green	**(2)**

Question Number	Answer	Additional Guidance	Mark
4(c)	• $MgCl_2$	Ignore names Do not award MgCl	**(1)**

Question number	Answer	Mark
4(d)(i)	**The only correct answer is D** (Substance **S**) ***A*** *is incorrect because copper exists as a giant metallic lattice* ***B*** *is incorrect because iodine exists as a simple molecular lattice* ***C*** *is incorrect because silicon(IV) oxide exists as a giant covalent lattice*	**(1)**

Question number	Answer	Mark
4(d)(ii)	**The only correct answer is A** (Substance **P**) ***B*** *is incorrect because iodine has a low melting temperature and does not conduct electricity* ***C*** *is incorrect because silicon(IV) oxide does not conduct electricity* ***D*** *is incorrect because sodium chloride does not conduct electricity when solid*	**(1)**

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>4(e)*</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>

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

	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

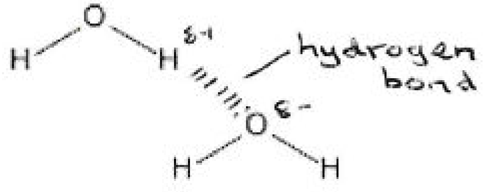
Comment:
Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning

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

General points to note
If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

Example of incorrect chemistry
Reference to ionic bonding/ions

Ignore reference to intermolecular forces other than London forces in H_2S

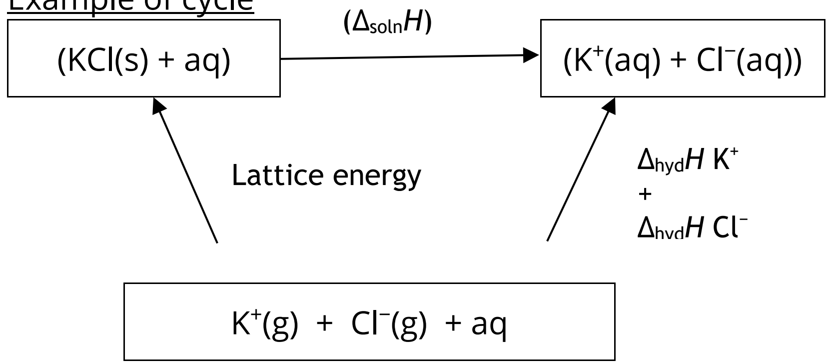
	Indicative content • **IP1 –** lone pair and dipole lone pair on oxygen in hydrogen bond **and** dipole shown with δ+ on any one H and δ− on any one O • **IP2 –** shape hydrogen bond labelled / or shown as a dotted line **and** hydrogen bond(s) shown as approximately linear or O-H-O bond angle labelled 180° • **IP3 –** London forces hydrogen sulfide has stronger London forces/ dispersion forces / van der Waals' forces (because it has more electrons) • **IP4 –** comparison hydrogen bonding is stronger than London forces / is the strongest intermolecular force / requires more energy to break/ requires more energy to overcome • **IP5 –** ice at 0^0C (water molecules are arranged) in a lattice / hexagon **or** hydrogen bonds are longer than covalent bonds • **IP6 –** water at 0^0C (water) molecules get closer / have less distance between them / more molecules in the same volume	 <u>Example of diagram</u> Comment: allow bond angles drawn between 170^0 and 190^0 if labelled 180^0 If multiple hydrogen bonds are drawn the majority must be within this tolerance Allow / attractions between temporary dipoles and induced dipoles / instantaneous dipole - induced dipole for London forces Do not award breaking of covalent bonds Allow hydrogen bonds take a lot of energy to break as long as hydrogen bonds are only mentioned as being present in the water Allow this shown in a diagram Allow rings (of 6 for hexagonal) Allow there are spaces / air / gaps in the structure Allow (water) molecules fill the spaces/gaps Allow reverse argument	

(Total for Question 4 = 12 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)	An answer that makes reference to the following point: • (the system / it) is not at constant pressure **or** enthalpy change is the heat change at a constant pressure	Allow a gas / carbon dioxide is produced and this increases the pressure Allow the pressure is increased / increases Ignore reference to temperature	**(1)**

Question Number	Answer	Additional Guidance	Mark
5(b)	An answer that makes reference to the following points: • (the enthalpy/energy change when) 1 mol of aluminium oxide **(1)** • is formed from its elements in their standard states **(1)** • at 100 kPa and a 'specified' / 'stated' temperature **(1)**	Allow $2Al(s) + 1½O_2(g) \rightarrow Al_2O_3(s)$ for M1 and M2 If state symbols are missing or incorrect only M1 can be awarded Allow M2 for multiples in equation provided state symbols for the elements are correct Allow 1 atm / 1 x 10^5 Pa / 101 kPa / 1.01 x 10^5 Pa for pressure Allow a value for the temperature of 298K / 25^0C Ignore 273K Ignore other standard conditions e.g. 1 mol dm^{-3} Do not allow ^oK	**(3)**

Question Number	Answer	Additional Guidance	Mark
5(c)(i)	An answer that makes reference to the following points: • (ionic) radius **(1)** • (ionic) charge **(1)**	Allow size (of ions) Do not award atomic radius/size of atoms Do not award atomic charge/charge of atoms Allow charge density for 1 mark if no other mark awarded	**(2)**

Question Number	Answer	Additional Guidance	Mark
5(c)(ii)	• correct species with state symbols in bottom box **(1)** • arrows in correct directions **and** labelled **(1)** • calculation of enthalpy change of hydration of Cl^- ions **(1)**	<u>Example of cycle</u>  Ignore missing aq Allow any clear labels for arrows, including values for lattice energy and $\Delta_{hyd}H$ K^+, e,g, LE, HE Allow arrow on left reversed if labelled **–** lattice energy/+711 Allow two separate arrows on the RHS Standalone mark $\Delta_{hyd}H$ Cl^- = −711 +17.2 – (−322) = −371.8 (kJ mol^{-1}) No TE on incorrect arrows Ignore SF apart from 1SF	**(3)**

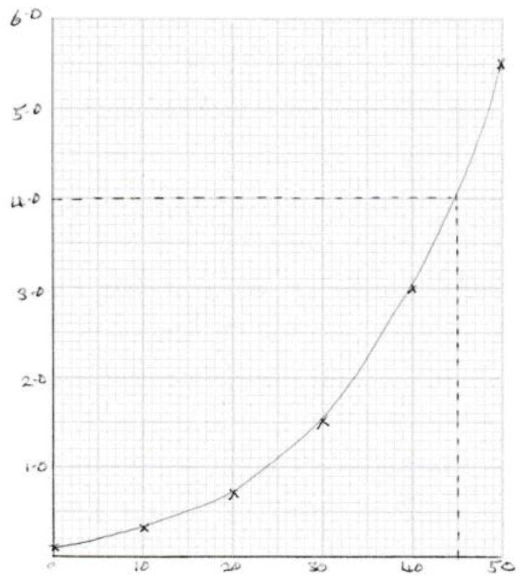
(Total for Question 5 = 9 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)	An answer that makes reference to the following point: • (a Brønsted-Lowry base is a) proton acceptor	Allow accepts protons / H^+ (ions) / hydrogen ions Do not award additional references to reacting with OH^- / alkali	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(b)	• balanced equation **(1)** • state symbols **(1)**	<u>Example of equation</u> $MgO(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(l)$ Allow multiples Conditional on M1 or near miss e.g. Mg^+ Allow a fully balanced equation with correct state symbols for 1 mark e.g. $MgO(s) + 2HCl(aq) \rightarrow MgCl_2(aq) + H_2O(l)$ e.g. $MgO(s) + H_2SO_4(aq) \rightarrow MgSO_4(aq) + H_2O(l)$ e.g. uncancelled spectator ions from the acid with (aq) Do not award M1 for $Mg^{2+}(s) + O^{2-}(s) + 2H^+(aq) \rightarrow Mg^{2+}(aq) + H_2O(l)$ But M2 can be awarded for correct state symbols	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(c)	• calculation of $[H^+(aq)]$	<u>Example of calculation</u> $[H^+(aq)] = 10^{-pH} = 10^{-9.43}$ $= 3.7154 \times 10^{-10}$ / 3.715×10^{-10} / 3.72×10^{-10} / 3.7×10^{-10} (mol dm^{-3}) Do not award $3.71 \text{ X } 10^{-10}$ Ignore units even if incorrect Ignore SF except 1 SF Correct answer with no working scores (1)	**(1)**

Question number	Answer	Mark
6(d)	**The only correct answer is A** (solution **J**: HCl(aq) and NH_3(aq), solution **K**: CH_3COOH(aq) and NaOH(aq)) ***B*** *is incorrect because the salt formed from a strong acid (HCl) and a strong base (NaOH) will have pH 7 while that formed from a weak acid (CH_3COOH) and a weak base (NH_3) will have pH close to 7* ***C*** *is incorrect because the salt formed from a weak acid and a strong base will have a pH of about 9 while that formed from a strong acid and a strong base will have pH 7* ***D*** *is incorrect because the salt formed from a weak acid and a weak base will have a pH of about 7 while that formed from a strong acid and a weak base will have pH of about 5*	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(e)(i)	• axes the correct way round, labelled, including units **and** suitable scale with points covering at least half the paper in both directions **(1)** • points plotted correctly (±1/2 small square) **and** smooth curve **(1)** • value of K_w at 45°C **(1)**	<u>Example of graph</u>  Allow K_w / 10^{-14} /mol^2 dm^{-6} as units on y axis Allow K_w x 10^{-14}/mol^2 dm^{-6} 4.0 x 10^{-14} (mol^2 dm^{-6}) Allow 3.8 to 4.2 x 10^{-14} (mol^2 dm^{-6}) with no working TE on their working from their graph If they have converted K_w to pK_w, drawn a graph with correctly labelled axes and line of best fit then they can access all three marks as long as their final answer is K_w	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(e)(ii)	• deduction of expression relating K_w and $[H^+(aq)]$ **(1)** • calculation of $[H^+(aq)]$ **(1)** • calculation of pH **(1)**	<u>Example of calculation</u> ($K_w = [H^+(aq)][OH^-(aq)]$ but $[H^+(aq)] = [OH^-(aq)]$ so) $K_w = [H^+(aq)]^2$ $[H^+(aq)]^2 = 1.47 \times 10^{-14}$ $[H^+(aq)] = \sqrt{1.47 \times 10^{-14}}$ (so $[H^+(aq)] = 1.2124 \times 10^{-7}$ (mol dm^{-3})) pH = $-\log 1.2124 \times 10^{-7}$ = 6.9163 / 6.916 / 6.92 / 6.9 Do not award 1SF or final answer of 7 or answer incorrectly rounded to 6.91 pH TE on $[H^+]$ Correct answer with no working scores (3) Allow alternative methods	**(3)**

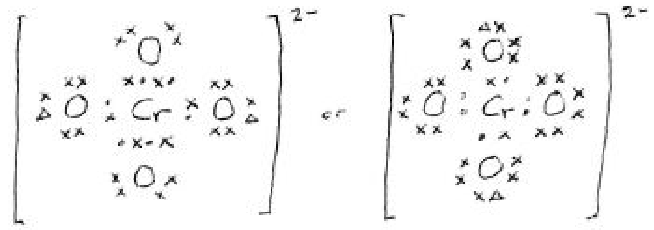
Question Number	Answer	Additional Guidance	Mark
6(f)(i)	• phenolphthalein **(1)** • pH at equivalence point / 9 is very close / ±1 to pK_{in} / 9.3 **or** pH range is (completely) within the (first) vertical jump in the titration curve / between the range of (pH) 8.5 - pH9.5 **(1)**	Allow recognisable spellings Allow indicator will change colour in the vertical section of the curve / at the end / equivalence point Accept correct reference to the pH range for phenolphthalein from the data book (8.2-10.0) if there is a connection to the graph Do not allow colourless to pink/red if the colour change of phenolphthalein is mentioned	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(f)(ii)	• equation	<u>Example of equation</u> $NaHCO_3 + HCl \rightarrow NaCl + H_2O + CO_2$ or $HCO_3^- + H^+ \rightarrow H_2O + CO_2$ Allow $NaHCO_3 + HCl \rightarrow NaCl + H_2CO_3$ Allow multiples Ignore state symbols even if incorrect	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(f)(iii)	• (solution at **X**) contains a large amount of / reservoir of carbonate ions / CO_3^{2-} **and** hydrogencarbonate ions/ HCO_3^- **(1)**	Allow there is a large amount of Na_2CO_3 and $NaHCO_3$ Allow solution at X contains a reservoir of an acid and its conjugate base	**(3)**
	• carbonate ions / CO_3^{2-} react with added hydrogen ions / H^+ / acid **or** $CO_3^{2-} + H^+ \rightarrow HCO_3^-$ **(1)**	Allow Na_2CO_3 reacts with added hydrogen ions / H^+ / acid to form $NaHCO_3$ **or** $CO_3^{2-} + HCl \rightarrow HCO_3^- + Cl^-$ **or** $A^- + H^+ \rightarrow HA$	
	• hydrogencarbonate ions / HCO_3^- react with added hydroxide ions / OH^- / alkali **or** $HCO_3^- + OH^- \rightarrow CO_3^{2-} + H_2O$ **(1)**	Allow $NaHCO_3$ reacts with added hydroxide ions (to form $Na_2CO_3 + H_2O$) Allow hydroxide ions react with hydrogen ions to form water **and** hydrogencarbonate ions dissociate to replace / form hydrogen ions **or** $OH^- + H^+ \rightarrow H_2O$ **and** $HCO_3^- \rightarrow CO_3^{2-} + H^+$ **or** $HA + OH^- \rightarrow A^- + H_2O$ Allow $\rightleftharpoons$ in equations Ignore state symbols	

(Total for Question 6 = 17 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)	An answer that makes reference to the following point: • there is only a gradual / steady increase in (successive ionisation energies)	Allow they / the (successive) ionisation energies are close in value / similar Allow the extra ionisation energy to increase oxidation state is similar to the increase in hydration enthalpy / lattice energy Ignore chromium is a transition element Ignore 3d (and 4s) orbitals have similar energy Ignore Cr is $[Ar]3d^5 4s^1$ so can lose 6 electrons Ignore reference to electrons being removed from the d-orbital	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(b)	• 2 double bonds and 2 single bonds shown as dots and crosses **(1)** • Another 4 electrons around each oxygen involved in the double bond and another 6 electrons around each oxygen involved in the single bond with one different symbol on each of two oxygens to indicate the extra electrons in the ion **(1)** **Or** • 2 single bonds shown as dots and crosses 2 dative bonds with the electrons being donated from the chromium **(1)** • another 6 electrons around each oxygen with one different symbol on two of the oxygens to indicate the extra electrons **(1)**	<u>Examples of diagrams</u>  Penalise extra electrons on chromium In both examples, M2 is conditional on M1 Allow overlapping circles with electrons in correct places Ignore missing brackets and charge / shape Ignore lines representing covalent bonds	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	• correct species **(1)** • balancing **(1)**	<u>Example of equation</u> $Cr_2O_7^{2-} + 14H^+ + 3Zn \rightarrow 2Cr^{3+} + 7H_2O + 3Zn^{2+}$ Allow multiples Allow $\rightleftharpoons$ provided equation written in direction shown Ignore state symbols even if incorrect Do not award uncancelled electrons	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	• calculation of $E^\ominus_{cell}$	<u>Example of calculation</u> ($E^\ominus_{cell}$ = 1.33 – (−0.76)) = (+) 2.09 (V) Allow –2.09 (V) if equation written in reverse in (c) (i) Correct answer with no working scores (1)	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(c)(iii)	yes/zinc and acid will reduce chromium(III) ions to chromium(II) ions **and** because $E^\ominus_{cell}$ for the reaction between Zn and Cr^{3+} is (+) 0.35 (V) **or** Zn^{2+} / Zn electrode potential / SEP / $E^\ominus$ value is more negative / less positive / lower than the Cr^{3+} / Cr^{2+} value **or** Zn/ Zn^{2+} electrode potential / SEP / $E^\ominus$ value is less negative / more positive / higher than the Cr^{3+} / Cr^{2+}	Allow positive or >0 if not calculated Allow explanations in terms of the anti-clockwise rule	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(c)(iv)	An explanation that makes reference to the following points: • the energy difference between the two sets of d orbitals is different in the two ions / Cr^{3+} and Cr^{2+} **or** there is different splitting of the d orbital**s** / d subshell **(1)** • electrons undergo different d-d transitions/ are promoted to a higher d-orbital absorbing/requiring a different amount of energy **or** a different amount of energy is absorbed the frequency / wavelength/colour of (visible) light absorbed is different **(1)**	Allow the d orbital energies are different Allow different charges / oxidation numbers alter the d orbital energies differently Do not award reference to a single d orbital splitting/ d orbital splitting Ignore references to charges/charge density/oxidation numbers/electron configurations of the ions Do not award references to electrons being excited and falling back to the ground state (or words to that effect) Allow the frequency / wavelength of (visible) light transmitted / reflected is different Do not award emitted instead of absorbed Ignore reference to different ligands	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(d)	• calculation of mol of $Cr_2O_7^{2-}$ **(1)** • calculation of mol Fe^{2+} in 25.0 cm^3 **(1)** • calculation of mol Fe^{2+} in 1.00 dm^3 **(1)** • calculation of mass of Fe in 1 nail **(1)** • calculation of percentage of iron **and** brand of nail **(1)**	<u>Example of calculation</u> mol $Cr_2O_7^{2-}$ used = (15.50 x 0.0167) ÷1000 = 2.5885 x 10^{-4} / 0.00025885 (mol) mol Fe^{2+} in 25.0 cm^3 = 6 x 2.5885 x 10^{-4} = 1.5531 x 10^{-3} = 0.0015531 (mol) mol Fe^{2+} in 1.00 dm^3 = (1.5531 x 10^{-3} x 1000) /25 = 6.2124 x 10^{-2} / 0.062124 (mol) mass of Fe = 6.2124 x 10^{-2} x 55.8 = 3.4665 (g) Allow 3.4789 (g) from A_r of 56 Percentage of iron = (3.4665/3.54) x 100 (=97.924)= 98 / 97.9 (%) Allow 98 / 98.3 from A_r of 56 **and** Brand **D** Do not award for a percentage of 84% or below Ignore SF except 1 SF Correct answer with some relevant working scores 5 Correct percentage (98%) and brand (D) with no working scores (1) Any other percentage and brand with no working scores (0)	**(5)**

(Total for Question 7 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
8(a)	• substitution of values into the equation **(1)** • calculation of K_c **(1)**	<u>Example of calculation</u> $\ln K_c = \dfrac{5 \times 0.15 \times 96\ 500}{8.31 \times 298}$ ($\ln K_c = 29.226$) $K_c = 4.9289 \times 10^{12}$ $= 4.9 \times 10^{12}$ / 4.93×10^{12} TE on their value for $\ln K_c$ Ignore SF except 1SF Correct answer with no working scores (2)	**(2)**

Question number	Answer	Mark
8(b)	**The only correct answer is A** ($4H^+(aq) + O_2(g) + 4e^- \rightarrow 2H_2O(l)$) ***B*** *is incorrect because methanol does not react with hydrogen* ***C*** *is incorrect because this reaction shows an oxidation* ***D*** *is incorrect because this reaction shows an oxidation*	**(1)**

Question Number	Answer	Additional Guidance	Mark
8(c)	• one half-equation **(1)** • other half-equation **(1)** • state symbols **(1)**	<u>Examples of half-equations</u> $Pb(s) + SO_4^{2-}(aq) \rightleftharpoons PbSO_4(s) + 2e^-$ Allow $Pb(s) + H_2SO_4(aq) \rightleftharpoons PbSO_4(s) + 2H^+(aq) + 2e^-$ $PbO_2(s) + 4H^+(aq) + SO_4^{2-}(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O(l)$ Allow $PbO_2(s) + 2H^+(aq) + H_2SO_4(aq) + 2e^- \rightleftharpoons PbSO_4(s) + 2H_2O(l)$ Allow multiples Allow single headed arrows in the forward direction Ignore missing charge on electrons Conditional on correct species in one equation that has scored either M1or M2	**(3)**

Question Number	Answer	Additional Guidance	Mark
8(d)	• calculation of initial mol I^- **(1)** • calculation of eqm mol I^- **(1)** • calculation of mol I^- reacted **(1)** • calculation of eqm mol-1 SO_4^{2-} **(1)** • calculation of eqm $[SO_4^{2-}(aq)]$ **and** calculation of eqm $[I^-(aq)]$ **(1)** • calculation of K_c **and** answer to 2 / 3 SF **(1)** • units **(1)**	<u>Example of calculation</u> initial mol I^- = (25.0 x 0.100) ÷1000) = 2.5×10^{-3} / 0.0025 (mol) eqm mol I^- (= mol Ag^+) = (12.20 x 0.0500) ÷1000 = 6.1×10^{-4} / 0.00061 (mol) mol I^- reacted = 2.5×10^{-3} – 6.1×10^{-4} = 1.89×10^{-3} / 0.00189 (mol) eqm mol SO_4^{2-}= mol I^- reacted / 2 =1.89×10^{-3} ÷ 2 = 9.45×10^{-4} / 0.000945 eqm $[SO_4^{2-}]$ = (9.45×10^{-4} x 1000) ÷ 25 = 0.0378 (mol dm^{-3}) **and** eqm $[I^-]$ = (6.1×10^{-4} x 1000) ÷ 25.0 = 2.44×10^{-2} / 0.0244 (mol dm^{-3}) K_c = 0.0378 ÷ 0.0244^2 = (63.49) = 63 / 63.5 Do not award unless their numbers are correct or are TE. Allow TE throughout. Correct answer with working gains 7 marks $dm^3\ mol^{-1}$ (standalone mark) Allow $dm^3\ mol^-$ / $mol^{-1}\ dm^3$ / $mol^-\ dm^3$	**(7)**

(Total for Question 8 = 13 mark)