

Pearson
Edexcel

Mark Scheme (Results)

Summer 2023

Pearson Edexcel GCE
In Chemistry (9CH0)
Paper 01: 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.

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.

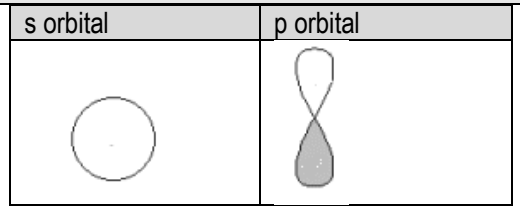
Full marks will be awarded if the candidate has demonstrated the above abilities.
Questions where QWC is likely to be particularly important are indicated (QWC) in the mark scheme, but this does not preclude others.

Question Number	Answer	Mark
1(a)	**The only correct answer is B** (2) **A** *is not correct because it is an s-block element* **C** *is not correct because it is a p-block element* **D** *is not correct because it is a d-block element in Period 5*	**(1)**

Question Number	Answer	Additional Guidance	Mark
1(b)	An answer that makes reference to the following point: • an element which has its last electron added to a d-subshell (according to the Aufbau principle)	Allow ‘d orbital(s)’ for ‘d-subshell’ throughout Do not award ‘d block orbital’ Allow an element with its valence / outer / outermost / last / highest energy electron in the d-subshell Allow outer occupied orbital is d Allow electronic configuration ends with d-subshell Allow 3d specified Ignore just ‘outer orbital is d’ Ignore reference to forming stable ions with incomplete d orbitals Ignore general properties of transition metals e.g. has variable oxidation states Do not award just ‘ has electron(s) in d orbitals / d-subshell’	**(1)**

(Total for Question 1 = 2 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)	An answer that makes reference to the following points: • a region / space (in an atom) in which there is a high probability of finding electron(s) / electron(s) are (most) likely to be found **(1)** • containing (a maximum of) 2 / a pair of electrons (with opposite spin) **(1)**	Mark independently Allow area / for region / space Allow a percentage between 90 and 98% for the probability Allow just 'a region / space (in an atom) that holds electrons' Allow an area of high electron density where an electron can be predicted to be found Allow region / space around the nucleus that holds electrons Ignore just 'where the electron(s) are' Ignore energy level / sub-level	**(2)**

Question Number	Answer	Additional Guidance	Mark
2(b)	An answer that makes reference to the following points: • s orbital shown as a sphere / circle **(1)** • p orbital shown as a figure of 8 / dumb-bell shaped **(1)**	 Allow p orbital in any orientation Lower p orbital does not need to be shaded Allow all 3 p orbitals shown separately or altogether Ignore x, y and/or z axes marked Do not award p-orbital lobes of very different sizes **Note** Do not award 2 p orbitals shown as a clover shape unless labelled as separate orbitals (p_x etc)	**(2)**

Question Number	Answer	Mark
2(c)	**The only correct answer is A** ($[Ar]4s^13d^{10}$) **B** *is not correct because a full d-subshell is more stable* **C** *is not correct because the atom does not have any 4p electrons* **D** *is not correct because the atom does not have any 4p electrons*	**(1)**

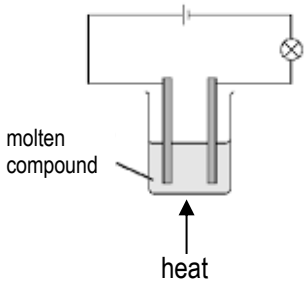
(Total for Question 2 = 5 marks)

Question Number	Answer	Mark
3(a)	**The only correct answer is D** (bromide ions reduce sulfuric acid forming sulfur dioxide) **A** *is not correct because bromide ions reduce sulfuric acid* **B** *is not correct because bromide ions reduce sulfuric acid* **C** *is not correct because bromide ions are not strong enough reducing agents to form sulfur*	**(1)**

Question Number	Answer	Mark
3(b)(i)	**The only correct answer is C** (a cream precipitate forms that dissolves in concentrated ammonia only) **A** *is not correct because bromide ions do not form a white precipitate* **B** *is not correct because bromide ions do not form a white precipitate* **D** *is not correct because the cream precipitate does not dissolve in dilute ammonia*	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(b)(ii)	An answer that makes reference to the following point: • to react with / remove carbonate / CO_3^{2-} / hydroxide / OH^- (ions, which could lead to a false positive)	Allow name or formula of ion but if both are given, both must be correct Allow other specified anions that would form a precipitate with Ag^+/ $AgNO_3$ e.g. hydrogencarbonate / sulfite Ignore just ' to prevent a false positive' Ignore just ' it reacts with impurities' Ignore just ' so it only reacts with Br^- '	**(1)**

Question Number	Answer	Additional Guidance	Mark
3(b)(iii)	An explanation that makes reference to the following points: • nitric acid / HNO_3 **(1)** • so that the anion (from the acid) does not form a precipitate (with silver ions) **(1)**	Mark independently Do not award incorrect formula for nitric acid / use of NH_3 Allow forms a precipitate with HCl / H_2SO_4 / other acids (giving a false positive) Allow so it doesn't form precipitates with HCl / H_2SO_4 / other acids (giving a false positive) Allow solid / ppt / ppte for precipitate Ignore colour of precipitate	**(2)**

Question Number	Answer	Additional Guidance	Mark
3(c)(i)	An answer that makes reference to the following points: • a diagram of a simple electrical circuit, containing electrodes, power supply and a bulb in series **(1)** • bulb lights **(1)**	 Allow alternatives to bulb e.g. buzzer / ammeter Allow low voltage supply instead of cell Allow a cell and electrodes dipping into the liquid but with no bulb / ammeter etc. Allow cell with connecting wires to filter paper on microscope slide Ignore missing heat / labels for molten compound / /electrodes, wires, etc. Do not award voltmeter instead of cell unless electrodes made from two different materials are specified Allow correct observation from alternatives buzzer – rings ammeter - shows a current Allow observation for formation of iodine or chlorine e.g. brown colour / purple vapour / bubbles / green gas	**(2)**

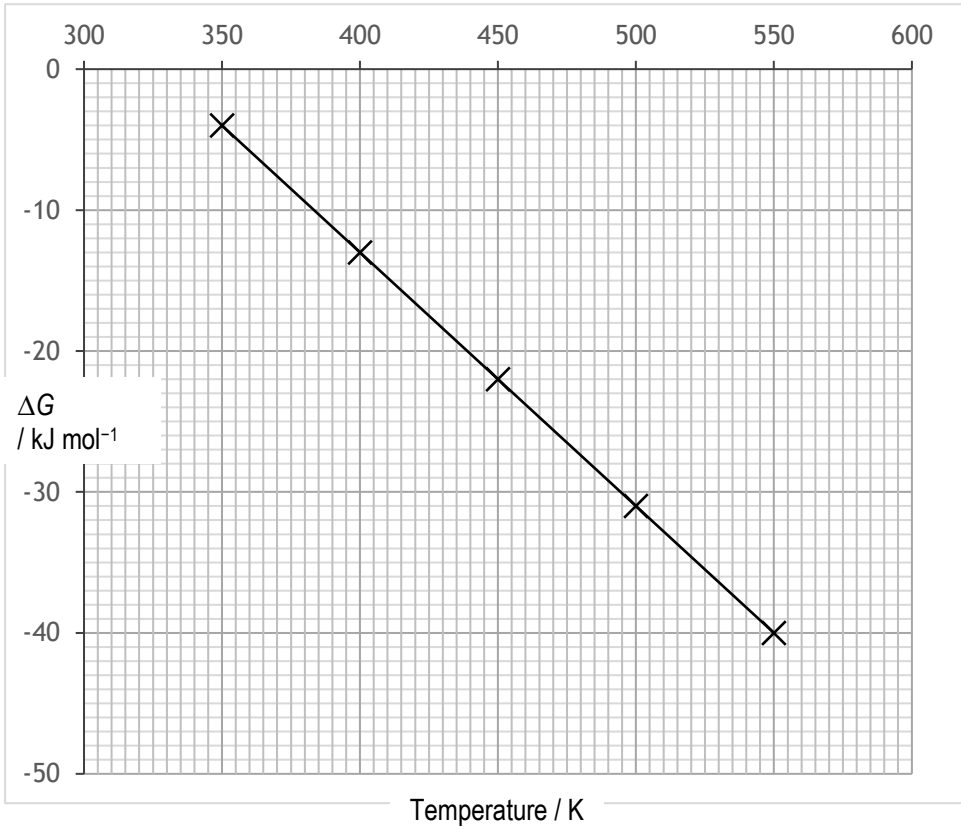
Question Number	Answer	Mark
3(c)(ii)	**The only correct answer is B** (square planar) **A** *is not correct because the central iodine atom only has four atoms attached and has two lone pairs of electrons* **C** *is not correct because the central iodine atom has four bond pairs and two lone pairs of electrons* **D** *is not correct because the central iodine atom only has four atoms attached and has two lone pairs of electrons*	**(1)**

Question Number	Answer	Mark
3(c)(iii)	**The only correct answer is D** (5.0×10^{-3}) **A** *is not correct because the value is greater than 1, which implies equilibrium lies to product side* **B** *is not correct because the value is greater than 1, which implies equilibrium lies to product side* **C** *is not correct because the value of 1 implies equilibrium concentrations of reactants and products are similar in magnitude*	**(1)**

(Total for Question 3 = 9 marks)

Question Number	Answer	Additional guidance	Mark
4	An explanation that makes reference the following trends: **Na, Mg and Al** • Na, Mg and Al have metallic bonding (in a giant lattice) **(1)** • charge on ion increases / (cation) radius decreases / charge density increases (so strength of metallic bonding increases and melting temperature increases) **(1)** **Si** • Si is giant covalent (lattice) / giant molecular / macromolecular **(1)** • so a lot of energy required to break (many strong) covalent bonds (and it has the highest melting temperature) **(1)** **P** • (large decrease from Si to) phosphorus as it consists of simple / discrete molecules / is simple molecular **(1)** • so only weak London forces (are broken on melting) **(1)**	**Allow marks for any relevant annotations on the graph** Ignore reference to boiling point Ignore general trends across the period Allow description of metallic bonding – attraction between cations and delocalised electrons Ignore aluminium missing from answer Do not award simple molecular / London forces / ionic for any of these metals Allow increasing number / more delocalised electrons Allow atomic radius decreases Ignore nuclear charge / number of protons increases Ignore any explanation about why Al has similar melting temperature to Mg Do not award silicon has metallic bonding / London forces Allow a lot of energy is needed to overcome the electrostatic forces (in the covalent bonds) Ignore covalent bonding is stronger than metallic bonding Allow P_4 molecules Ignore formula of phosphorus even if incorrect Do not award phosphorus has ionic / metallic bonding / permanent dipoles / hydrogen bonding Allow London forces are weaker than covalent bonds / covalent bonds are stronger than London forces Allow not a lot of energy is required to overcome the (London) forces Allow just 'weak intermolecular forces' Do not award covalent bonds broken in P Allow dispersion / temporary dipole-induced dipole / instantaneous dipole / van der Waals forces as alternatives to London forces throughout Ignore abbreviations e.g. LDF / VDW / ID-ID	**(6)**

(Total Question 4 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
5(a)(i)	A graph that shows • suitable scale, points must cover at least half the available space in both directions **(1)** • all points plotted correctly **and** straight line of best fit **(1)**	 Allow break in x axis Allow x axis values at top or bottom of graph y axis must go in correct direction Stand alone mark based on scale used Allow ± ½ a square	**(2)**

Question Number	Answer		Additional Guidance	Mark
5(a)(ii)	• deduction that gradient = $-\Delta S_{system}$	**(1)**	Example of calculation (y = mx + c so) m = $-\Delta S_{system}$ M1 could be subsumed within award of M2	**(3)**
	• calculation of gradient	**(1)**	(36 ÷ (−200)) = −0.18 (kJ K^{-1} mol^{-1}) TE on graph in (i) M2 can be subsumed within M3 Allow this left as a fraction e.g. -9/50 Penalise absence of negative sign once only in M1 and M2	
	• calculation of ΔS_{system} in J K^{-1} mol^{-1}	**(1)**	= (+)180 (J K^{-1} mol^{-1}) TE on M2 Correct answer, with or without working, scores (3) Ignore SF except 1 SF Do not award incorrect units but allow J K^{-} mol^{-} **Note** Allow use of 2 simultaneous equations or calculation of intercept and substitution	

Question Number	Answer	Mark
5(a)(iii)	**The only correct answer is C** (intercept of the y axis) **A** *is not correct because the value would have units of temperature* **B** *is not correct because the value would have units of temperature and be a negative value in K* **D** *is not correct because this value is* $-\Delta H$	**(1)**

Question Number	Answer	Mark
5(b)	**The only correct answer is C** (moves to the left, mixture gets lighter) **A** *is not correct because there are more particles on the right-hand side, so increase in P moves equilibrium to the left* **B** *is not correct because there are more particles on the right-hand side, so increase in P moves equilibrium to the left and* N_2O_4 *is colourless, so mixture lightens* **D** *is not correct because* N_2O_4 *is colourless, so mixture lighten*	**(1)**

(Total for Question 5 = 7 marks)

Question Number	Answer	Mark
6(a)	**The only correct answer is D** (base acid acid base) **A** *is not correct because HNO_3 is the stronger acid* **B** *is not correct because HNO_3 is the stronger acid* **C** *is not correct because $C_6H_5COOH_2^+$ is the conjugate acid, and NO_3^- is the conjugate base*	**(1)**

Question Number	Answer	Additional Guidance	Mark
6(b)	An explanation that makes reference to the following points • as the sodium ion / Na^+ is smaller / has a smaller ionic radius (but has the same charge) **(1)** • so sodium benzoate has stronger ionic bonds / electrostatic forces between ions (so more energy required to break the bonds) **(1)**	Allow reverse argument Allow (the sodium ion's) charge density is greater / the (oppositely charged) ions are closer together Ignore sodium ion has 1 less shell Ignore atomic radius Ignore just 'sodium is smaller' Ignore Na^+ has less shielding Do not award sodium ions have a higher charge Allow stronger attraction between ions Allow just 'sodium benzoate has stronger bonds' if ion mentioned / formula given in M1 Ignore reference to polarising power of cation / distortion of anion Do not award attraction of electrons to nucleus / electronegativity Do not award M2 if reference to other types of bonding	**(2)**

Question Number	Answer	Additional Guidance	Mark
6(c)(i)	• expression for K_a	Example of expression $K_a = \frac{[C_6H_5COO^-][H^+]}{[C_6H_5COOH]}$ Allow 6.28×10^{-5} instead of K_a Allow $[H_3O^+]$ for $[H^+]$ Ignore missing K_a Ignore state symbols, even if incorrect Do not award $K_a = \frac{[H^+]^2}{[C_6H_5COOH]}$ Do not award expression including $[H_2O]$ Ignore expression with HA / A^- instead of full formulae Do not award round brackets instead of [ ]	**(1)**

Question Number	Answer	Additional guidance	Mark
6(c)(ii)	• calculation of concentration of H^+ ions **(1)** • calculation of concentration of benzoic acid **(1)** • calculation of moles of benzoic acid **(1)** • calculation of mass of benzoic acid **(1)** **Alternative route for M2 to M4** • calculation of concentration of benzoic acid **(1)** • calculation of moles of benzoic acid **(1)** • calculation of mass of benzoic acid **(1)**	Example of calculation $10^{-3.51} = 3.0903 \times 10^{-4}$ (mol dm^{-3}) This can be subsumed in M2 $6.28 \times 10^{-5} = (3.0903 \times 10^{-4})^2 \div [C_6H_5CO_2H]$ $[C_6H_5CO_2H] = (3.0903 \times 10^{-4})^2 \div 6.28 \times 10^{-5}$ $= 1.5207 \times 10^{-3}$ (mol dm^{-3}) $= 1.5207 \times 10^{-3} \times (250 \div 1000)$ $= 3.8017 \times 10^{-4}$ (mol) $= 3.8017 \times 10^{-4} \times 122 = 0.046381$ / 4.6381 x 10^{-2} (g) Allow 46.381 mg $[C_6H_5CO_2H]_{eqm} = 1.5207 \times 10^{-3} = [C_6H_5CO_2H]_{int} - [H+]$ $[C_6H_5CO_2H]_{int} = [C_6H_5CO_2H]_{eqm} + [H+]$ $= 1.5207 \times 10^{-3} + 3.0903 \times 10^{-4}$ $= 1.82973 \times 10^{-3}$ (mol dm^{-3}) $1.82973 \times 10^{-3} / 4 = 4.5743 \times 10^{-4}$ (mol) $= 4.5743 \times 10^{-4} \times 122 = 0.055807$ / 5.5807 x 10^{-2} (g) Allow 55.807 mg Allow TE throughout Allow intermediate values shown as fractions Ignore SF except 1SF Ignore units Final correct answer, with or without working scores 4 marks	**(4)**

Question Number	Answer	Mark
6(d)(i)	**The only correct answer is D** (phenolphthalein) **A** *is not correct because bromothymol blue does not change colour within the region of rapid change of pH of this weak acid-strong base titration* **B** *is not correct because litmus does not change colour within the region of rapid change of pH of this weak acid-strong base titration* **C** *is not correct because methyl orange does not change colour within the region of rapid change of pH of this weak acid-strong base titration*	**(1)**

Question Number	Answer	Additional guidance	Mark
6(d)(ii)	• calculation of heat released **(1)** • calculation of moles of quinic acid **(1)** • calculation of standard enthalpy of neutralisation **and** value in kJ mol^{-1} **and** correct sign **(1)**	<u>Example of calculation</u> $50 \times 4.18 \times 2.9 = 606.1$ (J) Allow 0.6061 kJ Ignore any signs $(25 \div 1000) \times 0.500 = 0.0125$ (mol) Ignore calculation of moles of NaOH $\frac{-606.1}{0.0125 \times 1000} = -48.5$ (kJ mol^{-1}) Allow −30.305 (kJ mol^{-1}) as TE if M2 lost for only calculating mol NaOH Allow −48500 J mol^{-1} (units essential) Allow TE throughout Allow intermediate values shown as fractions Ignore SF except 1 SF Ignore missing / incorrect units in M1 and M2 Correct final answer with or without working scores (3) Penalise incorrect rounding once only e.g. 0.012 mol	**(3)**

Question Number	Answer	Additional Guidance	Mark
6(d)(iii)	An explanation that makes reference to the following points • HCN / the weak acid is only partially dissociated (but HCl is fully dissociated) **(1)** • (so releases less energy when neutralised as) energy is needed to break H-C bond(s) (in order to completely dissociate) **(1)**	Allow ionise for dissociate throughout Allow HCN is not fully dissociated Allow HCN dissociates less than HCl Allow HCN produces a lower concentration of H^+ ions (from the same concentration of acid as HCl) Allow (some) energy is needed to complete the dissociation (of HCN) Allow (some) energy is needed to remove / separate all the H^+ ions Ignore references to enthalpy of hydration of ions Ignore just energy is needed to break bonds Do not award fewer H^+ ions so less NaOH needed for neutralisation Do not award incorrect bond broken If no other mark is awarded allow 1 for HCl is fully dissociated so no energy is required to break the H-Cl bond	**(2)**

(Total for Question 6 = 14 marks)

Question Number	Answer	Additional Guidance	Mark
7(a)	An answer that makes reference to the following points • (atoms with) the same atomic number / number of protons **(1)** • but with a different mass number / number of neutrons **(1)**	Ignore atoms of the same element Ignore comments about same number of electrons Do not award compounds Do not award different number of electrons **Note** Allow both M1 and M2 in terms of Cr i.e. M1 Cr has 24 protons M2 but may have 26, 28, 29 or 30 / different numbers of neutrons	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(b)(i)	An answer that makes reference to the following point • $(1s^2)2s^22p^63s^23p^63d^4$	Allow numbers of electrons as subscripts but not as large numbers Allow the $2p^6$ written as $2p_x^2 2p_y^2 2p_z^2$ and similar for $3p^6$ Ignore $1s^2$ repeated Ignore $4s^0$	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	An explanation that makes reference to the following points: • calcium forms a +2 ion more readily as (the sum of) its first and second ionisation energies is lower **(1)** • as (calcium's atomic number is lower so) its nuclear charge is less **or** (calcium's metallic / atomic radius is greater so) its outer / valence electrons are further from the nucleus **(1)** • so the outer / valence electrons experience weaker attraction from the nucleus **(1)**	Allow reverse arguments Ignore references to group / period trends Allow it takes 1735 (kJ mol^{-1}) to form Ca^{2+} but 2245 (kJ mol^{-1}) to form Cr^{2+} so calcium forms a +2 ion most easily Allow just 'the ionisation energies of calcium are lower so it forms a +2 ion more easily' Allow calcium atoms have fewer protons Ignore shielding	**(3)**

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	• green	Allow violet Ignore shades of colours e.g. pale / light Do not award mixed colours e.g. blue-green	**(1)**

Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	An explanation that makes reference to the following points • the (highly charged, small) Cr^{3+} ion weakens / polarises / distorts the O-H bonds (in the water ligands) **(1)** • allowing some water ligands to release hydrogen ions / to form the oxonium ion **or** water molecule (from the solution) deprotonates (one of) the water ligands **(1)**	Mark independently Allow Cr^{3+} forms dative bonds with the O (of H_2O) so the H is less strongly attached Accept M2 for correct equation $[Cr(H_2O)_6]^{3+} + H_2O \rightleftharpoons [Cr(H_2O)_5OH]^{2+} + H_3O^+$ Allow $[Cr(H_2O)_6]^{3+} \rightleftharpoons [Cr(H_2O)_5OH]^{2+} + H^+$ Allow equations forming $[Cr(H_2O)_4(OH)_2]^+$ Allow just 'deprotonation of water ligand occurs' Allow H^+ ions released / donated from water ligands Ignore formation of $Cr(H_2O)_3(OH)_3$ and any chromium anions Ignore an acid-base reaction occurs Ignore chromium(III) hydroxide is amphoteric Ignore reference to sulfate ions forming sulfuric acid Do not award reference to ligand exchange	**(2)**

Question Number	Answer	Additional Guidance	Mark
7(d)	An answer that makes reference to the following points: • $E^{\ominus}_{cell}$ = −0.03V **and** so reaction / oxidation of chloride ions is not feasible (under standard conditions) **(1)** • (this is small so) changing the conditions may make $E^{\ominus}_{cell}$ positive so the oxidation reaction becomes feasible **(1)** • (it is possible under non-standard conditions if you) increase the concentration of HCl / H^+ / Cl^- **(1)** • so equilibrium 1 moves to RHS **or** equilibrium 2 moves to LHS (so oxidation of Cl^- ions is more likely / feasible) **(1)**	Allow $E^{\ominus}_{cell}$ = **+**0.03V for the reduction of chlorine (so oxidation of chloride not feasible) Allow Eqm 1 $E^{\ominus}$ is more negative / less positive Allow proof using anti-clockwise rule Allow $E^{\ominus}_{cell}$ is close to 0V / only just negative (so some Cl^- ions are oxidised) Allow increase the concentration of H^+ / Cl^- Ignore increasing the concentration of $Cr_2O_7^{2-}$ ions Allow changing / increasing / decreasing the temperature Allow so eqm 1 $E^{\ominus}$ becomes more positive / better at accepting electrons Allow eqm 2 $E^{\ominus}$ becomes more negative / better at donating electrons Allow Cl_2 that forms escapes driving eqm 2 to LHS Allow increasing the concentration of $Cr_2O_7^{2-}$ ions moves equilibrium 1 to RHS (so oxidation of Cl^- ions is more likely / feasible)	**(4)**

(Total for Question 7 = 13 marks)

<table>
<tr><th>Question Number</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr>
<td>8</td>
<td>
This question assesses the 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.

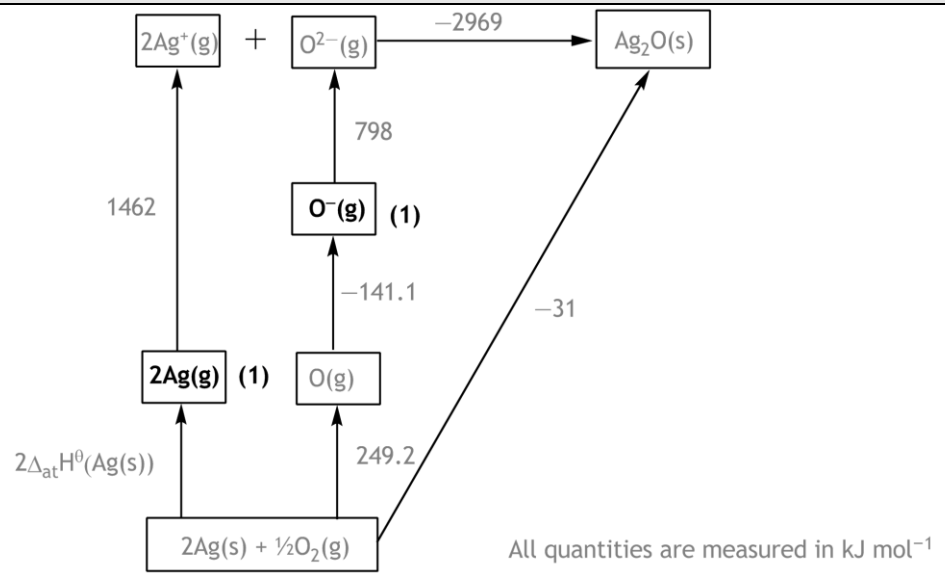
The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</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
<table>
<tr><td></td><td>Number of marks awarded for structure of answer and sustained lines of reasoning</td></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</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, a response with four 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 were no linkages between the points, then the same indicative marking points would yield and overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

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
</td>
<td>(6)</td>
</tr>
</table>

	Indicative Points **IP1 Similarity** both (increase the rate of a reaction) by providing an alternative mechanism / route with lower activation energy (and are chemically unchanged at the end of the reaction) **IP2 Heterogeneous / homogeneous** platinum is heterogenous / different physical state to reactants **and** Mn^{2+} is homogenous / same physical state to reactants **Platinum** **IP3** reactants adsorb onto platinum (surface) **IP4** the reactant bonds are weakened **and** the **products** are desorbed **Mn^{2+}** **IP5** the negative ions repel so the reaction starts slowly **IP6** Mn^{2+} acts as an autocatalyst **or** the reaction then speeds up as Mn^{2+} catalyst forms **or** the reaction is faster between positive ions / Mn^{2+} and negative ions	Allow specific states mentioned – Pt is a solid and the reactants are gases and Mn^{2+} and the reactants are all in aqueous solution Allow names / formulae of specific reactants (CO and NO / NO_2 /NO_x) and products (CO_2 and N_2) Allow active sites for platinum surface Allow broken for weakened Allow just MnO_4^- and $C_2O_4^{2-}$ ions repel (each other) Allow Mn^{2+} reduces MnO_4^- then the Mn species / Mn^{3+} formed oxidises the $C_2O_4^{2-}$ ions Allow Mn^{2+} acts as a catalyst as Mn has a (wide range of) variable oxidation states	

(Total for Question 8 = 6 marks)

Question Number	Answer	Additional Guidance	Mark
9(a)(i)		Allow $O^{1-}(g)$ Ignore + $\frac{1}{2}O_2(g)$ in left hand box Penalise missing state symbols once only Penalise incorrect / missing charges in each species Penalise addition of electrons once only	**(2)**

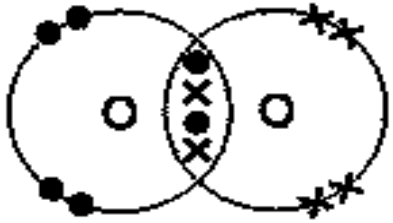
Question Number	Answer	Additional Guidance	Mark
9(a)(ii)	An explanation that makes reference to the following points: • (first electron affinity is exothermic / negative) due to attraction between (positive) nucleus (in neutral atom) and (incoming) electron **(1)** • (second electron affinity is endothermic / positive) due to repulsion **(1)** • between negative ion and (incoming) electron **(1)**	**Reference to removing electron(s) scores (0) overall** Ignore just 'negative species'	**(3)**

Question Number	Answer	Additional Guidance	Mark
9(a)(iii)	• expression based on Hess cycle **(1)** • calculation of missing value from cycle **(1)** • calculation of $\Delta_{at}H^{\ominus}$ **(1)**	$2\Delta_{at}H^{\ominus}$ + (1462 +249.2 - 141.1 + 798 - 2969) = −31 This can be subsumed in M2 $2\Delta_{at}H^{\ominus}$ = −31 − (1462 +249.2 - 141.1 + 798 - 2969) = 569.9 No TE on incorrect expression in M1 569.9 ÷ 2 = (+) 284.95 (kJ mol^{-1}) TE on M2 Correct answer, with or without working, scores (3) Ignore SF except 1 SF Ignore units	**(3)**

Question Number	Answer	Additional Guidance	Mark
9(b)(i)	An answer that makes reference to **two** of the following points: • model assumes bonding is 100% / completely / purely ionic **(1)** • the ions are (perfect) spheres **(1)** • the charge is distributed evenly across the ions / the ions are point charges **(1)** • ions are in contact with one another **(1)**	**Penalise use of atom / molecule / compound instead of ion once only** Ignore reference to standard conditions Allow there is no covalent bonding / character Allow no polarisation of ions / electron cloud Allow electrons are **fully** transferred Ignore almost 100% ionic Allow no distortion of ions / electron cloud Ignore circular Allow charge dispersed equally Ignore ions with fixed charges	**(2)**

Question Number	Answer	Additional guidance	Mark
9(b)(ii)	An answer that makes reference to the following points • as the silver ion polarises / distorts the chloride ion / electron cloud **(1)** • so the bonding (is ionic and) has some covalent character **(1)** • which is stronger (than ionic alone so experimental value is more exothermic / more negative) **(1)**	**Penalise use of incorrect ions in M1 only** Ignore reference to electronegativity Ignore silver chloride is a polar molecule Do not award if incorrect charges on ions Do not award if silver ion is larger than chloride ion Ignore just 'bonding is not purely ionic' Do not award covalent with ionic character Allow 'releases more energy when bond forms' (than ionic alone so experimental value is more exothermic / more negative)	**(3)**

(Total for Question 9 = 13 marks)

Question number	Answer	Additional guidance	Mark
10(a)	An answer that makes reference to the following points • dot-and-cross diagram for oxygen	 Allow diagram without circles Allow all dots or all crosses Allow bond pairs shown axially X X O O If circles are drawn, allow electrons anywhere in the overlap region / on the lines in the overlap region Ignore inner shells	**(1)**

Question Number	Answer	Additional Guidance	Mark
10(b)	An answer that makes reference to the following points • the oxygen is only sparingly soluble (in water) **(1)** • oxygen has (only weak) London forces (between molecules) **(1)** • water has (London forces, dipole- dipole attractions and strong) hydrogen bonds (between molecules) **(1)** • the (intermolecular) forces between oxygen and water would be London forces **and** which are weaker than the hydrogen bonds (in water) **(1)**	Allow abbreviations such as LDF / VDW as this has been penalised in q4 Allow H-bonds for hydrogen bonds Allow not very soluble / slightly soluble / low solubility / doesn't dissolve very well Do not award any additional forces / bonds between O_2 molecules Allow this shown on a diagram Allow the resultant forces between them would be London forces, which are not strong enough to overcome the hydrogen bonds (in water) Allow oxygen molecules are not able to disrupt the hydrogen bonds between water molecules Allow dispersion / temporary dipole-induced dipole / instantaneous dipole / van der Waals as alternatives to London forces throughout Ignore just 'results in fewer hydrogen bonds between water molecules' Ignore hydrogen bonds between oxygen and water	**(4)**

Question Number	Answer	Additional Guidance	Mark
10(c)(i)	• calculation of amount of $Na_2S_2O_3(aq)$ **(1)** • calculation of amount of $I_2(aq)$ **(1)** • calculation of amount of $O_2(aq)$ **(1)** • calculation of concentration of O_2 in mol dm^{-3} (aq) **(1)** • calculation of concentration of O_2 in g dm^{-3} (aq) **(1)**	Example of calculation $(34.2 \div 1000) \times 0.00518 = 1.7716 \times 10^{-4}$ (mol) $= (1.7716 \times 10^{-4}) \div 2 = 8.8578 \times 10^{-5}$ (mol) $= (8.8578 \times 10^{-5}) \div 2 = 4.4289 \times 10^{-5}$ (mol) $= 4.4289 \times 10^{-5} \times (1000/150) = 2.9526 \times 10^{-4}$ (mol dm^{-3}) $= 2.9526\ 10^{-4} \times 32 = 9.4483 \times 10^{-3}$ / 0.0094483 (g dm^{-3}) Allow steps in different orders Allow TE throughout Allow intermediate values quoted as fractions Ignore SF except 1 SF Ignore units even if incorrect Correct answer, with or without working, scores (5) Penalise incorrect rounding / truncation once only	**(5)**

Question Number	Answer	Additional Guidance	Mark
10(c)(ii)	• calculation of concentration of O_2 in ppm	Example of calculation $9.4483 \times 10^{-3} \times (1000000 \div 1000)$ = 9.4483 (ppm) Allow TE from (i) Ignore SF except 1 SF	**(1)**

Question Number	Answer	Additional Guidance	Mark
10(d)	An answer that makes reference to the following points • (some) Mn^{3+} (ions from half-cell B) will oxidise (other) Mn^{3+} (ions from half-cell A) **and** (some) Mn^{3+} (ions) will reduce (other) Mn^{3+} ions **(1)** • as $E^{\ominus}$ for half-cell B is more positive / higher than $E^{\ominus}$ for half-cell A **or** as $E^{\ominus}_{cell}$ = (+)0.56 V **(1)** • $2Mn^{3+}(aq) + 2H_2O(l) \rightarrow Mn^{2+}(aq) + MnO_2(s) + 4H^+(aq)$ **(1)** • disproportionation (reaction) **(1)**	Allow use of oxidation numbers instead of formulae of ions / molecules Allow Mn^{4+} to represent manganese(IV) in MnO_2 Allow Mn^{3+} is oxidised in one (half) equation and reduced in the other Allow Mn^{3+} is an oxidising agent in one (half) equation and a reducing agent in the other M2 can be shown by anti-clockwise rule, eg in table Ignore just $E^{\ominus}_{cell}$ is positive so reaction is feasible Allow reversible arrow Ignore state symbols Ignore just redox	**(4)**

(Total for Question 10 = 15 marks)

TOTAL FOR PAPER = 90 MARKS

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