2225 – 6215M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2025

Chemistry

Higher level

Paper 2

21 pages

Subject Details: Chemistry Higher Level Paper 2 Markscheme

Candidates are required to answer **ALL** questions. Maximum total = **[90 marks]**.

1. Each row in the "Question" column relates to the smallest subpart of the question.

2. The maximum mark for each question subpart is indicated in the "Total" column.

3. Each marking point in the "Answers" column is shown by means of a tick (✓) at the end of the marking point.

4. A question subpart may have more marking points than the total allows. This will be indicated by "**max**" written after the mark in the "Total" column. The related rubric, if necessary, will be outlined in the "Notes" column.

5. An alternative word is indicated in the "Answers" column by a slash (**/**). Either word can be accepted.

6. An alternative answer is indicated in the "Answers" column by "***OR***". Either answer can be accepted.

7. An alternative markscheme is indicated in the "Answers" column under heading **ALTERNATIVE 1** *etc*. Either alternative can be accepted.

8. Words inside chevrons **« »** in the "Answers" column are not necessary to gain the mark.

9. Words that are underlined are essential for the mark.

10. The order of marking points does not have to be as in the "Answers" column, unless stated otherwise in the "Notes" column.

11. If the candidate's answer has the same "meaning" or can be clearly interpreted as being of equivalent significance, detail and validity as that in the "Answers" column then award the mark. Where this point is considered to be particularly relevant in a question it is emphasized by ***OWTTE*** (or words to that effect) in the "Notes" column.

12. Remember that many candidates are writing in a second language. Effective communication is more important than grammatical accuracy.

13. Occasionally, a part of a question may require an answer that is required for subsequent marking points. If an error is made in the first marking point then it should be penalized. However, if the incorrect answer is used correctly in subsequent marking points then **follow through** marks should be awarded. When marking, indicate this by adding **ECF** (error carried forward) on the script.

14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

15. If a question specifically asks for the name of a substance, do not award a mark for a correct formula unless directed otherwise in the "Notes" column. Similarly, if the formula is specifically asked for, do not award a mark for a correct name unless directed otherwise in the "Notes" column.

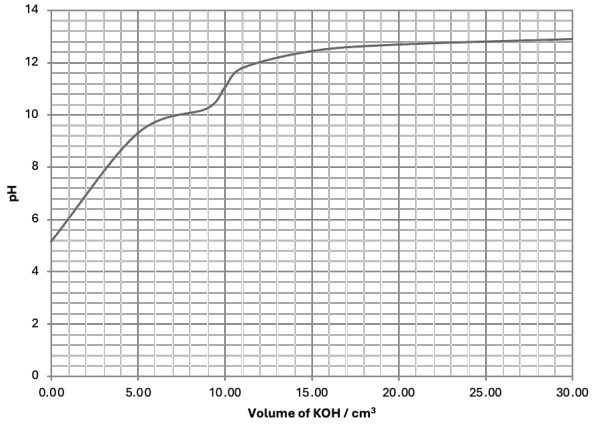
16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the "Notes" column.

17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

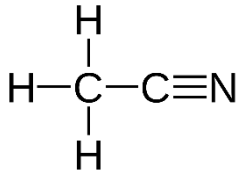
Question			Answers	Notes	Total
1	**(a)**	**(i)**	 ✓	*Accept any combination of dots or crosses to represent electrons, or lines to represent electron pairs.*	**1**
1	**(a)**	**(ii)**	*Hybridization:* sp ✓ *Sigma bonds:* 2 ***AND*** *Pi bonds:* 2 ✓		**2**
1	**(a)**	**(iii)**	*Molecular geometry:* linear ✓ *Explanation:* there are two electron domains around the carbon/central atom ***OR*** 2 bonding pairs and no lone pairs of electrons around the central atom «these take up the orientation where there is least electrostatic repulsion » ✓		**2**
1	**(a)**	**(iv)**	*Partial positive charge:* hydrogen/H ***AND*** *Partial negative charge:* nitrogen/N ✓	*Accept carbon/C for "Partial positive charge".*	**1**

Question			Answers	Notes	Total
1	**(a)**	**(v)**	N_2 «only» has London/dispersion forces ***AND*** HCN has dipole-dipole «and London(dispersion) »forces ***OR*** HCN has dipole-dipole force ***AND*** N_2 does not ✓ intermolecular forces are weaker in N_2 ***OR*** dipole-dipole forces stronger «than London(dispersion) forces»✓	*Accept instantaneous / transient / induced dipole attractions for London forces* *Do **not** accept van der Waals' forces for M1.*	**2**
1	**(b)**	**(i)**	$HCN(aq) \rightleftharpoons H^+(aq) + CN^-(aq)$ ✓ ***OR*** $HCN(aq) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CN^-(aq)$ ✓		**1**

Question			Answers	Notes	Total
1	**(b)**	**(ii)**	*Any two of:* measure pH «HCN has» higher pH ✓ measure electrical conductivity «HCN has» lower electrical conductivity ✓ react with a metal/metal oxide/metal hydroxide/metal carbonate/metal hydrogencarbonate «HCN» reacts more slowly ✓	*Award **[1]** for two correct methods without an observation.* *Accept neutralization/titration with a strong base;temperature rise is lower/equivalence point>7 for HCN* *Accept it would turn universal indicator yellow/orange rather than red.* *Accept other indicators with appropriate colour changes.* *Do **not** accept answers that refer to amounts rather than rates.*	**2 Max**
1	**b**	**(iii)**	$[H^+] = \langle\langle\sqrt{0.100\ x\ 4.90\ x\ 10^{-10}}\rangle\rangle$ = 7.00 x 10^{-6} «mol dm^{-3}» ✓ pH «= -log(7.00x10^{-6})» = 5.15 ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
1	**(b)**	**(iv)**	 sigmoidal curve ***AND*** equivalence point > 7 ✓ curve starts at 4< pH <6 ***AND*** end at 11< pH <14 ✓ vertical rise at volume of 10 cm^3 ✓		**3**
1	**(b)**	**(v)**	equivalence point on student graph labelled “Salt” ✓		**1**

Question			Answers	Notes	Total
1	**(b)**	**(vi)**	amount neutralised «= c x V = 0.100 x 0.0200» = 0.00200 «mol» ✓ ΔT ⟨⟨= $\frac{0.00200\ x\ 13300}{50.0\ x\ 4.18}$⟩⟩ = 0.127 «K / °C» ✓	*Award **[2]** for correct final answer.*	2
1	**(c)**	**(i)**	coordination ✓	*Accept dative/coordination covalent.*	**1**
1	**(c)**	**(ii)**	+2 ✓	*Accept II for +2 but do **not** accept 2+ or 2.*	**1**
1	**(c)**	**(iii)**	*Any 3 of:* partially filled d-orbitals ✓ «ligands cause the energies of the» d-orbitals to split ✓ electrons can absorb light energy as they move from lower to upper level / are promoted ✓ wavelength /energy gap corresponds to visible region ✓	*Do **not** award final marking point for colour observed is complementary colour of light absorbed.*	**3 Max**

Question			Answers	Notes	Total
1	**(c)**	**(iv)**	$\frac{[[Fe(CN)_6]^{4-}]}{[Fe^{2+}].\ [CN^-]^6}$ ✓ $[CN^-] = 6 \times [Fe^{2+}] = 1.32 \times 10^{-6}$ «mol dm^{-3}» ✓ $K = \langle\langle \frac{[[Fe(CN)_6]^{4-}]}{[Fe^{2+}].\ [CN^-]^6} = \frac{[1.00]}{[2.2 \times 10^{-7}].\ [1.32 \times 10^{-6}]^6} = \frac{[1.00]}{[2.2 \times 10^{-7}].[5.29 \times 10^{-36}]} = \frac{[1.00]}{[1.16x10^{-42}]} \rangle\rangle = 8.59x10^{41}$ ✓	*Award **[3]** for correct final answer.*	**3**
1	**(c)**	**(v)**	$E^{Ö}$ less positive/lower than «+0.77 V for» Fe^{3+}/Fe^{2+} ✓ the less positive $E^{Ö}$ the weaker the oxidizing agent / stronger the reducing agent ***OR*** thus, a weaker oxidizing agent✓		**2**
1	**(d)**	**(i)**	 / $H_3C-C\equiv N$ ✓		**1**
1	**(d)**	**(ii)**	S_N2 ***AND*** primary halogenoalkane ✓	*Accept "forms a primary carbocation".*	**1**

Question			Answers	Notes	Total
1	**(d)**	**(iii)**	«carry out the reaction with» different concentrations of the nucleophile/CN^- «with all other conditions unchanged» ✓ rate varies with [nucleophile]/[CN^-] then S_N2 ***OR*** rate does not vary with [nucleophile]/[CN^-] then S_N1 ✓		**2**
2	**(a)**	**(i)**	$^{203}_{81}Tl$ ✓		**1**
2	**(a)**	**(ii)**	«A_r» = (0.3 x 203) + (0.7 x 205) ✓ «A_r» = 204.40 ✓	*Award **[2]** for correct final answer.* *Do **not** accept 204.38 (value in data booklet) for M2.*	**2**

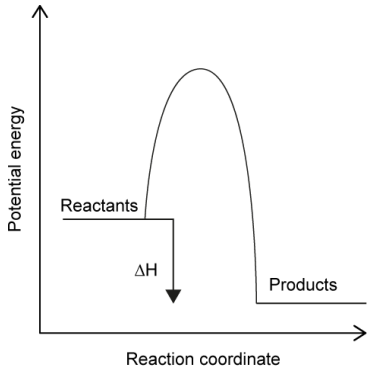
Question			Answers	Notes	Total
2	**(b)**	**(i)**	*Covalent bond between:* sulfur/S ***AND*** oxygen/O ✓ *Ionic bond between:* Tl^+ ***AND*** SO_4^{2-} ✓		**2**
2	**(b)**	**(ii)**	covalent bonding has shared electrons « between atoms» ***AND*** ionic bonding involves electron transfer «between atoms» ✓	*Accept "gain and loss"/donate instead of "transfer".*	**1**
2	**(b)**	**(iii)**	lattice enthalpy ✓		**1**
2	**(b)**	**(iv)**	$2\ TlOH(s) + H_2SO_4(aq) \rightarrow Tl_2SO_4(aq) + 2\ H_2O(l)$ correct formulas of products ✓ correct equation ✓		**2**

Question			Answers	Notes	Total
2	**(b)**	**(v)**	amount TlOH ⟨⟨= $\frac{10.0}{221.39}$⟩⟩ = 0.0452 ✓ amount H_2SO_4 = «0.0452 x ½ » = 0.0226 ✓ volume of H_2SO_4 <<= $\frac{0.0226}{2.00}$>> = 0.0113 dm^3/11.3 cm^3 ✓	*Award **[3]** for correct final answer.*	**3**
2	**(b)**	**(vi)**	yes ***AND*** in same group as aluminium/group 13 «which has an amphoteric oxide» ***OR*** no ***AND*** metallic character increases going down a group «so will have basic oxide like most metals» ✓		**1**

Question			Answers	Notes	Total
2	**(b)**	**(vii)**	***ALTERNATIVE 1:*** place thallium in a solution of copper sulfate ✓ if reaction occurs then thallium is more reactive ***OR*** if no reaction occurs then copper is more reactive ✓ ***ALTERNATIVE 2:*** place copper in a solution of thallium sulfate ✓ if reaction occurs then copper is more reactive ***OR*** if no reaction occurs then thallium is more reactive ✓		**2**

Question			Answers	Notes	Total
2	**(b)**	**(viii)**	*Anode:* oxygen ***AND*** water is more easily oxidized than sulfate ion ✓ *Cathode:* thallium ***AND*** thallium is more easily reduced than water ✓		**2**
2	**(c)**	**(i)**	limit of convergence «of continuum» ✓	*Accept high energy limit instead of limit of convergence.*	**1**

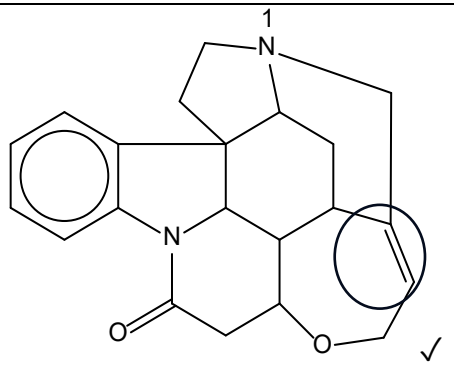
Question			Answers	Notes	Total
2	**(c)**	**(ii)**	IE ⟨⟨= $\frac{589\ x\ 10^{3}\ Jmol^{-1}}{6.02\ x\ 10^{23}\ mol^{-1}}$⟩⟩ = 9.78 x 10^{-19}«J $atom^{-1}$» ✓ frequency ⟨⟨= $\frac{E}{h}$ = $\frac{9.78\ x\ 10^{-19}\ J}{6.63\ x\ 10^{-34}\ Js}$⟩⟩ = 1.48 x 10^{15} «s^{-1}» ✓ wavelength ⟨⟨= $\frac{c}{f}$ = $\frac{3.00x10^{8}m\ s^{-1}}{1.48\ x\ 10^{15}\ s^{-1}}$⟩⟩ = 2.03 x 10^{-7} «m» / 203 «nm» ✓	*Award **[3]** for correct final answer.*	**3**
2	**(c)**	**(iii)**	nuclear charge of Tl less than that of Pb / increasing «effective» nuclear charge from Tl to Pb ✓ shielding effect/occupied energy levels stay the same ✓	*Do **not** accept the atomic radius of lead is less than that of thallium for M1.* *Do **not** accept that the loss of an electron from thallium leaves a complete subshell.*	**2**

Question			Answers	Notes	Total
3	**(a)**	**(i)**	$Cl_2(g) \rightarrow 2\ Cl\bullet(g)$ ✓	*Accept ½ $Cl_2(g) \rightarrow Cl\bullet(g)$.* *Do **not** accept equations without a dot indicating the radical.*	**1**
3	**(a)**	**(ii)**	homolytic ✓		**1**
3	**(a)**	**(iii)**	«bond breaking» = CO + Cl-Cl / 1077 + 242 / 1319 «kJ mol^{-1}» ✓ «bond forming» = C=O + 2 x C-Cl / 804 + 2 x 324 / 1452 «kJ mol^{-1}» ✓ «ΔH = 1319 – 1452 =» -133 «kJ mol^{-1}» ✓	*Award **[3]** for correct final answer.*	**3**
3	**(a)**	**(iv)**	 exothermic reaction profile ✓ ΔH correct ***AND*** labelled reactants and products ✓		**2**

Question			Answers	Notes	Total
3	**(a)**	**(v)**	entropy change «= 284 – 223 - 198» = -137 «J mol^{-1} K^{-1}» ✓		**1**
3	**(a)**	**(vi)**	$\Delta G^{Ö}$ «= $\Delta H^{Ö}$ -T$\Delta S^{Ö}$ = -133000 – (298x - 137) = -133000 + 40826» = -92174 «J mol^{-1}» ✓ ln K = $\langle\langle -\frac{\Delta G^{\circ}}{R.T} = -\frac{-92174}{8.31\ x\ 298}\rangle\rangle$ = 37.2 ✓ K «= $e^{37.2}$ = 1x10^{16}» too large for equilibrium ✓	*Accept answers in the range 1.2-1.5 x10^{16}.*	**3**

Question			Answers	Notes	Total
3	**(b)**	**(i)**	change in pressure per unit time «at constant volume» ***OR*** change in volume per unit time «at constant pressure» ✓	*Do **not** accept change in pH or titrating.*	**1**
3	**(b)**	**(ii)**	incorrect orientation ✓ «collision» energy is less than activation energy ✓		**2**
3	**(b)**	**(iii)**	«rate =» k $[Cl_2CO]$ $[H_2O]$ ✓		**1**
3	**(b)**	**(iv)**	$[H_2O]$ >> $[Cl_2CO]$ / $[H_2O]$ remains constant ✓		**1**
3	**(b)**	**(v)**	x-axis: 1/*T* ***AND*** y-axis: ln*k* ✓		**1**
3	**(b)**	**(vi)**	gradient $\langle\langle = \frac{\ln k}{1/T} = -\frac{E_a}{R} = -\frac{12000}{8.31} \rangle\rangle$ = -1444 «K» ✓	*Accept 1.4 -1.5 x 10^3«K».*	**1**
3	**(b)**	**(vii)**	higher temperature curve added with maximum lower and shifted to right ✓	*Do **not** award mark unless area under curve approximately the same, the curve starts at (0,0) and it remains above the x-axis.*	**1**

Question			Answers	Notes	Total
3	**(b)**	**(viii)**	E_a appropriately indicated ✓ explanation stating proportion of collisions/particles with $E > Ea$ ***OR*** area under curve when $E > Ea$ increases at higher temperature ✓		**2**
3	**(b)**	**(ix)**	not consumed in reaction / unchanged ✓ «reaction» rate increased «under same conditions» ✓		**2**
3	**(c)**	**(i)**	fragmentation ✓	*Accept molecule unstable/disintegrates in instrument/on ionization.*	**1**
3	**(c)**	**(ii)**	$Cl\text{-}CO^+$ ✓	*Do **not** award the mark if the + sign is missing.*	**1**
3	**(c)**	**(iii)**	*IR:* «absorption band due to C-Cl at » 600-800 cm^{-1} ***OR*** «absorption band due to C=O at »1700-1750 cm^{-1} ✓ *^1H NMR:* no signals «as no H atoms in molecule» ✓		**2**
4	**(a)**	**(i)**	«tertiary» amino ✓	*Accept amine.*	**1**

Question			Answers	Notes	Total
4	**(a)**	**(ii)**	*Direction of pH change:* increase ***AND*** *Reason for change:* accepts hydrogen ion/proton «from water» ✓	*Accept increase **AND** donates an electron pair.* *Accept increase **AND** acts as a base.*	**1**
4	**(a)**	**(iii)**	 ✓		**1**
4	**(a)**	**(iv)**	7 ✓		**1**
4	**(a)**	**(v)**	a «carbon» atom bonded to four different atoms «or groups of atoms» ✓	*Accept a carbon atom that is not superimposable on its mirror image.* *Accept four different substituents/functional groups.* *Do **not** accept answers that refer to optical properties.*	**1**

Question			Answers	Notes	Total
4	**(b)**		theoretical yield⟨⟨$= 48.73\ x\ \frac{2x334.4\ +\ 98.1}{2\ x\ 334.4}\ =\ 48.73\ x\ \frac{766.9}{668.8}$⟩⟩ = 55.87 g✓ percentage yield ⟨⟨$= 100\ x\ \frac{51.41}{55.87}$⟩⟩ «=100 x 51.41/ 55.87» = 92.00 «%» ✓	*Award **[2]** for correct final answer.*	**2**