2226 – 4230M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

May 2026

Chemistry

Higher level

Paper 2

17 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 <u>underlined</u> 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.

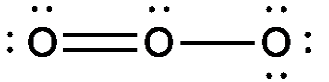
16. If a question asks for an equation for a reaction, a balanced symbol equation is usually expected, do not award a mark for a word equation or an unbalanced equation unless directed otherwise in the "Notes" column.

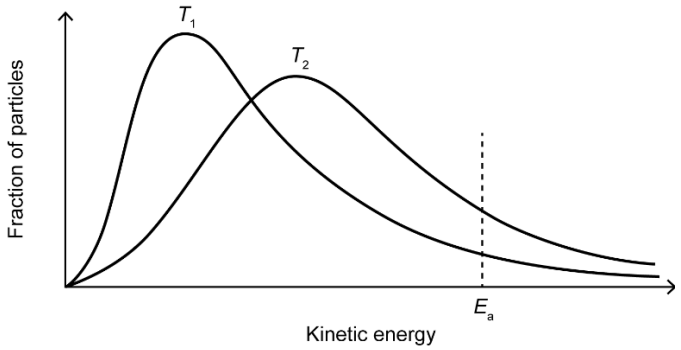
17. Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

Question			Answers	Notes	Total
1.	(a)	(i)	Li $1s^2 2s^1$ ***AND*** Cl $1s^2 2s^2 2p^6 3s^2 3p^5$ ✓ Li loses ***AND*** Cl gains $1e^-$ ***OR*** Li^+ ***AND*** Cl^- formed ***OR*** $1s^2$ ***AND*** $1s^2 2s^2 2p^6 3s^2 3p^6$ ✓ «oppositely charged» ions are electrostatically attracted ✓	*Accept condensed electron configurations.*	**3**
1.	(a)	(ii)	«observed electron configuration is» $[Ar]4s^1 3d^5$ ✓ promoting 4s electron to 3d level is more stable configuration ***OR*** half-occupied d-orbitals/d-sublevel more stable ✓	*Accept full electron configuration **OR** orbital diagram for M1.*	**2**
1.	(b)	(i)	«$0.0350\ dm^3 \times 0.550\ mol\ dm^{-3}$ =» 0.0193 «mol LiOH» ***AND*** «$0.0350\ dm^3 \times 0.250\ mol\ dm^{-3}$ =» 0.00875 «mol $Fe(NO_3)_3$» ✓ «3:1 ratio hence» LiOH is limiting reactant ✓ «$\frac{0.0193\ mol}{3} \times 106.88\ g\ mol^{-1}$ =» 0.688 «g $Fe(OH)_3$» ✓	*Award **[3]** for correct final answer with working.* *Do **not** award M2 without justification.*	**3**
1.	(b)	(ii)	«$\frac{0.542\ g}{0.688\ g} \times 100$ =» 78.8% ✓	*If 0.763 is used, the answer is 71.0%.*	**1**

Question			Answers	Notes	Total
1.	(c)	(i)	*Acid:* hydrochloric acid ***AND*** *Base:* ammonia ✓	*Accept hydrogen chloride (for acid) and ammonium hydroxide/carbonate/hydrogen carbonate (for base).* *Do **not** accept formulas only.*	**1**
1.	(c)	(ii)	less than 7 ✓	*Accept any value in range 3.5 - 6.9.* *Do **not** accept a range that includes pH = 7.*	**1**
1.	(c)	(iii)	***ALTERNATIVE 1:*** «$K_a = 10^{-4.76} = \frac{[H^+][A^-]}{[HA]}$» «$[H^+] = \frac{10^{-4.76} \times 0.350}{0.455}$ =» 1.34 x 10^{-5} «mol dm^{-3}» ✓ «pH = –log 1.34 x 10^{-5} =» 4.87 ✓ ***ALTERNATIVE 2:*** «pH = pK_a + log $\frac{[A^-]}{[HA]}$ =» «pH =» 4.76 + log $\frac{0.455}{0.350}$ / 4.76 + 0.114 ✓ «pH =» 4.87 ✓	*Award **[2]** for correct final answer.*	**2**

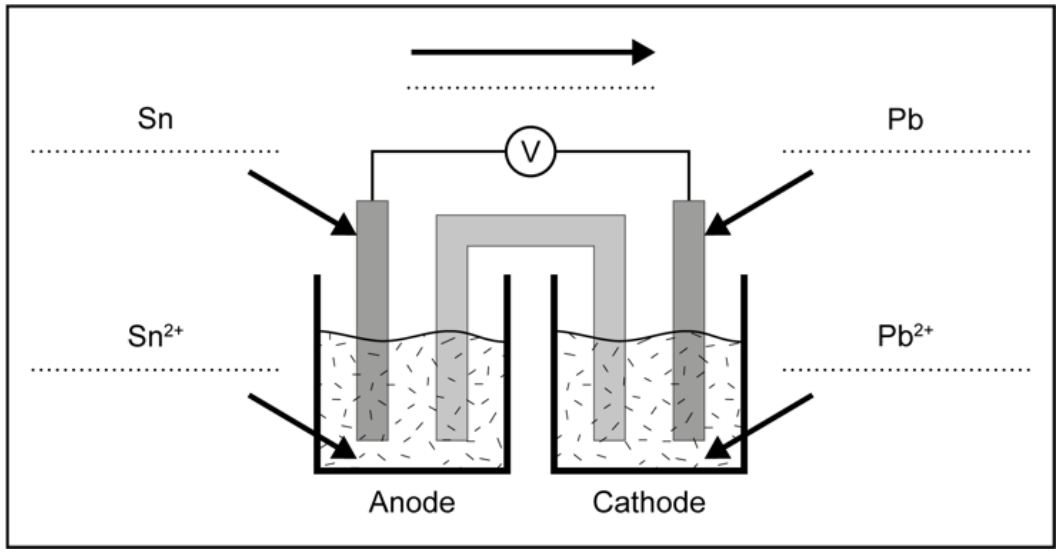
Question			Answers	Notes	Total
2.	(a)	(i)	$\frac{«+»285.4}{2}$ / «+»142.7 «kJ mol^{-1}» ***AND*** $\frac{«-»498.0}{2}$ / «–»249.0 «kJ mol^{-1}» ✓ «+142.7 + (–249.0) + (–199.9) =» –306.2 «kJ mol^{-1}» ✓	*Award **[2]** for final correct answer.*	**2**
2.	(a)	(ii)	*Bond angle:* 110˚ ≤ bond angle < 120° ✓ *Molecular geometry:* bent / V–shaped / angular ✓	*Accept any value in the range 110˚ – 119˚ (actual value is 116.8˚).*	**2**
2.	(a)	(iii)	«$V = \frac{1.75\ mol \times 8.31\ J\ K^{-1} mol^{-1} \times 348\ K}{115\ kPa}$ = » 44.0 «dm^3» ✓		**1**
2.	(a)	(iv)	«gases under» high pressures ***AND*** molecular volume cannot be ignored ***OR*** «gases» with strong IMF / at low temperature / at high pressure ***AND*** molecular attractions/IMFs cannot be ignored ✓		**1**

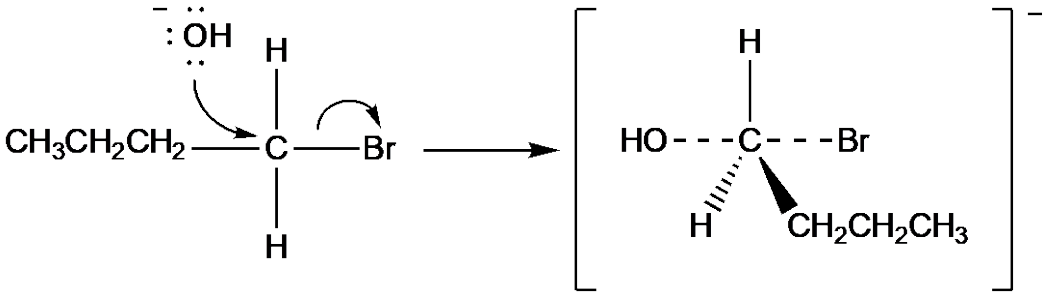
Question			Answers	Notes	Total
2.	(a)	(v)	 0 +1/+ –1/– ✓	*All three must be correct for the mark.*	1
2.	(b)	(i)	«K =»$\frac{[NO]^2[O_2]}{[NO_2]^2}$ ✓		1
2.	(b)	(ii)	*Equilibrium position*: shift to left/reactants ***AND*** fewer moles «of gas» ✓ *Value of equilibrium constant*: same ***AND*** only changes with temperature ✓	*Award **[1 max]** for correct effects without explanations.*	2
2.	(b)	(iii)	K calculated using equilibrium «concentrations» ***AND*** Q calculated «in the same way as K but» using non-equilibrium «concentrations» ✓ proceeds to the left / reverse reaction ***AND*** to use up excess products ***OR*** proceeds to the left / reverse reaction ***AND*** to decrease the value of Q «until it reaches equilibrium» ✓		2
2.	(b)	(iv)	more particles will possess the necessary activation energy ***OR*** more particles/collisions with $E \geq E_a$ ✓ more «successful» collisions per unit time ***OR*** the frequency of «successful» collisions increases ***OR*** greater proportion of collisions are successful per unit time ✓		2

Question			Answers	Notes	Total
2.	**(b)**	**(v)**	 T_2 curve starting at origin and asymptotic to x-axis with maximum lower ***AND*** to the right of T_1 maximum ✓		**1**
2.	**(b)**	**(vi)**	no effect ✓		**1**
2.	**(c)**	**(i)**	mechanism agrees with balanced/overall equation ✓ rate-determining step must be Step 2 ***AND*** based on rate equation ✓	*Accept "rate law" for "rate equation".* *Accept Step 1 is not the rate determining step **AND** based on rate equation for M2.*	**2**
2.	**(c)**	**(ii)**	$\frac{1.5\times10^{-4} mol\ dm^{-3}\ s^{-1}}{[1.6\times10^{-1} mol\ dm^{-3}]^2[2.4\times10^{-1} mol\ dm^{-3}]} = » 0.024$ ✓ $mol^{-2}\ dm^6\ s^{-1}$ ✓		**2**
3.	**(a)**	**(i)**	$190.96x + 192.96(1-x) = 192.22$ ***OR*** $\frac{190.96\ x+192.96(100-x)}{100} = 192.22$ ✓ *Ir-191:* 37% ***AND*** *Ir-193:* 63% ✓	*Award **[2]** for correct final answer.* *Award **[1 max]** for 0.37 and 0.63.*	**2**

Question			Answers	Notes	Total
3.	(a)	(ii)	<table><tr><th>Subatomic Particle</th><th>Number</th></tr><tr><td>Protons</td><td>77</td></tr><tr><td>Neutrons</td><td>116</td></tr><tr><td>Electrons</td><td>73</td></tr></table> ✓	*All 3 must be correct for mark.*	**1**
3.	(b)	(i)	*Any two of:* aluminium has smaller «ionic» radius ✓ aluminium has more delocalized electrons ✓ aluminium has greater «ionic» charge ✓	*Accept "Al has more valence electrons" for M2.*	**2 max**
3.	(b)	(ii)	$2Na(s) + 2H_2O(l) \rightarrow H_2(g) + 2NaOH(aq)$. correct products ***AND*** state symbols ✓ *correct balancing* ✓		**2**
3.	(b)	(iii)	Na has fewer occupied energy levels / lower shielding effect «than Cs» ***OR*** Na has valence electrons closer to the nucleus «than Cs» ✓	*Accept Na has a smaller «atomic» radius.*	**1**

Question			Answers	Notes	Total
3.	(b)	(iv)	*Wavelength:* «$E = \frac{376000\ J\ mol^{-1}}{6.02\times10^{23}\ mol^{-1}}$ = » 6.25×10^{-19} «J» ✓ «$\lambda = \frac{6.63\times10^{-34} J\ s \times 3.00\times10^{8} m\ s^{-1}}{6.25\times10^{-19} J}$ = » 3.18×10^{-7}«m» ✓ *Region:* ultraviolet/UV ✓		**3**
3.	(c)	(i)	ions/atoms of different radii/sizes ***AND*** layers cannot slide easily ***OR*** ions/atoms «added to the metal» disrupt lattice structure ***AND*** layers cannot slide easily ✓		**1**
3.	(c)	(ii)	*Any one of:* resistance to corrosion ✓ melting point ✓ density ✓ electrical conductivity ✓ magnetic behaviour ✓	*Accept "wear resistance" or "boiling point".* *Ignore malleability, ductility, strength, toughness, lustre or colour.*	**1 max**

Question			Answers	Notes	Total
3.	(d)	(i)	 all 4 species labeled correctly ✓ arrow showing electron flow from anode to cathode in external circuit ✓	*Do **not** accept arrow through the salt bridge.*	**2**
3.	(d)	(ii)	«replace voltmeter with external» battery/power supply ✓ force/change/reverse direction of electron flow/current ✓ rebuilds/increases mass of Sn/anode ***OR*** regenerates/increases «concentration of» Pb^{2+} ions ✓	*Accept diagrams for M1 and M2.*	**3**

Question			Answers	Notes	Total
3.	(e)	(i)	absorbs yellow light/575 – 585 «nm» ✓ complementary colour «violet» seen/transmitted ✓	*Accept any wavelength value within the given range for M1.* *Do **not** accept violet light is "emitted" for M2.*	**2**
3.	(e)	(ii)	coordination bond ✓	*Accept dative/coordinate «covalent» bond.*	**1**
4.	(a)	(i)	 $CH_3CH_2CH_2CH_2OH + Br^-$ curly arrow from lone pair/negative charge on O in ^-OH to carbon attached to Br ✓ curly arrow from C—Br to Br ✓ transition state showing negative charge ***AND*** partial bonds ✓	*Award **[2 max]** for correctly drawn S_N1 mechanism.* *For M2, accept curly arrow in the transition state.* *For M3, do **not** penalize if HO and Br are not at 180° or the square bracket is missing.* *Penalize bond connectivity (e.g. OH---C in the transition state) only once.* *Penalize missing charges only once.*	**3**
4.	(a)	(ii)	butan–1–ol ✓	*Accept 1–butanol.* *Do **not** accept structural formula.*	**1**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>4.</td><td>(b)</td><td>(i)</td><td>«$\Sigma(\Delta H_f^{\ominus}{}_{products})$» $4 \times (-394) + 5 \times (-286) / -3006$ «kJ mol^{-1}»
<i>AND</i>
«$\Sigma(\Delta H_f^{\ominus}{}_{reactants})$» –126 «kJ mol^{-1}» ✓

«$\Sigma(\Delta H_f^{\ominus}{}_{products}) - \Sigma(\Delta H_f^{\ominus}{}_{reactants}) = -3006 - (-126) =$» –2880 «kJ mol^{-1}» ✓</td><td>Award [2] for correct final answer.</td><td>2</td></tr>
<tr><td>4.</td><td>(b)</td><td>(ii)</td><td>«$T =$» 298 «K» AND «$\Delta S^{\ominus} =$» –0.4375 «kJ K^{-1} mol^{-1}» ✓

«$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus}$»
«$\Delta G^{\ominus}$ = –2880 kJ mol^{-1} – (–0.4375 kJ K^{-1} mol^{-1} × 298 K) =» –2750 «kJ mol^{-1}» ✓</td><td><i>Award [2] for correct final answer.</i>

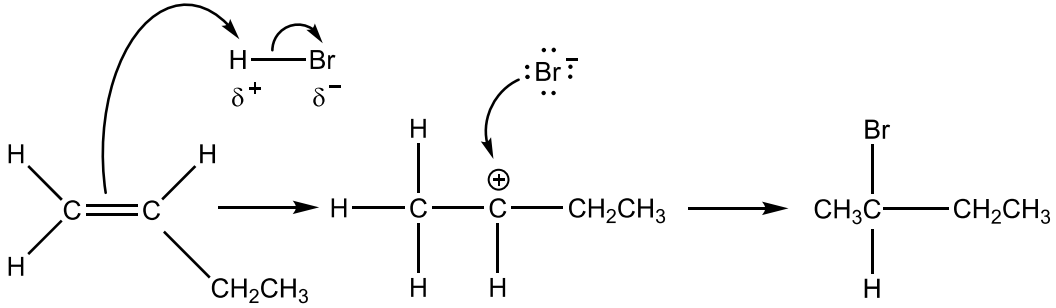
<i>If -2400 is used, the answer is –2270 «kJ mol^{-1}».</td><td>2</td></tr>
<tr><td>4.</td><td>(b)</td><td>(iii)</td><td><table><tr><th>Compound</th><th>Oxidation State</th></tr><tr><td>CH$_3$CH$_2$CH$_2$CH$_3$</td><td>–3 ✓</td></tr><tr><td>CO$_2$</td><td>+4 ✓</td></tr></table></td><td>Do not accept III or 3- for –3.

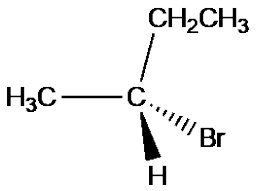
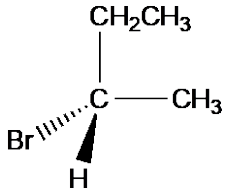
Accept IV for +4 but do not accept 4+ or 4.</td><td>2</td></tr>
<tr><td>4.</td><td>(c)</td><td>(i)</td><td>propanoic acid ✓

methanol ✓</td><td>Accept propanoyl chloride OR propanoic anhydride for M1.

Award [1 max] for CH$_3$CH$_2$COOH AND CH$_3$OH.</td><td>2</td></tr>
</table>

Question			Answers	Notes	Total
4.	**(c)**	**(ii)**	water ✓	*The by-product must match the reactants suggested in part (i). If the acid chloride was used the by-product is hydrochloric acid/hydrogen chloride, and if the anhydride was used the by-product is propanoic acid.* *Do **not** accept structural formula.*	**1**
4.	**(c)**	**(iii)**	prop-2-en-1-ol has hydrogen bonding «between molecules» ***AND*** propanone has dipole-dipole «forces between molecules» ✓ hydrogen bonds stronger «IMF» ✓		**2**
4.	**(d)**	**(i)**	provides energy for Cl—Cl / Cl_2 bond fission/breaking ***OR*** produces Cl«•» radicals ✓		**1**
4.	**(d)**	**(ii)**	*Propagation:* $CH_4 + Cl\bullet \rightarrow \bullet CH_3 + HCl$ ✓ $\bullet CH_3 + Cl_2 \rightarrow CH_3Cl + Cl\bullet$ ✓ *Termination:* $Cl\bullet + Cl\bullet \rightarrow Cl_2$ ***OR*** $Cl\bullet + \bullet CH_3 \rightarrow CH_3Cl$ ***OR*** $\bullet CH_3 + \bullet CH_3 \rightarrow CH_3CH_3$ ✓	*Penalize missing radicals once.* *Do **not** penalize location of radical dot on species.*	**3**

Question			Answers	Notes	Total
4.	(e)	(i)	but-1-ene: one carbon at C=C bond has two hydrogens/identical groups ***OR*** but-2-ene: both carbons at C=C bond have different groups attached ✓	*A structural drawing can be used as part of the explanation.*	**1**
4.	(e)	(ii)	sp^3 ***AND*** sp^2 ✓		**1**
4.	(e)	(iii)	*Number of signals:* 2 ✓ *Relative areas:* 1:3 ✓	*Accept relative areas in any order.* *Accept relative areas 2:6.* *Award **[1 max]** for 4 **AND** 1:1:3:3.*	**2**
4.	(e)	(iv)	 curly arrow from C=C bond to H of HBr ***AND*** curly arrow showing H—Br bond breaking ✓ carbocation with charge on correct atom ✓ curly arrow from lone pair/negative charge on Br^- to C^+ ✓	*Do **not** penalize missing partial charges on H—Br for M1.*	**3**

Question			Answers	Notes	Total
4.	(e)	(v)	 ***AND***  ✓	*Do **not** accept structures without wedge-dash representation.* *Do **not** accept structures with 90° angles.*	**1**
4.	(e)	(vi)	«rotate plane of» polarized light ***OR*** «use a» polarimeter ✓ «plane of polarized» light is rotated in opposite directions ✓		**2**
4.	(e)	(vii)	aromatic ring / «clouds of» delocalized electrons ✓ «addition would» disrupt stabilizing effect of delocalised electrons/resonance ***OR*** resonance energy must be overcome ***OR*** breaking aromatic ring requires more energy than breaking one pi-bond «in alkene» ✓	*Accept resonance structure for M1.*	**2**
4.	(f)	(i)	«bonds broken» 4C—H + 2O=O / 4 x 414 + 2 x 498 / 2652 «kJ mol^{-1}» ***AND*** «bonds formed» 2C=O + 4O —H / 2 x 804 + 4 x 463 / 3460 «kJ mol^{-1}» ✓ «ΔH = 2652 – 3460 =» –808 «kJ mol^{-1}» ✓	*Award **[2]** for correct final answer.*	**2**

Question			Answers	Notes	Total
4.	**(f)**	**(ii)**	zero ***AND*** element in the standard state ✓	*Accept $O_2(g)$ does not have an enthalpy of formation as it is an element in the standard state.*	**1**
4.	**(f)**	**(iii)**	*Any two of:* carbon «in CO» not fully oxidized ✓ one «triple» bond in CO weaker than two «double» bonds in CO_2 ✓ CO flammable ***OR*** combustion of CO exothermic ✓	*Accept fewer/weaker bonds formed in CO than in forming CO_2 for M2.*	**2 max**