2226 – 4218M

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 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.

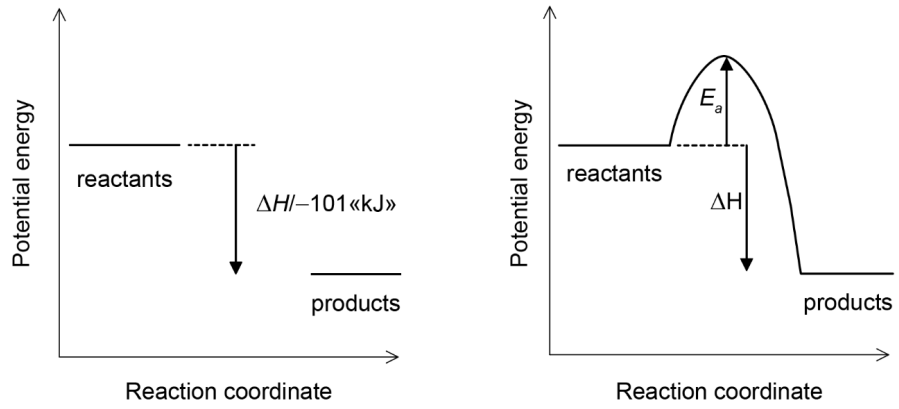
Ignore missing or incorrect state symbols in an equation unless directed otherwise in the "Notes" column.

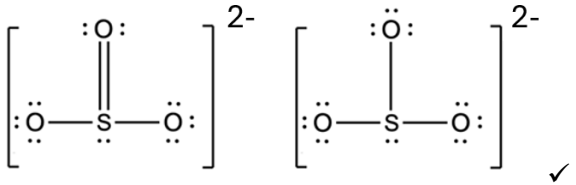
<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>1.</td><td>(a)</td><td>(i)</td><td>≪ $15.0\ \text{g} * \frac{1\ \text{mol}}{256.56\ \text{g}} * \frac{8\ \text{mol}}{1\ \text{mol}}$ =≫ 0.468 ≪mol≫ ✓

≪$0.468\ \text{mol} * \frac{22.7\ dm^3}{1\text{mol}}$ =≫ 10.6 ≪dm^3≫ ✓</td><td>Award [2] for correct final answer.</td><td>2</td></tr>
<tr><td>1.</td><td>(a)</td><td>(ii)</td><td>$\frac{10.6\ dm^3}{273\text{K}}$x298K ≪ =≫ 11.6 ≪ dm^3≫ ✓</td><td>Accept “16.4 ≪dm^3≫” if using 15.0 dm^3.
Accept use of 273.15K and 298.15K.</td><td>1</td></tr>
<tr><td>1.</td><td>(b)</td><td>(i)</td><td><table><tr><td>Compound</td><td>Oxidation State of Sulfur</td></tr><tr><td>SO$_2$</td><td>+4</td></tr><tr><td>SO$_3$</td><td>+6</td></tr></table></td><td>Accept IV AND VI.

Do not accept 4+/4 OR 6+/6.</td><td>1</td></tr>
<tr><td>1.</td><td>(b)</td><td>(ii)</td><td>$\frac{[SO_3]^2}{[SO_2]^2[O_2]}$ ✓</td><td>Square Brackets [ ] required.</td><td>1</td></tr>
<tr><td>1.</td><td>(b)</td><td>(iii)</td><td>decreases AND forward reaction exothermic ✓</td><td></td><td>1</td></tr>
<tr><td>1.</td><td>(b)</td><td>(iv)</td><td><table><tr><td>Decreasing volume</td><td>shifts to right/towards products AND fewer moles of gas/products ✓</td></tr><tr><td>Value of K</td><td>stays the same ✓</td></tr></table></td><td>Allow [1 max] if both directions correct without correct explanations.

Accept “shifts right/towards products AND to reduce the pressure” for M1</td><td>2</td></tr>
</table>

Question			Answers	Notes	Total
1.	(c)	(i)	 exothermic graph ***AND*** ΔH/-101 «kJ» labelled on arrow from reactants to products ✓ activation energy/E_a labelled on arrow from reactant to top of energy profile ✓	*Penalize incorrect arrows once only.* *Accept double headed arrows.*	**2**
1.	(c)	ii	covalent bonding between S and O/within H_2SO_4/HSO_4^-/SO_4^{2-} ***OR*** covalent bonding between H and O/within H_2O ✓ ionic bonding between H^+/H_3O^+ and HSO_4^-/SO_4^{2-} ions ✓	*Accept any named intermolecular force between named species for M2.* *Do **not** award mark without correct ion charge notations for M2*	**2**
1.	(d)	(i)	strong acids dissociate/ionize completely ***AND*** weak acids dissociate/ionize partially ≪in solution/water≫ ✓		**1**

Question			Answers	Notes	Total
1.	**(d)**	**(ii)**	*Lewis formula:*  2- 2- ✓ *Molecular Geometry:* trigonal pyramidal ✓	*Accept any combination of lines and dots* *Penalize missing brackets and/or negative charge for M1.* *Negative charges may be indicated on 2 singularly bonded oxygens without brackets.* *M2 mark must follow from Lewis structure shown*	**2**
1.	**(d)**	**(iii)**	sp^3 ✓	*ECF from Lewis structure in 1d(ii)*	**1**
1.	**(d)**	**(iv)**	delocalization of electrons/≪*negative*≫ *charges* ✓ forms resonance structures ✓		**2**
1.	**(e)**	**(i)**	$Pb(s) + 2H_2SO_4(aq) + PbO_2(s) \rightarrow 2PbSO_4(s) + 2H_2O(l)$ ***OR*** $Pb(s) + 4H^+(aq) + 2SO_4^{2-}(aq) + PbO_2(s) \rightarrow 2PbSO_4(s) + 2H_2O(l)$ ✓	*Accept "$Pb(s) + 2H^+(aq) + 2HSO_4^-(aq) + PbO_2(s) \rightarrow 2PbSO_4(s) + 2H_2O(l)$"*	**1**
1.	**(e)**	**(ii)**	≪1.69 V – (-0.36V) = ≫ 2.05 ≪V≫✓		**1**

Question			Answers	Notes	Total
1.	(e)	(iii)	«$\Delta G^o = -nFE^o$» n = 2 ***OR*** ΔG^o = «-»2×96,500×2.05 /«-»395,650 «J mol^{-1}» ✓ -396 «kJ mol^{-1}» ✓	*For n = 1, award **[1 max]** for -198 «kJ mol^{-1}».* *Award **[1 max]** for (+)396 «kJ mol^{-1}».* *Award **[2]** for correct final answer.* *Award **[2]** for "-241*«kJ mol^{-1}»*" from 1.25 V.*	**2**
1.	(f)	(i)	*Anode half-equation:* $H_2(g) + 2OH^-(aq) \rightarrow 2H_2O(l) + 2e^-$ ✓ *Cathode half-equation:* $O_2(g) + 4e^- + 2H_2O(l) \rightarrow 4OH^-(aq)$ ✓	*Allow [1 max] for "$H_2(g) \rightarrow 2H^+(aq) + 2e^-$ **AND** $O_2(g) + 4H^+(aq) + 4e^- \rightarrow 2H_2O(aq)$"* *Penalize the use of equilibrium arrows once only.*	**2**
1.	(f)	(ii)	electrons occupy ≪discrete/separate≫ energy levels ✓ higher energy levels converge ✓	*Accept other correct statements such as "energy levels spaced unequally" for M2*	**2**
1.	(f)	(iii)	≪434.0 nm $x \frac{1m}{1x10^9 nm} = 4.34x10^{-7}$ m ≫ ≪$f = c/\lambda = \frac{3.00x10^8 m\ s^{-1}}{4.34x10^{-7}\ m}$=≫ $6.91x10^{14}$ ≪s^{-1}≫ ✓ ≪$E=hf$ = $6.63x10^{-34}$J s x $6.91x10^{14}$ s^{-1}≫ = $4.58x10^{-19}$ ≪J≫ ✓	*Award **[2]** for correct final answer.*	**2**
2.	(a)	(i)	*Protons* 19 *Electrons* 18 *Neutrons* 20 ✓ ✓	*Award **[2]** for three correct answers, **[1]** for two correct answers.*	**2**

Question			Answers	Notes	Total
2.	**(a)**	**(ii)**	$1s^2 2s^2 2p^6 3s^2 3p^6$ ✓	*Ignore "$4s^0$"*	**1**
2.	**(a)**	**(iii)**	39.10 = x(0.9326) + 40.96(0.06730) ✓ ≪$\frac{36.34}{0.9326}$=≫x 38.97 ✓	*Do **not** award M1 without working.* *Do **not** award M2 without 4 significant figures.* *Allow other valid methods for determining answer.*	**2**
2.	**(b)**	**(i)**	potassium/K has fewer protons/lower nuclear charge/lower atomic number ✓ ≪both have≫ same shielding ≪by inner electrons≫/occupied energy levels ✓	*Accept "Ca has a smaller atomic radius/electron removed is closer to the nucleus" for M2*	**2**
2.	**(b)**	**(ii)**	valence e^- in potassium/K more shielded ≪by inner electrons≫/≪ occupied ≫ energy levels ✓	*Allow K has larger atomic radius than Na if not used as an explanation in 2b(i)*	**1**
2.	**(b)**	**(iii)**	phosphorous/P has «three» unpaired electrons in 3p sub-level/orbitals ***AND*** *sulfur/*S has one full 3p/paired and two unpaired electrons in 3p orbitals/sub-levels ***OR*** phosphorous/P $[Ne]3s^2 3p_x^1 3p_y^1 3p_z^1$ ***AND*** *sulfur/S* $[Ne]3s^2 3p_x^2 3p_y^1 3p_z^1$ ✓ repulsion between paired electrons in sulfur «and therefore less energy required to remove it» ✓	*Accept orbital diagrams for 3p sub-levels for M1.*	**2**

<table>
<tr><th colspan="3">Question</th><th>Answers</th><th>Notes</th><th>Total</th></tr>
<tr><td>2.</td><td>(c)</td><td>(i)</td><td>$2K(s) + 2H_2O(l) \rightarrow 2KOH(aq) + H_2(g)$

correct products and state symbols ✓

Correct balancing✓</td><td>Accept any correct multiples

Accept balanced ionic equation.

Only award M2 if products are correct</td><td>2</td></tr>
<tr><td>2.</td><td>(c)</td><td>(ii)</td><td>
<table>
<tr><td></td><td>Type of bonding</td><td>How valence electrons produce bonds</td></tr>
<tr><td>K</td><td>metallic bond</td><td>delocalized electrons attracted to cations/positive ions ≪in lattice structure≫ ✓
AND</td></tr>
<tr><td>H_2O</td><td>≪polar≫ covalent bonds</td><td>shared electrons ≪unequally between atoms/nuclei≫ ✓
AND</td></tr>
</table>
</td><td>Award [1 max] for any correct column.

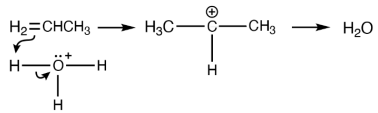
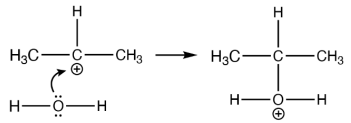
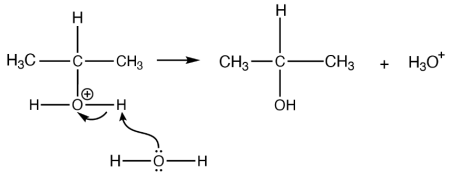
Do not accept protons/nucleus in place of cation/positive ions.</td><td>2</td></tr>
</table>

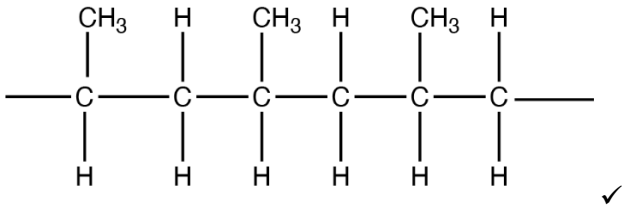
Question			Answers	Notes	Total
2.	**(d)**		*A Bond Enthalpy:* ≪ $\frac{242\text{kJ mol}-1}{2} = +$≫ 121 ≪kJ mol^{-1}≫ ✓ *B Electron Affinity:* -349 ≪kJ mol^{-1}≫ ✓ *C Lattice Enthalpy:* ≪89 + 419 + 121 -349 + 437 =+≫717 ≪kJ mol^{-1}≫ ✓	*Award [3] for 717 ≪kJ mol^{-1}≫* *Negative sign required for M2.* *Award **[2]** for -717≪kJ mol^{-1}≫ for M3.* *Award **[2]** for +838 ≪kJ mol^{-1}≫ for M3.* *Do **not** accept 720 ≪kJ mol^{-1}≫ for M3.*	**3**
2.	**(e)**	**(i)**	*Any two of:* variable oxidation state ✓ high melting/boiling point/hardness ✓ high density/dense ✓ catalysts ✓ form complex ions ✓ high electrical/thermal conductivity ✓	*Accept "magnetic/paramagnetic"* *Do **not** accept "partially filled d orbitals"*	**2**

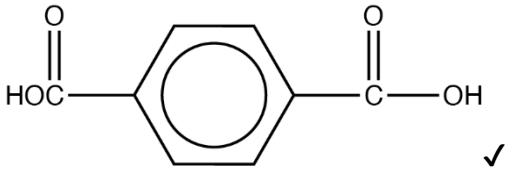
Question			Answers	Notes	Total
2.	**(e)**	**(ii)**	*Any three of:* partially filled d-orbitals ✓ d-orbitals split ✓ light is absorbed as electrons transition to a higher energy level «in d–d transitions» ***OR*** light is absorbed as electrons are promoted ✓ energy gap corresponds to light in the visible region of the spectrum ✓	*Accept "colour observed is the complementary colour" for M4 only if visible light is mentioned anywhere in the response.*	**3**
3.	**(a)**	**(i)**	*Bonds broken:* ≪2xC-C≫ + ≪8xC-H≫ + ≪5xO=O≫ 2x346≪kJ≫ + 8x 414≪kJ≫ + 5x 498≪kJ≫/6494≪kJ≫ ✓ *Bonds formed:* ≪6xC=O≫ + ≪8xO-H≫ 6x804≪kJ≫+ 8x463≪kJ≫/8528≪kJ≫ ✓ «Δ*H* = Σbonds broken − Σbonds formed =(6494 kJ − 8528 kJ) =» -2034«kJ» ✓	*Award **[3]** for correct final answer.* *Award **[2 max]** for final answer of ≪+≫2034 «kJ».*	**3**

Question			Answers	Notes	Total
3.	(a)	(ii)	$\ll \frac{25.0\ g}{44.11\ g\ mol^{-1}}$ =» 0.567 «mol C_3H_8» ***AND*** $\ll \frac{95.0\ g}{32.00\ g\ mol^{-1}}$ =» 2.97 «mol O_2» ✓ $\ll 0.567\ \text{mol} \times 5 = \gg 2.84 \ll \text{mol} \gg$ ***OR*** $\ll \frac{2.97\ mol}{5} = \gg 0.594 \ll$mol» ***AND*** propane/$C_3H_8$ limiting reagent ✓ $\ll 0.567\ \text{mol} \times 3 \times \frac{44.01\ g}{1\ mol} = \gg 74.9 \ll g \gg$ ✓	*Award [3] for correct final answer.* *Do not penalize the use of whole number molecular masses.* *Accept other valid methods for determining M1* ***AND/OR*** *M2.* *Accept final answers in the range 74.8-75.3* $\ll g \gg$.	3
3.	(a)	(iii)	bond enthalpy is an average «and may not be the precise value» ***OR*** $H_2O(g)$ in (a)(i) ***AND*** $H_2O(l)$ in section 14 ***OR*** condensation of water is exothermic ✓	*Accept ΔH_c data are more accurate/are not average values.*	1
3.	(b)	(i)	*Initiation:* Br-Br → Br· + Br· ✓ *Propagation:* Br· + $CH_3CH_2CH_3$ → HBr + ·$CH(CH_3)_2$ ✓ ·$CH(CH_3)_2$ + Br_2 → $CH_3CHBrCH_3$ + Br· ✓	*Radical electron required in structure. Penalize missing radical electron once only.* *Penalize use of · C_3H_7 instead of* ·$CH(CH_3)_2$ or incorrect hydrocarbon used, once only.	3

Question			Answers	Notes	Total
3.	**(b)**	**(ii)**	*Mechanism:* both/mixture of S_N1 ***AND*** S_N2 ✓ *Reason:* ≪2-bromopropane≫ secondary halogenoalkane ✓		**2**
3.	**(b)**	**(iii)**	*Number of signals:* 3 ✓ *Relative Intensities:* 1:1:6 ✓	*Award **[1 max]** for 4 signals **AND** 1:1:3:3.* *Award **[1]** if correct answers are reversed.* *Allow Relative intensities in any order for M2.*	**2**

Question			Answers	Notes	Total
3.	**(c)**	**(i)**	Step 2.  Step 3.  Step 4.  *Any 4 of:* arrow going from double bond to hydrogen on hydronium ion ✓ arrow showing water leaving ✓ structure of carbocation intermediate ✓ arrow from lone pair on water going to carbocation ✓ structure of oxonium ion intermediate ✓ arrow showing electrons going to oxygen on hydroxyl group ✓ lone pair from water/acid/HSO_4^- going to hydrogen to reform catalyst ✓		**4**

Question			Answers	Notes	Total
3.	(c)	(ii)	increases frequency of <<successful>> collisions/collisions per unit time ✓ increases energy of collisions and so increases proportion of successful collisions ***OR*** increases fraction/number of molecules that have $E \geq E_a$ ✓	*Reference to frequency or time required for M1.* *Do not accept chance or probability instead of frequency if no mention of time.* *Do **not** accept answers related to equilibrium shifting.*	**2**
3.	(c)	(iii)	propan-2-ol more soluble ***AND*** ≪has OH/hydroxyl group which≫ forms H-bond with water ✓ propene ≪less/not soluble and≫ non-polar/only has LDF/London forces /dispersion forces /induced/transient dipoles ✓	*Do **not** accept hydroxide for hydroxyl.* *Award **[1]** for "propan-2-ol is polar **AND** propene is nonpolar" alone.* *Award **[1]** for "propan-2-ol is soluble **AND** propene is not/less soluble" alone.*	**2**
3.	(c)	(iv)	 ✓	*Continuation bonds must be shown.* *Methyl groups may be drawn on opposite sides or head to tail.* *Penalize missing H atoms in structures once in paper.* *Ignore square brackets or "n".* *Accept skeletal formula.*	**1**

Question			Answers	Notes	Total
3.	**(c)**	**(v)**	 ✓ $HOCH_2CH_2OH$ ✓	*Accept skeletal formula.* *Accept two Cl instead of two OH in any **one** of the monomers, but **not** in both.*	**2**
3.	**(d)**	**(i)**	propanone ✓	*Accept "propan-2-one, **OR** 2-propanone"*	**1**
3.	**(d)**	**(ii)**	propan-2-ol has absorption 3200-3600 cm^{-1} ***AND*** OH/alcohol ***OR*** propan-2-ol has absorption 1050-1410 cm^{-1} ***AND*** C-O/alcohol ✓ propanone has absorption 1700-1750 cm^{-1} ***AND*** C=O/carbonyl/ketone ✓	*Accept "propan-2-one **OR** 2-propanone"* *Award **[1 max]** if only wavenumbers of the bonds are given **OR** identity of the bonds present in each.*	**2**
4.	**(a)**		*Alternative 1:* ≪$[H^+] = \frac{1.00x10^{-14}}{0.0685}$ = ≫ $1.460x10^{-13}$ ≪mol dm^{-3}≫ ✓ ≪pH = -log ($1.460x10^{-13}$) = ≫ 12.836 ✓ *Alternative 2:* ≪pOH = -log (0.0685) =≫ 1.164 ✓ ≪pH = 14.000 -1.164 =≫ 12.836 ✓	*Award **[2]** for correct final answer.* *Accept answers correctly rounded to 1dp, 1.2 and 12.8.*	**2**

Question			Answers	Notes	Total
4.	**(b)**		*volume of base* 33.3-33.7 ≪cm^3≫ ✓ ≪ $\frac{33.5\ cm^3 \times 0.0685\ mol\ dm^{-3}}{50.0\ cm^3}$ =≫ 0.0459 ≪mol dm^{-3}≫ ✓	*Award **[2]** for a final answer in the range 0.0456 - 0.0462≪mol dm^{-3}≫.*	**2**
4.	**(c)**		phenol red/phenolphthalein ***AND*** equivalence point falls within end point/pH point of indicator ✓	*Response must link equivalence point to indicator end point, "pKa in the range of rapid pH change".*	**1**
4.	**(d)**		organic acid/weak acid ***AND*** salt of acid ✓ partly neutralize portion of acid with base ≪to form mixture of organic/weak acid with its conjugate base≫ ✓	*Accept named base or reactive metal for salt formation/partial neutralization for M2.*	**2**
5.	**(a)**		*Reactant* / *Order of Reaction* *NO* / 2^{nd} ✓ H_2 / 1^{st} ✓	*Accept correct orders reversed for **[1 max]**.*	**2**
5.	**(b)**		≪rate =≫ $k[NO]^2[H_2]$ ✓	*Allow ecf only if both reactants are present in the expression.*	**1**
5.	**(c)**		≪$\frac{2.53x10^{-6} mol\ dm^{-3}\ s^{-1}}{(0.100\ mol\ dm^{-3})^2 x\ 0.100\ mol\ dm^{-3}}$ =≫ $2.53x10^{-3}$ ✓ $mol^{-2}\ dm^6\ s^{-1}$ ✓	*Award **[1 max]** for using data from experiments 2, 3 or 4.*	**2**