8825 – 6221M

Diploma Programme
Programme du diplôme
Programa del Diploma

Markscheme

November 2025

Chemistry

Higher level

Paper 2

19 pages

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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.

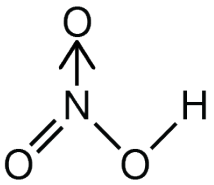
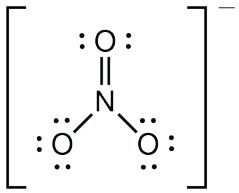
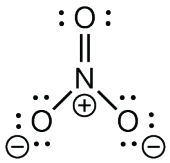
14. Do **not** penalize candidates for errors in units or significant figures, **unless** it is specifically referred to in the "Notes" column.

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.

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

Question			Answers	Notes	Total
1.	(a)		*Any one of:* forms nitrous acid / HNO_2 / nitric acid / HNO_3 ✓ contributes to acid rain ✓ catalyses decomposition of ozone / contributes to ozone hole/depletion ✓ «respiratory» irritant/toxic ✓	*Accept suitable equations showing acid rain formation or ozone depletion.* *Accept photochemical smog/forms NO_2.*	**1 max**
1.	(b)		$T = 200 + 273$ «K» ✓ «$n = PV/RT$» «$n = \frac{(1.0\times10^5)(1.0\times10^{-3})}{8.31(200+273)}$» «$n =$» 0.025 «mol» ✓ «0.10% × 0.025 =» 2.5×10^{-5} «mol» ✓	*Award **[3]** for correct final answer.*	**3**
1.	(c)		NO polar ***AND*** N_2 non-polar ***OR*** NO has dipole-dipole «and LDF» ***AND*** N_2 has London/dispersion «forces between molecules» ✓ stronger intermolecular forces in NO ***OR*** dipole-dipole «forces» are stronger «than LDF» ✓		**2**
1.	(d)	(i)	*Initial:* +2 ***AND*** *Final:* 0 ✓	*Accept II for initial oxidation state, but do **not** accept 2+ or 2.*	**1**
1.	(d)	(ii)	$2NO(g) + 2CO(g) \rightarrow 2CO_2(g) + N_2(g)$ ✓		**1**

Question			Answers	Notes	Total
2.	**(a)**	**(i)**	 ✓	*Accept other forms of labelling instead of an arrow. Mark is for identifying the bond.*	**1**
2.	**(a)**	**(ii)**	$Na_2CO_3(s) + 2HNO_3(aq) \rightarrow 2NaNO_3(aq) + H_2O(l) + CO_2(g)$ ✓		**1**
2.	**(b)**	**(i)**	 ***OR***  ✓	*Accept any combination of dots or crosses to represent electrons, or lines to represent electron pairs.* *Charge must be shown, but square brackets are **not** required.* *Do **not** accept delocalized structure.*	**1**
2.	**(b)**	**(ii)**	$Ni(NO_3)_2$ ✓		**1**
2.	**(b)**	**(iii)**	resonance / delocalization «of π-electrons» ✓		**1**
2.	**(b)**	**(iv)**	124 «pm» ✓	*Accept range 114 < x < 136 «pm».*	**1**

<table>
<tr>
<td>2.</td>
<td>(c)</td>
<td></td>
<td>
<table>
<tr><td>Metal added:</td><td colspan="2">Mn</td><td>Cu</td></tr>
<tr><td>Observations:</td><td>«solution»
colour changes
OR
solid/metal product /
coat «on metal»</td><td>AND</td><td>no change
«in solution colour»
OR
no solid/metal produced /
no coat «on metal» ✓</td></tr>
</table>

Explanation:

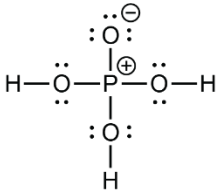
Mn lower/more negative $E^{\ominus}$ AND Cu higher/more positive $E^{\ominus}$ than Ni

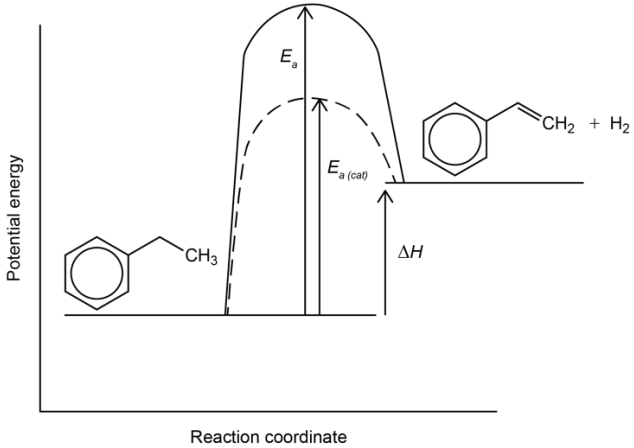
OR

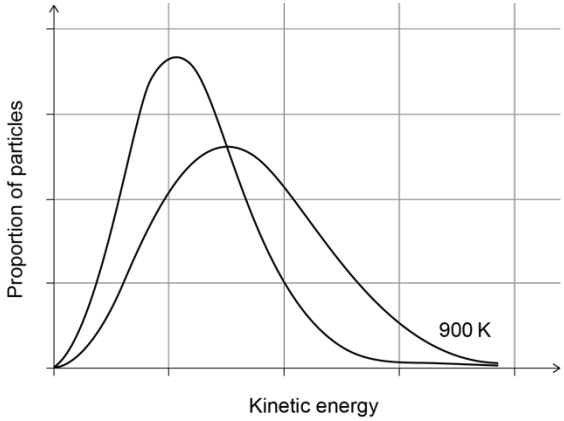
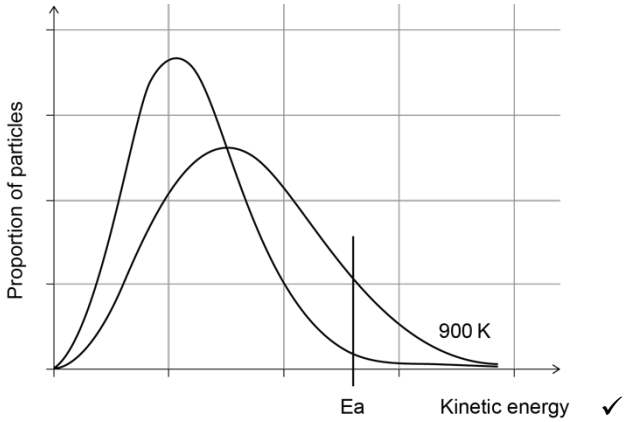
Mn more reactive/readily oxidized AND Cu less reactive/readily oxidized than Ni

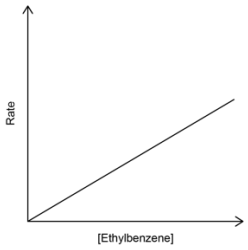
OR

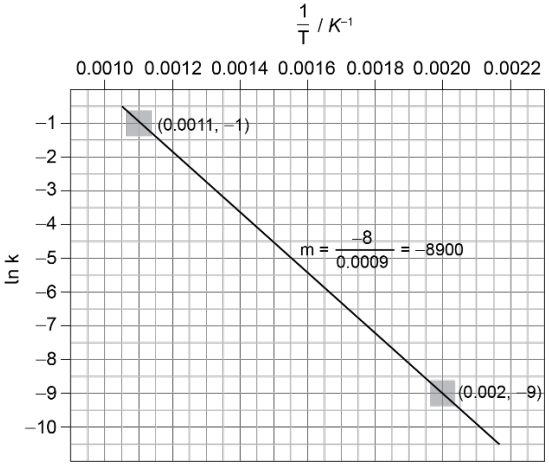
Mn stronger reducing agent AND Cu weaker reducing agent than Ni ✓
</td>
<td>Accept “no reaction” for Cu observation.

Award [1 max] for correct observation and explanation for one metal only.</td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>(d)</td>
<td>(i)</td>
<td>Lewis formula 1: O -1 AND P $+1$ «are the only formal charges» ✓
Lewis formula 2: formal charges zero/closest to zero «and hence preferred» ✓</td>
<td>Accept labelling for M1:
  </td>
<td>2</td>
</tr>
<tr>
<td>2.</td>
<td>(d)</td>
<td>(ii)</td>
<td>$H_2PO_4^-$ ✓</td>
<td></td>
<td>1</td>
</tr>
</table>

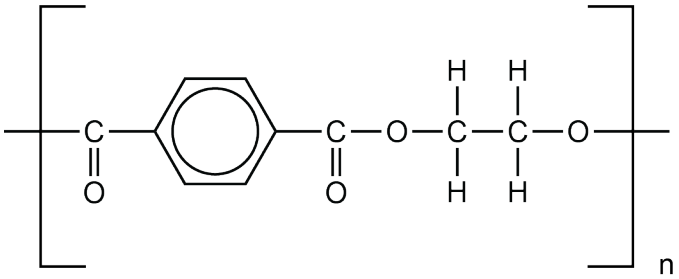
Question			Answers	Notes	Total
3.	**(a)**	**(i)**	«mol styrene = $\frac{90}{100} \times \frac{1000}{8(12.01)+10(1.01)}$ » «mol styrene =» 8.48 «mol» ✓ «mass styrene = 8.48 × (8(12.01) + 8(1.01)) = 882.88» «mass styrene =» 880 «g» ✓	*Award **[2]** for correct final answer in range 880-890 «g».*	**2**
3.	**(a)**	**(ii)**	«$100 \times \frac{104.16}{106.18}$ » = 98.1% ✓		**1**
3.	**(b)**		 two curves, each passing through a maximum ***AND** reaching* same energy level ✓ endothermic enthalpy change labelled ✓ both activation energies correctly labelled ✓	*Do **not** penalize curve showing multiple steps for the catalysis in M1.* *Accept double-headed arrows or lines in M2 and M3, but not arrows pointing down.*	**3**

3.	**(c)**	**(i)**	 curve with peak higher ***AND*** to left ***AND*** decreasing at lower KE ✓	*Do **not** award mark if line crosses x axis or rises above the 900K curve at high energy.*	**1**
3.	**(c)**	**(ii)**	 ✓	*Accept a correct label on x-axis or on a drawn line.*	**1**
3.	**(c)**	**(iii)**	correct reference to area under curve «to right of E_a» ✓ fewer particles with E ≥ E_a ✓		**2**

3.	**(c)**	**(iv)**	shifts left/to reactants ***AND*** more moles/molecules «gas» in products ✓		**1**
3.	**(c)**	**(v)**	«forward» reaction is endothermic ***AND*** shifts to left/reactants ***OR*** $E_{a\ fwd} > E_{a\ rev}$, so forward reaction more affected by temperature ***AND*** shifts to left/reactants ✓	*Accept "exothermic reverse reaction is favoured".*	**1**
3.	**(d)**	**(i)**	 straight line through origin ✓		**1**
3.	**(d)**	**(ii)**	*Rate equation:* «rate =» k [C_8H_{10}] ✓ *Units of k:* s^{-1} ✓		**2**

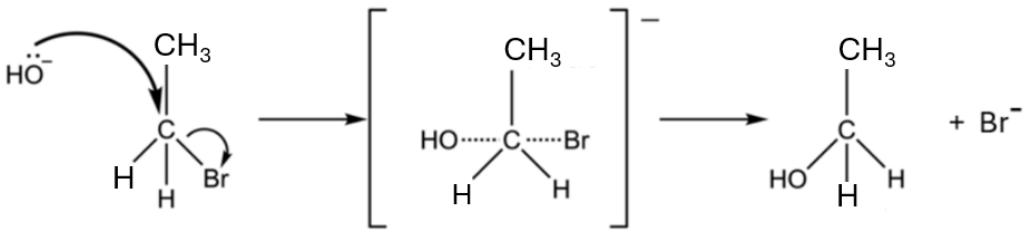
3.	**(d)**	**(iii)**	 gradient = –8900 ✓ «E_a = –(–8900 × 8.31) = +74 000 J mol^{-1} =» 74 kJ mol^{-1} ✓	*Award **[2]** for correct final answer.* *Accept E_a in the range 66 to 76 «kJ mol^{-1}».* *Do **not** accept E_a in J mol^{-1}.* *Award **[1 max]** for –74 «kJ mol^{-1}».* *Accept gradient in the range: –8000 to –9100 for M1.*	**2**
3.	**(e)**	**(i)**	isomers ✓	*Accept "same molecular formula".*	**1**
3.	**(e)**	**(ii)**	**Full structural formula** / **Functional group name** / **Homologous series** H–C(=O)– / carbonyl / aldehyde structure ✓ carbonyl ***AND*** aldehyde ✓	*Accept R/C attached to functional group in the full structural formula. Central C must have 4 bonds for M1.*	**2**
3.	**(e)**	**(iii)**	reflux ✓ oxidizing agent / oxidises B✓	*Accept heat **OR** acidified for M1.*	**2**

3.	**(f)**	**(i)**	$\frac{[C_6H_5COO^-][H^+]}{[C_6H_5COOH]}$	*Accept H_3O^+ for H^+.*	**1**
3.	**(f)**	**(ii)**	horizontal line from point on curve at 10 cm^3 of NaOH to y-axis ✓	*Accept line intersecting y-axis between 4.1 and 4.4.*	**1**
3.	**(f)**	**(iii)**	bromothymol blue ***OR*** phenol red ***OR*** phenolphthalein ✓		**1**
3.	**(f)**	**(iv)**	«benzoate ion» hydrolysis/reaction with water ***AND*** forms OH^- ***OR*** $C_6H_5COO^-(aq) + H_2O(l) \rightleftharpoons C_6H_5COOH(aq) + OH^-(aq)$ ✓		**1**
3.	**(f)**	**(v)**	«(0.020 × 0.010) ÷ 0.010 =» 0.020 «mol dm^{-3}» ✓		**1**
3.	**(g)**	**(i)**	partially neutralize benzoic acid with NaOH ***OR*** amount/moles of NaOH added is smaller «than amount of benzoic acid» ✓		**1**
3.	**(g)**	**(ii)**	remains constant «as $[A^-]$: [HA] ratio is unchanged» ✓	*Do **not** accept "slight/minimal change".*	**1**

3.	**(h)**	**(i)**	condensation ***OR*** polyester ✓		**1**
3.	**(h)**	**(ii)**	 ester linkage ✓ continuation bonds ***AND*** rest of structure ✓	*Accept without square brackets or n.* *Do **not** award M2 if more than one repeating unit is included.*	**2**

Question			Answers	Notes	Total
4.	**(a)**	**(i)**	electrophilic addition ✓		**1**
4.	**(a)**	**(ii)**	high electron density of C=C/pi bond ✓	*Do **not** accept only "presence of C=C".*	**1**

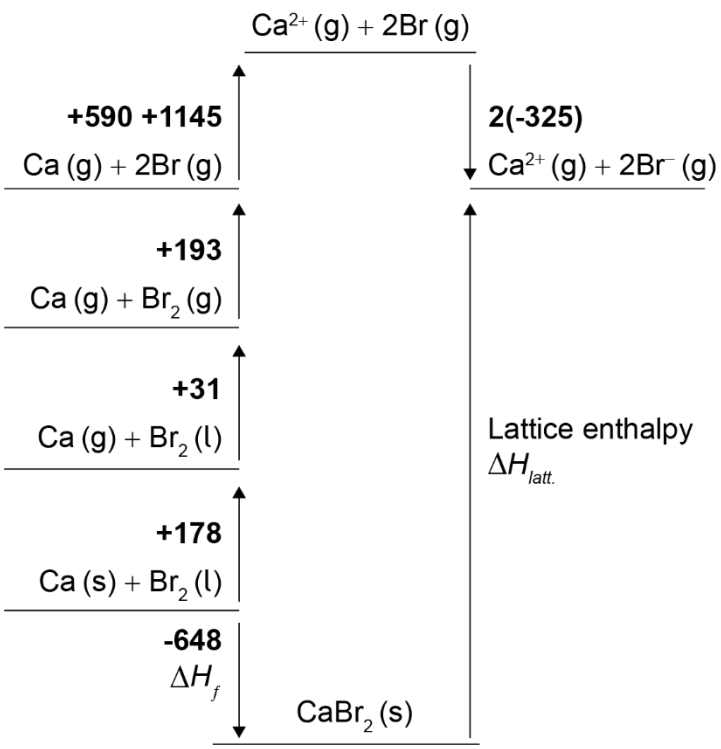
4.	**(b)**	**(i)**	**ALTERNATIVE 1:** «bonds broken» C=C + H–Br / 614 + 366 / 980 «kJ mol^{-1}» ***AND*** «bonds formed» C–C + C–H + C–Br / 346 + 414 + 285 / 1045 «kJ mol^{-1}» ✓ «Δ*H* = 980 – 1045 =» –65 «kJ mol^{-1}» ✓ **ALTERNATIVE 2:** «bonds broken» 1C=C + 4C–H + 1H–Br / 614 + 4×414 + 366 / 2636 «kJ mol^{-1}» ***AND*** «bonds formed» 1C–C + 5C–H + 1C–Br / 346 + 5×414 + 285 / 2701 «kJ mol^{-1}» ✓ «Δ*H* = 2636 – 2701 =» –65 «kJ mol^{-1}» ✓	*Award **[2]** for correct final answer.* *Award **[1 max]** for +65 «kJ mol^{-1}».*	**2**
4.	**(b)**	**(ii)**	*Any two of:* bond enthalpies are average values ✓ enthalpies of formation are specific to the compounds ✓ bond enthalpies apply to gases ***AND*** this reaction involves a liquid ✓ bond enthalpies do not account for the change of state ✓		**2 max**
4.	**(b)**	**(iii)**	two moles/molecules of reactants form one mole/molecule of product ***OR*** gaseous reactants form liquid product ✓		**1**

4.	**(b)**	**(iv)**	«ΔS = 199 – 220 – 199 =» –220 «J K^{-1} mol^{-1}» ✓ «ΔG^{θ} = –65 000 J mol^{-1} – (298 K × –220 J $K^{-1}mol^{-1}$) » «ΔG^{θ} = +»560 «J mol^{-1}» / «+»0.56 «kJ mol^{-1}» ***AND*** non-spontaneous ✓	*Award **[2]** for correct final answer (ΔG^{θ} value and spontaneity).* *If ΔH = –58 kJ mol^{-1} used, answer is «+»7600 «J mol^{-1}» / «+»7.6 «kJ mol^{-1}».*	**2**
4.	**(c)**	**(i)**	nucleophilic substitution ✓	*Accept S_N2, but **not** S_N1.*	**1**
4.	**(c)**	**(ii)**	 curly arrow from lone pair/negative charge on O in HO^- to C ✓ curly arrow from C–Br bond to Br ✓ transition state showing negative charge ***AND*** partial bonds ✓	*Award [**2 max**] for correct S_N1 mechanism if not stated in (i).* *Accept curly arrow going from C–Br bond to Br either in bromoethane or in the transition state for M2.* *Do **not** penalize if HO and Br are not at 180°, or the square bracket is missing, in M3.* *Do **not** award M3 if OH ---- C connection is seen.*	**3**
4.	**(c)**	**(iii)**	primary halogenoalkane ✓	*Accept reasons why, such as lack of steric hindrance or less stable carbocation.*	**1**
4.	**(c)**	**(iv)**	2 / second ✓		**1**

4.	**(c)**	**(v)**	iodoethane ***AND*** «C–I» bond weaker/easier to break ✓	*Accept "iodoethane **AND** I is a better leaving group".*	**1**
4.	**(c)**	**(vi)**	quartet / quadruplet / 4 ✓		**1**
4.	**(c)**	**(vii)**	bromoethane ***AND*** absence of O–H «peak» ***AND*** in 3200–3600 «cm^{-1} range» ***OR*** bromoethane ***AND*** C–Br «peak» ***AND*** 500–600 «cm^{-1}» ✓	*Accept specific value in 500 – 600 «cm^{-1}» range.*	**1**

Question			Answers	Notes	Total
5.	**(a)**		«two» more neutrons/n in ^{81}Br ✓		**1**
5.	**(b)**	**(i)**	*Any two of:* «Br_2 molecules made up of» ^{79}Br – ^{79}Br «158 peak» ***AND*** ^{79}Br – ^{81}Br «160 peak» ***AND*** ^{81}Br – ^{81}Br «162 peak» ✓ number/probability/abundance of ^{79}Br – ^{79}Br and ^{81}Br – ^{81}Br «molecules» is «nearly» same «hence peaks same height» ✓ number/probability/abundance of ^{79}Br – ^{81}Br «molecules» is double «of ^{79}Br – ^{79}Br and ^{81}Br – ^{81}Br molecules hence peak is double the height» ✓		**2 max**

5.	**(b)**	**(ii)**	$79 \times 50.75\% + 81 \times 49.25\%$ ✓ $= 79.99$ ✓	*Award **[2]** for correct final answer.* *Do **not** accept 79.90, the value in the data booklet.*	**2**
5.	**(c)**	**(i)**	«electronegativity difference =» 2.0 ***AND*** «average electronegativity =» 2.0 ✓ ionic ***AND*** 35% covalent ✓	*Accept range 30 - 40% for percentage covalent character.*	**2**

5.	**(c)**	**(ii)**	 three values from data booklet: «Br–Br enthalpy» 193 ***AND*** «1st IE Ca» 590 ***AND*** «EA of Br» –325 «kJ mol^{-1}» ✓ –325 x 2 / –650 «kJ mol^{-1}» ✓ 648 + 178 + 31 + 193 + 590 + 1145 = $\Delta H_{latt.}$ + 650 ***AND*** «$\Delta H_{latt.}$ = +2135 = +»2100 «kJ mol^{-1}» ✓	*Award **[3]** for correct final answer.* *Award **[2 max]** for –2100 «kJ mol^{-1}».* *M1 and M2 can be scored on the diagram.* *Award ECF for M3 for correct application of Hess's law based on the candidate's values/cycle.*	**3**

5.	**(c)**	**(iii)**	Ca^{2+} and Co^{2+} lost $4s^2$ electrons «so smaller than Br^-» ***OR*** Ca^{2+} and Co^{2+} have electrons in 3 shells/energy levels «so smaller than Br^-» ✓ Co^{2+} has greater «effective» nuclear charge/more protons than Ca^{2+} «so smaller» ✓ Br^- has electrons in 4 shells/energy levels / $4p^6$ «so larger than cations» ✓		**3**
5.	**(c)**	**(iv)**	cobalt(II) bromide ***AND*** «cation has» higher charge density / smaller radius ✓		**1**
5.	**(d)**	**(i)**	[Ar] $4s^2$ $3d^7$ / [Ar] $3d^7$ $4s^2$ ✓		**1**
5.	**(d)**	**(ii)**	incomplete/partially-filled d «sub-level» ✓		**1**
5.	**(d)**	**(iii)**	«wavelength = 3.00×10^8 ms^{-1} ÷ 4.5×10^{14} s^{-1} =» 6.7×10^{-7} «m» / 670 «nm» ✓ red is absorbed ***AND*** green is complementary ✓	*Accept any units for wavelength in M1.*	**2**

5.	**(e)**	**(i)**	*Anode:* $Co(s) \rightarrow Co^{2+}(aq) + 2e^{-}$ ✓ *Cathode:* $Co^{2+}(aq) + 2e^{-} \rightarrow Co(s)$ ✓	*Award **[1 max]** for correct half-equations at incorrect electrodes.*	**2**
5.	**(e)**	**(ii)**	$Cl_2(g) + 2Br^{-}(aq) \rightarrow 2Cl^{-}(aq) + Br_2(aq)$ ✓		**1**