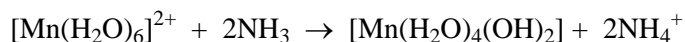
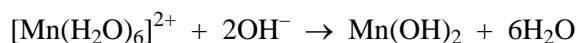


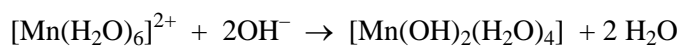
or



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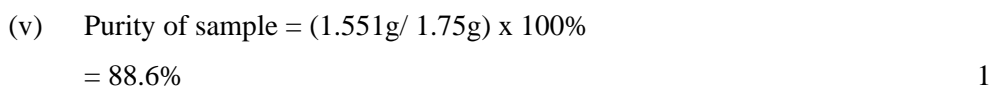
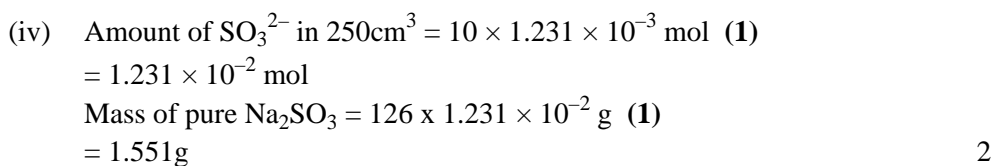
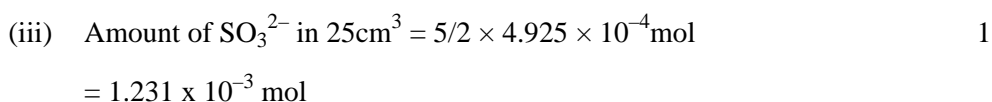
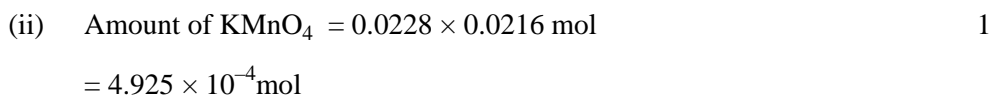
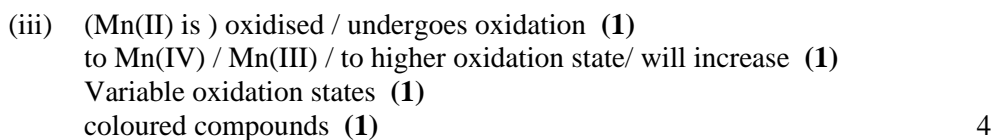


or



Any of above score 2 marks as follows:(1) mark for species (1) mark for balance

Deprotonation or Acid /base (1) 3



[16]

2. (a) (i) The potential difference between a standard hydrogen electrode and the (half-) cell (1)
all concentrations measured at 1 mol dm^{-3} and any gases are at 1 atm pressure (1) 2
- (ii) Fluorine or F_2 (1) 1
- (b) (i) all/listed (1) 1
- (ii) iodine **and** bromine (1) 1
- (iii) *This answer is consequential on part (ii)*
Mix solution of Cr(II) - blue with the oxidising agent given in (ii) (1)
goes green and **stays** green / but does not go orange (1) 2

[7]

3. (a) Sc [Ar]

↑				
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↑↓

- Cr [Ar]

↑	↑	↑	↑	↑
---	---	---	---	---

↑

- Cr³⁺ [Ar]

↑	↑	↑		
---	---	---	--	--

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- Cr³⁺ consequential on structure for Cr* 3

- (b) Electronic configuration differs from previous element by an electron in a d (sub) shell / electrons are filling the d-shell (1)
transition elements have one ion with partially-filled d-shell (1) 2
- Not 'highest energy shell is the 'd'-shell
outer electron in 'd' shell*

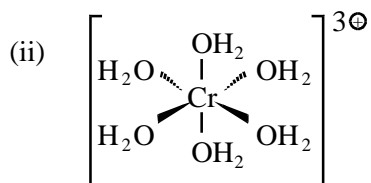
- (c) (i) [Ar]

↑	↑	↑	↑↓	↑↓
---	---	---	----	----

↑↓

↑↓	↑↓	↑↓
----	----	----
- Ligand electrons
- 2

Correct electron structure for complex ion (1)
ligand electrons identified (1) 6 pairs identified stand alone mark
Consequential on structure of Cr³⁺



*There must be some attempt to show a 3-D structure
'Octahedral' could rescue a poor diagram*

- (iii) d-orbitals split (in energy by ligands) / or diagram to illustrate electron transitions / jumps from **lower** to **higher** energy level (1)
absorbs light in visible region (1) 3
- (d) (i) **Green precipitate** (1)
(deep) green **solution** in excess sodium hydroxide (1) 2
- (ii) Deprotonation / acid base (1) 1
- [14]**
4. (a) (i) $[\text{Ar}]3d^6$ (1)
allow $1s^2$ etc 1
- (b) (i)
 - Zn / Iron (1) not the zinc ion or iron ion
 - more negative potential than -0.28V (1)
*NB this mark must show evidence of use of the data
gives +E for reduction reaction (1)
consequential on second mark* 3
- (ii)
 - rate too slow / activation energy too high / kinetically stable /
allow oxide layer if metal electrode specified (1)
 - non-standard conditions (1) 2
- (c) (i) $\text{Co}(\text{H}_2\text{O})_6^{2+}$ (1) 1
- (ii) Example:
 $\text{Co}(\text{H}_2\text{O})_6^{2+} + 4\text{Cl}^- \rightarrow \text{CoCl}_4^{2-} + 6\text{H}_2\text{O}$
Any valid equation that shows a ligand exchange but begins with
 $\text{Co}(\text{H}_2\text{O})_6^{2+}$ (1)
ligand exchange correctly balanced (1) 2
- [9]**
5. (a) An element that has at least one of its **ions** has an incomplete d shell (1) 1

- (b) (i) Coloured ions / compounds/ complexes/ solutions (1)
variable oxidation states (1) 2
- (ii) $\text{Cr}(\text{H}_2\text{O})_6^{2+}$ / hexa aqua chromium (II) ion (1)
Not Cr^{2+} or $\text{Cr}(\text{II})$. 1
- (c) (i)

Cr	Cl	H ₂ O
19.5 / 52	40 / 35.5	40.5 / 18 (1)
0.375	1.127	2.25
0.375/0.375	1.127/0.375	2.25/0.375 (1)
1	3	6

 2
- NB 2 method marks*
- (ii) Violet $\text{Cr}(\text{H}_2\text{O})_6^{3+} \cdot 3\text{Cl}^-$ (1)
Green is $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]^{2+} 2\text{Cl}^- \cdot \text{H}_2\text{O}$ (1) 2
NB for 2 marks must make clear which is which and must be a salt which adds up to $\text{Cr}(\text{H}_2\text{O})_6\text{Cl}_3$

[8]

6. (a) (i)

↑	↑	↑	↑	↑	↑
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 1
- (ii)

↑	↑	↑			
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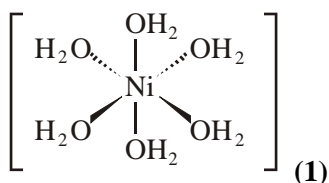
 1
- Allow single headed arrows or other suitable notation
[Mark (ii) consequentially on (i)]
- (b) (i) Covalent (1)
Coordinate or dative (1) 2
- (ii) Deprotonation or acid-base 1
- (iii) $[\text{Cr}(\text{H}_2\text{O})_3(\text{OH})_3]$ or $\text{Cr}(\text{OH})_3$ 1
- (iv) Ligand exchange or ligand substitution 1
- (v) $[\text{Cr}(\text{NH}_3)_6]^{3+}$ or $[\text{Cr}(\text{OH})_x (\text{H}_2\text{O})_y (\text{NH}_3)_z]^{\text{charge}}$ 1
 $x + y + z = 6$, z at least one, correct charge will be between 0 and +3, $x = \text{max } 3$

- (c)
- **d** – orbitals/subshell/energy level split (in energy by ligands)/diagram to illustrate (1)
 - Electron transitions/jumps from **lower** to **higher** energy level (1)
 - **Absorbs** light in visible region/reference to white light (1) 3
- If imply or state that emission is occurring, only the first marking point is available*

[11]

7. (a) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8 4s^2$ 1
- (ii) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^8$ 1

(b)

*Shape mark**Must be 3-D ie wedges or dashes*labelled covalent between O–H OR arrow to H₂O and labelled covalent bond (1)

labelled dative covalent between O atom and ion (1) 3

- (c) (i) $[\text{Ni}(\text{H}_2\text{O})_4(\text{OH})_2]$ 1
 ALLOW $\text{Ni}(\text{OH})_2$
- (ii) Deprotonation (1)
 two successive deprotonations / neutral species producing insoluble compound (1) 2
- (iii) Ligand exchange (1)
 giving (soluble) $[\text{Ni}(\text{H}_2\text{O})_0 \text{ or } 2(\text{NH}_3)_6 \text{ or } 4]^{2+}$ OR in words (1) 2

[10]

8. (a) (i) Use E^θ values for reduction of Fe^{3+} to Fe^{2+} by Zn ($E^\theta_{\text{cell}} = +1.53\text{V}$) (1)
and Fe^{2+} to Fe by Zn ($E^\theta_{\text{cell}} = +0.32\text{V}$) (1)
They have positive E^θ so are feasible (1) *NOT* “will happen”
OR
ALLOW Zn^{2+}/Zn is more negative than both $\text{Fe}^{3+}/\text{Fe}^{2+}$ and Fe^{2+}/Fe (1)
so zinc is a stronger reducing agent (1)
so zinc reducing both is feasible (1) 3
- (ii) Reduction of Fe^{2+} has high activation energy / kinetically stable 1
- (b) (i) $\text{MnO}_4^- + 5\text{Fe}^{2+} + 8\text{H}^+ \rightarrow \text{Mn}^{2+} + 5\text{Fe}^{3+} + 4\text{H}_2\text{O}$
Species (1)
Balance (1)
Any state symbols ignored. 2
- (ii) purple colour of MnO_4^- lost (1)
end point when yellow / colourless solution (1)
becomes (permanently) pink (1) 3
- (c) Amount MnO_4^- in 1st titration = $0.0182 \text{ dm}^3 \times 0.0200 \text{ mol dm}^{-3}$
= $3.64 \times 10^{-4} \text{ mol}$ (1)
Amount Fe^{2+} in original solution = $5 \times$ above value = $1.82 \times 10^{-3} \text{ mol}$ (1)
Amount Fe^{2+} in 2nd titration = amount of Fe^{2+} and Fe^{3+} original solution (1)
= $0.0253 \text{ dm}^3 \times 0.0200 \text{ mol dm}^{-3} \times 5 = 2.53 \times 10^{-3} \text{ mol}$
Amount of Fe^{3+} in original solution = $0.00253 - 0.00182 = 7.10 \times 10^{-4} \text{ mol}$ (1)
Amount zinc needed to reduce $\text{Fe}^{3+} = \frac{1}{2} \times 0.000710 = 0.000355 \text{ mol}$
Mass of zinc = $0.000355 \text{ mol} \times 65.4 \text{ g mol}^{-1} = 0.0232 \text{ g}$ (1) 2,3 or 4 SF
Consequential on their moles iron
The marks are for the following processes:
Either volume of MnO_4^- to moles of MnO_4^- (1)
Convert to moles of Fe^{2+} by multiplying either moles of MnO_4^- by 5 (1)
Realising that 2nd titration measures total number of moles of iron (1)
Subtracting to get original moles Fe^{3+} (1)
Going to moles Zn then mass Zn (1)

OR

Volume MnO_4^- for Fe^{3+} , which has been reduced by zinc (1) 3rd point

$$= 25.3 \text{ cm}^3 - 18.2 \text{ cm}^3 = 0.0253 \text{ dm}^3 - 0.0182 \text{ dm}^3 = 0.0071 \text{ dm}^3 \text{ (1) 4}^{\text{th}} \text{ point}$$

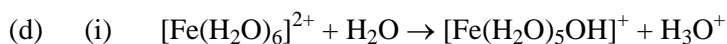
$$\text{Amount of } \text{MnO}_4^- = 0.0071 \text{ dm}^3 \times 0.0200 \text{ mol dm}^{-3} = 1.42 \times 10^{-4} \text{ mol (1) 1}^{\text{st}} \text{ point}$$

$$\text{Amount } \text{Fe}^{3+} \text{ reduced by zinc} = 5 \times \text{above value} = 7.10 \times 10^{-4} \text{ mol (1) 2}^{\text{nd}} \text{ point}$$

$$\text{Amount zinc needed} = \frac{1}{2} \times 7.10 \times 10^{-4} = 3.55 \times 10^{-4} \text{ mol}$$

$$\text{mass of zinc needed} = 3.55 \times 10^{-4} \text{ mol} \times 65.4 \text{ g mol}^{-1} = 0.00232 \text{ g (1) 5}^{\text{th}} \text{ point}$$

5

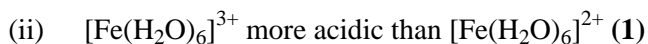


H_3O^+ in equation (1)

other ion in equation (1)

(Fe^{2+}) polarises the O–H bond in ligand (1)

3



Fe^{3+} higher charge density than Fe^{2+} (1)

Fe^{3+} ion if more polarising (1)

3

[20]

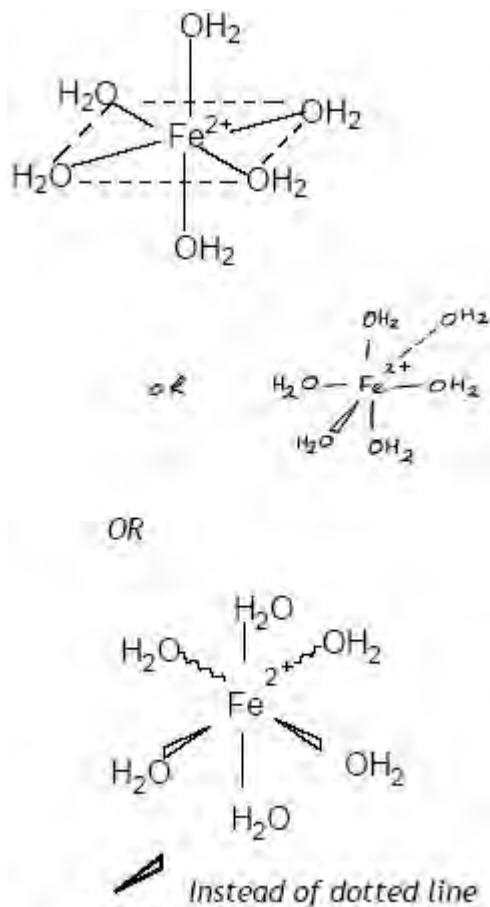
9. (a) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$ accept any order 1
- (ii) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ Conseq on (a) (i) 1
- (b) **d-block:** last (added) electron is in a d-(sub) shell / orbital (1)
Not transition: does not form ions with partially filled d-(sub) shell / orbitals (1) 2
- (c) 3D-drawing e.g. wedges / hatches or perspective diagram (1)
 Labels covalent bond within water molecule (1). This must be drawn out / use of a key is acceptable.
 Shows dative covalent bond from water to central Zn^{2+} (1)
 Labels a 90° angle (1)
 Ignore absence of charge on ion 4

- (d) (i) White precipitate /solid /suspension **(1)** NOT powder
Colourless solution (in excess ammonia) NOT “clear” **(1)** 2
- (ii) $[\text{Zn}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow [\text{Zn}(\text{OH})_2(\text{H}_2\text{O})_4] + 2\text{NH}_4^+$
Or
 $[\text{Zn}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Zn}(\text{OH})_2(\text{H}_2\text{O})_4] + 2\text{H}_2\text{O}$
Or
 $[\text{Zn}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow \text{Zn}(\text{OH})_2 + 6\text{H}_2\text{O}$
Or
 $[\text{Zn}(\text{H}_2\text{O})_6]^{2+} + 2\text{NH}_3 \rightarrow \text{Zn}(\text{OH})_2 + 2\text{NH}_4^+ + 4\text{H}_2\text{O}$ **(1)**
 $[\text{Zn}(\text{OH})_2(\text{H}_2\text{O})_4] + 4\text{NH}_3 \rightarrow [\text{Zn}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 2\text{OH}^- + 2\text{H}_2\text{O}$
Or
 $\text{Zn}(\text{OH})_2 + 4\text{NH}_3 \rightarrow [\text{Zn}(\text{NH}_3)_4]^{2+} + 2\text{OH}^-$
(1) for cation formed
(1) for balancing equation with the correct species **(2)** 3
- (e) (i) d-(sub) shell / orbitals are full / $3d^{10}$ arrangement of electrons **(1)**
No jumps of d-electrons /no d-d transitions **(1)**
Any mention of e^- falling back down or “no splitting of d-orbitals” and
second mark is not awarded 2
- (ii) Cr is a transition metal / Cr can have d-d transitions / CrO_4^{2-} is
yellow / Cr(+6) or Cr(VI) is yellow 1

[16]

10. (a) (i) Fe [Ar]
 $3d^6 4s^2$
or $3d_6 4s_2$
or $3d6 4s2$
or $4s^2 3d^6$ **(1)**
- Fe^{2+} [Ar]
 $3d^6$
or $3d_6$
or $3d^6 4s^0$ **(1)**
Letter d must be lower case
Any additional letters of numbers **(0)** 2

- (ii) The mark is for the shape

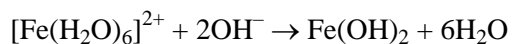


ALLOW bond to H of H₂O (except on left side if OH₂ is given)
 IGNORE charge unless incorrect

1

- (iii) $[\text{Fe}(\text{H}_2\text{O})_6]^{2+} + 2\text{OH}^- \rightarrow [\text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4] + 2\text{H}_2\text{O}$

OR



OR equations with 2NaOH as reactant and 2Na⁺ as product

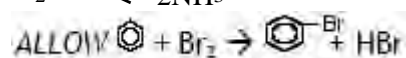
IGNORE state symbols

1

- (iv) Green precipitate / solid → foxy-red / red-brown / brown / orange
 Both colours and precipitate / solid needed
 NOT darkens

1

- (v) $\text{N}_2 + 3\text{H}_2 \rightarrow / \rightleftharpoons 2\text{NH}_3$



OR equation with Cl₂

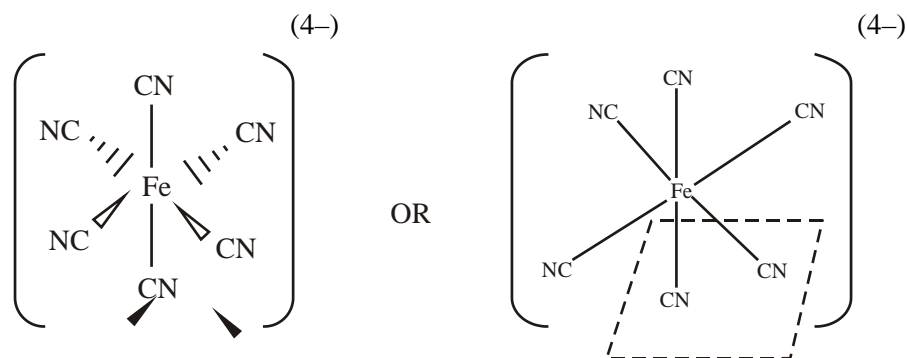
1

- (b) (i) Emf of cell / potential difference of cell containing Fe^{2+} and Fe (1)
and standard hydrogen electrode / half cell *NOT* 'SHE'
 OR hydrogen electrode and $1 \text{ mol dm}^{-3} \text{ H}^+$ and 1 atm H_2 (1)
 $1 \text{ mol dm}^{-3} \text{ Fe}^{2+}$
IGNORE temperature 3
- QWC*(ii) Emf of hydrogen electrode is zero – *stated or implied* (e.g. if
 calculate $E_{\text{cell}} = +0.44(\text{V})$) (1)
 $\text{Fe} + 2\text{H}^+ \rightarrow \text{Fe}^{2+} + \text{H}_2$ (1) – *equation stand alone*
 Potential for the reaction is positive so reaction is feasible (1)
 OR
 H^+ and $(\frac{1}{2})\text{H}_2$ has a more +ve electrode potential than Fe^{2+} and Fe (1)
 H^+ will oxidise Fe / H^+ is an oxidising agent / Fe is a reducing
 agent for H^+ / other correct redox statement (1)
 $\text{Fe} + 2\text{H}^+ \rightarrow \text{Fe}^{2+} + \text{H}_2$ (1) – *stand alone* 3
- (iii) High E_a so slow reaction / reactants are kinetically stable
IGNORE any mention of non-standard conditions 1
- (c) $2\text{Fe}^{3+} + 2\text{I}^- \rightarrow 2\text{Fe}^{2+} + \text{I}_2$ or words $E^0 = (+) 0.23\text{V}$ (1)
 So I^- would reduce Fe^{3+} / Fe^{3+} would oxidise I^- / E^0 positive so reaction
 L \rightarrow R (1)
 OR reverse argument (2)
 OR
 Fe^{3+} and Fe^{2+} has a more positive electrode potential than I_2 and I^- (1)
 I^- will reduce Fe^{3+} / Fe^{3+} will oxidise I^- (1) 2

[15]

11. (a) (i) Forms **ions** which have partially filled *d*-orbitals
 OR
 Forms ions which have a partially filled *d*-subshell 1
- (ii) Scandium / Sc **and** Zinc / Zn 1
- (b) (i) $\text{Fe}^{2+} [\text{Ar}] 3d^6$
 $\text{Mn}^{2+} [\text{Ar}] 3d^5$ (1) *for both correct* 1
- (ii) Fe^{3+} is $3d^5$ / half filled *d*-subshell which is more stable than $3d^6$ (1)
 Mn^{2+} is (already) $3d^5$ (which is more stable than $3d^4$) (1) 2

- (c) Shape (1)
Bonding to correct atoms (1)



2

- (d) Two As atoms oxidised from +3 to +5 per mole of As_2O_3
(loss of $4e^-$) (1)

\therefore if 5 moles oxidised, total $20e^-$ Lost / change in oxidation no. = 20 (1)

\therefore 4 moles MnO_4^- reduced, total $20e^-$ gained / change in oxidation no. 20

\therefore each Mn(VII) gains $5e^-$ / change in oxidation no. 5 (1)

\therefore Mn(II) / Mn^{2+} (1) *NOT standalone mark*

4

- (e) (i) $\text{VO}_3^- + 2\text{H}^+ / 2\text{H}_3\text{O}^+ \rightarrow \text{VO}_2^+ + \text{H}_2\text{O} / 3\text{H}_2\text{O}$

1

(ii) No because oxidation no. of V is +5 in VO_2^+ / Oxidation no. of V unchanged (at +5)

1

(iii) First green colour : VO_2^+ **and** VO^{2+} (1)

Second green colour : $\text{V}^{3+} / [\text{V}(\text{H}_2\text{O})_6]^{3+}$ (1)

Violet colour : $\text{V}^{2+} / [\text{V}(\text{H}_2\text{O})_6]^{2+}$, (1)

3

[16]

12. (a) $3\text{OCl}^- \rightarrow 2\text{Cl}^- + \text{ClO}_3^-$ (1)

chlorine (in OCl^-) is (simultaneously) oxidised from +1 to +5 (1)
and reduced from +1 to -1 (1)

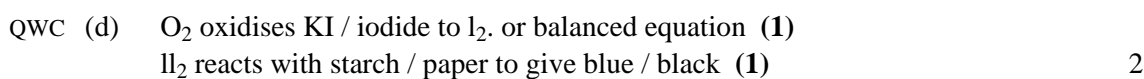
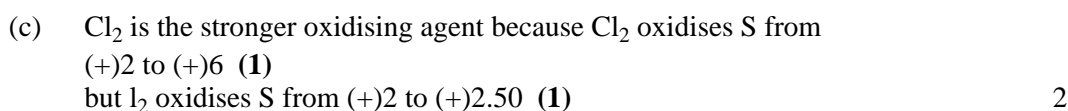
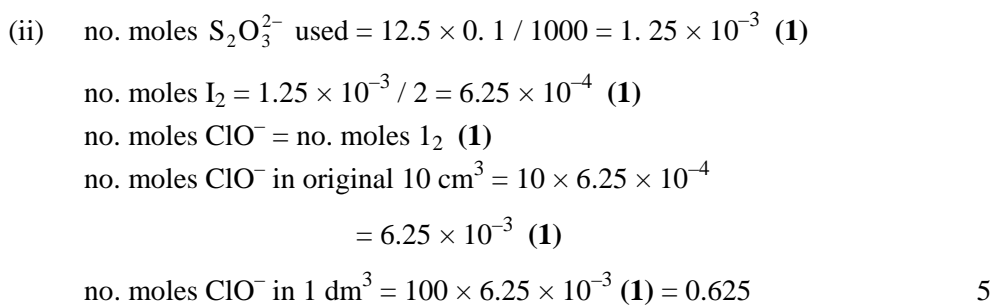
If only oxidation numbers given max 1 (out of 2)

If oxidation numbers omitted max 1 (out of 2)

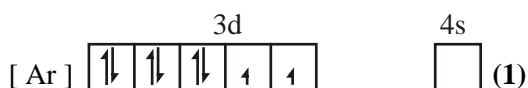
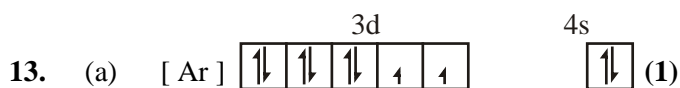
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- (b) (i) blue / black to colourless

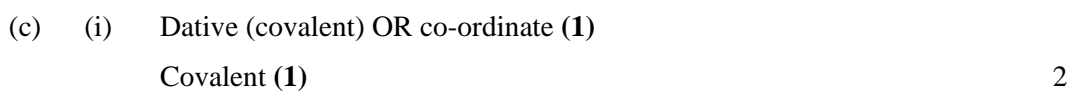
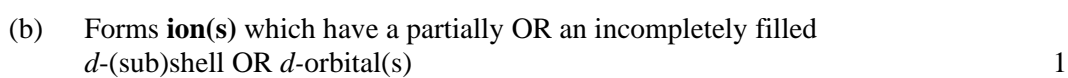
1



[14]



Allow \uparrow instead of \uparrow and \downarrow instead of \downarrow 2



- (ii) $[Ni(H_2O)_6]^{2+} + 2NH_3 \rightarrow [Ni(OH)_2(H_2O_4)] + 2NH_4^+$
 OR
 $[Ni(H_2O)_6]^{2+} + 2NH_3 \rightarrow Ni(OH)_2 + 4H_2O + 2NH_4^+$
 OR
 $[Ni(H_2O)_6]^{2+} + 2OH^- \rightarrow [Ni(OH)_2(H_2O_4)] + 2H_2O$
 OR
 $[Ni(H_2O)_6]^{2+} + 2OH^- \rightarrow Ni(OH)_2 + 6H_2O$
 IGNORE state symbols
 IGNORE missing square brackets in any formula 1
- (iii) H^+ removed (by NH_3 OR OH^-) (1)
 From (H_2O) ligands (1)
 NOT just from “complex” 2
- (iv) Ligand exchange
 OR ligand replacement
 OR ligand substitution 1
- (v) $[Ni(OH)_2(H_2O)_4] + 6NH_3 \rightarrow [Ni(NH_3)_6]^{2+} + 2OH^- + 4H_2O$
 OR
 $Ni(OH)_2 + 6NH_3 \rightarrow [Ni(NH_3)_6]^{2+} + 2OH^-$
 Allow formation of $[Ni(NH_3)_4]^{2+}$ OR $[Ni(NH_3)_4(H_2O)_2]^{2+}$
 cation formed (1)
 balancing equation (1) 2
- (d) d -orbitals split (in energy) by ligands (1)
 QWC ALLOW d -sublevel
absorbs light (in visible region) (1)
 NOT “uv light”
 electron is promoted OR electron moves to a **higher** energy level (1)
 Any mention of emission of light can only score 1st mark 3

[14]