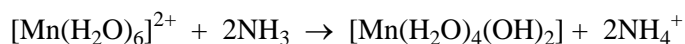
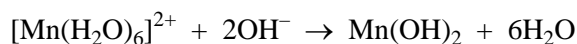


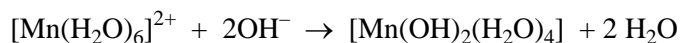
or



or

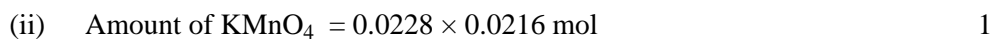
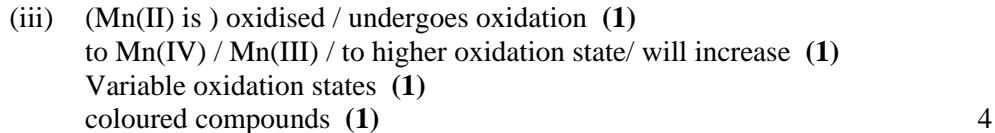


or

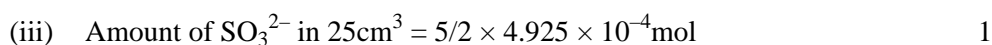


Any of above score 2 marks as follows: (1) mark for species (1) mark for balance

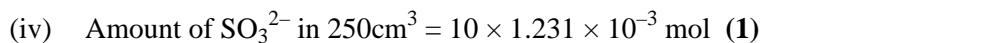
Deprotonation or Acid /base (1) 3



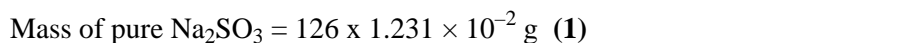
$= 4.925 \times 10^{-4} \text{ mol}$



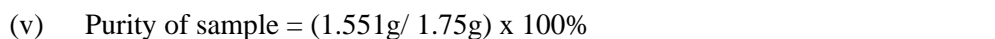
$= 1.231 \times 10^{-3} \text{ mol}$



$= 1.231 \times 10^{-2} \text{ mol}$



$= 1.551 \text{ g}$ 2



$= 88.6\%$ 1

[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]

↑				
---	--	--	--	--

↑↓

- Cr [Ar]

↑	↑	↑	↑	↑
---	---	---	---	---

↑

- Cr³⁺ [Ar]

↑	↑	↑		
---	---	---	--	--

--
- 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*

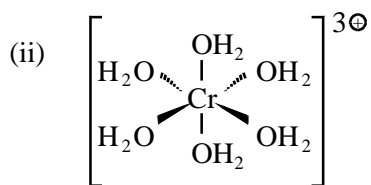
- (c) (i) [Ar]

↑	↑	↑	↑↓	↑↓
---	---	---	----	----

↑↓

↑↓	↑↓	↑↓
----	----	----
- 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)

↑	↑	↑	↑	↑	↑
---	---	---	---	---	---

 1
- (ii)

↑	↑	↑			
---	---	---	--	--	--

 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, $x = \text{max } 3$

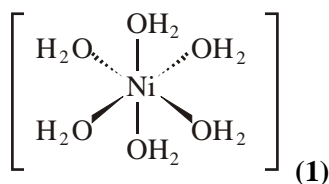
- (c) • **d** – orbitals/subshell/energy level split (in energy by ligands)/diagram to illustrate (1)
- Electron transitions/jumps from **lower** to **higher** energy level (1)
- **Absorbs** light in visible region/reference to white light (1) 3

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) $[\text{Ni}(\text{H}_2\text{O})_4(\text{OH})_2]$
ALLOW $\text{Ni}(\text{OH})_2$ 1
- (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^{\ominus} values for reduction of Fe^{3+} to Fe^{2+} by Zn ($E^{\ominus}_{\text{cell}} = +1.53\text{V}$) (1)
and Fe^{2+} to Fe by Zn ($E^{\ominus}_{\text{cell}} = +0.32\text{V}$) (1)
They have positive E^{\ominus} 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

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

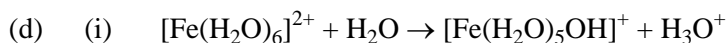
Amount of $\text{MnO}_4^- = 0.0071 \text{ dm}^3 \times 0.0200 \text{ mol dm}^{-3} = 1.42 \times 10^{-4} \text{ mol}$ (1) 1st point

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

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

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

5

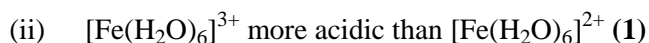


H_3O^+ in equation (1)

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 is more polarising (1)

3

[20]

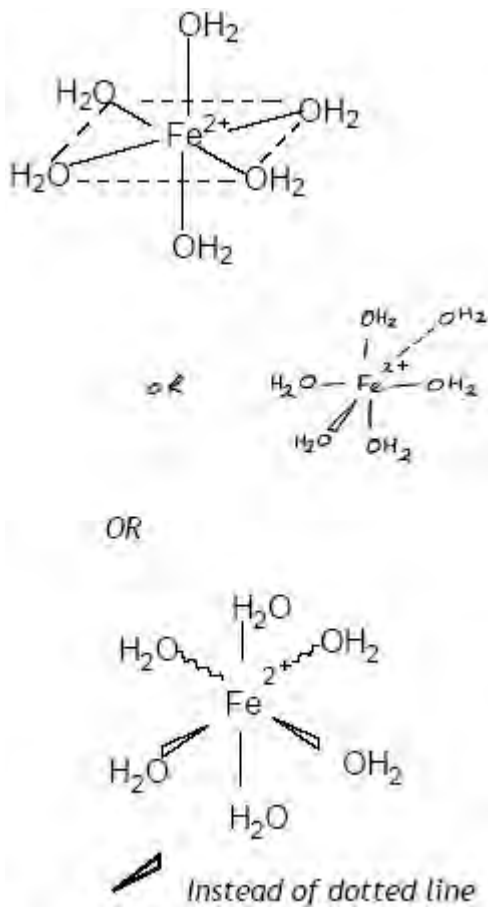
9. (a) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$ accept any order 1
- (ii) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$ Conseq on (a) (i) 1
- (b) **d-block:** last (added) electron is in a d-(sub) shell / orbital (1)
Not transition: does not form **ions** with partially filled d-(sub) shell / orbitals (1) 2
- (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]

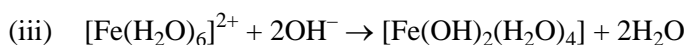
10. (a) (i) Fe [Ar]
 $3d^6 4s^2$
or $3d_6 4s_2$
or $3d6 4s2$
or $4s^2 3d^6$ **(1)**
- Fe²⁺ [Ar]
 $3d^6$
or $3d_6$
or $3d^6 4s^0$ **(1)**
Letter d must be lower case
Any additional letters or numbers **(0)** 2

(ii) The mark is for the shape

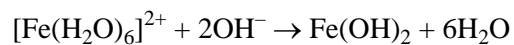


ALLOW bond to H of H₂O (except on left side if OH₂ is given)
 IGNORE charge unless incorrect

1



OR



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

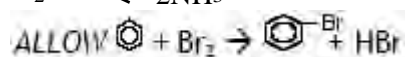
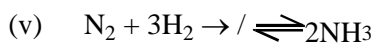
IGNORE state symbols

1

(iv) Green precipitate / solid → foxy-red / red-brown / brown / orange
 Both colours and precipitate / solid needed

NOT darkens

1



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
 $\text{L} \rightarrow \text{R}$ (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]

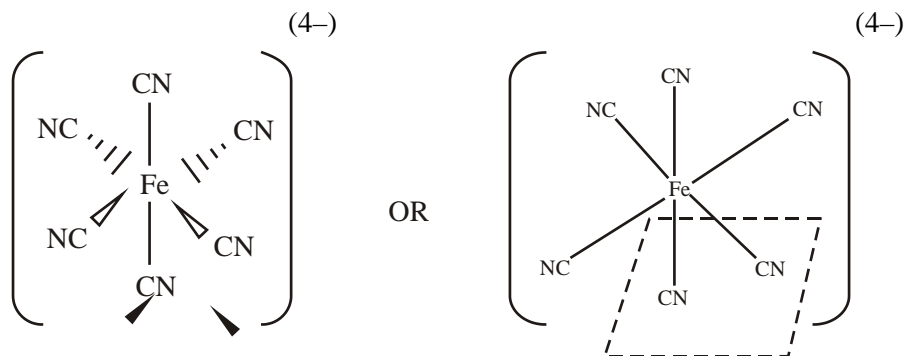
11. (a) (i) Forms **ions** which have partially filled *d*-orbitals
 OR
 Forms ions which have a partially filled *d*-subshell 1

(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)

3

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

1

(ii) no. moles $S_2O_3^{2-}$ used = $12.5 \times 0.1 / 1000 = 1.25 \times 10^{-3}$ (1)

no. moles $I_2 = 1.25 \times 10^{-3} / 2 = 6.25 \times 10^{-4}$ (1)

no. moles $ClO^- =$ no. moles I_2 (1)

no. moles ClO^- in original $10 \text{ cm}^3 = 10 \times 6.25 \times 10^{-4}$

$= 6.25 \times 10^{-3}$ (1)

no. moles ClO^- in $1 \text{ dm}^3 = 100 \times 6.25 \times 10^{-3}$ (1) = 0.625

5

(iii) mass $Cl_2 = 0.625 \times 71$

$= 44.4$ (g)

mark consequentially on (ii)

must be 3s.f. in final answer

1

(c) Cl_2 is the stronger oxidising agent because Cl_2 oxidises S from (+)2 to (+)6 (1)

but I_2 oxidises S from (+)2 to (+)2.50 (1)

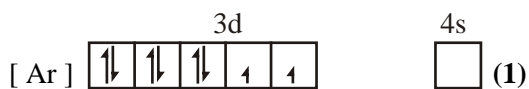
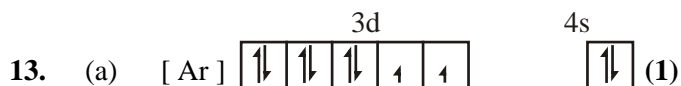
2

QWC (d) O_2 oxidises KI / iodide to I_2 . or balanced equation (1)

I_2 reacts with starch / paper to give blue / black (1)

2

[14]



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

2

(b) Forms **ion(s)** which have a partially OR an incompletely filled d -(sub)shell OR d -orbital(s)

1

(c) (i) Dative (covalent) OR co-ordinate (1)

Covalent (1)

2

