

1. (a) $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6 4s^2/4s^2 3d^6$ OR $3d^8 (4s^0)$ (1)
 Incomplete d shell (in the ion) (1) 2

(b) (i) $Ni(CO)_4$ 1
 (ii) 0 1

(c) (i) $Ni(H_2O)_6^{2+}(aq) + NH_3(aq) \rightarrow Ni(H_2O)_5(NH_3)^{2+}(aq) + H_2O(l)$ 1

QWC* (ii) ΔS is likely to be small / close to zero (1) – *No TE*
Same number of moles/molecules/particles in the same states
 on both sides of the equation (1) 2

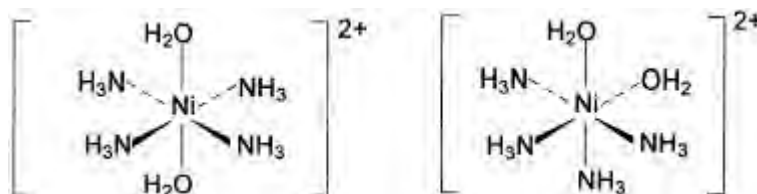
(d) (i) $Ag^+(aq) + Cl^-(aq) \rightarrow Ag^+Cl^-(s)$ 1

(ii) 1 mole of $AgCl$ has a mass of $143.5/(108+35.5)$ (1)
 OR 143.3 from Data Book (or 143.4)
 Number of moles of $AgCl = 6.133/143.5 = 0.0427(4)$ 0.04280 (1)
 Number of moles of complex = $0.04274/2 = 0.02137$
 Therefore mass of 1 mole = $5.000/0.02137 = 234/234.4$ (1)
3SF sufficient but not 2SF 3

(iii) $59 + 18 \times x + 17 \times (6 - x) + 71 = 234$
 $232 + x = 234$
 $x = 2$ 1

$[Ni(H_2O)_2(NH_3)_4]Cl_2$ Formula NOT needed for mark

(iv) The two water molecules could be at 180° or 90° to one another



Octahedral structure (1)
 ALLOW the word octahedral to explain diagram's shape 2

[14]

2. (a) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$
 OR
 $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$ 1

QWC*(ii) V and Mn have two 4s electrons / filled 4s (orbital) Cr has one (1)
 due to stability of half-filled shell/4s and 3d levels have similar
 energies (1) 2

- QWC*(b) $\text{Cr}^{3+}(\text{aq}), \text{Cr}^{2+}(\text{aq})(\text{IPt}) -0.41(\text{V})$ (1)
 $[\text{O}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})], 4\text{OH}^-(\text{aq})(\text{IPt}) +0.4(0) (\text{V})$ (1)
 ALLOW a state symbol omission in each.
 ALLOW half equations
 Can be given in a cell diagram
- by application of the anti-clockwise rule oxygen will oxidise Cr^{2+}
 OR
 E^0 cell = (+) 0.81(V) and this is **greater** than (+) 0.6 (V)
 OR
 Cr^{2+} has more negative electrode potential so will reduce oxygen /
 oxygen more positive etc. (1) 3
- QWC*(c) (i) Water acts as a ligand by a non-bonding pair (of electrons on
 the oxygen atom) (1)
 Making a dative (covalent)/co-ordinate bond (to the chromium ion) (1) 2
- (ii) Bidentate/chelate/bridging 1
- QWC*(iii) Two peaks in the NMR spectrum (1)
 Due to two different environments of hydrogen atoms /
 H in H_2O and H in CH_3 (1)
 Mark independently 2
- QWC*(iv) **Any two:**
 C-H just below 3000 / 2962-2853 / 1485-1365
 O-H 3200-3800
 C=O 1700-1750
 C-O 1230 - 1250
 ALLOW values or ranges within these ranges
 If more than two given, -1 for each incorrect 2
- (d) (i) $3\text{C}_2\text{H}_6\text{O}$ to $3\text{C}_2\text{H}_4\text{O}$ provided 1 $\text{Na}_2\text{Cr}_2\text{O}_7$ (1)
 $4\text{H}_2\text{SO}_4$ and $7\text{H}_2\text{O}$ (1)
 ACCEPT multiples 2
- (ii) Orange to green
 ALLOW qualified green e.g. blue-green
 NOT green to orange 1
- (iii) (Sodium dichromate(VI)) is a carcinogen / toxic / irritant
 In any combination
 Lose mark for anything else with these. 1

3. (a) (i) Add silver nitrate (solution) **(1)** *ACCEPT correct formula*
(pale) yellow **precipitate**/solid**(1)**
OR
Add chlorine (solution)/bromine (solution) **and** hydrocarbon solvent **(1)**
Solvent goes purple/pink/violet **(1)**
2nd mark is dependent on 1st 2
- (ii) Iodine /I **and** sulphur / S identified **(1)** -*NOT* I₂ /I⁻/iodide
Iodine
initial (+)5 final -1 **(1)**
Sulphur
initial (+)4 final (+)6 **(1)**
ACCEPT as roman numerals
ACCEPT +/- on either side/sub or superscript
ACCEPT as words 3
- (iii) $1 \times -6 = -6$, $3 \times +2 = +6$ *ALLOW TE from (ii)*
OR total change in oxidation number of +6 for S, -6 for I
ACCEPT justification in terms of electrons 1
- (b) (i) pipette
ALLOW burette
NOT measuring cylinder 1
- (ii) Starch (solution) **(1)**
blue/dark blue/blue-black/black to colourless **(1)**
ALLOW max 1 if candidate states "no indicator needed/self-indicating"
with colour change brown/yellow to colourless
If no indicator given but correct colour change 1 (out of 2) 2
- (iii) $\frac{24.0}{1000} \times 2.4(0) \times 10^{-4}$ *OR* 0.00024 (mol)
The mark is for the answer 1
- (iv) $\frac{2.40 \times 10^{-4}}{2} = 1.2(0) \times 10^{-4}$ (mol) *OR* 0.00012 (mol)
ALLOW TE from (iii)
The mark is for the answer 1

(v) $1.2 \times 10^{-4} \times 100 = 0.012(0)$ (mol dm⁻³)

ALLOW TE from (iv)

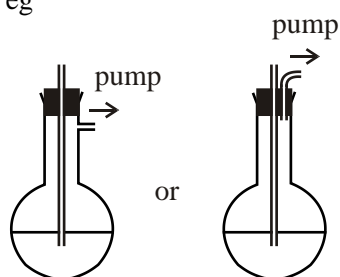
The mark is for the answer

1

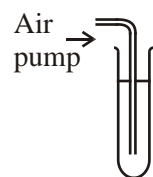
[12]

4. (i) (Buchner) flask / boiling tube connected to pump, glass tube through stopper into solution

eg



ACCEPT



But must be a test tube and tube to bottom as shown

1

- (ii) 8H^+ $4\text{H}_2\text{O}$

ACCEPT multiples

1

- (iii) Number of moles of manganate(VII) ion

$$= \frac{20 \times 0.020}{1000} = 0.0004(0) \text{ (1)}$$

Number of moles of electrons

$$= 5 \times 0.00040 = 0.002(0) \text{ (1)}$$

Number of moles of vanadium ions

$$= \frac{10 \times 0.10}{1000} = 0.001 \text{ (1)}$$

(as vanadium(V) is formed by loss of 2 moles of electrons)

Oxidation number of vanadium in aerated solution is +3 (1)

4

(iv) It is a powerful oxidising agent, $E^\ominus = +1.51 \text{ V}$

OR

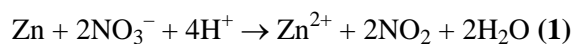
It is self-indicating

1

[7]

5. (a) (i) uses E^\ominus values to find $E_{\text{reaction}} = (+) 1.57 \text{ (V)}$ (1)

Reject - 1.57



2

Accept equation with equilibrium sign

Rejection equation with Zn on the right

(ii) E_{reaction} for the production of hydrogen is (+) 0.76 (V) (1)

smaller than reaction in (i) so is less likely (1)

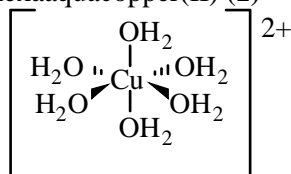
OR

NO_3^- being the oxidised form of a redox couple with a more positive E^\ominus than $E^\ominus \text{H}^+/\frac{1}{2} \text{H}_2$ (1)

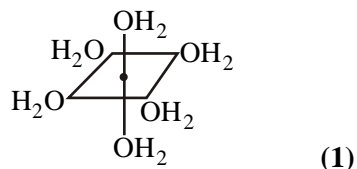
is a stronger oxidising agent than H^+ (1)

2

(iii) hexaaquacopper(II) (1)



OR



Both marks stand alone

[IGNORE charge]

[IGNORE how H_2O ligand is bonded to central cation]

2

Accept hexaquacopper(II)

Reject formula

- (iv) **ligand** exchange/replacement/substitution (1)
 $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{Cl}^- \rightleftharpoons \text{CuCl}_4^{2-} + 6\text{H}_2\text{O}$ (1)
 OR
 $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{HCl} \rightleftharpoons \text{CuCl}_4^{2-} + 4\text{H}^+ + 6\text{H}_2\text{O}$ (1) 2
ALLOW →
Accept $\text{H}_2\text{CuCl}_4 + 2\text{H}^+$ for $\text{CuCl}_4^{2-} + 4\text{H}^+$
- (b) (i) E^\ominus for the reaction is -0.39 (V) (so not feasible) [value is required]. 1
Accept Cu^{2+} being the oxidised form of the redox couple with the more negative E^\ominus , will not oxidise I^-
- (ii) CuI is a solid (so conditions are not standard) (1)
 Equilibrium is pulled over/moves to favour the r.h.s. (1) 2
Reject just 'conditions not standard'
- (iii) $[\text{Cu}(\text{NH}_3)_4]^+$
 OR $[\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^+$ 1
Accept $[\text{Cu}(\text{NH}_3)_2]^+$
Reject $[\text{Cu}(\text{NH}_3)_6]^+$
Reject any 2+ complex
- (iv) (atmospheric) oxygen (1)
 oxidises Cu^+ to Cu^{2+} (1) 2
Reject air for oxygen
- (c) (i) starch (1)
 blue-black/blue/black to colourless (1) 2
Reject clear for colourless
- (ii) (If added too early) insoluble complex/black solid formed, making titre too low
 OR (If added too early) insoluble complex/black solid formed, removes iodine from solution
 OR (If added too early) insoluble complex/black solid formed, causes inaccurate titre.
 OR (If added too early) insoluble complex/black solid formed, not all the iodine is titrated. 1

- (iii) Amount thiosulphate = $0.01655 \text{ dm}^3 \times 0.1 \text{ mol dm}^{-3}$ (1)
 = amount Cu^{2+} in $25.0 \text{ cm}^3 = 1.655 \times 10^{-3} \text{ mol}$ (1)
 amount of Cu^{2+} in $250 \text{ cm}^3 = 1.655 \times 10^{-3} \times 10$ (1)
 mass of Cu (in sample) = $1.655 \times 10^{-2} \times 63.5$ (1) = 1.051 g
 % Cu in brass = $1.051 \times 100/1.5 = 70 \%$ (1)
 [IGNORE sf]
 [mass of 1.051g with working scores (4);
 correct answer with no working scores (3).]
 Mark consequentially

5

[22]

6. (a) $3d^{10}4s^1$ and $3d^{10}$

1

Accept $4s^1 3d^{10}$

- (b) (i) QWC*

the (3)d sub-shell is full (1)

Accept orbitals (it must be plural) for sub-shell

Reject comments on partially filled sub-shell

so no d-d transitions are possible

OR no transitions in the right energy range are possible (1)

(and no light is absorbed)

Any mention of light emission loses 2nd mark

2

- (ii) combine the half-reactions to get $2\text{Cu}^+ \rightarrow \text{Cu}^{2+} + \text{Cu}$ (1)
 IGNORE state symbols

and show that E^\ominus for this is (+) 0.37 (V) (and as it is positive it is feasible) (1)

conditional on correct reaction

2

Reject just '> 0.3 (V)'

- (iii) activation energy (for the disproportionation) is high
 OR

Cu^+ is kinetically stable

1

Reject activation energy for one of the half-equations is too high

- (c) (i) divides each by atomic mass (1)

divides by smallest to obtain $\text{Cu}_2\text{SO}_6\text{H}_2$ (1)

2

Division by atomic number scores zero

- (ii) $\text{CuSO}_4 \cdot \text{Cu}(\text{OH})_2$ (2)

- If formula wrong but sulphate/ SO₄ is present scores 1 (out of 2) 2
- Accept Cu₂SO₄(OH)₂*
Accept Cu₂(OH)₂SO₄
Accept (CuOH)₂SO₄
Reject HSO₄ instead of SO₄
- (iii) [Cu(NH₃)₄(H₂O)₂]²⁺ 1
- Accept [Cu(NH₃)₄]²⁺*
Reject [Cu(NH₃)₆]²⁺
- (iv) ligand exchange / ligand substitution 1
- (d) (i) QWC
- (add aldehyde to 2,4–DNP) to obtain precipitate/ppt/solid/crystals (1)
 recrystallise derivative (1)
 determine melting temperature of derivative (1)
 compare with data tables (1) 4th mark conditional on melting temperature of a derivative being measured 4
- Reject any identification method based on IR, NMR or mass for last 2 marks*
- (ii) the aldehyde is distilled off as it is formed 1
- Reject any mention of reflux*
Reject just 'the aldehyde is distilled off'
- (iii) propanoic acid OR CH₃CH₂COOH OR CH₃CH₂CO₂H 1
- Accept C₂H₅ for CH₃CH₂*
- (iv) No (extra) oxygen present
 OR catalyst specific to formation of aldehyde / only lowers E_a of first oxidation
 OR presence of hydrogen gives reducing conditions
 OR copper is not an oxidising agent
 OR aldehydes rapidly leave catalyst surface 1

- (v) (At high pressure) all active sites are occupied/full
 OR
 (At higher pressures) rate controlled by availability of sites. 1
Accept reverse argument for low pressure

[20]

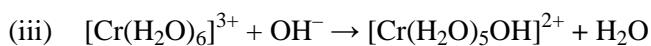
7. (a) (i) Cr: $[\text{Ar}] 3d^5 4s^1$
 Cu: $[\text{Ar}] 3d^{10} 4s^1$
Both needed for the mark 1

*Accept $4s^1 3d^5$
 Accept $4s^1 3d^{10}$
 Accept [Ar] written in full*

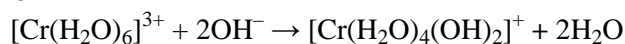
- (ii) all the others are $4s^2$ / have full 4s orbital (1)
*Accept Cr and Cu/they do not have a full 4s orbital
 Reject just 'only have one electron in 4s'
 OR
 Have incomplete 4s orbital*
 The d subshell is more stable when either half or fully filled
 OR
 A specific example of chromium having half-filled or
 copper having filled d sub-shell/set of d orbitals which
 is more stable (1) 2
*Accept sub-energy levels d shell
 Reject half-filled or filled d orbital(s)*

- (b) (i) Octahedral drawn must be 3-D
 IGNORE any or no charge 1
*Accept $-\text{H}_2\text{O}$ (bond to H) except on water molecules on left of
 Cr*

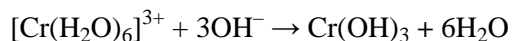
- (ii) Dative bond formed from electron pair/lone pair on oxygen
 (of the water molecule) to the ion
 This could be shown on a diagram 1
*Accept a clear description of the dative bond
 Reject 'dative' alone or from water
 Reject just "dative bond formed from oxygen"*



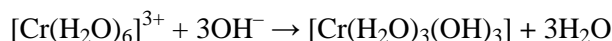
OR



OR



OR



First mark is for the correct Cr product

Second mark is conditional on the first and is for the rest of the equation correct and balanced

2

(iv) Forms a green precipitate (1)

IGNORE initial colour of solution

(which reacts or dissolves or changes to)

a **green solution** (with excess reagent) (1)

Accept any shade of green

2nd mark is conditional on an initial ppt

2

(v) acid / acidic

1

Accept amphoteric/able to be deprotonated

Reject coloured ions/ligand exchange/ deprotonation /partially filled d orbitals

(c) (i) **Check working – correct answer can be obtained by not dividing by 2 for 2nd mark and not multiplying by 2 for 4th mark**

amount thiosulphate in titre = $0.0372 \text{ dm}^3 \times 0.100 \text{ mol dm}^{-3}$
= $3.72 \times 10^{-3} \text{ mol}$ (1)

amount I_2 = $\frac{3.72 \times 10^{-3}}{2}$ (1) = $1.86 \times 10^{-3} \text{ mol}$

2nd mark cq on amount thiosulphate

amount dichromate in 25 cm^3

= $\frac{1.86 \times 10^{-3}}{3}$ (1) = $6.2 \times 10^{-4} \text{ mol}$

3rd mark cq on amount I_2

Total mass Cr = $6.2 \times 10^{-4} \text{ mol} \times 2 \times 10 \times 52 \text{ g mol}^{-1}$ (1)
= 0.645 g

4th mark cq on amount dichromate

% of Cr = 64.5 % (1)

IGNORE SF unless rounded to 1 SF cq on mass Cr, provided less than 1 g

Accept 64.48 %

OR

amount thiosulphate for whole sample
 $= 0.0372 \text{ dm}^3 \times 0.100 \text{ mol dm}^{-3} \times 10$
 $= 3.72 \times 10^{-2} \text{ mol (1)}$

amount $\text{I}_2 = 1.86 \times 10^{-2} \text{ mol (1)}$

amount dichromate $= 6.2 \times 10^{-3} \text{ mol (1)}$

mass Cr $= 6.2 \times 10^{-3} \text{ mol} \times 2 \times 52 \text{ g mol}^{-1} \text{ (1)}$
 $= 0.645 \text{ g}$

% of Cr $= 64.5\% \text{ (1)}$

IGNORE SF unless rounded to 1sf Mark consequentially, as above

Note:

Correct answer with no working (3)

5

- (ii) Colour at the end point would be green which
would prevent the loss of iodine colour being seen
OR

colour change at end point would be disguised by the colour of Cr^{3+}

1

Accept chromium instead of Cr^{3+}

Reject end point disguised by colour of $\text{Cr}_2\text{O}_7^{2-}$ /orange

[16]

8. (a) B

1

(b) C

1

[2]

9. C

[1]

10. D

[1]

11. D

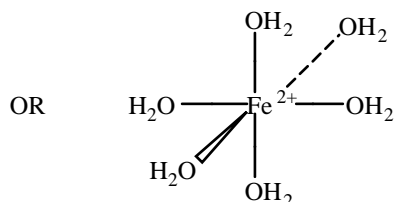
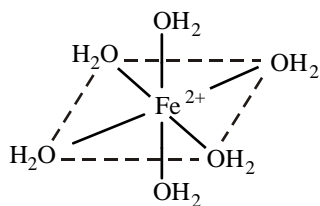
[1]

12. (a) (i) $\text{Fe}[\text{Ar}] 3d^6 4s^2$ in either order, allowing superscripts to be subscripts
 $\text{Fe}[\text{Ar}] 3d^6$ or $3d^6 4s^0$ in either order, allowing superscripts to be subscripts
 Letter d must be lower case

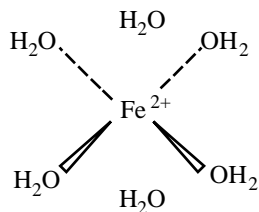
1

Reject any other letters

(ii)



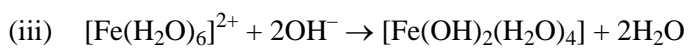
OR



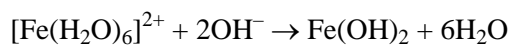
Instead of dotted line

ALLOW bond to H of H_2O (accept on left side if OH_2 is given)
 IGNORE charge unless incorrect

1



OR



1

- (iv) Green precipitate/solid \rightarrow Foxy-red/red-brown/
 brown/orange
 Both colours **and** precipitate/solid needed

1

Reject just "Darkens"

- (b) (i) QWC
 Emf of cell/ potential difference of cell containing Fe (1)
 dipping into a $1 \text{ mol dm}^{-3} \text{ Fe}^{2+}$ solution (1)
 And standard hydrogen electrode/half cell
 OR hydrogen electrode and $1 \text{ mol dm}^{-3} \text{ H}^+$ and 1 atm H_2
 OR description of standard hydrogen electrode (1)
 IGNORE temperature 3
Reject 'SHE'
- (ii) QWC
 Emf of hydrogen electrode is zero – *stated or implied*
 e.g. if calculate $E_{\text{cell}} = +0.44 \text{ V}$ (1)
 Potential for the reaction is positive so reaction is feasible
 OR Fe half cell has more negative electrode potential
 OR H^+ and $(\frac{1}{2})\text{H}_2$ has a more positive electrode potential (1) 2
- (iii) High E_a so slow reaction / reactants are kinetically stable
 IGNORE any mention of non-standard conditions 1

[10]