# Mark schemes

## Q1.

(a)

| This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question. | |
|---|---|
| **Level 3** **5-6 marks** | All stages are covered and the description of each stage is generally correct and virtually complete. Answer is communicated coherently and shows a logical progression from stage 1 to stage 2 and stage 3. |
| **Level 2** **3-4 marks** | All stages are covered but the description of each stage may be incomplete or may contain inaccuracies **OR** two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows progression from stage 1 to stage 2 and/or stage 3. |
| **Level 1** **1-2 marks** | Two stages are covered but the description of each stage may be incomplete or may contain inaccuracies, **OR** only one stage is covered but the explanation is generally correct and virtually complete. Answer includes isolated statements and these are presented in a logical order. |
| **Level 0** | **0 marks** Insufficient correct chemistry to gain a mark. |

Stage 1
1a Heterogeneous means in a different phase/state from reactants
1b Catalyst speeds up reaction and is left unchanged **OR** lowers the activation energy for the reaction

Stage 2
2a Hydrogen and nitrogen/reactants adsorb onto the surface/ active sites of the iron
2b Bonds weaken/reaction takes place
2c Products desorb/leave from the surface (of the iron)

Stage 3
3a Large surface area (of iron) by using powder or small pellets or support medium/mesh
3b Catalyst poisoned / sulfur poisons or binds to the catalyst
3c Active sites blocked

Ignore references to temperature and pressure

**6**

(b) Two negative ions repel

1

So activation energy is high

1

$2\ Fe^{2+} + S_2O_8^{2-} \rightarrow 2\ SO_4^{2-} + 2\ Fe^{3+}$

1

$2\ Fe^{3+} + 2\ I^- \rightarrow 2\ Fe^{2+} + I_2$

*Ignore any state symbols given*
*Allow multiples for both equations*
*Allow equations in either order*

1

(c) (Zn ions) have only one oxidation state
Or
$Zn^{2+}$ is the only ion

*Allow doesn't have variable oxidation state*
*Allow cannot be oxidised to $Zn^{3+}$*
*Ignore has a full d shell*

1

(d) M1 Amount of Fe = 0.998 ÷ 55.8 = 0.0179 mol

1

M2 Amount of HCl = 0.0300 mol

1

M3 HCl is the limiting reagent

1

M4 Amount of $H_2$ produced = 0.0150 mol

*M4 = M2÷2*

1

M5 T = 303 K P = 100 000 Pa

1

M6 $V\left(= \dfrac{0.0150 \times 8.31 \times 303}{100\ 000}\right) = 3.78 \times 10^{-4}$ ($m^3$)

*M6* $V\left(= \dfrac{M4 \times 8.31 \times 303}{100\ 000}\right)$ ($m^3$)

1

(e) $FeCO_3$ or iron(II) carbonate

1

Green

*Allow white*

1

(f) $Fe(H_2O)_3(OH)_3$

*Ignore square brackets if added*

1

brown

1

$2\ [Fe(H_2O)_6]^{3+} + 3\ CO_3^{2-} \rightarrow 2\ Fe(H_2O)_3(OH)_3 + 3\ H_2O + 3\ CO_2$

*Accept multiples*

1

(g) M1 $Fe^{3+}$ is smaller (than $Fe^{2+}$) **OR** $Fe^{3+}$ has a greater charge **OR** $Fe^{3+}$ has a greater charge density **OR** $Fe^{3+}$ has a greater charge to size ratio

*Penalise $Fe(H_2O)_6^{3+}$ ions once in M1 or M2*

1

M2 $Fe^{3+}$ ions are more polarising **OR** $Fe^{3+}$ ions polarise water molecules more

1

M3 So more O-H bonds (in the water ligands) break **OR** more $H^+$ ions released **OR** weaken O-H bonds in ligands more (in the $Fe^{3+}$ solution)

*Do not allow $Fe^{3+}$ releases $3H^+$ ions*

1

**[25]**

## Q2.

D

*$CoO + 4\ HCl \rightarrow [CoCl_4]^{2-} + H_2O + 2\ H^+$*

**[1]**

## Q3.

(a) **M1** (oxide ions react with water to) form/produce hydroxide **ions**

***M1*** *$O^{2-} + H_2O \rightarrow 2OH^-$*

*Ignore all non-ionic equations*

1

**M2** sodium hydroxide more soluble than magnesium hydroxide

***M2*** *ideas that more sodium hydroxide dissolves / dissociates*

*Allow sodium oxide more soluble / dissociates more than magnesium oxide NOT 'molecules' or 'atoms'*

1

(b) $P_4O_{10} + 6H_2O \rightarrow 4H_3PO_4$

*Allow multiples and fractions*

*Allow ionic products*

*NOT $P_2O_5$*

1

(c) **M1** $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$

*Allow 1 mark if both equations correct, but in wrong order*

1

**M2** $V_2O_4 + \frac{1}{2}O_2 \rightarrow V_2O_5$

*ALLOW multiples*

1

**[5]**

## Q4.

(a) **M1** absorb (some) wavelengths/frequencies/colours/energies of (visible) light

*wavelengths/frequencies/colours/energies of (visible) light only needed once in the answer*

*Allow absorption of a photon of light NOT uv light*

1

**M2** to promote/excite electrons in d-orbitals

*Allow d-subshell / d-energy level / d-electrons*
*Reference to 'd' can appear anywhere in the answer*

1

**M3** remaining/complementary wavelengths/frequencies/colours/energies of (visible) light reflected/transmitted (to give colour seen)

*NOT emissions/emitting or 'give out'*

1

(b) **M1** $(\Delta)E = \frac{hc}{\lambda}$

*Allow in two stages / expressed in words*

1

**M2** $490 \times 10^{-9}$

*M2 for conversion*

1

**M3** $= (6.63 \times 10^{-34} \times \frac{3.00 \times 10^{8}}{490 \times 10^{-9}}$ $490 \times 10^{-9}$ $) = 4.06 \times 10^{-19}$ J

*Correct answer scores 3 marks*

*$4.06 \times 10^{-n}$ scores 2 marks (no M2)*

*$9.75 \times 10^{-32}$ = 1 mark (M2)*

1

(c) **M1** **measure** absorbance for (a range of) known concentration<u>s</u>

*Insist on description of taking measurements*

1

**M2** plot graph absorbance v concentration

*Allow concentration v absorbance*

1

**M3** read value of concentration for the measured absorbance from this graph

*If no M1, must mention both variables*

*Need to describe HOW they use the graph*

**1**

(d) **M1** amount of iron in each tablet = $4.66 \times 10^{-3} \times \frac{250}{1000}$ (= 0.001165 mol)

**1**

**M2** mass of iron in each tablet = $4.66 \times 10^{-3} \times \frac{250}{1000} \times 55.8 = 0.0650\ g = 65\ mg$

*Correct answer = 2 marks*

*Allow M2 for (M1 x 55.8 x 1000)*

**1**

**[11]**

## Q5.

**B**

**[1]**

## Q6.

**A**

**[1]**

## Q7.

**D**

**[1]**

## Q8.

**A**

**[1]**

## Q9.

**C**

**[1]**

## Q10.

(a) $[Fe(OH)_3(H_2O)_3]$

**1**

Brown

***M2:*** *Allow red-brown*

**1**

$2[Fe(H_2O)_6]^{3+} + 3CO_3^{2-} \rightarrow 2[Fe(OH)_3(H_2O)_3] + 3CO_2 + 3H_2O$

***M3:*** *Allow correct equations with $Na_2CO_3$*
***M3:*** *Ignore State symbols*

**1**

(b) $[FeCl_4]^-$

**1**

$[Fe(H_2O)_6]^{3+} + 4\ Cl^- \rightarrow [FeCl_4]^- + 6\ H_2O$
***M2:*** *Allow correct equations with HCl*

**1**

(c) (XS) Zn (in acid or CHl or $H_2SO_4$)
*Allow KI/potassium iodide*

**1**

(d) $[Fe(OH)_2(H_2O)_4]$

**1**

green

**1**

(e)

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| **Level 2**<br>**3-4 marks** | All stages are covered but the description of each stage may be incomplete or may contain inaccuracies OR two stages are covered and the explanations are generally correct and virtually complete. Answer is mainly coherent and shows progression from stage 1 to stage 2 and/or stage 3.<br><br>Answer is illustrated using diagrams of at least 1 specific example of a pair of cobalt or platinum complex isomers. |
| **Level 1**<br>**1-2 marks** | Two stages are covered but the description of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete. Answer includes isolated statements and these are presented in a logical order.<br><br>Answer is illustrated using at least 1 appropriate diagram or formula. |
| **0 marks** | Insufficient correct chemistry to gain a mark. |

**Indicative Chemistry content**

**Stage 1: shapes of complexes**

1a octahedral or 6 co-ordinate diagram

1b tetrahedral or square planar or 4 co-ordinate diagram

**Stage 2: cis/ trans isomerism (or E-Z or geometric)**

2a cis/trans isomerism in either square planar and/or octahedral complexes

2b Diagrams showing cis <u>and</u> trans isomerism in a square planar complex

2c Diagrams showing cis <u>and</u> trans isomerism in both isomers of octahdedral complexes eg draw cis <u>and</u> trans $M(H_2O)_4(OH)_2$ or $[M(NH_3)_4(H_2O)_2]^{2+}$

**Stage 3: optical isomerism**

3a optical isomerism / non superimposable mirror images in octahedral complexes

3b occurs with a specific bidentate ligands eg.$C_2O_4^{2-}$ or $NH_2CH_2CH_2NH_2$

3c draw both optical isomers of eg $[M(NH_2CH_2CH_2NH_2)_3]^{2+}$

6

**[14]**

## Q11.

(a) $NaCl + H_2SO_4 \rightarrow NaHSO_4 + HCl$

*Allow $2\ NaCl + H_2SO_4 \rightarrow Na_2SO_4 + 2\ HCl$*

1

Proton donor

*Allow (Bronsted-Lowry) acid*

1

(b) $2\ NaBr + 2\ H_2SO_4 \rightarrow Na_2SO_4 + SO_2 + Br_2 + 2\ H_2O$
Or
$2\ NaBr + 3\ H_2SO_4 \rightarrow 2\ NaHSO_4 + SO_2 + Br_2 + 2\ H_2O$
Or
$2\ H^+ + 2\ Br^- + H_2SO_4 \rightarrow SO_2 + Br_2 + 2\ H_2O$
Or
$4\ H^+ + 2\ Br^- + SO_4^{2-} \rightarrow SO_2 + Br_2 + 2\ H_2O$

*Ignore $2\ NaBr + H_2SO_4 \rightarrow Na_2SO_4 + 2\ HBr$*

*Ignore $NaBr + H_2SO_4 \rightarrow NaHSO_4 + HBr$*

1

brown gas or brown fumes or orange gas or orange fumes

*Do not accept yellow solid*

*Ignore fizzing and misty fumes*

1

Oxidising agent

*Allow electron acceptor*

*Ignore acid / proton donor*

1

(c) (+)5 and -1

1

(d) Is oxidised and reduced

*Allow undergoes disproportionation*

*Allows gains and loses electrons*

1

(e) D AgBr

*Ignore state symbols*

1

E $Ag_2CO_3$

1

F $CO_2$

1

$2\ Ag^+ + CO_3^{2-} \rightarrow Ag_2CO_3$

1

$AgBr + 2\ NH_3 \rightarrow Ag(NH_3)_2^+ + Br^-$

*Or* $\rightarrow Ag(NH_3)_2Br$

*One mark for* $Ag(NH_3)_2^+$ *and 1 mark for equation*

*If D = AgCl, then allow 2 marks for*

$AgCl + 2\ NH_3 \rightarrow Ag(NH_3)_2^+ + Cl^-$

2

**[13]**

## Q12.

(a) **M1** Amount of $S_2O_3^{2-} = \frac{9.00 \times 0.0800}{1000} = 7.20 \times 10^{-4}$ mol

1

(From equations mol $S_2O_3^{2-}$ = mol $Cu^{2+}$ )

**M2** Amount of $Cu^{2+}$ in 25 $cm^3$ = $7.20 \times 10^{-4}$ mol

***M2** = answer to **M1** (1:1 ratio)*

1

**M3** Amount of $Cu^{2+}$ in 250 $cm^3$ = 7.20 v $10^{-4}$ **× 10** = $7.20 \times 10^{-3}$ mol

***M3** = **M2** × 10*

1

**M4** Mass of copper = $7.20 \times 10^{-3}$ mol **× 63.5** = 0.457 g

***M4** = **M3** × 63.5*

1

**M5** mass = 0.985 g

*__M5__ converting 985 mg to g*

1

**M6** $\% \text{ Cu} = 0.457 \times \frac{100}{0.985} = 46.4\ \%$

*__M6__ is for the answer to __3 sf__*

*Allow % Cu = 457 ×* $\frac{100}{985}$ *= 46.4 % for __M5__ and __M6__*

*Allow (__M4__ ×1000)/985 v 100 for __M5__ and __M6__*

1

(b) Use more of the alloy

1

Use a lower concentration of the thiosulfate solution/lower mass of $Na_2S_2O_3$ to make solution

1

(c) Oxidizing agent

*Allow electron acceptor*

1

(d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$

*Do not allow [Ar]3d* $^9$

1

(e) Full (3)d (sub)shell or (3)$d^{10}$

1

No (d-d) transitions possible/ cannot absorb visible/white light

*__M2__ is dependent on __M1__*

*Ignore reflects visible/white light*

1

(f) **M1**: n = (5.00/253.8) = 0.0197 mol

*Allow 254*

*If 126.9 or 127 used lose __M1__ only*

1

**M2**: T = 458 K and P = 100 000 Pa

1

**M3** $V = \frac{nRT}{P}$ or $\frac{0.0197 \times 8.31 \times 458}{100\ 000}$ or $7.50 \times 10^{-4}\ (m^3)$

*__M3__ If rearrangement incorrect can only score __M1__ and __M2__*

1

**M4**: V = 750 ($cm^3$)

*__M4__: Allow __M3__ ×* $10^6$

*__M4__: Allow 749*

1

**[16]**

## Q13.

(a) $Fe + H_2SO_4 \rightarrow FeSO_4 + H_2$

*Allow $Fe + 2H^+ \rightarrow Fe^{2+} + H_2$*

*Allow $Fe + 2H^+ + SO_4^{2-} \rightarrow Fe^{2+} + SO_4^{2-} + H_2$*

*Allow $Fe + H_2SO_4 \rightarrow Fe^{2+} + SO_4^{2-} + H_2$*

*Allow $Fe + 2H^+ + SO_4^{2-} \rightarrow FeSO_4 + H_2$*

*Allow multiples*

*Ignore state symbols*

1

(b) 22.65 ($cm^3$)

1

(c) $5\ Fe^{2+} + MnO_4^- + 8\ H^+ \rightarrow 5\ Fe^{3+} + Mn^{2+} + 4\ H_2O$

*Allow multiples*

*Ignore state symbols*

*NOT if electrons shown*

1

(d) colourless / (pale) green to (hint of) pink

*NOT …. to purple*

*Allow …. to pale / hint of purple*

1

(e) pipette

burette

*both needed*

*Allow (graduated/volumetric) pipette*

*Allow (graduated/volumetric) burette*

*NOT dropping pipette*

1

(f) 1.47(%)

*Allow 1.5(%)*

1

**[6]**

## Q14.

**D**

**[1]**

## Q15.

(a) ( $\Delta S = \Sigma(S\ products) - \Sigma(S\ reactants)$ )

= [ (4 × 211) + (6 × 189) ] - [ (4 × 193) + (5 × 205) ] = (1978 – 1797)

1

181 (J $K^{-1}$ $mol^{-1}$)

1

(b) ( $\Delta G = \Delta H - T\Delta S$ ) = - 905 - (600 + 273) × 181 × $10^{-3}$

*If answer to (a) is incorrect, mark consequentially:*

*- 905 - (873 × (a) × $10^{-3}$)*

1

$\Delta G$ = - 1063 / -1060 (kJ $mol^{-1}$)

If alternative value of $\Delta S$ = 211 used, answer = -1089 (kJ $mol^{-1}$)

1

(c) $\Delta G$ becomes more negative/less positive

*Ignore increase/decrease/larger/smaller $\Delta G$*

1

The entropy change / $\Delta S$ is positive / $T\Delta S$ gets bigger / $-T\Delta S$ gets more negative.

*Consequential on wrong (a)*

*If candidate does a calculation in (a) to produce $\Delta S$ negative then allow $\Delta G$ becomes less negative or more positive*

1

(d) Reactant(s) adsorbed onto the (platinum surface) / (platinum) provides a surface / active sites

1

Reaction (on the surface) or bond breaking(weakening) / bond making occurs (on the surface)

1

Desorption (of the product) or wtte

1

(e) (Oxidation state changes from) -3 to +2 OR (+) 5

1

(f) $2NH_3 + 2O_2 \rightarrow N_2O + 3H_2O$

*Allow multiples*

*Ignore state symbols*

1

**[11]**

## Q16.

(a) $Fe^{2+}$

*Accept any Fe(II) compound – correct formula or name*

1

$E^\ominus$ $VO_2^+$(/ $VO^{2+}$) > $E^\ominus$ $Fe^{3+}$(/$Fe^{2+}$) > $E^\ominus$ $VO^{2+}$(/$V^{3+}$)

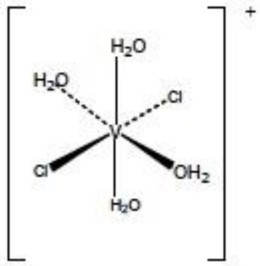
*If calculations of EMF are provided producing EMFs = 0.23(V) and -0.43(V), with a comment, allow M2* *allow $\underline{E^\ominus\ Fe^{3+}}$ ($/Fe^{2+}$) value of +0.77 is between the $E^\ominus$ values for the electrode half-equations containing the V species or wtte*

**1**

(b) (+) 4

*IV or four*

**1**

(c) 


*Ignore absence of charge*

*Wedges, dotted lines and [ ] not required*

*Do not penalise bond from H to V (in water ligands)*

**1**

Cis/trans

*allow E/Z, geometric and stereo(isomerism)*

**1**

(d) $2\ NH_4VO_3 \rightarrow V_2O_5 + H_2O + 2NH_3$

*Accept multiples*

*Ignore state symbols*

**1**

(e) $V_2O_5 + SO_2 \rightarrow V_2O_4 + SO_3$

$V_2O_4 + ½\ O2 \rightarrow V_2O_5$

*Both equations needed for 1 mark in this order*

*Allow multiples*

**1**

**[7]**

## Q17.

**C**

**[1]**

## Q18.

**B & C**

**[1]**

## Q19.

(a) Covalent

*Do not allow dative covalent or coordinate*

*(covalent)*

1

(b) $Cl^{(-)}$ not donating lone pair (to $Cu^{(2+)}$)

$Cl^{(-)}$ does not form a coordinate/dative bond (to $Cu^{(2+)}$)

*Allow without charges but penalise incorrect charges*

*$Cl^{-}$/it is bonded ionically (to $Cu^{2+}$)*

1

(c) $[Cu(H_2O)_6]^{2+} + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4H_2O$

1

Deep blue / Royal blue / Dark blue (solution)

1

*Allow combination of:*

$[Cu(H_2O)_6]^{2+} + 2NH_3 \longrightarrow [Cu(H_2O)_4(OH)_2] + 2NH_4^{+}$

$[Cu(H_2O)_4(OH)_2] + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2O + 2OH^{-}$

*Do not penalise missing square brackets*

*Ignore initial colour of $Cu^{2+}$ (aq)*

(d) $CuCO_3$ or copper carbonate

*Penalise incorrect oxidation state*

*Allow correct formula for basic copper carbonate*

1

(e) HCl/ hydrochloric acid

*Ignore concentration*

*Allow soluble chloride salt*

*Also allow any reagent which leads to a change in colour of solution due to a change in ligands (e.g. $NH_2CH_2CH_2NH_2$) or change in oxidation state (e.g. $SO_2$) and associated correct equations.*

1

$[Cu(H_2O)_6]^{2+} + 4Cl^{-} \longrightarrow [CuCl_4]^{2-} + 6H_2O$

$[Cu(H_2O)_6]^{2+} + 4HCl \longrightarrow [CuCl_4]^{2-} + 6H_2O + 4H^{+}$

*Mark independently*

1

(f) $(3)d^{10}$ or has full (3)d (sub) shell/orbital

*Penalise incorrect principal quantum number*

1

It is colourless/cannot absorb (frequencies of) visible light

*Ignore clear*

1

**[9]**

## Q20.

(a) Moles $MnO_4^-$ $\frac{26.50 \times 0.02}{1000}$ = $5.30 \times 10^{-4}$

1

Moles in 25cm$^3$ sample / pipette $C_2O_4^{2-}$ ( from acid and salt)
= $5.30 \times 10^{-4}$ **<u>× 5/2</u> = ($1.325 \times 10^{-3}$)**

1

Moles NaOH = $\frac{10.45 \times 0.1}{1000}$ ( = $1.045 \times 10^{-3}$)

1

So moles $C_2O_4^{2-}$ from acid in 25cm$^3$ sample / pipette
= $1.045 \times 10^{-3}$ **<u>÷ 2</u>** = $5.225 \times 10^{-4}$

1

Hence moles $C_2O_4^{2-}$ in sodium ethanedioate in 25 cm$^3$

= $1.325 \times 10^{-3} - 5.225 \times 10^{-4}$ (= $8.025 \times 10^{-4}$)

1

So moles $C_2O_4^{2-}$ in sodium ethanedioate in original sample
= $8.025 \times 10^{-4}$ **<u>× 10</u>** **(= $8.025 \times 10^{-3}$)**

1

Mass $Na_2C_2O_4$ = $8.025 \times 10^{-3}$ **<u>× 134(.0)</u> = 1.075(35) g**
So % sodium ethanedioate in original sample

1

$\frac{1.075(35)}{1.90}$ × 100 = 56.6 % to 3 sig fig

1

*The first CE is penalised by 2 marks; further errors are penalised by one mark each*

*M2 = M1 × 5/2*

*M4 = M3 ÷ 2*

*M5 = M2 – M4 (do not allow if negative and do not allow = M4-M2)*

***If no subtraction, max = 5 (M1, M2, M3, M4 and M6)***

***If incorrect subtraction, max = 6 (M1, M2, M3, M4, M6 and M7)***

*M6 = M5 × 10*

*(M6 can be scored by multiplying M2 <u>and</u> M4 by 10 before subtraction (giving $1.325 \times 10^{-2} - 5.225 \times 10^{-3} = 8.025 \times 10^{-3}$ )*

*M7 = M6 × 134*

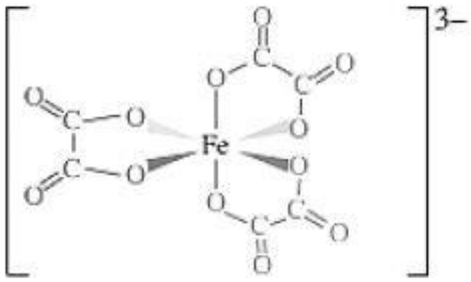
*M8 = (M7/1.90) × 100 Allow 56.5 – 56.8%*

(b) $[Fe(H_2O)_6]^{3+} + 3C_2O_4^{2-} \longrightarrow [Fe(C_2O_4)_3]^{3-} + 6H_2O$

1

There are <u>6</u> Fe–O bonds broken and then made / <u>same</u> number and type of bond being broken and made.

1

(c) 

*Ignore all charges even if wrong*
*Ignore absence of square brackets*
*Candidates do not need to show 3D shape*

1

90° or 180°

1

<u>optical</u>

1

(d) The ethanedioic acid is only present in small quantities/low concentration in these foods.

1

**[14]**

## Q21.

**C**

**[1]**

## Q22.

**B**

**[1]**

## Q23.

**D**

**[1]**

## Q24.

(a) $[Fe(H_2O)_6]^{3+} + 4Cl^- \longrightarrow FeCl_4^- + 6H_2O$

1

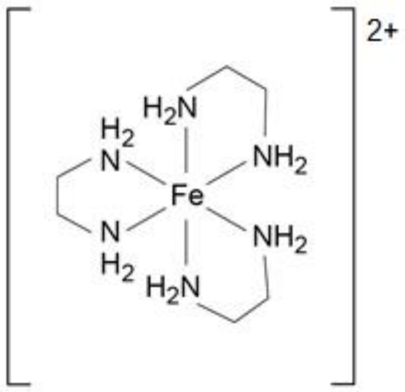
(b) $Cl^-$ is a bigger ligand

1

So only $4Cl^-$ can fit around the metal

*Allow fewer $Cl^-$ can fit around the metal*

1



(c)

*M1 for structure of complex*
*M2 for correct charge*

1
1

(d) Change in entropy is positive

1

(e) $5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

1

(f) Amount of manganate (VII) = $6.50 \times 10^{-4}$ mol

1

Amount of iron(II) = $3.25 \times 10^{-3}$ mol
*ie M1 × 5*

1

Mass of iron = 0.181 g = 181 mg
*Allow M2 × 55.8*

1

Percentage Fe = 181/1980 × 100 = 9.14(%) 3 sf

1

(g) Colourless to pale pink

1

**[12]**

## Q25.

(a) Multidentate − EDTA can form many / six dative bonds with central cation.

1

Ligand − lone pair (on N or O of EDTA) can form dative bond with copper(II) ions.

1

6 circles drawn on $EDTA^{4-}$ structure − 2 × N and 4 × −O

1

(b) Calibrate a colorimeter / produce a calibration curve.

1

By testing the colorimeter with solutions of copper-EDTA complex of known concentration. **1**

Add excess EDTA salt to the sample. **1**

(c) $[Cu(H_2O)_6]^{2+} + EDTA^{4-} \longrightarrow [Cu(EDTA)]^{2-} + 6H_2O$ **1**

Amount of copper(II) = $(25.0 \times 7.56 \times 10^{-5}) / 1000 = 1.89 \times 10^{-6}$ mol **1**

Volume of $EDTA^{4-}$ = $(1.89 \times 10^{-6} / 0.001) \times 1000 = 1.89$ cm$^3$ **1**

This is too small to be accurate. **1**

Dilute the $EDTA^{4-}$ solution / use larger volume of river water. **1**

**[11]**

## Q26.

D

**[1]**

## Q27.

D

**[1]**

## Q28.

(a) An electron pair on the ligand **1**

Is donated from the ligand to the central metal ion **1**

(b) Blue precipitate **1**

Dissolves to give a dark blue solution **1**

$[Cu(H_2O)_6]^{2+} + 2NH_3 \longrightarrow Cu(H_2O)_4(OH)_2 + 2NH_4^+$ **1**

$Cu(H_2O)_4(OH)_2 + 4NH_3 \longrightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 2OH^- + 2H_2O$ **1**

(c) $[Cu(NH_3)_4(H_2O)_2]^{2+} + 2H_2NCH_2CH_2NH_2 \longrightarrow$
$[Cu(H_2NCH_2CH_2NH_2)_2(H_2O)_2]^{2+} + 4NH_3$ **1**

(d) Cu–N bonds formed have similar enthalpy / energy to Cu–N bonds broken
**1**

And the same number of bonds broken and made
**1**

(e) 3 particles form 5 particles / disorder increases because more particles are formed / entropy change is positive
**1**

Therefore, the free-energy change is negative

*M2 can only be awarded if M1 is correct*
**1**

**[11]**