M1.(a) $FeSO_4 + Na_2C_2O_4 \rightarrow FeC_2O_4 + Na_2SO_4$

Allow multiples, including fractions.

Allow $Fe^{2+} + C_2O_4^{2-} \rightarrow FeC_2O_4$

Allow correct equation which includes water of crystallisation.

1

(b) M_r $FeSO_4.7H_2O$ = 277.9

Allow if shown clearly in the calculation.

Allow 278

1

Moles = 6.95 / 277.9 = 2.5(0) × 10^{-2}

Do not penalise precision but must be to a minimum of two significant figures.

Allow correct calculation using incorrect M_r.

Correct answer without working scores this mark only.

1

(c) 3(.00) × 10^{-2}

1

(d) Theoretical mass = 2.50 × 10^{-2} × 179.8 = 4.50g as long as 2.50 × 10^{-2} is the smaller of parts (b) and (c) **(M1)**

Allow consequential answer from parts (b) and (c).

Allow theoretical mass = (smaller of parts (b) and (c)) × 179.8

*If larger of parts (b) and (c) used, lose **M1** but can score **M2**.*

Allow answers based on moles of reactant and product.

1

Yield = 3.31 × 100 / 4.50 = 73.6% **(M2)**

Award this mark only if answer given to 3 significant figures.

Correct answer without working scores this mark only, provided answer given to 3 significant figures.

1

(e) Some left in solution / some lost during filtration

Do not allow 'incomplete reaction'.

Do not allow 'reaction is reversible'.

1

(f) MnO_4^- will oxidise the iron(II) ion and the ethanedioate ion

1

MnO_4^- does not oxidise the Cu^{2+} ion / larger volume needed for iron(II) ethanedioate

1

[9]

M2.(a) A ligand is an electron pair / lone pair donor

Allow uses lone / electron pair to form a co-ordinate bond

1

A bidentate ligand donates two electron pairs (to a transition metal ion) from different atoms / two atoms (on the same molecule / ion)

QoL

1

(b) $CoCl_4^{2-}$ diagram

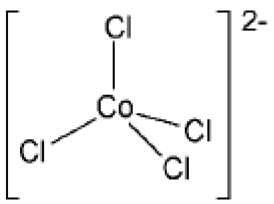
1

Tetrahedral shape

1

109°28'

1



Four chlorines attached to Co with net 2− charge correct

Charge can be placed anywhere, eg on separate formula

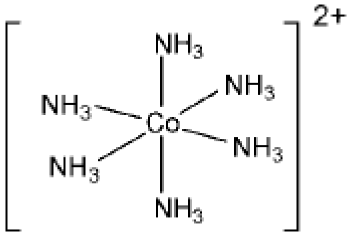
Penalise excess charges

Allow 109° to 109.5°

$[Co(NH_3)_6]^{2+}$ diagram 1

Octahedral shape 1

90° 1



Six ammonia / NH_3 molecules attached to Co with 2+ charge correct

Allow 180° if shown clearly on diagram

CE= 0 if wrong complex but mark on if only charge is incorrect

(c) In different complexes the <u>d</u> orbitals / <u>d</u> electrons (of the cobalt) will have different energies / <u>d</u> orbital splitting will be different 1

Light / energy is absorbed causing an electron to be excited 1

Different frequency / wavelength / colour of light will be absorbed / transmitted / reflected 1

(d) 1 mol of H_2O_2 oxidises 2 mol of Co^{2+}

Or $H_2O_2 + 2Co^{2+} \rightarrow 2OH^- + 2Co^{3+}$ 1

M_r $CoSO_4.7H_2O = 281$

If M_r wrong, max 3 for M1, M4, M5 1

Moles Co^{2+} = 9.87 / 281 = 0.03512

1

Moles H_2O_2 = 0.03512 / 2 = 0.01756

M4 is method mark for (M3) / 2 (also scores M1)

1

Volume H_2O_2 = (moles × 1000) / concentration
= 0.01756 × 1000) / 5.00

= 3.51 cm^3 / (3.51 × 10^{-3} dm^3)

Units essential for answer

M5 is method mark for (M4) x 1000 / 5
Allow 3.4 to 3.6 cm^3

If no 2:1 ratio or ratio incorrect Max 3 for M2, M3 & M5

Note: Answer of 7 cm^3 scores 3 for M2, M3, M5 (and any other wrong ratio max 3)

Answer of 16.8 cm^3 scores 3 for M1, M4, M5 (and any other wrong M_r max 3)

Answer of 33.5 cm^3 scores 1 for M5 only (so wrong M_r AND wrong ratio max 1)

1

[16]

M3.(a) Orange dichromate

Allow max 2 for three correct colours not identified to species but in correct order

1

Changes to purple / green / ruby / red-violet / violet Chromium(III)
(Note green complex can be $[Cr(H_2O)_5Cl]^{2+}$ etc)

Do not allow green with another colour

1

That changes further to blue Chromium(II)

Allow max 1 for two correct colours not identified but in correct order

1

$[Cr_2O_7]^{2-} + 14H^+ + 3Zn \rightarrow 2Cr^{3+} + 3Zn^{2+} + 7H_2O$

$2Cr^{3+} + Zn \rightarrow 2Cr^{2+} + Zn^{2+}$ /

Ignore any further reduction of Cr^{2+}

1

$[Cr_2O_7]^{2-} + 14H^+ + 4Zn \rightarrow 2Cr^{2+} + 4Zn^{2+} + 7H_2O$

Ignore additional steps e.g. formation of CrO_4^{2-}

1

(b) Green precipitate

1

(Dissolves to form a) green solution

Solution can be implied if 'dissolves' stated

1

$[Cr(H_2O)_6]^{3+} + 3OH^- \rightarrow Cr(H_2O)_3(OH)_3 + 3H_2O$

Penalise $Cr(OH)_3$ once only

1

$Cr(H_2O)_3(OH)_3 + 3OH^- \rightarrow [Cr(OH)_6]^{3-} + 3H_2O$

Allow $[Cr(H_2O)_6]^{3+} + 6OH^- \rightarrow [Cr(OH)_6]^{3-} + 6H_2O$

Allow formation of $[Cr(H_2O)_2(OH)_4]^-$ and $[Cr(H_2O)(OH)_5]^{2-}$ in balanced equations

Ignore state symbols, mark independently

1

(c) (ligand) substitution / replacement / exchange

Allow nucleophilic substitution

1

The energy levels/gaps of the <u>d</u> electrons are <u>different</u> (for each complex)

Ignore any reference to emission of light

1

So a <u>different</u> wavelength/frequency/colour/energy of light is absorbed (when d electrons are excited)

OR light is absorbed and a different wavelength/frequency/colour/energy (of light) is transmitted/reflected

1

(d) *E* O_2 (/ H_2O) > *E* Cr^{3+} (/ Cr^{2+}) / e.m.f = 1.67 V

Allow E(cell) = 1.67

1

So Cr^{2+} ions are oxidised by oxygen/air

Allow any equation of the form:

$Cr^{2+} + O_2 \rightarrow Cr^{3+}$

1

With $[Cr(H_2O)_6]^{2+}$ get $CrCO_3$

If named must be chromium(II) carbonate

1

with $[Cr(H_2O)_6]^{3+}$ get $Cr(H_2O)_3(OH)_3$ / $Cr(OH)_3$

Allow 0 to 3 waters in the complex

1

and CO_2

Can score M3, M4, M5 in equations even if unbalanced

1

Cr(III) differs from Cr(II) because it is acidic / forms H^+ ions

1

because Cr^{3+} ion polarises <u>water</u>

Ignore charge/size ratio and mass/charge

1

[19]

M4.(a) Co-ordinate / dative / dative covalent / dative co-ordinate

Do not allow covalent alone

1

(b) (lone) pair of electrons on <u>oxygen/O</u>

If co-ordination to O^{2-}, CE=0

1

forms co-ordinate bond with <u>Fe</u> / donates electron pair to <u>Fe</u>

'Pair of electrons on O donated to Fe' scores M1 and M2

1

(c) 180° / 180 / 90

Allow any angle between 85 and 95

Do not allow 120 or any other incorrect angle

Ignore units eg °C

1

(d) (i) 3 : 5 / 5 FeC_2O_4 reacts with 3 MnO_4^-

Can be equation showing correct ratio

1

(ii) **M1** Moles of MnO_4^- per titration = 22.35 × 0.0193/1000 = <u>4.31×10^{-4}</u>

Method marks for each of the next steps (no arithmetic error allowed for M2):

Allow <u>4.3×10^{-4}</u> (2 sig figs)

Allow other ratios as follows:

eg from given ratio of 7/3

1

M2 moles of FeC_2O_4= ratio from (d)(i) used correctly × 4.31×10^{-4}

M2 *= 7/3 × 4.31×10^{-4} = 1.006×10^{-3}*

1

M3 moles of FeC_2O_4 in 250 cm^3 = M2 ans × 10

__M3__ = 1.006 × 10^{-3} × 10 = 1.006 × 10^{-2}

1

M4 Mass of $FeC_2O_4.2H_2O$ = M3 ans × 179.8

__M4__ = 1.006 × 10^{-2} × 179.8 = 1.81 g

1

M5 % of $FeC_2O_4.2H_2O$ = (M4 ans/1.381) × 100

__M5__ = 1.81 × 100/1.381 = 131 % (130 to 132)

1

(OR for M4 max moles of $FeC_2O_4.2H_2O$ = 1.381/179.8 (= 7.68 × 10^{-3})
for M5 % of $FeC_2O_4.2H_2O$ = (M3 ans/above M4ans) × 100)
eg using correct ratio 5/3:
Moles of FeC_2O_4 = 5/3 × 4.31 × 10^{-4} = 7.19 × 10^{-4}
Moles of FeC_2O_4 in 250 cm^3 = 7.19 × 10^{-4} × 10 = 7.19 × 10^{-3}
Mass of $FeC_2O_4.2H_2O$ = 7.19 × 10^{-3} × 179.8 = 1.29 g
% of $FeC_2O_4.2H_2O$ = 1.29 × 100/1.381 = 93.4 (allow 92.4 to 94.4)
Note correct answer (92.4 to 94.4) scores 5 marks

Allow consequentially on candidate's ratio

eg __M2__ = 5/2 × 4.31 × 10^{-4} = 1.078 × 10^{-3}

__M3__ = 1.0078 × 10^{-3} × 10 = 1.078 × 10^{-2}

__M4__ = 1.078 × 10^{-2} × 179.8 = 1.94 g

__M5__ = 1.94 × 100/1.381 = 140 % (139 to 141)

Other ratios give the following final % values

1:1 gives 56.1% (55.6 to 56.6)

5:1 gives 281% (278 to 284)

5:4 gives 70.2% (69.2 to 71.2)

[10]