M1.(a) 164.0

Must be 1 decimal place

1

(b) 17.1(%) (= 28.0 × 100 / Qa)

Consequential on their (a)

Ignore precision but must be to at least 2 sig fig.

(i.e. accept 17 or 17.07)

1

(c) (i) *Absorption* depends on (proportional to) path length / distance travelled through solution

Do not allow size.

1

(ii) To select the colour / frequency / wavelength that is (most strongly) absorbed (by the sample)

Allow the filter is chosen to complement the colour of the solution

1

(iii) Quicker to analyse extracted samples than by titration / uses smaller volumes of solution

1

[5]

M2.(a) $\Delta E = hv$

Allow = hf

1

$v = \Delta E / h = 2.84 \times 10^{-19} / 6.63 \times 10^{-34} = 4.28 \times 10^{14}$ s^{-1} / Hz

Allow 4.3×10^{14} s^{-1} / Hz

Answer must be in the range:

$4.28 - 4.30 \times 10^{14}$

1

(b) (One colour of) light is absorbed (to excite the electron)

If light emitted, CE = 0

1

The remaining colour / frequency / wavelength / energy is transmitted (through the solution)

Allow light reflected is the colour that we see.

1

(c) Bigger

1

Blue light would be absorbed

OR light that has greater energy than red light would be absorbed
OR higher frequency (of light absorbed / blue light) leads to higher *ΔE*

Can only score M2 if M1 is correct.

1

(d) Any **three** from:

- (Identity of the) metal
- Charge (on the metal) / oxidation state / charge on complex
- (Identity of the) ligands
- Co-ordination number / number of ligands
- Shape

3 max

[9]

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 d electrons are different (for each complex)

Ignore any reference to emission of light

1

So a different 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 water

Ignore charge/size ratio and mass/charge

1

[19]

M4.(a)*For reactions 1 to 3 must show complex ions as reactants and products*
Take care to look for possible identification on flow chart

Reaction 1

ammonia solution

1

W is $[Co(NH_3)_6]^{2+}$

1

$[Co(H_2O)_6]^{2+} + 6NH_3 \rightarrow [Co(NH_3)_6]^{2+} + 6H_2O$
Correct equation scores all 3 marks

1

Reaction 2
Allow oxygen, Do not allow air

H_2O_2

1

X is $[Co(NH_3)_6]^{3+}$

1

$2[Co(NH_3)_6]^{2+} + H_2O_2 \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$
Allow $2[Co(NH_3)_6]^{2+} + ½O_2 + H_2O \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$
Correct equations score all 3 marks

1

Reaction 3

HCl

Do not allow Cl^- but mark on

1

Y is $[CoCl_4]^{2-}$

1

$[Co(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CoCl_4]^{2-} + 6H_2O$/

Correct equation scores previous mark

$[Co(H_2O)_6]^{2+} + 4HCl \rightarrow [CoCl_4]^{2-} + 6H_2O + 4H_+$

This equation scores all three marks

1

Reaction 4

Na_2CO_3 Or $NaOH/NH_3$

Do not allow $CaCO_3$ as a reagent but mark on

1

Z is $CoCO_3$ $Co(OH)_2/Co(H_2O)_4(OH)_2$

1

$[Co(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow CoCO_3 + 6H_2O$ $[Co(H_2O)_6]^{2+} + 2OH^- \rightarrow Co(H_2O)_4(OH)_2 + 2H_2O$ etc

Allow waters to stay co-ordinated to Co. This mark also previous mark

Or $[Co(H_2O)_6]^{2+} + Na_2CO_3 \rightarrow CoCO_3 + 6H_2O + 2Na^+$

Allow $Co^{2+} + CO_3^{2-} \rightarrow CoCO_3$

1

(b) $SO_3^{2-} + ½O_2 \rightarrow SO_4^{2-}$

Allow multiples

1

The activation energy is lower (for the catalysed route)

Or Co^{3+} attracts SO_3^{2-}/Co^{2+} attracts SO_3^{2-}/oppositely charged

ions attract

1

$\frac{1}{2}O_2 + 2Co^{2+} + 2H^+ \rightarrow H_2O + 2Co^{3+}$

1

$2Co^{3+} + SO_3^{2-} + H_2O \rightarrow 2Co^{2+} + SO_4^{2-} + 2H^+$

Allow these equations in either order

1

[16]