

**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

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

*Allow  $4.3 \times 10^{14} \text{ s}^{-1} / \text{Hz}$*

*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  $\Delta E$

*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  $[\text{Cr}(\text{H}_2\text{O})_5\text{Cl}]^{2+}$  etc)

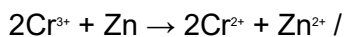
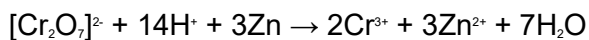
*Do not allow green with another colour*

1

That changes further to blue Chromium(II)

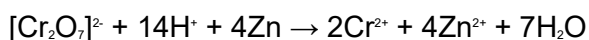
*Allow max 1 for two correct colours not identified but in correct order*

1



*Ignore any further reduction of Cr<sup>2+</sup>*

1



*Ignore additional steps e.g. formation of CrO<sub>4</sub><sup>2-</sup>*

1

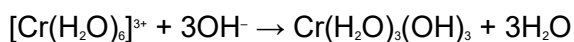
(b) Green precipitate

1

(Dissolves to form a) green solution

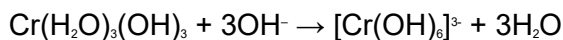
*Solution can be implied if 'dissolves' stated*

1



*Penalise Cr(OH)<sub>3</sub> once only*

1



*Allow [Cr(H<sub>2</sub>O)<sub>6</sub>]<sup>3+</sup> + 6OH<sup>-</sup> → [Cr(OH)<sub>6</sub>]<sup>3-</sup> + 6H<sub>2</sub>O*

*Allow formation of [Cr(H<sub>2</sub>O)<sub>2</sub>(OH)<sub>4</sub>]<sup>-</sup> and [Cr(H<sub>2</sub>O)(OH)<sub>3</sub>]<sup>2-</sup> 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*

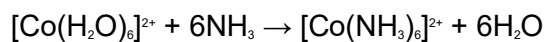
**Reaction 1**

ammonia solution

1

**W** is  $[\text{Co}(\text{NH}_3)_6]^{2+}$

1



*Correct equation scores all 3 marks*

1

**Reaction 2**

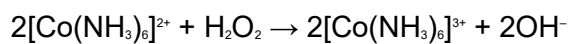
*Allow oxygen, Do not allow air*

$\text{H}_2\text{O}_2$

1

**X** is  $[\text{Co}(\text{NH}_3)_6]^{3+}$

1



*Allow  $2[\text{Co}(\text{NH}_3)_6]^{2+} + \frac{1}{2}\text{O}_2 + \text{H}_2\text{O} \rightarrow 2[\text{Co}(\text{NH}_3)_6]^{3+} + 2\text{OH}^-$*

*Correct equations score all 3 marks*

1

**Reaction 3**

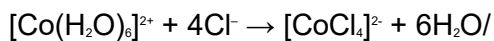
HCl

*Do not allow Cl<sup>-</sup> but mark on*

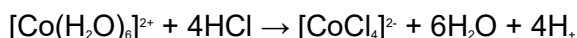
1

Y is  $[\text{CoCl}_4]^{2-}$

1



*Correct equation scores previous mark*



*This equation scores all three marks*

1

#### Reaction 4

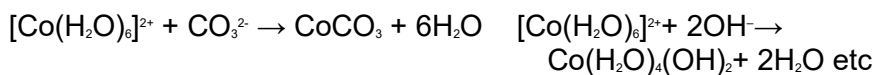
$\text{Na}_2\text{CO}_3$  Or NaOH/NH<sub>3</sub>

*Do not allow CaCO<sub>3</sub> as a reagent but mark on*

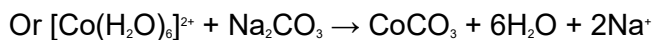
1

Z is  $\text{CoCO}_3$   $\text{Co}(\text{OH})_2/\text{Co}(\text{H}_2\text{O})_4(\text{OH})_2$

1

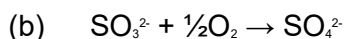


*Allow waters to stay co-ordinated to Co. This mark also previous mark*



*Allow  $\text{Co}^{2+} + \text{CO}_3^{2-} \rightarrow \text{CoCO}_3$*

1



*Allow multiples*

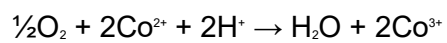
1

The activation energy is lower (for the catalysed route)

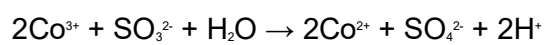
*Or  $\text{Co}^{3+}$  attracts  $\text{SO}_3^{2-}/\text{Co}^{2+}$  attracts  $\text{SO}_3^{2-}/\text{oppositely charged}$*

*ions attract*

1



1



*Allow these equations in either order*

1

**[16]**