A-Level Chemistry

Formation of Coloured Ions

Mark Scheme

Time available: 60 minutes
Marks available: 56 marks

1.

(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 490×10^{-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

4.06×10^{-n} scores 2 marks (no M2)

9.75×10^{-32} = 1 mark (M2)

1

(c) **M1** **measure** absorbance for (a range of) known concentrations

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

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2.

(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 $4.3 \times 10^{14}\ s^{-1}$ / 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

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3.

(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

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4. (a) (i) absorbs (certain frequencies of) (white) light / photons

not absorbs white / u.v. light

1

<u>d</u> electrons excited / promoted

or <u>d</u> electrons move between levels / orbitals

d electrons can be implied elsewhere in answer

1

the colour observed is the light not absorbed / light reflected / light transmitted

allow blue light transmitted

penalise emission of light in M3

1

(ii) ΔE is the energy gained by the (excited) electrons (of Cu^{2+})

allow:

- *energy difference between orbitals / sub-shells*
- *energy of photon / light absorbed*
- *change in energy of the electrons energy lost by excited electrons*
- *energy of photon / light emitted*

1

h (Planck's) constant

1

ν frequency of light (absorbed by $Cu^{2+}(aq)$)

do not allow wavelength

If energy lost / photon lost / light emitted in M1 do not penalised light emitted

1

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

note that $[CuCl_4^-]^{2-}$ is incorrect

penalise charges shown separately on the ligand and overall

penalise HCl

1

tetrahedral

1

Cl^- / Cl / chlorine too big (to fit more than 4 round Cu)

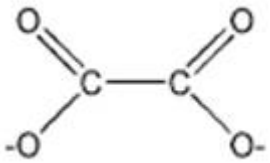
allow

water smaller than Cl^-

explanation that change in shape is due to change in co-ordination number

1

(b)



allow:

- *ion drawn with any bond angles*
- *ion in square brackets with overall / 2- charge shown outside the brackets*
- *ion with delocalised O=C–O bonds in carboxylate group(s)*

1

lone pair(s) on O^- / O

allow position of lone pair(s) shown on O in the diagram even if the diagram is incorrect.

1

(c) (i) $[Cu(H_2O)_6]^{2+} + 2C_2O_4^{2-} \rightarrow [Cu(C_2O_4)_2(H_2O)_2]^{2-} + 4H_2O$

product correct

1

equation balanced

1

6

note can only score M3 and M4 if M1 awarded or if complex in equation has 2 waters and 2 ethanedioates

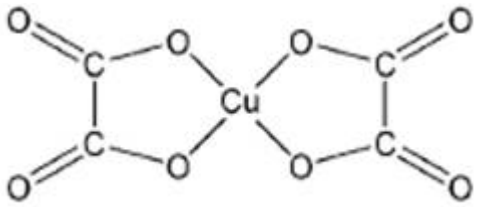
1

octahedral

If this condition is satisfied the complex can have the wrong charge(s) to allow access to M3 and M4 but not M1

1

(ii)



ignore charges

diagram must show both ethanedioates with correct bonding

ignore water

1

90°

allow 180°

mark bond angle independently but penalise if angle incorrectly labelled / indicated on diagram

1

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