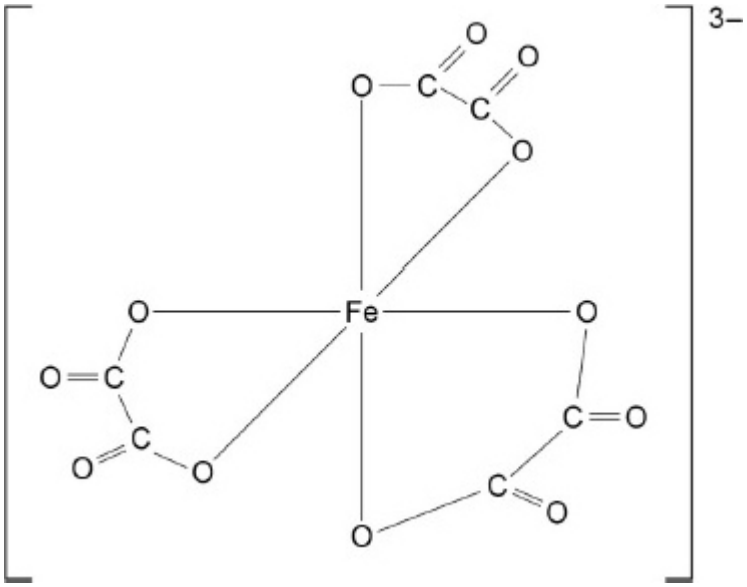
Mark schemes

Q1.

(a)



M1: 1 Mark for structure

Allow skeletal

M2: 1 mark for charge of 3-

Ignore charges inside bracket

2

(b) **M1** When bidentate/multidentate ligands replace monodentate ligands (to form a more stable complex)

M2 Because there is an increase in entropy/positive entropy change/disorder or more particles formed (so ΔG is negative and ΔH is approximately 0)

M2 Allow S increases or ΔS is positive.

Do not accept ΔS increases or S is positive

2

(c) 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.

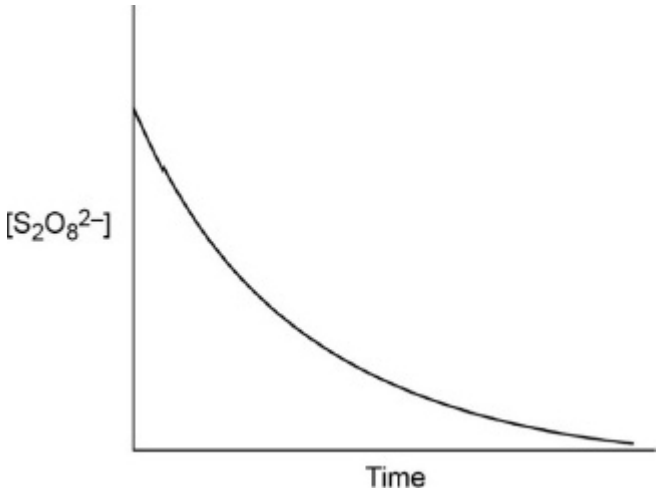
Level 1
1-2 marks
Two stages are covered but the description of each stage may be incomplete or may contain inaccuracies, OR only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes isolated statements and these are presented in a logical order.

Level 0
0 marks
Insufficient correct chemistry to gain a mark.

Indicative Chemistry Content

stage 1



1a labelled axes
and *concentration (of $S_2O_8^{2-}$ ions) decreasing with time (ignore units)*
1b downwards curve of reducing steepness

stage 2 explanation
2a (reaction slow) because $S_2O_8^{2-}$ and I^- repel/high Ea
OR
(reaction slow) because two negative ions repel/high Ea

2b Fe^{2+} attracts the $S_2O_8^{2-}$ so lower E_a
OR
Fe^{2+} and $S_2O_8^{2-}$ oppositely charged so lower Ea

2c Iron/Fe has a variable oxidation state

OR

Fe^{2+} oxidised to Fe^{3+}
OR
$Fe^{2+} \rightarrow Fe^{3+} + e^-$
stage 3 equations
3a $2 Fe^{2+} + S_2O_8^{2-} \rightarrow 2 SO_4^{2-} + 2 Fe^{3+}$
3b $2 Fe^{3+} + 2 I^- \rightarrow 2 Fe^{2+} + I_2$
3c $S_2O_8^{2-} + 2 I^- \rightarrow 2 SO_4^{2-} + I_2$
Allow equations with hexaaqua ions

6

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

1

(e) Green precipitate

$[Fe(H_2O)_6]^{2+} + Na_2CO_3 \rightarrow FeCO_3 + 6\ H_2O + 2Na^+$

OR

$[Fe(H_2O)_6]^{2+} + CO_3^{2-} \rightarrow FeCO_3 + 6\ H_2O$
Ignore state symbols

2

(f) $2[Fe(H_2O)_6]^{3+} + 3\ Na_2CO_3 \rightarrow 2\ [Fe(H_2O)_3(OH)_3] + 3\ CO_2 + 3\ H_2O + 6Na^+$

OR

$2\ [Fe(H2O)6]^{3+} + 3\ CO3^{2-} \rightarrow 2\ [Fe(H2O)3(OH)3] + 3\ CO2 + 3\ H2O$
Ignore state symbols

1

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Q2.

(a)

This question is marked using Levels of Response. Refer to the Mark Scheme Instructions for Examiners for guidance.	
Level 3 5-6 marks	All stages are covered, and the explanation of each stage is correct and virtually complete Answer communicates the whole explanation coherently and shows a logical progression through all three stages.
Level 2 3-4 marks	All stages are covered but the explanation 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 coherent and shows some progression through all three stages. Some steps in each stage may be incomplete.
Level 1 1-2 marks	Two stages are covered but the explanation 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 shows some progression between two stages.
0 mark	Insufficient correct chemistry to gain a mark.

Indicative Chemistry content

<u>Stage 1 absorption of light</u>
(3/4 virtually complete, 1/4 for covered)

1a d orbitals have different energy/d orbital (energies) are split

1b Electrons move to higher (energy) (d) orbitals/electrons move to excited state

1c Absorb visible/white light

1d Colour seen is that from complementary colours/colours transmitted/reflected/not absorbed

Stage 2 reasons for different colours
(3/4 virtually complete, 1/4 for covered)

2a The metal

2b The oxidation state (of the metal)/charge of metal (ion)

2c The ligand(s)

2d The co-ordination number/shape

Stage 3 Colorimetry
(2/3 virtually complete, 1/3 for covered)

3a Measure the absorbance for a range of (known) concentrations

3b Plot graph of absorbance v concentration/calibration curve (of absorbance v concentration)

3c Measure absorbance of the coloured complex **and** find concentration from graph

6

(b) **M1** Wavelength = 800 (nm) ± 5
Range 2.47 x 10^{-19} to 2.502 x 10^{-19} = 3/3
Range 2.47 x 10^{-28} to 2.502 x 10^{-28} = 2/3
800 nm on bottom of expression scores M1

M2 $\Delta E \left(= \frac{hc}{\lambda}\right) = \frac{6.63 \times 10^{-34} \times 3.00 \times 10^{8}}{M1 \times 10^{-9}}$

M3 2.49 × 10^{-19} (J) (allow ECF from M1 or M2)
At least 2sf
NOT ECF from M2 if equation re-arranged incorrectly

3

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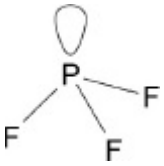
Q3.

(a) (Central) metal atom/ion surrounded by ligands

Allow complex in which number of coordinate bonds exceeds oxidation state of the metal

1

(b)



Allow diagram with 3 bonds <u>and</u> 1 lone pair

Pyramidal or tetrahedral

Allow triangular pyramid

2

(c) PF_3 is neutral **and** the complex is neutral

*Allow PF_3 has no charge **and** the complex has no charge*

Ignore electronegativity

1

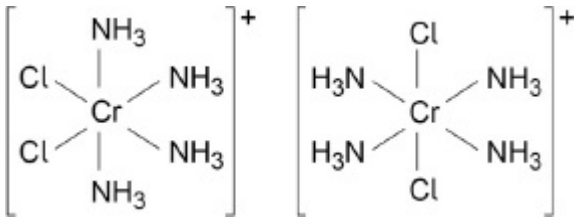
(d) (+)3

1

(e) Covalent (bond)

1

(f)



M1 for the two isomers

M2 for the charge on the complex ion.

Allow 1 mark for one correct isomer with + charge

Cis-trans/geometric/E-Z isomerism

Ignore stereoisomerism

3

(g) $[Cr(H_2O)_5Cl]Cl_2$

Allow $[Cr(H_2O)_5Cl]^{2+}$ + 2 Cl^-

1

[10]

Q4.

(a) $1s^2\ 2s^2\ 2p^6$

Allow $[He]\ 2s^2 2p^6$

1

(b) $Al_2(SO_4)_3 + 12\ H_2O \rightarrow 2\ [Al(H_2O)_6]^{3+} + 3\ SO_4^{2-}$

Allow $[Al(H_2O)_6]_2(SO_4)_3$

1

(c) **M1** Al^{3+} has a high charge **and** small size

OR

Al^{3+} has a high charge density

M2 Al^{3+} weakens the O-H bond (in water ligands and donates H^+ to water or forms H_3O^+ ions with water)

M2 *Al^{3+} attracts electrons from the O-H bond (in the ligand and releases H^+ or H_3O^+ ions)*

OR

Al^{3+} polarises the O-H bond/water molecule

2

(d) Colourless (solution)

Allow no d-d transitions (as there are no d electrons)

OR

Doesn't absorb visible light

1

(e) $[Al(H_2O)_6]^{3+} + 3\ NH_3 \rightarrow Al(H_2O)_3(OH)_3 + 3\ NH_4^+$

White ppt or white solid

*Do **not** accept effervescence*

*Do **not** accept white ppt dissolves in excess NH_3*

Ignore state symbols

2

(f) $[Al(H_2O)_6]^{3+}$

1

(g) A circle around one or more N

A circle around one or more O^-

2

(h) M1 n ($EDTA^{4-}$) added = $\underline{5 \times 10^{-4}}$ mol

alternative methods will be allowed

M2 n (Zn^{2+}) = $\underline{1.89 \times 10^{-4}}$ mol

M3 n ($EDTA^{4-}$) reacted with the 25 cm^3 sample of Al^{3+} = $5 \times 10^{-4} - 1.89 \times 10^{-4} = 3.11 \times 10^{-4}$ mol

M3 = M1 − M2

M4 n $EDTA^{4-}$ reacted with the 250 cm^3 sample of Al^{3+} = 3.11×10^{-4} **x 10** = 3.11×10^{-3} mol

$$M4 = \frac{M3 \times 250}{25}$$

M5 n $Al_2(SO_4)_3\ xH_2O$ = 3.11×10^{-3} **÷ 2** = 1.555×10^{-3} mol

M5 = M4 ÷ 2

M6 M_r $Al_2(SO_4)_3\ xH_2O$ = $1.036 \div 1.555 \times 10^{-3} = 666.2$

M6 = 1.036 ÷ M5

M7 342.3 + 18 *x* = 666(.2) so *x* = 18

$$M7 = \frac{M6 - 342.3}{18}$$ *and answer as integer*

7

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Q5.

(a) (visible/white) light <u>absorbed</u> (and (d) electrons excited)

*do **not** accept absorbs yellow light*

1

only yellow light transmitted/reflected

*do **not** accept emitted*

1

reference to light required in M1 or M2

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

*allow with **or** without numbers*

1

$6(.00) \times 10^{14}$ (s^{-1})

1

(c) (change in) oxidation state (of metal)

1

(change of) ligand

allow (change the) number of ligands

1

(change in) co-ordination number

1

(d) tetrahedral

allow tetrahedron

1

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

1

(f) deep blue

allow dark blue

1

$[CuCl_4]^{2-} + 4NH_3 + 2H_2O \rightarrow [Cu(NH_3)_4(H_2O)_2]^{2+} + 4Cl^-$

1

(g) $[Cu(EDTA)]^{2-}$

ignore absence of brackets

1

[12]

Q6.

(a) **M1** $C_{14}H_{30} \rightarrow C_6H_{12} + C_8H_{18}$ or $C_{14}H_{30} \rightarrow 2\ C_3H_6 + C_8H_{18}$

***M1** Allow any correct structural representation of tetradecane, octane, and a cycloalkane with formula C_6H_{12} OR C_3H_6*

1

M2 (catalyst is in) different phase/state (to reactants)

***M2** Assume that 'it' refers to the catalyst*

***Allow** ..... to reactants and products*

***Not** ..... to products*

1

(b) **M1** autocatalysis: product of the reaction catalyses the reaction

***Not** 'reactant'*

1

M2 slow: negative ions repel / ions of same charge repel

1

M3 high E_a

Allow** catalyst reduces E_a as an alternative for **M3

1

M4 attraction between oppositely charged ions / negative reactant ion(s) and positive catalyst / Mn^{2+} / Mn^{3+}

Not** catalyst reduces E_a as an alternative for **M4

1

M5 $4\ Mn^{2+} + MnO_4^- + 8\ H^+ \rightarrow 5\ Mn^{3+} + 4\ H_2O$

1

M6 $2\ Mn^{3+} + C_2O_4^{2-} \rightarrow 2\ Mn^{2+} + 2\ CO_2$

***Ignore** state symbols*

1

(c) **M1** idea of interchange between Co^{2+} and Co^{3+} and back to Co^{2+}

1

M2 *E*⦵ $S_2O_8^{2-}$ / SO_4^{2-} > *E*⦵ Co^{3+} / Co^{3+} and so $S_2O_8^{2-}$ ions oxidise Co^{2+}

or Co^{2+} reduce $S_2O_8^{2-}$

M2 alternatives

electrode potential for $S_2O_8^{2-}$ greater than Co^{3+} so $S_2O_8^{2-}$ ions oxidise Co^{2+}

***or** Co^{2+} ions reduce $S_2O_8^{2-}$*

***OR** 2.01 (V) > 1.82 (V) so $S_2O_8^{2-}$ ions oxidise Co^{2+}*
***or** Co^{2+} ions reduce $S_2O_8^{2-}$*

***OR** $2\ Co^{2+} + S_2O_8^{2-} \longrightarrow 2\ Co^{3+} + 2\ SO_4^{2-}$ E_{cell} = (+)0.19 (V)*

1

M3 $E^{\ominus}$ Co^{3+} / Co^{2+}) > $E^{\ominus}$ I_2 / I^- and so Co^{3+} ions oxidise I^- **or** I^- ions reduce Co^{3+}

M3 alternatives

electrode potential for Co^{3+} greater than I_2 so Co^{3+} ions oxidise I^- or I^- ions reduce Co^{3+}

***OR** 1.82 (V) > 0.54 (V) so Co^{3+} ions oxidise I^- or I^- ions reduce Co^{3+}*

***OR** $2\ Co^{3+} + 2\ I^- \longrightarrow 2\ Co^{2+} + I_2$ E_{cell} = (+)1.28 (V)*

1

*for **M2** and **M3 Allow** 1 mark (out of 2 marks) (if neither M2 or M3 already given) for combined:*

Co^{2+} ions reduce $S_2O_8^{2-}$ AND Co^{3+} oxidises I^-,

OR

*$2\ Co^{2+} + S_2O_8^{2-} \longrightarrow 2\ Co^{3+} + 2\ SO_4^{2-}$ **AND***

$2\ Co^{3+} + 2\ I^- \longrightarrow 2\ Co^{2+} + I_2$

***Not** if with negative E_{cell} value*

***Allow** if incorrect positive E_{cell} values*

[11]