Q1.

This question is about aqueous ions of the metal iron.

When an aqueous $[Fe(H_2O)_6]^{3+}$ ion reacts with ethanedioate ions, an iron(III) complex ion **X** is formed.

The only ligands in **X** are ethanedioate ions.

(a) Draw the structure of **X**.

Include the charge.

(2)

(b) The formation of **X** is an example of the chelate effect.

Explain the meaning of the chelate effect.

_____

_____

_____

_____

_____

(2)

(c) Outline how Fe^{2+} ions catalyse the reaction between $S_2O_8^{2-}$ ions and I^- ions in aqueous solution.

In your answer you should include

- a sketch graph to show how the concentration of $S_2O_8^{2-}$ ions changes over time
- an explanation of how Fe^{2+} ions catalyse the reaction, including equations
- an overall equation for the reaction.

_____

_____

_____

_____

_____

_____

(6)

(d) A student adds dilute ammonia solution to a solution containing $[Fe(H_2O)_6]^{2+}$ ions.

Give the formula of the precipitate that forms.

_____

(1)

(e) The student adds sodium carbonate solution to a solution containing $[Fe(H_2O)_6]^{2+}$ ions.

State **one** observation the student would make.

Give an equation for the reaction.

Observation _____

Equation

_____

(2)

(f) A solution containing $[Fe(H_2O)_6]^{2+}$ ions changes to a yellow-brown colour after several hours in contact with air.

The student adds sodium carbonate to the yellow-brown solution.

Give an equation for the reaction with sodium carbonate.

_____

(1)

(Total 14 marks)

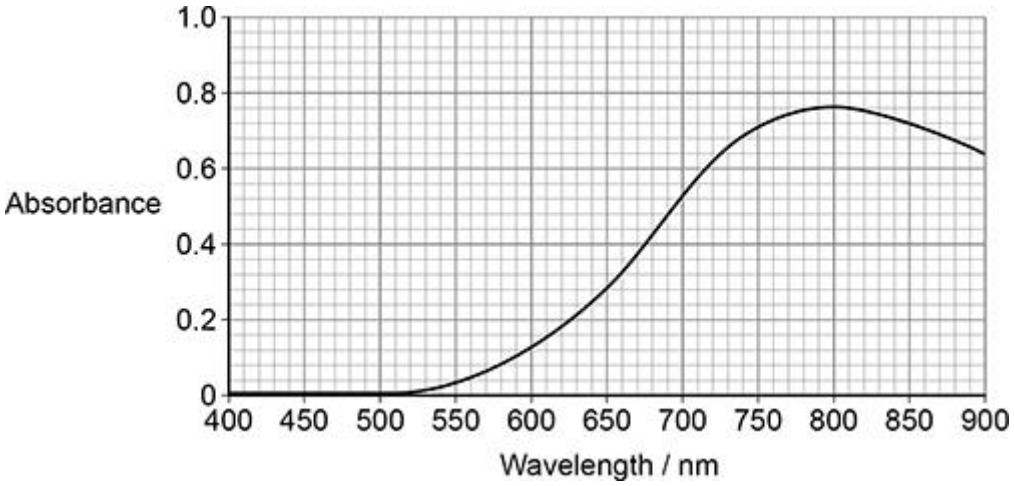
Q2.

(a) Some complexes containing transition metal ions are coloured.

- Explain why some complexes containing transition metal ions are coloured.
- List the factors that affect the colour.
- Describe how colorimetry can be used to determine the concentration of a coloured complex.

(6)

(b) The figure below shows the visible spectrum of $[Cu(H_2O)_6]^{2+}$



Use the wavelength at the peak of the curve in the figure to calculate the change in energy, in J, of an electron when it absorbs radiation with this wavelength.

The Planck constant, $h = 6.63 \times 10^{-34}$ J s

Speed of light, $c = 3.00 \times 10^{8}$ m s^{-1}

Change in energy _____ J

(3)

(Total 9 marks)

Q3.

This question is about complexes of the transition metal chromium.

(a) State the meaning of the term transition metal complex.

_____

_____

(1)

$Cr(PF_3)_6$ is a complex of chromium that contains molecules of PF_3

(b) The electron pair repulsion theory can be used to predict the shape of a PF_3 molecule.

Draw the shape of a PF_3 molecule.
Include any lone pairs of electrons that influence the shape.

Name the shape.

Shape

Name of shape _____

(2)

(c) Suggest why the oxidation state of chromium is zero in $Cr(PF_3)_6$

_____

_____

_____

(1)

The compound $[Cr(NH_3)_4Cl_2]Cl$ contains ammonia molecules.

(d) Deduce the oxidation state of chromium in $[Cr(NH_3)_4Cl_2]Cl$

_____

(1)

(e) Name the type of bond between N and H in ammonia.

_____

(1)

(f) The compound $[Cr(NH_3)_4Cl_2]Cl$ contains a complex ion that shows isomerism.

Draw the two isomers of the complex ion.

State the type of isomerism shown.

Isomer 1 Isomer 2

Type of isomerism _____

(3)

(g) Complete the equation to show the formation of **one** complex that contains chromium in its +3 oxidation state.

$CrCl_3 + 5\ H_2O \rightarrow$ _____

(1)

(Total 10 marks)

Q4.

This question is about complexes containing the aluminium ion.

(a) Give the electron configuration of the Al^{3+} ion.

_____

(1)

(b) When anhydrous aluminium sulfate, $Al_2(SO_4)_3$, is added to water a solution forms that contains the complex aluminium ion, $[Al(H_2O)_6]^{3+}$

Give the equation for the reaction.

_____

(1)

(c) Explain why the solution containing $[Al(H_2O)_6]^{3+}$ is acidic.

_____

_____

_____

_____

_____

(2)

(d) State why the concentration of aluminium sulfate solution can **not** be determined by colorimetry.

_____

_____

_____

(1)

(e) An excess of aqueous ammonia is added to a solution containing $[Al(H_2O)_6]^{3+}$

Give an ionic equation for the reaction and state one observation.

Equation

_____

Observation _____

(2)

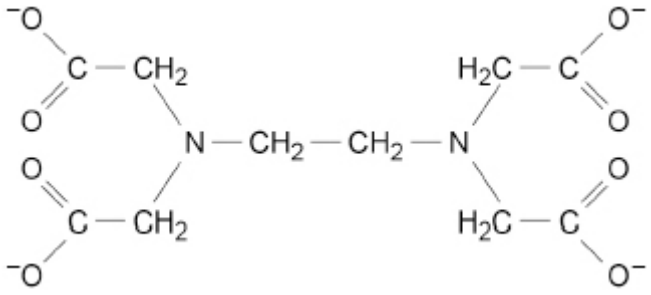
(f) An excess of dilute sulfuric acid is added to the products of the reaction in part (e).

Identify the aluminium species produced.

_____

(1)

(g) The figure below shows the structure of the $EDTA^{4-}$ ion.



Atoms of two different elements in $EDTA^{4-}$ can form co-ordinate bonds with an aluminium ion.

On the figure above, draw circles around the atoms of **two** different elements that would link to an aluminium ion by a co-ordinate bond.

(2)

(h) Hydrated aluminium sulfate, $Al_2(SO_4)_3.xH_2O$, is soluble in water.

The relative formula mass and value of *x* can be found from a titration experiment.

Aqueous $[Al(H_2O)_6]^{3+}$ ions react to form a stable complex when treated with an excess of $EDTA^{4-}$ ions.

The excess of $EDTA^{4-}$ ions is determined by titration with $ZnSO_4$ solution.

Method

- Dissolve 1.036 g of $Al_2(SO_4)_3.xH_2O$ in distilled water and make up to 250 cm^3
- Add 25.0 cm^3 of this solution to 50.0 cm^3 of a solution containing $EDTA^{4-}$ ions of concentration 0.0100 mol dm^{-3}
- Determine the excess of $EDTA^{4-}$ ions by titrating with $ZnSO_4$ solution in the presence of an indicator.

The excess of $EDTA^{4-}$ ions requires 18.00 cm^3 of 0.0105 mol dm^{-3} $ZnSO_4$ solution to react completely.

The equations for the reactions are

$$[Al(H_2O)_6]^{3+} + EDTA^{4-} \rightarrow [AlEDTA]^{-} + 6\ H_2O$$
$$[Zn(H_2O)_6]^{2+} + EDTA^{4-} \rightarrow [ZnEDTA]^{2-} + 6\ H_2O$$

For $Al_2(SO_4)_3$ M_r = 342.3

Use the information given to calculate the M_r of $Al_2(SO_4)_3.xH_2O$

Calculate x
Give your answer as an integer.

M_r _____

x _____

(7)

(Total 17 marks)

Q5.

Copper(II) complexes are coloured.
The colour is caused by the d electrons of copper moving from their ground state to an excited state.

(a) Explain why aqueous solutions containing $[CuCl_4]^{2-}$ ions are yellow.

_____

_____

_____

_____

_____

(2)

(b) When a d electron moves from the ground state to the excited state in a copper complex, the energy change is 3.98×10^{-19} J

The Planck constant, $h = 6.63 \times 10^{-34}$ J s

Calculate the frequency, in s^{-1}, of the light absorbed.

Frequency _____ s^{-1}

(2)

(c) State **three** ways in which a transition metal complex can be changed to alter its colour.

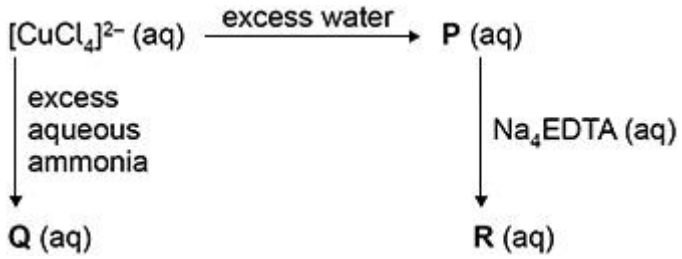
1 _____

2 _____

3 _____

(3)

Consider the following reaction scheme in which **P**, **Q** and **R** are different complex ions of copper.



(d) Name the shape of the $[CuCl_4]^{2-}$ ion.

_____

(1)

(e) Give an ionic equation for the conversion of $[CuCl_4]^{2-}$ to complex ion **P**.

_____

(1)

(f) State the colour of the solution containing the complex ion **Q**.

Give an ionic equation for the conversion of $[CuCl_4]^{2-}$ to **Q**.

Colour _____

Equation

_____

(2)

(g) Identify complex ion **R**.

_____

(1)

(Total 12 marks)

Q6.

This question is about catalysis.

(a) Zeolites are used as heterogeneous catalysts in the catalytic cracking of alkanes.

Tetradecane ($C_{14}H_{30}$) can be cracked to form octane and a cycloalkane.

Give an equation for this reaction.

State the meaning of the term heterogeneous.

Equation

_____

Heterogeneous _____

_____

_____

(2)

(b) A student determines the concentration of ethanedioate ions in an acidified solution by titration with potassium manganate(VII) solution.

$$2\ MnO_4^- + 5\ C_2O_4^{2-} + 16\ H^+ \rightarrow 2\ Mn^{2+} + 10\ CO_2 + 8\ H_2O$$

The mixture is warmed before the addition of potassium manganate(VII) solution because the reaction is slow at first. When more potassium manganate(VII) solution is added, the mixture goes colourless quickly due to the presence of an autocatalyst.

Explain the meaning of the term autocatalyst.

Explain, using equations where appropriate, why the reaction is slow at first and then goes quickly.

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(c) The reaction between peroxodisulfate ions and iodide ions in aqueous solution can be catalysed by Co^{2+} ions.

$$S_2O_8^{2-} + 2\ I^- \rightarrow 2\ SO_4^{2-} + I_2$$

The table below gives relevant standard electrode potentials.

Electrode half-equation	$E^\ominus$ / V
$S_2O_8^{2-}(aq) + 2\ e^- \rightarrow 2\ SO_4^{2-}(aq)$	+2.01
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+1.82
$I_2(aq) + 2\ e^- \rightarrow 2\ I^-(aq)$	+0.54

Use the electrode potential data to suggest how Co^{2+} catalyses the reaction.

(3)

(Total 11 marks)