Q1.

This question is about iron and its ions.

(a) Discuss the role of iron as a heterogeneous catalyst in the Haber process.

$$3\ H_2 + N_2 \rightleftharpoons 2\ NH_3$$

Your answer should include:

- the meaning of the term heterogeneous catalyst
- how iron acts as a heterogeneous catalyst
- the factors that affect the efficiency and lifetime of the catalyst.

(6)

(b) Fe^{2+} ions catalyse the reaction between peroxodisulfate(VI) ions and iodide ions in aqueous solution.

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

Explain why this reaction is slow before the catalyst is added.
Give **two** equations to show how Fe^{2+} ions catalyse this reaction.

Why reaction is slow before catalyst added _____

_____

Equation 1

_____

Equation 2

_____

(4)

(c) Give a reason why Zn^{2+} ions do **not** catalyse the reaction in part (b).

_____

_____

(1)

(d) Iron reacts with dilute hydrochloric acid to form iron(II) chloride and hydrogen.

$$Fe(s) + 2\ HCl(aq) \rightarrow FeCl_2(aq) + H_2(g)$$

A 0.998 g sample of pure iron is added to 30.0 cm^3 of 1.00 mol dm^{-3} hydrochloric acid.

One of these reagents is in excess and the other reagent limits the amount of hydrogen produced in the reaction.

Calculate the maximum volume, in m^3, of hydrogen gas produced at 30 ^oC and 100 kPa.

Give your answer to 3 significant figures.

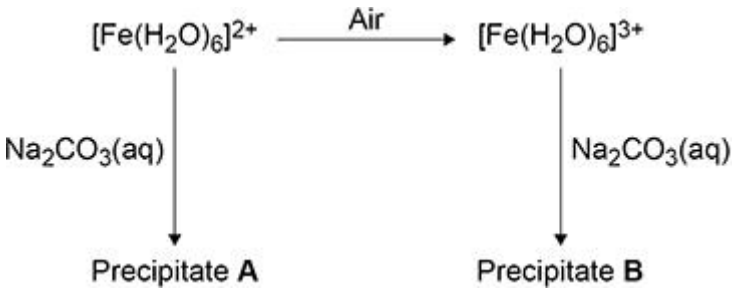
In your answer you should identify the limiting reagent in the reaction.

The gas constant, R = 8.31 J K^{-1} mol^{-1}

Volume of hydrogen _____ m^3

(6)

The figure below shows some reactions of iron ions in aqueous solution.



(e) Identify **A** and state its colour.

Identity _____

Colour _____

(2)

(f) Give the formula of **B** and state its colour.

Give an ionic equation for the reaction of $[Fe(H_2O)_6]^{3+}$ with aqueous Na_2CO_3 to form **B**.

Formula _____

Colour _____

Ionic equation

_____

(3)

(g) Explain why an aqueous solution containing $[Fe(H_2O)_6]^{3+}$ ions has a lower pH than an aqueous solution containing $[Fe(H_2O)_6]^{2+}$ ions.

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(Total 25 marks)

Q2.

Which equation does **not** show the reduction of a transition metal?

A $TiCl_4 + 2\ Mg \rightarrow Ti + 2\ MgCl_2$ ⬭

B $2\ FeCl_3 + 2\ KI \rightarrow 2\ FeCl_2 + 2\ KCl + I_2$ ⬭

C $MnO_2 + 4\ HCl \rightarrow MnCl_2 + Cl_2 + 2\ H_2O$ ⬭

D $CoO + 4\ HCl \rightarrow [CoCl_4]^{2-} + H_2O + 2\ H^+$ ⬭

(Total 1 mark)

Q3.

This question is about oxides.

(a) Sodium oxide forms a solution with a higher pH than magnesium oxide when equal amounts, in moles, of each oxide are added separately to equal volumes of water.

State why both oxides form alkaline solutions.

Suggest why sodium oxide forms a solution with a higher pH than the solution formed from magnesium oxide.

_____

_____

_____

_____

_____

(2)

(b) Give an equation for the reaction between phosphorus(V) oxide and water.

_____

(1)

(c) In the Contact process, sulfur(IV) oxide is converted into sulfur(VI) oxide using vanadium(V) oxide as a catalyst.

Give **two** equations to show how the vanadium(V) oxide acts as a catalyst in this process.

Equation 1

_____

Equation 2

_____

(2)

(Total 5 marks)

Q4.

(a) Explain why complexes formed from transition metal ions are coloured.

_____

_____

_____

_____

_____

_____

_____

(3)

The iron content of iron tablets can be determined by colorimetry.

Method:

- Dissolve a tablet in sulfuric acid.
- Oxidise all the iron from the tablet to $Fe^{3+}(aq)$.
- Convert the $Fe^{3+}(aq)$ into a complex that absorbs light of wavelength 490 nm
- Make the solution up to 250 cm^3
- Measure the absorbance of light at 490 nm with a colorimeter.
- Use a calibration graph to find the concentration of the iron(III) complex.

(b) Calculate the energy, in J, gained by each excited electron in the absorption at 490 nm

Speed of light, $c = 3.00 \times 10^{8}$ m s^{-1}
Planck constant, $h = 6.63 \times 10^{-34}$ J s

Energy gained by each electron _____ J

(3)

(c) Describe how a calibration graph is produced and used to find the concentration of the iron(III) complex.

_____

_____

_____

_____

_____

_____

_____

(3)

(d) The concentration of iron(III) in the solution is 4.66×10^{-3} mol dm^{-3}

Calculate the mass, in mg, of iron in the tablet used to make the 250 cm^3 of solution.

Mass of iron in the tablet _____ mg

(2)

(Total 11 marks)

Q5.

Which shows the electron configuration of an atom of a transition metal?

A [Ar] $4s^2 3d^0$ ⬭

B [Ar] $4s^2 3d^8$ ⬭

C [Ar] $4s^2 3d^{10}$ ⬭

D [Ar] $4s^2 3d^{10} 4p^1$ ⬭

(Total 1 mark)

Q6.

Which will **not** act as a ligand in the formation of a complex ion?

A CH_4 ⬭

B CO ⬭

C H_2O ⬭

D NH_3 ⬭

(Total 1 mark)

Q7.

Which shows the correct oxidation state and co-ordination number of cobalt in $[Co(NH_3)_5Cl]Cl_2$?

	oxidation state	co-ordination number	
A	+2	5	○
B	+2	6	○
C	+3	5	○
D	+3	6	○

(Total 1 mark)

Q8.

Which statement is **not** correct?

A $CuCl_4^{2-}$ is square planar. ○

B NH_4^+ is tetrahedral. ○

C $[Co(H_2NCH_2CH_2NH_2)_3]^{2+}$ is octahedral. ○

D $[Fe(H_2O)_6]^{2+}$ is octahedral. ○

(Total 1 mark)

Q9.

Which compound decolourises acidified potassium manganate(VII) solution?

A $Al_2(SO_4)_3$ ○

B $CuSO_4$ ○

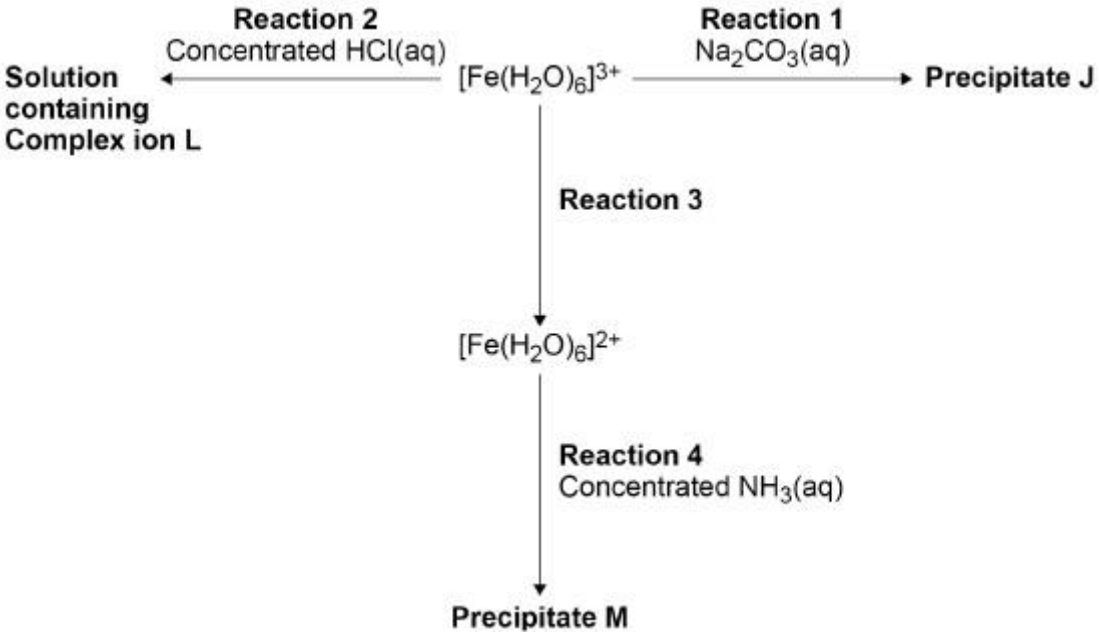
C $FeSO_4$ ○

D $Fe_2(SO_4)_3$ ○

(Total 1 mark)

Q10.

The diagram shows some reactions of aqueous iron ions.



(a) Give the formula of **Precipitate J** and state its colour.

Give an equation for **Reaction 1**.

Formula of **J**

_____

Colour

_____

Equation

_____

(3)

(b) Give the formula of **L** and an equation for **Reaction 2**.

Formula of **L**

_____

Equation

_____

(2)

(c) Suggest a reagent for **Reaction 3**.

_____

(1)

(d) Give the formula of **Precipitate M** and state its colour.

Formula of **M**

_____

Colour

_____

(2)

(e) Transition metal complexes have different shapes and many show isomerism.

Describe the different shapes of complexes and show how they lead to different types of isomerism.
Use examples of complexes of cobalt(II) and platinum(II).

You should draw the structures of the examples chosen.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(6)

(Total 14 marks)

Q11.

This question is about some Group 7 compounds.

(a) Solid sodium chloride reacts with concentrated sulfuric acid.

Give an equation for this reaction.
State the role of the sulfuric acid in this reaction.

Equation

_____

Role

_____

(2)

(b) Fumes of sulfur dioxide are formed when sodium bromide reacts with concentrated sulfuric acid.

For **this** reaction
- give an equation
- give **one** other observation
- state the role of the sulfuric acid.

Equation

_____

Observation

_____

_____

Role

_____

(3)

(c) Chlorine reacts with hot aqueous sodium hydroxide as shown in the equation.

$$3\ Cl_2 + 6\ NaOH \rightarrow NaClO_3 + 5\ NaCl + 3\ H_2O$$

Give the oxidation state of chlorine in $NaClO_3$ and in NaCl

$NaClO_3$ _____

NaCl _____

(1)

(d) State, in terms of redox, what happens to chlorine in the reaction in part **(c)**.

_____

_____

(1)

(e) Solution **Y** contains **two** different negative ions.

To a sample of solution **Y** in a test tube a student adds
- silver nitrate solution
- then an excess of dilute nitric acid
- finally an excess of concentrated ammonia solution.

The observations after each addition are recorded in the table.

Reagent added to solution Y	**Observation**
silver nitrate solution	cream precipitate containing compound **D** and compound **E**
excess dilute nitric acid	cream precipitate **D** and bubbles of gas **F**
excess concentrated ammonia solution	colourless solution containing complex ion **G**

Give the formulas of **D**, **E** and **F**.
Give an **ionic** equation to show the formation of **E**.
Give an equation to show the conversion of **D** into **G**.

Formula of **D**

_____

Formula of **E**

_____

Formula of **F**

_____

Ionic equation to form **E**

_____

Equation to show the conversion of **D** into **G**

_____

(6)

(Total 13 marks)

Q12.

A student does an experiment to determine the percentage of copper in an alloy.

The student

- reacts 985 mg of the alloy with concentrated nitric acid to form a solution (all of the copper in the alloy reacts to form aqueous copper(II) ions)
- pours the solution into a volumetric flask and makes the volume up to 250 cm^3 with distilled water
- shakes the flask thoroughly
- transfers 25.0 cm^3 of the solution into a conical flask and adds an excess of potassium iodide
- uses exactly 9.00 cm^3 of 0.0800 mol dm^{-3} sodium thiosulfate ($Na_2S_2O_3$) solution to react with all the iodine produced.

The equations for the reactions are

$$2\ Cu^{2+} + 4\ I^- \rightarrow 2\ CuI + I_2$$

$$2\ S_2O_3^{2-} + I_2 \rightarrow 2\ I^- + S_4O_6^{2-}$$

(a) Calculate the percentage of copper by mass in the alloy.

Give your answer to the appropriate number of significant figures.

% copper _____

(6)

(b) Suggest **two** ways that the student could reduce the percentage uncertainty in the measurement of the volume of sodium thiosulfate solution, using the same apparatus as this experiment.

1 _____

_____

2 _____

_____

3 _____

_____

(2)

(c) State the role of iodine in the reaction with sodium thiosulfate.

_____

(1)

(d) Give the full electron configuration of a copper(II) ion.

_____

(1)

(e) Copper(I) iodide is a white solid.

Explain why copper(I) iodide is white.

_____

_____

_____

_____

_____

_____

(2)

(f) Iodine vaporises easily.

Calculate the volume, in cm^3, that 5.00 g of iodine vapour occupies at 185 °C and 100 kPa

The gas constant $R = 8.31\ J\ K^{-1}\ mol^{-1}$

Give your answer to 3 significant figures.

Volume _____ cm^3

(4)

(Total 16 marks)

Q13.

The percentage by mass of iron in a steel wire is determined by a student.

The student

- reacts 680 mg of the wire with an excess of sulfuric acid, so that all of the iron in the wire forms $Fe^{2+}(aq)$
- makes up the volume of the $Fe^{2+}(aq)$ solution to exactly 100 cm^3
- takes 25.0 cm^3 portions of the $Fe^{2+}(aq)$ solution
- titrates each portion with 0.0200 mol dm^{-3} potassium manganate(VII) solution.

(a) Give the equation for the reaction between iron and sulfuric acid.

_____

(1)

(b) The titration results are shown in the table.

	1	**2**	**3**
Final volume / cm^3	22.90	45.60	22.60
Initial volume / cm^3	0.00	22.90	0.00
Titre / cm^3	22.90	22.70	22.60

Calculate the mean titre.

Mean titre _____ cm^3

(1)

(c) Give the overall ionic equation for the oxidation of Fe^{2+} by manganate(VII) ions, in acidic conditions.

_____

(1)

(d) State the colour change seen at the end point of the titration.

_____

(1)

(e) Name the piece of apparatus used for these stages of the method.

Taking the 25.0 cm^3 portions _____

Adding the
potassium manganate(VII) solution _____

(1)

(f) The balance used to weigh the 680 mg of iron wire has an uncertainty of ±0.005 g

A container was weighed and its mass was subtracted from the total mass of the container and wire.

Calculate the percentage uncertainty in using the balance.

% uncertainty _____

(1)

(Total 6 marks)

Q14.

What is observed when concentrated hydrochloric acid is added to an aqueous solution of $CuSO_4$until no further change occurs?

A A colourless gas is evolved and a precipitate forms. ⬭

B A colourless gas is evolved and no precipitate forms. ⬭

C A precipitate forms that dissolves in an excess of concentrated hydrochloric acid. ⬭

D The solution changes colour and no precipitate forms. ⬭

(Total 1 mark)

Q15.

The equation for the reaction between ammonia and oxygen is shown.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -905 \text{ kJ mol}^{-1}$$

Some standard entropies are given in the table.

Gas	S^o **/ J K^{-1} mol^{-1}**
$NH_3(g)$	193
$O_2(g)$	205
$NO(g)$	211
$H_2O(g)$	189

(a) Calculate the entropy change for the reaction between ammonia and oxygen.

Entropy change _____ J K^{-1} mol^{-1}

(2)

(b) Calculate a value for the Gibbs free-energy change (ΔG), in kJ mol^{-1}, for the reaction between ammonia and oxygen at 600 °C

(If you were unable to obtain an answer to part (a), you should assume that the entropy change is 211 J K^{-1} mol^{-1}. This is not the correct answer.)

ΔG _____ kJ mol^{-1}

(2)

(c) The reaction between ammonia and oxygen was carried out at a higher temperature.

Explain how this change affects the value of ΔG for the reaction.

_____

_____

_____

_____

_____

(2)

(d) Platinum acts as a heterogeneous catalyst in the reaction between ammonia and oxygen. It provides an alternative reaction route with a lower activation energy.

Describe the stages of this alternative route.

_____

_____

_____

_____

_____

_____

_____

_____

_____

_____

(3)

(e) Deduce the change in oxidation state of nitrogen, when NH_3 is oxidised to NO

_____

(1)

(f) When ammonia reacts with oxygen, nitrous oxide (N_2O) can be produced instead of NO

Give an equation for this reaction.

_____

(1)

(Total 11 marks)

Q16.

This question is about vanadium compounds and ions.

(a) Use data from Table 4 to identify the species that can be used to reduce VO_2^+ ions to VO^{2+} in aqueous solution and no further.

Explain your answer.

Electrode half-equation	$E^\ominus$ / V
$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
$Cl_2(aq) + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76

Reagent

_____

Justification

_____

_____

_____

(2)

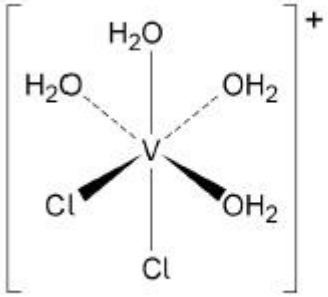
(b) Give the oxidation state of vanadium in $[VO(H_2O)_5]^{2+}$

_____

(1)

(c) The $[V(H_2O)_4Cl_2]^+$ ion exists as two isomers. One isomer is shown.

Draw the structure of the other isomer and state the type of isomerism.



Type of isomerism

_____

(2)

(d) Heating NH_4VO_3 produces vanadium(V) oxide, water and one other product.

Give an equation for the reaction.

_____

(1)

(e) Vanadium(V) oxide is the catalyst used in the manufacture of sulfur trioxide.

Give **two** equations to show how the catalyst is used and regenerated.

_____

_____

(1)

(Total 7 marks)

Q17.

Which statement is correct about this reaction?

$$[Co(NH_3)6]^{2+} + 3H_2NCH_2CH_2NH_2 \rightarrow [Co(H_2NCH_2CH_2NH_2)_3]^{2+} + 6NH_3$$

A The co-ordination number of cobalt decreases. ⬭

B The enthalpy change is large and positive. ⬭

C The entropy change is large and positive. ⬭

D The shape of the complex changes from octahedral. ⬭

(Total 1 mark)

Q18.

Which complex exists as optical isomers?

A $[Ag(NH_3)_2]^+$ ⬭

B $[Co(C_2O_4)_3]^{4-}$ ⬭

C $[Cu(EDTA)]^{2-}$ ⬭

D $[Cu(NH_3)_4(H_2O)_2]^{2+}$ ⬭

(Total 1 mark)

Q19.

Solution **A** contains the compound $[Cu(H_2O)_6]Cl_2$

(a) State the type of bonding between the oxygen and hydrogen in this compound.

_____

(1)

(b) State why the chloride ions in this compound are **not** considered to be ligands.

_____

_____

_____

(1)

(c) An excess of ammonia was added to a sample of solution **A** to form solution **B**.

Write an ionic equation for the reaction that occurs when solution **A** is converted into solution **B** and state the colour of solution **B**.

Equation

_____

_____

Colour

_____

(2)

(d) Aqueous sodium carbonate was added to another sample of solution **A** to form a blue-green solid **C**.

Identify the blue-green solid **C**.

_____

(1)

(e) Reagent **D** was added to another sample of solution **A** to form a yellow-green solution.

Identify reagent **D** and write an ionic equation for the reaction that occurs when the yellow-green solution is formed from solution **A**.

Identity of reagent **D**

_____

Equation

_____

_____

(2)

(f) Explain why colorimetry cannot be used to determine the concentration of solutions containing $[CuCl_2]^-$

In your answer refer to the electron configuration of the metal ion.

_____

_____

_____

_____

(2)

(Total 9 marks)

Q20.

This question is about compounds containing ethanedioate ions.

(a) A white solid is a mixture of sodium ethanedioate ($Na_2C_2O_4$), ethanedioic acid dihydrate ($H_2C_2O_4.2H_2O$) and an inert solid. A volumetric flask contained 1.90 g of this solid mixture in 250 cm^3 of aqueous solution.

Two different titrations were carried out using this solution.

In the first titration 25.0 cm^3 of the solution were added to an excess of sulfuric acid in a conical flask. The flask and contents were heated to 60 °C and then titrated with a 0.0200 mol dm^{-3} solution of potassium manganate(VII). When 26.50 cm^3 of potassium manganate(VII) had been added the solution changed colour.

The equation for this reaction is

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

In the second titration 25.0 cm^3 of the solution were titrated with a 0.100 mol dm^{-3} solution of sodium hydroxide using phenolphthalein as an indicator. The indicator changed colour after the addition of 10.45 cm^3 of sodium hydroxide solution.

The equation for this reaction is

$$H_2C_2O_4 + 2OH^- \rightarrow C_2O_4^{2-} + 2H_2O$$

Calculate the percentage by mass of sodium ethanedioate in the white solid.

Give your answer to the appropriate number of significant figures.

Show your working.

Percentage by mass of sodium ethanedioate _____ %

(8)

(b) Ethanedioate ions react with aqueous iron(III) ions in a ligand substitution reaction.

Write an equation for this reaction.

Suggest why the value of the enthalpy change for this reaction is close to zero.

_____

_____

_____

_____

(2)

(c) Draw the displayed formula of the iron complex produced in the reaction in part (b)

Indicate the value of the O—Fe—O bond angle.

State the type of isomerism shown by the iron complex.

Bond angle

_____

Type of isomerism

_____

(3)

(d) Ethanedioate ions are poisonous because they react with iron ions in the body. Ethanedioate ions are present in foods such as broccoli and spinach.

Suggest one reason why people who eat these foods do not suffer from poisoning.

_____

_____

(1)

(Total 14 marks)

Q21.

Which is **not** a correct statement?

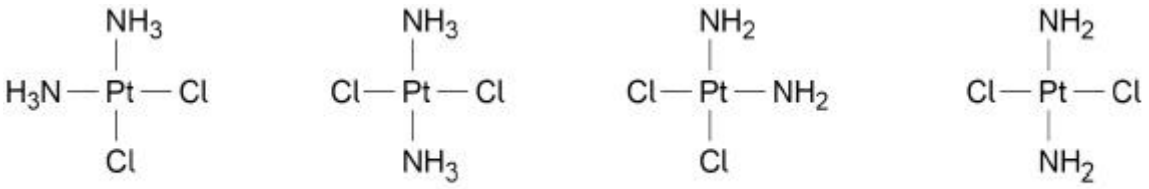
A	Transition metals form coloured ions and complexes	⬭
B	Transition metals display variable oxidation states	⬭
C	A ligand accepts a pair of electrons from a transition metal	⬭
D	A complex is a central metal atom or ion surrounded by ligands	⬭

(Total 1 mark)

Q22.

Cisplatin is an anti-cancer drug.

Which structure represents a stereoisomer of cisplatin?



A **B** **C** **D**

A ⬭

B ⬭

C ⬭

D ⬭

(Total 1 mark)

Q23.

A solution absorbs light with wavelengths corresponding to red, yellow and green light.

Which ion is most likely to be in the solution?

A $Cr_2O_7^{2-}(aq)$ ⬭

B $Fe^{2+}(aq)$ ⬭

C $Fe^{3+}(aq)$ ⬭

D $Cu^{2+}(aq)$ ⬭

(Total 1 mark)

Q24.

Iron forms many complexes that contain iron in oxidation states +2 and +3.

(a) Hexaaquairon(III) ions react with an excess of hydrochloric acid in a ligand substitution reaction.

Write an equation for this reaction.

_____

(1)

(b) Explain why the initial and final iron(III) complexes in the equation above have different shapes.

_____

_____

_____

_____

_____

(2)

(c) Hexaaquairon(II) ions react with an excess of $H_2NCH_2CH_2NH_2$ in a ligand substitution reaction.

Draw the structure of the iron(II) complex formed showing its charge.

(2)

(d) Hexaaquairon(II) ions react with an excess of $H_2NCH_2CH_2NH_2$ in a ligand substitution reaction.

Which of the following shows the correct change in entropy for a reaction of hexaaquairon(II) ions with $H_2NCH_2CH_2NH_2$?

Tick (✓) **one** box.

change in entropy is negative ☐

change in entropy is close to zero ☐

change in entropy is positive ☐

(1)

(e) The percentage of iron(II) sulfate in iron tablets can be determined by titration with potassium manganate(VII) in acidic solution.

Deduce an ionic equation for the reaction of iron(II) ions with manganate(VII) ions.

_____

(1)

(f) A student dissolved 1980 mg of iron tablets in an excess of dilute sulfuric acid.
The solution was titrated with 0.0200 mol dm^{-3} potassium manganate(VII) solution. A 32.50 cm^3 volume of potassium manganate(VII) solution was required to reach the end point in the titration.

Calculate the percentage of iron in the sample of iron tablets.

Give your answer to the appropriate number of significant figures.

Percentage _____ %

(4)

(g) State the colour change at the end point in this titration.

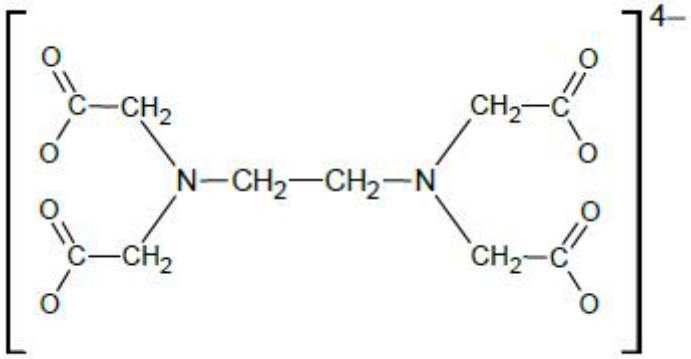
_____

(1)

(Total 12 marks)

Q25.

EDTA is a useful laboratory chemical and is found in a wide variety of commercial products including detergents. It is very soluble in water and is often used in its ionic form $EDTA^{4-}$ as shown in the diagram below.



(a) $EDTA^{4-}$ can act as a multidentate ligand.

Explain the meanings of the terms **multidentate** and **ligand** with reference to the reaction of $EDTA^{4-}$ with $[Cu(H_2O)_6^{2+}](aq)$ ions to form a complex ion.

Draw on the diagram above a separate circle around each atom that bonds to the Cu^{2+} ion in this complex ion.

Multidentate

_____

_____

Ligand

_____

_____

(3)

(b) Copper(II) compounds may be used as fungicides in vineyards. When used in this way, copper(II) ions can enter the water supply and cause problems because they are toxic in high concentrations.

The water supply near a vineyard can be tested for copper(II) ions by forming a blue aqueous complex with $EDTA^{4-}$ ions. The concentration of this complex can be determined using a colorimeter.

Outline the practical steps that you would follow, using colorimetry, to determine the concentration of this complex in a sample of water.

_____

_____

_____

_____

_____

_____

(3)

(c) The concentration of copper(II) ions, in the sample of water, determined by colorimetry was 7.56×10^{-5} mol dm^{-3}.

This result was checked by titrating a sample of the water with a solution containing $EDTA^{4-}(aq)$ ions.

The $EDTA^{4-}(aq)$ used in the titration had a concentration of 1.00×10^{-3} mol dm^{-3}.

Write an equation for the reaction between $[Cu(H_2O)_6]^{2+}$ and $EDTA^{4-}$ ions.

Calculate the volume of the $EDTA^{4-}$ solution needed to react with a 25.0 cm^3 sample of the water.

Justify whether this titration will give an accurate value for the concentration of copper(II) ions. If necessary, suggest a practical step that would improve the accuracy.

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(5)

(Total 11 marks)

Q26.

Electrons in copper(II) ions can be excited by the absorption of light with a wavelength of 600 nm.

What is the increase in energy, in J, for each electron excited?

Speed of light, c = 3.00 × 10^{8} m s^{-1}
Planck's constant, h = 6.63 × 10^{-34}J s

A 3.98 × 10^{-40} ⬭

B 1.33 × 10^{-39} ⬭

C 3.32 × 10^{-28} ⬭

D 3.32 × 10^{-19} ⬭

(Total 1 mark)

Q27.

An oxide of vanadium catalyses the following reaction:

$$SO_2(g) + \frac{1}{2}O_2(g) \rightleftharpoons SO_3(g)$$

What is the formula of the vanadium-containing intermediate formed in this reaction?

A V_2O ○

B VO ○

C V_2O_3 ○

D V_2O_4 ○

(Total 1 mark)

Q28.

(a) A co-ordinate bond is formed when a transition metal ion reacts with a ligand.

Explain how this co-ordinate bond is formed.

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(2)

(b) Describe what you would observe when dilute aqueous ammonia is added dropwise, to excess, to an aqueous solution containing copper(II) ions. Write equations for the reactions that occur.

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(4)

(c) When the complex ion $[Cu(NH_3)_4(H_2O)_2]^{2+}$ reacts with 1,2-diaminoethane, the ammonia molecules but not the water molecules are replaced.

Write an equation for this reaction.

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(1)

(d) Suggest why the enthalpy change for the reaction in part **(c)** is approximately zero.

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(2)

(e) Explain why the reaction in part **(c)** occurs despite having an enthalpy change that is approximately zero.

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(2)

(Total 11 marks)