

**Q1.**A green solution, **X**, is thought to contain  $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$  ions.

- (a) The presence of these ions can be confirmed by reacting separate samples of solution **X** with aqueous ammonia and with aqueous sodium carbonate.

Write equations for each of these reactions and describe what you would observe.

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(4)

- (b) A  $50.0 \text{ cm}^3$  sample of solution **X** was added to  $50 \text{ cm}^3$  of dilute sulfuric acid and made up to  $250 \text{ cm}^3$  of solution in a volumetric flask.

A  $25.0 \text{ cm}^3$  sample of this solution from the volumetric flask was titrated with a  $0.0205 \text{ mol dm}^{-3}$  solution of  $\text{KMnO}_4$   
At the end point of the reaction, the volume of  $\text{KMnO}_4$  solution added was  $18.70 \text{ cm}^3$ .

- (i) State the colour change that occurs at the end point of this titration and give a reason for the colour change.

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- (ii) Write an equation for the reaction between iron(II) ions and manganate(VII)

ions.

Use this equation and the information given to calculate the concentration of iron(II) ions in the original solution **X**.

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(5)  
(Total 11 marks)

**Q2.** Transition metal compounds have a range of applications as catalysts.

- (a) State the general property of transition metals that allows the vanadium in vanadium(V) oxide to act as a catalyst in the Contact Process.

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(1)

- (b) Write **two** equations to show how vanadium(V) oxide acts as a catalyst in the Contact Process.

Equation 1

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Equation 2

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(2)

(c) In the Contact Process, vanadium(V) oxide acts as a heterogeneous catalyst.

(i) Give the meaning of the term *heterogeneous*.

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(ii) Give **one** reason why impurities in the reactants can cause problems in processes that use heterogeneous catalysts.

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(1)

(d) The oxidation of  $\text{C}_2\text{O}_4^{2-}$  ions by  $\text{MnO}_4^-$  ions in acidic solution is an example of a reaction that is autocatalysed.

(i) Give the meaning of the term *autocatalysed*.

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(1)

(ii) Identify the autocatalyst in this reaction.

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(1)

(iii) Write **two** equations to show how the autocatalyst is involved in this oxidation of  $\text{C}_2\text{O}_4^{2-}$  ions.

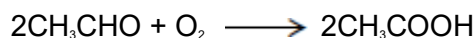
Equation 1

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Equation 2  
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(2)  
(Total 9 marks)

**Q3.** This question explores some reactions and some uses of cobalt compounds.

- (a) Ethanal is oxidised to ethanoic acid by oxygen. The equation for this reaction is



This redox reaction is slow at room temperature but speeds up in the presence of cobalt compounds.

Explain why a cobalt compound is able to act as a catalyst for this process.

Illustrate your explanation with **two** equations to suggest how, in the presence of water and hydrogen ions,  $\text{Co}^{3+}$  and then  $\text{Co}^{2+}$  ions could be involved in catalysing this reaction.

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- (b) In aqueous solution, the  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$  ion reacts with an excess of ethane-1,2-diamine to form the complex ion **Y**.

- (i) Write an equation for this reaction.

Explain, in terms of the chelate effect, why the complex ion **Y** is formed in preference to the  $[\text{Co}(\text{H}_2\text{O})_6]^{2+}$  complex ion.

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(3)

(ii) Draw a diagram that shows the shape of the complex ion **Y** and shows the type of bond between the ethane-1,2-diamine molecules and the cobalt.

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(c) Compound **Z** is a complex that contains only cobalt, nitrogen, hydrogen and chlorine.

A solid sample of **Z** was prepared by reaction of  $50 \text{ cm}^3$  of  $0.203 \text{ mol dm}^{-3}$  aqueous cobalt(II) chloride with ammonia and an oxidising agent followed by hydrochloric acid.

When this sample of **Z** was reacted with an excess of silver nitrate,  $4.22 \text{ g}$  of silver chloride were obtained.

Use this information to calculate the mole ratio of chloride ions to cobalt ions in **Z**.

Give the formula of the complex cobalt compound **Z** that you would expect to be formed in the preparation described above.

Suggest **one** reason why the mole ratio of chloride ions to cobalt ions that you have calculated is different from the expected value.

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(5)  
(Total 15 marks)

**Q4.** The table below shows some successive ionisation energy data for atoms of three different elements **X**, **Y** and **Z**.

Elements **X**, **Y** and **Z** are Ca, Sc and V but not in that order.

	First	Second	Third	Fourth	Fifth	Sixth
<b>X</b>	648	1370	2870	4600	6280	12 400
<b>Y</b>	590	1150	4940	6480	8120	10 496
<b>Z</b>	632	1240	2390	7110	8870	10 720

(a) Which element is calcium?

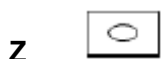
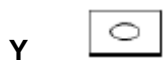
**X**

**Y**

**Z**

(1)

(b) Which element is vanadium?



(1)

(c) Justify your choice of vanadium in part (b)

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(1)

(d) An acidified solution of  $\text{NH}_4\text{VO}_3$  reacts with zinc.

Explain how observations from this reaction show that vanadium exists in at least two different oxidation states.

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(e) The vanadium in  $50.0 \text{ cm}^3$  of a  $0.800 \text{ mol dm}^{-3}$  solution of  $\text{NH}_4\text{VO}_3$  reacts with  $506 \text{ cm}^3$  of sulfur(IV) oxide gas measured at  $20.0 \text{ }^\circ\text{C}$  and  $98.0 \text{ kPa}$ .

Use this information to calculate the oxidation state of the vanadium in the solution after the reduction reaction with sulfur(IV) oxide.

Explain your working.

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

Oxidation state = .....

(6)  
(Total 11 marks)

**Q5.**When iodine molecules are dissolved in aqueous solutions containing iodide ions, they react to form triiodide ions ( $I_3^-$ ).



The reaction above between  $I^-$  ions and  $S_2O_8^{2-}$  ions has a high activation energy and  $S_2O_8^{2-}$  ions are only reduced slowly to  $SO_4^{2-}$  ions.  
The reaction is catalysed by  $Fe^{2+}$  ions.

(a) Explain why the reaction between  $I^-$  ions and  $S_2O_8^{2-}$  ions is slow.

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(1)

(b) Other than having variable oxidation states, explain why  $Fe^{2+}$  ions are good catalysts for this reaction.

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(c) Write a half-equation for the reduction of  $\text{S}_2\text{O}_8^{2-}$  ions to  $\text{SO}_4^{2-}$  ions.

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(d) Construct an overall equation for the reaction between  $\text{S}_2\text{O}_8^{2-}$  ions and  $\text{I}^-$  ions.

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(1)

(Total 4 marks)

**Q6.** A student carried out an experiment to find the mass of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  in an impure sample, **X**. The student recorded the mass of **X**. This sample was dissolved in water and made up to  $250 \text{ cm}^3$  of solution. The student found that, after an excess of acid had been added,  $25.0 \text{ cm}^3$  of this solution reacted with  $21.3 \text{ cm}^3$  of a  $0.0150 \text{ mol dm}^{-3}$  solution of  $\text{K}_2\text{Cr}_2\text{O}_7$ .

(a) Use this information to calculate a value for the mass of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  in the sample of **X**.

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(5)

- (b) The student found that the calculated mass of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  was greater than the actual mass of the sample that had been weighed out. The student realised that this could be due to the nature of the impurity.

Suggest **one** property of an impurity that would cause the calculated mass of  $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$  in **X** to be greater than the actual mass of **X**.  
Explain your answer.

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(2)

(Total 7 marks)