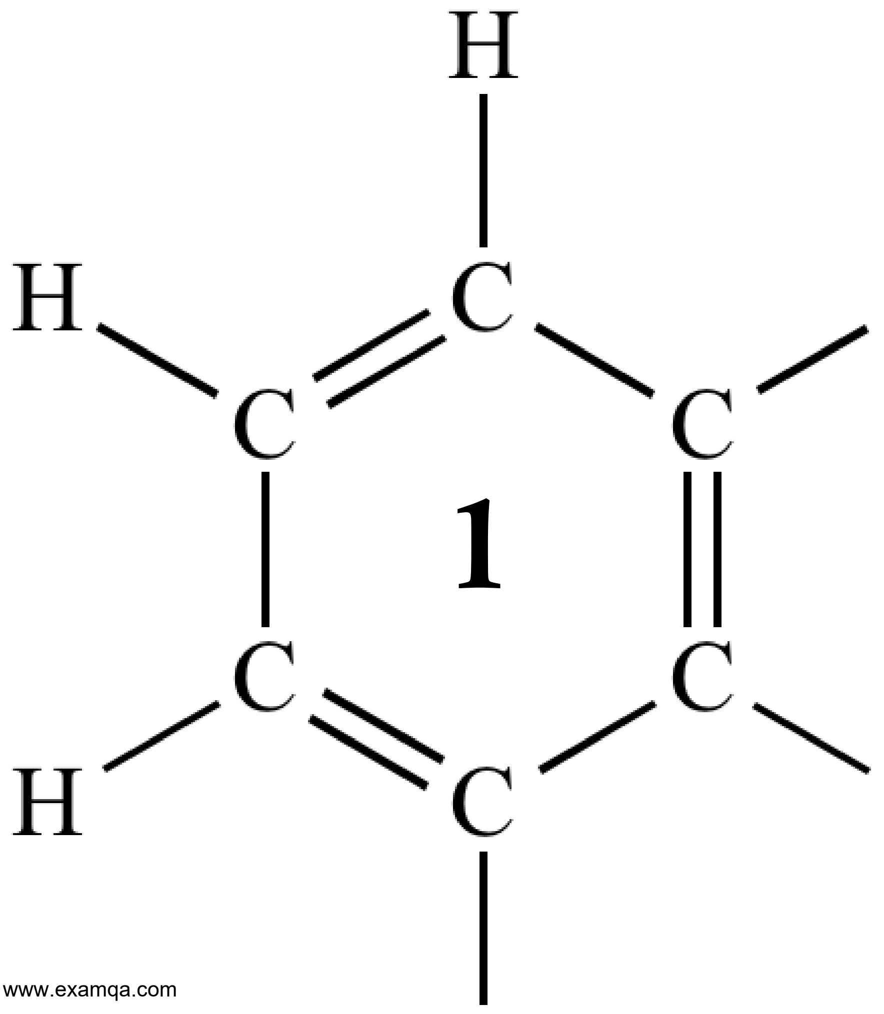
LONDON SCIENCE COLLEGE

OCR A2 CHEMISTRY

MODULE 5.6

TRANSITION ELEMENTS



1 In the Contact Process sulfur dioxide reacts with oxygen to form sulfur trioxide as shown in the equation.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$$

The table shows some thermodynamic data.

	$\Delta H_f^\ominus$/kJ mol^{-1}	$S^\ominus$/J K^{-1} mol^{-1}
$SO_2(g)$	–297	248
$O_2(g)$	0	205
$SO_3(g)$	–395	256

(a) Use data from the table to calculate the standard enthalpy change for this reaction.

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(2)

(b) Use data from the table to calculate the standard entropy change for this reaction.

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(2)

(c) State what the sign of the entropy change in your answer to part **(b)** indicates about the product of this reaction relative to the reactants.

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(1)

(d) Use your answers to parts **(a)** and **(b)** to calculate a value for the free–energy change for this reaction at 50°C.

(If you were unable to calculate ΔH in part **(a)** assume a value of –250 kJ mol^{-1}.
If you were unable to calculate ΔS in part **(b)** assume a value of –250 J K^{-1} mol^{-1}.
These are not the correct values.)

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(3)

(e) Use your answer to part **(d)** to explain whether the reaction is feasible at 50°C.

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(1)

(f) Vanadium(V) oxide acts as a heterogeneous catalyst in the Contact Process.

(i) State what is meant by the term heterogeneous.

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(1)

(ii) Write **two** equations that show how this catalyst is involved in the Contact Process.

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(2)

(iii) Suggest why the vanadium(V) oxide is used in small pellet form rather than as large lumps.

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(1)

(iv) State why the reactants should be purified before they come into contact with the vanadium(V) oxide.

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(1)
(Total 14 marks)

2 This question is about cobalt chemistry.

(a) Give the electron configuration of the Co atom and of the Co^{2+} ion.

State three characteristic features of the chemistry of cobalt and its compounds.

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(5)

(b) Ethane-1,2-diamine can act as a bidentate ligand. When $[Co(H_2O)_6]^{2+}(aq)$ ions are treated with an excess of ethane-1,2-diamine, the water ligands are replaced.

Explain what is meant by the term bidentate ligand.

Explain, with the aid of an equation, the thermodynamic reasons why this reaction occurs.

Draw a diagram to show the structure of the complex ion formed.

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(7)
(Total 12 marks)

3 A student weighed out a 2.29 g sample of impure $K_3[Fe(C_2O_4)_3].3H_2O$ and dissolved it in water.
This solution was added to a 250 cm^3 volumetric flask and made up to 250 cm^3 with distilled water.
A 25.0 cm^3 portion was pipetted into a conical flask and an excess of acid was added.
The mixture was heated to 60°C and titrated with 0.0200 mol dm^{-3} $KMnO_4$ solution.
26.40 cm^3 of $KMnO_4$ solution were needed for a complete reaction.

In this titration only the $C_2O_4^{2-}$ ions react with the $KMnO_4$ solution.

(a) The reaction between $C_2O_4^{2-}$ ions and MnO4– ions is autocatalysed.

Explain what is meant by the term autocatalysed and identify the catalyst in the reaction.

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(2)

(b) Select from the list the most suitable substance used to acidify the solution in the conical flask.
Put a tick (✓) in the correct box.

$H_2C_2O_4$ ☐

H_2SO_4 ☐

HCl ☐

HNO_3 ☐

(1)

(c) The reaction between $C_2O_4^{2-}$ ions and MnO_4^- ions is very slow at first.
Explain why the reaction is initially slow.

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(3)

(d) Write an equation for the reaction between $C_2O_4^{2-}$ ions and MnO_4^- ions in acidic solution.
Calculate the percentage purity of the original sample of $K_3[Fe(C_2O_4)_3].3H_2O$.
Give your answer to 3 significant figures.

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(7)

(e) A solution of $KMnO_4$ has an unknown concentration.

Describe briefly how colorimetry can be used to determine the concentration of this solution.

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(3)
(Total 16 marks)

4 (a) Explain how the electron pair repulsion theory can be used to deduce the shape of, and the bond angle in, PF_3

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(6)

(b) State the full electron configuration of a cobalt(II) ion.

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(1)

(c) Suggest **one** reason why electron pair repulsion theory **cannot** be used to predict the shape of the $[CoCl_4]^{2-}$ ion.

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(1)

(d) Predict the shape of, and the bond angle in, the complex rhodium ion $[RhCl_4]^{2-}$.

Shape ....

Bond angle ....

(2)
(Total 10 marks)

5 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**
X	648	1370	2870	4600	6280	12 400
Y	590	1150	4940	6480	8120	10 496
Z	632	1240	2390	7110	8870	10 720

(a) Which element is calcium?

X ☐

Y ☐

Z ☐

(1)

(b) Which element is vanadium?

X ☐

Y ☐

Z ☐

(1)

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

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(1)

(d) An acidified solution of NH_4VO_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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(2)

(e) The vanadium in 50.0 cm^3 of a 0.800 mol dm^{-3} solution of NH_4VO_3 reacts with 506 cm^3 of sulfur(IV) oxide gas measured at 20.0 °C and 98.0 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 J K^{-1} mol^{-1}.

Oxidation state = ...

(6)
(Total 11 marks)

6 (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)

7 A green solution, **X**, is thought to contain $[Fe(H_2O)_6]^{2+}$ 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 cm^3 sample of solution **X** was added to 50 cm^3 of dilute sulfuric acid and made up to 250 cm^3 of solution in a volumetric flask.

A 25.0 cm^3 sample of this solution from the volumetric flask was titrated with a 0.0205 mol dm^{-3} solution of $KMnO_4$
At the end point of the reaction, the volume of $KMnO_4$ solution added was 18.70 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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(2)

(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)

8 The redox reaction, in aqueous solution, between acidified potassium manganate(VII) and sodium ethanedioate is autocatalysed.

(a) Write an equation for this redox reaction.

Identify the species that acts as the catalyst.

Explain how the properties of the species enable it to act as a catalyst in this reaction.

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(6)

(b) Sketch a graph to show how the concentration of MnO_4^- ions varies with time in this reaction.
Explain the shape of the graph.

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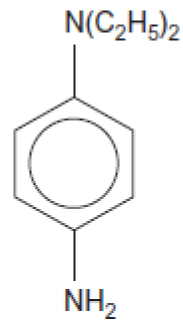
(4)
(Total 10 marks)

9 Chlorine can be found in water. One method for the determination of chlorine in water is to use colorimetry.

A colourless sample of water from a vase of flowers was analysed after the addition of compound Z as the addition of Z resulted in a purple solution.

Compound W



(a) Calculate the M_r of Compound **W**.

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(1)

(b) Determine the percentage, by mass, of nitrogen in this compound.

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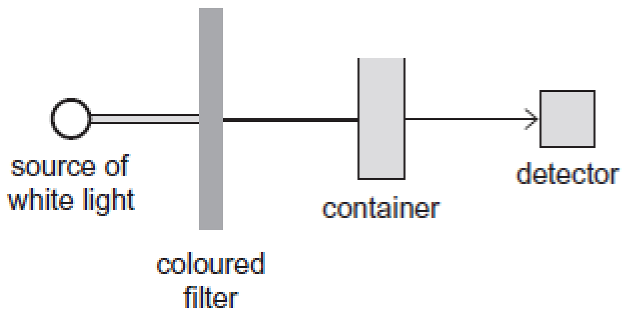
(1)

(c) A simplified diagram of a colorimeter is shown below.



(i) Suggest why it is important that the container for each sample has the same dimensions.

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(1)

(ii) Suggest why the coloured filter is used.

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(1)

(iii) Suggest **one** reason why a colorimetric method might be chosen in preference to titration.

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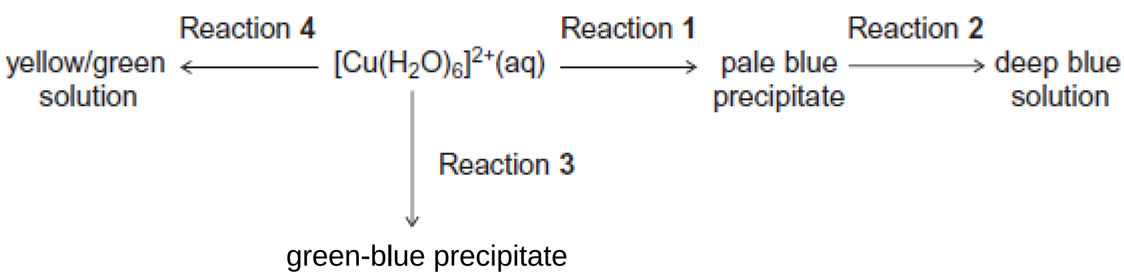
(1)

(Total 5 marks)

10 Consider the following reaction scheme that starts from aqueous $[Cu(H_2O)6]^{2+}$ ions.



For each of the reactions **1** to **4**, identify a suitable reagent, give the formula of the copper-containing species formed and write an equation for the reaction.

(a) Reaction **1**

Reagent ....

Copper-containing species ....

Equation ....

(3)

(b) Reaction **2**

Reagent ....

Copper-containing species ....

Equation ....

(3)

(c) Reaction **3**

Reagent ....

Copper-containing species ....

Equation ....

(3)

(d) Reaction **4**

Reagent ....

Copper-containing species ....

Equation ....

(3)
(Total 12 marks)