Section A

Answer **all** questions in the spaces provided.

1 This question is about bond dissociation enthalpies and their use in the calculation of enthalpy changes.

1 (a) Define *bond dissociation enthalpy* as applied to chlorine.

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(2 marks)

1 (b) Explain why the enthalpy of atomisation of chlorine is exactly half the bond dissociation enthalpy of chlorine.

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(1 mark)

1 (c) The bond dissociation enthalpy for chlorine is +242 kJ mol^{-1} and that for fluorine is +158 kJ mol^{-1}.
The standard enthalpy of formation of ClF(g) is –56 kJ mol^{-1}.

1 (c) (i) Write an equation, including state symbols, for the reaction that has an enthalpy change equal to the standard enthalpy of formation of gaseous ClF

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(1 mark)

1 (c) (ii) Calculate a value for the bond enthalpy of the Cl—F bond.

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(2 marks)

1 (c) (iii) Calculate the enthalpy of formation of gaseous chlorine trifluoride, $ClF_3(g)$.
Use the bond enthalpy value that you obtained in part **(c) (ii)**.

(If you have been unable to obtain an answer to part **(c) (ii)**, you may assume that the Cl—F bond enthalpy is +223 kJ mol^{-1}. This is **not** the correct value.)

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(3 marks)

1 (c) (iv) Explain why the enthalpy of formation of $ClF_3(g)$ that you calculated in part **(c) (iii)** is likely to be different from a data book value.

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(1 mark)

1 (d) Suggest why a value for the Na—Cl bond enthalpy is **not** found in any data book.

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(1 mark)

11

Turn over ▶

2 This table contains some values of lattice dissociation enthalpies.

Compound	$MgCl_2$	$CaCl_2$	MgO
Lattice dissociation enthalpy / kJ mol^{-1}	2493	2237	3889

2 (a) Write an equation, including state symbols, for the reaction that has an enthalpy change equal to the lattice dissociation enthalpy of magnesium chloride.

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(1 mark)

2 (b) Explain why the lattice dissociation enthalpy of magnesium chloride is greater than that of calcium chloride.

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(2 marks)

(Extra space) .....

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2 (c) Explain why the lattice dissociation enthalpy of magnesium oxide is greater than that of magnesium chloride.

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(2 marks)

(Extra space) .....

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2 (d) When magnesium chloride dissolves in water, the enthalpy of solution is –155 kJ mol^{-1}. The enthalpy of hydration of chloride ions is –364 kJ mol^{-1}.

Calculate the enthalpy of hydration of magnesium ions.

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(3 marks)

(Extra space) .....

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2 (e) Energy is released when a magnesium ion is hydrated because magnesium ions attract water molecules.

Explain why magnesium ions attract water molecules.
You may use a labelled diagram to illustrate your answer.

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(2 marks)

2 (f) Suggest why a value for the enthalpy of solution of magnesium oxide is **not** found in any data books.

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(1 mark)

11

Turn over ▶

3 The feasibility of a physical or a chemical change depends on the balance between the thermodynamic quantities of enthalpy change (ΔH), entropy change (ΔS) and temperature (T).

3 (a) Suggest how these quantities can be used to predict whether a change is feasible.

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(2 marks)

3 (b) Explain why the evaporation of water is spontaneous even though this change is endothermic.
In your answer, refer to the change in the arrangement of water molecules and the entropy change.

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(4 marks)

Question 3 continues on the next page

3 (c) This table contains some thermodynamic data for hydrogen, oxygen and water.

	$S^{\ominus}$ / J K^{-1} mol^{-1}	$\Delta H_f^{\ominus}$ / kJ mol^{-1}
$H_2(g)$	131	0
$O_2(g)$	205	0
$H_2O(g)$	189	–242
$H_2O(l)$	70	

3 (c) (i) Calculate the temperature above which the reaction between hydrogen and oxygen to form gaseous water is **not** feasible.

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(4 marks)

3 (c) (ii) State what would happen to a sample of gaseous water that was heated to a temperature higher than that of your answer to part **(c) (i)**.
Give a reason for your answer.

What would happen to gaseous water .....

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Reason .....

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(2 marks)

3 (d) When hydrogen is used as a fuel, more heat energy can be obtained if the gaseous water formed is condensed into liquid water.

Use entropy data from the table in part **(c)** to calculate the enthalpy change when one mole of gaseous water is condensed at 373 K.
Assume that the free-energy change for this condensation is zero.

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(3 marks)

15

Turn over for the next question

4 Some melting points of Period 3 oxides are given in this table.

	Na_2O	SiO_2	SO_2	SO_3
Melting point / K	1548	1883	200	290

4 (a) Explain, in terms of structure and bonding, why sodium oxide has a high melting point.

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(2 marks)

4 (b) Explain, in terms of structure and bonding, why sulfur trioxide has a higher melting point than sulfur dioxide.

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(2 marks)

4 (c) Some Period 3 oxides have basic properties.

State the type of bonding in these basic oxides.
Explain why this type of bonding causes these oxides to have basic properties.

Type of bonding .....

Explanation .....

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(3 marks)

4 (d) Sulfur dioxide reacts with water to form a weakly acidic solution.

4 (d) (i) Ions are formed when sulfur dioxide reacts with water.
Write an equation for this reaction.

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(1 mark)

4 (d) (ii) With reference to your equation from part **(d) (i)**, suggest why sulfur dioxide forms a weakly acidic solution.

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(1 mark)

4 (e) Suggest why silicon dioxide is described as an acidic oxide even though it is insoluble in water.

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(1 mark)

10

Turn over for the next question

5 This question is about test-tube reactions of some ions in aqueous solution.

For each reaction in parts **(a)** to **(d)**, state the colour of the original solution.
State what you would observe after the named reagent has been added to the solution.
In each case, write an equation for the reaction that occurs.

5 (a) An excess of dilute sulfuric acid is added to a solution containing CrO_4^{2-} ions.

Colour of original solution .....

Observation after an excess of reagent has been added .....

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Equation

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(3 marks)

5 (b) Sodium hydroxide solution is added to a solution containing $[Fe(H_2O)_6]^{3+}$ ions.

Colour of original solution .....

Observation after reagent has been added .....

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Equation

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(3 marks)

5 (c) An excess of ammonia solution is added to a solution containing $[Cu(H_2O)_6]^{2+}$ ions.

Colour of original solution .....

Observation after an excess of reagent has been added .....

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Equation

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(3 marks)

5 (d) Sodium carbonate solution is added to a solution containing $[Al(H_2O)_6]^{3+}$ ions.

Colour of original solution .....

Observations after reagent has been added .....

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Equation

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(4 marks)

13

Turn over for the next question

6 Transition metal compounds have a range of applications as catalysts.

6 (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 mark)

6 (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 marks)

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

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

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(1 mark)

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

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(1 mark)

6 (d) The oxidation of $C_2O_4^{2-}$ ions by MnO_4^- ions in acidic solution is an example of a reaction that is autocatalysed.

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

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(1 mark)

6 (d) (ii) Identify the autocatalyst in this reaction.

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(1 mark)

6 (d) (iii) Write **two** equations to show how the autocatalyst is involved in this oxidation of $C_2O_4^{2-}$ ions.

Equation 1

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Equation 2

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(2 marks)

9

Turn over for the next question

Section B

Answer **all** questions in the spaces provided.

7 This table shows some standard electrode potential data.

Electrode half-equation	$E^{\ominus}$ / V
$Au^{+}(aq) + e^{-} \longrightarrow Au(s)$	+1.68
$\frac{1}{2}O_2(g) + 2H^{+}(aq) + 2e^{-} \longrightarrow H_2O(l)$	+1.23
$Ag^{+}(aq) + e^{-} \longrightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^{-} \longrightarrow Fe^{2+}(aq)$	+0.77
$Cu^{2+}(aq) + 2e^{-} \longrightarrow Cu(s)$	+0.34
$Fe^{2+}(aq) + 2e^{-} \longrightarrow Fe(s)$	–0.44

7 (a) Draw a labelled diagram of the apparatus that could be connected to a standard hydrogen electrode in order to measure the standard electrode potential of the Fe^{3+}/Fe^{2+} electrode.

In your diagram, show how this electrode is connected to the standard hydrogen electrode and to a voltmeter. Do **not** draw the standard hydrogen electrode.

State the conditions under which this cell should be operated in order to measure the standard electrode potential.

Conditions .....

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(5 marks)

7 (b) Use data from the table to deduce the equation for the overall cell reaction of a cell that has an e.m.f. of 0.78 V.
Give the conventional cell representation for this cell.
Identify the positive electrode.

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(4 marks)

7 (c) Use data from the table to explain why Au^+ ions are **not** normally found in aqueous solution.
Write an equation to show how Au^+ ions would react with water.

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(3 marks)

7 (d) Use data from the table to predict and explain the redox reactions that occur when iron powder is added to an excess of aqueous silver nitrate.

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(3 marks)

Turn over for the next question

15

8 (a) Explain the meaning of the terms *ligand* and *bidentate* as applied to transition metal complexes.

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(2 marks)

8 (b) Aqueous cobalt(II) ions react separately with an excess of chloride ions and with an excess of ammonia.

For each reaction, draw a diagram to illustrate the structure of, the shape of and the charge on the complex ion formed.

In each case, name the shape and indicate, on the diagram, a value for the ligand–metal–ligand bond angle.

(6 marks)

Do not write outside the box

8 (c) The complex ion formed in aqueous solution between cobalt(II) ions and chloride ions is a different colour from the $[Co(H_2O)_6]^{2+}$ ion.

Explain why these complex ions have different colours.

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(3 marks)

8 (d) In aqueous ammonia, cobalt(II) ions are oxidised to cobalt(III) ions by hydrogen peroxide. The H_2O_2 is reduced to hydroxide ions.

Calculate the minimum volume of $5.00\,mol\,dm^{-3}$ H_2O_2 solution required to oxidise the Co^{2+} ions in 9.87 g of $CoSO_4.7H_2O$

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(5 marks)

END OF QUESTIONS

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