Q1. Chlorine is an important industrial chemical.

(a) Chlorine is formed when $KMnO_4$ reacts with hydrochloric acid.
The ionic equation for this redox reaction is

$$16H^+ + 2MnO_4^- + 10Cl^- \longrightarrow 2Mn^{2+} + 8H_2O + 5Cl_2$$

(i) Deduce the half-equation for the oxidation of chloride ions to chlorine.

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(1)

(ii) Give the oxidation state of manganese in the MnO_4^- ion.

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(1)

(iii) Deduce the half-equation for the reduction of the MnO_4^- ions in acidified solution to manganese(II) ions and water.

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(1)

(b) Chlorine behaves as an oxidising agent in the extraction of bromine from seawater.
In this process, chlorine gas is bubbled through a solution containing bromide ions.

(i) Write the **simplest ionic** equation for the reaction of chlorine with bromide ions.

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(1)

(ii) Give **one** observation that would be made during this reaction.

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(1)

(iii) In terms of electrons, state the meaning of the term **oxidising agent**.

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(1)

(c) In sunlight, chlorine can also oxidise water slowly to form oxygen.

Write an equation for this reaction.

Give the oxidation state of chlorine in the chlorine-containing species that is formed.

Equation

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Oxidation state of chlorine in the species formed .....

(2)

(d) Explain why chlorine has a lower boiling point than bromine.

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(2)

(Total 10 marks)

Q2. A student carried out an experiment to find the mass of $FeSO_4.7H_2O$ in an impure sample, **X**.
The student recorded the mass of **X**. This sample was dissolved in water and made up to 250 cm^3 of solution.
The student found that, after an excess of acid had been added, 25.0 cm^3 of this solution reacted with 21.3 cm^3 of a 0.0150 mol dm^{-3} solution of $K_2Cr_2O_7$

(a) Use this information to calculate a value for the mass of $FeSO_4.7H_2O$ in the sample of **X**.

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(5)

(b) The student found that the calculated mass of $FeSO_4.7H_2O$ 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 $FeSO_4.7H_2O$ in **X** to be greater than the actual mass of **X**.
Explain your answer.

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(2)
(Total 7 marks)

Q3. Vanadium is an important metal. Ferrovanadium, an alloy of iron and vanadium, is used to make a strong type of vanadium-steel. Pure vanadium is used in nuclear reactors.

(a) The table shows some standard enthalpy of formation data.

	V_2O_5(s)	**CaO(s)**
ΔH_f^θ / kJ mol^{-1}	−1560	−635

In the oldest method of extraction of vanadium, V_2O_5 is reacted with calcium at a high temperature.

$$5Ca(s) + V_2O_5(s) \longrightarrow 2V(s) + 5CaO(s)$$

Use data from the table and the equation to calculate the standard enthalpy change for this reaction.

State the type of reaction that V_2O_5 has undergone.

Suggest **one** major reason why this method of extracting vanadium is expensive, other than the cost of heating the reaction mixture.

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(5)

(b) Ferrovanadium is produced by the reaction of aluminium with a mixture of V_2O_5 and iron(III) oxide.

Write an equation for the reaction of aluminium with iron(III) oxide.

State the change in oxidation state of aluminium in this reaction.

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(2)

(c) Pure vanadium, for nuclear reactors, is formed by the reaction of hydrogen with purified VCl_2

Write an equation for this reaction in which the only other product is HCl gas.

Identify **two** hazards in this process, other than the fact that it operates at a high temperature.

Deduce why this process produces **pure** vanadium, other than the fact that purified

VCl_2 is used.

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(4)
(Total 11 marks)

Q4. Antimony is a solid element that is used in industry. The method used for the extraction of antimony depends on the grade of the ore.

(a) Antimony can be extracted by reacting scrap iron with low-grade ores that contain antimony sulfide (Sb_2S_3).

(i) Write an equation for the reaction of iron with antimony sulfide to form antimony and iron(II) sulfide.

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(1)

(ii) Write a half-equation to show what happens to the iron atoms in this reaction.

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(1)

(b) In the first stage of the extraction of antimony from a high-grade ore, antimony sulfide is roasted in air to convert it into antimony(III) oxide (Sb_2O_3) and sulfur dioxide.

(i) Write an equation for this reaction.

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(1)

(ii) Identify **one** substance that is manufactured directly from the sulfur dioxide formed in this reaction.

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(1)

(c) In the second stage of the extraction of antimony from a high-grade ore, antimony(III) oxide is reacted with carbon monoxide at high temperature.

(i) Use the standard enthalpies of formation in the table and the equation given below the table to calculate a value for the standard enthalpy change for this reaction.

	$Sb_2O_3(s)$	CO(g)	Sb(l)	$CO_2(g)$
$\Delta H_f^{\ominus}$ / kJ mol^{-1}	-705	-111	+20	-394

$$Sb_2O_3(s) + 3CO(g) \longrightarrow 2Sb(l) + 3CO_2(g)$$

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(3)

(ii) Suggest why the value for the standard enthalpy of formation of liquid antimony, given in the table above, is **not** zero.

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(1)

(iii) State the type of reaction that antimony(III) oxide has undergone in this reaction.

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(1)

(d) Deduce **one** reason why the method of extraction of antimony from a low-grade ore, described in part (a), is a low-cost process. Do **not** include the cost of the ore.

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(1)

(Total 10 marks)

Q5. In which reaction is the metal oxidised?

A $2Cu^{2+} + 4I^- \longrightarrow 2CuI + I_2$ ⬭

B $[Fe(H_2O)_6]^{3+} + Cl^- \longrightarrow [Fe(H_2O)_5(Cl)]^{2+} + H_2O$ ⬭

C $[CoCl_4]^{2-} + 6H_2O \longrightarrow [Co(H_2O)_6]^{2+} + 4Cl^-$ ⬭

D $Mg + S \longrightarrow MgS$ ⬭

(Total 1 mark)

Q6. In which reaction is hydrogen acting as an oxidising agent?

A $Cl_2 + H_2 \longrightarrow 2HCl$ ⬭

B $(CH_3)_2CO + H_2 \longrightarrow (CH_3)_2CHOH$ ⬭

C $N_2 + 3H_2 \longrightarrow 2NH_3$ ⬭

D $2Na + H_2 \longrightarrow 2NaH$ ⬭

(Total 1 mark)

Q7. Which substance is **not** produced in a redox reaction when solid sodium iodide reacts with concentrated sulfuric acid?

A H_2S ⬭

B HI ⬭

C SO_2 ⬭

D I_2 ⬭

(Total 1 mark)

Q8. For many years, swimming pool water has been treated with chlorine gas. The chlorine is added to kill any harmful bacteria unintentionally introduced by swimmers. Pool managers are required to check that the chlorine concentration is high enough to kill the bacteria without being a health hazard to the swimmers.

When chlorine reacts with water in the absence of sunlight, the chlorine is both oxidised and reduced and an equilibrium is established.

(a) Write an equation for this equilibrium.

For each chlorine-containing species in the equation, write the oxidation state of chlorine below the species.

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(2)

(b) The pool manager maintains the water at a pH slightly greater than 7.0

Explain how this affects the equilibrium established when chlorine is added to water.

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(2)

(c) Explain why chlorine is used to kill bacteria in swimming pools, even though chlorine is toxic.

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(2)
(Total 6 marks)

Q9. Which of the following shows chlorine in its correct oxidation states in the compounds shown?

	HCl	$KClO_3$	HClO	
A	−1	+3	+1	⬭
B	+1	−5	−1	⬭
C	−1	+5	+1	⬭
D	+1	+5	−1	⬭

(Total 1 mark)

Q10. Which of these species is the best reducing agent?

A Cl_2 ⬭

B Cl^- ⬭

C I_2 ⬭

D I^- ⬭

(Total 1 mark)