AQA A-LEVEL CHEMISTRY · 7405

CHEMISTRY



EXAM QUESTION PACK

3.1.7 OXIDATION, REDUCTION AND REDOX EQUATIONS

SCORE	PERCENTAGE
/235	%

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Q1.

Chlorine is used to decrease the numbers of microorganisms in water.

When chlorine is added to water, there is a redox reaction, as shown by the equation

$$Cl_2 + H_2O \rightleftharpoons HClO + HCl$$

(a) Deduce the oxidation state of chlorine in HClO and the oxidation state of chlorine in HCl

Oxidation state of chlorine in HClO _____

Oxidation state of chlorine in HCl _____

(1)

(b) Give two half-equations to show the oxidation and reduction processes that occur in this redox reaction.

Oxidation half-equation _____

Reduction half-equation _____

(2)

(c) Chlorine is reacted with cold, aqueous sodium hydroxide in the manufacture of bleach.

Give an equation for this reaction between chlorine and sodium hydroxide.

_____

(1)

(d) The concentration of ClO^- ions in bleach solution can be found by reaction with iodide ions.

The overall equation for this reaction is shown.

$$ClO^- + 2I^- + 2H^+ \rightarrow I_2 + Cl^- + H_2O$$

A sample of bleach solution was found to contain ClO^- ions with a concentration of 0.0109 mol dm^{-3}

Potassium iodide is added to a 20.0 cm^3 portion of this bleach solution.

Calculate the mass, in mg, of potassium iodide needed to react with all of the ClO^- ions in the sample of bleach.
Give your answer to the appropriate number of significant figures.
Give **one** observation during this reaction.

Mass of potassium iodide _____ mg

Observation _____

_____

_____

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_____

(4)

(e) Potassium chlorate(VII), $KClO_4$, is used in fireworks. When potassium chlorate(VII) decomposes, it produces potassium chloride and oxygen.

Give an equation for the decomposition of potassium chlorate(VII).
Use the data in the table to calculate the enthalpy change for this reaction.

Substance	$\Delta_f H$ **/ kJ mol^{-1}**
$KClO_4(s)$	– 434
KCl(s)	– 436

Equation _____

Enthalpy change _____ kJ mol^{-1}

(2)
(Total 10 marks)

Q2.

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° **/ J K^{-1} mol^{-1}**
$NH_3(g)$	193
$O_2(g)$	205

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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}

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(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)

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Q3.

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)

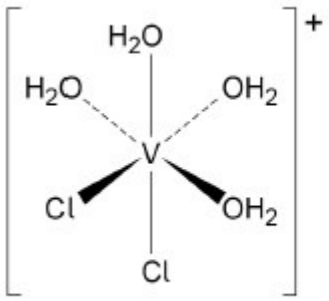
(b) Give the oxidation state of vanadium in $[VO(H_2O)_5]^{2+}$

_____

(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.

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_____

(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)

Q4.

When an acidified solution of sodium nitrite ($NaNO_2$) is added to aqueous potassium iodide, iodine and nitrogen monoxide (NO) are formed.

(a) Give the oxidation state of nitrogen in the following species.

NO_2^- _____

NO _____

(2)

(b) Write a half-equation for the conversion of NO_2^- in an acidic solution into NO

_____

(1)

(c) Write a half-equation for the conversion of I^- into I_2

_____

(1)

(d) Write an overall ionic equation for the reaction of NO_2^- in an acidic solution with I^-

_____

(1)

(e) State the role of NO_2^- in the reaction with I^-

_____

(1)

(f) In aqueous solution, nitrite ions react with acidified chlorate(V) ions according to the equation

$$2ClO_3^- + 5NO_2^- + 2H^+ \longrightarrow Cl_2 + 5NO_3^- + H_2O$$

25.0 cm^3 sample of an aqueous solution of sodium nitrite required 27.40 cm^3 of a 0.0200 mol dm^{-3} solution of potassium chlorate(V) for complete reaction.

Calculate the concentration, in g dm^{-3}, of sodium nitrite in the sample.

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Concentration of sodium nitrite _____ g dm^{-3}

(4)

(Total 10 marks)

Q5.

Which of these is **not** a redox reaction?

A $Cu_2O + H_2SO_4 \longrightarrow CuSO_4 + Cu + H_2O$ ⬭

B $MgO + 2HCl \longrightarrow MgCl_2 + H_2O$ ⬭

C $SnCl_2 + HgCl_2 \longrightarrow Hg + SnCl_4$ ⬭

D $MnO_2 + 4HCl \longrightarrow MnCl_2 + 2H_2O + Cl_2$ ⬭

(Total 1 mark)

Q6.

Which species is **not** produced by a redox reaction between solid sodium iodide and concentrated sulfuric acid?

A Na_2SO_4 ⬭

B H_2S ⬭

C S ⬭

D SO_2 ⬭

(Total 1 mark)

Q7.

The table shows some electrode half-equations and their standard electrode potentials.

Electrode half-equation	$E^\ominus$ / V
$Cl_2(g) + 2e^- \longrightarrow 2Cl^-(aq)$	+1.36
$NO_3^-(aq) + 4H^+(aq) + 3e^- \longrightarrow NO(aq) + 2H_2O(aq)$	+0.96
$Fe^{3+}(aq) + e^- \longrightarrow Fe^{3+}(aq)$	+0.77
$Cu^{2}+(aq) + 2e^- \longrightarrow Cu(s)$	+0.34
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \longrightarrow SO2(g) + 2H_2O(aq)$	+0.17
$2H^+(aq) + 2e^- \longrightarrow H_2(g)$	0.00
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	−0.44

(a) Deduce the oxidation state of nitrogen in NO_3^- and in NO

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Nitrogen in NO_3^- _____

Nitrogen in NO _____

(2)

(b) State the weakest reducing agent in the table.

_____

(1)

(c) Use data from the table to identify an acid that will oxidise copper.

Explain your choice of acid.

Use these data to suggest a possible equation for the reaction.

Calculate the EMF of the cell that has the same overall reaction.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 7 marks)

Q8.

V_2O_5 can be used as a catalyst in the Contact Process.

Which is a step in the Contact Process in which the vanadium is oxidised?

A $SO_2 + V_2O_5 \rightarrow SO_3 + 2VO_2$ ⬭

B $SO_3 + 2VO_2 \rightarrow SO_2 + V_2O_5$ ⬭

C $2VO_2 + \frac{1}{2}O_2 \rightarrow V_2O_5$ ⬭

D $V_2O_5 \rightarrow 2VO_2 + \frac{1}{2}O_2$ ⬭

(Total 1 mark)

Q9.

Which of these shows nitrogen in its correct oxidation states in the compounds given?

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	NH_3	N_2O	HNO_2	
A	+3	−1	+5	○
B	−3	+1	+3	○
C	−3	+1	−5	○
D	+3	−1	−3	○

(Total 1 mark)

Q10.

Which of these is a redox reaction?

A $CaO + SiO_2 \longrightarrow CaSiO_3$ ○

B $H_2SO_4 + Na_2O \longrightarrow Na_2SO_4 + H_2O$ ○

C $NaBr + H_2SO_4 \longrightarrow NaHSO_4 + HBr$ ○

D $Mg + S \longrightarrow MgS$ ○

(Total 1 mark)

Q11.

This question is about the element iodine and its compounds.

(a) Iodine is in Group 7 of the Periodic Table.

Complete the electron configuration of an iodine atom.

[Kr] _____

(1)

(b) Part of the structure of an iodine crystal is shown in the diagram.



Use your knowledge of structure and bonding to explain why the melting point of iodine is low (113.5 °C) and why that of hydrogen iodide is very low (–50.8 °C).

(6)

(c) State why iodine does **not** conduct electricity.

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_____

_____

_____

(1)

(d) Deduce an equation for the formation of hydrogen iodide from its elements.

_____

(1)

(e) The triiodide ion is formed when an iodine molecule is bonded to an iodide ion.

What is the formula of ammonium triiodide?

Tick (✔) **one** box.

NH_3I_3 ☐

NH_3I_4 ☐

NH_4I ☐

NH_4I_3 ☐

(1)

(f) Draw the shape of the IF_3 molecule and the shape of the IF_4^- ion.
Include any lone pairs of electrons that influence each shape.

(2)

(g) Deduce the oxidation state of iodine in the following species.

$Ba(IO_3)_2$

_____

$[H_4IO_6]^-$

_____

(2)

(Total 14 marks)

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Q12.

Which of these species is the best reducing agent?

A Cl_2 ○

B Cl^- ○

C I_2 ○

D I^- ○

(Total 1 mark)

Q13.

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)

Q14.

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)

Q15.

In which reaction is hydrogen acting as an oxidising agent?

A $Cl_2 + H_2 \longrightarrow 2HCl$ ○

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

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

D $2Na + H_2 \longrightarrow 2NaH$ ⬭

(Total 1 mark)

Q16.

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)

Q17.

Sodium bromate(V) is a primary standard. This means that its solution can be used to check the concentration of other solutions.

(a) The half-equations for the reaction between bromate(V) ions and thiosulfate ions in the presence of acid are

$$2S_2O_3^{2-} \longrightarrow S_4O_6^{2-} + 2e^-$$

$$BrO_3^- + 6H^+ + 6e^- \longrightarrow Br^- + 3H_2O$$

Use these half-equations to deduce an overall equation for this reaction.

_____

_____

(1)

(b) A laboratory technician decided to use a 5.00×10^{-3} mol dm^{-3} solution of sodium bromate(V) to check the concentration of a sodium thiosulfate solution that was labelled as 1.00×10^{-3} mol dm^{-3}. The sodium bromate(V) solution was placed in the burette and 25.0 cm^3 of the sodium thiosulfate solution was pipetted into a conical flask.

Use the concentration of the sodium thiosulfate solution to calculate the expected titre value in this experiment.
Show your working.

_____

_____

_____

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_____

_____

(2)

(c) Consider the titre value that you have calculated in part **(b)**.

Suggest one change to the experimental procedure in part **(b)** that would enable you to calculate a more accurate value for the concentration of the sodium thiosulfate solution.

_____

_____

_____

(1)

(Total 4 marks)

Q18.

Iodide ions are present in seawater but at very low concentrations. Certain types of seaweed are able to extract and concentrate iodide ions in their cells up to about 3% by mass. This seaweed could be a source of the element iodine (I_2).

The following is an account of a method that was used to extract I_2 from Laminaria seaweed. The solvent tetrachloromethane (CCl_4) is no longer used because it is very toxic.

A. Collect and dry some seaweed. Heat it very strongly in a crucible until a small quantity of ash is formed.
B. Add distilled or deionised water to the cooled ash in a beaker. Boil the suspension for 5 minutes. Allow to cool.
C. Filter the suspension.
D. Gradually add dilute sulfuric acid to the filtrate until the solution is acidic.
E. Add hydrogen peroxide solution. A brown solution will be formed.
F. Transfer the solution to a separating funnel.
G. Add CCl_4 to the funnel. It forms a separate organic layer. This organic layer changes from a colourless liquid to a purple solution.
H. Add the organic layer to an evaporating basin and place this in a fume cupboard. Grey-black crystals of iodine will form as the solvent evaporates.

(a) In Step A of the method, explain how it could have been confirmed that the decomposition of the seaweed was complete.

_____

_____

_____

_____

(2)

(b) The suspension was filtered in Step C.
Suggest an advantage of using vacuum filtration for this part of the method.

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_____

_____

(1)

(c) Describe how, in Step D, the solution could have been tested to show when it became acidic. Your method should **not** contaminate the solution.

_____

_____

(2)

(d) Write an overall equation showing the oxidation of iodide ions to iodine in Step E using hydrogen peroxide solution in acidic conditions. (No oxygen is evolved in this reaction.)

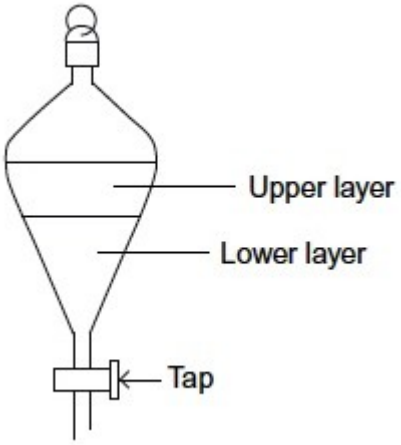
_____

_____

_____

(1)

(e) A diagram of a separating funnel is shown below.



Aqueous solutions and tetrachloromethane are immiscible. When added to the separating funnel they form two layers as shown in the diagram. Prolonged shaking of the mixture allows iodine (dissolved in the aqueous layer) to pass into the tetrachloromethane layer. The densities of some liquids are shown in the table.

Liquid	**H_2O**	**Filtrate from Step C**	**CCl_4**	**Concentrated H_2SO_4**
Density / g cm^{-3}	1.0	1.2	1.6	1.8

Explain briefly whether the upper layer or the lower layer in the separating funnel is likely to show a purple colouration after Step G.

_____

_____

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(1)

(f) The iodine in the separating funnel quickly establishes an equilibrium after shaking the contents. The concentrations of iodine in the aqueous layer and in the CCl_4 layer become constant. This is shown by the relationship

$$K = \frac{[I_2 \text{ in } CCl_4]}{[I_2 \text{ in aqueous layer}]}$$

A sample of *Laminaria* seaweed, mass 56.4 g, was processed by the method given. After Step H, 1.673 g of iodine remained in the evaporating basin. The volume of each layer was 50.0 cm^3. The seaweed contains 3.00% iodine by mass.

Calculate the value of *K* from these data. Show your working.

_____

_____

_____

(3)

(g) It has been suggested that cyclohexene could be used to extract the iodine from the aqueous layer.
Explain why this would **not** be a suitable solvent.

_____

_____

_____

_____

(2)

(h) The iodine produced at the end of Step H is impure and needs to be recrystallised from a suitable inert solvent.
Explain the essential feature to consider when choosing a suitable inert solvent for this recrystallisation.

_____

_____

_____

_____

(2)

(Total 14 marks)

Q19.

A student oxidised a solution of hydrochloric acid with a few drops of sodium chlorate(I) solution. The reaction mixture effervesced and turned pale green. The gas formed bleached universal indicator paper.

(a) Write a half-equation for the oxidation of chloride ions.

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_____

(1)

(b) Write a half-equation for the reduction of chlorate(I) ions to chlorine in acidic conditions.

_____

(1)

(c) Write an overall equation for the redox reaction of chlorate(I) ions with hydrochloric acid.

_____

(1)

(d) A solution of sodium chlorate(I) was added to a colourless solution of potassium iodide.
Suggest what is observed.

Explain the reaction that leads to this observation.

_____

_____

_____

_____

_____

(3)

(Total 6 marks)

Q20.

Which species contains an element with an oxidation state of +4?

A NO_2^+ ⬭

B ClO_3^- ⬭

C H_2SO_3 ⬭

D PCl_5 ⬭

(Total 1 mark)

Q21.

Refer to the unbalanced equation below when answering this question.

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$K_2Cr_2O7 + 3H_2C_2O_4 + _H_2SO_4 \longrightarrow Cr_2(SO_4)_3 + _H_2O + 6CO_2 + K_2SO_4$

In the balanced equation the mole ratio for sulfuric acid to water is

A 1 : 4 ⬭

B 1 : 2 ⬭

C 4 : 7 ⬭

D 4 : 9 ⬭

(Total 1 mark)

Q22.

Refer to the unbalanced equation below when answering this question.

$K_2Cr_2O7 + 3H_2C_2O_4 + _H_2SO_4 \longrightarrow Cr_2(SO_4)_3 + _H_2O + 6CO_2 + K_2SO_4$

What is the reducing agent in this reaction?

A H^+ ⬭

B $C_2O_4^{2-}$ ⬭

C K^+ ⬭

D $Cr_2O_7^{2-}$ ⬭

(Total 1 mark)

Q23.

The halogens are the elements in Group 7.

(a) The electronegativities of the halogens are shown in the table.

Halogen	**Fluorine**	**Chlorine**	**Bromine**	**Iodine**
Electronegativity	4.0	3.0	2.8	2.5

Explain the trend in electronegativities shown by the halogens.

_____

_____

_____

_____

(2)

(b) The halogens can all behave as oxidising agents in reactions.

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(i) Explain, in terms of electron transfer, the meaning of the term oxidising agent.

_____

_____

(1)

(ii) An equation for the reaction that takes place when chlorine gas is bubbled through aqueous potassium bromide is shown.

$$Cl_2(g) + 2KBr(aq) \longrightarrow Br_2(aq) + 2KCl(aq)$$

Explain, with reference to the oxidation states, why this is a redox reaction.

_____

_____

_____

(1)

(c) Solid sodium halides react with concentrated sulfuric acid.

(i) A sample of solid sodium iodide is reacted with concentrated sulfuric acid. A black solid forms and hydrogen sulfide gas is produced.

Write a half-equation for the reaction of sulfuric acid to form hydrogen sulfide.

_____

(1)

(ii) Write a half-equation for the formation of the black solid.

_____

(1)

(iii) Use your answers to parts (c) (i) and (c) (ii) to write an overall equation for the reaction of sodium iodide with concentrated sulfuric acid.

_____

(1)

(iv) Give the role of sulfuric acid in its reaction with sodium iodide.

Tick (✔) **one** box.

Acid	☐
Oxidising agent	☐
Reducing agent	☐
Electrophile	☐

(1)

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(v) Write an equation for the reaction of concentrated sulfuric acid with solid sodium fluoride.

_____

(1)

(vi) Suggest **one** reason why the reaction of sodium fluoride with concentrated sulfuric acid is different from the reaction with sodium iodide.

_____

(1)

(d) Chlorine reacts with water to form an equilibrium mixture containing hydrochloric acid and chloric(I) acid.

(i) Write an equation for the formation of this equilibrium mixture.

_____

(1)

(ii) Household bleach contains sodium chlorate(I) and sodium chloride.
State and explain, with reference to your equation in part **(d)(i)**, why it is dangerous to acidify an aqueous mixture of sodium chlorate(I) and sodium chloride.

_____

_____

_____

(2)

(Total 13 marks)

Q24.

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.

_____

(1)

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

_____

(1)

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

_____

(1)

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(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.

_____

(1)

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

_____

_____

(1)

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

_____

_____

(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

_____

Oxidation state of chlorine in the species formed _____

(2)

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

_____

_____

_____

_____

_____

_____

_____

(2)

(Total 10 marks)

Q25.

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.

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

	$V_2O_5(s)$	CaO(s)
$\Delta H_f^\ominus$ / 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.

(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.

(2)

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(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.

_____

_____

_____

_____

_____

_____

_____

_____

(4)

(Total 11 marks)

Q26.

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.

_____

(1)

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

_____

(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.

_____

(1)

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

_____

(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

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

_____

_____

_____

_____

_____

(3)

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

_____

_____

(1)

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

_____

(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.

_____

_____

(1)

(Total 10 marks)

Q27.

This question is about Group 7 chemistry.

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(a) Sea water is a major source of iodine.
The iodine extracted from sea water is impure. It is purified in a two-stage process.

Stage **1** $I_2 + 2H_2O + SO_2 \longrightarrow 2HI + H_2SO_4$

Stage **2** $2HI + Cl_2 \longrightarrow I_2 + 2HCl$

(i) State the initial oxidation state and the final oxidation state of sulfur in Stage **1**.

Oxidation state of S in SO_2 _____

Oxidation state of S in H_2SO_4 _____

(2)

(ii) State, in terms of electrons, what has happened to chlorine in Stage **2**.

_____

_____

(1)

(b) When concentrated sulfuric acid is added to potassium iodide, iodine is formed in the following redox equations.

$$.....KI + ...H_2SO_4 \longrightarrow .....KHSO_4 + ...I_2 + S + ...H_2O$$

$$8KI + 9H_2SO_4 \longrightarrow 8KHSO_4 + 4I_2 + H_2S + 4H_2O$$

(i) Balance the equation for the reaction that forms sulfur.

(1)

(ii) Deduce the half-equation for the formation of iodine from iodide ions.

_____

(1)

(iii) Deduce the half-equation for the formation of hydrogen sulfide from concentrated sulfuric acid.

_____

(1)

(c) A yellow precipitate is formed when silver nitrate solution, acidified with dilute nitric acid, is added to an aqueous solution containing iodide ions.

(i) Write the **simplest ionic** equation for the formation of the yellow precipitate.

_____

(1)

(ii) State what is observed when concentrated ammonia solution is added to this yellow precipitate.

_____

_____

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(1)

(iii) State why the silver nitrate solution is acidified when testing for iodide ions.

_____

_____

_____

(1)

(iv) Explain why dilute hydrochloric acid is **not** used to acidify the silver nitrate solution in this test for iodide ions.

_____

_____

_____

(1)

(d) Chlorine is toxic to humans. This toxicity does not prevent the large-scale use of chlorine in water treatment.

(i) Give **one** reason why water is treated with chlorine.

_____

_____

(1)

(ii) Explain why the toxicity of chlorine does **not** prevent this use.

_____

_____

_____

(1)

(iii) Write an equation for the reaction of chlorine with cold water.

_____

(1)

(e) Give the formulas of the **two** different chlorine-containing compounds that are formed when chlorine reacts with cold, dilute, aqueous sodium hydroxide.

Formula 1 _____

Formula 2 _____

(1)

(Total 14 marks)

Q28.

The table below shows some standard electrode potential data.

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	$E^{\ominus}$ / V
$ZnO(s) + H_2O(l) + 2e^- \longrightarrow Zn(s) + 2OH^-(aq)$	–1.25
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	–0.44
$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$	+0.40
$2HOCl(aq) + 2H^+(aq) + 2e^- \longrightarrow Cl_2(g) + 2H_2O(l)$	+1.64

(a) Give the conventional representation of the cell that is used to measure the standard electrode potential of iron as shown in the table.

_____

(2)

(b) With reference to electrons, give the meaning of the term **reducing agent**.

_____

_____

(1)

(c) Identify the weakest reducing agent from the species in the table.

Explain how you deduced your answer.

Species _____

Explanation _____

_____

(2)

(d) When HOCl acts as an oxidising agent, one of the atoms in the molecule is reduced.

(i) Place a tick (✓) next to the atom that is reduced.

Atom that is reduced	Tick (✓)
H	
O	
Cl	

(1)

(ii) Explain your answer to part (i) in terms of the change in the oxidation state of this atom.

_____

_____

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(1)

(e) Using the information given in the table, deduce an equation for the redox reaction that would occur when hydroxide ions are added to HOCl

_____

_____

_____

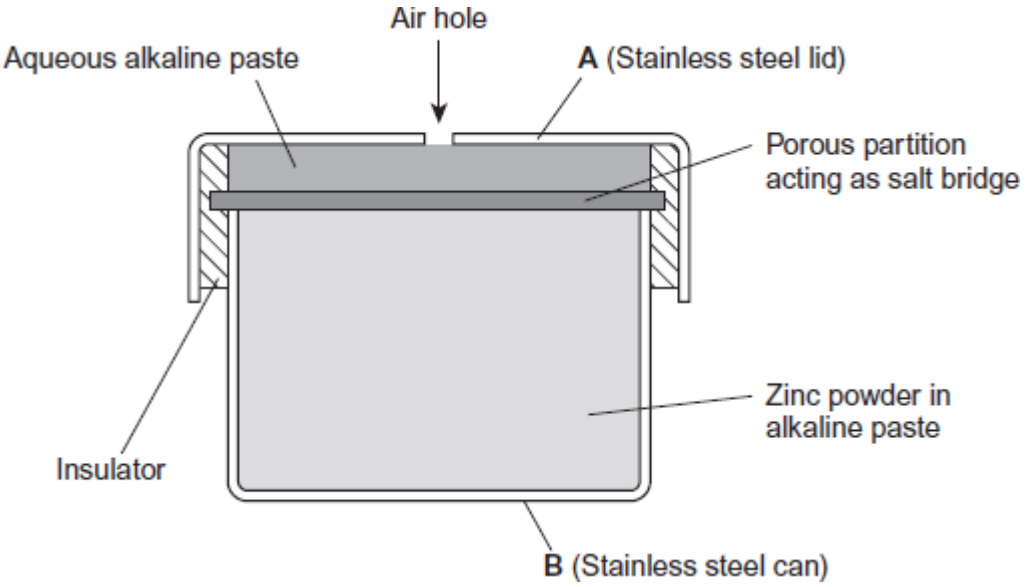
(2)

(f) The table is repeated to help you answer this question.

	$E^{\ominus}$ / V
$ZnO(s) + H_2O(l) + 2e^- \longrightarrow Zn(s) + 2OH^-(aq)$	–1.25
$Fe^{2+}(aq) + 2e^- \longrightarrow Fe(s)$	–0.44
$O_2(g) + 2H_2O(l) + 4e^- \longrightarrow 4OH^-(aq)$	+0.40
$2HOCl(aq) + 2H^+(aq) + 2e^- \longrightarrow Cl_2(g) + 2H_2O(l)$	+1.64

The half-equations from the table that involve zinc and oxygen are simplified versions of those that occur in hearing aid cells.

A simplified diagram of a hearing aid cell is shown in the following figure.



(i) Use data from the table to calculate the e.m.f. of this cell.

_____

_____

Answer = _____

(1)

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(ii) Use half-equations from the table to construct an overall equation for the cell reaction.

_____

_____

_____

(1)

(iii) Identify which of **A** or **B**, in the figure, is the positive electrode. Give a reason for your answer.

Positive electrode _____

Reason _____

_____

_____

(2)

(iv) Suggest **one** reason, other than cost, why this type of cell is **not** recharged.

_____

_____

(1)

(Total 14 marks)

Q29.

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.

_____

_____

_____

_____

(2)

(Total 7 marks)

Q30.

The price of copper is increasing as supplies of high-grade ores start to run out.
The mineral covellite (CuS), found in low-grade ores, is a possible future source of copper.

(a) When copper is extracted from covellite, a reaction occurs between copper(II) sulfide and nitric acid to form a dilute solution of copper(II) sulfate.

(i) Balance the equation for this reaction.

$3CuS(s) + ...HNO_3(aq) \longrightarrow .....CuSO_4(aq) + ...NO(g) + ...H_2O(l)$

(1)

(ii) Give the oxidation state of nitrogen in each of the following.

HNO_3 _____

NO _____

(2)

(iii) Deduce the redox half-equation for the reduction of the nitrate ion in acidified solution to form nitrogen monoxide and water.

_____

(1)

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(iv) Deduce the redox half-equation for the oxidation of the sulfide ion in aqueous solution to form the sulfate ion and $H^+(aq)$ ions.

_____

(1)

(b) Use your knowledge of metal reactivity to state and explain a low-cost method for the extraction of copper from a dilute aqueous solution of copper(II) sulfate.
Write the **simplest ionic** equation for the reaction that occurs during this extraction process.

_____

_____

_____

_____

_____

_____

Simplest ionic equation

_____

(4)

(Total 9 marks)

Q31.

The manufacture of food grade phosphoric acid for use in cola drinks begins with the production of pure white phosphorus from the mineral fluoroapatite, $Ca_5F(PO_4)_3$

(a) Complete the following equation for the manufacture of phosphorus.

$$....Ca_5F(PO_4)_3 + 9SiO_2 + ...C \longrightarrow 9CaSiO_3 + CaF_2 + ...CO + ...P$$

(1)

(b) As the phosphorus cools, it forms white phosphorus, P_4

Give the oxidation state of phosphorus in each of the following.

P_4_____

H_3PO_4_____

(2)

(c) Fertiliser grade phosphoric acid is manufactured from sulfuric acid and calcium phosphate.
Use the following precise relative atomic mass data to show how mass spectrometry can be used to distinguish between pure sulfuric acid (H_2SO_4) and pure phosphoric acid (H_3PO_4) which both have M_r = 98 to two significant figures.

Atom	Precise relative atomic mass

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^{1}H	1.00794
^{16}O	15.99491
^{31}P	30.97376
^{32}S	32.06550

_____

_____

_____

_____

(1)

(d) Concentrated phosphoric acid is used as a catalyst in the hydration of propene to form the alcohol $CH_3CH(OH)CH_3$ as the main organic product.
The industrial name for this alcohol is isopropyl alcohol.

(i) State the meaning of the term *catalyst*.

_____

_____

_____

(1)

(ii) State the meaning of the term *hydration*.

_____

_____

_____

(1)

(iii) Write an equation for the hydration of propene to form isopropyl alcohol.
Give the IUPAC name for isopropyl alcohol.

Equation _____

IUPAC name _____

(2)

(Total 8 marks)

Q32.

Metals can be extracted by different methods.

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(a) Give **one** reason why titanium cannot be extracted directly from titanium(IV) oxide using carbon.

_____

_____

(1)

(b) Titanium steel is an alloy of titanium and iron. Titanium steel is extracted from the mineral ilmenite ($FeTiO_3$) in a two-stage process.
Purified $FeTiO_3$ is first converted into a mixture of two metal chlorides. These two metal chlorides are then reduced simultaneously using sodium.

(i) Write an equation for the reaction of $FeTiO_3$ with chlorine and carbon to produce iron(III) chloride ($FeCl_3$), titanium(IV) chloride and carbon monoxide.

_____

(1)

(ii) Write an equation for the simultaneous reduction of the mixture of iron(III) chloride and titanium(IV) chloride to iron and titanium using sodium.

_____

(1)

(c) Scrap iron is used to extract copper from dilute aqueous solutions containing copper(II) ions.
Explain, in terms of redox, what happens to the copper(II) ions in this extractio.

_____

_____

_____

_____

(2)

(d) Aluminium is an expensive metal because it is extracted from molten aluminium oxide using electrolysis.
Write the half-equation for the reaction that occurs at the positive electrode during this extraction.

_____

(1)

(Total 6 marks)

Q33.

(a) Iron is extracted from iron(III) oxide using carbon at a high temperature.

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(i) State the type of reaction that iron(III) oxide undergoes in this extraction.

_____

(1)

(ii) Write a half-equation for the reaction of the iron(III) ions in this extraction.

_____

(1)

(b) At a high temperature, carbon undergoes combustion when it reacts with oxygen.

(i) Suggest why it is **not** possible to measure the enthalpy change directly for the following combustion reaction.

$$C(s,graphite) + \frac{1}{2}O_2(g) \longrightarrow CO(g)$$

_____

_____

(1)

(ii) State Hess's Law.

_____

_____

_____

(1)

(iii) State the meaning of the term *standard enthalpy of combustion.*

_____

_____

_____

_____

_____

(3)

(c) Use the standard enthalpies of formation in the table below and the equation to calculate a value for the standard enthalpy change for the extraction of iron using carbon monoxide.

	$Fe_2O_3(s)$	CO(g)	Fe(l)	$CO_2(g)$
ΔH_f/ kJ mol^{-1}	- 822	- 111	+14	- 394

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$Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(l) + 3CO_2(g)$

_____

_____

_____

_____

_____

_____

(3)

(d) (i) Write an equation for the reaction that represents the standard enthalpy of formation of carbon dioxide.

_____

(1)

(ii) State why the value quoted in part (c) for the standard enthalpy of formation of $CO_2(g)$ is the same as the value for the standard enthalpy of combustion of carbon.

_____

_____

(1)

(Total 12 marks)

Q34.

Iodine reacts with concentrated nitric acid to produce nitrogen dioxide (NO_2).

(a) (i) Give the oxidation state of iodine in each of the following.

I_2 _____

HIO_3 _____

(2)

(ii) Complete the balancing of the following equation.

$I_2 + 10HNO_3 \longrightarrow$ .....HIO_3 + ...NO_2 + ...H_2O

(1)

(b) In industry, iodine is produced from the $NaIO_3$ that remains after sodium nitrate has been crystallised from the mineral Chile saltpetre.
The final stage involves the reaction between $NaIO_3$ and NaI in acidic solution.
Half-equations for the redox processes are given below.

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$$IO_3^- + 5e^- + 6H^+ \longrightarrow 3H_2O + \frac{1}{2}I_2$$

$$I^- \longrightarrow \frac{1}{2}I_2 + e^-$$

Use these half-equations to deduce an overall ionic equation for the production of iodine by this process. Identify the oxidising agent.

Overall ionic equation

The oxidising agent _____

(2)

(c) When concentrated sulfuric acid is added to potassium iodide, solid sulfur and a black solid are formed.

(i) Identify the black solid.

_____

(1)

(ii) Deduce the half-equation for the formation of sulfur from concentrated sulfuric acid.

_____

(1)

(d) When iodide ions react with concentrated sulfuric acid in a different redox reaction, the oxidation state of sulfur changes from +6 to -2. The reduction product of this reaction is a poisonous gas that has an unpleasant smell.
Identify this gas.

_____

(1)

(e) A yellow precipitate is formed when silver nitrate solution, acidified with dilute nitric acid, is added to an aqueous solution containing iodide ions.

(ii) Write the **simplest ionic** equation for the formation of the yellow precipitate.

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_____

(1)

(ii) State what is observed when concentrated ammonia solution is added to this precipitate.

_____

_____

(1)

(iii) State why the silver nitrate is acidified when testing for iodide ions.

_____

_____

(1)

(f) Consider the following reaction in which iodide ions behave as reducing agents.

$$Cl_2(aq) + 2I^-(aq) \longrightarrow I_2(aq) + 2Cl^-(aq)$$

(i) In terms of electrons, state the meaning of the term *reducing agent*.

_____

_____

(1)

(ii) Write a half-equation for the conversion of chlorine into chloride ions.

_____

(1)

(iii) Suggest why iodide ions are stronger reducing agents than chloride ions.

_____

_____

_____

_____

(2)

(Total 15 marks)

Q35.

A sample of nitrogen dioxide gas (NO_2) was prepared by the reaction of copper with concentrated nitric acid.

(a) (i) Balance the equation for the reaction of copper with concentrated nitric acid.

$$Cu + ... HNO_3 \rightarrow Cu(NO_3)_2 + ... NO_2 + ... H_2O$$

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(1)

(ii) Give the oxidation state of nitrogen in each of the following compounds.

HNO_3 _____

NO_2 _____

(2)

(iii) Deduce the half-equation for the conversion of HNO_3 into NO_2 in this reaction.

_____

(1)

(b) The following equilibrium is established between colourless dinitrogen tetraoxide gas (N_2O_4) and dark brown nitrogen dioxide gas.

$$N_2O_4(g) \rightleftharpoons 2NO_2(g) \qquad \Delta H = 58 \text{ kJ mol}^{-1}$$

(i) Give two features of a reaction at equilibrium.

Feature 1 _____

_____

_____

_____

Feature 2 _____

_____

_____

_____

(2)

(ii) Use Le Chatelier's principle to explain why the mixture of gases becomes darker in colour when the mixture is heated at constant pressure.

_____

_____

_____

_____

_____

_____

(2)

(iii) Use Le Chatelier's principle to explain why the amount of NO_2 decreases when the pressure is increased at constant temperature.

_____

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_____

_____

_____

_____

_____

(2)

(Total 10 marks)

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