**Q1.** This question is about Group 7 chemistry.

(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**.

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**(1)**

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

$$\text{.....}KI + \text{.....}H_2SO_4 \longrightarrow \text{.....}KHSO_4 + \text{.....}I_2 + S + \text{.....}H_2O$$

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

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

**(1)**

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

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**(1)**

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

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**(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.

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**(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.

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**(1)**

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

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**(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.

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**(1)**

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

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**(1)**

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

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**(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)**

**Q2.** The table below shows some standard electrode potential data.

| | $E^{\ominus}$ / 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.

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**(2)**

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

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**(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

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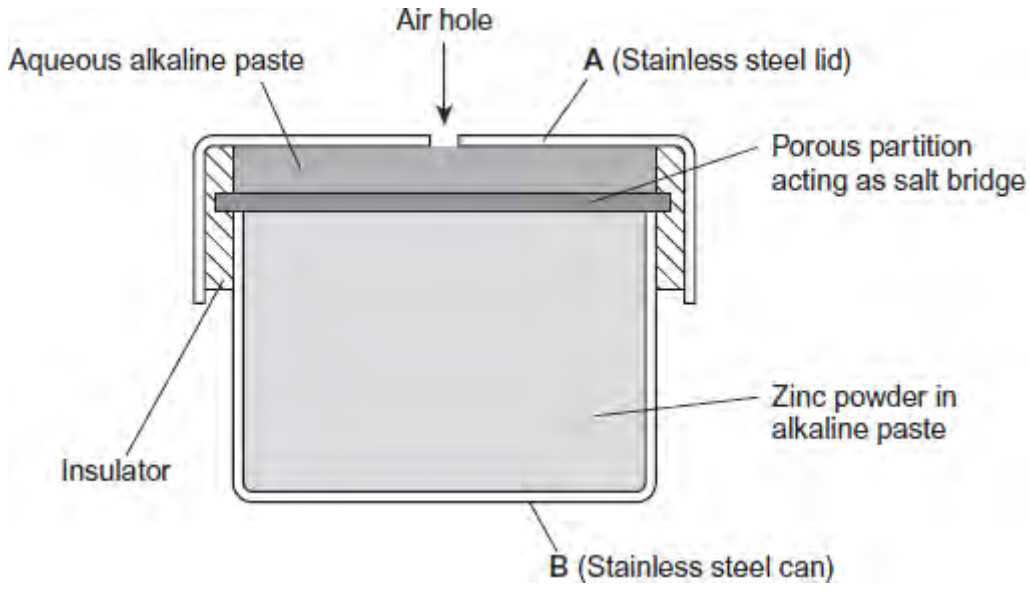
**(2)**

(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.

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Answer = .....

**(1)**

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

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**(1)**

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

Positive electrode .....

Reason .....

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**(2)**

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

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**(1)**

**(Total 14 marks)**

**Q3.** The silicon chip industry requires the production of pure silicon. Silicon is extracted from its ore, silicon dioxide ($SiO_2$), by a process similar to that used in the extraction of titanium.

(a) (i) Write an equation for the formation of $SiCl_4$ from $SiO_2$ using chlorine and

carbon.

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**(1)**

(ii) Suggest how the liquid $SiCl_4$ is purified.

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**(1)**

(b) The final stage in the extraction of silicon involves the use of hydrogen gas to convert the $SiCl_4$ into silicon and hydrogen chloride.

(i) Write an equation for this reaction.

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**(1)**

(ii) State the role of hydrogen in this reaction.

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**(1)**

(iii) Give **one** risk associated with the use of hydrogen gas.

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**(1)**

(c) The magnesium used to make magnesium ferrosilicon alloys is extracted from magnesium oxide using silicon.
Write an equation for this reaction to produce magnesium and silicon dioxide.

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**(1)**
**(Total 6 marks)**

**Q4.** 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.

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**(1)**

(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.

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**(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.

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Simplest ionic equation

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**(4)**
**(Total 9 marks)**

**Q5.**Metals can be extracted by different methods.

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

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**(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.

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**(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.

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**(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.

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**(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.

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**(1)**
**(Total 6 marks)**

**Q6.** 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 |
|---|---|
| $^{1}H$ | 1.00794 |
| $^{16}O$ | 15.99491 |
| $^{31}P$ | 30.97376 |
| $^{32}S$ | 32.06550 |

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**(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*.

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*(Extra space)* .....

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**(1)**

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

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*(Extra space)* .....

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**(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)**