1 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)

(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.

....

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(2)
(Total 10 marks)

2 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.

....

....

....

....

(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)

3 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.

....

....

....

....

....

(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.

....

....

....

....

....

(2)

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

....

....

....

....

....

(2)
(Total 6 marks)

4 Which of these species is the best reducing agent?

A Cl_2 ○

B Cl^- ○

C I_2 ○

D I^- ○

(Total 1 mark)

5 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)

6 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)

7 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)

8 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)

9 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)

(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)

10 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**.

....

....

(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.

....

....

(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)

11 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.

....

(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.

....

....

(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

....

....

....

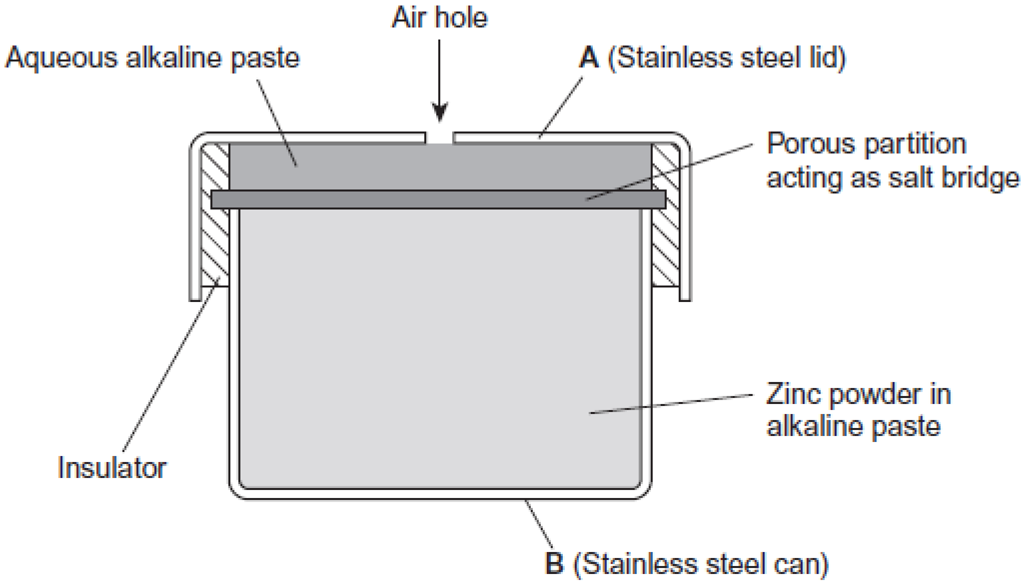
(2)

(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)

(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)

12 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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....

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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)

13 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)

(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)

14 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

....

....

....

....

(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*.

....

....

....

(Extra space) ....

....

(1)

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

....

....

....

(Extra space) ....

....

(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)

15 Metals can be extracted by different methods.

(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)

16 A student investigated the chemistry of the halogens and the halide ions.

(a) In the first two tests, the student made the following observations.

Test	**Observation**
1. Add chlorine water to aqueous potassium iodide solution.	The colourless solution turned a brown colour.
2. Add silver nitrate solution to aqueous potassium chloride solution.	The colourless solution produced a white precipitate.

(i) Identify the species responsible for the brown colour in Test **1**.

Write the **simplest ionic** equation for the reaction that has taken place in Test **1**.

State the type of reaction that has taken place in Test **1**.

....

....

....

....

....

(Extra space) ....

....

(3)

(ii) Name the species responsible for the white precipitate in Test **2**.

Write the **simplest ionic** equation for the reaction that has taken place in Test **2**.

State what would be observed when an excess of dilute ammonia solution is added to the white precipitate obtained in Test **2**.

....

....

....

....

....

(Extra space) ....

....

(3)

(b) In two further tests, the student made the following observations.

Test	**Observation**
3. Add concentrated sulfuric acid to solid potassium chloride.	The white solid produced misty white fumes which turned blue litmus paper to red.
4. Add concentrated sulfuric acid to solid potassium iodide.	The white solid turned black. A gas was released that smelled of rotten eggs. A yellow solid was formed.

(i) Write the **simplest ionic** equation for the reaction that has taken place in Test **3**.

Identify the species responsible for the misty white fumes produced in Test **3**.

....

....

(Extra space) ....

....

(2)

(ii) The student had read in a textbook that the equation for one of the reactions in Test **4** is as follows.

$$8H^+ + 8I^- + H_2SO_4 \longrightarrow 4I_2 + H_2S + 4H_2O$$

Write the **two** half-equations for this reaction.

State the role of the sulfuric acid and identify the yellow solid that is also observed in Test **4**.

....

....

....

....

....

....

(Extra space) ....

....

(4)

(iii) The student knew that bromine can be used for killing microorganisms in swimming pool water.
The following equilibrium is established when bromine is added to cold water.

$$Br_2(l) + H_2O(l) \rightleftharpoons HBrO(aq) + H^+(aq) + Br^-(aq)$$

Use Le Chatelier's principle to explain why this equilibrium moves to the right when sodium hydroxide solution is added to a solution containing dissolved bromine.

Deduce why bromine can be used for killing microorganisms in swimming pool water, even though bromine is toxic.

....

....

....

....

....

....

(Extra space) ....

....

(3)
(Total 15 marks)

17 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.

....

(1)

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

....

....

(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.

....

(1)

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

....

(1)

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

....

(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.

....

(1)
(Total 6 marks)

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

(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.*

....

....

....

....

....

(Extra space) ....

....

(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.

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

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

....

....

....

....

....

....

(Extra space) ....

....

(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)

19 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.

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

(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.

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

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

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.

....

(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.

....

....

....

....

(Extra space) ....

....

(2)

(Total 15 marks)

20 Metals are usually extracted from oxides.

Some of these oxides occur naturally. Other oxides are made by roasting sulfide ores in air, producing sulfur dioxide as a by-product.

For the extraction of some metals, the oxide needs to be converted into a chloride.

(a) The ore molybdenite contains molybdenum disulfide (MoS_2).
The first stage in the extraction of molybdenum is to roast the ore in air to form molybdenum oxide (MoO_3) and sulfur dioxide.

(i) Write an equation for the first stage in this extraction.

....

(1)

(ii) The release of sulfur dioxide into the atmosphere causes environmental problems and wastes a valuable resource. Identify **one** environmental problem and identify **one** use for the sulfur dioxide.

Environmental problem ....

....

....

Use for sulfur dioxide ....

....

....

(2)

(iii) Pure molybdenum is formed in the second stage by the reduction of MoO_3 using hydrogen.

Write an equation for this reaction.

....

(1)

(iv) State **one** risk in using hydrogen gas in metal extractions.

....

....

(1)

(b) Calcium is an expensive metal. It is extracted by the electrolysis of molten calcium chloride.

(i) State why calcium chloride must be molten for electrolysis to occur.

....

....

(1)

(ii) Write an equation for the reaction that takes place at the negative electrode during this electrolysis.

....

(1)

(iii) Identify the major cost in this extraction of calcium.

....

....

(1)
(Total 8 marks)

21 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.

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

(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 ....

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(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.

....

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(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)

22 The method of extraction of zinc has changed as different ores containing the element have been discovered and as technology has improved.

Extraction process 1
In the earliest process, calamine (impure zinc carbonate) was heated with charcoal in earthenware pots. This two-stage process gave a low yield of zinc.

$$ZnCO_3(s) \rightarrow ZnO(s) + CO_2(g)$$

$$ZnO(s) + C(s) \rightarrow Zn(s) + CO(g)$$

Extraction process 2
Deposits of calamine were being used up and a new two-stage process was developed using zinc sulfide ores. All of the waste gases from this process were released into the atmosphere.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

$$ZnO(s) + C(s) \rightarrow Zn(s) + CO(g)$$

Extraction process 3

The modern process uses the electrolysis of aqueous solutions of very pure zinc sulfate. The first step in this process is the same as the first step in Extraction process **2**. The second step uses sulfuric acid made from the SO_2 collected in the first step. The third step involves the electrolysis of zinc sulfate solution to form pure zinc.

$$2ZnS(s) + 3O_2(g) \rightarrow 2ZnO(s) + 2SO_2(g)$$

$$ZnO(s) + H_2SO_4(aq) \rightarrow ZnSO_4(aq) + H_2O(l)$$

$$ZnSO_4(aq) \xrightarrow{\text{electrolysis}} Zn(s)$$

(a) In the first stage of Extraction process **1** the following equilibrium is established when zinc carbonate is heated in a closed container.

$$ZnCO_3(s) \rightleftharpoons ZnO(s) + CO_2(g)$$

Use Le Chatelier's principle to suggest and explain the effect on the yield of zinc oxide of allowing the carbon dioxide to escape from the container.

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(3)

(b) State and explain **one** environmental reason why Extraction process **3** is an improvement over Extraction process **2**.

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(3)

(c) Give **one** reason why Extraction process **3** is an expensive method of making zinc but one which is justified in terms of the product formed.

....

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(2)

(d) Deduce the half-equation for the formation of zinc from zinc ions during the electrolysis of zinc sulfate solution and identify the electrode at which this reaction occurs.

....

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....

(2)

(e) Identify **one** reaction from the three extraction processes that is **not** a redox reaction and state the type of reaction that it is. In terms of redox, state what happens to the carbon in Extraction process **2**.

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(3)

(f) Zinc and magnesium both react with steam in a similar way. Write an equation for the reaction of zinc with steam and name the products of this reaction.

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(2)
(Total 15 marks)

23 The electrons transferred in redox reactions can be used by electrochemical cells to provide energy.

Some electrode half-equations and their standard electrode potentials are shown in the table below.

Half-equation	**$E^\ominus$/V**
$Cr_2O_7^{2-}(aq) + 14H^+(aq) + 6e^- \rightarrow 2Cr^{3+}(aq) + 7H_2O(l)$	+1.33
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0.00
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Li^+(aq) + e^- \rightarrow Li(s)$	–3.04

(a) Describe a standard hydrogen electrode.

....

....

....

....

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(4)

(b) A conventional representation of a lithium cell is given below.
This cell has an e.m.f. of +2.91 V

$Li(s) \mid Li^+(aq) \parallel Li^+(aq) \mid MnO_2(s)\ ,\ LiMnO_2(s) \mid Pt(s)$

Write a half-equation for the reaction that occurs at the positive electrode of this cell.

Calculate the standard electrode potential of this positive electrode.

....

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....

(2)

(c) Suggest what reactions occur, if any, when hydrogen gas is bubbled into a solution containing a mixture of iron(II) and iron(III) ions. Explain your answer.

....

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....

....

(2)

(d) A solution of iron(II) sulfate was prepared by dissolving 10.00 g of $FeSO_4.7H_2O$ (M_r = 277.9) in water and making up to 250 cm^3 of solution. The solution was left to stand, exposed to air, and some of the iron(II) ions became oxidised to iron(III) ions. A 25.0 cm^3 sample of the partially oxidised solution required 23.70 cm^3 of 0.0100 mol dm^{-3} potassium dichromate(VI) solution for complete reaction in the presence of an excess of dilute sulfuric acid.

Calculate the percentage of iron(II) ions that had been oxidised by the air.

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(6)
(Total 14 marks)

24 (a) When a solution containing iron(II) ions is treated with a slight excess of a solution containing ethanedioate ions a bright yellow precipitate of hydrated iron(II) ethanedioate, $FeC_2O_4.2H_2O$, is formed. The precipitate is filtered off, washed with propanone and then allowed to dry. A typical yield of the solid is 95%.

(i) Propanone boils at 56 °C and is miscible with water in all proportions. Suggest **two** reasons why washing with propanone is an effective method for producing a pure, dry precipitate.

Reason 1 ....

....

Reason 2 ....

....

(2)

(ii) By suggesting a simple test tube reaction, state how the filtrate could be tested to show that all of the iron(II) ions have been removed from the solution. State what you would observe.

Test ....

Observation ....

(2)

(iii) Suggest **one** reason why the typical yield of iron(II) ethanedioate is less than 100%.

....

....

(1)

(iv) Calculate the mass of hydrated iron(II) ethanedioate, $FeC_2O_4.2H_2O$ that can be formed from 50.0 cm^3 of a 0.50 mol dm^{-3} solution of iron(II) sulfate when the yield of the reaction is 95%. Show your working.

....

....

....

....

....

(3)

(v) The identity of the precipitate can be confirmed by dissolving it in sulfuric acid and titrating the mixture with potassium manganate(VII).

Deduce the number of moles of iron(II) ethanedioate that would react with one mole of potassium manganate(VII) in acidic solution.

....

....

(1)

(b) Ethanedioate ions can be used to remove calcium ions from blood plasma.
A precipitate of calcium ethanedioate is formed. Write an ionic equation for the reaction of ethanedioate ions with calcium ions.

....

....

(1)

(c) Ethanedioic acid is used to clean marble, a form of calcium carbonate. Suggest **one** reason why the reaction between ethanedioic acid and marble stops after a short time.

....

....

(1)

(d) Tea leaves contain ethanedioic acid. Suggest **one** reason why tea drinkers do **not** suffer from ethanedioic acid poisoning.

....

(1)

(e) Ethanedioic acid is produced by the oxidation of carbon monoxide in a multi-step process.
The equation which summarises the reactions taking place is shown below.

$$4CO + 4NaOH + O_2 + 4HCl \rightarrow 2H_2C_2O_4 + 4NaCl + 2H_2O$$

Calculate the percentage atom economy for the formation of ethanedioic acid in this reaction. Show your working.

....

....

....

(2)
(Total 14 marks)

25 Hydrogen gas is used in the chemical industry.

(a) Tungsten is extracted by passing hydrogen over heated tungsten oxide (WO_3).

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

....

(1)

(ii) Write an equation for this reaction.

....

(1)

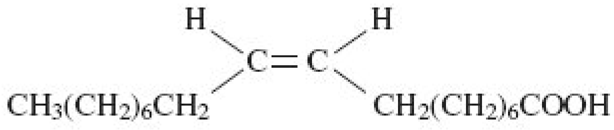
(iii) State **one** risk of using hydrogen gas in metal extractions.

....

....

(1)

(b) Hydrogen is used to convert oleic acid into stearic acid as shown by the following equation.



$$+ H_2 \xrightarrow[\text{catalyst}]{150°C} CH_3(CH_2)_{16}COOH$$

stearic acid

(i) Use your knowledge of the chemistry of alkenes to deduce the type of reaction that has occurred in this conversion.

....

(1)

(ii) State the type of stereoisomerism shown by oleic acid.

....

(1)

(c) Hydrogen reacts with nitrogen in the Haber Process. The equation for the equilibrium that is established is shown below.

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$$

(i) State Le Chatelier's principle.

....

....

(1)

(ii) Use Le Chatelier's principle to explain why an increase in the total pressure of this equilibrium results in an increase in the equilibrium yield of ammonia.

....

....

....

....

(2)

(d) Hydrogen reacts with oxygen in an exothermic reaction as shown by the following equation.

$$H_2(g) + \frac{1}{2} O_2(g) \rightarrow H_2O(g) \qquad \Delta H = -242 \text{ kJ mol}^{-1}$$

Use the information in the equation and the data in the following table to calculate a value for the bond enthalpy of the H–H bond.

	O–H	O=O
Mean bond enthalpy / kJ mol^{-1}	+ 463	+ 496

....

....

....

....

(3)
(Total 11 marks)

26 Nitric acid is manufactured from ammonia in a process that involves several stages.

(a) In the first stage, ammonia is converted into nitrogen monoxide and the following equilibrium is established.

$$4NH_3(g) + 5O_2(g) \rightleftharpoons 4NO(g) + 6H_2O(g) \qquad \Delta H = -905 \text{ kJ mol}^{-1}$$

The catalyst for this equilibrium reaction is a platinum–rhodium alloy in the form of a gauze. This catalyst gauze is heated initially but then remains hot during the reaction.

(i) In terms of redox, state what happens to the ammonia in the forward reaction.

....

(1)

(ii) Suggest a reason why the catalyst must be hot.

....

(1)

(iii) Suggest a reason why the catalyst remains hot during the reaction.

....

(1)

(iv) State how a catalyst increases the rate of a reaction.

....

....

....

....

(2)

(b) In the second stage, nitrogen monoxide is converted into nitrogen dioxide. The equation for the equilibrium that is established is shown below.

$2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$ $\quad\quad\quad \Delta H = -113 \text{ kJ mol}^{-1}$

Explain why the equilibrium mixture is cooled during this stage of the process.

....

....

....

....

(2)

(c) In the final stage, nitrogen dioxide reacts with water as shown by the following equation.

$2NO_2(g) + H_2O(l) \rightarrow H^+(aq) + NO_3^-(aq) + HNO_2(aq)$

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

NO_2 ....

NO_3^- ....

HNO_2 ....

(3)
(Total 10 marks)

27 Copper is extracted from the ore chalcopyrite ($CuFeS_2$) in a three-stage process.

(a) In the first stage of this extraction, the chalcopyrite is heated with silicon dioxide and oxygen.

(i) Balance the following equation for this first stage in which copper(I) sulfide is formed.

.......$CuFeS_2$ + ...SiO_2 + ...$O_2 \rightarrow Cu_2S$ + ...$FeSiO_3$ + ...SO_2

(1)

(ii) Give **one** environmental reason why the SO_2 gas formed in this reaction is not allowed to escape into the atmosphere.

....

....

(1)

(iii) State **one** use for the sulfur dioxide formed in this reaction.

....

....

(1)

(b) In the second stage of this extraction, the copper(I) sulfide is converted into copper(II) oxide. This occurs by roasting the sulfide with oxygen at high temperature.
Write an equation for this reaction.

....

(1)

(c) In the third stage of this extraction, copper(II) oxide is reduced to copper by its reaction with carbon. Write an equation for this reaction.

....

(1)

(d) Scrap iron can be used to extract copper from dilute aqueous solutions containing copper(II) ions.

(i) Explain why this is a low-cost method of extracting copper.

....

....

(1)

(ii) Write the **simplest ionic** equation for the reaction of iron with copper(II) ions in aqueous solution.

....

(1)
(Total 7 marks)

28 This question is about the extraction of metals.

(a) Coke is mainly carbon and is a raw material used in the extraction of iron from iron(III) oxide.

(i) Write an equation for the formation of carbon monoxide from carbon.

....

(1)

(ii) Write an equation for the reduction of iron(III) oxide to iron by carbon monoxide.

....

(1)

(iii) The Earth's resources of iron(III) oxide are very large and commercial ores have a high iron content. Give **one** economic and **one** environmental reason for recycling scrap iron and steel.

Economic reason ....

....

Environmental reason ....

....

(2)

(b) Pure titanium is extracted by the reduction of titanium(IV) chloride, but not by the direct reduction of titanium(IV) oxide using carbon.

(i) Write an equation for the conversion of titanium(IV) oxide into titanium(IV) chloride.

....

(2)

(ii) Write an equation for the extraction of titanium from titanium(IV) chloride.

....

(2)

(iii) State why titanium is not extracted directly from titanium(IV) oxide using carbon.

....

(1)

(c) Aluminium is extracted by the electrolysis of a molten mixture containing aluminium oxide.

(i) State why the electrolysis needs to be of a *molten* mixture.

....

(1)

(ii) Write an equation for the reaction of oxide ions at the positive electrode during the electrolysis.

....

(1)

(iii) State why the positive electrodes need frequent replacement.

....

(1)

(iv) Give the major reason why it is less expensive to recycle aluminium than to extract it from aluminium oxide by electrolysis.

....

(1)
(Total 13 marks)

29 In the past 150 years, three different processes have been used to extract bromine from potassium bromide. These processes are illustrated below.

Extraction Process **1**

$2KBr + MnO_2 + 2H_2SO_4 \rightarrow MnSO_4 + K_2SO_4 + 2H_2O + Br_2$

Extraction Process **2**

The reaction of solid potassium bromide with concentrated sulfuric acid.

Extraction Process **3**

The reaction of aqueous potassium bromide with chlorine gas.

(a) Write a half-equation for the conversion of MnO_2 in acid solution into Mn^{2+} ions and water. In terms of electrons, state what is meant by the term *oxidising agent* and identify the oxidising agent in the overall reaction.

....

....

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....

....

(3)

(b) Write an equation for Extraction Process **2** and an equation for Extraction Process **3**. Calculate the percentage atom economy for the extraction of bromine from potassium bromide by Extraction Process **3**. Suggest why Extraction Process **3** is the method in large-scale use today.

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(5)

(c) Bromine has been used for more than 70 years to treat the water in swimming pools. The following equilibrium is established when bromine is added to water.

$$Br_2 + H_2O \rightleftharpoons HBrO + HBr$$

Give the oxidation state of bromine in HBr and in HBrO

Deduce what will happen to this equilibrium as the HBrO reacts with micro-organisms in the swimming pool water. Explain your answer.

....

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....

(4)
(Total 12 marks)

30 Oxidation and reduction can de defined in terms of electron transfer.

(a) Define the term *reduction* in terms of electrons.

....

(1)

(b) The oxide of nitrogen formed when copper reacts with nitric acid depends upon the concentration and the temperature of the acid. The reaction of copper with cold, dilute acid produces NO as indicated by the following equation.

$$3Cu + 8H^+ + 2NO_3^- \rightarrow 3Cu^{2+} + 4H_2O + 2NO$$

In warm, concentrated acid, NO_2 is formed.

Oxidation states can be used to understand electron transfer in these reactions.

(i) Give the oxidation states of nitrogen in NO_3^-, NO and NO

Oxidation state in NO_3^- ....

Oxidation state in NO_2 ....

Oxidation state in NO ....

(ii) Identify, as oxidation or reduction, the formation of NO_2 from NO_3^- ions in the presence of H^+ ions. Deduce the half-equation for the reaction.

NO from NO_3^- ....

Half-equation .;..

(iii) Deduce the half-equation for the formation of NO_2 from NO_3^- ions in the presence of H+ ions.

....

....

(iv) Deduce the overall equation for the reaction of copper with NO_3^- ions and H^+ ions to produce Cu^{2+} ions, NO_2 and water.

....

....

(8)
(Total 9 marks)

31 (a) The term oxidation was used originally to describe a reaction in which a substance gained oxygen. The oxygen was provided by the oxidising agent. Later the definition of oxidation was revised when the importance of electron transfer was recognised.

An aqueous solution of sulfur dioxide was reacted in separate experiments as follows.

Reaction **1** with HgO

$$H_2O + SO_2 + HgO \rightarrow H_2SO_4 + Hg$$

Reaction **2** with chlorine

$$2H_2O + SO_2 + Cl_2 \rightarrow H_2SO_4 + 2HCl$$

(i) In Reaction **1**, identify the substance that donates oxygen and therefore is the oxidising agent.

....

(ii) Show, by writing a half-equation, that this oxidising agent in reaction **1** is an electron acceptor.

....

(iii) Write a half-equation for the oxidation process occurring in reaction **2**.

....

(iv) Write a half-equation for the reduction process occurring in reaction **2**.

....

(4)

(b) Use the standard electrode potential data given in the able below to answer the questions which follow.

	E / V
$V^{3+}(aq) + e^- \rightarrow V^{2+}(aq)$	–0.26
$SO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow H_2SO_3(aq) + H_2O(l)$	+0.17
$VO^{2+}(aq) + 2H^+(aq) + e^- \rightarrow V^{3+}(aq) + H_2O(l)$	+0.34
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$VO_2^+(aq) + 2H^+(aq) + e^- \rightarrow VO^{2+}(aq) + H_2O(l)$	+1.00
$MnO_4^-(aq) + 8H^+(aq) + 5e^- \rightarrow Mn^{2+}(aq) + 4H_2O(l)$	+1.52

Each of the above can be reversed under suitable conditions

(i) An excess of potassium manganate(VII) was added to a solution containing $V^{2+}(aq)$ ions. Determine the vanadium species present in the solution at the end of this reaction. State the oxidation state of vanadium in this species and write a half-equation for its formation from $V^{2+}(aq)$.

Vanadium species present at the end of the reaction ....

....

Oxidation state of vanadium in the final species ....

....

Half-equation ....

(ii) The cell represented below was set up under standard conditions.

$$Pt|H_2SO_3(aq),SO_4^{2-}(aq),H^+(aq)||Fe^{3+}(aq),Fe^{2+}(aq)|Pt$$

Calculate the e.m.f. of this cell and state, with an explanation, how this e.m.f. will change if the concentration of $Fe^{3+}(aq)$ ions is increased.

Cell e.m.f. ....

Change in cell e.m.f. ....

Explanation ....

....

(7)

(c) Consider the cell below

$$\overset{-}{Pt}|H_2(g)|H^+(aq)||O_2(g)|OH^-(aq)|\overset{+}{Pt}$$

(i) Using half-equations, deduce an overall equation for the cell reaction.

....

....

....

(ii) State how, if at all, the e.m.f. of this cell will change if the surface area of each platinum electrode is doubled.

....

(3)

(d) Currently, almost all hydrogen is produced by the high-temperature reaction between methane, from North Sea gas, and steam. Give one economic and one environmental disadvantage of this method of producing hydrogen.

Economic disadvantage ....

Environmental disadvantage ....

(2)

(e) Hydrogen can also be produced by the electrolysis of acidified water using electricity produced using solar cells. Give one reason why this method is not used on a large scale.

....

(1)

(Total 17 marks)

32 Which one of the following is the electron arrangement of the strongest reducing agent?

A $1s^2\ 2s^2\ 2p^5$

B $1s^2\ 2s^2\ 2p^6\ 3s^2$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

(Total 1 mark)

33 Which one of the following is **not** a redox reaction?

A $Br_2 + SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2Br^-$

B $SnCl_2 + HgCl_2 \rightarrow Hg + SnCl_4$

C $Cu_2O + H_2SO_4 \rightarrow CuSO_4 + Cu + H_2O$

D $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$

(Total 1 mark)

34 At high temperatures, nitrogen is oxidised by oxygen to form nitrogen monoxide in a reversible reaction as shown in the equation below.

$$N_2(g) + O_2(g) \rightleftharpoons 2NO(g) \qquad \Delta H^{\ominus} = +180\ \text{kJ mol}^{-1}$$

(a) In terms of electrons, give the meaning of the term *oxidation*.

....

(1)

(b) State and explain the effect of an increase in pressure, and the effect of an increase in temperature, on the yield of nitrogen monoxide in the above equilibrium.

Effect of an increase in pressure on the yield ....

Explanation ....

....

....

....

....

Effect of an increase in temperature on the yield ....

Explanation ....

....

....

(6)

(c) Nitrogen monoxide, NO, is formed when silver metal reduces nitrate ions, NO_3^- in acid solution.

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

NO..

NO_3^- ....

(ii) Write a half-equation for the reduction of NO_3^- ions in acid solution to form nitrogen monoxide and water.

....

(iii) Write a half-equation for the oxidation of silver metal to $Ag^+(aq)$ ions.

....

(iv) Hence, deduce an overall equation for the reaction between silver metal and nitrate ions in acid solution.

....

(5)
(Total 12 marks)

35 Refer to the following reaction

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g) \qquad \Delta H^{\ominus} = -11\ \text{kJ mol}^{-1}, \qquad \Delta S^{\ominus} = +20\ \text{J K}^{-1}\ \text{mol}^{-1}$$

Which one of the following statements is correct?

A This is a redox reaction.

B The reaction is **not** feasible below 298 K

C At equilibrium, the yield of hydrogen iodide is changed by increasing the pressure.

D At equilibrium, the yield of hydrogen iodide increases as the temperature is increased.

(Total 1 mark)

36 Photochromic glass contains silver ions and copper ions. A simplified version of a redox equilibrium is shown below. In bright sunlight the high energy u.v. light causes silver atoms to form and the glass darkens. When the intensity of the light is reduced the reaction is reversed and the glass lightens.

$$Cu^+(s) + Ag^+(s) \rightleftharpoons Cu^{2+}(s) + Ag(s)$$

clear glass   dark glass

When the photochromic glass darkens

A the Ag^+ ion is acting as an electron donor.

B the Cu^+ ion is acting as a reducing agent.

C the Ag^+ ion is oxidised.

D the Cu^+ ion is reduced.

(Total 1 mark)

37 (a) By referring to electrons, explain the meaning of the term *oxidising agent*.

....

(1)

(b) For the element **X** in the ionic compound **MX**, explain the meaning of the term *oxidation state*.

....

(1)

(c) Complete the table below by deducing the oxidation state of each of the stated elements in the given ion or compound.

	Oxidation state
Carbon in CO_3^{2-}	
Phosphorus in PCl_4^+	
Nitrogen in Mg_3N_2	

(3)

(d) In acidified aqueous solution, nitrate ions, NO_3^-, react with copper metal forming nitrogen monoxide, NO, and copper(II) ions.

(i) Write a half-equation for the oxidation of copper to copper(II) ions.

....

(ii) Write a half-equation for the reduction, in an acidified solution, of nitrate ions to nitrogen monoxide.

....

(iii) Write an overall equation for this reaction.

....

(3)
(Total 8 marks)

38 Which one of the following statements is **not** correct?

A The first ionisation energy of iron is greater than its second ionisation energy.

B The magnitude of the lattice enthalpy of magnesium oxide is greater than that of barium oxide.

C The oxidation state of iron in $[Fe(CN)_6]^{3-}$ is greater than the oxidation state of copper in $[CuCl_2]^-$

D The boiling point of C_3H_8 is lower than that of CH_3CH_2OH

(Total 1 mark)

39 The vanadium does **not** have an oxidation state of +3 in

A $[V(H_2O)_6]^{3+}$

B $[V(C_2O_4)_3]^{3-}$

C $[V(OH)_3(H_2O)_3]$

D $[VCl_4]^{3-}$

(Total 1 mark)

40 Chlorine and bromine are both oxidising agents.

(a) Define an *oxidising agent* in terms of electrons.

....

(1)

(b) In aqueous solution, bromine oxidises sulphur dioxide, SO_2, to sulphate ions, SO_4^{2-}

(i) Deduce the oxidation state of sulphur in SO_2 and in SO_4^{2-}

SO_2 ....

SO_4^{2-} ....

(ii) Deduce a half-equation for the reduction of bromine in aqueous solution.

....

(iii) Deduce a half-equation for the oxidation of SO_2 in aqueous solution forming SO_4^{2-} and H^+ ions.

....

(iv) Use these two half-equations to construct an overall equation for the reaction between aqueous bromine and sulphur dioxide.

....

(5)

(c) Write an equation for the reaction of chlorine with water. Below each of the chlorine-containing products in your equation, write the oxidation state of chlorine in that product.

....

....

(3)

(d) Give a reason why chlorine is not formed when solid potassium chloride reacts with concentrated sulphuric acid.

....

(1)

(e) Write an equation for the reaction between solid potassium chloride and concentrated sulphuric acid.

....

(1)

(f) Solid potassium bromide undergoes a redox reaction with concentrated sulphuric acid.

(i) Give the oxidation product formed from potassium bromide.

....

(ii) Give the reduction product formed from sulphuric acid.

....

(2)
(Total 13 marks)

41 In which one of the following reactions does hydrogen **not** act as a reducing agent?

A $H_2 + Ca \rightarrow CaH_2$

B $2H_2 + O_2 \rightarrow 2H_2O$

C $H_2 + CH_2{=}CH_2 \rightarrow CH_3CH_3$

C $2H_2 + CH_3COCH_3 \rightarrow CH_3CH_2CH_3 + H_2O$

(Total 1 mark)

42 In which one of the following reactions is the role of the reagent stated correctly?

	Reaction	**Role of reagent**
A	$TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$	TiO_2 is an oxidising agent
B	$HNO_3 + H_2SO_4 \rightarrow H_2NO_3^+ + HSO_4^-$	HNO_3 is a Brønsted-Lowry acid
C	$CH_3COCl + AlCl_3 \rightarrow CH_3CO^+ + AlCl_4^-$	$AlCl_3$ is a Lewis base
D	$2CO + 2NO \rightarrow 2CO_2 + N_2$	CO is a reducing agent

(Total 1 mark)

43 Which one of the following is a redox reaction?

A $2CrO_4^{2-} + 2H^+ \rightarrow Cr_2O_7^{2-} + H_2O$

B $3Cl_2 + 6OH^- \rightarrow 5Cl^- + ClO_3^- + 3H_2O$

C $HNO_3 + 2H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2HSO_4^-$

D $CaCO_3 + SiO_2 \rightarrow CaSiO_3 + CO_2$

(Total 1 mark)

44 (a) In terms of electrons, what happens to an oxidising agent during a redox reaction?

....

(1)

(b) Consider the following redox reaction.

$$SO_2(aq) + 2H_2O(l) + 2Ag^+(aq) \rightarrow 2Ag(s) + SO_4^{2-}(aq) + 4H^+(aq)$$

(i) Identify the oxidising agent and the reducing agent in this reaction.

Oxidising agent ....

Reducing agent ....

(ii) Write a half-equation to show how sulphur dioxide is converted into sulphate ions in aqueous solution.

....

(3)

(c) Fe^{2+} ions are oxidised to Fe^{3+} ions by ClO_3^- ions in acidic conditions. The ClO_3^- ions are reduced to Cl^- ions.

(i) Write a half-equation for the oxidation of Fe^{2+} ions in this reaction.

....

(ii) Deduce the oxidation state of chlorine in ClO_3^- ions.

....

(iii) Write a half-equation for the reduction of ClO_3^- ions to Cl^- ions in acidic conditions.

....

(iv) Hence, write an overall equation for the reaction.

....

(4)

(d) Write an equation to show how sulphur is removed from impure iron obtained from the Blast Furnace. Identify the oxidising agent in this reaction.

Equation ....

Oxidising agent ....

(2)
(Total 10 marks)

45 Which one of the following is **not** a redox reaction?

A $TiO_2 + 2Cl_2 + C \rightarrow TiCl_4 + CO_2$

B $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

C $MgO + 2HCl \rightarrow MgCl_2 + H_2O$

D $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$

(Total 1 mark)

46 In which one of the following reactions is H_2O_2 behaving as a reducing agent?

A $H_2O_2 + 2I^- + 2H^+ \rightarrow I_2 + 2H_2O$

B $H_2O_2 + 2[Co(NH_3)_6]^{2+} \rightarrow 2[Co(NH_3)_6]^{3+} + 2OH^-$

C $5H_2O_2 + - 2MnO_4^- + 6H+ \rightarrow 2Mn^{2+} + 8H_2O + 5O_2$

D $3H_2O_2 + 2[Cr(OH)_6]^{3-} \rightarrow 2CrO_4^{2-} + 8H_2O + 2OH^-$

(Total 1 mark)

47 In which one of the following reactions do two H ions and one electron have to be added to the left-hand side in order to balance the equation?

A $CH_3CHO \rightarrow CH_3CH_2OH$

B $VO^{2+} \rightarrow V^{3+} + H_2O$

C $NO_3^- \rightarrow HNO_2 + H_2O$

D $HOCl \rightarrow \frac{1}{2}Cl_2 + H_2O$

(Total 1 mark)

48 Which equation does **not** involve the reduction of a transition metal compound?

A $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

B $TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$

C $Cr_2O_3 + 2Al \rightarrow 2Cr + Al_2O_3$

D $TiCl_4 + 4Na \rightarrow Ti + 4NaCl$

(Total 1 mark)

49 (a) Concentrated sulphuric acid can be reduced by some solid sodium halides to H_2S

(i) Give the oxidation state of sulphur in H_2S

....

(ii) Give **one** solid sodium halide which will reduce concentrated sulphuric acid, forming H_2S

....

(iii) State **one** way in which the presence of H_2S could be recognised.

....

(iv) Write a half-equation for the formation of H_2S from sulphuric acid.

....

(4)

(b) A different solid sodium halide reacts with concentrated sulphuric acid without reduction forming a halogen-containing product **X**.

(i) Suggest an identity for **X**.

....

(ii) Identify the solid sodium halide which produces **X**.

....

(iii) State the role of sulphuric acid in the formation of **X**.

....

(iv) Write an equation for the reaction with concentrated sulphuric acid in which **X** is formed.

....

(4)
(Total 8 marks)

50 (a) In terms of electron transfer, what does the reducing agent do in a redox reaction?

....

(1)

(b) What is the oxidation state of an atom in an uncombined element?

....

(1)

(c) Deduce the oxidation state of nitrogen in each of the following compounds.

(i) NCl_3 ....

(ii) Mg_3N_2 ....

(iii) NH_2OH ....

(3)

(d) Lead(IV) oxide, PbO_2, reacts with concentrated hydrochloric acid to produce chlorine, lead(II) ions, Pb^{2+}, and water.

(i) Write a half-equation for the formation of Pb^{2+} and water from PbO_2 in the presence of H^+ ions.

....

(ii) Write a half-equation for the formation of chlorine from chloride ions.

....

(iii) Hence deduce an equation for the reaction which occurs when concentrated hydrochloric acid is added to lead(IV) oxide, PbO_2

....

(3)
(Total 8 marks)

51 Which one of the following is the electronic configuration of the strongest reducing agent?

A $1s^2\ 2s^2\ 2p^5$

B $1s^2\ 2s^2\ 2p^6\ 3s^2$

C $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

D $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$

(Total 1 mark)

52 The compound lithium tetrahydridoaluminate(III), $LiAlH_4$, is a useful reducing agent. It behaves in a similar fashion to $NaBH_4$. Carbonyl compounds and carboxylic acids are reduced to alcohols. However, $LiAlH_4$ also reduces water in a violent reaction so that it must be used in an organic solvent.

Which one of the following concerning the violent reaction between $LiAlH_4$ and water is **false**?

A A gas is produced.

B The activation energy for the reaction is relatively high.

C The reaction has a negative free-energy change.

D Aqueous lithium ions are formed.

(Total 1 mark)

53 (a) The following is an equation for a redox reaction.

$$2NO + 12H^+ + 10I^- \rightarrow 2NH_4^+ + 2H_2O + 5I_2$$

(i) Define *oxidation* in terms of electrons.

....

(ii) Deduce the oxidation state of nitrogen in NO and of nitrogen in NH_4^+

Oxidation state of nitrogen in NO ....

Oxidation state of nitrogen in NH_4^+ ....

(iii) Identify the species formed by oxidation in this reaction.........................

(4)

(b) When chlorine gas is bubbled into an aqueous solution of sulphur dioxide, hydrogen ions, sulphate ions and chloride ions are formed.

(i) Write a half-equation for the formation of chloride ions from chlorine.

....

(ii) Write a half-equation for the formation of hydrogen ions and sulphate ions from sulphur dioxide and water.

....

(iii) Hence, deduce an overall equation for the reaction which occurs when chlorine is bubbled into aqueous sulphur dioxide.

....

(3)
(Total 7 marks)

54 (a) Samples of solid sodium fluoride, sodium chloride, sodium bromide and sodium iodide are each warmed separately with concentrated sulphuric acid. All four compounds react with concentrated sulphuric acid but only two can reduce it.

(i) Identify the **two** halides which do **not** reduce concentrated sulphuric acid. Write an equation for the reaction which does occur with **one** of these two halides.

(ii) Identify the **two** halides which reduce concentrated sulphuric acid to sulphur dioxide. Using half-equations for the oxidation and reduction processes, deduce an overall equation for the formation of sulphur dioxide when concentrated sulphuric acid reacts with **one** of these halides.

(iii) In addition to sulphur dioxide, two further reduction products are formed when one of these two halides reacts with concentrated sulphuric acid. Identify the two reduction products and write a half-equation to show the formation of **one** of them from concentrated sulphuric acid.

(9)

(b) How would you distinguish between separate solutions of sodium chloride, sodium bromide and sodium iodide using solutions of silver nitrate and ammonia?

(6)
(Total 15 marks)

55 In which one of the following reactions does the metal species undergo reduction?

A $MnO_2 + 4HCl \rightarrow MnCl_2 + 2H_2O + Cl_2$

B $[Cu(H_2O)_6]^{2+} + 4Cl^- \rightarrow [CuCl_4]^{2-} + 6H_2O$

C $CrO_7^{2-} + 2OH^- \rightarrow 2CrO_4^{2-} + H_2O$

D $TiO_2 + 2C + 2Cl_2 \rightarrow TiCl_4 + 2CO$

(Total 1 mark)

56 Which one of the following contains the metal with the lowest oxidation state?

A CrO_2F_2

B $[Cr_2O_7]^2$

C $[MnCl_6]^{2-}$

D $[Mn(CN)_6]^{3-}$

(Total 1 mark)

57

Summarised directions for recording responses to multiple completion questions			
A (i), (ii) and (iii) only	**B** (i) and (iii) only	**C** (ii) and (iv) only	**D** (iv) alone

In which of the following conversions is the copper reduced?

(i) $[Cu(H_2O)_6]^{2+} \rightarrow [CuCl_4]^{2-}$

(ii) $[Cu(H_2O)_6]^{2+} \rightarrow Cu(H_2O)_4(OH)_2$

(iii) $Cu \rightarrow CuCl_2$

(iv) $[Cu(H_2O)_6]^{2+} \rightarrow CuCl$

(Total 1 mark)

Mark schemes

1 (a) (i) $\mathbf{2}Cl^- \longrightarrow Cl_2 + \mathbf{2}e^-$

Ignore state symbols

Credit loss of electrons from LHS

Credit multiples

Do not penalise absence of charge on electron

1

(ii) +7 ***OR*** 7 ***OR*** VII ***OR*** +VII

Allow Mn^{+7} *and 7+*

1

(iii) $MnO_4^- + 8H^+ + 5\mathbf{e}^- \longrightarrow Mn^{2+} + 4H_2O$

Ignore state symbols

Credit loss of electrons from RHS

Credit multiples

Do not penalise absence of charge on electron

1

(b) (i) $Cl_2 + \mathbf{2}Br^- \longrightarrow \mathbf{2}Cl^- + Br_2$

OR

$\frac{1}{2}Cl_2 + Br^- \longrightarrow Cl^- + \frac{1}{2}Br_2$

One of these two equations only

Ignore state symbols

1

(ii) (Turns to) yellow / orange / brown (solution)

Penalise "red / reddish" as the only colour

Accept "red-brown" and "red-orange"

Ignore "liquid"

Penalise reference to a product that is a gas or a precipitate

1

(iii) (Chlorine) gains electron(s) / takes electron(s) / accepts electron(s) (from the bromide ions)

OR

(Chlorine) causes another species (Br^-) to lose electron(s)

Penalise "electron pair acceptor"

Not simply "causes loss of electrons"

1

(c) **M1** $\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$

$(\mathbf{4}H^+ + \mathbf{4}Cl^-)$

M2 Oxidation state **−1**

Ignore state symbols

Credit multiples

***M2** consequential on HCl or Cl^- which **must** be the only chlorine-containing product in the (un)balanced equation.*

*For **M2** allow Cl^{-1} or Cl^{1-} but **not** Cl^-*

2

(d) **M1 The relative size (of the molecules / atoms)**

Chlorine is <u>smaller</u> than bromine ***OR*** has fewer electrons / electron shells

*For **M1** ignore whether it refers to molecules or atoms.*

OR It is smaller / It has a smaller atomic radius / it is a smaller molecule / atom (or converse)

***CE=0** for the clip for reference to (halide) ions or incorrect statements about relative size*

Ignore molecular mass and M_r

M2 How size of the <u>intermolecular force</u> affects energy needed

Ignore shielding

The <u>forces between</u> chlorine / Cl_2 <u>molecules</u> are weak<u>er</u> (than the forces between bromine / Br_2 <u>molecules</u>)
(or converse for bromine)
OR chlorine / Cl_2 has <u>weaker / fewer / less</u> (VdW) <u>intermolecular forces / forces between molecules</u>
(or converse for bromine)

***QoL in M2** for clear reference to the difference in size <u>of the force between molecules</u>. Reference to Van der Waals forces alone is not enough.*

*Penalise **M2** if (covalent) bonds are broken*

2

[10]

2 (a) **M1 (could be scored by a correct mathematical expression)**

M1 $\Delta H = \Sigma\Delta H_f$ **(products)** $- \Sigma\Delta H_f$ **(reactants)**

OR a correct cycle of balanced equations

M2 = 5(−635) − (−1560)

= − 3175 + 1560

(This also scores M1)

M3 = **− 1615** (kJ mol^{-1})

Award 1 mark ONLY for (+) 1615

*Correct answer to the calculation gains all of **M1**, **M2** and **M3***

Credit 1 mark for(+) 1615 (kJ mol^{-1})

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (**M1** and **M2**)*
- *If no AE, check for a correct method; this requires either a correct cycle with V_2O_5 and 5CaO OR a clear statement of **M1** which could be in words and scores **only M1***

M4 Type of reaction is

- reduction
- redox
- (or accept) V_2O_5 / it / V(V) has been reduced

*In **M4** not "vanadium / V is reduced"*

M5 Major reason for expense of extraction − the answer must be about calcium

Calcium is produced / extracted by electrolysis
OR calcium is expensive to extract
OR calcium extraction uses electricity
OR calcium extraction uses large amount of energy
OR calcium is a (very) reactive metal / reacts with water or air
OR calcium needs to be extracted / does not occur native

QoL

Accept calcium is expensive "to produce" but not "to source, to get, to obtain, to buy" etc.

*In **M5** it is neither enough to say that calcium is "expensive" nor that calcium "must be purified"*

5

(b) **M1**

$2Al + Fe_2O_3 \longrightarrow 2Fe + Al_2O_3$

Ignore state symbols

Credit multiples of the equation

M2

(Change in oxidation state) <u>**0** to (+)**3**</u>

OR

(changed by) <u>**+3**</u>

*In **M2** if an explanation is given it must be correct and unambiguous*

2

(c) **M1**

$VCl_2 + H_2 \longrightarrow V + 2HCl$

*In **M1** credit multiples of the equation*

M2 and **M3**

Two hazards in either order

- <u>HCl / hydrogen chloride / hydrochloric acid is acidic / corrosive / toxic / poisonous</u>
- Explosion risk <u>with hydrogen</u> (gas) OR <u>H_2 is flammable</u>

*For **M2 / M3** there must be reference to hydrogen; it is not enough to refer simply to an explosion risk*

*For **M2 / M3** with HCl hazard, require reference to acid(ic) / corrosive / toxic <u>only</u>*

M4

The only other product / the HCl is easily / readily <u>removed / lost / separated because it is a gas</u> *OR* <u>will escape</u> (or this idea strongly implied) <u>as a gas</u>

OR vanadium / it is the <u>only solid product</u> (and is easily separated)

OR vanadium / it is a <u>solid and the other product / HCl is a gas</u>

*In **M4** it is not enough to state simply that HCl is a gas, since this is in the question.*

4

[11]

3 (a) $Cl_2 + H_2O \rightleftharpoons HOCl + HCl$

Allow the products shown as ions.

1

$Cl_2 = 0$, $HOCl = +1$ and $HCl = -1$

1 mark for all three oxidation states correct. Allow a reaction arrow in this equation.

Oxidation states must match the species

1

(b) Hydroxide / alkali ions react with the acids

Mark independently

1

Equilibrium moves to the right

1

(c) Only used in small amounts

1

The health benefits outweigh the risks

1

[6]

4 D

[1]

5 C

[1]

6 B

[1]

7 D

[1]

8 D

[1]

9 (a) (i) $\mathbf{3}Fe + Sb_2S_3 \longrightarrow \mathbf{3}FeS + \mathbf{2}Sb$

Or multiples.

Ignore state symbols.

1

(ii) $Fe \longrightarrow Fe^{2+} + 2e^-$

Ignore charge on the electron unless incorrect.

Or multiples.

Credit the electrons being subtracted on the LHS.

Ignore state symbols.

1

(b) (i) $Sb_2S_3 + \mathbf{4.5}O_2 \longrightarrow Sb_2O_3 + \mathbf{3}SO_2$

Or multiples.

Ignore state symbols.

1

(ii) SO_3 or sulfur trioxide / sulfur (VI) oxide

Credit also the following ONLY.

H_2SO_4 or sulfuric acid.

OR

Gypsum / $CaSO_4$ or plaster of Paris.

1

(c) (i) **M1 (could be scored by a correct mathematical expression)**

Correct answer gains full marks.

M1 $\underline{\Delta H_r = \Sigma\Delta H_f(\textbf{products}) - \Sigma\Delta H_f(\textbf{reactants})}$

OR a correct cycle of balanced equations / correct numbers of moles

Credit 1 mark for +104 (kJ mol^{-1}).

M2 $= 2(+20) + 3(-394) - (-705) - 3(-111)$

$= 40 - 1182 + 705 + 333$

$= -1142 - (-1038)$

(This also scores M1)

M3 = $\underline{\mathbf{-104}}$ (kJ mol^{-1})

(Award 1 mark ONLY for + 104)

For other incorrect or incomplete answers, proceed as follows:

- *Check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks.*
- *If no AE, check for a correct method; this requires either a correct cycle with 3CO, 2Sb and 3CO$_2$ OR a clear statement of **M1** which could be in words and scores **only M1**.*

3

(ii) It / Sb is not in its standard state

OR

Standard state (for Sb) is solid / (s)

OR

(Sb) liquid is not its standard state

Credit a correct definition of standard state as an alternative to the words 'standard state'.

QoL

1

(iii) Reduction **OR** reduced **OR** redox

1

(d) Low-grade ore extraction / it

- uses (cheap) scrap / waste iron / steel
- is a single-step process

uses / requires less / low(er) energy

Ignore references to temperature / heat or labour or technology.

1

[10]

10 (a) (i) **M1** (+) 4 **OR** IV

M2 (+) 6 **OR** VI

2

(ii) It / Chlorine has gained / accepted electron(s)

OR

Correctly balanced half-equation eg $Cl_2 + \mathbf{2}e^- \longrightarrow \mathbf{2}Cl^-$

Credit 1 or 2 electrons but not lone pair.

The idea of 'reduction' alone is not enough.

1

(b) (i) $\mathbf{6}KI + \mathbf{7}H_2SO_4 \longrightarrow \mathbf{6}KHSO_4 + \mathbf{3}I_2 + S + \mathbf{4}H_2O$

1

(ii) $\mathbf{2}I^- \longrightarrow I_2 + \mathbf{2}e^-$

OR

$8I^- \longrightarrow 4\mathbf{I}_2 + 8e^-$

Ignore charge on the electron unless incorrect.

Or multiples.

Credit the electrons being subtracted on the LHS.

Ignore state symbols.

1

(iii) $H_2SO_4 + \mathbf{8}H^+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$

OR

$SO_4^{2-} + \mathbf{10}H^+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$

Ignore charge on the electron unless incorrect.

Or multiples.

Credit the electrons being subtracted on the RHS.

Ignore state symbols.

1

(c) (i) $Ag^+ + I^- \longrightarrow AgI$ ONLY

Ignore state symbols.

Not multiples.

1

(ii) The precipitate / solid / it does not dissolve / is insoluble / remains

OR a <u>white / cream / yellow</u> <u>solid / precipitate</u>

OR stays the same

OR no (visible / observable) change

OR no effect / no reaction

Ignore 'nothing (happens)'.

Ignore 'no observation'.

1

(iii) The silver nitrate is acidified to

- react with / remove <u>(an)ions that would interfere</u> with the test

  Credit a correct reference to <u>ions</u> that give a 'false positive'.

- prevent the formation of other <u>silver precipitates /</u> <u>insoluble silver compounds</u> that would interfere with the test

  Do not penalise an incorrect formula for an ion that is written in addition to the name.

- remove (other) <u>ions that react with the silver nitrate</u>

  If only the formula of the ion is given, it must be correct.

- react with / remove carbonate / hydroxide / sulfite (ions)

  Ignore 'sulfate'.

1

(iv) HCl would <u>form a</u> (white) <u>precipitate /</u> (white) <u>solid</u> (with silver nitrate and this would interfere with the test)

It is not sufficient simply to state either that it will interfere ***or*** *simply that the ions / compounds react to form AgCl*

1

(d) (i) Any **one** from

Ignore 'to clean water'.

- to sterilise / disinfect water

  Ignore 'water purification' and 'germs'.

- to destroy / kill microorganisms / bacteria / microbes / pathogens

  Credit 'remove bacteria etc' / prevent algae.

1

(ii) The (health) benefit outweighs the risk

OR

a clear statement that once it has done its job, little of it remains

OR

used in (very) dilute concentrations / small amounts / low doses

1

(iii) $Cl_2 + H_2O \longrightarrow HClO + HCl$

OR

$Cl_2 + H_2O \longrightarrow \mathbf{2}H^+ + ClO^- + Cl^-$

OR

$\mathbf{2}Cl_2 + \mathbf{2}H_2O \longrightarrow \mathbf{4}HCl + O_2$

Credit HOCl or ClOH

Or multiples.

Credit other ionic or mixed representations.

Ignore state symbols.

1

(e) **In either order - Both required for one mark only**

Credit correct ionic formulae.

NaClO (OR NaOCl) **and** NaCl

Give credit for answers in equations unless contradicted.

1

[14]

11 (a) $Pt|H_2|H^+||Fe^{2+}|Fe$

Allow 1 for correct order of symbols but lose second mark for a wrong phase boundary(s) / Pt missing / extra Pt on RHS, additional phase boundary

Note, allow one mark only for correct symbol in reverse:

$Fe|Fe^{2+}||H^+|H_2|Pt$

Allow dashed lines for salt bridge

Ignore state symbols

Ignore 2 if used before H^+

2

(b) Electron donor

Allow (species that) loses electrons

Do not allow reference to electron pairs

1

(c) Cl_2 / chlorine

If M1 blank or incorrect cannot score M2

1

(Species on RHS / electron donor) has most positive / largest $E^{\ominus}$ / has highest potential

Do not allow reference to e.m.f. or E(cell)

1

(d) (i) Cl / chlorine

1

(ii) Chlorine +1 to chlorine 0

CE if chlorine not identified in part (i)

Allow chlorine +1 to chlorine –1 (in Cl^-)

Allow oxidation state decreases by one OR two

Allow oxidation state changes by –1 OR –2

1

(e) $4HOCl + 4H^+ + 4OH^- \rightarrow 2Cl_2 + O_2 + 6H_2O$

OR

$4HOCl \rightarrow 2Cl_2 + O_2 + 2H_2O$

Allow one mark for any incorrect equation that shows $HOCl \rightarrow Cl_2 + O_2$

Allow multiples

Ignore state symbols

Penalise one mark for uncancelled or uncombined species (eg $H_2O + H_2O$ *instead of* $2H_2O$*)*

2

(f) (i) e.m.f. = 0.40 – (–1.25) = <u>1.65</u> (V) / <u>+1.65</u> (V)

Allow –1.65 (V)

1

(ii) $2Zn + O_2 \rightarrow 2ZnO$

Allow multiples

Ignore state symbols

Do not allow uncancelled species

If more than one equation given, choose the best

1

(iii) **A** / stainless lid

If M1 incorrect or blank CE=0

1

$\underline{O_2}$ (electrode) has a more positive $\underline{E^\ominus}$ / <u>oxygen</u> (electrode) requires / gains electrons from external circuit

Or reference to the overall equation and a link to electrons going into A

Allow oxygen is reduced and reduction occurs at the positive electrode

OR <u>Zinc</u> (electrode) has more negative $E^\ominus$

Do not allow reference to e.m.f. or E(cell)

1

(iv) (Cell) reaction(s) cannot be reversed / zinc oxide cannot be reduced to zinc by passing a current through it / zinc cannot be regenerated

Allow danger from production of gas / oxygen produced / hydrogen produced

1

[14]

12 (a) moles of $Cr_2O_7^{2-}$ per titration = 21.3 × 0.0150 / 1000 = $\underline{3.195 \times 10^{-4}}$

1

($Cr_2O_7^{2-} + 14H^+ + 6Fe^{2+} \rightarrow 2Cr^{3+} + 7H_2O + 6Fe^{3+}$) $Cr_2O_7^{2-}:Fe^{2+}$ = 1:6

If 1:6 ratio incorrect cannot score M2 or M3

1

moles of $Fe^{2+} = 6 \times 3.195 \times 10^{-4} = 1.917 \times 10^{-3}$

Process mark for M1 × 6 (also score M2)

1

original moles in 250 $cm^3 = 1.917 \times 10^{-3} \times 10 = 1.917 \times 10^{-2}$

Process mark for M3 × 10

1

mass of $FeSO_4.7H_2O = 1.917 \times 10^{-2} \times 277.9 = 5.33$ (g)

Mark for answer to M4 × 277.9

(allow 5.30 to 5.40)

*Answer **must** be to at least 3 sig figs*

Note that an answer of 0.888 scores M1, M4 and M5 (ratio 1:1 used)

1

(b) (Impurity is a) reducing agent / reacts with dichromate / impurity is a version of $FeSO_4$ with fewer than 7 waters (not fully hydrated)

Allow a reducing agent or compound that that converts Fe^{3+} into Fe^{2+}

1

Such that for a given mass, the impurity would react with more dichromate than a similar mass of $FeSO_4.7H_2O$

OR for equal masses of the impurity and $FeSO_4.7H_2O$, the impurity would react with more dichromate.

Must compare mass of impurity with mass of $FeSO_4.7H_2O$

1

[7]

13 (a) (i) $3CuS(s) + \mathbf{8}HNO_3(aq) \longrightarrow \mathbf{3}CuSO_4(aq) + \mathbf{8}NO(g) + \mathbf{4}H_2O(l)$

1

(ii) **(+) 5**
(+) 2

2

(iii) $\mathbf{4}H^+ + NO_3^- + \mathbf{3}e^- \longrightarrow \mathbf{2}H_2O + NO$

Ignore state symbols.

*Credit multiples of **this equation only**.*

Ignore absence of charge on the electron.

1

(iv) $S^{2-} + \mathbf{4}H_2O \longrightarrow SO_4^{2-} + \mathbf{8}e^- + \mathbf{8}H^+$

Ignore state symbols.

*Credit multiples of **this equation only**.*

Ignore absence of charge on the electron.

1

(b) M1 add scrap / recycled / waste iron (or steel) to the aqueous solution

*If **M1** refers to iron / steel, but does not make it clear in the text that it is "scrap" / "waste" / "recycled", penalise **M1** but mark on.*

M2 the iron is a more reactive metal ***OR*** Fe is a better reducing agent

*Credit zinc or magnesium as an alternative to iron for **M2**, **M3** and **M4** only, penalising **M1***

M3 Cu^{2+} / copper ions are reduced / gain electrons
OR $Cu^{2+} + 2e^- \longrightarrow Cu$
OR copper / Cu is displaced by Fe

Ignore absence of charge on the electron.

M4 $Fe + Cu^{2+} \longrightarrow Fe^{2+} + Cu$ ONLY

*For **M4**, ignore state symbols*

4

[9]

14 (a) $\mathbf{2}Ca_5F(PO_4)_3 + 9SiO_2 + \mathbf{15}C \longrightarrow 9CaSiO_3 + CaF_2 + \mathbf{15}CO + \mathbf{6}P$

1

(b) **M1** (P_4 =) **0**

M2 (H_3PO_4 =) **(+) 5**

*Accept Roman numeral V for **M2***

2

(c) H_2SO_4

***Both numbers** required*

M_r = 2(1.00794) + 32.06550 + 4(15.99491)

= **98.06102 or 98.0610 or 98.061 or 98.06 or 98.1**

Calculations not required

and

H_3PO_4

M_r = 3(1.00794) + 30.97376 + 4(15.99491)

= **97.97722 or 97.9772 or 97.977 or 97.98 or 98.0**

1

(d) (i) A substance that speeds up a reaction OR alters / increases the rate of a reaction **AND** is chemically unchanged at the end / not used up.

***Both ideas** needed*

Ignore reference to activation energy or alternative route.

1

(ii) The addition of water (**QoL**) to a molecule / compound

QoL- for the underlined words

1

(iii) **M1** $CH_3CH{=}CH_2 + H_2O \longrightarrow CH_3CH(OH)CH_3$

(C_3H_6)

*For **M1** insist on correct structure for the alcohol but credit correct equations using either C_3H_6 or double bond not given.*

M2 propan-2-ol

2

[8]

15 (a) Ti is not produced

OR

TiC / carbide is produced OR titanium reacts with carbon

OR

Product is brittle

OR

Product is a poor engineering material

Penalise "titanium carbonate"

Ignore "impure titanium"

Credit "it / titanium is brittle"

1

(b) (i) $FeTiO_3 + \mathbf{3½}Cl_2 + \mathbf{3}C \longrightarrow FeCl_3 + TiCl_4 + \mathbf{3}CO$

Ignore state symbols

Credit multiples

1

(ii) $FeCl_3 + TiCl_4 + \mathbf{7}Na \longrightarrow \mathbf{7}NaCl + Fe + Ti$

OR (for example)

$2FeCl_3 + TiCl_4 + \mathbf{10}Na \longrightarrow \mathbf{10}NaCl + 2Fe + Ti$

Ignore state symbols

Credit multiples including ratios other than 1:1

Ignore working

1

(c) Either order

*Penalise reference to incorrect number of electrons in **M1***

M1 The Cu^{2+} / copper(II) ions / they have gained (two) electrons

OR $Cu^{2+} + 2^{e-} \longrightarrow Cu$

*For **M1**, accept "copper" if supported by correct half-equation or simplest ionic equation*

OR oxidation state / number decreases (or specified from 2 to 0)

Ignore charge on the electron

M2 The Cu²⁺ / copper(II) ions / they have been reduced

*For **M2** do **not** accept "copper" alone*

2

(d) $2O^{2-} \longrightarrow O_2 + \mathbf{4}e^{-}$

Or multiples including

$\mathbf{3}O^{2-} \longrightarrow \mathbf{1.5}\ O_2 + \mathbf{6}e^{-}$

Ignore state symbols

Ignore charge on the electron

Credit the electrons being subtracted on the LHS

1

[6]

16 (a) (i) **M1** iodine ***OR*** I_2 OR I_3^-

Ignore state symbols

*Credit **M1** for "iodine solution"*

M2 $Cl_2 + \mathbf{2}I^- \longrightarrow \mathbf{2}Cl^- + I_2$

OR

$\frac{1}{2}\ Cl_2 + I^- \longrightarrow Cl^- + \frac{1}{2}\ I_2$

Penalise multiples in M2 except those shown

***M2** accept correct use of* I_3^-

M3 redox or reduction-oxidation or displacement

3

(ii) **M1** (the white precipitate is) <u>silver chloride</u>

***M1** <u>must be named</u> and for <u>this mark</u> ignore incorrect formula*

M2 $Ag^+ + Cl^- \longrightarrow AgCl$

*For **M2** ignore state symbols*

Penalise multiples

M3 (white) precipitate / <u>it dissolves</u>

OR <u>colourless solution</u>

Ignore references to "clear" alone

3

(b) (i) **M1** $H_2SO_4 + \mathbf{2}Cl^- \longrightarrow \mathbf{2}HCl + SO_4^{2-}$

*For **M1** ignore state symbols*

OR $H_2SO_4 + Cl^- \longrightarrow HCl + HSO_4^-$

Penalise multiples for equations and apply the list principle

OR $H^+ + Cl^- \longrightarrow HCl$

M2 hydrogen chloride ***OR*** HCl ***OR*** hydrochloric acid

2

(ii) **M1 and M2 in either order**

*For **M1** and **M2**, ignore state symbols and credit multiples*

M1 $\mathbf{2}I^- \longrightarrow \mathbf{I_2} + \mathbf{2}e^-$

OR

$\mathbf{8}I^- \longrightarrow \mathbf{4}I_2 + \mathbf{8}e\ –$

Do not penalise absence of charge on the electron

Credit electrons shown correctly on the other side of each equation

M2 $H_2SO_4 + \mathbf{8}H^+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$

OR

$SO_4^{2-} + \mathbf{10}H+ + \mathbf{8}e^- \longrightarrow H_2S + \mathbf{4}H_2O$

Additional equations should not contradict

M3 <u>oxidising agent</u> / <u>oxidises the iodide</u> (ions)

OR

<u>electron acceptor</u>

M4 sulfur ***OR*** S ***OR*** S_2 ***OR*** S_8 ***OR*** sulphur

4

(iii) **M1** The NaOH / OH^- / (sodium) hydroxide reacts with / neutralises the H^+ / acid / HBr (lowering its concentration)

OR a correct neutralisation equation for H^+ or HBr with NaOH or with hydroxide ion

Ignore reference to NaOH reacting with bromide ions

Ignore reference to NaOH reacting with HBrO alone

M2 Requires a correct statement for M1

The (position of) equilibrium moves / shifts(from L to R)

- to replace the H^+ / acid / HBr that has been removed / lost
- ***OR*** to increase the H^+ / acid / HBr concentration
- ***OR*** to make more H^+ / acid / HBr / product(s)
- ***OR*** to oppose the loss of H^+ / loss of product(s)
- ***OR*** to oppose the decrease in concentration of product(s)

*In **M2**, answers must refer to the (position of) equilibrium shifts / moves and is not enough to state simply that it / the system / the reaction shifts to oppose the change.*

M3 The (health) benefit outweighs the risk or wtte

OR

a clear statement that once it has done its job, little of it remains

OR

used in (very) dilute concentrations / small amounts / low doses

3

[15]

17 (a) (i) $SiO_2 + \mathbf{2}Cl_2 + \mathbf{2}C \longrightarrow SiCl_4 + \mathbf{2}CO$

Ignore state symbols

Credit multiples of either equation

OR

$SiO_2 + \mathbf{2}Cl_2 + C \longrightarrow SiCl_4 + CO_2$

1

(ii) (fractional) distillation

OR

G(L)C or gas (–liquid–) chromatography

1

(b) (i) $SiCl_4 + \mathbf{2}H_2 \longrightarrow Si + \mathbf{4}HCl$

Ignore state symbols
Credit multiples
Penalise ionic HCl

1

(ii) Reducing agent / reductant / reduces $SiCl_4$ / reduces (silicon) / electron donor

1

(iii) Explosion / explosive

OR

(highly) flammable / inflammable

OR

<u>readily</u> / <u>easily</u> ignites / burns / combusts

1

(c) $\mathbf{2}MgO + Si \longrightarrow \mathbf{2}Mg + SiO_2$

Ignore state symbols
Credit multiples

1

[6]

18 (a) (i) reduction **OR** reduced **OR** redox ***OR*** reduction–oxidation

Not "oxidation" alone

1

(ii) $Fe^{3+} + \mathbf{3}e^- \longrightarrow Fe$

Ignore state symbols
Do not penalise absence of charge on electron
Credit $Fe^{3+} \longrightarrow Fe - \mathbf{3}e^-$
Credit multiples

1

(b) (i) **Because (one of the following)**

CO is not the only product ***OR***

Reference to "incomplete combustion to form CO" does not answer the question

(Some) complete combustion (also)occurs ***OR***

CO_2 is (also) formed

Further oxidation occurs

1

(ii) The enthalpy change / heat (energy) change at constant pressure in a reaction is independent of the route / path taken (and depends only on the initial and final states)

1

(iii) **M1** The enthalpy change / heat change at constant pressure when 1 mol of a compound / substance / element

For M1, credit correct reference to molecule/s or atom/s

M2 is burned completely / undergoes complete combustion in (excess) oxygen

M3 with all reactants and products / all substances in standard states

For M3

Ignore reference to 1 atmosphere

OR all reactants and products / all substances in normal / specified states under standard conditions / 100 kPa / 1 bar and specified T / 298 K

3

(c) **M1 (could be scored by a correct mathematical expression which <u>must</u> have <u>all</u> <u>ΔH</u> symbols and the $\sum$)**

Correct answer gains full marks

Credit 1 mark ONLY for –1 (kJ mol^{-1})

M1 ΔH_r **=** $\sum\Delta H_f$ (**products**) **–** $\sum\Delta H_f$ (**reactants**)

Credit 1 mark ONLY for – 27 (kJ mol^{-1}) i.e. assuming value for Fe(l) = 0

OR <u>correct cycle of balanced equations with 2Fe, 3C and 3O_2</u>

M2 ΔH_r = 2(+14) + 3(– 394) – (– 822) – 3(–111)

= 28 –1182 + 822 + 333

(This also scores M1)

M3 = **(+) 1** (kJ mol^{-1})

(Award 1 mark ONLY for – 1)

(Award 1 mark ONLY for – 27)

For other incorrect or incomplete answers, proceed as follows

- *check for an arithmetic error (AE), which is either a transposition error or an incorrect multiplication; this would score 2 marks (M1 and M2)*
- *If no AE, check for a correct method; this requires either a correct cycle with 2Fe, 3C and 3O_2 OR a clear statement of M1 which could be in words and scores <u>only M1</u>*

3

(d) (i) C(s) + O_2(g) CO_2(g)

State symbols essential

Possible to include C(s, graphite)

1

(ii) These two enthalpy changes are for <u>the same reaction / same equation / same reactants and products</u>

Penalise reference to CO_2 being produced by a different route

OR

They <u>both make one mole of carbon dioxide only from carbon and oxygen</u> (or this idea clearly implied)

“both form CO_2” is not sufficient (since other products might occur e.g.CO)

OR

The <u>same number and same type of bonds are broken and formed</u>

1

[12]

19 (a) (i) **M1 0**

M2 (+) 5

Accept Roman V for M2

2

(ii) $I_2 + 10HNO_3 \longrightarrow \mathbf{2}HIO_3 + \mathbf{10}NO_2 + \mathbf{4}H_2O$

Accept multiples

1

(b) **M1** $IO_3^- + \mathbf{6}H^+ + \mathbf{5}I^- \longrightarrow \mathbf{3}I_2 + \mathbf{3}H_2O$

For M1, ignore state symbols

Credit multiples

Accept 2½I_2 + ½I_2 as alternative to 3I_2

Electrons must be cancelled

M2 $NaIO_3$ ***OR*** IO_3^- ***OR*** iodate ions ***OR*** iodate(V) ions etc.

For M2 Do not penalise an incorrect name for the correct oxidising agent that is written in addition to the formula.

Accept “the iodine in iodate ions” but NOT “iodine” alone

Accept “the iodine / I in iodate ions” but NOT “iodine” alone

2

(c) (i) Iodine ***OR*** I_2

Insist on correct name or formula

1

(ii) $H_2SO_4 + \mathbf{6}H^+ + \mathbf{6}e^- \longrightarrow S + \mathbf{4}H_2O$

Ignore state symbols

$SO_4^{2-} + \mathbf{8}H+ + \mathbf{6}e^- \longrightarrow S + \mathbf{4}H_2O$

Credit multiples

Do not penalise absence of charge on the electron

1

(d) hydrogen sulfide

OR H_2S

OR hydrogen sulphide

1

(e) (i) $Ag^+ + I^- \longrightarrow AgI$ ONLY

Ignore state symbols

No multiples

1

(ii) The (yellow) precipitate / solid / it does not dissolve / is insoluble

ignore "nothing (happens)"

OR turns to a <u>white solid</u>

ignore "no observation"

OR stays the same

OR no (visible/ observable) change

OR no effect / no reaction

1

(iii) The silver nitrate is acidified to

- react with / remove <u>(an)ions that would interfere</u> with the test

  Ignore reference to "false positive"

- prevent the formation of other <u>silver precipitates / insoluble silver compounds</u> that would interfere with the test

  Do not penalise an incorrect formula for an ion that is written in addition to the name.

- remove (other) <u>ions that react with the silver nitrate</u>

- react with / remove carbonate / hydroxide / sulfite (ions)

  If only the formula of the ion is given, it must be correct

1

(f) (i) An electron donor

Penalise "electron pair donor"

OR (readily) donates / loses / releases / gives (away) electron(s)

Penalise "loss of electrons" alone

Accept "electron donator"

1

(ii) $Cl_2 + \mathbf{2}e^- \longrightarrow \mathbf{2}Cl^-$

Ignore state symbols

Do not penalise absence of charge on electron

Credit $Cl_2 \longrightarrow \mathbf{2}Cl^- - \mathbf{2}e^-$

Credit multiples

1

(iii) For M1 and M2, iodide ions are stronger reducing agents than chloride ions, because

Ignore general statements about Group VII trends or about halogen molecules or atoms. Answers must be specific

M1 Relative size of ions

CE=0 for the clip if "iodine ions / chlorine ions" ***QoL***

Iodide ions / they are larger /have more electron levels(shells) (than chloride ions) / larger atomic / ionic radius

CE=0 for the clip if "iodide ions are bigger molecules / atoms" ***QoL***

OR electron to be lost/outer shell/level (of the iodide ion) is further the nucleus

OR iodide ion(s) / they have greater / more shielding

Insist on iodide ions in M1 and M2 or the use of it / they / them, in the correct context (or chloride ions in the converse argument)

OR converse for chloride ion

M2 Strength of attraction for electron(s)

Must be comparative in both M1 and M2

The electron(s) lost /outer shell/level electron from (an) iodide ion(s) less strongly held by the nucleus compared with that lost from a chloride ion

OR converse for a chloride ion

2

[15]

20 (a) (i) $\mathbf{2}MoS_2 + \mathbf{7}O_2 \longrightarrow \mathbf{2}MoO_3 + \mathbf{4}SO_2$

OR

$MoS_2 + \mathbf{3}\ {}^1\!/_2\ O_2 \rightarrow MoO_3 + \mathbf{2}SO_2$

Allow multiples

Ignore state symbols

1

(ii) **M1 Environmental problem**

Acid rain

OR

An effect either from acid rain or from an acidic gas in the atmosphere.

M2 Use

SO_2 could be used to make / to form / to produce (or wtte) H_2SO_4 / sulfuric acid

OR

To make / to form / to produce (or wtte) gypsum / $CaSO_4$ or plaster of Paris / plaster board

Ignore references to the greenhouse effect

Penalise reference to the ozone layer using the list principle

2

(iii) $MoO_3 + \mathbf{3}H_2 \rightarrow Mo + \mathbf{3}H_2O$

Allow multiples

Ignore state symbols

1

(iv) One from

H_2 is

- Explosive
- (in)flammable
- easily ignited

Ignore "burns"

1

(b) (i) To allow <u>ions</u> to <u>move</u> (when molten)

OR

<u>Ions cannot move in the solid</u>

1

(ii) $Ca^{2+} + \mathbf{2}e^{-} \longrightarrow Ca$

Or multiples

Ignore state symbols

Ignore charge on the electron unless incorrect and accept loss of two electrons on the RHS

1

(iii) (High) <u>electricity</u> / <u>electrical energy</u> (cost)

Ignore "energy" and ignore "current"

[8]

21 (a) (i) $Cu + \mathbf{4}HNO_3 \longrightarrow Cu(NO_3)_2 + \mathbf{2}NO_2 + \mathbf{2}H_2O$

Or multiples

Ignore state symbols

1

(ii) **M1** HNO_3 (+) **5**

M2 NO_2 (+) **4**

Ignore working out

M1 Credit (V)

M2 Credit (IV)

2

(iii) $HNO_3 + H^+ + e^- \longrightarrow NO_2 + H_2O$

OR

$NO_3^- + 2H^+ + e^- \longrightarrow NO_2 + H_2O$

Or multiples

Ignore state symbols

Ignore charge on the electron unless incorrect and accept loss of electron on the RHS

1

(b) (i) **In either order**

M1 Concentration(s) (of reactants and products) remain(s) constant / stay(s) the same / remain(s) the same / do(es) not change

M2 Forward rate = Reverse / backward rate

For M1 accept [ ] for concentration

NOT "equal concentrations" and NOT "concentration(s) is/are the same"

NOT "amount"

Ignore "dynamic" and ignore "speed"

Ignore "closed system"

It is possible to score both marks under the heading of a single feature

2

(ii) **M1**

The (forward) reaction / to the right is endothermic or takes in / absorbs heat

OR

The reverse reaction / to the left is exothermic or gives out / releases heat

M2 depends on correct M1 and must refer to temperature/heat

The equilibrium shifts / moves left to right to oppose the increase in temperature

M2 depends on a correct statement for M1

For M2, the equilibrium shifts/moves

to absorb the heat OR

to lower the temperature OR

to cool the reaction

2

(iii) **M1 refers to number of moles**

There are fewer moles (of gas) on the left OR more moles (of gas) on the right.
OR there is one mole (of gas) on the left and 2 moles on the right.

M2 depends on correct M1 and must refer to pressure
The equilibrium shifts / moves right to left to oppose the increase in pressure

M2 depends on a correct statement for M1

For M2, the equilibrium shifts/moves to lower the pressure.

2

[10]

22 (a) **M1** The yield of zinc oxide increases/greater

If M1 is given as "decrease" OR "no effect" then CE= 0

M2 Removal of the carbon dioxide results in the **equilibrium**
Either
Shifting/moving/goes to the right
shifting/moving/goes L to R
favours the forward reaction/towards the products

M3 (By Le Chatelier's principle) the reaction/equilibrium will respond so as to replace the CO_2/lost product
OR to make more CO_2
OR to increase concentration of CO_2

For M3, not simply "to oppose the change/to oppose the loss of CO_2/to oppose the removal of carbon dioxide."

3

(b) **M1** Process 2 produces/releases SO_2
OR Process 2 produces/releases CO

M2 It/Process 3 avoids the release of SO_2 OR CO
OR It/Process 3 (captures and) converts SO_2 to H_2SO_4

M3 SO_2 causes acid rain OR is toxic/poisonous
OR CO is toxic/poisonous

3

Ignore "global warming" and "greenhouse gases" and "the ozone layer"

If both CO and SO_2 claimed to form acid rain, treat as contradiction

(c) **M1** Process 3 (is expensive because it) uses electrolysis
OR due to high electricity/electrical consumption

M2 this is justified because the product/zinc is pure

Ignore "energy"

Penalise "purer"

2

(d) **M1** $Zn^{2+} + 2e^{-} \longrightarrow Zn$

Ignore state symbols

M2 the negative electrode OR the cathode

Ignore absence of negative charge on electron

Accept electrons subtracted from RHS

2

(e) **M1** The reaction of ZnO with sulfuric acid
OR the second reaction in Extraction process 3

M2 neutralisation or acid-base

OR alternatively

M1 The reaction of zinc carbonate in Extraction process 1

M1 could be the equation written out in both cases

M2 (thermal) decomposition

M2 depends on correct M1

M3 It/carbon is oxidised/gains oxygen/changes oxidation state/number from 0 to +2/increase in oxidation state/number in Process 2

Do not forget to award this mark
Ignore reference to electron loss but penalise electron gain

Ignore "carbon is a reducing agent"

3

(f) **M1** $Zn + H_2O \longrightarrow ZnO + H_2$

M2 Zinc oxide and hydrogen

OR as an alternative

M1 $Zn + 2H_2O \longrightarrow Zn(OH)_2 + H_2$

M2 Zinc hydroxide and hydrogen

Mark independently

If ZnO_2 *is given for zinc oxide in the equation, penalise M1 and mark on*

If ZnOH is given for zinc hydroxide in the equation, penalise M1 and mark on

Ignore state symbols

Credit multiples of the equation

If M1 is blank, either of the M2 answers could score

To gain both marks, the names must match the correct equation given.

2

[15]

23 (a) Hydrogen/H_2 gas/bubbles

1

1.0 mol dm^{-3} HCl/H^+

1

At 298K and 100kPa

Allow 1 bar instead of 100 kPa
Do not allow 1 atm

1

Pt (electrode)

1

(b) $Li^+ + MnO_2 + e^- \rightarrow LiMnO_2$

Ignore state symbols

1

–0.13(V)

1

(c) Fe^{3+} ions reduced to Fe^{2+}

Can score from equation/scheme

1

Because $E(Fe^{3+}(/Fe^{2+})) > E(H^+/H_2)/E$(hydrogen)

Allow emf/E_{cell} +ve/0.77V

Allow Fe^{3+} better oxidising agent than H^+

Allow H_2 better reducing agent than Fe^{2+}

Only award this explanation mark if previous mark given

1

(d) Moles $Cr_2O_7^{2-}$ =$\underline{23.7 \times 0.01/1000}$ = 2.37×10^{-4}

1

1 mol $Cr_2O_7^{2-}$ reacts with 6 mol Fe^{2+} so moles

Fe^{2+} in 25 cm^3 = $6 \times 2.37 \times 10^{-4} = 1.422 \times 10^{-3}$

1

M1 × 6

Moles Fe^{2+} in 250 cm^3 = 1.422×10^{-2}

M2 × 10 or M4/10

1

Original moles Fe^{2+} = $\underline{10.00/277.9}$ = 0.0360

Independent mark

1

Moles Fe^{2+} oxidised = 0.0360 – 0.0142 = 0.0218

M4 – M3

1

% oxidised = (0.0218 × 100)/0.0360 = 60.5%

(M5 × 100)/M4
Allow 60 to 61
Note Max 3 if mol ratio for M2 wrong
eg 1:5 gives 67.1%
1:1 gives 93.4%

Note also, 39.5% (39-40) scores M1, M2, M3 and M4 (4 marks)

1

[14]

24 (a) (i) Propanone evaporates (or similar)

1

Removes water (from the precipitate)

Accept ‘removes impurities / excess reagents’.

Accept ‘salt insoluble in propanone’.

1

(ii) Add NaOH / NH_3 / Na_2CO_3

1

No green ppt

Accept 'no visible change'.

Must have correct reagent to score this mark.

1

(iii) Some salt dissolves (in propanone) **or** some lost in filtration **or** some Fe^{2+} gets oxidised (to Fe^{3+} in air)

Do not accept 'reaction reversible' or 'incomplete reaction' or similar.

1

(iv) Moles $Fe^{2+} = 2.50 \times 10^{-2}$

Accept 2.5×10^{-2}

1

M_r of salt = 179.8

Allow 180

Allow if 179.8 or 180 appears in a calculation.

1

Mass of salt = $179.8 \times 2.5 \times 10^{-2} \times 0.95 = 4.27$ (g)

Correct answer with no working scores this mark only.

Allow range 4.2 to 4.3 (g)

1

(v) 1.67 mol or correct ratio of $5FeC_2O_4 : 3MnO_4^-$

1

(b) $Ca^{2+} + C_2O_4^{2-} \rightarrow CaC_2O_4$

Accept multiples.

1

(c) (Insoluble) calcium ethanedioate coats surface

Allow 'calcium ethanedioate is insoluble'.

Do not allow answers based on ethanedioic acid being a weak acid.

Do not accept 'acid used up' or 'reaction very fast'.

1

(d) Small amount of tea used **or** concentration of the acid in tea is low

Accept 'high temperature decomposes the acid'.

Accept 'calcium ions in milk form a precipitate with the acid'.

Do not accept 'do not drink tea often' or similar.

1

(e) Mass of acid = 180.0 and mass of reagents = 450.0

Accept 180 and 450.

1

(180 / 450 × 100 =) 40.0%

Do not penalise precision.

Correct answer without working scores this mark only.

1

[14]

25 (a) (i) Reducing agent

OR

Reduce(s) (WO_3/tungsten oxide)

OR

electron donor

OR

to remove oxygen (from WO_3/tungsten oxide or to form water);

1

(ii) $WO_3 + \mathbf{3}H_2 \rightarrow W + \mathbf{3}H_2O$

Or multiples

1

(iii) *One from*

H_2 is

- explosive
- flammable or inflammable
- easily ignited

Ignore reference to pressure or temperature

1

(b) (i) Addition

Ignore "electrophilic"

Penalise "nucleophilic addition"

OR

(catalytic) hydrogenation

OR

Reduction

1

(ii) Geometric(al)

OR

cis/trans OR E Z OR E/Z

1

(c) (i) (If any factor is changed which affects an equilibrium), the position of equilibrium will shift/move/change/respond/act so as to oppose the change.

OR

(When a system/reaction in equilibrium is disturbed), the equilibrium shifts/moves in a direction which tends to reduce the disturbance

A variety of wording will be seen here and the key part is the last phrase and must refer to movement of the equilibrium.

QoL

1

(ii) **M1 – Statement of number of moles/molecules**

There are more moles/molecules (of gas) on the left/of reactants

OR

fewer moles/molecules (of gas) on the right./products

OR

there are 4 moles/molecules (of gas) on the left and 2 moles/ molecules on the right.

Ignore "volumes" for M1

Mark independently

M2 – Explanation of response/movement in terms of pressure

Increase in pressure is opposed (or words to that effect)

OR

pressure is lowered by a shift in the equilibrium (from left) to right/favours forward reaction.

2

(d) ΣB(reactants) – ΣB(products) = Δ*H* (**M1**)

OR

Sum of bonds broken – Sum of bonds formed = ΔH (**M1**)

B(H–H) + ½B(O=O) – 2B(O–H) = – 242 (**M1**)

B(H–H) = – 242 – ½(+496) + 2(+463) (this scores **M1** and **M2**)

B(H–H) = (+)436 (kJ mol^{-1}) (**M3**)

Award 1 mark for – 436

Candidates may use a cycle and gain full marks.

M1 could stand alone

Award full marks for correct answer.

Ignore units.

Two marks can score with an arithmetic error in the working.

3

[11]

26 (a) (i) Oxidation

OR

Oxidised ONLY

1

(ii) Any one from

- to provide/overcome activation energy
- to provide the minimum energy to make the reaction go/start

NOT simply to increase the (initial) reaction rate.

1

(iii) The reaction is exothermic OR releases heat (energy)

1

(iv) M1

Catalysts provide an alternative route/pathway OR an alternative mechanism

OR

(in this case) surface adsorption occurs (or a description of adsorption)

Ignore reference to "surface" alone

M2

Lowers the activation energy

OR

of lower activation energy

2

(b) M1

The (forward) reaction is exothermic OR the (forward) reaction releases heat

OR

The reverse reaction is endothermic or absorbs heat

M2 – Direction of change N.B. M2 depends on correct M1

At lower temperatures,

- the equilibrium yield of NO_2 is greater
- more NO_2 is formed
- equilibrium shifts (left) to right
- (equilibrium) favours the forward reaction

(***OR*** converse for higher temperatures)

2

(c) NO_2	(+) 4
NO_3^-	(+) 5
HNO_2	(+) 3

3

[10]

27 (a) (i) $\mathbf{2}CuFeS_2 + \mathbf{2}SiO_2 + \mathbf{4}O_2 \rightarrow Cu_2S + \mathbf{2}FeSiO_3 + \mathbf{3}SO_2$

1

(ii) Acid rain

OR

an effect either from acid rain or from an acidic gas in the atmosphere

1

(iii) SO_2 could be used to make H_2SO_4

OR

to make gypsum/plaster or $CaSO_4$ (xH_2O)

1

(b) $Cu_2S + \mathbf{2}O_2 \rightarrow \mathbf{2}CuO + SO_2$

Or multiples
Ignore state symbols

1

(c) $\mathbf{2}CuO + C \rightarrow \mathbf{2}Cu + CO_2$

OR

$CuO + C \rightarrow Cu + CO$

Or multiples
Ignore state symbols

1

(d) (i) *Any one from the following two ONLY*

Apply the list principle

- (Scrap) iron is cheap
- Low energy requirement
  Not "less energy"

1

(ii) $Fe + Cu^{2+} \rightarrow Fe^{2+} + Cu$

Or multiples
Ignore state symbols

1

[7]

28 (a) (i) $\mathbf{2}C + O_2 \rightarrow \mathbf{2}CO$

OR

$C + CO_2 \rightarrow 2CO$

Or multiples.
Ignore state symbols.

1

(ii) $Fe_2O_3 + 3CO \rightarrow 2Fe + 3CO_2$

Or multiples
Penalise FE and Fe_2
Ignore state symbols

1

(iii) **Economic:**

- Scrap iron/steel has higher iron content.
- Recycling involves lower energy consumption
- Blast furnace not required

Ignore cost
Assume that "it" means recycling for both reasons

1

Environmental:

- Reduces greenhouse gas / CO_2 / SO_2 emission.
- Reduces acid rain
- Reduces mining
- Reduces landfill
- Removes an eyesore

1

(b) (i) **M1** Use of Cl_2 and C

M2 Balanced equation consequential on correct reactants

EITHER

$TiO_2 + \mathbf{2}Cl_2 + \mathbf{2}C \rightarrow TiCl_4 + \mathbf{2}CO$

OR

$TiO_2 + \mathbf{2}Cl_2 + C \rightarrow TiCl_4 + CO_2$

Or multiples
Ignore state symbols

2

(ii) **M1** Use of Na OR Mg

M2 Balanced equation consequential on correct reactants

EITHER

$TiCl_4 + \mathbf{4}Na \rightarrow Ti + \mathbf{4}NaCl$

OR

$TiCl_4 + \mathbf{2}Mg \rightarrow Ti + \mathbf{2}MgCl_2$

Or multiples
Ignore state symbols

2

(iii) One from

- TiC / carbide is produced
- Product is brittle
- Product is a poor engineering material

1

(c) (i) One from

To allow

- <u>ions</u> to <u>move</u>
- <u>current</u> to <u>flow</u>
- it to <u>conduct electricity</u>

1

(ii) $2O^{2-} \rightarrow O_2 + 4e^-$

Or multiples including
$\mathbf{3}O^{2-} \rightarrow \mathbf{1.5}\ O_2 + 6e^-$
Ignore state symbols
Ignore charge on the electron
Credit the electron being subtracted on the LHS

1

(iii) Carbon / graphite / the electrodes <u>oxidise</u>
OR
Carbon / graphite / the electrodes <u>burn in</u> / <u>react with</u> the <u>oxygen</u> formed
OR
carbon dioxide / CO_2 is formed

1

(iv) Recycling involves lower electricity OR less energy consumption

OR

The converse for electrolysis

Ignore references to raw materials
Assume that "it" means recycling
The answer MUST show some evidence of comparison e.g. lower or less

1

[13]

29 (a) **M1** $MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$

1

OR multiples

M2 An oxidising agent is an electron acceptor OR receives / accepts / gains electrons

Ignore state symbols

M2 NOT an "electron pair acceptor"

1

M3 MnO_2 is the oxidising agent

Ignore "takes electrons" or "takes away electrons"

1

(b) **M1** Formation of SO_2 and Br_2 (could be in an equation)

1

M2 Balanced equation

Several possible equations

$\mathbf{2}KBr + \mathbf{3}H_2SO_4 \rightarrow \mathbf{2}KHSO_4 + Br_2 + SO_2 + \mathbf{2}H_2O$

OR

$\mathbf{2}KBr + 2H_2SO_4 \rightarrow K_2SO_4 + Br_2 + SO_2 + \mathbf{2}H_2O$

1

M3 $\mathbf{2}KBr + Cl_2 \rightarrow \mathbf{2}KCl + Br_2$

M2 Could be ionic equation with or without K^+

$\mathbf{2}Br^- + \mathbf{6}H^+ + \mathbf{3}SO_4^{2-} \rightarrow Br_2 + \mathbf{2}HSO_4^- + SO_2 + \mathbf{2}H_2O$
$(\mathbf{3}H_2SO_4)$

$\mathbf{2}Br^- + \mathbf{4}H^+ + SO_4^{2-} \rightarrow Br_2 + SO_2 + \mathbf{2}H_2O$
$(\mathbf{2}HBr + H_2SO_4)$

Accept HBr and H_2SO_4 *in these equations as shown or mixed variants that balance.*
Ignore equations for KBr reacting to produce HBr

M3 Could be ionic equation with or without K^+

$\mathbf{2}Br^- + Cl_2 \rightarrow \mathbf{2}Cl^- + Br_2$

1

M4 % atom economy of bromine

$$= \frac{Br_2}{2KBr + Cl_2} \times 100 = \frac{(2 \times 79.9)}{238 + 71} \times 100 = \frac{159.8}{309} \times 100$$

= **51.7%** OR **52%**

M4 Ignore greater number of significant figures

1

M5 One from:

- High atom economy
- Less waste products
- Cl_2 is available on a large-scale
- No SO_2 produced
- Does not use concentrated H_2SO_4
- (Aqueous) KBr or bromide (ion) in seawater.
- Process 3 is simple(st) or easiest to carry out

M5 Ignore reference to cost
Ignore reference to yield

1

(c) **M1** HBr **–1**

1

M2 HBrO **(+)1**

1

M3 Equilibrium will shift <u>to the right</u>
OR
<u>L to R</u>
OR
Favours forward reaction
OR
Produces more HBrO

1

M4 **<u>Consequential on correct M3</u>**
OR
to <u>oppose the loss</u> of HBrO
OR
<u>replaces</u> (or implied) the HBrO (that has been used up)

1

[12]

30 (a) Gain of electrons

1

(b) (i) (+)5 or V or N^{5+}

1

(+)4 or IV or N^{4+}

1

(+)2 or II or N^{2+}

1

(ii) Reduction

1

$4H^+ + NO_3^- + 3e^{(-)} \rightarrow NO + 2H_2O$

1

(iii) $2H^+ + NO_3^- + e^{(-)} \rightarrow NO_2 + H_2O$

1

(iv) $Cu + 4H^+ + 2\ NO_3^- \rightarrow Cu^{2+} + 2H_2O + 2NO_2$

species

1

balanced
If electrons included, **mark CE if these are not balanced**

1

[9]

31 (a) (i) HgO

1

(ii) $Hg^{2+} + 2e^- \rightarrow Hg$

1

(iii) $2H_2O + SO_2 \rightarrow H_2SO_4 + 2e^-$ etc

1

(iv) $Cl_2 + 2e^- \rightarrow 2Cl^-$

1

(b) (i) Vanadium species: VO_2^+

1

Oxidation state: 5

1

Half-equation: $V^{2+} + 2H_2O \rightarrow VO_2^+ + 4H^+ + 3e^-$

1

(ii) Cell e.m.f 0.06 V

1

Change in e.m.f , Increases

1

More Fe^{3+} ions to accept electrons

1

Fe^{3+}/Fe^{2+} electrode becomes more positive

1

(c) (i) $2H_2 \rightarrow 4H^+ + 4e^-$

1

$4e^- + O_2 + 2H_2O \rightarrow 4OH^-$

1

Overall equation $2H_2 + O_2 \rightarrow 2H_2O$

(ii) Unchanged

1

(d) Economic disadvantage; Use of CH_4 or cost of producing or high temp

1

Environmental disadvantage; Makes CO_2

1

(e) Cost of manufacture of solar cells

1

[17]

32 D **[1]**

33 D **[1]**

34 (a) removal/loss of electrons 1

(b) no change 1

equal number of gaseous moles on either side 1

both sides affected equally 1

increases 1

equilibrium moves to lower the temperature/oppose the change 1

endothermic reaction favoured /forward reaction is endothermic 1

(c) (i) +2 1

+5 1

(ii) $NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$ 1

(iii) $Ag \rightarrow Ag^+ + e^-$ 1

(iv) $NO_3^- + 4H^+ + 3Ag \rightarrow NO + 2H_2O + 3Ag^+$ 1

[12]

35 A **[1]**

36 B **[1]**

37 (a) Accepts electrons 1

(b) Charge on the ion (or element or atom) 1

(c) +4

1

+5

1

–3

1

(d) (i) $Cu^- \rightarrow Cu^{2+} + 2e^-$

1

(ii) $NO_3^- + 4H^+ \ 3e^- \rightarrow NO_2 \ H_2O$

1

(iii) $3Cu + 2NO_3^- + 8H^+ \rightarrow 3Cu^{2+} + 2NO + 4H_2O$

1

[8]

38 A

[1]

39 D

[1]

40 (a) Gains electrons (or removes electrons)

1

(b) (i) +4

1

+6

1

(ii) $Br_2 + 2e^- \rightarrow 2Br^-$

1

(iii) $SO_2 + 2H_2O \rightarrow 4H^+ + SO_4^{2-} + 2e^-$

1

(iv) $Br_2 + SO_2 + 2H_2O \rightarrow 2Br^- + 4H^+ + SO_4^{2-}$

1

(c) $Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$

1

Chloride: –1

1

Chlorate(I): +1

1

(d) Chloride ions cannot reduce sulphuric acid

(Or chloride ions are weak reducing agents

Or sulphuric acid is not a strong enough oxidising agent

Or sulphuric acid is a weaker oxidising agent than chlorine)

1

(e) $KCl + H_2SO_4 \rightarrow HCl + KHSO_4$

(Allow $2KCl + H_2SO_4 \rightarrow 2HCl + K_2SO_4$)

1

(f) (i) Bromine

1

(ii) Sulphur dioxide

1

[13]

41 A

[1]

42 D

[1]

43 B

[1]

44 (a) gains electrons **(1)**
or accepts/takes electrons

Allow an electron
or just 'gains'
or reduction is gain of electrons, but NOT OILRIG even if stated

Do not allow mention of electron pair(s)

1

(b) (i) *Oxidising agent*: Ag^+ **(1)** (*or Ag I*)

Reducing agent: SO_2 **(1)** (*or S^{VI}, not sulphur*)

(ii) $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ **(1)** (*or $H_2SO_4 + 2H^+ + 2e^-$*)

allow e i.e. no charge

penalise E^- once only

allow $-e^-$ on LHS

3

(c) (i) $Fe^{2+} \rightarrow Fe^{3+} + e^-$ **(1)**

(ii) 5 **(1)** (*or V or +5*)

(iii) $ClO_3^- + 6H^+ + 6e^- \rightarrow Cl^- + 3H_2O$ **(1)**

(iv) $ClO_3^- + 6H^+ + 6Fe^{2+} \rightarrow Cl^- + 3H_2O + 6Fe^{3+}$ **(1)**
Mark parts (i) to (iv) independently

4

(d) *Equation*: $Mg + S \rightarrow MgS$ **(1)**

allow FeS + Mg → MgS + Fe
allow Ca

Oxidising agent: S **(1)**

Only award mark if first answer given unless no first answer then can allow

2

[10]

45 C

[1]

46 C

[1]

47 B

[1]

48 B

[1]

49 (a) (i) –2 OR 2–

(ii) NaI or NaAt or I^- or iodide or At^-or Astatide **(1)**

<u>Not</u> atoms or molecules

(iii) Smell of bad eggs **(1)**

Allow $PbAc_2$ *goes black and* $K_2Cr_2O_7/H^+$ *goes cloudy green*

(iv) $8\,e^- + 8\,H^+ + H_2SO_4 \rightarrow H_2S + 4H_2O$ **(1)**

OR $10\,H^+ + SO_4^{2-}$

4

(b) (i) HF or HCl **(1)**

CE = 0 if redox answer given

If wrong halide given allow max one in b(iii)

If NaF or NaCl, or F^- or Cl^- given lose mark in (i)

Mark on if X is e.g. HF_2 or H_2F

(ii) NaF or NaCl or F^- or Cl^- **(1)**

(iii) A proton donor or an acid **(1)**

(iv) $H^+ + F^- \rightarrow HF$

OR $H_2SO_4 + NaF \rightarrow NaHSO_4 + HF$

OR $H_2SO_4 + 2\ NaF \rightarrow Na_2SO_4 + 2\ HF$

OR for chloride

4

[8]

50 (a) A reducing agent gives electrons **(1)**

Not electron pairs

1

(b) Zero **(1)**

1

(c) (i) (+)3 **(1)**

(ii) –3 **(1)**

(iii) –1 **(1)**

Allow answers in roman

3

(d) (i) $PbO_2 + 4H^+ + 2e^- \rightarrow Pb_2^+ + 2H_2O$ **(1)**

(ii) $2Cl^- \rightarrow Cl_2 + 2e^{(-)}$ **(1)**

(iii) $PbO_2 + 4H^+ + 2Cl^- \rightarrow Pb^{2+} + Cl_2 + 2H_2O$ **(1)**

Or molecular

3

[8]

51 D

[1]

52 B

[1]

53 (a) (i) Loss (of electrons) **(1)**

(ii) *Oxidation state of nitrogen in NO:* (+) 2 **(1)**

Oxidation state of nitrogen in NH^+*:* –3 **(1)**

(iii) I_2 **(1)**

4

(b) (i) $Cl_2 + 2e^- \rightarrow 2Cl^-$ **(1)**

(ii) $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$ **(1)**

(iii) $SO_2 + 2H_2O + Cl_2 \rightarrow SO_4^{2-} + 2Cl^- + 4H^+$ **(1)**
or $H_2SO_4 + 2HCl$ etc

Ignore state symbols in equation

Allow multiples of all equations

3

[7]

54 (a) (i) Halides:- Fluoride
Chloride **(1)**

Equation:- $H^+ + F^- \rightarrow HF$ *(or molecular / for a correct halide)* **(1)**

(ii) Halides:- Bromide and iodide **(1)**

Equation:- H_2SO_4 *(or* $2H^+ + SO_4^{2-}$*)* $+ 2H^+ + 2e^- \rightarrow SO_2 + 2H_2O$ **(1)**

$2Br^- \rightarrow Br_2 + 2e^-$ **(1)**

$H_2SO_4 + 2H^+ + 2Br^-$ (or 2HBr) $\rightarrow Br_2 + SO_2 + 2H_2O$ **(1)**

Q of L penalise wrong symbol for fluoride or bromide once
Ignore state symbols in equations

(iii) Products Sulphur (or S_8 not S_4) **(1)**
Hydrogen sulphide **(1)**

Equation:- H_2SO_4 *(or* $2H^+ + SO_4^{2-}$*)* $+6H^+ + 6e^- \rightarrow S + 4H_2O$ **(1)**

OR

H_2SO_4 *(or* $2H^+ + SO_4^{2-}$*)* $+ 8H^+ + 8e^- \rightarrow H_2S + 4H_2O$

9

Ignore halide if given even if incorrect
Do not allow elements, molecules or atoms in part (a)

(b) Addition of silver nitrate

Chloride gives white precipitate / solid **(1)**
Bromide gives cream precipitate / solid **(1)**
Iodide gives yellow precipitate / solid **(1)**

Addition of ammonia

Chloride precipitate soluble in dilute **(1)**
Bromide precipitate soluble in concentrated **(1)**
Iodide precipitate insoluble **(1)**

Do not allow halogen or sodium halide

6

[15]

55 A **[1]**

56 D **[1]**

57 D **[1]**