

AQA A-LEVEL CHEMISTRY • 7405

CHEMISTRY



EXAM QUESTION PACK

3.1.7 OXIDATION, REDUCTION AND REDOX EQUATIONS

SCORE

/235

PERCENTAGE

%

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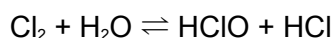
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Q1.

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

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



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

Oxidation state of chlorine in HClO _____

Oxidation state of chlorine in HCl _____

(1)

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

Oxidation half-equation _____

Reduction half-equation _____

(2)

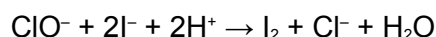
- (c) Chlorine is reacted with cold, aqueous sodium hydroxide in the manufacture of bleach.

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

(1)

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

The overall equation for this reaction is shown.



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

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

Calculate the mass, in mg, of potassium iodide needed to react with all of the ClO^- ions in the sample of bleach.

Give your answer to the appropriate number of significant figures.

Give **one** observation during this reaction.

Mass of potassium iodide _____ mg

Observation _____

(4)

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

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

Substance	$\Delta_f H / \text{kJ mol}^{-1}$
$\text{KClO}_4(\text{s})$	- 434
$\text{KCl}(\text{s})$	- 436

Equation _____

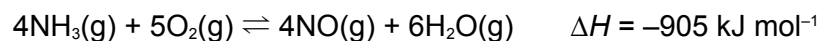
Enthalpy change _____ kJ mol^{-1}

(2)

(Total 10 marks)

Q2.

The equation for the reaction between ammonia and oxygen is shown.



Some standard entropies are given in the table.

Gas	$S^\circ / \text{J K}^{-1} \text{ mol}^{-1}$
$\text{NH}_3(\text{g})$	193
$\text{O}_2(\text{g})$	205

NO(g)	211
H ₂ O(g)	189

- (a) Calculate the entropy change for the reaction between ammonia and oxygen.

Entropy change _____ J K⁻¹ mol⁻¹

(2)

- (b) Calculate a value for the Gibbs free-energy change (ΔG), in kJ mol⁻¹, for the reaction between ammonia and oxygen at 600 °C

(If you were unable to obtain an answer to part (a), you should assume that the entropy change is 211 J K⁻¹ mol⁻¹. This is not the correct answer.)

ΔG _____ kJ mol⁻¹

(2)

- (c) The reaction between ammonia and oxygen was carried out at a higher temperature.

Explain how this change affects the value of ΔG for the reaction.

(2)

- (d) Platinum acts as a heterogeneous catalyst in the reaction between ammonia and oxygen. It provides an alternative reaction route with a lower activation energy.

Describe the stages of this alternative route.

(3)

- (e) Deduce the change in oxidation state of nitrogen, when NH_3 is oxidised to NO

(1)

- (f) When ammonia reacts with oxygen, nitrous oxide (N_2O) can be produced instead of NO

Give an equation for this reaction.

(1)

(Total 11 marks)

Q3.

This question is about vanadium compounds and ions.

- (a) Use data from Table 4 to identify the species that can be used to reduce VO_2^+ ions to VO^{2+} in aqueous solution and no further.

Explain your answer.

Electrode half-equation	$E^\ominus / \text{V}$
$\text{VO}_2^+(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{VO}^{2+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+1.00
$\text{VO}^{2+}(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightarrow \text{V}^{3+}(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+0.34
$\text{Cl}_2(\text{aq}) + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{aq})$	+1.36
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Zn}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Zn}(\text{s})$	-0.76

Reagent _____

Justification _____

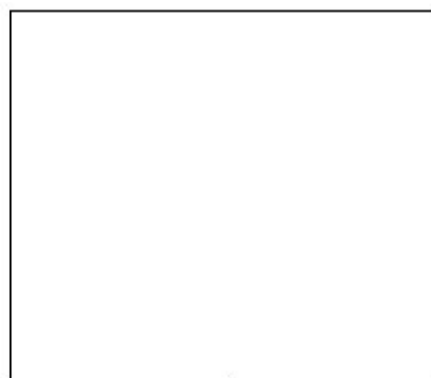
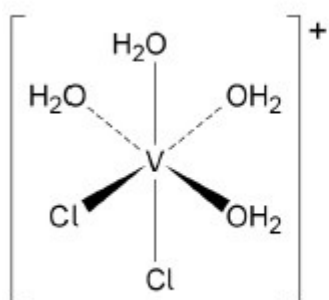
(2)

- (b) Give the oxidation state of vanadium in $[\text{VO}(\text{H}_2\text{O})_5]^{2+}$

(1)

- (c) The $[\text{V}(\text{H}_2\text{O})_4\text{Cl}_2]^+$ ion exists as two isomers. One isomer is shown.

Draw the structure of the other isomer and state the type of isomerism.



Type of isomerism _____

(2)

- (d) Heating NH_4VO_3 produces vanadium(V) oxide, water and one other product.

Give an equation for the reaction.

(1)

- (e) Vanadium(V) oxide is the catalyst used in the manufacture of sulfur trioxide.

Give **two** equations to show how the catalyst is used and regenerated.

(1)

(Total 7 marks)

Q4.

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

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

NO_2^- _____

NO _____

(2)

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

(1)

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

(1)

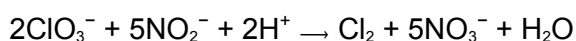
- (d) Write an overall ionic equation for the reaction of NO_2^- in an acidic solution with I^-

(1)

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

(1)

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



25.0 cm³ sample of an aqueous solution of sodium nitrite required 27.40 cm³ of a 0.0200 mol dm⁻³ solution of potassium chlorate(V) for complete reaction.

Calculate the concentration, in g dm⁻³, of sodium nitrite in the sample.

Concentration of sodium nitrite _____ g dm⁻³

(4)

(Total 10 marks)

Q5.

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

- A** $\text{Cu}_2\text{O} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{Cu} + \text{H}_2\text{O}$ ☐
- B** $\text{MgO} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2\text{O}$ ☐
- C** $\text{SnCl}_2 + \text{HgCl}_2 \rightarrow \text{Hg} + \text{SnCl}_4$ ☐
- D** $\text{MnO}_2 + 4\text{HCl} \rightarrow \text{MnCl}_2 + 2\text{H}_2\text{O} + \text{Cl}_2$ ☐

(Total 1 mark)

Q6.

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

- A** Na_2SO_4 ☐
- B** H_2S ☐
- C** S ☐
- D** SO_2 ☐

(Total 1 mark)

Q7.

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

Electrode half-equation	E° / V
$\text{Cl}_2(\text{g}) + 2\text{e}^- \rightarrow 2\text{Cl}^-(\text{aq})$	+1.36
$\text{NO}_3^-(\text{aq}) + 4\text{H}^+(\text{aq}) + 3\text{e}^- \rightarrow \text{NO}(\text{aq}) + 2\text{H}_2\text{O}(\text{aq})$	+0.96
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Cu}(\text{s})$	+0.34
$\text{SO}_4^{2-}(\text{aq}) + 4\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{SO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{aq})$	+0.17
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightarrow \text{H}_2(\text{g})$	0.00
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \rightarrow \text{Fe}(\text{s})$	-0.44

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

Nitrogen in NO_3^- _____

Nitrogen in NO _____

(2)

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

(1)

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

Explain your choice of acid.

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

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

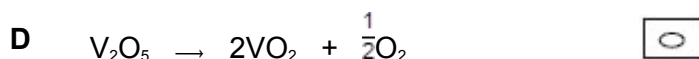
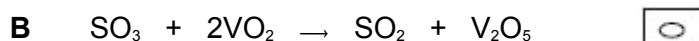
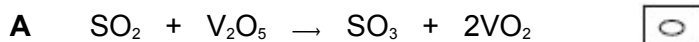
(4)

(Total 7 marks)

Q8.

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

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



(Total 1 mark)

Q9.

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

	NH_3	N_2O	HNO_2	
A	+3	-1	+5	☐
B	-3	+1	+3	☐
C	-3	+1	-5	☐
D	+3	-1	-3	☐

(Total 1 mark)

Q10.

Which of these is a redox reaction?

- A** $\text{CaO} + \text{SiO}_2 \rightarrow \text{CaSiO}_3$ ☐
- B** $\text{H}_2\text{SO}_4 + \text{Na}_2\text{O} \rightarrow \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}$ ☐
- C** $\text{NaBr} + \text{H}_2\text{SO}_4 \rightarrow \text{NaHSO}_4 + \text{HBr}$ ☐
- D** $\text{Mg} + \text{S} \rightarrow \text{MgS}$ ☐

(Total 1 mark)

Q11.

This question is about the element iodine and its compounds.

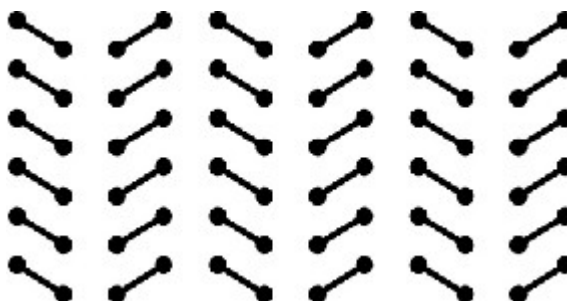
- (a) Iodine is in Group 7 of the Periodic Table.

Complete the electron configuration of an iodine atom.

[Kr]

(1)

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



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

(6)

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

(1)

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

(1)

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

What is the formula of ammonium triiodide?

Tick (✓) **one** box.

NH_3I_3

☐

NH_3I_4

☐

NH_4I

☐

NH_4I_3

☐

(1)

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

(2)

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

$\text{Ba}(\text{IO}_3)_2$

$[\text{H}_4\text{IO}_6]^-$

(2)

(Total 14 marks)

Q12.

Which of these species is the best reducing agent?

- A Cl_2 ☐
- B Cl^- ☐
- C I_2 ☐
- D I^- ☐

(Total 1 mark)

Q13.

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

	HCl	KClO ₃	HClO	
A	-1	+3	+1	☐
B	+1	-5	-1	☐
C	-1	+5	+1	☐
D	+1	+5	-1	☐

(Total 1 mark)

Q14.

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

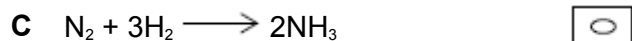
- A H_2S ☐
- B HI ☐
- C SO_2 ☐
- D I_2 ☐

(Total 1 mark)

Q15.

In which reaction is hydrogen acting as an oxidising agent?

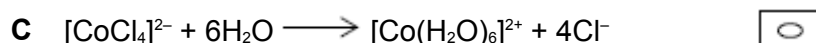
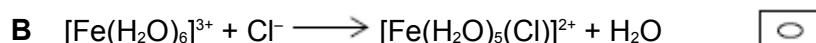
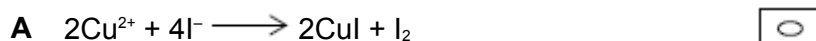
- A $\text{Cl}_2 + \text{H}_2 \longrightarrow 2\text{HCl}$ ☐
- B $(\text{CH}_3)_2\text{CO} + \text{H}_2 \longrightarrow (\text{CH}_3)_2\text{CHOH}$ ☐



(Total 1 mark)

Q16.

In which reaction is the metal oxidised?

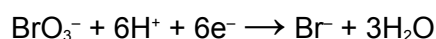
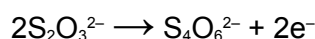


(Total 1 mark)

Q17.

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

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



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

(1)

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

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

(2)

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

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

(1)

(Total 4 marks)

Q18.

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

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

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

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

(2)

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

(1)

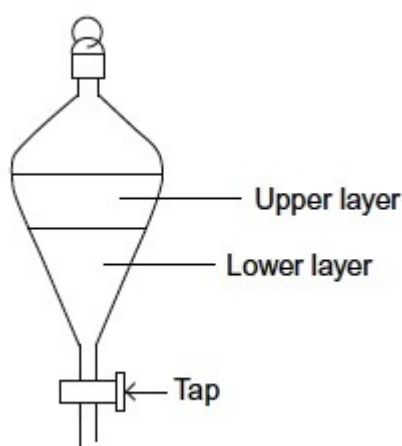
- (c) Describe how, in Step D, the solution could have been tested to show when it became acidic. Your method should **not** contaminate the solution.

(2)

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

(1)

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



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

Liquid	H ₂ O	Filtrate from Step C	CCl ₄	Concentrated H ₂ SO ₄
Density / g cm ⁻³	1.0	1.2	1.6	1.8

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

(1)

- (f) The iodine in the separating funnel quickly establishes an equilibrium after shaking the contents. The concentrations of iodine in the aqueous layer and in the CCl₄ layer become constant. This is shown by the relationship

$$K = \frac{[\text{I}_2 \text{ in CCl}_4]}{[\text{I}_2 \text{ in aqueous layer}]}$$

A sample of *Laminaria* seaweed, mass 56.4 g, was processed by the method given. After Step H, 1.673 g of iodine remained in the evaporating basin. The volume of each layer was 50.0 cm³. The seaweed contains 3.00% iodine by mass.

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

(3)

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

(2)

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

(2)

(Total 14 marks)

Q19.

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

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

- _____ (1)
- (b) Write a half-equation for the reduction of chlorate(I) ions to chlorine in acidic conditions.

- _____ (1)
- (c) Write an overall equation for the redox reaction of chlorate(I) ions with hydrochloric acid.

- _____ (1)
- (d) A solution of sodium chlorate(I) was added to a colourless solution of potassium iodide.
Suggest what is observed.

Explain the reaction that leads to this observation.

_____ (3)
(Total 6 marks)

Q20.

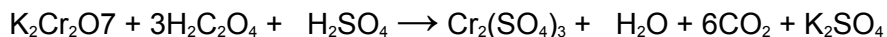
Which species contains an element with an oxidation state of +4?

- | | |
|----------------------------------|--------------------------|
| A NO_2^+ | ☐ |
| B ClO_3^- | ☐ |
| C H_2SO_3 | ☐ |
| D PCl_5 | ☐ |

(Total 1 mark)

Q21.

Refer to the unbalanced equation below when answering this question.



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

A 1 : 4

☐

B 1 : 2

☐

C 4 : 7

☐

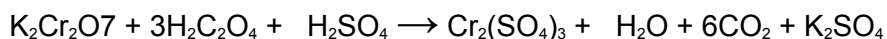
D 4 : 9

☐

(Total 1 mark)

Q22.

Refer to the unbalanced equation below when answering this question.



What is the reducing agent in this reaction?

A H^+

☐

B $\text{C}_2\text{O}_4^{2-}$

☐

C K^+

☐

D $\text{Cr}_2\text{O}_7^{2-}$

☐

(Total 1 mark)

Q23.

The halogens are the elements in Group 7.

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

Halogen	Fluorine	Chlorine	Bromine	Iodine
Electronegativity	4.0	3.0	2.8	2.5

Explain the trend in electronegativities shown by the halogens.

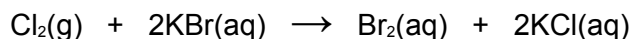
(2)

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

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

(1)

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



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

(1)

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

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

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

(1)

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

(1)

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

(1)

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

Tick (✓) **one** box.

Acid

☐

Oxidising agent

☐

Reducing agent

☐

Electrophile

☐

(1)

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

(1)

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

(1)

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

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

(1)

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

(2)
(Total 13 marks)

Q24.

Chlorine is an important industrial chemical.

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



- (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.

(2)

(Total 10 marks)

Q25.

Vanadium is an important metal. Ferrovandium, 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.

	$\text{V}_2\text{O}_5(\text{s})$	$\text{CaO}(\text{s})$
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-1560	-635

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



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

State the type of reaction that V_2O_5 has undergone.

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

(5)

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

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

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

(2)

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

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

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

Deduce why this process produces **pure** vanadium, other than the fact that purified VCl_2 is used.

(4)

(Total 11 marks)

Q26.

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

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

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

(1)

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

(1)

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

- (i) Write an equation for this reaction.

(1)

- (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.

	Sb₂O₃(s)	CO(g)	Sb(l)	CO₂(g)
$\Delta H_f^\ominus / \text{kJ mol}^{-1}$	-705	-111	+20	-394



(3)

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

(1)

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

(1)

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

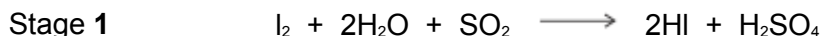
(1)

(Total 10 marks)

Q27.

This question is about Group 7 chemistry.

- (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.



- (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.



- (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)

Q28.

The table below shows some standard electrode potential data.

	$E^\ominus / \text{V}$
$\text{ZnO(s)} + \text{H}_2\text{O(l)} + 2\text{e}^- \longrightarrow \text{Zn(s)} + 2\text{OH}^-(\text{aq})$	-1.25
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Fe(s)}$	-0.44
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O(l)} + 4\text{e}^- \longrightarrow 4\text{OH}^-(\text{aq})$	+0.40
$2\text{HOCl(aq)} + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cl}_2(\text{g}) + 2\text{H}_2\text{O(l)}$	+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

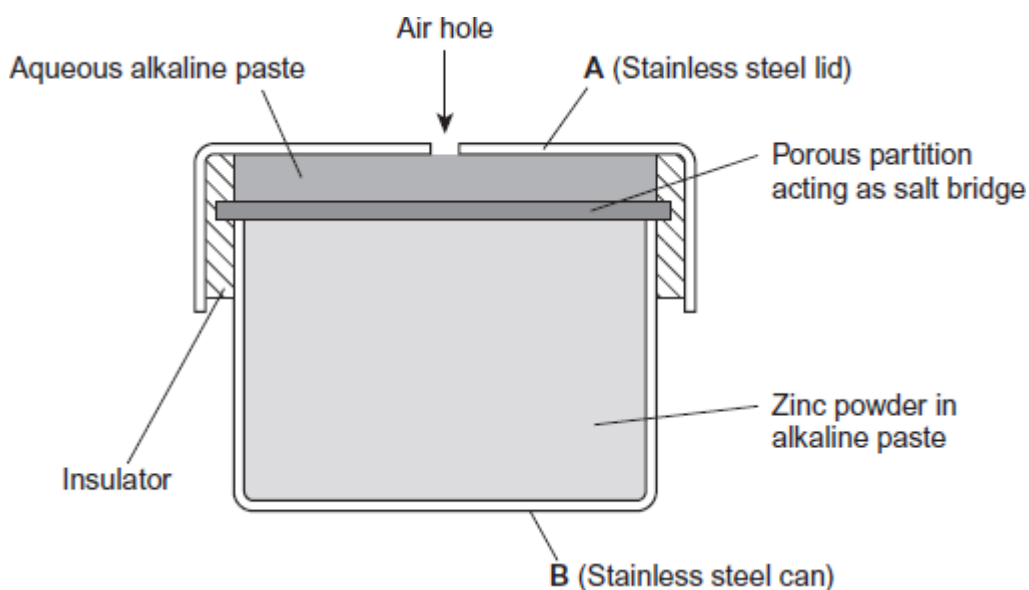
(2)

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

	$E^\ominus / \text{V}$
$\text{ZnO(s)} + \text{H}_2\text{O(l)} + 2\text{e}^- \longrightarrow \text{Zn(s)} + 2\text{OH}^-(\text{aq})$	-1.25
$\text{Fe}^{2+}(\text{aq}) + 2\text{e}^- \longrightarrow \text{Fe(s)}$	-0.44
$\text{O}_2(\text{g}) + 2\text{H}_2\text{O(l)} + 4\text{e}^- \longrightarrow 4\text{OH}^-(\text{aq})$	+0.40
$2\text{HOCl(aq)} + 2\text{H}^+(\text{aq}) + 2\text{e}^- \longrightarrow \text{Cl}_2(\text{g}) + 2\text{H}_2\text{O(l)}$	+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)

Q29.

A student carried out an experiment to find the mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ 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 $0.0150 \text{ mol dm}^{-3}$ solution of $\text{K}_2\text{Cr}_2\text{O}_7$

- (a) Use this information to calculate a value for the mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ in the sample of **X**.

(5)

- (b) The student found that the calculated mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ 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 $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$ in **X** to be greater than the actual mass of **X**.
Explain your answer.

(2)

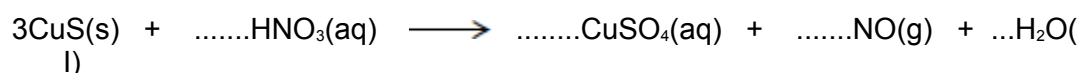
(Total 7 marks)

Q30.

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

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

- (i) Balance the equation for this reaction.



(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 $\text{H}^+(\text{aq})$ ions.

(1)

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

Simplest ionic equation

(4)

(Total 9 marks)

Q31.

The manufacture of food grade phosphoric acid for use in cola drinks begins with the production of pure white phosphorus from the mineral fluoroapatite, $\text{Ca}_5\text{F}(\text{PO}_4)_3$

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



(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
------	------------------------------

^1H	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 $\text{CH}_3\text{CH}(\text{OH})\text{CH}_3$ as the main organic product.
The industrial name for this alcohol is isopropyl alcohol.

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

(1)

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

(1)

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

Equation _____

IUPAC name _____

(2)

(Total 8 marks)

Q32.

Metals can be extracted by different methods.

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

(1)

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

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

(1)

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

(1)

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

(2)

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

(1)

(Total 6 marks)

Q33.

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

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

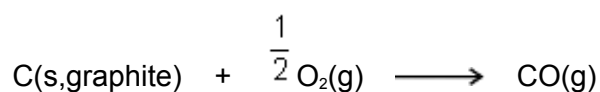
_____ (1)

- (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.



_____ (1)

- (ii) State Hess's Law.

_____ (1)

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

_____ (3)

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

	Fe ₂ O ₃ (s)	CO(g)	Fe(l)	CO ₂ (g)
ΔH_f° / kJ mol ⁻¹	- 822	- 111	+14	- 394



(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 $\text{CO}_2(\text{g})$ is the same as the value for the standard enthalpy of combustion of carbon.

(1)

(Total 12 marks)

Q34.

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

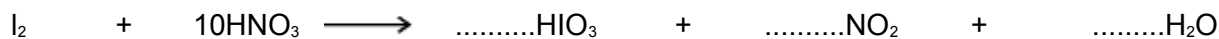
- (a) (i) Give the oxidation state of iodine in each of the following.

I_2 _____

HIO_3 _____

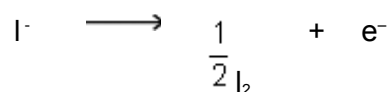
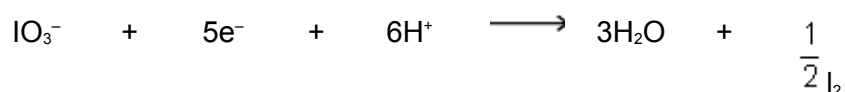
(2)

- (ii) Complete the balancing of the following equation.



(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.



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.



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

_____ (1)

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

_____ (1)

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

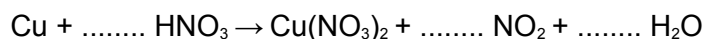
_____ (2)

(Total 15 marks)

Q35.

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

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



(1)

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

HNO₃ _____

NO₂ _____

(2)

- (iii) Deduce the half-equation for the conversion of HNO₃ into NO₂ in this reaction.

(1)

- (b) The following equilibrium is established between colourless dinitrogen tetroxide gas (N₂O₄) and dark brown nitrogen dioxide gas.



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

Feature 1 _____

Feature 2 _____

(2)

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

(2)

- (iii) Use Le Chatelier's principle to explain why the amount of NO₂ decreases when the pressure is increased at constant temperature.

(2)
(Total 10 marks)

Mark schemes

Q1.

- (a) Two correct Cl ox states: $\text{HClO} = +1$ $\text{HCl} = -1$

1

- (b) Oxidation:
 $\text{Cl}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{HClO} + 2\text{H}^+ + 2\text{e}^-$
Accept - 2e^- on the other side
Allow $\text{Cl}_2 + 2\text{H}_2\text{O} \rightarrow 2\text{ClO}^- + 2\text{e}^-$

1

Reduction:
 $\text{Cl}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow 2\text{HCl}$
Allow $\text{Cl}_2 + 2\text{e}^- \rightarrow 2\text{Cl}^-$
If both equations correct but incorrect order, allow 1
Ignore state symbols

1

- (c) $2\text{NaOH} + \text{Cl}_2 \rightarrow \text{NaCl} + \text{NaClO} + \text{H}_2\text{O}$
Allow
 $2\text{OH}^- + \text{Cl}_2 \rightarrow \text{Cl}^- + \text{ClO}^- + \text{H}_2\text{O}$
Allow NaOCl
Ignore state symbols

1

- (d) $\text{mol ClO}^- = \text{conc} \times \text{vol} = 0.0109 \times 0.02$
 $= \underline{0.000218 / 2.18 \times 10^{-4}} \text{ mol}$

1

$\text{mol KI} = 0.000218 \times 2 = 0.000436 \text{ mol}$
 $M2 = M1 \times 2$
If incorrect ratio, $M2 \& M3 = 0$

1

$\text{mass KI} = M_r \times \text{mol} = 166.0 \times 0.000436$
 $= 0.072376 \text{ g}$
 $= 72.4 \text{ (mg)}$

$M3 = M1 \times 2 \times 166.0 \times 1000$
Must be to 3 sig figs

1

black solid/ppt appears/forms (in a colourless solution)
 or (colourless solution) turns brown (solution)
Not purple. Not red. Not brown ppt/solid
Ignore grey.

1

- (e) $\text{KClO}_4 \rightarrow \text{KCl} + 2\text{O}_2$
Ignore state symbols
Allow multiples

1

$$\Delta H = -436 - -434 = -2 \text{ kJ mol}^{-1}$$

Must be negative

Mark independently

Allow consequential for multiples

1

[10]

Q2.

(a) $(\Delta S = \Sigma(S \text{ products}) - \Sigma(S \text{ reactants}))$

$$= [(4 \times 211) + (6 \times 189)] - [(4 \times 193) + (5 \times 205)] = (1978 - 1797)$$

1

$$181 \text{ (J K}^{-1} \text{ mol}^{-1}\text{)}$$

1

(b) $(\Delta G = \Delta H - T\Delta S) = -905 - (600 + 273) \times 181 \times 10^{-3}$

If answer to (a) is incorrect, mark consequentially:

$$-905 - (873 \times (a) \times 10^{-3})$$

1

$$\Delta G = -1063 / -1060 \text{ (kJ mol}^{-1}\text{)}$$

If alternative value of $\Delta S = 211$ used, answer = -1089 (kJ mol⁻¹)

1

(c) ΔG becomes more negative/less positive

Ignore increase/decrease/larger/smaller ΔG

1

The entropy change / ΔS is positive / $T\Delta S$ gets bigger / $-T\Delta S$ gets more negative.

Consequential on wrong (a)

If candidate does a calculation in (a) to produce ΔS negative then allow ΔG becomes less negative or more positive

1

(d) Reactant(s) adsorbed onto the (platinum surface) / (platinum) provides a surface / active sites

1

Reaction (on the surface) or bond breaking(weakening) / bond making occurs (on the surface)

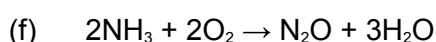
1

Desorption (of the product) or wtte

1

(e) (Oxidation state changes from) -3 to +2 OR (+) 5

1



Allow multiples

Ignore state symbols

1

[11]

Q3.

- (a) Fe^{2+}

Accept any Fe(II) compound – correct formula or name

1

$$E^\ominus \text{VO}_2^+ / \text{VO}^{2+} > E^\ominus \text{Fe}^{3+} / \text{Fe}^{2+} > E^\ominus \text{VO}^{2+} / \text{V}^{3+}$$

If calculations of EMF are provided producing EMFs = 0.23(V) and -0.43(V), with a comment, allow M2

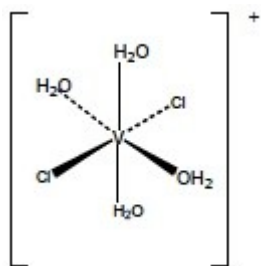
allow $E^\ominus \text{Fe}^{3+} / \text{Fe}^{2+}$ value of +0.77 is between the $E^\ominus$ values for the electrode half-equations containing the V species or wtte

1

- (b) (+) 4

IV or four

1



- (c)

Ignore absence of charge

Wedges, dotted lines and [] not required

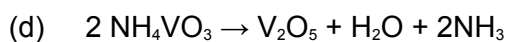
Do not penalise bond from H to V (in water ligands)

1

Cis/trans

allow E/Z, geometric and stereo(isomerism)

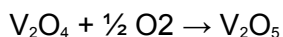
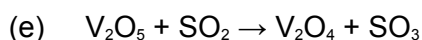
1



Accept multiples

Ignore state symbols

1



Both equations needed for 1 mark in this order

Allow multiples

1

[7]

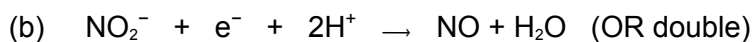
Q4.

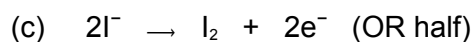
- (a) NO_2^- +3 or III or 3 or 3+

1

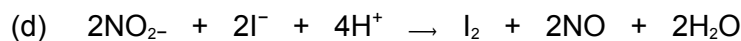
NO +2 or II or 2 or 2+

1





1



1

(e) Oxidising agent

Allow to accept / gain electrons

Allow Oxidant

Do not allow accept / gain pairs of electrons

Do not allow Oxidise

1

1

(f) $\text{Mol ClO}_3^- = 0.02 \times \frac{27.4}{1000} = 5.48 \times 10^{-4}$

1

$\text{Mol NO}_2^- = \frac{5}{2} (0.02 \times \frac{27.4}{1000}) = 1.37 \times 10^{-3}$

1

$[\text{NO}_2^-] = \text{mol NO}_2^- / (\frac{25}{1000})$
 $[\text{NaNO}_2] = 0.0548 \text{ mol dm}^{-3}$

1

$\text{Conc NaNO}_2 = (0.0548) \times 69.0 = 3.78 \text{ g dm}^{-3}$

1

Minimum 2 sf

[10]

Q5.

B

[1]

Q6.

A

[1]

Q7.

(a) (+) 5

1

(+) 2

1

Allow Roman numerals

(b) Cl^- / chloride (ions)

Allow 2Cl^-

Do not allow chlorine / Cl / Cl_2

Ignore (aq)

1

(c) nitric acid / HNO_3

If not nitric acid then CE = 0

If NO_3^- ions identified, lose M1 and mark on

Allow $0.96\text{V} > 0.34\text{V}$

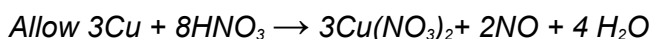
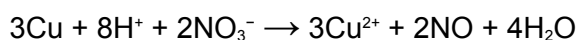
1

the $E^\ominus \text{NO}_3^- (\text{NO}) > E^\ominus \text{Cu}^{2+} (\text{Cu})$ or in words

Allow NO_3^- is a better oxidising agent than Cu^{2+}

Allow NO_3^- has a more positive $E^\ominus$ than Cu^{2+}

1



1

EMF for the reaction is 0.62(V)

1

[7]

Q8.

C

[1]

Q9.

B

[1]

Q10.

D

[1]

Q11.

(a) $[\text{Kr}] 5s^2 4d^{10}5p^5$

1

(b) This question is marked using levels of response. Refer to the Mark Scheme Instructions for Examiners for guidance on how to mark this question.

Level 3

All stages are covered and the explanation of each stage is correct and complete.

Answer communicates the whole explanation coherently and shows a logical progression from stage 1 to stage 2 and then stage 3.

5-6 marks

Level 2

All stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies **OR** two stages are covered and the explanations are generally correct and virtually complete.

Answer is mainly coherent and shows a progression through the stages. Some

steps in each stage may be out of order and incomplete.

3-4 marks

Level 1

Two stages are covered but the explanation of each stage may be incomplete or may contain inaccuracies, **OR** only one stage is covered but the explanation is generally correct and virtually complete.

Answer includes some isolated statements, but these are not presented in a logical order or show confused reasoning.

1-2 marks

Level 0

Insufficient correct chemistry to warrant a mark.

0 marks

Indicative Chemistry content

Stage 1

I₂ is molecular.

HI is molecular.

Stage 2

IMF hold the molecules together.

There are weak IMF forces hence the melting point is low in both substances.

I₂ bigger molecule than HI so I₂ has more electrons.

Stage 3

Therefore stronger van der Waals between molecules in I₂ that need more energy to break causing the melting point to be higher.

HI also shows permanent dipole-dipole attraction between molecules but these forces are less than the vdW forces in iodine.

6

- (c) No delocalised electrons or ions

1

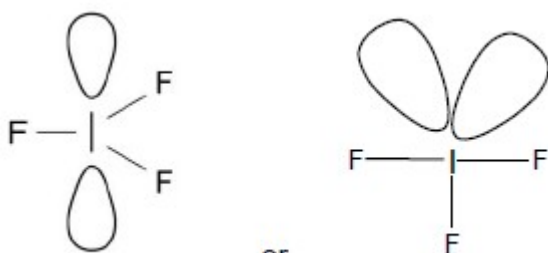
- (d) $\frac{1}{2} \text{H}_2 + \frac{1}{2} \text{I}_2 \rightarrow \text{HI}$

Allow multiples

1

- (e) NH_4I_3

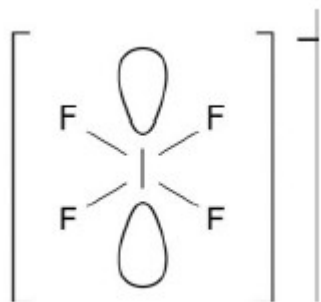
1



- (f)

Allow any shape with 3 bond pairs and 2 lone pairs

1



Allow any shape with 4 bond pairs and 2 lone pairs (e.g. lone pairs in equatorial positions)

1

(g) +5

1

+7

1

[14]

Q12.

D

[1]

Q13.

C

[1]

Q14.

B

[1]

Q15.

D

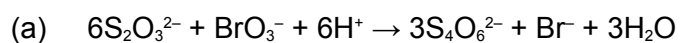
[1]

Q16.

D

[1]

Q17.



Check the formulae and charges carefully and penalise any transcription errors.

Allow multiples and fractions.

Ignore state symbols.

1

(b) Mol of thio = $25.0 \times 0.00100 / 1000 = 2.50 \times 10^{-5}$

and

Mol of bromate(V) = $(1/6) \times 2.5 \times 10^{-5} = 4.17 \times 10^{-6}$

If equation in Q5a is wrong, mark consequentially.

1

Vol of bromate(V) = $(4.17 \times 10^{-6} / 0.005) \times 1000 = 0.83 \text{ cm}^3$

Lose this mark if (correct) unit of volume not given.

Do not penalise precision.

1

(c) Use a more dilute solution of sodium bromate

Allow 'use a bigger volume of sodium thiosulfate solution'.

1

[4]

Q18.

(a) Reheat the sample at least once.

Heat to constant mass gains both marks.

1

Mass of ash should not have changed.

Mark independently.

1

(b) Vacuum filtration is quicker / saves time

Allow 'easier to wash residue to extract all iodide ions'.

1

(c) Use indicator (paper) on a withdrawn sample / place a pH probe into the solution

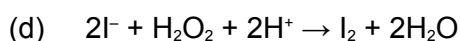
If any indicator (including paper) is used directly on the solution lose this mark but then mark on.

1

Keep testing until paper shows acidity / until pH drops below 7.

Indicator does not need to be specified but if it is then correct colour must be quoted.

1



Do not accept $2\text{I}^- + \text{H}_2\text{O}_2 \rightarrow \text{I}_2 + 2\text{OH}^-$ as reaction conditions are acidic.

Accept multiples and fractions.

Ignore state symbols.

1

(e) Lower layer – as it will be the denser CCl_4

Mark is for correct identification and correct reasoning.

1

(f) Iodine in seaweed = $56.4 \times (3/100) = 1.692 \text{ g}$

1

Iodine left in aqueous layer = $1.692 - 1.673 = 0.0190 \text{ g}$

1

$$K = (1.673 / (253.8 \times 0.05)) / (0.0190 / (253.8 \times 0.05)) = 88.1$$

Neither 253.8 nor 0.05 have to appear in working since they cancel.

Accept 88

1

- (g) It would react with the iodine

*Allow (electrophilic) addition **OR** forms 1,2 – diiodocyclohexane **OR** addition across a double bond for **both** marks.*

1

It is unsaturated

1

- (h) Solubility (of the iodine in the solvent) is high when hot and low when cold

1

(Therefore, on cooling a solution,) a significant quantity of crystals appear

1

[14]

Q19.

- (a) $2\text{Cl}^- \rightarrow \text{Cl}_2 + 2\text{e}^{(-)}$

Allow $2\text{Cl}^- - 2\text{e}^{(-)} \rightarrow \text{Cl}_2$

Allow correct equation forming ClO^- but not Cl^+

1

- (b) $2\text{ClO}^- + 4\text{H}^+ + 2\text{e}^- \rightarrow \text{Cl}_2 + 2\text{H}_2\text{O}$

Allow HClO in correctly balanced equation

1

- (c) $\text{ClO}^- + \text{Cl}^- + 2\text{H}^+ \rightarrow \text{Cl}_2 + \text{H}_2\text{O}$

allow $\text{HClO} + \text{HCl} + \rightarrow \text{Cl}_2 + \text{H}_2\text{O}$

1

- (d) Goes brown (or shades of brown)

Allow black ppt/solid but NOT black solution or purple

1

Due to iodine or I_3^-

Correct $\frac{1}{2}$ equation scores M2 and M3

1

Because I^- oxidised

1

[6]

Q20.

C

[1]

Q21.

C

[1]

Q22.

B

[1]

Q23.

- (a) Increasing atomic radius / shielding / number of shells / size (down group) or reverse argument

NOT 'molecules'

1

Decreasing attraction of nucleus/protons for shared (electron) pair / bond electrons

NOT if attraction for single electron implied

1

- (b) (i) Electron acceptor / species that accepts electrons / species that gains electrons

NOT electron pair

NOT just 'gain of electrons'

1

- (ii) Chlorine 0 to -1 / oxidation state/number of chlorine decreases
AND

Bromine -1 to 0 / oxidation state/number of bromine increases

Penalise if oxidised for chlorine and/or reduced for bromine

Credit oxidation states if labelled on equation

1

- (c) (i) $\text{H}_2\text{SO}_4 + 8\text{H}^+ + 8\text{e}^{(-)} \rightarrow \text{H}_2\text{S} + 4\text{H}_2\text{O}$

ALLOW $\text{SO}_4^{2-} + 10\text{H}^+ + 8\text{e}^{(-)} \rightarrow \text{H}_2\text{S} + 4\text{H}_2\text{O}$

ALLOW fractions/multiples

IGNORE state symbols

1

- (ii) $2\text{I}^- \rightarrow \text{I}_2 + 2\text{e}^{(-)}$

ALLOW fractions/multiples

IGNORE state symbols

ALLOW $2\text{I}^- - 2\text{e}^{(-)} \rightarrow \text{I}_2$

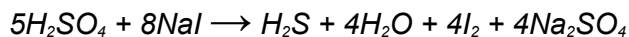
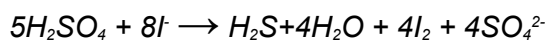
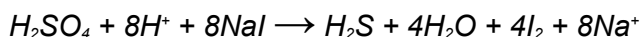
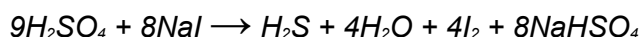
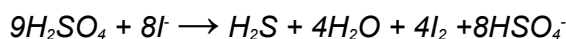
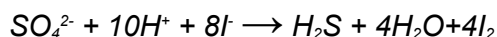
1

- (iii) $\text{H}_2\text{SO}_4 + 8\text{H}^+ + 8\text{I}^- \rightarrow \text{H}_2\text{S} + 4\text{H}_2\text{O} + 4\text{I}_2$

ALLOW

$\text{H}_2\text{SO}_4 + 8\text{HI} \rightarrow \text{H}_2\text{S} + 4\text{H}_2\text{O} + 4\text{I}_2$

$\text{SO}_4^{2-} + 2\text{H}^+ + 8\text{HI} \rightarrow \text{H}_2\text{S} + 4\text{H}_2\text{O} + 4\text{I}_2$



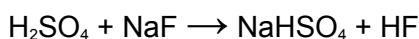
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(iv) 'Oxidising agent' box ticked

1



OR



1

(vi) Fluoride less powerful reducing agent (than iodide)

OR

Fluoride less easily oxidised than iodide

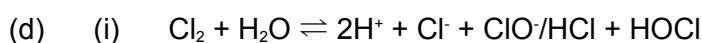
Or reverse argument in either case

NOT general group VII trend statement

NOT fluorine/F or iodine/I

Must be comparative

1



ALLOW $\rightarrow$ for $\rightleftharpoons$

1

(ii) Equilibrium shifts/moves left

1

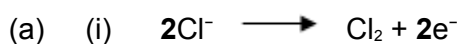
(Producing) chlorine (which) is toxic/poisonous

Mark independently

1

[13]

Q24.



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

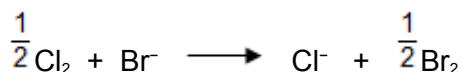


Ignore state symbols
Credit loss of electrons from RHS
Credit multiples
Do not penalise absence of charge on electron

1



OR



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)

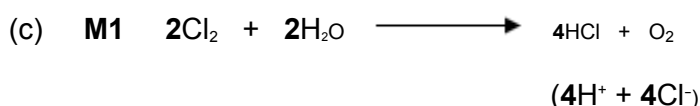
OR

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

Penalise "electron pair acceptor"

Not simply "causes loss of electrons"

1



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^- or $\text{Cl}^{\ominus}$ but **not** Cl^-

2

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

Chlorine is smaller 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 intermolecular force affects energy needed

Ignore shielding

The forces between chlorine / Cl_2 molecules are weaker (than the forces between bromine / Br_2 molecules)

(or converse for bromine)

OR chlorine / Cl_2 has weaker / fewer / less (VdW) intermolecular forces / forces between molecules

(or converse for bromine)

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

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

2

[10]

Q25.

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

M1 $\Delta H = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$

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

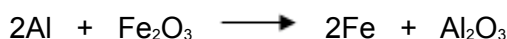
QoL

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**



Ignore state symbols

Credit multiples of the equation

M2

(Change in oxidation state) **0 to (+)3**

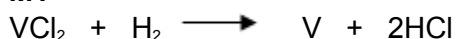
OR

(changed by) **+3**

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

2

(c) **M1**



In **M1** credit multiples of the equation

M2 and M3

Two hazards in either order

- HCl / hydrogen chloride / hydrochloric acid is acidic / corrosive / toxic / poisonous
- Explosion risk with hydrogen (gas) OR H₂ is flammable

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 only

M4

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

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

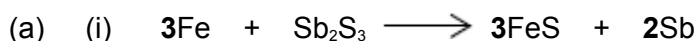
OR vanadium / it is a solid and the other product / HCl is a gas

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

4

[11]

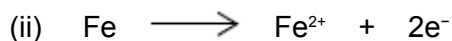
Q26.



Or multiples.

Ignore state symbols.

1



Ignore charge on the electron unless incorrect.

Or multiples.

Credit the electrons being subtracted on the LHS.

Ignore state symbols.

1



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 $\Delta H_r = \sum \Delta H_f(\text{products}) - \sum \Delta H_f(\text{reactants})$

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

(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]

Q27.

(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 $\text{Cl}_2 + 2\text{e}^- \longrightarrow 2\text{Cl}^-$

Credit 1 or 2 electrons but not lone pair.

The idea of 'reduction' alone is not enough.

1

(b) (i) $6\text{KI} + 7\text{H}_2\text{SO}_4 \longrightarrow 6\text{KHSO}_4 + 3\text{I}_2 + \text{S} + 4\text{H}_2\text{O}$

1

(ii) $2\text{I}^- \longrightarrow \text{I}_2 + 2\text{e}^-$

OR

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

Ignore charge on the electron unless incorrect.

Or multiples.

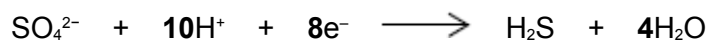
Credit the electrons being subtracted on the LHS.

Ignore state symbols.

1

(iii) $\text{H}_2\text{SO}_4 + 8\text{H}^+ + 8\text{e}^- \longrightarrow \text{H}_2\text{S} + 4\text{H}_2\text{O}$

OR



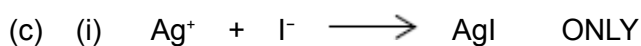
Ignore charge on the electron unless incorrect.

Or multiples.

Credit the electrons being subtracted on the RHS.

Ignore state symbols.

1



Ignore state symbols.

Not multiples.

1

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

OR a white / cream / yellow solid / precipitate

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 (an)ions that would interfere with the test
Credit a correct reference to ions that give a 'false positive'.
- prevent the formation of other silver precipitates / insoluble silver compounds 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) ions that react with the silver nitrate
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 form a (white) precipitate / (white) solid (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

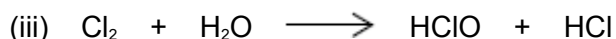
OR

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

OR

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

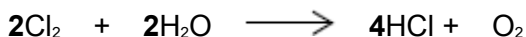
1



OR



OR



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

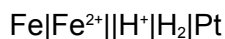
[14]

Q28.

- (a) $\text{Pt}|\text{H}_2|\text{H}^+||\text{Fe}^{2+}|\text{Fe}$

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:



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 $E(\text{cell})$ 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) $4\text{HOCl} + 4\text{H}^+ + 4\text{OH}^- \rightarrow 2\text{Cl}_2 + \text{O}_2 + 6\text{H}_2\text{O}$
 OR
 $4\text{HOCl} \rightarrow 2\text{Cl}_2 + \text{O}_2 + 2\text{H}_2\text{O}$
Allow one mark for any incorrect equation that shows
 $\text{HOCl} \rightarrow \text{Cl}_2 + \text{O}_2$
Allow multiples
Ignore state symbols
Penalise one mark for uncanceled or uncombined species
(eg $\text{H}_2\text{O} + \text{H}_2\text{O}$ instead of $2\text{H}_2\text{O}$) 2
- (f) (i) e.m.f. = $0.40 - (-1.25) = \underline{1.65} \text{ (V)}$ / $\underline{+1.65} \text{ (V)}$
Allow -1.65 (V) 1
- (ii) $2\text{Zn} + \text{O}_2 \rightarrow 2\text{ZnO}$
Allow multiples
Ignore state symbols
Do not allow uncanceled species
If more than one equation given, choose the best 1
- (iii) **A** / stainless lid
If M1 incorrect or blank CE=0 1
- O_2 (electrode) has a more positive $E^\ominus$ / oxygen (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 Zinc (electrode) has more negative $E^\ominus$

Do not allow reference to e.m.f. or $E(\text{cell})$

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

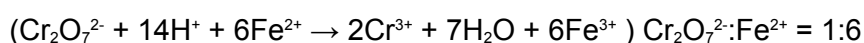
1

[14]

Q29.

- (a) moles of $\text{Cr}_2\text{O}_7^{2-}$ per titration = $21.3 \times 0.0150 / 1000 = \underline{3.195 \times 10^{-4}}$

1



If 1:6 ratio incorrect cannot score M2 or M3

1

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

Process mark for $M1 \times 6$ (also score M2)

1

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

Process mark for $M3 \times 10$

1

mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O} = 1.917 \times 10^{-2} \times 277.9 = 5.33 \text{ (g)}$

Mark for answer to $M4 \times 277.9$

(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 $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

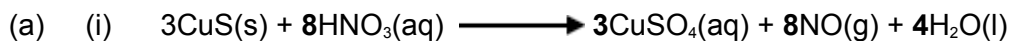
OR for equal masses of the impurity and $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$, the impurity would react with more dichromate.

Must compare mass of impurity with mass of $\text{FeSO}_4 \cdot 7\text{H}_2\text{O}$

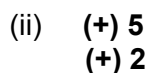
1

[7]

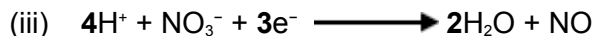
Q30.



1



2



Ignore state symbols.

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

Ignore absence of charge on the electron.

1



Ignore state symbols.

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

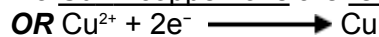
Ignore absence of charge on the electron.

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 Cu²⁺ / copper ions are reduced / gain electrons



OR copper / Cu is displaced by Fe

Ignore absence of charge on the electron.



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

4

[9]

Q31.



1



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

2



Both numbers required

$$\begin{aligned} M_r &= 2(1.00794) + 32.06550 + 4(15.99491) \\ &= \mathbf{98.06102 \text{ or } 98.0610 \text{ or } 98.061 \text{ or } 98.06 \text{ or } 98.1} \end{aligned}$$

Calculations not required

and



$$M_r = 3(1.00794) + 30.97376 + 4(15.99491) \\ = 97.97722 \text{ or } 97.9772 \text{ or } 97.977 \text{ or } 97.98 \text{ or } 98.0$$

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** $\text{CH}_3\text{CH}=\text{CH}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}(\text{OH})\text{CH}_3$



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]

Q32.

- (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) $\text{FeTiO}_3 + 3\frac{1}{2}\text{Cl}_2 + 3\text{C} \longrightarrow \text{FeCl}_3 + \text{TiCl}_4 + 3\text{CO}$

Ignore state symbols

Credit multiples

1

- (ii) $\text{FeCl}_3 + \text{TiCl}_4 + 7\text{Na} \longrightarrow 7\text{NaCl} + \text{Fe} + \text{Ti}$

OR (for example)



Ignore state symbols

Credit multiples including ratios other than 1:1

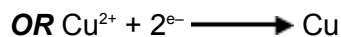
Ignore working

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



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 Cu^{2+} / copper(II) ions / they have been reduced

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

2



Or multiples including



Ignore state symbols

Ignore charge on the electron

Credit the electrons being subtracted on the LHS

1

[6]

Q33.

(a) (i) reduction **OR** reduced **OR** redox **OR** reduction–oxidation
Not "oxidation" alone

1



Ignore state symbols

Do not penalise absence of charge on electron



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**

CO₂ 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 must have all ΔH symbols and the Σ)

Correct answer gains full marks

Credit 1 mark ONLY for -1 (kJ mol⁻¹)

M1 $\Delta H_r = \Sigma \Delta H_f$ (products) – $\Sigma \Delta H_f$ (reactants)

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

OR correct cycle of balanced equations with 2Fe, 3C and 3O₂

M2 $\Delta H_r = 2(+14) + 3(-394) - (-822) - 3(-111)$

$$= 28 - 1182 + 822 + 333$$

(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 3O₂ OR a clear*

statement of M1 which could be in words and scores
only M1

3

- (d) (i) $\text{C(s)} + \text{O}_2\text{(g)} \rightarrow \text{CO}_2\text{(g)}$
State symbols essential
Possible to include C(s, graphite)

1

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

Penalise reference to CO_2 being produced by a different route

OR

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

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

OR

The same number and same type of bonds are broken and formed

1

[12]

Q34.

- (a) (i) **M1 0**

M2 (+) 5

Accept Roman V for M2

2



Accept multiples

1

- (b) **M1** $\text{IO}_3^- + 6\text{H}^+ + 5\text{I}^- \longrightarrow 3\text{I}_2 + 3\text{H}_2\text{O}$

For M1, ignore state symbols

Credit multiples

Accept $2\frac{1}{2}\text{I}_2 + \frac{1}{2}\text{I}_2$ 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



Ignore state symbols



Credit multiples

Do not penalise absence of charge on the electron

1

(d) hydrogen sulfide

OR H_2S

OR hydrogen sulphide

1



Ignore state symbols

No multiples

1

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

ignore "nothing (happens)"

OR turns to a white solid

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 (an)ions that would interfere with the test

Ignore reference to "false positive"

- prevent the formation of other silver precipitates / insoluble silver compounds 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) ions that react with the silver nitrate

- 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



Ignore state symbols

Do not penalise absence of charge on electron

Credit $\text{Cl}_2 \longrightarrow 2\text{Cl}^- - 2\text{e}^-$

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

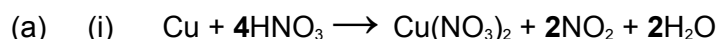
The electron(s) lost /outer shell/level electron from (an) iodide ion(s) less strongly held by the nucleus compared with that lost from a chloride ion

OR converse for a chloride ion

2

[15]

Q35.



Or multiples

Ignore state symbols

1

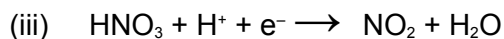


Ignore working out

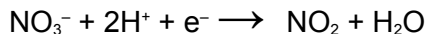
M1 Credit (V)

M2 Credit (IV)

2



OR



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]

Examiner reports

Q1.

- (a) This was answered well – nearly all students (83.8%) were able to state two correct oxidation states.
- (b) Very few students were able give the first half-equation for the oxidation of chlorine whereas the second half-equation was more regularly correct.
- (c) Only some students (23.1%) were able to recall this equation from the specification.
- (d) Some students successfully calculated the mass of potassium iodide. However, many did not appreciate that this reaction was not 1:1 and so used the incorrect reacting ratio in their calculations. Many students stated incorrectly that the iodine formed would be observed as purple fumes or as a purple solution. This question discriminated particularly well.
- (e) Most students were able both to write the correct equation and calculate the enthalpy change. Only 8.4% of students were unable to score at least one mark.

Q2.

- (a) Nearly all students (91.1%) gained both marks here.
- (b) Although 73.9% of students scored two marks, common errors here included a failure to convert temperature into kelvin or using inconsistent energy units.
- (c) Students found the explanation in this part more challenging and many could not state that the Gibbs free-energy would become more negative. Many students, however, scored the second mark for a correct reference to a change in entropy.
- (d) Many students discussed the general principles of homogeneous catalysis or the lowering of activation energy rather than the reaction on the platinum surface. The mark most commonly missed was the idea that the product desorbed from or left the surface of the catalyst. Surprisingly, over 10% of students made no attempt at this question.
- (e) 74.4% of students answered this correctly, although a few students thought the oxidation state of N in ammonia was +3.
- (f) Many students gave hydrogen as the other product or failed to balance an equation in which water was the other product.

Q3.

- (a) Only 11.3% of students scored both marks here; sometimes Fe^{2+} was chosen but students could not explain their choice. The most common incorrect answer was Zn^{2+} .
- (b) Just over three-quarters of students could give the oxidation state.
- (c) The structure was often given, incorrectly, as a mirror image and the type of isomerism as optical; only 37.2% of students scored both marks.

- (d) This was poorly answered, with only just over a third of students giving the correct equation.
- (e) Over half of the students (55.6%) gave the correct equations; incorrect equations included charged vanadium species. Surprisingly, 12% of students were unable to make any attempt at this question.

Q4.

- (a) Students showed admirable ability to calculate the oxidation states and 71.8% of them gained both marks.
- (b) This question was well answered with 44.6% of students gaining the mark.
- (c) 62.4% of students gained the mark for this familiar half-equation.
- (d) This question discriminated better than the previous two part-questions; surprisingly, 8.5% of students did not even attempt it.
- (e) 56.3% of students were successful in gaining this mark.
- (f) Despite the challenging mole ratio, this question was answered really well. The familiar context of the question requiring manipulation of concentrations and volumes proved to be more accessible. The final answer required unfamiliar units and failure to grasp that aspect often limited students to three marks.

Q5.

Although 47.8% of students scored here, the three distractors all drew significant attention.

Q6.

Only 42.2% of students selected the correct answer. Perhaps many students did not appreciate that a range of sulfur-based products are formed in the reaction.

Q7.

- (a) The oxidation states were well known, with 92.2% of students gaining both marks; +7 was the commonest wrong answer for the nitrate ion.
- (b) Just under half of students could identify the weakest reducing agent.
- (c) "Nitrate ions" was a common insufficient answer, and sulfuric acid a common incorrect answer. Only the very best students scored mark point two; the common incorrect answer was that the $E^\ominus$ for NO_3^- was more positive than the $E^\ominus$ for copper. The equation was often unbalanced, but the cell emf was generally calculated correctly.

Q17.

Half-equation manipulation was well done in (a) and the mole calculation in (b) elicited many good answers. Answers to (c) were sometimes poorly expressed or incomplete.

Q18.

Students appeared to understand **(a)** but, again, answers were often penalised for poor chemical expression. Surprisingly, **(b)** generated some unusual responses, possibly because students were looking for too complex an answer! **(c)** was too generously marked by a significant number of schools – the need to extract a sample to prevent contamination or to state what the pH probe should record was often overlooked and had to be penalised on moderation. Part **(d)** was well done but **(e)** resulted in a few contradictory answers as students struggled to explain the process. In **(f)**, despite the unfamiliar context, there were many excellent answers but in **(g)** explanations were occasionally too brief and did not cover both marking points. Answers to the final question, **(h)**, identified those students who had carried out recrystallisation and had thought about the background principles involved.

Q19.

This question was answered poorly. Even the half equation in (a) was usually not answered correctly and the more challenging equations in (b) and (c) were only seen from the better students. In (d) the explanation that iodide ions are oxidised wasn't seen very often but a reasonable proportion of students scored some marks on this question.

Q20.

Usually well answered.

Q22.

It was surprising to see that this question was answered poorly but it did give further evidence that redox ideas are not well understood by large numbers of students at this level.

Q23.

In a definition of electronegativity students must make it clear that they are referring to the attraction between the nucleus and the shared pair of bond electrons. Most students were awarded the first mark but many answers were too vague in their references to gain the second mark. Most of the rest of this question was well answered although there were some issues with balancing charges in the redox equations.

Very few students showed the acids formed in part (d)(i) as being dissociated and this, in turn, seemed to make part (d)(ii) harder than expected because many students failed to spot that addition of acid would shift the equilibrium to the left and so produce toxic chlorine gas. Although there was no specific reference to le Chatelier in the question (which would have given a more specific clue) the stem of part (d) did refer to an equilibrium mixture and this was intended to point students in the right direction.

Q24.

This was a relatively straightforward start to the paper, but the usual errors were made in balancing equations. The idea of oxidation state is relatively well understood. In part (d), students demonstrated a lack of clarity in what happens during the process of boiling, often alluding to bond breakage and rarely referring to the forces between molecules.

Q25.

This question provided a range of challenges. The calculation in part (a) was answered well and the necessity to focus on either the extraction or the reactivity of calcium was understood by many. In part (b), many students were unable to write a correct formula

either for iron(III) oxide or for aluminium oxide and there was often a lack of clarity when stating the change in oxidation state of aluminium in this reaction. The equation in part (c) was generally done well and many students correctly linked an appropriate hazard to each of hydrogen and hydrogen chloride. The idea that the HCl could escape as a gas and the only other product was vanadium, was necessary to gain the final mark.

Q26.

Too many students had problems writing and balancing the equations in each of parts (a)(i), (a)(ii) and (b)(i). The calculation in part (c)(i) was straightforward and most students scored all 3 marks although errors were seen in simple mathematical operations. The remainder of the question was also relatively high scoring.

Q27.

Part (a) was answered well but part (b) proved more demanding. Only about one-third of students were able to balance the equation in part (b)(i) and only about half of students gave correct half-equations in parts (b)(ii) and (b)(iii). The halide ion analysis in part (c) was well known with the lowest scoring part being (c)(iv), with many having failed to recognise that it is insufficient to simply state that AgCl is formed. Any question involving NaClO is always demanding and part (e) was no exception with less than half of the students scoring the mark.

Q28.

Few correct answers were seen to part (a). Some students did not comply with the convention of placing the hydrogen electrode on the left when measuring the standard electrode potential. Some failed to include all the phase boundaries, putting a comma between H_2 and H^+ instead of a solidus, whilst other students included too many phase boundaries at the extremities or an incorrect, additional platinum connected to iron. Parts (b) and (c) were answered well. All the elements were chosen by students in part (d)(i) and where the correct answer of chlorine was selected, the oxidation states in part (d)(ii) and the equation in part (e) were usually correct. It was pleasing to find that answers to parts (f)(i) and (f)(ii) were usually correct. Most students identified the positive electrode correctly in part (f)(iii) but only the highest-scoring students used an appropriate electrode potential from the table to explain their answer.

Q29.

Many good answers were seen to part (a) in which full marks were scored. However, most students used an incorrect ratio for the amount, in moles, of iron(II) that reacts with one mole of dichromate ions. For these students, the maximum they could score was three out of a possible five marks. In part (b), many students suggested, correctly, that the impurity was likely to be a reducing agent but very few went on to explain that the impurity must react with more moles of dichromate than would the same mass of $FeSO_4 \cdot 7H_2O$.

Q30.

The balancing in part (a)(i) proved demanding and only approximately 60% scored this mark. The oxidation states in part (a)(ii) were high scoring with the vast majority of students gaining two marks. However, the construction of redox equations in parts (a)(iii) and (a)(iv) were of much higher demand and only 28% and 21%, respectively, gained these marks.

Few students scored full marks in part (b) despite its more open-ended approach to this topic. The question required recognition that this was about the use of scrap iron, but one

mark was possible even for those students who chose an expensive method such as electrolysis.

Q31.

Balancing the equation in part (a) taxed some students but most were able to score at least one mark in part (b). There was a need for students to use correct chemical terminology in part (d), requiring, for example, reference to the “addition of water” in part (d)(ii). It was surprising to see how many made simple errors in the relatively straightforward part (d)(iii), for example, naming the alcohol as propanol rather than propan-2-ol.

Q32.

Most students have some familiarity with the extraction of titanium and many were able to apply their ideas in the novel context presented in part (b). Part (c) produced many good answers but the equation in part (d) was only answered correctly by the best students.

Q33.

The thinking required in part (b)(i) proved too much for many and only a few were able to state that, in practice, CO is not the only product and that some complete combustion to form CO₂ would occur. The answer of +1 kJ mol⁻¹ was seen frequently in part (c), but some were disconcerted by this value and sought to find an alternative. State symbols were often missed in part (d)(i) and a clear statement in part (d)(ii) that the same reaction occurs for the two specified standard enthalpies was not well understood.

Q34.

Many very good answers were seen throughout this question. In part (b), the oxidising agent was not well answered by some. In parts (c), (d) and (e), the answers requiring observations suggest that not all students have had the chance either to see or to perform these simple experiments. Part (f) was well answered with the correct use of chemical names and terminology.

Q35.

Candidates struggled to balance the equation in part (a)(i) with 30% failing to complete it correctly. Part (b)(i) is straight from the specification and two thirds of candidates did not have a problem. In parts (b)(ii) and (b)(iii) candidates demonstrated that they are learning how to express their ideas with clarity and some very good answers were seen. Some answers suffered from contradictory statements while others included statements that were open to different interpretations.