

OCR A-LEVEL CHEMISTRY B (SALTERS) • H433

CHEMISTRY



EXAM QUESTION PACK

DEVELOPING METALS (DM)

SCORE

/374

PERCENTAGE

%

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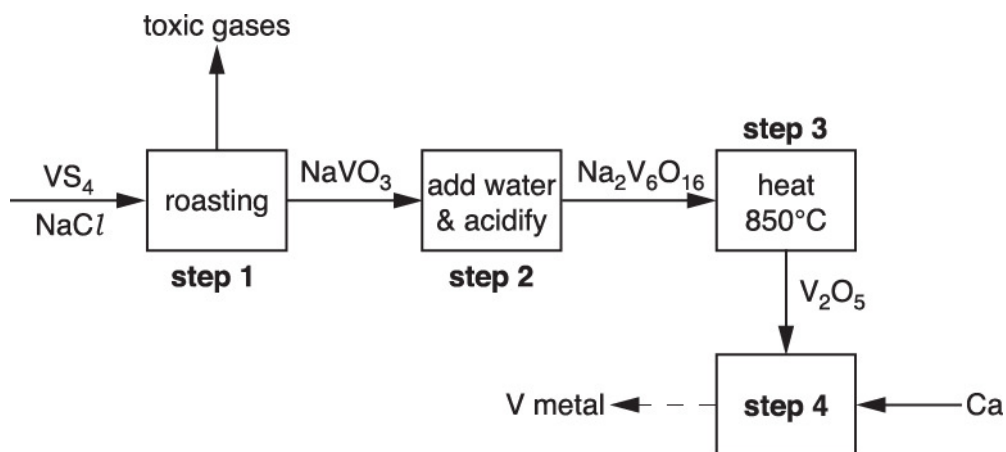
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- 1(a) In 1908, Henry Ford advertised his Model T car by boasting that 'vanadiumsteel is used throughout the entire car and has superior properties to other steels'.

The flow diagram below outlines one method of extracting vanadium from its ore, VS_4 .



- (i) Name a possible toxic gas given off in step 1.

----- [1]

- (ii) The anion in VS_4 has the formula S_2^{2-} .

Complete the table below giving the oxidation state of vanadium in each of the four vanadium compounds involved in the extraction process.

Compound	Oxidation state of vanadium
VS_4	
NaVO_3	
$\text{Na}_2\text{V}_6\text{O}_{16}$	
V_2O_5	

[2]

- (iii) In which of steps 1-3 is vanadium involved in a redox reaction?

Give a reason for your answer.

step(s) _____

reason _____

[2]

(iv) NaVO_3 forms a yellow solution with water.

Explain, in terms of frequencies, why solutions of transition metal ions are often coloured.



In your answer, you should use appropriate technical terms, spelled correctly.

[2]

(v) Give the equation for the reaction in **step 4**. State symbols are not required.

→

[1]

- (b) Some vanadium is used to make compounds for industrialelectrochemical batteries.

An industrial ‘vanadium battery’ uses a half-cell containing V^{2+} and V^{3+} ions with another halfcell using VO_2^+ and VO^{2+} ions.

Some data about vanadium and iodide ions are given below.

Table 4.1

half-reaction	$E^\ominus / V$
$V^{3+} + e^- \rightarrow V^{2+}$	-0.26
$VO^{2+} + 2H^+ + e^- \rightarrow V^{3+} + H_2O$	+0.34
$I_2 + 2e^- \rightarrow 2I^-$	+0.54
$VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$	+1.00

A student carries out an experiment to find the E_{cell} of a ‘vanadium battery’. The student works at room temperature (about 20 °C) and uses approximately 0.1 mol dm⁻³ solutions of each of the ions.

- (i) Draw a labelled diagram of the apparatus the student sets up to measure this E_{cell} .

[4]

- (ii) Use the data in Table 4.1 to calculate a value for this E_{cell} .

$E_{\text{cell}} = \text{-----} V$ [1]

- (iii) Give two reasons, other than experimental error, why the E_{cell} value that the student measures is different from that calculated in (ii).

[2]

- (iv) Write an ionic equation for the reaction taking place in the cell in (i) when it is producing a current. State symbols are not required.

→

[2]

- (v) The student was going to use a solution of NaI in the salt bridge.

However, on considering the data in **Table 4.1**, the student decided that NaI would react with one of the vanadium ions and so affect the result of the experiment.

Which vanadium ion will NaI react with?

Give your reasoning, including an equation (in the box below) for the reaction taking place.

State symbols are not required.

formula of ion

reasoning

→

[2]

- (c) The student used a titration method to determine the amount of iron in a piece of vanadium-iron alloy. An outline of the method used is shown below.

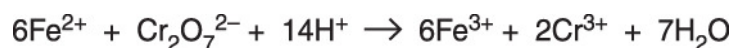
Stage 1. 100 cm³ of 2.0 mol dm⁻³ sulfuric acid and about 1 g of sodium hydrogencarbonate were added to a conical flask connected to a non-return valve.

Stage 2. 0.175 g of the wire alloy was added. The mixture was warmed gently until all of the iron in the wire had reacted to form a solution of iron (II) ions.

Stage 3. The flask was then cooled and its contents titrated with $0.0216 \text{ mol dm}^{-3}$ potassium dichromate(VI).

The student recorded a titre of 23.50 cm^3 .

The equation for the reaction between iron(II) ions and dichromate(VI) ions in acid solution is given below.



(i) Calculate the percentage by mass of iron in the alloy.

Give your answer to an **appropriate** number of significant figures.

percentage = _____ % [5]

(ii) The non-return valve only allows gases out of the flask. The sodium hydrogencarbonate and the non-return valve are to prevent iron (II) ions being oxidised to iron (III) ions before the end of stage 2.

Explain how iron (II) could be changed into iron (III) and suggest how sodium hydrogencarbonate and the non-return valve prevent this from occurring.

----- [3]

(d) The student tests another flask at the end of stage 2 for iron (II) ions.

- (i) Describe what is seen when excess NaOH is added to an acidified solution of iron (II) ions taken from the flask.

Observations **before** addition

Observations **after** addition

[2]

- (ii) Give an ionic equation for the reaction of the iron (II) ions in (i). Include state symbols.



[2]

2 Which of the following is a correct statement about the test for Fe^{2+} ions in solution?

- A add NaOH(aq); brown precipitate formed, soluble in $\text{NH}_3(\text{aq})$
- B add NaOH(aq); brown precipitate formed, insoluble in $\text{NH}_3(\text{aq})$
- C add NaOH(aq); green precipitate formed, soluble in $\text{NH}_3(\text{aq})$
- D add NaOH(aq); green precipitate formed, insoluble in $\text{NH}_3(\text{aq})$

Your answer

[1]

3 Some possible ligands are shown below.

Which of the following could be bidentate ligands?

1: $\text{NH}_2\text{CH}_2\text{CH}_2\text{NH}_2$

2: $(\text{COO}^-)_2$

3: $\text{C}_2\text{H}_5\text{OH}$

A 1, 2 and 3

B Only 1 and 2

C Only 2 and 3

D Only 1

Your answer

☐

[1]

- 4 Aqueous solutions of $\text{Ce}(\text{SO}_4)_2$ and KMnO_4 can be used as oxidising agents in redox titrations. In both cases reactions are carried out in acidic solutions.

(i) KMnO_4 should **not** be acidified with hydrochloric acid.

Select and use data from the table below to determine which acid can be used with Ce^{4+} to oxidise Cl^- .

Explain your answer.

Half-reaction	$E^\ominus / \text{V}$
$\text{Ce}^{4+} + \text{e}^- \rightleftharpoons \text{Ce}^{3+}$	+1.28 measured in $1 \text{ mol dm}^{-3} \text{ HCl(aq)}$
$\text{Cl}_2 + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-$	+1.36
$\text{Ce}^{4+} + \text{e}^- \rightleftharpoons \text{Ce}^{3+}$	+1.44 measured in $1 \text{ mol dm}^{-3} \text{ H}_2\text{SO}_4(\text{aq})$
$\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+} + 4\text{H}_2\text{O}$	+1.51

[3]

(ii) A student devises an experiment to find out how much cerium is present in an impure sample of ceria, CeO_2 .

First the student converts 2.5 g of powdered ceria into 100 cm^3 of a solution of $\text{Ce}(\text{SO}_4)_2$ in sulfuric acid. Then 25.0 cm^3 of this $\text{Ce}(\text{SO}_4)_2$ solution is titrated with a standard solution of arsenic(III) in sulfuric acid. In the reaction Ce^{4+} is reduced to Ce^{3+} .

1.00 dm^3 of solution is made up by dissolving 0.250 mol of As_2O_3 in sulfuric acid. The arsenic is present in the solution as AsO_3^{3-} ions. 25.0 cm^3 samples of the $\text{Ce}(\text{SO}_4)_2$ solution required an average titre of 3.00 cm^3 of this AsO_3^{3-} solution.

The half-equation for the oxidation of AsO_3^{3-} ions is given below.



Calculate the percentage purity of the student's ceria sample.

Show **all** your working.

Give your answer to an **appropriate** number of significant figures.

percentage purity = _____ % [5]

- (iii) Suggest one improvement to the student's method that will reduce the percentage error in the answer to (ii) without changing the apparatus.

Give a reason for your choice.

----- [1]

- (iv) Calculate the number of oxygen atoms in 2.5 g of **pure** ceria, CeO_2

Show **all** your working.

number of atoms = _____ [2]

- (v) Ceria is also used as a heterogeneous oxidation catalyst for self-cleaning ovens. Ceria is incorporated on the surface of the inside panels of an oven.

Describe how a heterogeneous catalyst works.

----- [4]

- 5 Aluminium can be used to clean silver cutlery that has been 'tarnished' by a layer of black silver sulfide. The silver object is placed in a hot solution of sodium carbonate in contact with a piece of aluminium foil. An electrochemical reaction occurs and the tarnished silver becomes shiny again.

	$E^\ominus / \text{V}$
$\text{Al}^{3+} + 3\text{e}^- \rightleftharpoons \text{Al}$	-1.66
$\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag}$	+0.80

- (i) Draw a labelled diagram of the cell you could set up in a laboratory to measure the $E^\ominus_{\text{cell}}$ of the reaction involved in cleaning tarnished silver.

[3]

- (ii) When $[\text{Al}^{3+}]$ ions are charged in a half cell the E_{cell} value for the half cell is given by

$$E_{\text{cell}} = E^\ominus_{\text{cell}} - \frac{RT}{nF} \ln [\text{Al}^{3+}]$$

Where R = gas constant

T = temperature in kelvin

F = Faraday constant, $9.65 \times 10^4 \text{ C mol}^{-1}$

n = number of electrons transferred

Calculate the electrode potential of a cell at $T = 298 \text{ K}$ and $[\text{Al}^{3+}] = 0.1 \text{ mol dm}^{-3}$.

Show **all** your working.

$$E_{\text{cell}} = \text{-----} \text{ V [2]}$$

6 Which row is correct about the ions of copper and iron?

	Element	Ion formed	Colour of aqueous ion
A	copper	3+	green
B	iron	2+	yellow
C	copper	1+	blue
D	iron	3+	orange

Your answer

[1]

7 Which one of the equations is **not** correct?

- A $\text{Fe}^{2+} + 2\text{OH}^- \rightarrow \text{Fe}(\text{OH})_2$
 B $\text{Cu}^{2+} + 2\text{OH}^- \rightarrow \text{Cu}(\text{OH})_2$
 C $\text{Cu}^{2+} + 4\text{NH}_3 \rightarrow \text{Cu}(\text{NH}_3)_4^{2+}$
 D $\text{Fe}^{2+} + 4\text{NH}_3 \rightarrow \text{Fe}(\text{NH}_3)_4^{2+}$

Your answer

[1]

8 Which row is correct?

	Species	Electron configuration
A	V^{2+}	$[\text{Ar}] 3\text{d}^3$
B	Fe^{3+}	$[\text{Ar}] 3\text{d}^3 4\text{s}^2$
C	Sc^{3+}	$[\text{Ar}] 4\text{s}^1$
D	Cu	$[\text{Ar}] 3\text{d}^9 4\text{s}^2$

Your answer

[1]

9 What is correct about the ethanedioate ion?

- A it can form two co-ordinate bonds to certain cations
- B it has two lone pairs of electrons
- C it has a single negative charge
- D it contains four sigma bonds

Your answer

[1]

10 Which of the following is / are correct about the catalytic action of transition metals and their compounds?

Statement 1: They can act as homogeneous catalysts using their variable oxidation states.

Statement 2: They provide an alternative route of lower activation enthalpy.

Statement 3: They do not take part in the reaction.

- A 1, 2 and 3
- B Only 1 and 2
- C Only 2 and 3
- D Only 1

Your answer

[1]

11 In 1869 a green emission line was seen in the Sun during an eclipse. At first this was thought to be caused by a new element. Later it was found to be due to a highly ionised form of iron, Fe^{13+} .

Suggest the electronic configuration of the Fe^{13+} ion in terms of sub-shells and atomic orbitals.

-----[1]

12 The rusting of steel reinforcements can affect the strength of the structure.

- (i) Write the half-equations (as equilibria) for the formation of hydroxide ions and Fe^{2+} ions in the first stage of rusting.

[2]

- (ii) $\text{Fe}(\text{OH})_2$ is oxidised by O_2 to give rust, Fe_2O_3 .

Use this information and your answer from part (i) to suggest why iron is less likely to rust in alkaline conditions.

[3]

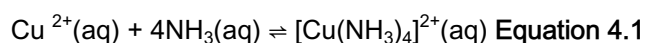
13(a) When brass objects are used in the presence of horses, the brass tends to corrode. This is because ammonia from horse urine reacts with copper in the brass to form the soluble compound $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$.

Draw a diagram to show the square planar shape of the complex ion $[\text{Cu}(\text{NH}_3)_4]^{2+}$ and give the co-ordination number.

On your diagram name the type of bond joining atoms to the metal ion.

[2]

- (b) This complex ion forms when ammonia solution is added to copper(II) sulfate solution.
The equation for the reaction can be represented as below.



- (i) High concentrations of ammonia in horse's urine can be a sign of infection. Adding a fixed amount of copper(II) sulfate solution to a given volume of urine produces the deep blue / purple ion, $[\text{Cu}(\text{NH}_3)_4]^{2+}(\text{aq})$ in equation 4.1.

Suggest how the production of this ion can be used as a measure of the ammonia content in the horse's urine.

----- [2]

- (ii) Write an equation for the equilibrium constant, K_c , of the reaction in equation 4.1.

[1]

- (iii) A solution initially contains 0.10 mol dm^{-3} of $\text{Cu}(\text{II})$ ions and 0.40 mol dm^{-3} of ammonia. At equilibrium, the concentration of $[\text{Cu}(\text{NH}_3)_4]^{2+}$ formed is x .

Write an expression for the equilibrium constant K_c in terms of x .

[2]

- (iv) Two students wanted to measure the concentration of ammonia in the complex solution at equilibrium. One suggested that they titrate samples of the complex solution with standard sulfuric(VI) acid. The other said the results would be inaccurate.

Comment on who is correct and give a reason for your answer.

----- [2]

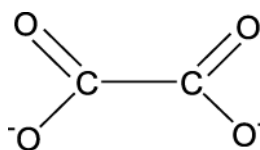
- (c) Copper(II) ions also form a complex with the bidentate ligand $\text{NH}_2\text{-CH}_2\text{-CH}_2\text{-NH}_2$.

Suggest the formula of the complex ion formed with this ligand and give the co-ordination number.

----- [2]

14(a) *Bar Keeper's Friend* is a powdered cleaning agent invented over 100 years ago and still in use today. It is particularly effective at removing rust stains.

The active ingredients are the ethanedioate ion, shown below, and ethanedioic acid.



Ethanedioate ion

A student decides to investigate how *Bar Keeper's Friend* removes rust stains. The student finds that the ethanedioate ions act as bidentate ligands which form complexes with Fe^{3+} ions.

- (i) On the diagram above show how this bidentate ligand bonds to a Fe^{3+} ion.
On the diagram, name the type of bond formed.

[3]

- (ii) The complex ion formed between the ethanedioate ligands, $\text{C}_2\text{O}_4^{2-}$, and Fe^{3+} has a charge of 3–.

Give the formula and name the shape of the complex.

formula: _____

Name of functional group: _____

[2]

(b) The student also investigates whether ethanedioic acid (COOH)₂ undergoes a redox reaction with Fe³⁺ ions.

Half-reaction	$E^\ominus/V$
$2\text{CO}_2 + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons (\text{COOH})_2$	-0.43
$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	+0.77

(i) Use data from the table to explain why (COOH)₂ and Fe³⁺ ions react.

[2]

(ii) Write an ionic equation for the reaction between (COOH)₂ and Fe³⁺ in solution.

[2]

(iii) Draw arrows in the appropriate boxes to show the outer electron configurations for Fe²⁺ and Fe³⁺.

3d

4s

Fe²⁺

Fe³⁺

[2]

(c) Ethanedioate ions react with manganate(VII) ions as shown below.



(i) Complete the tables below to show the oxidation states of manganese and carbon in the reagents and products.

Mn	MnO_4^-	Mn^{2+}
oxidation states		

C	$\text{C}_2\text{O}_4^{2-}$	CO_2
oxidation states		

[2]

(ii) Explain how the oxidation states can be used to balance the equation.

[1]

(d) The reaction can be used to find the concentration of an ethanedioate solution.

The ethanedioate solution is titrated with a standard potassium manganate(VII) solution in acid conditions. The reaction is slow at room temperature and needs to be heated above 60°C.

(i) * Describe how the titration would be carried out and explain how the end-point of the reaction can be recognised without an indicator.

----- [6]

(ii) A student makes up 0.100 dm^3 of a $\text{K}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ solution.

The student finds that 25.0 cm^3 of this solution react with 18.40 cm^3 of $0.0500 \text{ mol dm}^{-3}$ KMnO_4 solution.

Calculate the mass of $\text{K}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ used to make up the solution.

Give your answer to an **appropriate** number of significant figures.

mass of $\text{K}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ = ----- g [5]

15(a) This question refers to the Fig. 1 that is provided as an insert to this paper.

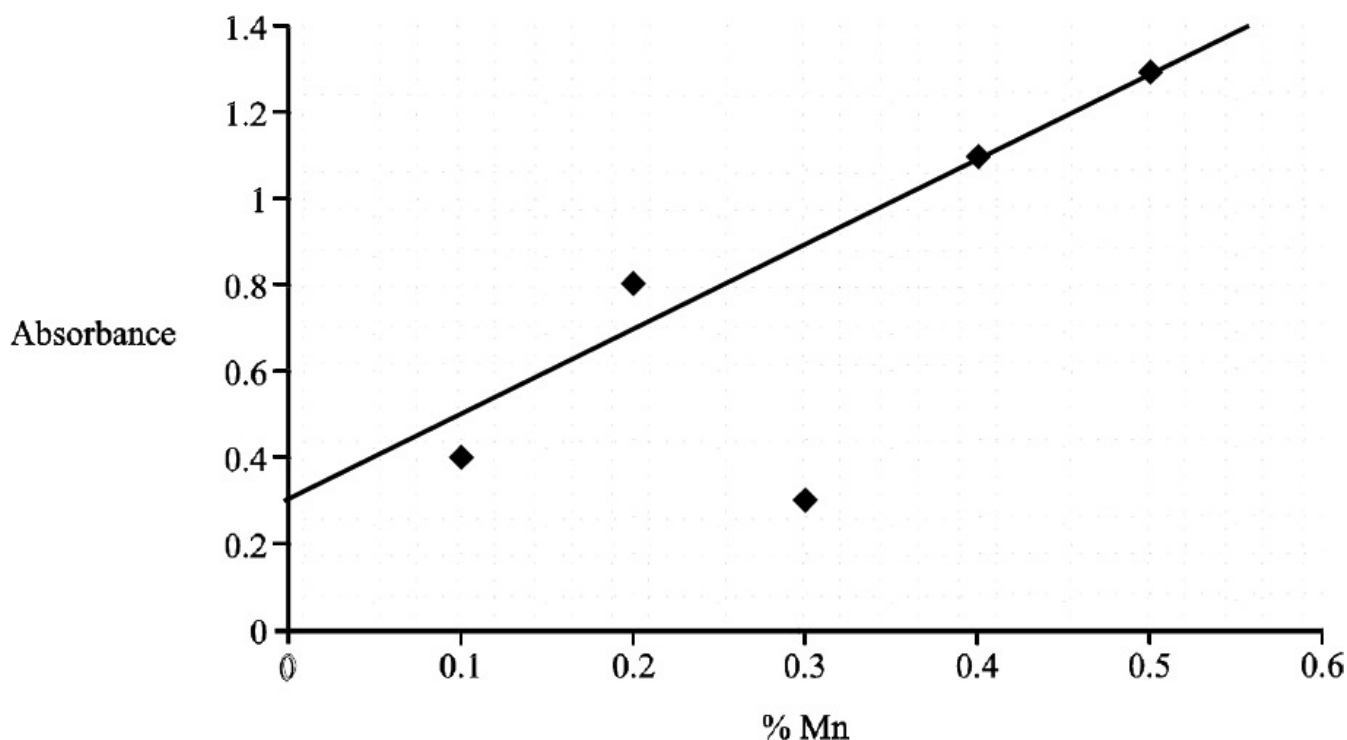


Fig. 1 % Mn against absorbance

- (i) Name a suitable piece of apparatus (with its size) that could be used to measure 25 cm³ of dilute sulfuric acid into the conical flask in **Part 1**.

----- [1]

- (ii) Suggest **two** reasons why the conical flask in **Part 1** was fitted with a bung carrying a capillary tube, apart from loss of spray.

----- [2]

- (iii) Use the student's results in **Part 1** to calculate the percentage of iron in the paper clip.

Show **all** your working.

percentage of iron = _____ % [4]

(b)

- (i) In **Part 2**, the student was given a solution labelled '2% Mn'.

Calculate the concentration (in g dm^{-3}) of a solution of potassium manganate(VII) that contains the same concentration of Mn as would be in 100 cm^3 of a solution made from 0.25 g of paper clips if they contained '2% Mn' by mass.

Show **all** your working.

concentration = _____ g dm^{-3} [3]

- (ii) Explain why a '2% Mn' solution made by dissolving potassium manganate(VII) crystals would be more accurate than a '0.5% Mn' solution made using the same method.

----- [1]

- (iii) * Describe how the student could use the '2% Mn' solution and a colorimeter to produce a calibration curve suitable for finding the concentration of manganese in the paper clip solution.

[1]

Use the line drawn by the student on the calibration graph to read off a value for the % Mn in the paper clip solution.

----- [1]

[2]

[1]

- (d) Suggest another method, other than using a titration or a colorimeter, that the student could use to find the concentration of Fe^{2+} ions in a solution made from paper clips.

-----[1]

16(a) This question refers to the *Practical Insert* that is provided as an insert to this paper.

- (i) Explain why different numbers of drops of water are added to the wells in the preliminary experiment.

----- [1]

- (ii) The pale blue precipitate formed in wells A3 and A4 is copper hydroxide.

Write an ionic equation for the reaction that forms the precipitate.
Include state symbols.

[2]

- (iii) The pale blue precipitate dissolves when more ammonia solution is added because the reaction produces a soluble, deep blue complex ion.

This ion can be represented as $[\text{Cu}(\text{NH}_3)_x]^{2+}(\text{aq})$, where x is a whole number and the ammonia molecules are acting as ligands.

Name the bonds between the ammonia molecules and the central copper ion.

----- [1]

(b) In the main experiment:

- (i) What would be a suitable piece of apparatus to measure the volumes of the solutions shown in the table in the main experiment on page 3 of the Insert?

-----[1]

- (ii) A filter with the complementary colour to the solution being tested would be suitable for the experiment. However, the student was unsure which of the filters represented this complementary colour.

Explain how the filters could be tested to see which was the appropriate complementary colour.

-----[2]

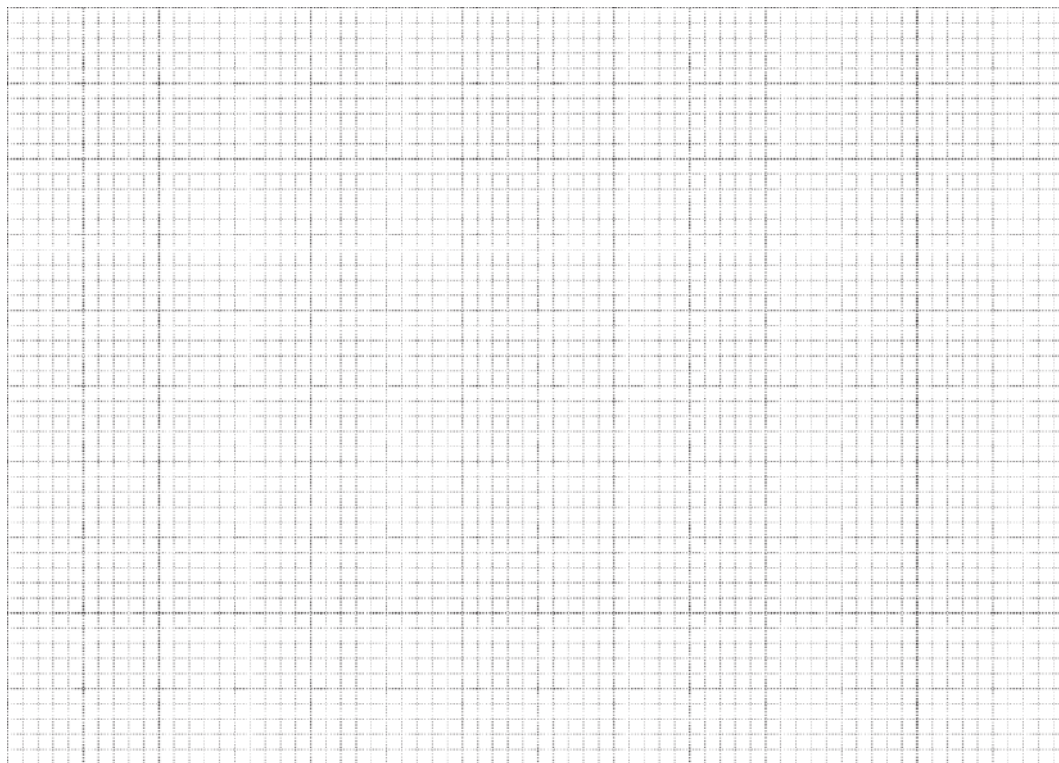
- (iii) The ammonia solution was made up by dilution from a more concentrated stock solution.

Describe how the student could make up 250 cm³ of a 0.100 mol dm⁻³ solution of ammonia, from a stock solution of concentration 0.500 mol dm⁻³.

-----[3]

- (c) Use the graph paper below to plot a graph of the results from page 4 of the Insert. This should enable you to find the maximum whole number ratio of the volume of the copper ion solution to ammonia solution.

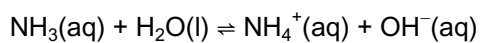
Use your graph to suggest the formula of the copper-ammonia complex ion.



formula of the copper-ammonia complex ion _____ [5]

- (d) The student noticed that 'in the main experiment' no precipitate formed in any of the mixtures. The student assumed this was due to the presence of the ammonium sulfate.

Some of the ammonia molecules that dissolve in water to form ammonia solution react with water as shown in the equilibrium reaction below:



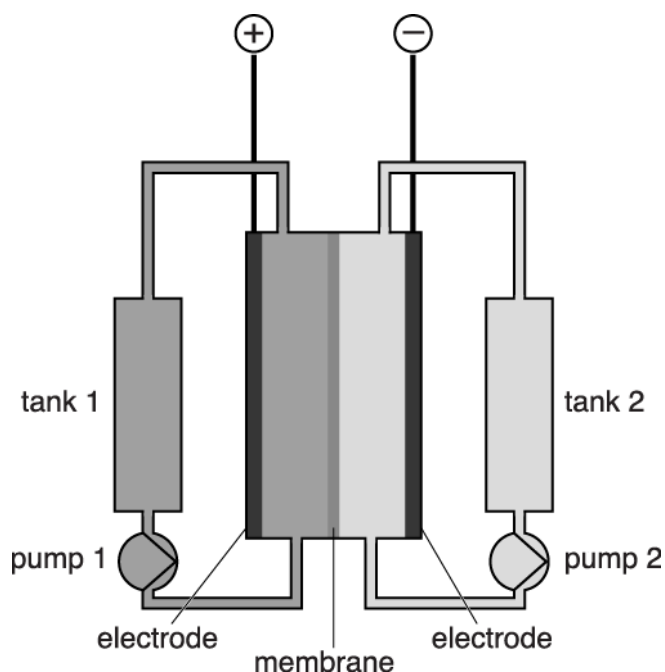
Use your knowledge of chemical equilibrium to suggest why the presence of the ammonium sulfate prevents a precipitate from forming.

[4]

17(a) Large flow electrochemical cells are used to power agricultural machinery in California.

The flow cell contains two solutions. **Solution A** contains Cr^{2+} and Cr^{3+} and **Solution B** contains Fe^{2+} and Fe^{3+} .

The cell has a membrane between two half-cells and each half-cell has a different solution pumped through it.



(i) Use the data in the table below to determine which solution is in tank 1 and which solution is in tank 2.

Give your reasoning.

Half-reaction	E°/V
$\text{Cr}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Cr}^{2+}(\text{aq})$	-0.41
$\text{Fe}^{3+}(\text{aq}) + \text{e}^- \rightarrow \text{Fe}^{2+}(\text{aq})$	+0.77

[2]

- (ii) Write an ionic equation for the reaction taking place in the cell when it is producing electrical energy. State symbols are not required.

→

[1]

- (iii) The two tanks and cell are made from steel that has a protective coating.

Give **two** reasons for coating the steel and suggest a suitable substance for the coating.

Reasons

Coating substance _____

[3]

- (iv) Suggest **one** function of the membrane shown in the diagram on page 6.

[1]

- (v) Name a suitable material to use for the electrodes.

[1]

- (b) A student decided to investigate whether a solution of V^{2+} and V^{3+} ions could be used instead of a solution of Cr^{2+} and Cr^{3+} ions (solution A).

The student found that the $E^\ominus_{\text{cell}}$ was 1.03 V and the Fe^{3+}/Fe^{2+} electrode had the same sign as in the cell opposite.

Calculate $E^\ominus$ for the V^{3+} / V^{2+} half-cell.

$E^\ominus$ for half-cell = _____ V [1]

- (c) A solution containing only $Fe^{3+}(aq)$ and $Fe^{2+}(aq)$ cations is left open to the atmosphere for a few hours. On addition of aqueous hydroxide ions, only a red-brown precipitate forms.

Explain why only a red-brown precipitate forms.

In your answer, suggest equations for the reactions taking place. Include state symbols.

----- [5]

18(a) One way of measuring the amount of an alkene in a sample is by titrating it with standard bromine solution. This method enables a value for the bromine number of the sample to be calculated.

The bromine number is the mass (in g) of bromine, Br₂, absorbed by 100 g of a sample.

Calculate the bromine number of a pure sample of hexa-2,4-diene (C₆H₁₀).

Give your answer to the nearest whole number.

bromine number = _____ [2]

(b) A student decides to determine the bromine number of a solution of hexa-2,4-diene in cyclohexane.

The student makes a bromine solution as follows. 100 cm³ of an acidified solution of 0.167 mol dm⁻³ KBr is reacted with 100 cm³ of 0.0500 mol dm⁻³ KBrO₃. The total volume is 200 cm³.

The equation for the reaction is given below.



(i) Show that the KBrO₃ is in excess.

- (ii) 10.0 g of the hexa-2,4-diene solution required 82.0 cm³ of the bromine solution to produce the first permanent yellow tinge to the mixture.

Calculate the bromine number of the hexa-2,4-diene solution.

Give your answer to the nearest whole number.

bromine number = _____ [5]

(c) Hexa-2,4-diene, $\text{CH}_3\text{CH}=\text{CHCH}=\text{CHCH}_3$, can form several *E* / *Z* isomers.

(i) Give **two** reasons why *E/Z* isomers exist.

[2]

(ii) Draw structural diagrams to represent all the *E* / *Z* isomers.
Label the appropriate parts of each formula with **E** or **Z**.

[4]

(d) To ensure that the alkene is fully brominated in the reaction, a mercury catalyst is sometimes used.

Explain how transition metals can act as heterogeneous catalysts.

[3]

19(a) Ancient paintings have been discovered in caves. The paintings were made using *ochre*, a natural pigment. Ochre owes its colour to the presence of $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$.

- (i) Give the oxidation state of Fe in $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$ and complete the electron configuration for the iron ion in the compound.

oxidation state _____ [1]

electron configuration:

$1s^2 2s^2$ _____ [1]

- (ii) When heated gently, 1.282 g of $\text{FeO}(\text{OH}) \cdot n\text{H}_2\text{O}$ loses 0.216 g of water.

Calculate the value of n in the formula of ochre, showing your working.

$n =$ _____ [2]

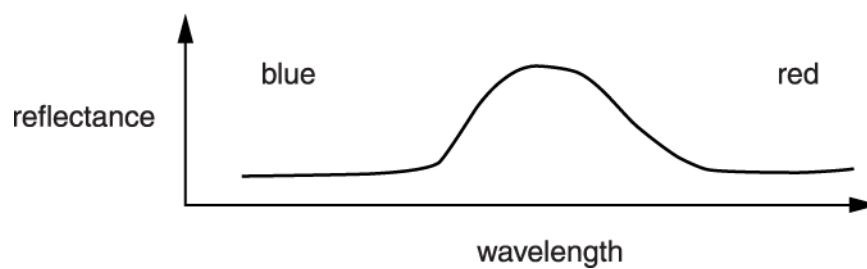
- (iii) On stronger heating, the same sample lost another 0.140 g to form Fe_3O_y .

Calculate the value of y in Fe_3O_y .

$y =$ _____ [2]

(b)

(i) The reflectance spectrum of ochre is shown below.



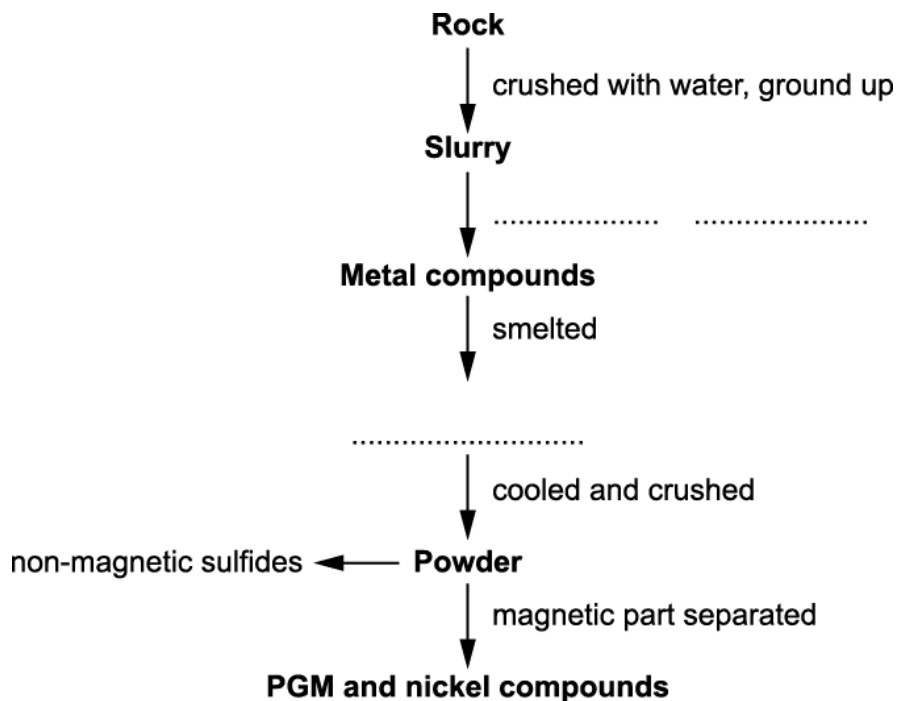
Suggest, with a reason, the colour of ochre.

----- [1]

(ii) Explain why the iron compound is coloured.

----- [4]

- (i) Write words on the dotted lines to complete the flowchart below to summarise the extraction of PGM from rocks.



[1]

- (ii) Suggest an equation for the reaction of one of the 'non-magnetic sulfides' with sulfuric acid to form a sulfate.

[1]

- (iii) How is the metal obtained from the solution of its sulfate?

[1]

(b)

- (i) Suggest **two** reasons why PGM are used in catalytic converters rather than other equally effective catalysts.

----- [1]

- (ii) Write the equation for a reaction in which both CO and NO are removed from exhaust gases in a catalytic converter.

[1]

- (c) Complete the electron configuration of Rh^{3+} , by comparison with Co^{3+} .

[Kr] ----- [1]

(d)

- (i) $[\text{Ru}_2\text{OCl}_{10}]^{4-}$ has an oxygen atom connecting two Ru atoms.

Draw a three-dimensional diagram to suggest the shape of this ion. Give the co-ordination number of Ru in your structure.

co-ordination number ----- [2]

- (ii) Suggest a **name** for the shape of $[\text{AuCl}_4]^-$.

----- [1]

- (e) Give the formula of a 'bulky organic monocation' from the article and explain why three such species are needed by $[\text{MC}_6]^{3-}$.

----- [2]

(f) Estimate how much faster $[\text{Ag}(\text{H}_2\text{O})_2]^+$ exchanges chloride ions compared with $[\text{Ru}(\text{H}_2\text{O})_6]^{3+}$.

----- [1]

(g) Give the equation for a ligand exchange reaction of copper involving ammonia. Give the starting and finishing colours involved.

[2]

(h) A student says that silver(I) salts are colourless because the d subshells are not split by the ligands.

Discuss this statement. (Ag has the same outer electron configuration as Cu.)

----- [3]

- (i) *Describe how compounds of palladium, platinum and osmium are each extracted from a mixture of PGM chlorides, giving chemical details from the article.

[6]

21 What is the electronic configuration of a Cr^{3+} ion?

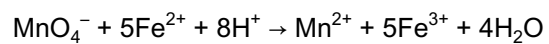
- A** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 4s^2$
B $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 4s^2$
C $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 4s^0$
D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^0$

Your answer

11

[1]

22 MnO_4^- ions react with Fe^{2+} ions according to the equation shown below.



What volume of $0.100 \text{ mol dm}^{-3}$ potassium manganate(VII) is needed to react with 0.250 grams of iron dissolved in sulfuric acid?

- A 8.96 cm^3
- B 22.4 cm^3
- C 44.8 cm^3
- D 224 cm^3

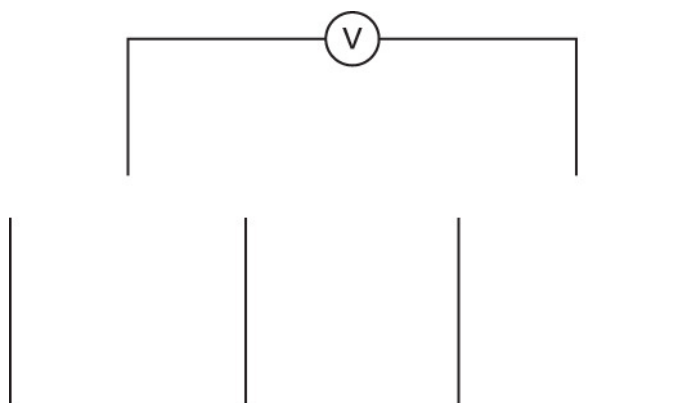
Your answer

[1]

23(a) A student wants to measure the $E^\ominus_{\text{cell}}$ when ClO^- oxidises I^- ions.

Half reaction	$E^\ominus/\text{V}$
$\text{I}_2(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{I}^-(\text{aq})$	+0.54
$\text{ClO}^-(\text{aq}) + 2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cl}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+1.50

Complete and label the diagram below to show how the cell should be set up in the laboratory. On your diagram show the direction of the flow of electrons and give the equation for the reaction taking place.



Equation:

[5]

(b) Students want to oxidise $\text{HCl}(\text{aq})$ to chlorine.

Use the electrode potentials below to suggest which oxidising agent(s) would enable them to prepare chlorine.
Explain your answer and give balanced equation(s) for any reaction(s).

Half reaction	$E^\ominus/\text{V}$
$\text{MnO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$	+1.23
$\text{Cr}_2\text{O}_7^{2-}(\text{aq}) + 14\text{H}^+(\text{aq}) + 6\text{e}^- \rightleftharpoons 2\text{Cr}^{3+}(\text{aq}) + 7\text{H}_2\text{O}(\text{l})$	+1.33
$\text{Cl}_2(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	+1.36
$\text{MnO}_4^-(\text{aq}) + 8\text{H}^+(\text{aq}) + 5\text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq}) + 4\text{H}_2\text{O}(\text{l})$	+1.51

Equation(s):

[3]

(See Insert for H433/02, June 2017)

- (i) Name the piece of apparatus which is most suitable for removing the 25.0 cm^3 of the Cu^{2+} ion solution.

----- [1]

- (ii) Use the student's results in the *Practical Insert* to work out an average titre that the student should use in calculating the amount of Cu^{2+} in the 'coin solution'.

average titre = ----- cm^3 [1]

- (iii) Use your answer from (a)(ii) to calculate the percentage by mass of copper in the coin.
Give your answer to an **appropriate** number of significant figures.

percentage by mass of copper in coin =----- % [4]

(iv) The student considers the uncertainties of measurement in the experiment.

The percentage measurement uncertainty marked on the apparatus used to transfer the 25 cm^3 of the 'copper' solution is $\pm 0.24\%$.

The volumetric flask is marked $\pm 0.08\%$.

Calculate the measurement uncertainties of the other pieces of apparatus used.

Which piece of apparatus contributes most to the measurement uncertainty in this experiment?

[2]

(v) Name another method that the student could use to find the concentration of Cu^{2+} ions in the 'coin solution'.

-----[1]

25 An element forms ions with a charge of $3+$.

What could be the electron configuration of the atoms of the element?

A $1s^2 2s^2 2p^3$

B $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1 4s^2$

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

D $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^3$

Your answer

[1]

26 A student is given the electrode potentials below.



The student sets up a cell from the two half cells.

Which statement is correct?

- A The cell voltage is 1.14 V.
- B Cu^{2+} is reduced by Ag.
- C Cu is oxidised by Ag^{+} .
- D Cu^{2+} is oxidised by Ag.

Your answer

[1]

27 Which ion is coloured?

- A Zn^{2+}
- B Sc^{3+}
- C Ti^{3+}
- D Ti^{4+}

Your answer

[1]

28 Which statement(s) about rusting is/are correct?

- 1 Rust contains Fe^{3+} ions.
- 2 Oxygen molecules are reduced during rusting.
- 3 The first step in rusting is $\text{Fe} \rightarrow \text{Fe}^{3+} + 3\text{e}^-$.

- A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

Your answer

☐

[1]

29 Which statement(s) about the $[\text{Fe}(\text{C}_2\text{O}_4)]^{3-}$ ion is/are correct?

- 1 The bond angles around the metal are 90° .
- 2 The shape is octahedral.
- 3 The co-ordination number is 6.

- A 1, 2 and 3
B Only 1 and 2
C Only 2 and 3
D Only 1

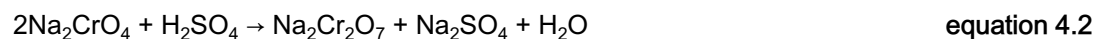
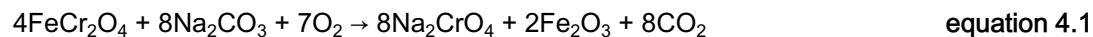
Your answer

☐

[1]

30(a) Chromium is a metal with many uses, one of which is the production of a shiny chromium plating on steel.

Chromium is made from its ore chromite, FeCr_2O_4 , by the following reactions. Iron has one of its common oxidation states in chromite.



- (i) Complete the table below showing the oxidation states of chromium species in the equations above. For each equation state whether chromium has been reduced, oxidised or neither.

Equation no.	Oxidation state of Cr in reactant	Oxidation state of Cr in product	Has Cr been oxidised, reduced or neither?
4.1			
4.2			
4.3			
4.4			

[4]

- (ii) Calculate the maximum mass of chromium (in kg) that could be obtained from 1000 g of chromite.

mass = _____ kg [2]

(b) Chromium plating is carried out using a solution of chromium(III) chloride with a graphite anode.

(i) Write the electron configuration of a Cr^{3+} ion, using sub-shells and atomic orbitals.

-----[1]

(ii) Draw a labelled diagram of a simple apparatus to carry out chromium plating of a steel object in a student laboratory.

[3]

(iii) Write a half-equation for the cathode reaction in the cell in (b)(ii).

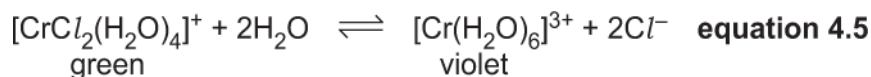
[1]

(iv) A 'mole of electrons' is 96 500 coulombs and a coulomb is a current of 1 amp flowing for 1 second.

Calculate the time (in hours) needed to deposit 26 g of chromium at a current of 5.0 amps in the cell in (b)(ii).

time = ----- hours [3]

(c) In a solution of chromium(III) chloride an equilibrium exists, as shown in **equation 4.5**.



(i) **Name** the ligands in the green complex.

-----[1]

(ii) Some students have a violet solution of chromium(III) chloride.

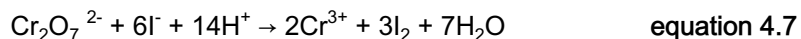
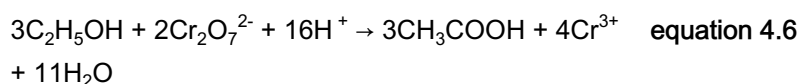
Use your knowledge of equilibria to suggest and explain how they might make the violet solution turn green.

Give the **name** of any reagent required.

-----[2]

(d) The concentration of an ethanol solution can be measured using the following steps.

- add excess acidified dichromate, $\text{Cr}_2\text{O}_7^{2-}$, some of which reacts with the ethanol.
- add excess iodide that reacts with the remaining dichromate.
- titrate the iodine produced with sodium thiosulfate.



- (i) Some students add acid and 20.0 cm^3 of $0.200 \text{ mol dm}^{-3} \text{ Cr}_2\text{O}_7^{2-}$ to 25.0 cm^3 of a 'low-alcohol' beer.

They add excess iodide ions and find that the iodine produced reacts with 27.6 cm^3 of $0.100 \text{ mol dm}^{-3} \text{ Na}_2\text{S}_2\text{O}_3$.

Calculate the concentration of the ethanol in the beer (in mol dm^{-3}) and then the percentage of ethanol (in g per 100 cm^3).

concentration of ethanol = _____ . mol dm^{-3}

% ethanol = _____ . g/100 cm^3 [6]

- (ii) Suggest one assumption the students have to make when giving their result.

----- [1]

31(a)

(i) What is acting as the acid in the equation shown below?



-----[1]

(ii) Draw a diagram to illustrate the shape of the $[Al(OH)(H_2O)_5]^{2+}$ ion, naming the shape.

name of shape-----[2]

(b) This question is based on the article **Saving paper** from *Education in Chemistry*, March 2013, published by the Royal Society of Chemistry which comes as an insert with this paper.

The article gives two equations for the 'Fenton mechanism'.

Give the overall equation represented by the two equations.

Explain why the two equations alone do not show that Fe^{2+} is acting as a catalyst. Overall equation:

Explanation: -----

-----[2]

32 Colorimetry is used to find the concentration of an orange solution of iodine. Which statement is correct?

- A The more concentrated the solution the more light is transmitted.
- B A yellow coloured filter should be used.
- C The absorbance of solutions of known concentration should be measured to get a calibration curve.
- D Orange light is absorbed.

Your answer

[1]

33 What is correct for the complex $[\text{Fe}(\text{C}_2\text{O}_4)_3]^{3-}$?

- A The charge on each ligand is 2-.
- B The co-ordination number of the metal ion is 3.
- C The oxidation state of the iron is +2.
- D The ligand is monodentate.

Your answer

[1]

34 Which row gives the correct appearances of the products of the reactions?

	$[\text{Fe}(\text{H}_2\text{O})_6]^{3+}(\text{aq})$ and sodium hydroxide solution	$[\text{Cu}(\text{H}_2\text{O})_6]^{2+}(\text{aq})$ and excess conc. ammonia solution
A	Green precipitate	Green solution
B	Orange precipitate	Blue/violet solution
C	Orange precipitate	Green precipitate
D	Orange solution	Yellow solution

Your answer

[1]

35(a) A company was investigating the corrosion of metal parts used in oil rigs in the North Sea.

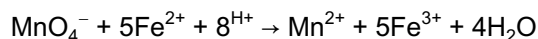
Chemists took two identical bolts. One was unused and the other had been exposed to the seawater for several weeks. They reacted each bolt with dilute sulfuric acid. All the unreacted iron was converted to $\text{Fe}^{2+}(\text{aq})$ ions and the rust reacted to form $\text{Fe}^{3+}(\text{aq})$.

Describe how the chemists would dissolve one bolt and make the solution up to 1.00 dm^3 .

[2]

- (b) The chemists then titrated 10.0 cm^3 portions of their solutions with a solution of $0.200 \text{ mol dm}^{-3}$ potassium manganate(VII).

The MnO_4^- ions oxidise the Fe^{2+} to Fe^{3+} and the Fe^{3+} ions do not react.
The equation for the reaction is given below.

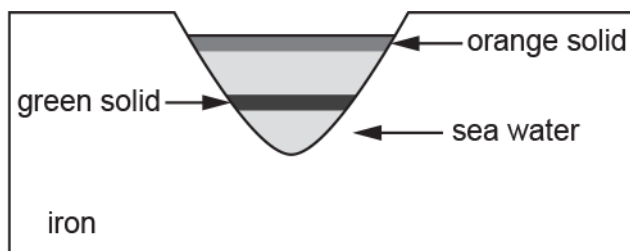


Use the titration results below to find the mass of the bolt that had rusted away.

Type of bolt	Average volume of $0.200 \text{ mol dm}^{-3}$ KMnO_4 used in the titration / cm^3
Unused bolt	17.92
Rusted bolt	9.75

mass of bolt that had rusted away = ----- g [3]

- (c) The iron rusted in small dips in the surface. The chemists noticed a green solid that turned orange at the surface of the water.



- (i) Give the half-equations for the processes occurring during the rusting.

[2]

- (ii) What are the **formulae** of the green and orange solids?

Green solid

Orange solid

[1]

- (iii) Suggest why rusting takes place faster in seawater than in rainwater.

.....
..... [1]

(d) Give the electron configuration of the Fe^{2+} ion.

-----[1]

The chemists investigated making the bolts from a nickel-copper alloy that has high strength and resistance to corrosion.

They reacted the alloy with sulfuric acid and filtered off the unreacted solid, which they found was copper.

(e) Use the electrode potentials in the table below to explain why only the nickel reacts.

Half reaction	$E^\ominus / \text{V}$
$\text{Ni}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Ni}(\text{s})$	- 0.25
$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	0.00
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+ 0.34

-----[2]

(f) The solution they obtained was green due to $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$. The chemists added some EDTA^{4-} solution and the colour changed to blue. EDTA^{4-} is a polydentate ligand.

(i) Suggest why the colour changes as the EDTA^{4-} is added and name the type of reaction taking place.

----- [1]

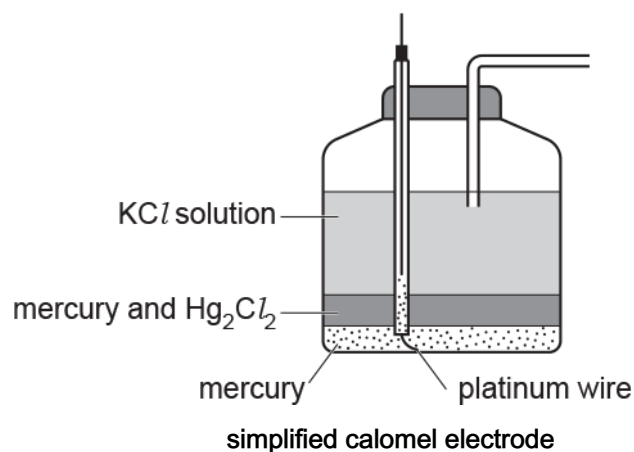
(ii) In a separate experiment, 25.0 cm^3 of a $0.250 \text{ mol dm}^{-3}$ $[\text{Ni}(\text{H}_2\text{O})_6]^{2+}$ solution is found to react exactly with 41.7 cm^3 of $0.150 \text{ mol dm}^{-3}$ EDTA^{4-} solution.

Calculate the formula of the complex ion that nickel forms with EDTA^{4-} .

formula of the complex ion = ----- [2]

*A student investigating the rusting of iron is given a calomel electrode.

The diagram shows a simplified calomel electrode.



The student wants to use this electrode to measure the standard electrode potential of a $\text{Fe}^{2+}(\text{aq})|\text{Fe}(\text{s})$ half-cell.

Give instructions on how to do this, justifying the uses of the pieces of apparatus you name.

You may add to the diagram above to illustrate your answer.

[6]

38(a) This question concerns the article The Strange Story of Napoleon's Wallpaper that is supplied as Insert for H433/02, June 2018.

One reason arsenic is poisonous because it reacts with –SH groups in amino acids.

Suggest how the removal of –SH groups might interfere with the way these amino acids form proteins.

----- [1]

(b) Arsenate(V) can replace phosphate(V) in nucleic acids.

Draw the skeletal formula of a DNA nucleotide containing thymine and with As instead of P.

(c) Write an equation for the reaction of a solution of As^{3+} with hydrogen sulfide. Show state symbols. [2]

[2]

(d) A Marsh test is carried out for arsenic in a sample of As_2O_3 .

(i) Draw a labelled diagram of a suitable apparatus, showing the reactants and products.

[3]

(ii) Write equations for the formation and decomposition of arsine in the apparatus.

[2]

(e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$.

(i) Suggest a '*dot-and-cross*' diagram for the anion in Scheele's green.

[2]

(ii) State which part of Scheele's green is responsible for the green colour.

-----[1]

(f) State and explain the C–As–C bond angle in trimethylarsine.

[4]

(g) Summarise the evidence that Napoleon was killed by his wallpaper.

[3]

39 The steps involved in measuring the concentration of a coloured solution with a colorimeter are given below in a random order.

1. Measure the absorbance of several known concentrations of the solution.
2. Measure the absorbance of the sample of unknown concentration.
3. Plot a calibration curve.
4. Select a suitable coloured filter.

What is the correct order for these steps?

- A 1, 2, 3, 4
- B 4, 3, 2, 1
- C 4, 1, 3, 2
- D 3, 1, 4, 2

Your answer

[1]

40 Excess ammonia solution is added separately to $\text{Cu}^{2+}(\text{aq})$ and $\text{Fe}^{2+}(\text{aq})$.
The solutions are left in the air.

Which row of the table represents the colour changes seen?

	$\text{Cu}^{2+}(\text{aq})$	$\text{Fe}^{2+}(\text{aq})$
A	Pale blue precipitate → dark blue solution	Dark green precipitate → orange precipitate
B	Green/blue solution → dark blue solution	Green precipitate remaining green
C	Pale blue precipitate → green/blue solution	Orange precipitate → dark green precipitate
D	Pale blue precipitate → dark blue solution	Orange precipitate → dark green precipitate

Your answer

[1]

41 Please refer to the Practical material that is supplied as **Insert for H433/03, June 2019.**

*There are several d block metal ions, including complex ions, mentioned in the insert. These ions are different colours.

Explain the term **complex ion** and why different complexes of d block elements have different colours.

Give examples from the Insert.

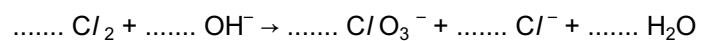
[6]

42(a) Chlorine is made by electrolysis of sodium chloride solution.

Sodium chlorate(V) is made by letting the chlorine react with the hydroxide ions that are also produced.

When chlorine reacts with hot hydroxide ions, part of the chlorine is oxidised to chlorate(V) and the rest of the chlorine is reduced to chloride.

Use oxidation states to balance the equation for the reaction.



[2]

(b) ClO_2 can be made by reacting ClO_3^- with concentrated hydrochloric acid.



ClO_2 is used for water purification and for bleaching the pulp used to make paper.

Table 3.1 shows some electrode potential data.

Half-reaction	$E^\ominus / \text{V}$
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{I}_2(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{I}^-(\text{aq})$	+0.54
$\text{ClO}_3^-(\text{aq}) + 2\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{ClO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+1.15
$\text{Cl}_2(\text{aq}) + 2\text{e}^- \rightleftharpoons 2\text{Cl}^-(\text{aq})$	+1.36

Table 3.1

(i) The forward reaction in **equation 3.1** does **not** occur under standard conditions.

Use data from **Table 3.1** to explain why.

[2]

(ii) Suggest why the forward reaction in **equation 3.1** **does** occur in the presence of concentrated hydrochloric acid.

[2]

(c) A student investigates the reactions of some halogen compounds using the data in Table 3.1.

Half-reaction	$E^{\ominus} / \text{V}$
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{I}_2(\text{aq}) + 2\text{e}^{-} \rightleftharpoons 2\text{I}^{-}(\text{aq})$	+0.54
$\text{ClO}_3^{-}(\text{aq}) + 2\text{H}^{+}(\text{aq}) + \text{e}^{-} \rightleftharpoons \text{ClO}_2(\text{aq}) + \text{H}_2\text{O}(\text{l})$	+1.15
$\text{Cl}_2(\text{aq}) + 2\text{e}^{-} \rightleftharpoons 2\text{Cl}^{-}(\text{aq})$	+1.36

Table 3.1

(i) The student uses a $\text{Cu}^{2+}(\text{aq})/\text{Cu}(\text{s})$ half-cell to confirm the $E^{\ominus}$ of a $\text{Cl}_2(\text{aq})/\text{Cl}^{-}(\text{aq})$ half-cell.

Complete and label the diagram of the apparatus the student would set up.

Show state symbols.

Indicate how standard conditions are achieved.



[4]

(ii) Give the value of $E^{\ominus}_{\text{cell}}$ for the cell in (i).

$E^{\ominus}_{\text{cell}} = \dots\dots\dots \text{V}$ [1]

(iii) State where the electrons move and which way they are moving when the cell delivers a current.

[1]

(iv) A standard hydrogen electrode is used to measure $E^\ominus$ values, such as those in Table 3.1.

Give the half-cell reaction that occurs at a hydrogen electrode.

Show state symbols.

[1]

(v) The E value for the copper electrode at 298 K varies with the concentration of copperions. The equation for this is shown below.

$$E = E^\ominus + 0.0128 \ln [\text{Cu}^{2+}]$$

Calculate the E value for a copper electrode where $[\text{Cu}^{2+}] = 0.010 \text{ mol dm}^{-3}$.

$E = \dots\dots\dots\text{V}$ [2]

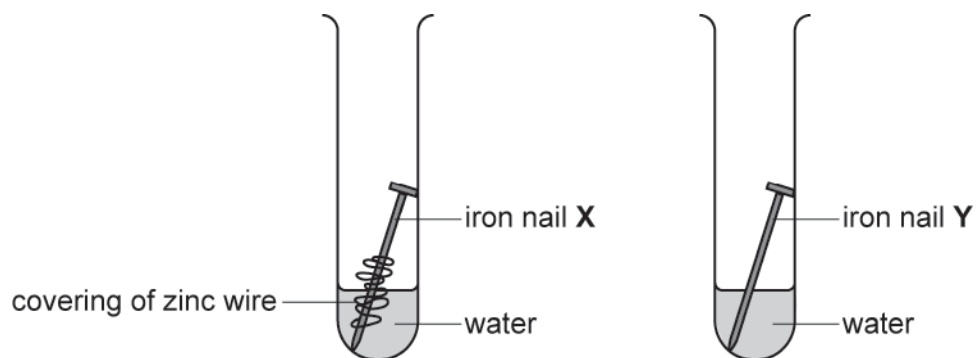
43 Which ion would have a coloured chloride?

- A Cu^+
- B Sc^{3+}
- C Ti^{3+}
- D Zn^{2+}

Your answer

[1]

44 X is an iron nail partially covered in zinc. Y is a plain iron nail.



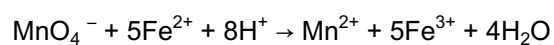
Which statement about rusting is correct?

- A X will rust at the same rate as Y as it is not fully covered.
- B Y will rust faster than X, which is protected by the zinc.
- C X will rust faster than Y since zinc is more reactive than iron.
- D Y will rust faster than X if copper replaces the zinc around X.

Your answer

[1]

45 Manganate(VII) and iron(II) ions react as shown.



What volume, in cm^3 , of $0.10 \text{ mol dm}^{-3} \text{Fe}^{2+}$ will react with 25 cm^3 of $0.050 \text{ mol dm}^{-3} \text{MnO}_4^-$?

- A 2.5
- B 12.5
- C 62.5
- D 125

Your answer

[1]

46 Some students want to synthesise dyes that will bind well to wool fibres.

They read that they can make coloured molecules using coupling reactions between phenols and diazonium ions.

* The students have some wool samples that they have dyed. They want to find out how much of the dye washes out of the wool at different temperatures. They decide to use colorimetry.

Describe a suitable method for this experiment. Include the control variables in your answer.

[6]

Cisplatin is a neutral molecule.

- (i) Explain why the oxidation state of the platinum in cisplatin is +2.

----- [1]

- (ii) Suggest the electronic configuration of the outermost sub-shell in a Pt^{2+} ion.

----- [1]

- (iii) Is platinum a transition metal?

Give a reason.

----- [1]

- (b) Some ligands are described as bidentate.

Give the **full** structural formula of a bidentate ligand from a compound in the article.

[2]

- (c) **Fig. 5.1** is a diagram from page 3 of the article. It shows a possible way in which a compound derived from cisplatin is thought to attach to a base in DNA. Two bonds have been labelled **B** and **C**.

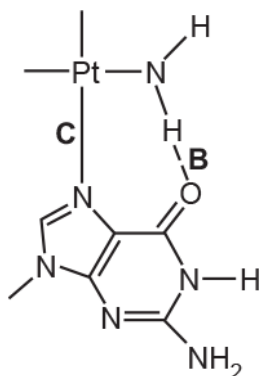


Fig. 5.1

- (i) What is the name of the base in **Fig. 5.1**? Use the Data Sheet to help you.

----- [1]

- (ii) What is the name of the type of bond at **B** in **Fig. 5.1**?

----- [1]

- (iii) Name the type of bond at **C** in **Fig. 5.1** and describe how it is formed.

 ----- [2]

(d) Satraplatin was designed to be taken by mouth as it is soluble.

(i) Name the shape of a satraplatin molecule around the Pt atom.

----- [1]

(ii) Give the co-ordination number of Pt in satraplatin.

----- [1]

(iii) Suggest, in terms of intermolecular bonds, why satraplatin is soluble whereas cisplatin is not.

----- [3]

48(a) Some students use a method based on an electrochemical cell to measure the concentration of silver ions in solution.

They set up a cell as shown in Fig. 2.1.

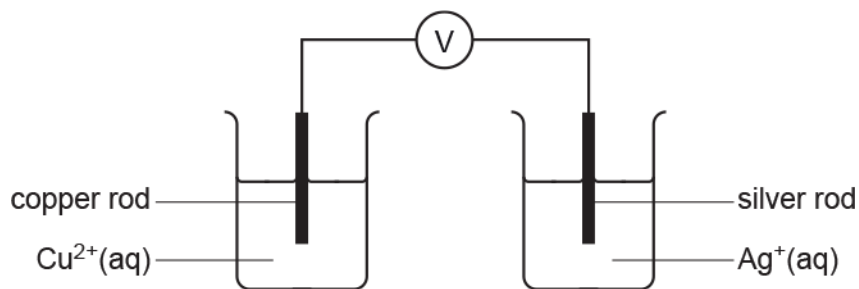


Fig. 2.1

- (i) There is something missing from the diagram.

State what it is and describe what it is made of.

----- [2]

- (ii) State **two** conditions necessary for the cell to measure electrode potentials under **standard** conditions.

1 -----

2 -----

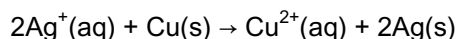
[2]

- (b) Table 2.1 shows the electrode potential data for the cell in Fig. 2.1.

Half-equation	E° / V
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$\text{Ag}^{+}(\text{aq}) + \text{e}^{-} \rightleftharpoons \text{Ag}(\text{s})$	+0.80

Table 2.1

Equation 2.1 shows the reaction that occurs when the standard cell delivers a current.



Equation 2.1

- (i) Identify the oxidising agent in equation 2.1.

----- [1]

- (ii) State and explain which way electrons flow in the wire when the standard cell is delivering a current.

----- [1]

- (c) Silver bromide, AgBr, is usually described as 'insoluble' but a small amount can dissolve in water.

The students have a saturated solution of AgBr. This contains as much AgBr as will dissolve. They place this saturated solution in the right-hand beaker of the cell in Fig. 2.1.

They measure the cell potential against a standard copper electrode. Their result is 0.09 V (with the same electrode polarity as in the standard cell).

The students are told that the relationship between their measured cell potential, E_{cell} , and the concentration of silver ions is given by:

$$E_{\text{cell}} = E^{\circ}_{\text{cell}} + 0.06 \log[\text{Ag}^{+}]$$

Calculate the silver ion concentration in the saturated solution of AgBr.

$$[\text{Ag}^{+}] = \dots\dots\dots \text{mol dm}^{-3} \quad [4]$$

- (d) Some students make an electrochemical cell, using two different half cells as shown in Table 2. 2.

Half-reaction	E° / V
$\text{Cu}^{2+}(\text{aq}) + 2\text{e}^{-} \rightleftharpoons \text{Cu}(\text{s})$	+0.34
$2\text{IO}_3^{-}(\text{aq}) + 12 \text{H}^{+}(\text{aq}) + 10\text{e}^{-} \rightleftharpoons \text{I}_2(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$	+1.19

Table 2.2

- (i) Write an equation for the reaction that occurs when the cell delivers a current.

[2]

- (ii) Draw a labelled diagram to show how the $\text{IO}_3^{-} / \text{I}_2$ electrode is made up.
You do **not** need to give concentrations.

[2]

- (iii) The students are told that in a standard $\text{IO}_3^{-} / \text{I}_2$ electrode $[\text{IO}_3^{-}] = [\text{I}_2]$.

They plan to prepare 40 cm^3 of the solution for the electrode by mixing 20 cm^3 of $0.08 \text{ mol dm}^{-3} \text{ I}_2(\text{aq})$ with 20 cm^3 of $\text{IO}_3^{-}(\text{aq})$.

Calculate the concentration of IO_3^{-} needed so that $[\text{IO}_3^{-}]^2 = [\text{I}_2]$.

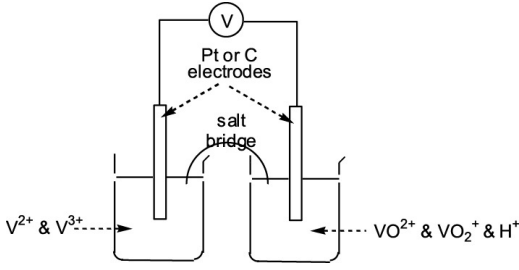
$[\text{IO}_3^{-}] = \dots\dots\dots \text{mol dm}^{-3}$ [3]

END OF QUESTION PAPER

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance										
1	a	i	sulfur dioxide / sulfur trioxide OR chlorine ✓	1	IGNORE formulae ALLOW hydrogen chloride NOT hydrochloric acid or sulfur (di)chloride Examiner's Comments If the gas was correctly recognised the mark was often lost for giving the formula instead of the name.										
		ii	<table><tr><th>compound</th><th>oxidation state of vanadium</th></tr><tr><td>VS₄</td><td>+4</td></tr><tr><td>NaVO₃</td><td>+5</td></tr><tr><td>Na₂V₆O₁₆</td><td>+5</td></tr><tr><td>V₂O₅</td><td>+5</td></tr></table> VS ₄ correct ✓ rest correct ✓	compound	oxidation state of vanadium	VS ₄	+4	NaVO ₃	+5	Na ₂ V ₆ O ₁₆	+5	V ₂ O ₅	+5	2	ONLY penalise ONCE for lack of sign sign must be before number, ecf after first error Examiner's Comments Unlike (i), this part was very well done; the main error being that the vanadium in VS ₄ was often given an oxidation state of +8. A few also had +32 for the vanadium in Na ₂ V ₆ O ₁₆ .
compound	oxidation state of vanadium														
VS ₄	+4														
NaVO ₃	+5														
Na ₂ V ₆ O ₁₆	+5														
V ₂ O ₅	+5														
		iii	step 1 ✓ oxidation state of V changes / increases ✓	2	more than step 1 is a CON but mark explanation separately ALLOW electron loss by V ALLOW ecf for the 2 nd mark, from wrong oxidation state for VS ₄ in table in ii, e.g. +8 (for VS ₄) to +5, so oxidation state decreases If two steps in first part, both reasons must refer correctly to the data in ii Examiner's Comments Well answered with the majority clearly stating the change in oxidation number										

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	absorb (specific) frequencies (or wavelengths) in (specific) parts of the visible spectrum ✓  absorb must be spelled correctly to gain this mark transmit complementary colour / frequencies (or wavelengths) not absorbed / yellow light ✓	2	MUST use frequency / frequencies / wavelength (s) for 1st mark IGNORE any reference to energy levels and electrons ALLOW 'light' for visible or any of its variants e.g. absorbed, absorbing, absorption etc. ALLOW only complementary colour / frequencies (or wavelengths) can be seen DO NOT ALLOW reflect / emit / absorption Examiner's Comments Many gained both marks eventually, but candidates wanted to explain d orbital splitting and electron promotion. This sometimes resulted in them arguing that energy is emitted when electrons fall back to the ground state, or omitting to mention the terms frequency or wavelength.
		v	$\text{V}_2\text{O}_5 + 5\text{Ca} \rightarrow 2\text{V} + 5\text{CaO}$	1	IGNORE state symbols Examiner's Comments Very variable responses; a concerning number seem to think that vanadium is diatomic or that calcium oxide might be CaO_5 or Ca_2O_5.
b	i		 <i>diagram shows minimum requirements for 4 marks</i> both electrodes correct ✓ correct vanadium species in each cell ✓ H^+ ions in VO^{2+} and VO_2^+ solution ✓ salt bridge labelled & dipping into solutions AND voltmeter attached correctly AND circuit complete ✓	4	ALLOW half-cells reversed IGNORE anions, charges on electrodes, water, temperature and concentrations Examiner's Comments Some very weak responses with apparatus drawn correctly but with ions used as electrodes and no liquids in the beakers! Many were correct, but only a very few got the last mark for having H^+ in the correct beaker

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$E_{\text{cell}} = 1.26 \text{ V}$	1	IGNORE any sign Examiner's Comments Usually correct. Answer: $E_{\text{cell}} = 1.26 \text{ V}$
		iii	temperature is not standard / 25°C ✓ concentrations of ions in a half-cell are not equal ✓	2	DO NOT ALLOW conditions not standard, must be specific to temperature and / or concentration ALLOW concentration not 1 mol dm^{-3} DO NOT ALLOW 1 mol(e) for concentration Examiner's Comments Too many just stated that the experiment was not done under standard conditions without any clarification.
		iv	$\text{VO}_2^{+} + 2\text{H}^{+} + \text{V}^{2+} \rightarrow \text{VO}^{2+} + \text{H}_2\text{O} + \text{V}^{3+}$ vanadium species correct ✓ equation correct ✓	2	GIVE 1 mark if equation has species and balancing correct but is reversed Examiner's Comments Very well-done with very few reversing the reaction.
		v	VO_2^{+} AND $E^{\ominus}(\text{I}_2/\text{I}^{-})$ must be more negative / less positive than the V ion being reduced ORA ✓ $2\text{VO}_2^{+} + 4\text{H}^{+} + 2\text{I}^{-} \rightarrow 2\text{VO}^{2+} + 2\text{H}_2\text{O} + \text{I}_2$ ✓	2	ORA V half-cell is the only one with a more positive $E^{\ominus}$ than the I_2/I^{-} half-cell ALLOW balanced equation with $\frac{1}{2} \text{I}_2$ IGNORE state symbols Examiner's Comments Candidates had to work hard for both marks and many did well, comparing the correct standard electrode potentials and also balancing the equation, although others had some difficulty with the balancing aspect.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	moles of $\text{Cr}_2\text{O}_7^{2-}$ used = $0.02160 \times 23.50 / 1000 = 0.0005076$ (5.076×10^{-4}) ✓ moles of Fe^{2+} reacted = 6×0.0005076 ✓ = 0.0030456 (3.0456×10^{-3}) mass of Fe in alloy = 0.0030456×55.8 ✓ = 0.16994448 g % Fe = $0.16994448 \times 100 / 0.1750$ ✓ = 97.1 % ✓	5	DO NOT award marks for random numbers without any explanation to what they refer to marks are for working out shown in bold OR actual answers at each stage must be 3 sig. figs. 97% gains 4 marks, 97.1% 5 marks, irrespective of working Examiner's Comments Many correct answers with all marks scored, a few lost the significant figure mark but on the whole this was well-done. Answer: 97.1%
		ii	oxygen / air (and water) will oxidise / change Fe^{2+} (to Fe^{3+}) ✓ NaHCO_3 reacts with acid to form CO_2 ✓ air / gas is dispelled which cannot return AW ✓	3	Examiner's Comments Most realised that Fe^{2+} was being oxidised, but often the oxidising agent was omitted and the NaHCO_3, H_2SO_4 and even $\text{Cr}_2\text{O}_7^{2-}$ (not present at this stage) were equal contenders for the role. This was the only mark most candidates scored. Despite the fact that in question 3(a), many had actually used NaHCO_3 to test for anacid, they did not recognise its function here. Instead many thought that NaHCO_3 offered some form of sacrificial protection. Few appreciated the full significance of the non-return valve concentrating on preventing O_2 entering ignoring allowing gas/CO_2 to escape.

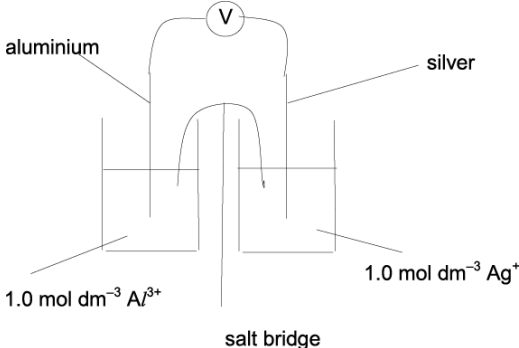
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d	i	green solution ✓ forms a green precipitate ✓	2	IGNORE any qualifying of green such as pale, dark, dirty, rust etc. ALLOW ppt ALLOW solid for precipitate Examiner's Comments This was answered much better than in the past, although a number of colourless/clear solutions and brown precipitates cropped up regularly. The equation was good too, with only a handful adding NaOH.
		ii	$\text{Fe}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Fe}(\text{OH})_2(\text{s})$ formulae correct & balanced ✓ state symbols correct for precipitation reaction ✓	2	
			Total	31	
2			D	1	
			Total	1	
3			B	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
4		i	$E^\ominus$ of $\text{Ce}^{4+}/\text{Ce}^{3+}$ in $\text{H}_2\text{SO}_4(\text{aq})$ is more positive than $E^\ominus$ of Cl_2/Cl^- ✓ So will oxidise Cl^- to Cl_2 ✓ In $\text{HCl}(\text{aq})$ $E^\ominus$ of $\text{Ce}^{4+}/\text{Ce}^{3+}$ is less positive so will not oxidise Cl^- to Cl_2 AND so $\text{H}_2\text{SO}_4(\text{aq})$ is used ✓	3	ALLOW less negative ALLOW more negative
		ii	FIRST CHECK ANSWER ON ANSWER LINE answer = 83% to 2 sig figs award 5 marks $n(\text{AsO}_3^{3-})$ used in titration = $3.00/1000 \times 0.500$ OR 0.00150 (mol) (conc. of AsO_3^{3-} is double that of As_2O_3) ✓ $n(\text{Ce}^{4+})$ used in titration = $2 \times (3.00/1000 \times 0.500)$ OR 2×0.00150 OR 0.00300 (mol) ✓ M_r of CeO_2 = 172.1 ✓ mass CeO_2 present in 100 cm^3 of solution = $4 \times 172.1 \times 0.00300 = 2.0652 \text{ g}$ ✓ % purity of CeO_2 sample = $2.0652 \times 100/2.5 = 83\%$ to 2 sig figs ✓	5	ALLOW ECF from first marking point ALLOW ECF from second marking point
		iii	Use a more dilute AsO_3^{3-} solution to increase volume of titre / reduce % error in titre OR Use more ceria sample to increase volume of titre / reduce % error in titre ✓	1	
		iv	FIRST CHECK ANSWER ON ANSWER LINE answer = 1.7×10^{22} atoms of oxygen award 2 marks $n(\text{CeO}_2) = 2.5/172.1 = 0.01453$ (mol) ✓ $n(\text{O}) = 0.01453 \times 2 = 0.02905$ (mol)	2	

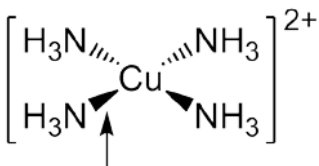
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	$0.02905 \times 6.02 \times 10^{23} = 1.7 \times 10^{22}$ atoms of oxygen ✓		ALLOW ECF from first marking point ALLOW 2 or more sig figs
		v	Reactants adsorbed onto surface of catalyst and form bonds to surface (AW) ✓ Bonds within reactants weaken and break ✓ New bonds form (AW) ✓ Products formed desorb / leave from catalyst (AW) ✓	4	
			Total	15	
5		i	 aluminium silver 1.0 mol dm⁻³ Al³⁺ 1.0 mol dm⁻³ Ag⁺ salt bridge labelled metal rods in labelled solutions of corresponding ions ✓ both ions 1.0 mol dm⁻³ ✓ wires, voltmeter and salt bridge ✓	3	ALLOW: - cell either way round - any unambiguous representation of the voltmeter - descriptions of solutions as, e.g., 'AgNO₃' and 'Al(NO₃)₃' (but molarity must be correct, in next mark, for, e.g., Al₂(SO₄)₃). IGNORE temperature any other label on salt bridge
		ii	FIRST CHECK ANSWER ON ANSWER LINE Answer = 1.68 V award 2 marks $\frac{RT}{nF} \ln 0.1 = 8.314 \times 298$ $\times (-2.3) / 3 \times 9.65 \times 10^4$ $= -0.02 \text{ } (-0.0197) \text{ (V) } \checkmark$ $E_{\text{cell}} = -1.66 - 0.02 = 1.68 \text{ V } \checkmark$	2	
			Total	5	

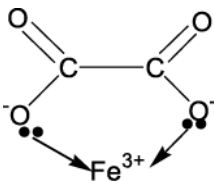
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
6			D	1	
			Total	1	
7			D	1	
			Total	1	
8			A	1	
			Total	1	
9			A	1	
			Total	1	
10			B	1	
			Total	1	
11			Fe ¹³⁺ 1s ² 2s ² 2p ⁶ 3s ² 3p ¹ ✓	1	ALLOW capital letters but numbers must be superscript.
			Total	1	
12		i	O ₂ + 2H ₂ O + 4e ⁻ ⇌ 4OH ⁻ ✓ Fe ⇌ Fe ²⁺ + 2e ⁻ ✓	2	ALLOW 'e' without minus IGNORE state symbols ALLOW ½ or ¼ equation for OH ⁻
		ii	high [OH ⁻] pushes first equilibrium to left (AW) ✓ electrons (formed) push second equilibrium to left ✓ so less Fe ²⁺ (and hence rust) formed ✓	3	
			Total	5	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
13	a		 dative covalent / coordinate Structure ✓ Bond name ✓	2	IGNORE 2+ ALLOW a flat structure, i.e. viewed from above
	b	i	intensity of colour OR absorbance of (suitable wavelength) light ✓ gives a measure of concentration (of complex / ammonia) OR (directly) proportional to concentration (of complex / ammonia) ✓	2	
		ii	$= \frac{[\text{Cu}(\text{NH}_3)_4]^{2+}}{[\text{Cu}^{2+}][\text{NH}_3]^4} \quad \checkmark$	1	
		iii	$\frac{x}{(0.1 - x)(0.4 - 4x)^4}$ correct apart from a wrong value for $[\text{NH}_3]$ ✓ (0.4 - 4x) for $[\text{NH}_3]$ ✓	2	ALLOW ECF from (ii)
		iv	Inaccurate / second student correct because Reaction of (OH⁻ in) ammonia solution with H₂SO₄ causes equilibrium to move so all the ammonia is neutralised (AW) OR equilibrium 4.1 shifts to the left as the acid reacts with the ammonia ✓ so titre / measured concentration will be too large ✓	2	
	c		$\text{Cu}(\text{C}_2\text{H}_8\text{N}_2)_2^{2+} \quad \checkmark$ 4 ✓	2	ALLOW a more structured formula for ethane diamine 2+ must be present ALLOW $\text{Cu}(\text{C}_2\text{H}_8\text{N}_2)_3^{2+} \quad \checkmark \quad 6 \quad \checkmark$
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance												
14	a	i	 lone pairs as shown, linking to some drawn line to represent the bond ✓ two bonds shown as arrows from O⁻ pointing to one Fe³⁺ ✓ dative covalent / co-ordinate bond labelled ✓	3													
		ii	[Fe(C ₂ O ₄) ₃] ³⁻ ✓ octahedral ✓	2	ALLOW without square brackets ALLOW structural formula												
	b	i	The E [⊖] of CO ₂ /(COOH) ₂ half cell is more negative / less positive than that of the Fe ³⁺ /Fe ²⁺ half cell (COOH) ₂ will release electrons / reduce Fe ³⁺ OR Fe ³⁺ will gain electrons / oxidise (COOH) ₂ ✓	2	ALLOW abbreviated descriptions of half cells as 'Fe ³⁺ ' etc (since there are only two of them) IGNORE 'greater than', 'less than'												
		ii	2Fe ³⁺ + (COOH) ₂ → 2Fe ²⁺ + 2CO ₂ + 2H ⁺ species ✓ balancing with correct species ✓	2													
		iii	Fe ²⁺ double arrow in one 3d box, single arrows (same direction) in the other 3d boxes. 4s box empty ✓ Fe ³⁺ single arrows in all 3d boxes (same direction). 4s box empty ✓	2													
	c	i	<table border="1" data-bbox="303 1314 818 1377"><tr><td>Mn</td><td>MnO₄⁻</td><td>Mn²⁺</td></tr><tr><td>oxidation states</td><td>+7</td><td>+2</td></tr></table> <table border="1" data-bbox="303 1404 818 1467"><tr><td>C</td><td>C₂O₄²⁻</td><td>CO₂</td></tr><tr><td>oxidation states</td><td>+3</td><td>+4</td></tr></table> ✓ ✓ 1 mark for either one row or one column correct	Mn	MnO ₄ ⁻	Mn ²⁺	oxidation states	+7	+2	C	C ₂ O ₄ ²⁻	CO ₂	oxidation states	+3	+4	2	
Mn	MnO ₄ ⁻	Mn ²⁺															
oxidation states	+7	+2															
C	C ₂ O ₄ ²⁻	CO ₂															
oxidation states	+3	+4															
		ii	oxidation state increase of C is +10 oxidation state decrease of Mn is -10	1	because the oxidation state decrease of manganese must equal the increase of C												

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d	i	<i>First please read point 10 of the instructions for marking 'Level of Response' mark-schemes</i> Level 3 (5–6 marks) Learners analyse the information from the stem of the question to develop and refine the practical procedure and evaluate the use of the indicator, making most of the scientific points. <i>The explanation is relevant and logically structured and contains no errors.</i> Level 2 (3–4 marks) Learners partially analyse the information from the stem of the question to develop and refine the practical procedure and evaluate the use of the indicator, making some of the scientific points. <i>The explanation is generally relevant and logically structured and contains few errors.</i> Level 1 (1–2 marks) Learners show some ability to analyse the information from the stem of the question to develop and refine the practical procedure and evaluate the use of the indicator, making a few of the scientific points. <i>A partial explanation is attempted and has some structure.</i> Level 0 (no marks) No response or no response worthy of credit	6	indicative scientific points may include: <i>titration</i> • manganate(VII) (solution) in burette • pipette known / stated volume of ethanedioate • OR use graduated / volumetric pipette for ethanedioate. • add sulfuric acid • some indication that sulfuric acid is in excess • warm / heat solution / 60°C • titrate (AW) until pink colour persists / remains (AW) • add (manganate(VII)) dropwise (AW) near end • repeat for concordance (AW) <i>indicator</i> • MnO_4^{2-} / manganate(VII) is only coloured reagent • colour change takes place during reaction from colourless to pale pink

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	FIRST CHECK ANSWER ON ANSWER LINE IF answer = 1.69(g) award 5 marks • amount KMnO_4 used = $18.4 / 1000 \times 0.0500$ OR 0.0009200 (mol) ✓ • amount potassium ethanedioate used = $5/2 \times 0.0009200$ OR 0.002300 (mol) ✓ • amount in 0.100 dm^3 = 4×0.002300 OR 0.009200(mol) ✓ • mass $\text{K}_2\text{C}_2\text{O}_4 \cdot \text{H}_2\text{O}$ = $184(.2) \times 0.009200$ OR $1.69(\dots)$ (g) ✓ • answer = 1.69 (3 sf) (g) ✓	5	ALLOW ECF throughout
			Total	25	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
15	a	i	25 / 50 / 100 cm ³ measuring cylinder ✓	1	Capacity of measuring cylinder MUST be given DO NOT ALLOW pipette or burette or syringe
		ii	To allow hydrogen to escape ✓ To prevent air getting in (and oxidising Fe ²⁺ to Fe ³⁺) ✓	2	IGNORE to stop spray escaping
		iii	FIRST CHECK THE ANSWER ON THE ANSWER LINE percentage of iron = 98.1% award 4 marks Select appropriate titres $\frac{22.50 + 22.55 + 22.45}{3} = 22.50$ ✓ $n(\text{MnO}_4^-) = 22.50 \times \frac{0.02}{1000} = 0.00045$ (mol) ✓ $n(\text{Fe}^{2+})$ in 250 cm ³ = 0.00045 × 5 × 10 = 0.0225 (mol) ✓ % iron = $\frac{0.0225 \times 55.8}{1.28} \times 100 = 98.1\%$ ✓	4	 ALLOW ECF from incorrect selection of data ALLOW 98% or 98.09%
	b	i	FIRST CHECK THE ANSWER ON THE ANSWER LINE concentration = 0.14 (g dm ⁻³) award 3 marks Mass of Mn = $\frac{2}{100} \times 0.25 = 0.005$ g ✓ $n(\text{KMnO}_4)$ in 100 cm ³ = $n(\text{Mn}) = 0.005 / 54.9 = 0.000091$ mol ✓ concentration of KMnO ₄ = 0.000091 × 158 × 10 = 0.14 (g dm ⁻³) ✓	3	 ALLOW ECF from first marking point ALLOW 0.144 (g dm ⁻³)
		ii	(Larger mass of KMnO ₄ dissolved so) smaller weighing error ✓	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iii	<i>* Please refer to point 10 of the marking instructions of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Applies knowledge of colorimetry to give a detailed step by step method to allow the production of suitable calibration curve over a suitable range of data. Detail about the dilutions and filters required will be included. <i>The method is detailed, clear and logically structured. The measurements are carefully considered to ensure the calibration curve covers the appropriate range.</i> Level 2 (3–4 marks) Applies knowledge of colorimetry to give steps which allow the production of a suitable calibration curve from the 2% Mn solution over a suitable range of data. <i>The method is suitable and in a logical order. Measurements are included to allow an appropriate calibration curve to be produced. Response may lack the fine details of dilution / appropriate filter.</i> Level 1 (1–2 marks) Applies knowledge of colorimetry to give a basic set of steps to produce a calibration curve from the 2% Mn solution. <i>The method is basic and unstructured. There is little or no detail in the description of steps</i> 0 marks No response or no response worthy of credit.	6	Indicative scientific points may include: Steps (italics indicate details that would differentiate higher level from lower level answers): • Dilute 2% Mn solution <i>using burettes and pipettes</i> • To include range 0.1 to 0.4% <i>includes volumes to achieve dilution (these could include 2 cm³ of 2% + 8 cm³ of water to give 0.4%, or details of a serial dilution,)</i> • Mix each dilution thoroughly <i>to ensure standard solution</i> • Makes a zero reading (on the colorimeter) <i>using water / base solvent</i> • Selects an appropriate filter / wavelength <i>chooses green-blue filter OR sets (spectrophotometer) to green-blue</i> • Measures absorbance of diluted solutions <i>ensure each sample is in a clean cuvette</i> • Plot absorbance against dilution <i>and draw line of best fit</i>
		iv	The line should be drawn through the zero–zero point ✓	1	
		v	0.17% ✓	1	ALLOW between 0.16 and 0.18%

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	Titration 4 ✓ (because) it requires the smallest volume of KMnO_4 solution ✓	2	
		ii	The solution contains nitric acid / potassium iodate(VII) that would also oxidise Fe^{2+} ✓	1	ALLOW the solution contains other oxidising agents
	d		Use the solution in an electrochemical cell ✓	1	
			Total	23	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
16	a	i	keep total volume constant ✓	1	ALLOW to keep concentration of copper (sulfate) the same
		ii	$\text{Cu}^{2+}(\text{aq}) + 2\text{OH}^{-}(\text{aq}) \rightarrow \text{Cu}(\text{OH})_2(\text{s})$ ✓✓	2	one mark for equation second mark for state symbols (provided '(aq) + (aq) → (s)')
		iii	coordinate / dative bond (to central metal ion)	1	
	b	i	burette / graduated / volumetric pipette	1	
		ii	try different filters with 'complex' solution ✓ choose one showing maximum absorption ✓	2	
		iii	use $c_1V_1 = c_2V_2$ to calculate volume to dilute ✓ transfer 50cm^3 stock using burette / volumetric pipette ✓ to 250cm^3 volumetric flask and make up to mark ✓	3	
	c			5	see scanned graph
	d		Dissolved $(\text{NH}_4)_2\text{SO}_4$ means concentration of NH_4^+ high ✓ Equilibrium (position) shifts to left to (maintain K_c), (removing some of added NH_4^+) ✓ Concentration of OH^- reduced ✓ Not enough / too low a concentration to cause precipitate. ✓	4	ALLOW $[\text{NH}_4^+]$ increases ALLOW solubility product not exceeded IGNORE no OH^- ions.
			Total	19	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
17	a	i	$E^\ominus$ / half-cell potential of $\text{Cr}^{3+}/\text{Cr}^{2+}$ / solution A is more negative (than $E^\ominus$ of $\text{Fe}^{3+}/\text{Fe}^{2+}$) ORA✓ so $\text{Cr}^{3+}/\text{Cr}^{2+}$ will be the negative electrode / cathode / lose electrons ORA AND $\text{Cr}^{3+}/\text{Cr}^{2+}$ / solution A goes into tank 2 and / or $\text{Fe}^{3+}/\text{Fe}^{2+}$ / solution B into tank 1 ✓	2	IGNORE comments about reducing and oxidising agents NOT $E^\ominus_{\text{cell}}$ Examiner's Comments A definite improvement in comparing electrode potential data and in using the technical; language correctly. However, some candidates had the chemistry correct but inexplicably put the solutions in the wrong tanks.
		ii	$\text{Cr}^2 + \text{Fe}^{3+} \rightarrow \text{Cr}^{3+} + \text{Fe}^{2+}$ ✓	1	Examiner's Comments Excellent, only a few tried to adjust the stoichiometry of the equation resulting in unbalanced charges.
		iii	prevent corrosion / rusting / oxidation of iron / steel ✓ iron / steel would act as an electrode / react with solutions / electrolytes / forms ions ✓ polymer / plastic / paint	3	If LIST then use 1st substance ONLY NOT zinc / galvanising or grease ALLOW any named polymer ALLOW ceramic Examiner's Comments Most realised that rusting was a major problem, but far fewer thought about the effect of the solutions. Coatings varied, the commonest was the use of zinc followed by oil and grease!

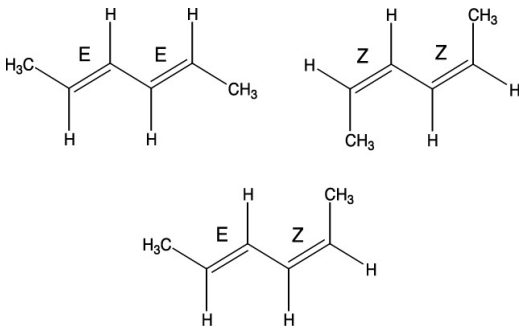
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	allow charge flow / transfer AW or act as a salt bridge or allows ion flow ✓	1	IGNORE prevent mixing of the solutions CON electron flow NOT flow of current Examiner's Comments How an electrochemical cell works is clearly not understood. Many had 'electrons flowing through solutions' and often conned 'salt bridge' by qualifying it in the same way. Prevention of mixing was also a common response.
		v	carbon / graphite / platinum ✓	1	Examiner's Comments Despite the expense, platinum was by far the commonest answer.
	b		-0.26 ✓	1	correct sign must be present Examiner's Comments This proved trickier and many got the wrong or no sign whilst 1.80V was fairly common. (-0.26V).
	c		(red brown ppt.) is $\text{Fe}(\text{OH})_3$ / iron(III) hydroxide ✓ Fe^{2+} ions will have been <u>oxidised</u> to Fe^{3+} ions by <u>oxygen</u> (from the air) ✓ $4\text{Fe}^{2+} + \text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{Fe}^{3+} + 4\text{OH}^-$ OR $2\text{H}_2\text{O} + \text{O}_2 + 4\text{e}^- \rightarrow 4\text{OH}^-$ AND $\text{Fe}^{2+} \rightarrow \text{Fe}^{3+} + \text{e}^-$ ✓ $\text{Fe}^{3+}(\text{aq}) + 3\text{OH}^-(\text{aq}) \rightarrow \text{Fe}(\text{OH})_3(\text{s})$ ✓ state symbols correct for species in correct precipitation equation ✓	5	Allow mark if precipitation equation has $\text{Fe}(\text{OH})_3(\text{s})$ as product ALLOW red ppt. CON is $\text{Fe}(\text{OH})_2$ is formed first oxygen may be seen in the equation Examiner's Comments Although there were many excellently constructed answers, many confused the precipitate with rust. Often iron(II) hydroxide was initially formed as a green precipitate before being oxidised to iron(III) hydroxide or hydrated iron(III) oxide. Not surprisingly only the best candidates could correctly construct an equation for the oxidation of Fe^{2+} ions.
			Total	14	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
18	a		moles of C_6H_{10} in 100 g = $100/82.0 = (1.22) \checkmark$ bromine number = $100/82.0 \times 2 \times 159.8 = 390 \checkmark$	2	ECF ALLOW M_r for bromine = 160 IGNORE g units with answer Examiner's Comments Most candidates correctly calculated the moles of C_6H_{10} but many of these were unable to convert this into the bromine number. (390)
	b	i	Method 1 MOLES moles of $BrO_3^- = 0.005$ AND moles of $Br^- = 0.0167 \checkmark$ to be in excess moles of BrO_3^- has to be $> (0.0167/5 =) 0.00334 \text{ mol dm}^{-3} \checkmark$ Method 2 CONCENTRATIONS $[BrO_3^-] = 0.0250$ AND $[Br^-] = 0.0835 \checkmark$ to be in excess $[BrO_3^-]$ has to be $> (0.0835/5 =) 0.0167 \text{ mol dm}^{-3} \checkmark$	2	must have words as well as numbers for 2nd mark Examiner's Comments Generally well attempted by a variety of methods but many not using words to explain their calculation and subsequent understanding.
		ii	moles of Br^- (forming Br_2) = $0.167 \times 100 / 1000$ or $(0.0167) \checkmark$ moles of Br_2 reacted with 10 g sample = $0.0167 \times 3/5 \checkmark$ $\times 82/200 \checkmark = (0.00411)$ mass of Br_2 reacted with 10 g sample = $0.0167 \times 3/5 \times 82/200 \times 159.8 = (0.656 \text{ g}) \checkmark$ bromine number = $0.0167 \times 3/5 \times 82/200 \times 159.8 \times 10 = 6.56 = 7 \checkmark$	5	Alternative method: moles of Br_2 formed in reaction in $200 \text{ cm}^3 = 0.0167 \times 3/5 = (0.01002) \checkmark$ $[Br_2] = 0.0167 \times 3/5 \times 5 = (0.501) \checkmark$ moles of Br_2 used in adding to sample = $0.501 \times 82/1000 = 0.0411 \checkmark$ mass of Br_2 added to 10.0 g sample = $0.0411 \times 159.8 = (6.56) \text{ g} \checkmark$ bromine number = 7 $\checkmark$ ECF throughout calculation IGNORE g units with answer $\checkmark$ Examiner's Comments Only the most able scored full marks with their working often clearly presented. The majority usually got off on the wrong foot, calculating moles of the C_6H_{10} and thereafter losing their way Some ignored the request for a whole number. (7).

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c	i	restrictive rotation about C=C bonds ✓ two different atoms / groups attached to both carbon atoms of the C=C bond ✓	2	ALLOW C=C bonds cannot rotate ALLOW 'lack of free rotation' NOT just 'double bonds' IGNORE functional Examiner's Comments Well understood, although some asymmetric carbons were still in evidence.
		ii	1 mark for each correct isomer provided no more than 3 ✓✓✓ 1 mark for labels drawn correctly on the 3 correct structures ✓ 	4	extra structures are each CON to one isomer mark already scored (watch out for E-Z and Z-E which is a CON) ALLOW skeletal structures Examiner's Comments Some very good attempts but only the best gained full marks. Frequently E / Z and Z / E isomers were both included. Labelling was often good though some just focused on drawing structural formulae for molecules with one C=C bond and hence only one label.
	d		atoms / transition metals (on surface) can use d (and s) electrons / subshell / orbital(s) ✓ to form (weak) bonds to / interactions with reactants ✓ providing a route of lower E_a ✓	3	IGNORE orbital numbers ALLOW chemisorption BUT NOT adsorption Examiner's Comments Many began by unnecessarily filling up the answer space by explaining the phrase 'heterogeneous catalyst'. Further discussion either involved a catalytic theory based on an intermediate or variable oxidation states. Candidates often managed the final mark for lowering the activation enthalpy.
			Total	18	

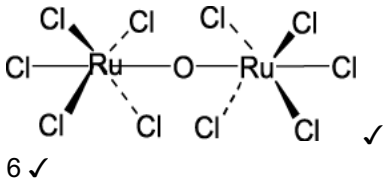
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
19	a	i	+3 ✓ 1s ² 2s ² 2p ⁶ 3s ² 3p ⁶ 3d ⁵ ✓	2	NOT 3+ or 3 ALLOW capital letters but numbers must be superscripts. ALLOW ecf for Fe ²⁺ only (3d ⁶) ALLOW repetition of '1s ² 2s ² ' IGNORE 4s ⁰ Examiner's Comments This was well done with most candidates giving +3 as the oxidation state and 2p ⁶ 3s ² 3p ⁶ 3d ⁵ as the configuration. 3d ³ 4s ² was rarely seen.
		ii	Amount of water = 0.216/18 = 0.012 mol ✓ (Mass of anhydrous = 1.066 = 0.012 mol so) n = 1 ✓	2	Mark separately n = 1 on the answer line (without first marking point) scores second mark only Examiner's Comments Many correctly calculated the moles of water (and anhydrous salt) as 0.012 and obtained the correct answer of n=1. It was often difficult to see the method of those who got another answer for n.
		iii	Amount Fe = 0.012 mol = 0.670 g Mass O = 1.066 – 0.670 – 0.140 = 0.256 ✓ Amount O = 0.256/16 = 0.016, y = 4 ✓ OR 1 mole FeO(OH) → 1/3 mole Fe ₃ O _x so 0.012 mol → 0.004 mol 0.004 moles have a mass of (1.066- 0.14)g = 0.926g ✓ 1 mole weighs 0.926/0.004 = 231.5g Mass of the 3 Fe atoms subtracted = 64g so 4 moles of O y = 4 ✓	2	working must be checked look for mass O = 0.256 or 0.004 moles weigh 0.926g for 1 mark y = 4 without coherent working scores 1 Examiner's Comments A very few candidates managed to get through this tricky calculation, usually spotting that 0.926g of Fe ₃ O _y represented 0.004 moles, which led to y = 4.
	b	i	Yellow/green (or 'yellow/green' or orange) because it reflects this/ reflects between red and blue	1	must say 'reflects' (or a derived word) or 'maximum reflectance' and give colour to score Examiner's Comments Most candidates managed to name an appropriate colour (yellow or green) and say that it was reflected. Just a few answers of 'purple' were seen.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	(3)d energy levels/subshells/orbitals split (by ligands) ✓ electrons excited (or move) to higher energy level/shell/orbital or be excited/move up from lower level ✓ light absorbed and $\Delta E = h\nu$ or hf ✓ complementary frequency/colour/wavelength reflected/transmitted →	4	IGNORE 'D' ALLOW 'frequency proportional to energy gap/difference' for '$\Delta E = h\nu$' (or $E = h\nu$ if 'energy gap/difference' is implied). (or 'photon energy $h\nu$') ALLOW 'complimentary' or 'frequencies not absorbed are reflected/transmitted'. IGNORE 'emitted' but any indication of light being given out when electrons fall CONs last marking point. Examiner's Comments Many candidates correctly stated that the d energy levels were split and that electrons were excited to a higher energy level. This absorbed light where $\Delta E = h\nu$. The complementary colour was reflected. Trips and slips were using 'D' rather than 'd' to describe the energy levels; not saying where the electrons were excited to; not mentioning $\Delta E = h\nu$ or not making it clear that the frequency was <i>proportional</i> to the energy (some confusion between wavelength and frequency was also noted); and not saying that the complementary frequencies were <i>reflected</i> (or transmitted).
			Total	11	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
20	a	i	froth/detergent flotation AND matte ✓	1	
		ii	$\text{NiS} + \text{H}_2\text{SO}_4 \rightarrow \text{NiSO}_4 + \text{H}_2\text{S}$ OR $\text{CuS} + \text{H}_2\text{SO}_4 \rightarrow \text{CuSO}_4 + \text{H}_2\text{S}$	1	IGNORE state symbols
		iii	electrolysis	1	
	b	i	high melting AND unreactive	1	
		ii	$2\text{CO} + 2\text{NO} \rightarrow \text{N}_2 + 2\text{CO}_2$	1	ALLOW halves or multiples IGNORE state symbols
	c		$4d^6$	1	
	d	i		2	ALLOW bridging oxygen bonding in axial or equatorial positions IGNORE brackets and charges.
		ii	square planar OR tetrahedral	1	
	e		R_2NH_2^+ ✓ 3 + balances 3– (AW) ✓	2	
	f		$10^7 - 10^{10}$ or any value in that range ✓	1	
	g		$[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 4\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_4(\text{H}_2\text{O})_2]^{2+} + 4\text{H}_2\text{O}$ ✓ (light)blue dark blue/violet/purple/mauve ✓	2	ALLOW $[\text{Cu}(\text{H}_2\text{O})_6]^{2+} + 6\text{NH}_3 \rightarrow [\text{Cu}(\text{NH}_3)_6]^{2+} + 6\text{H}_2\text{O}$ IGNORE state symbols
	h		Wrong: d subshells still split ✓ Ag^+ is d^{10} OR Ag has full d subshell ✓ so no movement possible (AW) ✓	3	

Mark Scheme

Question		Answer/Indicative content	Marks	Guidance
	i	<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Describes in detail the methods of extraction and gives chemical details from the article of all three compounds. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Describes in detail the methods of extraction of all three compounds AND Gives the chemical details from the article for either Pd, Pt or Os <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Outlines the methods of extractions for of all three compounds AND Gives the chemicals details from the article for either Pd, Pt or Os. OR Describes in detail the method of extraction for one of the compounds and gives chemical details from the article concerning this compound. <i>The information is basic and communicated in an unstructured way. The information is supported by limited evidence and the relationship to the evidence may not be clear.</i> 0 marks No response or no response worthy of credit	6	Indicative Scientific points include: Description of extraction of Pd: - extracted by ligand exchange - followed by dissolving in organic solvent Chemical details from article concerning Pd: - equation, eg $[\text{Pd}(\text{H}_2\text{O})_6]^{2+}(\text{aq}) + 4\text{Cl}^-(\text{aq}) \rightarrow [\text{PdCl}_4]^{2-}(\text{aq}) + 6\text{H}_2\text{O}(\text{l})$ - this reaction is much slower for other PGMs Description of extraction of Pt: - anion exchange - reacted with $\text{R}_2\text{NH}_2^+ \text{Cl}^-$. Chemical details from article concerning Pt: $2[\text{R}_2\text{NH}_2^+ \text{Cl}^-] + [\text{PtCl}_6]^{2-}(\text{aq}) \rightleftharpoons (\text{R}_2\text{NH}_2^+)_2 [\text{PtCl}_6]^{2-} + 2\text{Cl}^-$ $(\text{R}_2\text{NH}_2^+)_2 [\text{PtCl}_6]^{2-}$ is soluble in organic solvents whereas the equivalent salts of other PGMs have lower solubility. Description of extraction of Os: - oxidation - oxide volatile and can be removed by heating Chemical details from article concerning Os: - oxidised to OsO_4 - may be mixed with RuO_4
		Total	23	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
21			D	1	
			Total	1	
22			A	1	
			Total	1	
23	a		Beakers: ClO^- and Cl^- and H^+ and Pt electrode ✓ I_2 and I^- and Pt electrode ✓ Salt bridge ends in both solutions AND 1 mol dm ⁻³ for all solutions ✓ Electron flow in wire from I_2/I^- to ClO^-/Cl^- ✓ $\text{ClO}^- + 2\text{H}^+ + 2\text{I}^- \rightarrow \text{Cl}^- + \text{H}_2\text{O} + \text{I}_2$ ✓	5	
	b		MnO_4^- as its E^θ value is more positive than Cl_2/Cl^- ✓ and thus electrons will flow there from the other half cell AW ✓ $2\text{MnO}_4^-(\text{aq}) + 16\text{H}^+(\text{aq}) + 10\text{Cl}^-(\text{aq}) \rightarrow 2\text{Mn}^{2+}(\text{aq}) + 8\text{H}_2\text{O}(\text{l}) + 5\text{Cl}_2(\text{aq})$ ✓	3	
			Total	8	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
24		i	(25cm ³) <u>Volumetric</u> pipette	1	DO NOT ALLOW Bulb / graduated pipette Examiner's Comments The most suitable apparatus to use in this experiment is a <u>volumetric</u> pipette. A large number of candidates were imprecise in their answer and lost this mark.
		ii	Calculates titre values and Uses average of titre 2, 3, 4 = 22.60 (cm ³) ✓	1	Examiner's Comments The average of titres 2, 3 and 4 give a value of 22.60. Examiners expected to see the answer to two decimal points in order to score the mark.
		iii	FIRST CHECK ANSWER LINE If answer = 80.6 (%) award 4 marks Moles of thiosulfate = $0.200 \times 0.02260 = 4.52 \times 10^{-3}$ ✓ Moles of Cu in original 250cm ³ = 4.52×10^{-2} ✓ Mass of Cu = $(4.52 \times 10^{-2}) \times 63.5 = 2.8702\text{g}$ ✓ % = $2.87655/3.56 = 80.624$ (%) 80.6 sf mark ✓	4	No working but answer of 81 scores 3 marks (loses sf) 3sf Examiner's Comments This proved the most discriminating question on the whole paper. Candidates usually successfully calculated the number of moles of thiosulfate used in the titration, but then commonly got confused by the ratio, often wrongly dividing by two. The scaling up by 10 was also missed in many cases, though multiplying by 63.5 often score on error carried forward. The final answer was needed to 3 sig. figs. in order to score the final evaluation mark.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	Burette error = $0.10/22.60 \times 100 = 0.44\%$ Electric balance = $0.005/3.56 \times 100 = 0.14\%$ (biggest error burette)	1	Mark for calculations DO NOT ALLOW decision on which apparatus gives biggest error Examiner's Comments This question was disappointingly answered. The calculation of uncertainties has become increasingly important in GCE specifications in recent years. This question expected candidates to calculate the percentage uncertainties associated with the electric balance and the use of the burette in the titration.
		v	Colourimetry / gravimetric/cell emf's	1	ALLOW an actual method e.g. <i>react with sodium hydroxide – weigh.</i> ALLOW gravimetric type detail such as precipitate and find mass produced. DO NOT ALLOW pH change DO NOT ALLOW Calorimetry Examiner's Comments Examiners were expecting a different type of method in answer to this question e.g. colorimetry or gravimetric.
			Total	9	
25			B	1	
			Total	1	
26			C	1	
			Total	1	
27			C	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
28			B	1	
			Total	1	
29			A	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content				Marks	Guidance
30	a	i	Equation no.	Oxidation state of Cr in reactant	Oxidation state of Cr in product	Has Cr been oxidised, reduced or neither?	4	Mark each row separately Penalise (+) omitted /3+ etc once only Examiner's Comment: This question, was very well answered, most candidates correctly calculated the oxidation state of the Chromium atom in the various species and correctly stated the change that occurred in each step of the reaction sequence.
			4.1	+3	+6	oxidised		
			4.2	+6	+6	neither		
			4.3	+6	+3	reduced		
			4.4	+3	0	reduced		
		ii	FIRST CHECK ANSWER LINE If answer = 0.46 or rounding to 0.465 (kg) award 2 marks amount chromite = 1000/223.8 OR 4.468 (mol) V mass Cr = 2 x 4.468 x 52/1000 = 0.46467 (kg) ✓				2	ALLOW 2 or more sf ALLOW 0.232kg for 1 mark Examiner's Comment: This calculation was attempted by most candidates, with many scoring full marks. Most scored one mark for correctly calculating the number of moles of chromite in 1000g of chromite, but if they did not appreciate that there were 2 atoms of Cr in the ore then they did not score the second mark for the mass of chromium being 0.465(kg).
	b	i	1s ² 2s ² 2p ⁶ 3s ² 3p ⁶ 3d ³				1	ALLOW any sized letters but numbers must be superscripts Accept [Ar] 3d³ ALLOW 4s⁰ Examiner's Comment: This question was well answered by most candidates, the only common error was to give the outer electron structure as 4s² 3d¹.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	beaker (etc) with solution and two electrodes with battery / power supply connected ✓ solution labelled chromium(III) chloride / CrCl_3 / Cr^{3+} ✓ +ve electrode / anode labelled 'graphite' AND –ve electrode / cathode labelled 'steel (object)'. ✓	3	If two beaker diagram drawn, allow 1 mark for a steel electrode inserted into a chromium(III)chloride solution Ignore battery convention UNLESS polarity of electrodes not otherwise indicated Examiner's Comment: This question produced a variety of diagrams. Many candidates recognised the need for a power supply and a solution containing the correct electrolyte, but a common error was to use graphite electrodes for both the anode and cathode, or to label the anode as being the steel object. Another common error was to draw a diagram containing a two beakers, a salt bridge, and a high resistance voltmeter, however, provided that they labelled one of the electrodes as a steel electrode (not an anode) and had this inserted into a $\text{Cr}^{3+}(\text{aq})$ solution they could still score 1 mark. Very few candidates did not attempt this question, and almost all who did scored at least 2 marks.
		iii	$\text{Cr}^{3+} + 3\text{e}^{(-)} \rightarrow \text{Cr}$ ✓	1	IGNORE state symbols ALLOW ecf from labelled cathode half cell if present in b(ii) Examiner's Comment: A common error in this question was that the equation was written as if the Cr atom was being ionised rather than the Cr^{3+} ion being reduced.

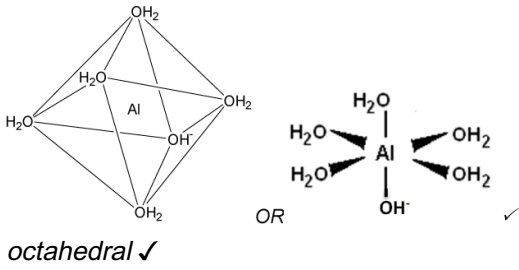
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		iv	FIRST CHECK ANSWER LINE If answer = 8 (hours) award 3 marks moles of electrons = $3 \times 26/52$ OR 1.5 ✓ time = $1.5 \times 96500/5$ OR 28950 (sec) ✓ time in hours = $28950/3600 = 8(.04)$ (hours) ✓	3	ALLOW ecf ALLOW any sf If final answer rounds to 2.7 hours scores 2 Examiner's Comment: This calculation was attempted by most candidates, with many scoring at least two marks. The most common error made was not recognising that each Cr^{3+} ion required 3 electrons to become reduced, and so the required number of moles of electrons was 1.5 rather than 0.5, consequently many candidates calculated the time required as 2.7 hours and so scored 2 marks. The correct expected answer being $3 \times 2.7 = 8.1$ hours.
	c	i	chloride (ions) AND water (molecules)	1	IGNORE formulae NOT chlorine ALLOW chloro and aqua Examiner's Comment: This question produced a variety of responses. Most marks were lost for identifying Cl as a chlorine ligand when it should have been chloride, or only identifying water as a ligand.
		ii	Add a named ionic chloride (solution) or hydrochloric acid / HCl ✓ to move equilibrium to the left / reactants ✓	2	Mark independently Examiner's Comment: Most scored one mark for correctly indicating that the equilibrium needed to move to the left to restore the green colour of the solution, but a common error was to suggest that this could be achieved by evaporating water from the complex ion.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	d	i	FIRST CHECK ANSWER LINE If answer = 0.977 (g/100cm³) on second answer line award 6 marks If answer = 0.21 (mol dm⁻³) on first answer line award 5 marks amount Cr₂O₇²⁻ init. = $20 \times 0.2/1000$ OR 4×10^{-3} (mol) ✓ amount Na₂S₂C₃ = $27.6 \times 0.1/1000$ OR 2.76×10^{-3} (mol) ✓ amount Cr₂C₇²⁻ left = $2.76 \times 10^{-3}/6$ OR 4.6×10^{-4} (mol) ✓ amount Cr₂C₇²⁻ used = 3.54×10^{-3} (mol) ✓ conc ethanol = $(1.5 \times 3.54 \times 10^{-3} \times 40)$ = 0.212(4) (mol dm⁻³) ✓ % (= 0.0212×46) = 0.975/0.977 (g/100cm³) ✓	6	ALLOW two or more sf ALLOW ecf throughout. Examiner's Comment: A pleasing aspect of this question was that there were very few candidates who did not attempt it. However, it posed a challenge to weaker students who struggled to organise their response and so produced a set of numbers where it was difficult to identify what they were trying to do. It is hoped that centres will spend some time when they are preparing candidates for this paper in trying to ensure that they realise that it is vital in this type of calculation to try to identify what they are trying to work out. Where candidates did do this they often scored some marks, usually for calculating the number of moles of dichromate and thiosulfate used. But after this many candidates scaled up or down with no reference made to what they were attempting and it became very difficult to give them any further marks as the numbers produced often did not bear any resemblance to those given in the mark scheme. Where candidates did correctly calculate the concentration of the ethanol the only subsequent error was in calculating the percentage as 9.77 rather than 0.977 as they had not recognised the units as g per 100cm³ and had simply converted from mol dm⁻³ to g dm⁻³.
		ii	no other oxidising agents / reducing agents in the beer	1	Examiner's Comment: Very few candidates scored this mark. Most gave answers linked to all of the ethanol reacting with the dichromate, and failed to consider that there could have been other substances in the beer that might have interfered with the reaction.
			Total	24	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
31	a	i	$[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ / H_2O ligand/ in complex ✓	1	Allow water / aqua for H_2O . Examiner's Comment: This question was generally well answered with $[\text{Al}(\text{H}_2\text{O})_6]^{3+}$ being the most common correct answer given.
		ii		2	IGNORE charges Allow diagrams that are unambiguous in showing adjacent equatorial ligands with two coming out of the plane, and two going into the plane of the paper Do Not allow bonds to H atoms, must be to O as bonding is to the lone pair of electrons Mark independently Examiner's Comment: Common errors here included incorrect bonding to the water molecules in the diagram, or not clearly showing the 3D nature of the bonds in the equatorial region of the molecule resulting in a diagram that gave the impression of all of the equatorial ligands being in the same plane as the polar ligands. Most candidates, however, did give the correct description for the shape of the complex ion.
	b		$2\text{Fe}^{2+} + \text{O}_2 + 2\text{H}^+ \rightarrow 2\text{Fe}^{3+} + \text{H}_2\text{O}_2$ ✓ Idea that Fe^{2+} is not recycled ✓	3	Examiner's Comment: Responses to this question often produced 2 marks, where a mark was lost usually for not balancing the equation correctly.
			Total	5	
32			C	1	Examiner's Comments This practical technique was very well known.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
33			A	1	<u>Examiner's Comments</u> More than 50% of candidates scored this mark but B was a common incorrect answer.
			Total	1	
34			B	1	
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
35	a		Dissolve bolt in warm sulfuric acid ✓ Transfer to 1 dm ³ <u>volumetric</u> flask, (transfer washings) and make up to the mark (AW) ✓	2	Conc sulfuric acid is CON <u>Examiner's Comments</u> This was a question that proved one of the most difficult, both in terms of low scores and omission rates. The ideas we were looking for were practical points on how to dissolve the bolt. The first was dissolving the bolt, many candidates selected a solvent other than sulfuric acid despite it being given in the stem of the question, some even chose water. Very few realised that heat would be needed. The second point was making the solution up to 1 dm³. We expected the use of a volumetric flask here and making up to the line.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance						
	b		FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = 45.6 or rounds to 46 (g) award 3 marks Moles of MnO_4^- not needed by the rusty nail $= (0.01792 - 0.00975) \times 0.2 (= 1.634 \times 10^{-3})$ ✓ Moles of Iron rusted in 10cm^3 solution $= 5 \times 1.634 \times 10^{-3} (= 8.17 \times 10^{-3})$ ✓ In 1dm^3 mass $= 0.817 \times 55.8 = 45.6(\text{g})$ ✓	3	ALLOW 2 or more sf ALLOW ECF between steps An answer rounding to 0.46 scores 2 (omission of the factor of 100 from 10cm^3 to 1000cm^3) <u>Examiner's Comments</u> Most candidates were able to score some of the marks here. The most frequently scored was the multiplication of the moles of MnO_4^- by 5. Other marks were lost because the final answer was not multiplied by 100 (to account for the fact that 10cm^3 portions were titrated), or the difference between the titration results was not used. Sometimes 2 calculations were done with the subtraction as the final step – this was an acceptable alternative route. Exemplar 5 <table border="1"><thead><tr><th>Type of bolt</th><th>Average volume of 0.200mol dm^{-3} KMnO_4 used in the titration / cm^3</th></tr></thead><tbody><tr><td>Unused bolt</td><td>17.92</td></tr><tr><td>Rusted bolt</td><td>9.75</td></tr></tbody></table> $\frac{9.75}{1000} \times 0.2 = 1.95 \times 10^{-3} \text{ moles } \text{KMnO}_4 \text{ (rusted)}$ $\times 5 = 9.75 \times 10^{-3} \text{ moles Fe} \times 55.8 = 0.54405 \text{ g}$ $\frac{17.92}{1000} \times 0.2 = 3.584 \times 10^{-3} \text{ moles } \text{KMnO}_4 \text{ (unused bolt)}$ $\times 5 = 0.01792 \times 55.8 = 0.9999 \text{ g (1)}$ $1 - 0.54405 = 0.4559$ ✓✓ mass of bolt that had rusted away = 0.4559 g [3] This is an example where the subtraction has been done at the end. The final mark is not scored as the mass has not been scaled up to 1dm^3.	Type of bolt	Average volume of 0.200mol dm^{-3} KMnO_4 used in the titration / cm^3	Unused bolt	17.92	Rusted bolt	9.75
Type of bolt	Average volume of 0.200mol dm^{-3} KMnO_4 used in the titration / cm^3										
Unused bolt	17.92										
Rusted bolt	9.75										
	c	i	$\text{O}_2 + 2\text{H}_2\text{O} + 4\text{e}^- \rightarrow 4\text{OH}^-$ ✓ $\text{Fe} \rightarrow \text{Fe}^{2+} + 2\text{e}^-$ OR $\text{Fe} - 2\text{e}^- \rightarrow \text{Fe}^{2+}$ ✓	2	ALLOW halved ALLOW reversible reactions shown either direction Extra half equations beyond 2 CONs 1 mark each <u>Examiner's Comments</u> The process of rusting was not well known, and d block chemistry in general proved challenging. Sometimes correct half equations were contradicted by extra ones.						

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Green solid is $\text{Fe}(\text{OH})_2$ AND orange solid is $\text{Fe}_2\text{O}_3 \cdot x\text{H}_2\text{O}$	1	ALLOW $\text{Fe}(\text{OH})_3$, $[\text{Fe}(\text{OH})_2(\text{H}_2\text{O})_4]$, $[\text{Fe}(\text{OH})_3(\text{H}_2\text{O})_3]$ <u>Examiner's Comments</u> This was well answered and we accepted the formulae of iron(III) oxide or hydroxide for the orange solid.
		iii	(Faster in salt water as) more (dissolved) ions (make it a better conductor) ✓ More OH^- ions is CON	1	ALLOW '(water acts as a) 'salt bridge' and sea water contains a higher concentration of ions' ALLOW (the salt) acts as an electrolyte <u>Examiner's Comments</u> Very few candidates knew the answer to this. A few had memorised the definition provided in text books..
	d		$\text{Fe}^{2+} 1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ ✓	1	IGNORE $4s^0$ IGNORE working elsewhere. No of electrons in orbitals must be superscripts NOT [Ar]... <u>Examiner's Comments</u> More than half of the candidates scored here. The main reason for not getting the mark was ending the electron configuration with $4s^2$, $3d^4$. There were a significant number with the numbers as subscripts.

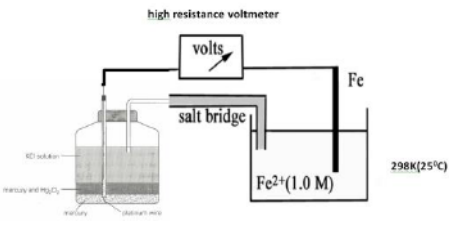
Mark Scheme

Question		Answer/Indicative content	Marks	Guidance								
	e	Ni(/Ni²⁺) electrode potential is more negative than H₂(H⁺) AND thus H⁺ can oxidise Ni to Ni²⁺ (ORA) ✓ Cu(/Cu²⁺) electrode potential is more positive than H₂(H⁺) so H⁺ cannot oxidise Cu to Cu²⁺ (ORA) ✓	2	ALLOW answers in terms of electron flow instead of oxidation We need a comment about each metal in relation to hydrog <u>Examiner's Comments</u> This was a difficult question. Many answers compared the electrode potentials of nickel and copper with each other rather than with hydrogen. They also answered in terms of Cu²⁺ ions being reduced, when the point of the exercise is that there are none. Exemplar 6 Nickel only reacts because ~~the~~ Ni/Ni²⁺ has a more negative E° than 2H⁺/H₂ so it is oxidised because electrons flow from negative to positive. [2] This is an example has a very clear explanation of why nickel reacts but has not mentioned copper. Exemplar 7 <table><tr><th>Half reaction</th><th>E°/V</th></tr><tr><td>Ni²⁺(aq) + 2e⁻ ⇌ Ni(s)</td><td>-0.25</td></tr><tr><td>2H⁺(aq) + 2e⁻ ⇌ H₂(g)</td><td>0.00</td></tr><tr><td>Cu²⁺(aq) + 2e⁻ ⇌ Cu(s)</td><td>+0.34</td></tr></table> Cu²⁺/Cu half cell is more positive than the Ni²⁺/Ni half cell. This means Cu²⁺ is reduced to Cu and Ni oxidised to Ni²⁺. Ni²⁺ can react with H₂SO₄ more. [2] This is an example where neither of the metal electrode potentials has been compared with the hydrogen half-cell.	Half reaction	E°/V	Ni ²⁺ (aq) + 2e ⁻ ⇌ Ni(s)	-0.25	2H ⁺ (aq) + 2e ⁻ ⇌ H ₂ (g)	0.00	Cu ²⁺ (aq) + 2e ⁻ ⇌ Cu(s)	+0.34
Half reaction	E°/V											
Ni ²⁺ (aq) + 2e ⁻ ⇌ Ni(s)	-0.25											
2H ⁺ (aq) + 2e ⁻ ⇌ H ₂ (g)	0.00											
Cu ²⁺ (aq) + 2e ⁻ ⇌ Cu(s)	+0.34											

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	f	i	Reaction is ligand substitution/exchange AND new ligand splits the d-orbitals differently ✓	1	ALLOW new complex ion has a different colour ALLOW nucleophilic substitution <u>Examiner's Comments</u> Most candidates knew this was ligand substitution, but the explanations were less clear. Some thought the blue was due to Cu^{2+} .
		ii	FIRST CHECK THE ANSWER ON THE ANSWER LINE If answer = $[\text{Ni}(\text{EDTA})]^{2-}$ award 2 marks Moles of $\text{Ni}^{2+} = 0.025 \times 0.25 = 6.25 \times 10^{-3}$ AND Moles EDTA = $0.0417 \times 0.15 = 6.26 \times 10^{-3}$ ✓ Ratio is 1:1 so formula is $[\text{Ni}(\text{EDTA})]^{2-}$ ✓	2	DO NOT ALLOW charges inside brackets <u>Examiner's Comments</u> The majority of candidates scored at least 1 mark on this question for getting the mole ratios as 1:1. The second mark may not have been scored due to extra water ligands in the final complex, incorrect charges or an incorrect number of EDTA ligands despite the 1:1 ratio having been calculated.
			Total	15	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
36	Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question. Level 3 (5 – 6 marks) Detailed instructions on how to set-up the apparatus including the conditions <u>and</u> some justification of the apparatus used. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Learners present a workable setup of the apparatus including the conditions but little or no justification of the apparatus used. <i>The information presented is relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Learners present a partial set-up OR a simple labelled diagram with some relevant labels. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> Level 0 (no marks) No response or no response worthy of credit	6	Indicative scientific points may include: Set up • make sure reading on voltmeter is positive • electrode/half-cell connected to positive terminal of voltmeter is the positive electrode • discussion of how E_{cell} can be used to find electrode potential of iron half cell Description of the apparatus used and why • high resistance voltmeter so negligible current is taken (so concs of ions stay the same) • salt bridge to keep the charge in each beaker constant. • both the above correctly connected to <u>both</u> cells • iron electrode and $\text{Fe}^{2+}(\text{aq})$ solution in beaker so the reaction $\text{Fe}(\text{s}) \rightleftharpoons \text{Fe}^{2+}(\text{aq})$ can take place Conditions/concentrations • $298\text{K}/25^{\circ}\text{C}$ • $1.00\text{ mol dm}^{-3} \text{Fe}^{2+}(\text{aq})$ solution as E° is changed with higher temp and conc Note: some of the above points may be scored from a suitably labelled diagram, such as the one below 

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			Examiner's Comments Many candidates produced, solid, well-structured responses, although some seemed to think that Fe was a material. However, there were only a limited number of responses which came to grips with the requirement to justify the apparatus and conditions which would allow access to the higher mark level. Justification of apparatus would include some comment as to role of the salt bridge and perhaps why a high resistance voltmeter is desirable. A top answer would also make it clear that conditions, e.g. concentration of electrolyte, affect electrode potentials; hence standard conditions have to be employed. Exemplar 1 Put around 100cm³ of a 1mol dm⁻³ solution of Fe²⁺ ions in a beaker. Dip the other end of the salt bridge into the solution. Attach the wire from the calomel electrode to a high resistance voltmeter - ensure no current flows so the maximum potential difference is recorded. Connect the other side of the voltmeter to an iron metal electrode which also dips into the Fe²⁺ ion solution - allows contact between the Fe atom and Fe²⁺ ions involved. The salt bridge allows electrical contact between the solutions without them mixing to balance charge. The voltmeter reading is equal to the more positive potential minus the more negative half cell potential. Given that the potential of calomel is +0.27V, rearrange the equation to find the iron reading. Subtract 0.27 from the standard potential. This response addresses all the chemical ideas involved in the practical use of electrochemical cells, including how to calculate the standard potential from E_{cell}, the role of the salt bridge and high resistance voltmeter; it is also clear and well-organised and could be followed and set-up by a fellow candidate. Examiners are not looking for the 'perfect' answer to score top marks but a scientifically accurate, well-developed discussion.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
			Total	6	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
37	Please refer to the marking instructions on page 5 of this mark scheme for guidance on how to mark this question. Level 3 (5 – 6 marks) Detailed practical procedure and explains clearly how to process the results. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) Learners present a workable practical procedure and some explanation of analysis but some detail lacking. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) Learners present a partial practical procedure, with some relevant points. OR Learners present some detail on the analysis/processing of results. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> Level 0 (no marks) No response or no response worthy of credit	6	indicative scientific points may include: Procedure • make a range of iodine solutions of different concentrations in hexane • minimum of 5 different concentrations • select filter showing maximum absorbance/complimentary colour • zero colorimeter using pure solvent (hexane) • measure absorbance for each of known concentrations of iodine solution Processing of results Use of calibration graph • plot a calibration curve of concentration against absorbance • measure absorbance of unknown sample and use calibration curve to determine concentration of unknown solution Arriving at mass of iodine in sample • convert mole concentration to mass ($\times 253.8$) • $\div 50$ (or $\times 20/1000$) and convert to μg ($\times 10^6$) <u>Examiner's Comments</u> This level of response question proved to be slightly easier than 2(c) to obtain the higher marks, probably because the practical technique was more familiar. Many candidates chose to zero the colorimeter with water instead of hexane, however the majority of candidates explained the choice of filter. The transfer of graphical information to calculation of mass was not so well explained. In terms of the communication criteria, a good rule of thumb to help with explaining the requirements of this extended question would be to consider whether a fellow candidate could successfully follow the candidate's methodology and successfully

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
			complete the experiment. Exemplar 2 First, you need to produce standard solutions of iodine dissolved in hexane. You need to dissolve different masses of iodine into the same volume of hexane to produce many different standard solutions of different known concentrations. ~~100g/100g~~ then will all be of different colour intensities. Select appropriate filter for colorimeter - filter with maximum absorbance - yellow. Filter is appropriate as is complementary colour to purple. Set colorimeter to zero (calibrate using blank - hexane with no iodine dissolved). ~~Then~~ Fill each cuvette with sample from each standard solution and measure and record their percentage absorbance using the colorimeter. Plot a calibration curve of percentage absorbance along the y-axis and concentration (i.e. mass of iodine dissolved) along x-axis and join points with a line of best fit to produce a calibration curve. Take sample of unknown iodine mass and place in cuvette and measure percentage absorbance. Read value along from the y-axis to the line of best fit and down to the corresponding concentration of iodine. From this, you can work out the moles of iodine $n = \text{conc} \times \text{volume}$ and then use the M_r to work out the mass of iodine in unknown hexane sample.

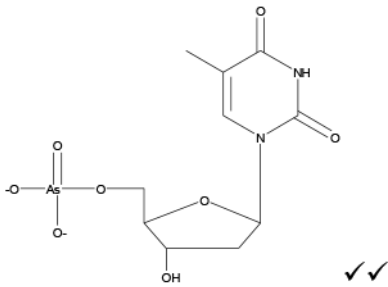
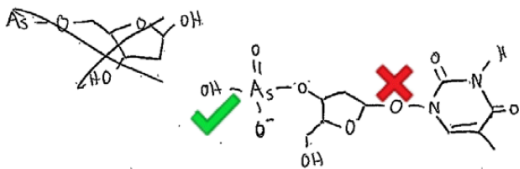
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
					This candidate response avoided the trap of zeroing with water and explained how to transfer data from the graph in order to calculate the mass of iodine. A suggestion of the number of standard solutions appropriate to plot the graph would have been helpful, but overall this is a well explained and workable response.
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
38	a		will not allow formation of S-S bonds	1	ALLOW idea that As interferes with sulfur bridges / S-S bonds in the protein Examiner's Comments Question 5 required that centres had given candidates time and opportunity to study the pre-release article "The Strange Story of Napoleon's Wallpaper". It was anticipated that teachers would have spent some time discussing some of the chemistry within the article. The focus of the article should have prompted teachers to guide candidates towards looking at the properties and reactivity of Group V elements, nitrogen and phosphorous. These could be used to predict some of the reactions and properties of arsenic by extending the group trend(s). In part (a) most candidates recognised that the removal of the –SH groups would interfere with the ability of the protein to form the correct tertiary structure. However, to score the mark here they had to make it clear that the arsenic was preventing the formation of S—S bonds (disulfide bridges). It was pleasing to see that in the vast majority of responses that this was the answer given.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
b		2	ALLOW arsenate group partially, or fully protonated bonded to either OH group on the ribose ring for 2 marks Correct structure with one error scores 1 mark <u>Examiner's Comments</u> In part (b) candidates needed to make use of the relevant section from the Data Sheet provided. They needed to select the appropriate sugar structure (deoxyribose) and derive the structure of thymine. Finally they needed to substitute As for P in the phosphate group and then join the fragments together in order to produce the correct structure. Many candidates succeeded in this and scored both of the marks available. The two most commonly seen errors were the inclusion of a bridging O atom between the thymine molecule and the deoxyribose ring, or the omission of the C=C within the thymine structure. Exemplar 11  Exemplar response showing the incorrect depiction of a bridging O between thymine and the deoxyribose ring

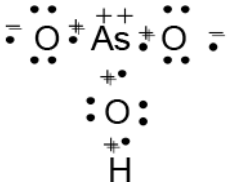
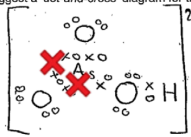
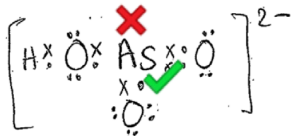
Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	c		$2\text{As}^{3+}(\text{aq}) + 3\text{H}_2\text{S}(\text{g})/(\text{aq}) \rightarrow \text{As}_2\text{S}_3(\text{s}) + 6\text{H}^+(\text{aq})$ balanced equation ✓ Correct state symbol for As_2S_3 ✓	2	<u>Examiner's Comments</u> This was found difficult by candidates, with. Most candidates did not realise the need to balance the charges within the equation and so gave $3\text{H}_2(\text{g})$ as a product rather than $6\text{H}^+(\text{aq})$, losing 1 mark. Many gave the formula of $\text{As}_2\text{S}_3(\text{s})$ in an unbalanced equation, and this was allowed for 1 mark.
	d	i	generating flask containing zinc, sulfuric acid and As_2O_3 ✓ heated tube leaving flask ✓ silvery-black film / Arsenic (metal) labelled ✓	3	ALLOW 'sample' for As_2O_3 IGNORE closed tube <u>Examiner's Comments</u> This was a well answered question and most candidates scored full marks. There were some examples of apparatus that, whilst being impractical or potentially dangerous, did match to the description given in the pre-release material. The marks were not for designing something that would meet today's Health and Safety requirements, but for recognising candidates' ability to extrapolate a description into a suitable diagram of a set up that might work. Therefore sealed tubes, or open tubes with hydrogen escaping near a naked flame, did not result in the loss of any marks. The only common error evident was in failing to label the apparatus appropriately (e.g. failing to label where the arsenic metal would be deposited, or failing to label the heating of the glass tube leaving the reaction flask) Marks were lost through carelessness rather than an inability to produce a suitable diagram..

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	$\text{As}_2\text{O}_3 + 6\text{H}_2 \rightarrow 2\text{AsH}_3 + 3\text{H}_2\text{O} \checkmark$ $2\text{AsH}_3 \rightarrow 2\text{As} + 3\text{H}_2 \checkmark$	2	ALLOW $\text{As}_2\text{O}_3 + 6\text{Zn} + 6\text{H}_2\text{SO}_4 \rightarrow 2\text{AsH}_3 + 3\text{H}_2\text{O} + 6\text{ZnSO}_4$ for equation 1 IGNORE state symbols <u>Examiner's Comments</u> Many candidates did not write a balanced equation for the formation of arsine in the reaction vessel, but were able to write a balanced equation for the decomposition of arsine to form arsenic and hydrogen as the products and so scored 1 mark here. In the first equation a common error that was observed was the inclusion of oxygen gas, O_2, as one of the products of an otherwise balanced equation, which resulted in the mark not being credited.

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
e i	 8 electrons around As atom ✓ completely correct including lone pair on As ✓	2	ALLOW 'spare' electrons on oxygen as different symbol or the same as others on that oxygen IGNORE overall charge of 2- Examiner's Comments A number of candidates identified the anion present in <i>Scheele's Green</i>, but were unable to then draw the appropriate dot and cross diagram. The most common errors were to produce diagrams containing double bonds to one or more oxygen atom giving ten or more electrons around the central As atom, failing to include a lone pair of electrons on the As atom, and failing to check that each oxygen atom satisfied the octet rule. Exemplar 12 (e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$. (i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green.  Commonly seen incorrect dot and cross diagram for bonding of Scheele's Green anion. Exemplar 13 (e) The structure of Scheele's green can be represented as $\text{Cu}^{2+}(\text{AsO}_2\text{OH})^{2-}$. (i) Suggest a 'dot-and-cross' diagram for the anion in Scheele's green.  No lone pair on central As atom, but each atom has its full complement of electrons around its outer shell arrived at by drawing a double bond to one of the oxygen atoms.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
		ii	Cu^{2+} (ion) ✓	1	ALLOW Copper(II) / copper ion <u>Examiner's Comments</u> Most candidates scored this mark as they recognised that coloured substances usually contain a transition metal ion, and so gave Cu^{2+} or copper(II) as their answer. The only common errors were the omission of the charge on the ion, or the omission of the oxidation state after the name of the element.
	f		107.5 (°) ✓ Four pairs of electrons (around As) ✓ Repel and get as far away as possible / move apart to minimise repulsion ✓ Lone pair : bond pair repulsion > bond pair : bond pair repulsion / lone pair repels more (than bond pair) / lone pair takes up more room (AW) ✓	4	ALLOW 107 – 108 ALLOW 'areas of electron density'/'groups of electrons' for 'pairs of electrons' / 3 bonding pairs AND 1 lone pair must be clear that it is electrons repelling to score third mark <u>Examiner's Comments</u> Most candidates scored at least three marks here, and many went on to score all four marks. The only common omission was in failing to make it clear that the lone pair of electrons present on the central arsenic atom had a stronger repulsion on the bonding pairs of electrons and that this produced the bond angle of 107.5°.

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
	g		Any three from: arsenic found in Napoleon's hair ✓ wallpaper (might have) contained arsenic /contained Scheele's Green ✓ Dampness / mould on the wallpaper released toxic arsenic vapours ✓ wallpaper poisoned others ✓	3	ALLOW (wallpaper) linked to Gosio's Disease <u>Examiner's Comments</u> Most of the candidates were able to provide a response here that scored two if not all three marks. They had clearly studied the pre-release material appropriately and were able to summarise the three key pieces of evidence accurately. Where candidates only scored two marks was often a result of omitting marking point 1 – that traces of arsenic were found in the sample of Napoleon's hair. Most candidates made the link between the Scheele's Green pigment found in the wall paper sample, and that the island environment would have caused the paper to become mouldy. This would then result in releasing toxic arsenic compounds as a vapour that Napoleon would have been exposed to over a period of time.
			Total	20	
39			C	1 AO 1.1	<u>Examiner's Comments</u> Candidates had clearly done this practically and could use their experience to narrow the choice down well. Having decided selecting the coloured filter was the first step, they then only had to decide between B and C and the absorbances would be required before plotting the calibration curve, so C was a straightforward choice.
			Total	1	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
40			A	1 AO 1.1	<u>Examiner's Comments</u> This proved one of the more difficult questions due to the detailed knowledge required. There was evidence of quick elimination of C and D on the basis of the initial colour of the iron precipitate, but many candidates were unaware that iron(II) hydroxide oxidises in the air.
			Total	1	

Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
41	<i>*Please refer to the marking instructions on page 4 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5 – 6 marks) Detailed explanation of the structure of complex ions. AND Detailed explanation of the origin of colour and why there are different colours. AND Gives at least one example from the titration in the Insert. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3 – 4 marks) An explanation of the structure of complex ions. AND An explanation of the origin of colour and why there are different colours. AND Gives at least one example from the titration in the Insert. OR Detailed explanation of the structure of complex ions. AND Detailed explanation of the origin of colour and why there are different colours. OR Detailed explanation of the structure of complex ions. AND Gives at least one example from the titration in the Insert. OR Detailed explanation of the origin of colour and why there are different colours. AND Gives at least one example from the titration in the Insert.	6(1.2 x4)(3.1 x2)	Complex ions: • Central metal ion • Ligands • Co-ordinate(dative) bonds to central metal Colour: • d-orbitals • splitting of d orbitals • gap of magnitude/right size to allow.. • absorption of energy in visible/light energy.... • causes electrons move to higher/excited level/shell • frequency absorbed $\Delta E = h\nu$ • colour seen is complementary colour/due to missing wavelength/frequency Different colours: • Different gaps in d split orbitals • Different wavelengths/frequency absorbed • Gives different complementary colours <i>Fine detail</i> • Gap size affected by different ligands • Gap size affected by central metal ion • Gap size affected by oxidation state Examples $\text{MnO}_4^- / [\text{Mn}(\text{H}_2\text{O})_6]^{2+} / [\text{Fe}(\text{H}_2\text{O})_6]^{2/3+}$ References to emission make it difficult to be Level 3 <u>Examiner's Comments</u> This was less well answered than LoR Question 2 (g). Many candidates had a better idea of what constituted "colour" than what constituted a complex ion. Failure to give an example of

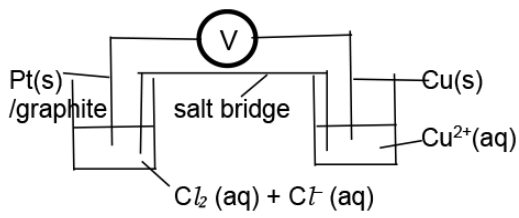
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
	<i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1 – 2 marks) An explanation of the structure of complex ions. OR An explanation of the origin of colour. OR An explanation as to why there are different colours. OR Gives at least one example from the titration in the Insert. <i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> Level 0 (0 marks) No response or response has no merit.		a complex ion (from the insert) resulted in the loss of marks and “emission” as the cause of colour is still being seen frequently. Exemplar 1 below is a response of a very good response given a Level 3. Exemplar 1 The term complex ion denotes a transition metal which is bonded to ligands by coordinate covalent bonds. A ligand is a molecule/ion which has a lone pair of electrons which it can form covalent bonds with. Complex ions have different coloured compounds and this is because when ligands form coordinate bonds with transition metals they cause the d orbitals to split as they gain energy with the electrons usually occupying the lower energy orbitals. As the electrons gain energy they absorb light energy they move up to the next orbital with the higher energy level ($\Delta E = h\nu$) and the complementary colour is transmitted. Difference in colour of complex ions is due to the difference of ΔE for each complex which is affected by the type of ligand (as different ligands cause d subshells to split differently), type of metal ion, etc. An example seen in the insert is the Fe^{2+} which is Additional answer space if required shown can be shown as $[\text{Fe}(\text{H}_2\text{O})_6]^{2+}$ which is green whilst $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ (also written as Fe^{3+}) is orange. So, colour on complex ions can also be affected by oxidation state. Another example is $[\text{Mn}(\text{H}_2\text{O})_6]^{2+}$ which is pink. The colours of these complexes differ due to different oxidation states or metal ions. The exemplar above uses all the key chemistry expected to answer this question. It has a clear logical structure and avoids the pitfalls such as emission of light being responsible for the colour as well as giving clear examples. This is a Level 3 response.
	Total	6	

Mark Scheme

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42	a		$3\text{Cl}_2 + 6\text{OH}^- \rightarrow \text{ClO}_3^- + 5\text{Cl}^- + 3\text{H}_2\text{O}$ Numbers in front of chlorine species ✓ Numbers in front of OH^- and H_2O correct ✓	2(2.5 x 2)	ALLOW '1' in front of ClO_3^- / correct multiples <u>Examiner's Comments</u> This was a question that many lower attaining candidates left blank, as they struggled to use ideas about oxidation states to determine the changes evident in the disproportionation of the chlorine molecule. Some candidates did determine the need for six hydroxide ions producing three water molecules and providing the oxygen atoms required for the chlorate(V) ion to score one mark. However, they then thought that this was all that was required and did not consider the changes in the oxidation state of the chlorine atoms.
	b	i	$\text{ClO}_3^-/\text{ClO}_2$ is less positive/ more negative than Cl_2/Cl^- ✓ so ClO_2 is oxidised AND Cl_2 is reduced / electrons flow from $\text{ClO}_3^-/\text{ClO}_2$ (ora) / half equations are reversed ✓	2(AO2.8 x 2)	IGNORE 'larger'/'smaller' <u>Examiner's Comments</u> Many candidates found this question particularly challenging. In particular they often described the difference between the two relevant half-cells in simple terms such as 'the chlorine half-cell is more than/larger than the chlorate half-cell'. This may be numerically correct but it is important to use the correct terminology and identify the polarity of each half-cell accordingly. Marking point one was for identifying that the correct polarity, e.g. 'the Cl_2/Cl^- half-cell is <u>more positive</u> than the $\text{ClO}_3^-/\text{ClO}_2$ half-cell'. The second mark was for then stating what the effect of this would be and so why the forward reaction does not happen. Essentially, this meant that what was being looked for was the idea of the two relevant half-cells having been reversed, or the effect this would have on the equilibrium in equation 3.1, e.g. ClO_2 is oxidised and Cl_2 is reduced which is the reverse of the reaction outlined.

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		ii	Larger $[H^+] / [Cl^-]$ ✓ Equilibrium / equation 3.1 moves to right ✓	2(AO3.1 x 2)	IGNORE 'more' ALLOW $E^\ominus$ for ClO_3^- / ClO_2 more positive OR $E^\ominus Cl_2 / Cl^-$ becomes more negative <u>Examiner's Comments</u> This question was more successfully answered by many candidates as they identified that the addition of concentrated hydrochloric acid introduced a larger concentration of H^+ or Cl^- ions. This would cause the position of the equilibrium in equation 3.1 to move to the right (and therefore the cell would no longer be under standard conditions) and so the forward reaction becomes favourable.
	c	i	 voltmeter and salt bridge ✓ $Cu^{2+}(aq)$ and $Cu(s)$ ✓ $Cl_2(aq) / Cl^-(aq)$ and Pt / C electrode ✓ solutions 1 mol dm^{-3} and 298 K ✓	4(AO3.4 x 4)	IGNORE description of makeup of salt bridge IGNORE '2' in front of 'Cl^-' ALLOW Cu and Pt/C without state symbols. ALLOW one mark for points 2 and 3 if all state symbols omitted ALLOW electrodes around the other way If no solution shown in either half cell MP2 OR MP3 cannot score If no solution shown in both half cells only penalise once.
		ii	1.02 (V) ✓	1(AO2.8)	IGNORE sign

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Question			Answer/Indicative content	Marks	Guidance
		iii	<u>in the wire</u> from Cu (ora) ✓	1(AO2.8)	ALLOW movement of electrons correctly labelled on the diagram. Examiner's Comments The first part of this question required candidates to complete the diagram to show how this electrochemical cell could be set up. Most candidates scored at least 3 marks here for correctly identifying and labelling a salt bridge and voltmeter, and giving the correct electrolytes and electrodes for each half-cell. Where they missed out on a mark was not giving the details required to identify that each cell had been constructed under standard conditions i.e. 1 mol/dm³ for each solution and at a temperature of 298K. In part (ii) they then needed to determine the E_{cell} value. Most candidates did this successfully, arriving at a value of 1.02V. Finally, in part (iii), they were required to identify the direction of flow of the electrons when the cell is delivering a current. This could be a point that centres need to pay attention to as many candidates lost this mark. Although they correctly identified that the direction of flow would be from the copper half-cell to the chlorine half-cell, they either did not indicate that it happens through the wire, or stated that it went through the salt bridge which is incorrect.

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		iv	$2\text{H}^+(\text{aq}) + 2\text{e}^- \rightleftharpoons \text{H}_2(\text{g})$	1(AO1.2)	ALLOW equation: • halved • with arrow • other way round Examiner's Comments Most candidates correctly scored this mark. Where candidates did not score this mark it was because they had the electrons on the wrong side of their equation, i.e. being added to the $\text{H}_{2(\text{g})}$ molecule rather than to the H^+ ions. The other common error was in not including the relevant state symbols as required in the question.
		v	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = +0.28 (V) award 2 marks $\ln 0.01 = -4.6 \checkmark$ $E = +0.34 - (0.0128 \times 4.6) = +0.28 \text{ (V)} \checkmark$	2(AO2.8 x 2)	ALLOW 2 or more sf + sign essential. (0.28 with no sign = 1) $\lg 0.01$ answer is +0.31V for 1 mark only ALLOW If MP1 not clearly stated then by implication it can be credited from a subsequent calculation eg; $E_{\text{cell}} = 1.02$ answer is +0.96V for 1 mark only Examiner's Comments This question threw up an omission by many candidates that cost them a mark. Many candidates correctly arrived at a value of 0.281V but did not include the + sign in front of this which was an essential part of the required answer. Other commonly seen errors included using +1.02 rather than +0.34 which gave a value of +0.96V for 1 mark, or using $\log_{10}$ rather than $\ln$ which gives a value of +0.31V again for 1 mark.
			Total	15	
43			C	1 (AO2.1)	
			Total	1	

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Question			Answer/Indicative content	Marks	Guidance
44			B	1 (AO2.7)	
			Total	1	
45			C	1 (AO2.8)	
			Total	1	

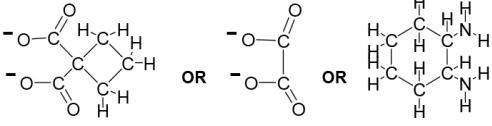
Mark Scheme

Question	Answer/Indicative content	Marks	Guidance
46	<i>Please refer to the marking instructions on pages 4/5 of this mark scheme for guidance on how to mark this question.</i> Level 3 (5–6 marks) Detailed description of calibration of the colorimeter. AND Detailed description of testing of fabric samples. AND Includes several controlled variables. <i>There is a well-developed line of reasoning which is clear and logically structured. The information presented is relevant and substantiated.</i> Level 2 (3–4 marks) Detailed description of calibration of the colorimeter. OR Detailed description of testing of fabric samples. AND Includes several controlled variables. OR Outline description of calibration of the colorimeter. AND Outline description of testing of fabric samples. AND Includes a few controlled variables. <i>There is a line of reasoning presented with some structure. The information presented is relevant and supported by some evidence.</i> Level 1 (1–2 marks) Outline description of calibration of the colorimeter. OR Outline description of testing of fabric samples. OR Identifies a few controlled variables.	6 (AO3.1 × 2)(AO3.3 × 2)(AO3.4 × 2)	Indicative scientific points may include: Calibration of the colorimeter: • Make up several solutions of dye of known concentration. • Select a colour filter complementary to the dye colour. • Zero colorimeter with a cuvette of water. • Measure the absorbance of the standard dye solutions. • Plot a calibration curve. Testing the fabric samples: • Immerse fabric in water at the desired temperature for a fixed time and stir. • Remove fabric and test remaining water to find absorbance. • Use calibration curve to find concentration of dye washed out of the fabric. • Repeat using water of different temperatures. Controlled variables. • Immerse the fabric in water for a fixed time. • Use the same volume of water each time. • Keep the stirring constant • Cut the fabric into equal sized pieces for testing. • Same type of fabric

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			<i>There is an attempt at a logical structure with a line of reasoning. The information is in the most part relevant.</i> 0 marks No response or no response worthy of credit		
			Total	6	

Mark Scheme

Question			Answer/Indicative content	Marks	Guidance
47	a	i	Two C/s / chlorines/two Cl-/ chloride ligands are each -1 ✓	1 (AO1.1)	
		ii	5d ⁸ ✓	1 (AO1.1)	Examiner's Comments This part was generally well done; the only common error was giving an incorrect principal quantum number in (ii).
		iii	Yes, it has an ion with an incomplete d subshell (in a compound) ✓	1 (AO1.1)	
	b		 correct identification ✓ full structural (with O- for first two)✓	2 (AO1.1 × 2)	Examiner's Comments In this part most candidates could correctly identify a bidentate ligand but did not include the charges required for the oxygen ions.
	c	i	guanine✓	1 (AO1.1)	
		ii	hydrogen (bond)✓	1 (AO2.1)	
		iii	(dative) covalent / co-ordinate (bond) ✓ (lone) pair on nitrogen donated to Pt ✓	2 (AO2.1 × 2)	
	d	i	octahedral ✓	1 (AO2.1)	
		ii	6 ✓	1 (AO2.1)	
		iii	Satraplatin also has ethanoate / ester/C=O groups/(4) O atoms (in addition to NH ₃ groups that cisplatin also has) ✓ (These form more) H-bonds with water(ORA for cisplatin) ✓ and (more than) compensate for 'insoluble' (AW) ring OR H-bonds broken in water ✓	3 (AO3.1 × 3)	Oxygen MOLECULES is CON Examiner's Comments In (iii) most candidates recognised that satraplatin formed more hydrogen bonds with water than cisplatin, but some did not state why this was happening, and very few candidates could explain why this resulted in greater solubility compared to cisplatin.
			Total	14	

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Question			Answer/Indicative content	Marks	Guidance
48	a	i	salt bridge ✓ filter paper and potassium nitrate (solution) ✓	2 (AO3.4 × 2)	ALLOW ion bridge ALLOW any Gr I / II nitrate solution <u>Examiner's Comments</u> Most candidates scored some marks in this part but did not score full marks as they gave incomplete answers. For example, in part (i), although they correctly identified the need for a salt bridge, its composition was often incorrectly stated.
		ii	298 K/ 25°C ✓ concentrations of solutions 1 mol dm ⁻³ ✓	2 (AO1.2 × 2)	
	b	i	silver <u>ions</u> / Ag ⁺ ✓	1 (AO1.2)	<u>Examiner's Comments</u> Most candidates scored some marks in this part but did not score full marks as they gave incomplete answers. In part (i) the temperature was usually stated but not the concentration of the solutions.
		ii	From Cu to Ag AND Cu electrode potential is more negative / less positive ✓	1 (AO2.3)	ALLOW Ag electrode is more positive / less negative ALLOW Cu is oxidised / loses electrons ALLOW Ag ⁺ ions are reduced / accept electrons
	c		FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 6.8 × 10 ⁻⁷ (mol dm ⁻³) award 4 marks E° = 0.46 ✓ Rearrange equation: 0.06 log[Ag ⁺] = E – E° ✓ log [Ag ⁺] = –6.17 ✓ [Ag ⁺] = 6.8 × 10 ⁻⁷ (mol dm ⁻³) ✓	4 2.8 × 4	ALLOW 1 or more sf (0.06 in equation) ALLOW ecf throughout

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Question			Answer/Indicative content	Marks	Guidance
	d	i	Equation showing that IO_3^- reacts with Cu ✓ $2\text{IO}_3^- + 12\text{H}^+ + 5\text{Cu} \rightarrow \text{I}_2 + 6\text{H}_2\text{O} + 5\text{Cu}^{2+}$ ✓	2 (AO2.8 × 2)	Mark separately Second mark can be scored for reverse equation. ALLOW equilibrium sign IGNORE state symbols
		ii	Pt / graphite electrode ✓ IO_3^- and I_2 and H^+ in solution ✓	2 (AO3.3 × 2)	Examiner's Comments This theme was continued in 2(d)(ii) where most candidates correctly stated that the standard cell should contain a platinum (or graphite) electrode, but then did not include any H^+ ions in the solution which they should have been able to identify from the information provided in table 2.2.
		iii	FIRST CHECK THE ANSWER ON ANSWER LINE If answer = 0.4 (mol dm^{-3}) award 3 marks $[\text{I}_2] = 0.04$ ✓ $\sqrt{0.04} = 0.2$ ✓ $[\text{IO}_3^-] = 0.4$ (mol dm^{-3}) ✓	3 (AO2.8 × 3)	0.28.... (omission of factors of 2) scores 1 mark 0.56 and 0.2 score 2 marks ALLOW ecf from any statement that begins "[I ₂] ="
			Total	17	