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Halogen 1

CHEMISTRY

Question Paper

AQA

AS & A LEVEL

Inorganic Chemistry

1 Chlorine is an important industrial chemical.

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

$$16H^+ + 2MnO_4^- + 10Cl^- \longrightarrow 2Mn^{2+} + 8H_2O + 5Cl_2$$

(i) Deduce the half-equation for the oxidation of chloride ions to chlorine.

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(1)

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

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(1)

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

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(1)

(b) Chlorine behaves as an oxidising agent in the extraction of bromine from seawater.
In this process, chlorine gas is bubbled through a solution containing bromide ions.

(i) Write the **simplest ionic** equation for the reaction of chlorine with bromide ions.

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(1)

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

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(1)

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

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(1)

(c) In sunlight, chlorine can also oxidise water slowly to form oxygen.

Write an equation for this reaction.
Give the oxidation state of chlorine in the chlorine-containing species that is formed.

Equation

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Oxidation state of chlorine in the species formed .....

(2)

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

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(2)
(Total 10 marks)

2 The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair of compounds, give a reagent (or combination of reagents) that, when added separately to each compound, could be used to distinguish between them.
State what is observed in each case.

(a) Butan-2-ol and 2-methylpropan-2-ol

Reagent .....

Observation with butan-2-ol

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Observation with 2-methylpropan-2-ol

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(3)

(b) Propane and propene

Reagent .....

Observation with propane

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Observation with propene

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(3)

(c) Aqueous silver nitrate and aqueous sodium nitrate

Reagent .....

Observation with aqueous silver nitrate

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Observation with aqueous sodium nitrate

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(3)

(d) Aqueous magnesium chloride and aqueous barium chloride

Reagent .....

Observation with aqueous magnesium chloride

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Observation with aqueous barium chloride

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(3)
(Total 12 marks)

3 For many years, swimming pool water has been treated with chlorine gas. The chlorine is added to kill any harmful bacteria unintentionally introduced by swimmers. Pool managers are required to check that the chlorine concentration is high enough to kill the bacteria without being a health hazard to the swimmers.

When chlorine reacts with water in the absence of sunlight, the chlorine is both oxidised and reduced and an equilibrium is established.

(a) Write an equation for this equilibrium.

For each chlorine-containing species in the equation, write the oxidation state of chlorine below the species.

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(2)

(b) The pool manager maintains the water at a pH slightly greater than 7.0

Explain how this affects the equilibrium established when chlorine is added to water.

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(2)

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

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(2)

(Total 6 marks)

4 This question is about the chemical properties of chlorine, sodium chloride and sodium bromide.

(a) Sodium bromide reacts with concentrated sulfuric acid in a different way from sodium chloride.

Write an equation for this reaction of sodium bromide and explain why bromide ions react differently from chloride ions.

Equation .....

Explanation .....

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.....

(3)

(b) A colourless solution contains a mixture of sodium chloride and sodium bromide.

Using aqueous silver nitrate and any other reagents of your choice, develop a procedure to prepare a pure sample of silver bromide from this mixture.
Explain each step in the procedure and illustrate your explanations with equations, where appropriate.

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(6)

(c) Write an ionic equation for the reaction between chlorine and cold dilute sodium hydroxide solution.
Give the oxidation state of chlorine in each of the chlorine-containing ions formed.

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(2)
(Total 11 marks)

5 Which of these species is the best reducing agent?

A Cl_2 ⬭

B Cl^- ⬭

C I_2 ⬭

D I^- ⬭

(Total 1 mark)

6 Which of these substances reacts most rapidly to produce a silver halide precipitate with acidified silver nitrate?

A CH_3Br ⬭

B CH_3Cl ⬭

C CH_3F ⬭

D CH_3I ⬭

(Total 1 mark)

7 Copper(II) sulfate solution, together with copper(II) carbonate ($CuCO_3$) powder, can be used to determine the identity of three solutions **A, B** and **C**. The three solutions are known to be hydrochloric acid, barium chloride, and sodium chloride.

In **Experiment 1** a small amount of copper(II) carbonate powder was added to each of the three solutions.

In **Experiment 2** a dropping pipette was used to add 2 cm^3 of copper(II) sulfate solution to each of the three solutions.

The results of these experiments are shown in the table below.

	Experiment 1 Addition of copper(II) carbonate powder	**Experiment 2** Addition of copper(II) sulfate solution
Solution **A**	no visible change	white precipitate
Solution **B**	no visible change	no visible change
Solution **C**	effervescence (bubbles of gas)	no visible change

(a) Use the observations in the table to deduce which of the solutions, **A, B** or **C** is

hydrochloric acid .....

barium chloride .....

(2)

(b) Explain why a precipitate was formed when copper(II) sulfate solution was added to solution **A**.
Write an equation for the reaction that occurred.

Explanation .....

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Equation .....

(2)

(c) Suggest the identity for the colourless gas produced when copper(II) carbonate powder was added to solution **C**.

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(1)

(d) Identify the two reagents that could be used in a test to confirm that the solutions contained chloride ions, **not** bromide ions. State what would be observed on addition of each reagent.

Reagent 1 .....

Observation 1 .....

.....

Reagent 2 .....

Observation 2 .....

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(4)

(e) Copper(II) sulfate is toxic. Suggest **one** safety precaution you would take to minimise this hazard when wiping up a spillage of copper(II) sulfate solution.

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(1)

(Total 10 marks)

8 Reactions that involve oxidation and reduction are used in a number of important industrial processes.

(a) Iodine can be extracted from seaweed by the oxidation of iodide ions.
In this extraction, seaweed is heated with MnO_2 and concentrated sulfuric acid.

(i) Give the oxidation state of manganese in MnO_2

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(1)

(ii) Write a half-equation for the reaction of MnO_2 in acid to form Mn^{2+} ions and water as the only products.

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(1)

(iii) In terms of electrons, state what happens to the iodide ions when they are oxidised.

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(1)

(b) Chlorine is used in water treatment. When chlorine is added to cold water it reacts to form the acids HCl and HClO
The following equilibrium is established.

$$Cl_2(aq) + H_2O(l) \rightleftharpoons H^+(aq) + Cl^-(aq) + HClO(aq)$$

(i) Give the oxidation state of chlorine in Cl_2 and in HClO

Cl_2 .....

HClO .....

(2)

(ii) Deduce what happens to this equilibrium as the HClO reacts with bacteria in the water supply. Explain your answer.

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(2)

(c) Concentrated sulfuric acid is reduced when it reacts with solid potassium bromide.
Concentrated sulfuric acid is **not** reduced when it reacts with solid potassium chloride.

(i) Write the two half-equations for the following redox reaction.

$$2H^+ + 2Br^- + H_2SO_4 \longrightarrow Br_2 + SO_2 + 2H_2O$$

Half-equation 1

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Half-equation 2

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(2)

(ii) Write an equation for the reaction of solid potassium chloride with concentrated sulfuric acid.

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(1)

(iii) Explain why chloride ions are weaker reducing agents than bromide ions.

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(2)
(Total 12 marks)

9 Desalination is a technique for making drinking water by the removal of salts from sea water. It is used in parts of the world where fresh water is in short supply. A problem with this technique is the increase in the concentration of salts, particularly of sodium chloride, in the effluent (the solution returned to the sea).

Desalination uses a process called reverse osmosis. In this process, sea water under high pressure is passed over a special membrane which allows only pure water to pass through it.

The owners of a desalination plant have asked for the effluent to be analysed at different operating pressures. This is needed to find an **approximate** value for the maximum operating pressure that gives an effluent that has a minimum harmful effect on the environment.

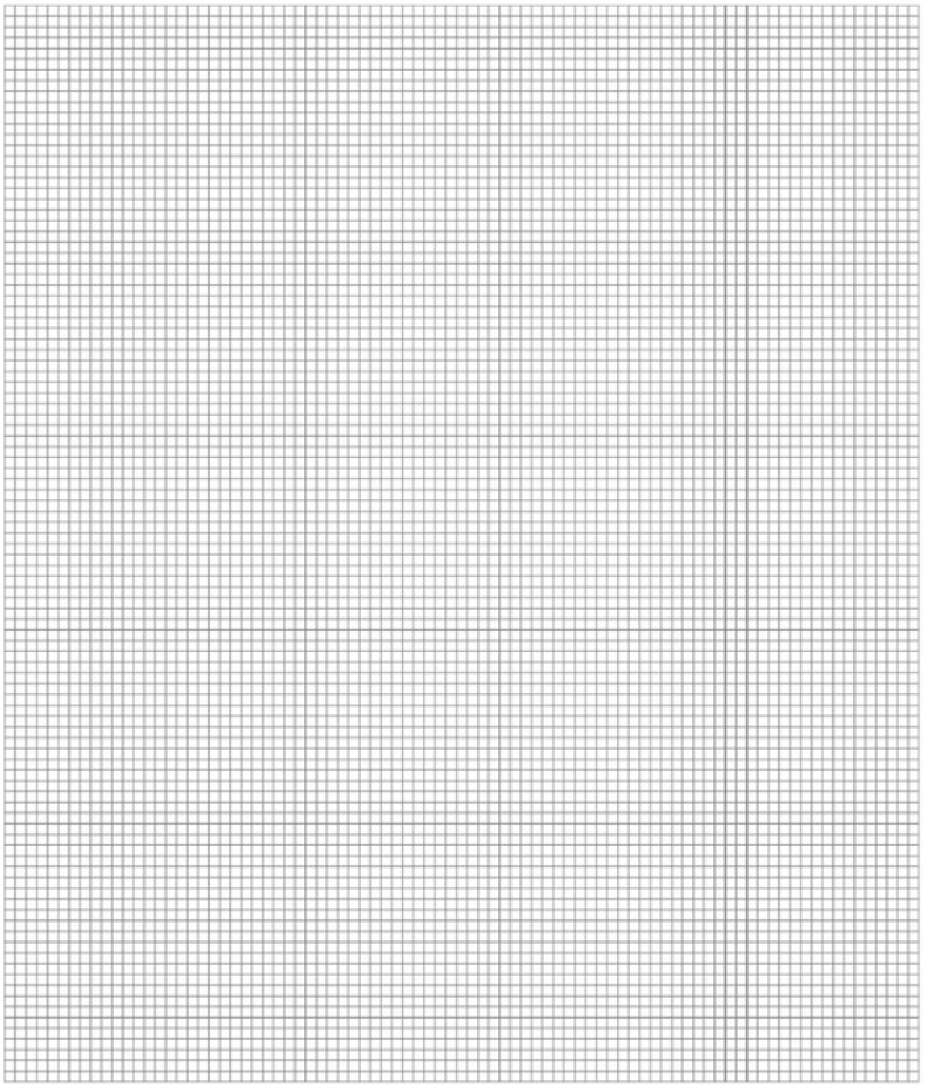
A chemist sampled the effluent at different pressures. For each pressure, a 250 cm^3 sample of effluent was taken in a measuring cylinder and poured into a weighed beaker. The water was evaporated by heating and the beaker reweighed. The following results were obtained.

Experiment	**1**	**2**	**3**	**4**	**5**	**6**
Pressure / MPa	0.1	0.5	1.0	2.5	4.0	8.0
Beaker mass before heating / g	55.3	55.5	55.0	55.1	55.3	56.3
Beaker mass after heating / g	62.5	64.9	65.3	66.6	67.5	69.4
Mass of solid in beaker / g						

(a) Complete the table above to determine the mass of solid that remains in the beaker at each pressure.

Plot a graph of mass of solid (y-axis) against pressure on the graph paper.

Draw a smooth curve through the points.



(4)

(b) To minimise harmful effects on the environment, the concentration of sodium chloride in the effluent should not exceed 44.0 g dm^{-3}. Use your graph to find a value for the pressure, in MPa, that the chemist should advise to be the maximum operating pressure.

Assume that all the solid left in the beaker is sodium chloride.

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(1)

(c) In Experiment **1** the 250 cm^3 sample of the effluent contained the same amount of sodium chloride as the original sea water. Calculate the concentration, in mol dm^{-3}, of sodium chloride in sea water.

Assume that all the solid left in the beaker is sodium chloride.
Show your working.

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(2)

(d) For the measuring cylinder and the balance, the maximum total errors are shown below. These errors take into account multiple measurements.

250 cm^3 measuring cylinder	±1.0 cm^3
balance	±0.1 g

Estimate the maximum percentage error in using these pieces of apparatus, and hence estimate their combined error.

You should use the mass of the solid in the beaker in Experiment **1** to estimate the percentage error in using the balance.
Show your working.

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(2)

(e) Consider your graph.

(i) Is the curve good enough to use with confidence to predict the intermediate values? Explain your answer.

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(1)

(ii) Identify the anomalous results, if any.

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(1)

(f) Give **one** reason why the owners of the plant were satisfied with the maximum operating pressure determined in part (b) despite the combined errors you have calculated in part (d).

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(1)

(g) (i) Suggest **one** harmful effect that effluent with a high concentration of sodium chloride might have if it is returned to the sea.

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(1)

(ii) Suggest **one** low cost method of treating the effluent so that this harmful effect could be reduced.

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(1)

(h) Bromine can be obtained by reacting the bromide ions in the concentrated sea water using chlorine gas in a displacement reaction. Write an equation for this reaction.

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(1)

(i) The solid obtained by the chemist after heating the effluent to dryness was treated with concentrated sulfuric acid. A vigorous reaction resulted, including the formation of a purple vapour of iodine. Give **one** reason why this procedure could **not** be adapted to be an economic method for producing iodine from sea water on an industrial scale.

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(1)

(j) Sea water contains some organic material. After removing all the water, by heating the effluent samples strongly, it was noticed that the solid formed contained black particles. These particles are insoluble in water.

On heating very strongly in air these particles burned to give a colourless gas.

(i) Identify these black particles.

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(1)

(ii) Suggest how these black particles are formed by heating the effluent strongly.

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(1)

(iii) Suggest how a sample of the black particles could be separated from the solid formed.

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(2)

(k) The water produced by some desalination plants is acidic due to the presence of hydrochloric acid. Lime, $Ca(OH)_2$, is added to neutralise this acid. Write an equation for this reaction.

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(1)

(l) Lime is used because it is relatively inexpensive and available in large quantities. Identify **one** other large-scale use of lime.

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(1)

(Total 22 marks)

10 (a) When chlorine gas dissolves in cold water, a pale green solution is formed. In this solution, the following equilibrium is established.

$$Cl_2(g) + H_2O(l) \rightleftharpoons H^+(aq) + Cl^-(aq) + HClO(aq)$$

Give the formula of the species responsible for the pale green colour in the solution of chlorine in water.

Use Le Chatelier's principle to explain why the green colour disappears when sodium hydroxide solution is added to this solution.

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(3)

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

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

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

Deduce the half-equation for the conversion of chlorine into chloride ions.

Explain why iodide ions are stronger reducing agents than chloride ions.

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(4)

(c) When chlorine reacts with water in bright sunlight, only two products are formed. One of these products is a colourless, odourless gas and the other is an acidic solution that reacts with silver nitrate solution to give a white precipitate.

Write an equation for the reaction of chlorine with water in bright sunlight.

Name the white precipitate and state what you would observe when an excess of aqueous ammonia is added to it.

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(3)

(d) The reaction of chlorine with ethene is similar to that of bromine with ethene.

Name and outline a mechanism for the reaction of chlorine with ethene to form 1,2-dichloroethane, as shown by the following equation.

$$H_2C{=}CH_2 + Cl_2 \rightarrow ClCH_2CH_2Cl$$

(5)
(Total 15 marks)

11 For each of the following reactions, select from the list below, the **formula** of a sodium halide that would react as described.

NaF NaCl NaBr NaI

Each **formula** may be selected once, more than once or not at all.

(a) This sodium halide is a white solid that reacts with concentrated sulfuric acid to give a brown gas.

Formula of sodium halide .....

(1)

(b) When a solution of this sodium halide is mixed with silver nitrate solution, no precipitate is formed.

Formula of sodium halide .....

(1)

(c) When this solid sodium halide reacts with concentrated sulfuric acid, the reaction mixture remains white and steamy fumes are given off.

Formula of sodium halide .....

(1)

(d) A colourless aqueous solution of this sodium halide reacts with orange bromine water to give a dark brown solution.

Formula of sodium halide .....

(1)
(Total 4 marks)

12 Chlorine is a useful industrial chemical.

(a) Chlorine gas is used in the manufacture of chlorine-containing organic compounds.

(i) Write equations for the following steps in the mechanism for the reaction of chlorine with ethane to form chloroethane (CH_3CH_2Cl).

Initiation step

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First propagation step

.....

Second propagation step

.....

A termination step producing butane.

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(4)

(ii) Give **one** essential condition and name the type of mechanism in this reaction of chlorine with ethane.

Essential condition .....

Type of mechanism .....

(2)

(b) Chlorine reacts with cold water.

(i) Write an equation for this reaction.

.....

(1)

(ii) Give **one** large-scale application of the use of chlorine in water. Explain why it is used in this application even though chlorine is very toxic. Do **not** include cost.

Example of application.....

Explanation of use .....

(2)

(iii) Two different chlorine-containing compounds are formed when chlorine reacts with cold, dilute sodium hydroxide solution. One of these compounds is sodium chloride. Name the other chlorine-containing compound formed.

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(1)

(c) Chlorine is used in the extraction of bromine from seawater.

(i) Write the **simplest** ionic equation for the reaction of chlorine with bromide ions.

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(1)

(ii) Explain why bromine has a higher boiling point than chlorine.

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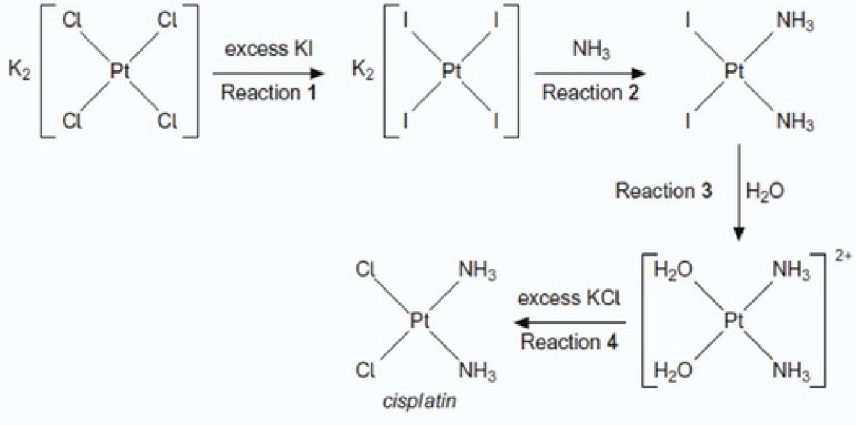
(2)
(Total 13 marks)

13 Complexes containing transition elements have a wide variety of uses including acting as dyestuffs like *Prussian Blue*.

Cisplatin is a platinum-based chemotherapy drug used to treat various types of cancers. It was the first member of a class of anti-cancer drugs that react with DNA in tumour cells.

Cisplatin is prepared from K_2PtCl_4 according to the following scheme.

All the reactions shown are reversible.



(a) Name the type of reaction occurring in all four steps of the scheme.

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(1)

(b) Explain why an excess of potassium iodide is used in Reaction **1**.

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(2)

(c) (i) Write an equation for Reaction **1**.

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(1)

(ii) Calculate the percentage atom economy for the formation of K_2PtI_4 in Reaction **1**. Show your working.

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(2)

(d) In Reaction **3**, silver nitrate solution is added to improve the yield of product.

(i) Write the **simplest ionic** equation for the reaction of iodide ions with silver nitrate.

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(1)

(ii) Suggest why addition of silver nitrate improves the yield of product from Reaction **3**.

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(1)

(e) Suggest two reasons, other than poor practical technique, why the overall yield of *cisplatin* in this synthesis may be low.

Reason 1 .....

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Reason 2 .....

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(2)

(f) The *cisplatin* formed in Reaction **4** is impure. Outline how the impure solid is purified by recrystallisation.

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(3)

(g) Platinum compounds are highly toxic.

(i) State why *cisplatin* is used in cancer treatment despite its toxicity.

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(1)

(ii) Suggest a suitable precaution that should be taken by medical staff when using *cisplatin*.

.....

(1)

(Total 15 marks)

14 (a) Propanoic acid can be made from propan-1-ol by oxidation using acidified potassium dichromate(VI). Propanal is formed as an intermediate during this oxidation.

(i) State the colour of the chromium species after the potassium dichromate(VI) has reacted.

.....

(1)

(ii) Describe the experimental conditions and the practical method used to ensure that the acid is obtained in a high yield. Draw a diagram of the assembled apparatus you would use.

Conditions .....

.....

Apparatus

(4)

(iii) Describe the different experimental conditions necessary to produce propanal in high yield rather than propanoic acid.

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(2)

(b) Propan-1-ol is a volatile, flammable liquid.
Give **one** safety precaution that should be used during the reaction to minimise this hazard.

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(1)

(c) A student followed the progress of the oxidation of propan-1-ol to propanoic acid by extracting the organic compounds from one sample of reaction mixture.

(i) Give a chemical reagent which would enable the student to confirm the presence of propanal in the extracted compounds.
State what you would observe when propanal reacts with this reagent.

Reagent .....

Observation .....

.....

(2)

(ii) Give a chemical reagent that would enable the student to confirm the presence of propanoic acid in the extracted compounds.
State what you would observe when propanoic acid reacts with this reagent.

Reagent .....

Observation .....

.....

(2)

(d) Predict which **one** of the compounds, propan-1-ol, propanal and propanoic acid will have the highest boiling point. Explain your answer.

Prediction .....

Explanation .....

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(3)
(Total 15 marks)

15 The presence of halide ions in solution can be detected by adding silver nitrate solution and dilute nitric acid.

(a) State the purpose of the nitric acid in this test.

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(1)

(b) Explain how the addition of an ammonia solution can be used to confirm that a precipitate is silver bromide.

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(2)
(Total 3 marks)

16 The table below shows observations of changes from some test-tube reactions of aqueous solutions of compounds **Q**, **R** and **S** with five different aqueous reagents. The initial colours of the solutions are not given.

	$BaCl_2$ + HCl	$AgNO_3$ + HNO_3	NaOH	Na_2CO_3	HCl (conc)
Q	no change observed	pale cream precipitate	white precipitate	white precipitate	no change observed
R	no change observd	white precipitate	white precipitate, dissolves in excess of NaOH	white precipitate, bubbles of a gas	no change observed
S	white precipitate	no change observed	brown precipitate	brown precipitate, bubbles of a gas	yellow solution

(a) Identify each of compounds **Q**, **R** and **S**.
You are **not** required to explain your answers.

Identity of **Q** .....

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Identity of **R** .....

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Identity of **S** .....

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(6)

(b) Write ionic equations for each of the positive observations with **S**.

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(4)
(Total 10 marks)

17 This question is about Group 7 chemistry.

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

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

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

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

Oxidation state of S in SO_2 .....

Oxidation state of S in H_2SO_4 .....

(2)

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

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(1)

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

.....KI + ...H_2SO_4 ⟶ .....$KHSO_4$ + ...I_2 + S + ...H_2O

8KI + 9H_2SO_4 ⟶ 8$KHSO_4$ + 4I_2 + H_2S + 4H_2O

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

(1)

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

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(1)

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

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(1)

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

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

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(1)

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

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(1)

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

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(1)

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

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(1)

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

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

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(1)

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

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(1)

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

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(1)

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

Formula 1 .....

Formula 2 .....

(1)
(Total 14 marks)

18 Organic reaction mechanisms help chemists to understand how the reactions of organic compounds occur.
The following conversions illustrate a number of different types of reaction mechanism.

(a) When 2-bromopentane reacts with ethanolic KOH, two structurally isomeric alkenes are formed.

(i) Name and outline a mechanism for the conversion of 2-bromopentane into pent-2-ene as shown below.

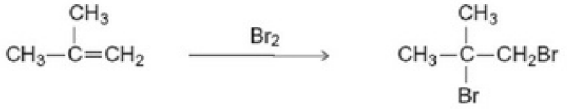
$$CH_3CH_2CH_2CHBrCH_3 \xrightarrow{\text{ethanolic KOH}} CH_3CH_2CH{=}CHCH_3$$

(4)

(ii) Draw the structure of the other structurally isomeric alkene produced when 2-bromopentane reacts with ethanolic KOH.

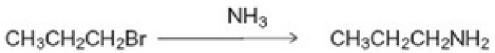
(1)

(b) Name and outline a mechanism for the following conversion.



(5)

(c) Name and outline a mechanism for the following conversion.



(5)
(Total 15 marks)

19 (a) Some scientists thought that the waste water from a waste disposal factory contained **two** sodium halides.

They tested a sample of the waste water.

They added three reagents, one after the other, to the same test tube containing the waste water.

The table below shows their results.

Reagent added	Observations
1. Silver nitrate solution (acidified with dilute nitric acid)	A cream precipitate formed
2. Dilute ammonia solution	A yellow precipitate remained
3. Concentrated ammonia solution	The yellow precipitate did not dissolve

(i) Identify the yellow precipitate that did **not** dissolve in concentrated ammonia solution.
Write the **simplest** ionic equation for the formation of this precipitate from silver ions and the correct halide ion.
Identify the other sodium halide that must be present in this mixture of two sodium halides.

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(3)

(ii) Give **one** reason why the silver nitrate solution was acidified before it was used in this test.

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(1)

(iii) The method that the scientists used could **not** detect one type of halide ion. Identify this halide ion.
Give **one** reason for your answer.

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(2)

(b) The scientists thought that the waste water also contained dissolved barium ions. An aqueous solution of sodium sulfate can be used to test for the presence of dissolved barium ions.

Write the **simplest** ionic equation for the reaction between barium ions and sulfate ions to form barium sulfate.

State what is observed in this reaction.

Give a use for barium sulfate in medicine and explain why this use is possible, given that solutions containing barium ions are poisonous.

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(4)

(c) The scientists also analysed the exhaust gases from an incinerator used to destroy waste poly(ethene).
Mass spectrometry showed that there was a trace gas with a precise $M_r = 28.03176$ in the exhaust gases from the incinerator.

The table below contains some precise relative atomic mass data.

Atom	Precise relative atomic mass
^{12}C	12.00000
^{1}H	1.00794
^{16}O	15.99491

Use the data to show that the trace gas is ethene. Show your working.

Suggest why both ethene and carbon monoxide might have been identified as the trace gas if the scientists had used relative atomic masses to a precision of only one decimal place.

Write an equation for the incomplete combustion of ethene to form carbon monoxide and water only.

Ethene is used to make poly(ethene).
Draw the displayed formula for the repeating unit of poly(ethene).
Name this type of polymer.

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(5)
(Total 15 marks)

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

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

I_2 .....

HIO_3.....

(2)

(ii) Complete the balancing of the following equation.

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

(1)

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

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

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

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

Overall ionic equation

The oxidising agent .....

(2)

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

(i) Identify the black solid.

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(1)

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

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(1)

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

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(1)

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

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

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(1)

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

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(1)

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

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(1)

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

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

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

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(1)

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

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(1)

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

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(Extra space) .....

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(2)
(Total 15 marks)

21 Fluorine and iodine are elements in Group 7 of the Periodic Table.

(a) Explain why iodine has a higher melting point than fluorine.

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(Extra space).....

.....

(2)

(b) (i) Draw the shape of the NHF_2 molecule and the shape of the BF_3 molecule.

Include any lone pairs of electrons that influence the shape. In each case name the shape.

Shape of NHF_2 Shape of BF_3

Name of shape of NHF_2 .....

Name of shape of BF_3 .....

(4)

(ii) Suggest a value for the F—N—F bond angle in NH_2I

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(1)

(c) State the strongest type of intermolecular force in a sample of NHF_2

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(1)

(d) A molecule of NHF_2 reacts with a molecule of BF_3 as shown in the following equation.

$$NHF_2 + BF_3 \longrightarrow F_2HNBF_3$$

State the type of bond formed between the N atom and the B atom in F_2HNBF_3.

Explain how this bond is formed.

Name of type of bond .....

How bond is formed .....

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(2)
(Total 10 marks)

22 (a) Give the **formula** of a Group 2 metal hydroxide used in agriculture.

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(1)

(b) Identify a sodium halide that does **not** undergo a redox reaction when added as a solid to concentrated sulfuric acid.

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(1)

(c) Chlorine gas reacts with cold dilute sodium hydroxide solution to form sodium chloride and another chlorine-containing compound, **X**.

Give the **formula** of **X**.

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(1)

(d) Give the **formula** of the substance responsible for the orange colour when chlorine gas is bubbled through an aqueous solution of sodium bromide.

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(1)

(e) Solid sodium iodide undergoes a redox reaction with concentrated sulfuric acid.

Give the **formula** for each of the following in this reaction.

Formula of the solid reduction product .....

Formula of the oxidation product .....

(2)

(f) Draw the structure of each of the following organic compounds.

(i) The hydrocarbon that is a chain isomer of methylpropene, but does **not** exhibit E–Z stereoisomerism.

(1)

(ii) The alcohol that is a position isomer of butan-2-ol.

(1)

(iii) The hydrocarbon that has a peak, due to its molecular ion, at $m/z = 44$ in its mass spectrum.

(1)

(iv) The bromoalkane that reacts with sodium cyanide to produce propanenitrile.

(1)
(Total 10 marks)

23 (a) Strontium chloride is used in toothpaste for sensitive teeth.
Both strontium carbonate and strontium sulfate are white solids that are insoluble in water.

(i) Write an equation for the reaction between strontium chloride solution and sodium sulfate solution.
Include state symbols in your equation.

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(1)

(ii) Strontium carbonate reacts with nitric acid to produce a solution of strontium nitrate. Strontium sulfate does not react with nitric acid.

Describe briefly how you could obtain strontium sulfate from a mixture of strontium carbonate and strontium sulfate.
You are **not** required to describe the purification of the strontium sulfate.

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(2)

(b) A solution of magnesium sulfate is sometimes given as first aid to someone who has swallowed barium chloride.

Explain why drinking magnesium sulfate solution is effective in the treatment of barium poisoning.

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(1)

(c) Medicines for the treatment of nervous disorders often contain calcium bromide.
Silver nitrate, acidified with dilute nitric acid, can be used together with another reagent to test for the presence of bromide ions in a solution of a medicine.

Describe briefly how you would carry out this test and state what you would observe.

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(3)
(Total 7 marks)

24 (a) Anhydrous strontium chloride is not used in toothpaste because it absorbs water from the atmosphere. The hexahydrate, $SrCl_2.6H_2O$, is preferred.

A chemist was asked to determine the purity of a sample of strontium chloride hexahydrate. The chemist weighed out 2.25 g of the sample and added it to 100 cm^3 of water. The mixture was warmed and stirred for several minutes to dissolve all of the strontium chloride in the sample. The mixture was then filtered into a conical flask. An excess of silver nitrate solution was added to the flask and the contents swirled for 1 minute to make sure that the precipitation was complete.

The silver chloride precipitate was separated from the mixture by filtration. The precipitate was washed several times with deionised water and dried carefully. The chemist weighed the dry precipitate and recorded a mass of 1.55 g.

(i) Calculate the amount, in moles, of AgCl in 1.55 g of silver chloride (M_r = 143.4).

.....

(1)

(ii) The equation for the reaction between strontium chloride and silver nitrate is

$$SrCl_2 + 2AgNO_3 \longrightarrow 2AgCl + Sr(NO_3)_2$$

Use your answer from part (i) and this equation to calculate the amount, in moles, of $SrCl_2$ needed to form 1.55 g of silver chloride.

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(1)

(iii) Use data from the Periodic Table to calculate the M_r of strontium chloride hexahydrate. Give your answer to 1 decimal place.

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(1)

(iv) Use your answers from parts (a)(ii) and (a)(iii) to calculate the percentage by mass of strontium chloride hexahydrate in the sample. Show your working.
Give your answer to the appropriate precision.

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(2)

(v) Several steps in the practical procedure were designed to ensure an accurate value for the percentage by mass of strontium chloride hexahydrate in the sample.

1 Explain why the solution of strontium chloride was filtered to remove insoluble impurities before the addition of silver nitrate.

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(1)

2 Explain why the precipitate of silver chloride was washed several times with deionised water.

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(1)

(b) Magnesium hydroxide and magnesium carbonate are used to reduce acidity in the stomach. Magnesium hydroxide can be prepared by the reaction of solutions of magnesium chloride and sodium hydroxide.

(i) Write the **simplest ionic** equation for the reaction that occurs between magnesium chloride and sodium hydroxide.
Include state symbols in your equation.

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(1)

(ii) Other than cost, explain one advantage of using magnesium hydroxide rather than magnesium carbonate to reduce acidity in the stomach.

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(1)

(c) Calcium ethanoate, $(CH_3COO)_2Ca$, is used in the treatment of kidney disease.
Thermal decomposition of calcium ethanoate under certain conditions gives propanone and **one** other product.

Write an equation for the thermal decomposition of calcium ethanoate.

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(1)

(d) Salts containing the chromate(VI) ion are usually yellow in colour.
Calcium chromate(VI) is soluble in water.
Strontium chromate(VI) is insoluble in water, but will dissolve in a solution of ethanoic acid.
Barium chromate(VI) is insoluble in water and is also insoluble in a solution of ethanoic acid.

Describe a series of tests using solutions of sodium chromate(VI) and ethanoic acid that would allow you to distinguish between separate solutions of calcium chloride, strontium chloride and barium chloride.
State what you would observe in each test.

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(3)

(e) The strontium salt of ranelic acid is used to promote bone growth. Analysis of a pure sample of ranelic acid showed that it contained 42.09% of carbon, 2.92% of hydrogen, 8.18% of nitrogen, 37.42% of oxygen and 9.39% of sulfur by mass.

Use these data to calculate the empirical formula of ranelic acid.
Show your working.

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(2)
(Total 15 marks)

25 The following pairs of compounds can be distinguished by simple test-tube reactions.

For each pair, give a suitable reagent that could be added separately to each compound to distinguish between them.
Describe what you would observe in each case.

(a) AgBr(s) and AgI(s)

Reagent .....

Observation with AgBr(s).....

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Observation with AgI(s) .....

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(3)

(b) HCl(aq) and HNO_3(aq)

Reagent .....

Observation with HCl(aq) .....

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Observation with HNO_3(aq) .....

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(3)

(c) Cyclohexane and cyclohexene

Reagent .....

Observation with cyclohexane .....

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Observation with cyclohexene .....

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(3)

(d) Butanal and butanone

Reagent .....

Observation with butanal .....

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Observation with butanone .....

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(3)
(Total 12 marks)

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

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

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

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

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

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

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(Extra space) .....

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(3)

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

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

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

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(Extra space) .....

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(3)

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

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

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

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

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(Extra space) .....

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(2)

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

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

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

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

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(Extra space) .....

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(4)

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

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

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

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

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(Extra space) .....

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(3)
(Total 15 marks)

27 Aldehydes can be prepared from acyl chlorides.

State how an aldehyde could be tested to show whether it is contaminated with traces of unreacted acyl chloride.
State what you would observe.

Test .....

Observation .....

.....

(Total 2 marks)

28 Concentrated sulfuric acid reacts with solid potassium iodide as shown in the equation.

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

Give **two** observations that you would make when this reaction occurs.

In terms of electrons, state what happens to the iodide ions in this reaction.

State the **change** in oxidation state of sulfur that occurs during this formation of H_2S and deduce the half-equation for the conversion of H_2SO_4 into H_2S

(Total 5 marks)

29 Chlorine is a powerful oxidising agent.

(a) Write the **simplest ionic** equation for the reaction between chlorine and aqueous potassium bromide.

State what is observed when this reaction occurs.

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(Extra space) .....

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(2)

(b) Write an equation for the reaction between chlorine and cold, dilute, aqueous sodium hydroxide.

Give a major use for the solution that is formed by this reaction.

Give the IUPAC name of the chlorine-containing compound formed in this reaction in which chlorine has an oxidation state of +1.

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(Extra space) .....

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(3)

(c) Write an equation for the equilibrium reaction that occurs when chlorine gas reacts with cold water.

Give **one** reason why chlorine is used for the treatment of drinking water even though the gas is very toxic.

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(Extra space) .....

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(2)

(d) State how you could test a sample of water to show that it contains chloride ions.

In your answer, give a reagent, **one** observation and the **simplest ionic** equation for the reaction with the reagent.

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(Extra space) .....

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(3)
(Total 10 marks)

30 (a) Chlorine displaces iodine from aqueous potassium iodide.

(i) Write the **simplest ionic** equation for this reaction.

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(1)

(ii) Give **one** observation that you would make when this reaction occurs.

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(1)

(b) In bright sunlight, chlorine reacts with water to form oxygen as one of the products.
Write an equation for this reaction.

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(1)

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

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(Extra space) .....

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(2)
(Total 5 marks)