**Q1.**          (a)     Samples of solid sodium fluoride, sodium chloride, sodium bromide and sodium iodide are each warmed separately with concentrated sulphuric acid. All four compounds react with concentrated sulphuric acid but only two can reduce it.

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

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

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

**(9)**

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

**(6)**

**(Total 15 marks)**

**Q2.**          An excess of potassium iodide was added to an aqueous solution of chlorine. In a titration the liberated iodine required 28.2 cm3 of a 0.360 mol dm–3 solution of sodium thiosulphate for complete reaction.

(a)     Calculate the number of moles of sodium thiosulphate used in the titration.

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**(2)**

(b)     Write an equation for the reaction between thiosulphate ions and iodine.

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**(1)**

(c)     Calculate the number of moles of iodine which reacted with the sodium thiosulphate used in the titration.

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**(1)**

(d)     Write an equation for the reaction between potassium iodide and chlorine.

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**(1)**

(e)     Calculate the mass of chlorine in the original solution which reacted with potassium iodide.

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**(3)**

(f)      Name an indicator which could be used when a solution of iodine is titrated with sodium thiosulphate solution from a burette. State the colour change at the end-point.

*Indicator*........................................................................................................

*Colour change ….*.........................................................................................

**(2)**

**(Total 10 maks)**

**Q3.**          (a)     State why chlorine is added to drinking water.

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**(1)**

(b)     Write an equation for the reaction which occurs when chlorine is bubbled into water.  
Identify the substance which causes the resulting solution to be pale green.

*Equation* ......................................................................................................

*Identity of substance* ....................................................................................

**(2)**

(c)     Write an equation for the reaction which occurs when chlorine is bubbled into an excess of cold aqueous sodium hydroxide.

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**(1)**

(d)     The amount of chlorine which has been added to water can be determined by treating a measured volume of the solution with an excess of potassium iodide and titrating the liberated iodine against a standard solution of sodium thiosulphate.

(i)      Write an equation for the reaction between chlorine and potassium iodide.

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(ii)     Write an equation for the reaction between iodine and sodium thiosulphate.

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(iii)     An excess of potassium iodide was added to 1.00 dm3 of water from a swimming pool. The liberated iodine reacted with 7.20 cm3 of a 0.0150 mol dm–3 solution of sodium thiosulphate. Calculate the mass of chlorine which had been added to each 1.00 dm3 of swimming pool water.

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**(6)**

**(Total 10 marks)**

**Q4.**          (a)     When using silver nitrate to test for the presence of chloride ions in an aqueous solution, it is important to add another reagent to prevent interference by any carbonate ions which would form a white precipitate of Ag2CO3

(i)      Identify this other reagent.

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(ii)     Write an equation to show how this other reagent reacts with sodium carbonate.

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**(2)**

(b)     The presence of some halide ions in solution can be detected using aqueous silver nitrate and aqueous ammonia.

(i)      Identify a halide ion which, on addition of aqueous silver nitrate, forms a precipitate that is insoluble in concentrated aqueous ammonia.

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(ii)     Identify a halide ion which cannot be detected using these reagents.

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**(2)**

(c)     A mixture of two precipitates, **P** and **Q**, was formed by adding aqueous silver nitrate to a solution containing two different halide ions. Precipitate **P** dissolved on addition of an excess of dilute aqueous ammonia. The remaining precipitate, **Q**, was filtered off.

(i)      Identify the halide ion in **P**.

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(ii)     Precipitate **Q** was soluble in concentrated aqueous ammonia. Identify the halide ion in **Q**.

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**(2)**

**(Total 6 marks)**

**Q5.**          (a)     Concentrated sulphuric acid can be reduced by some solid sodium halides to H2S

(i)      Give the oxidation state of sulphur in H2S

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(ii)     Give **one** solid sodium halide which will reduce concentrated sulphuric acid, forming H2S

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(iii)     State **one** way in which the presence of H2S could be recognised.

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(iv)    Write a half-equation for the formation of H2S from sulphuric acid.

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**(4)**

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

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

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

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

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

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**(4)**

**(Total 8 marks)**

**Q6.**          (a)     State and explain the trend in electronegativity down Group VII from fluorine to iodine.

*Trend* ...........................................................................................................

*Explanation* …...............................................................................................

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**(3)**

(b)     (i)      Describe what you would observe when an aqueous solution of bromine is added to an aqueous solution containing iodide ions. Write an equation for the reaction occurring.

*Observation* .........................................................................................

*Equation* ..............................................................................................

(ii)     Explain why bromine does not react with aqueous chloride ions.

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**(3)**

(c)     Describe what you would observe when aqueous silver nitrate is added to separate aqueous solutions of potassium fluoride and potassium bromide.

*Observation with KF(aq)* ..............................................................................

*Observation with KBr(aq)* .............................................................................

**(2)**

(d)     Write an equation to show how solid potassium fluoride reacts with concentrated sulphuric acid.

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**(1)**

(e)     Write an equation for the redox reaction of sodium bromide with concentrated sulphuric acid.

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**(2)**

**(Total 11 marks)**

**Q7.**(a)     Describe and explain the trend in the boiling points of the elements down Group VII from fluorine to iodine.

**(4)**

(b)     Describe what you would observe when aqueous silver nitrate, followed by dilute aqueous ammonia, is added to separate aqueous solutions of sodium chloride and sodium bromide.

**(4)**

(c)     State the trend in the oxidising abilities of the elements down Group VII from chlorine to iodine.  
Explain how this trend can be shown by displacement reactions between halogens and halide ions in aqueous solutions.  
Illustrate your answer with appropriate observations and equations.

**(7)**

**(Total 15 marks)**

**Q8.**          (a)     Identify the halogen that is the strongest oxidising agent.

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**(1)**

(b)     Give the formula of the halide ion that is the strongest reducing agent.

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**(1)**

(c)     Describe what you would observe in each case when aqueous silver nitrate is added separately to dilute aqueous sodium fluoride and to dilute aqueous sodium iodide. Write an equation, including state symbols, for the reaction between aqueous sodium iodide and aqueous silver nitrate.

*Observation with NaF(aq)* .............................................................................

*Observation with NaI(aq)* ..............................................................................

*Equation* .......................................................................................................

**(3)**

(d)     Describe what you would observe when concentrated sulphuric acid is added to solid sodium chloride. Write an equation for the reaction that occurs.

*Observation* ..................................................................................................

*Equation* .......................................................................................................

**(2)**

(e)     Describe two observations that you would make when concentrated sulphuric acid is added to solid sodium iodide. Write an equation for a reaction that occurs in which iodide ions are oxidised by the sulphuric acid.

*Observation 1* ...............................................................................................

*Observation 2* ...............................................................................................

*Equation* .......................................................................................................

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**(4)**

(f)      Describe the colour change that you would observe when an aqueous solution of iodine, to which starch solution has been added, reacts with an excess of Na2S2O3. Write an equation for the reaction that occurs between iodine and Na2S2O3.

*Observation* ..................................................................................................

*Equation* .......................................................................................................

**(3)**

**(Total 14 marks)**

**Q9.**(a)     State the trend in the boiling points of the halogens from fluorine to iodine and explain this trend.

*Trend* ............................................................................................................

*Explanation ..*.................................................................................................

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**(4)**

(b)     Each of the following reactions may be used to identify bromide ions. For each reaction, state what you would observe and, where indicated, write an appropriate equation.

(i)      The reaction of aqueous bromide ions with chlorine gas

*Observation* ........................................................................................

*Equation* ..............................................................................................

(ii)     The reaction of aqueous bromide ions with aqueous silver nitrate followed by the addition of concentrated aqueous ammonia

*Observation with aqueous silver nitrate* ...............................................

*Equation* ..............................................................................................

*Observation with concentrated aqueous ammonia* ..............................

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(iii)     The reaction of solid potassium bromide with concentrated sulphuric acid

*Observation 1* .....................................................................................

*Observation 2 .*....................................................................................

**(7)**

(c)     Write an equation for the redox reaction that occurs when potassium bromide reacts with concentrated sulphuric acid.

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**(2)**

**(Total 13 marks)**

**Q10.**          (a)     State and explain the trend in electronegativity down Group VII from fluorine to iodine.

*Trend* ...........................................................................................................

*Explanation* ...................................................................................................

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**(3)**

(b)     State what you would observe when chlorine gas is bubbled into an aqueous solution of potassium iodide. Write an equation for the reaction that occurs.

*Observation* .................................................................................................

*Equation* …...................................................................................................

**(2)**

(c)     Identify **two** sulphur-containing reduction products formed when concentrated sulphuric acid oxidises iodide ions. For each reduction product, write a half-equation to illustrate its formation from sulphuric acid.

*Reduction product 1* ...................................................................................

*Half*-*equation .*.............................................................................................

*Reduction product 2* ...................................................................................

*Half*-*equation .*.............................................................................................

**(4)**

(d)     Write an equation for the reaction between chlorine gas and dilute aqueous sodium hydroxide. Name the **two** chlorine-containing products of this reaction and give the oxidation state of chlorine in each of these products.

*Equation* ......................................................................................................

*Name of product 1* .......................................................................................

*Oxidation state of chlorine in product 1* ........................................................

*Name of product 2* .......................................................................................

*Oxidation state of chlorine in product 2* ........................................................

**(5)**

**(Total 14 marks)**

**Q11.**          (a)     State the trend in electronegativity of the elements down Group VII. Explain this trend.

*Trend* ...........................................................................................................

*Explanation .*.................................................................................................

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**(3)**

(b)     (i)      State the trend in reducing ability of the halide ions down Group VII.

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(ii)     Give an example of a reagent which could be used to show that the reducing ability of bromide ions is different from that of chloride ions.

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**(2)**

(c)     The addition of silver nitrate solution followed by dilute aqueous ammonia can be used as a test to distinguish between chloride and bromide ions. For each ion, state what you would observe if an aqueous solution containing the ion was tested in this way.

*Observations with chloride ions* ...................................................................

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*Observations with bromide ions .*..................................................................

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**(4)**

(d)     Write an equation for the reaction between chlorine and cold, dilute aqueous sodium hydroxide. Give two uses of the resulting solution.

*Equation* .....................................................................................................

*Use 1* ..........................................................................................................

*Use 2* ...........................................................................................................

**(3)**

**(Total 12 marks)**

**Q12.**          (a)     Explain, by referring to electrons, the meaning of the terms *reduction* and *reducing agent*.

**(2)**

(b)     Iodide ions can reduce sulphuric acid to three different products.

(i)      Name the **three** reduction products and give the oxidation state of sulphur in each of these products.

(ii)     Describe how observations of the reaction between solid potassium iodide and concentrated sulphuric acid can be used to indicate the presence of any **two** of these reduction products.

(iii)     Write half-equations to show how two of these products are formed by reduction of sulphuric acid.

**(10)**

(c)     Write an equation for the reaction that occurs when chlorine is added to cold water. State whether or not the water is oxidised and explain your answer.

**(3)**

**(Total 15 marks)**

**Q13.**          (a)     In Peru, chlorine was removed from the water supply due to concerns about it reacting with organic chemicals in the water to produce toxic substances. This resulted in the death of ten thousand people due to cholera. The cholera epidemic ceased when chlorination of the water supply was restarted.

State why chlorine is added to the water supply and give a reason why the amount of chlorine must be carefully monitored. Write an equation for the reaction of chlorine with water.

**(3)**

(b)     How can the addition of an aqueous solution of chlorine be used to distinguish between aqueous solutions of sodium bromide and sodium iodide?

State any observations you would make and write equations for the reactions occurring.

**(4)**

(c)     How can reactions with concentrated sulphuric acid be used to distinguish between solid samples of sodium bromide and sodium iodide?

State the observations you would make and give all the oxidation and reduction products formed in both reactions. Using half-equations, construct an overall equation for **one** of these redox reactions.

**(11)**

**(Total 18 marks)**

**Q14.**          In the past 150 years, three different processes have been used to extract bromine from potassium bromide. These processes are illustrated below.

Extraction Process **1**

2KBr + MnO2 + 2H2SO4 → MnSO4 + K2SO4 + 2H2O + Br2

Extraction Process **2**

The reaction of solid potassium bromide with concentrated sulfuric acid.

Extraction Process **3**

The reaction of aqueous potassium bromide with chlorine gas.

(a)     Write a half-equation for the conversion of MnO2 in acid solution into Mn2+ ions and water. In terms of electrons, state what is meant by the term *oxidising agent* and identify the oxidising agent in the overall reaction.

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**(3)**

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

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**(5)**

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

Br2   +   H2O      HBrO + HBr

Give the oxidation state of bromine in HBr and in HBrO

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

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**(4)**

**(Total 12 marks)**

**Q15.**          Acidified silver nitrate solution can be used to identify and distinguish between halide ions in solution.

(a)     Explain why hydrochloric acid should **not** be used to acidify the silver nitrate.

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**(1)**

(b)     State and explain what would be observed when acidified silver nitrate solution is added to a solution of sodium fluoride.

Observation .................................................................................................

Explanation …..............................................................................................

**(2)**

(c)     State what would be observed when acidified silver nitrate solution is added to a solution containing iodide ions. Write the **simplest ionic** equation for the reaction that occurs.

Observation .................................................................................................

Explanation ..................................................................................................

**(2)**

**(Total 5 marks)**

**Q16.**          (a)     When chlorine gas dissolves in cold water, a pale green solution is formed. In this solution, the following equilibrium is established.

Cl2(g) + H2O(l)  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.

Cl2(aq) + 2I–(aq) → I2(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.

H2CCH2 + Cl2 → ClCH2CH2Cl

**(5)**

**(Total 15 marks)**

**Q17.**          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)**

**Q18.**          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 (CH3CH2Cl).

Initiation step

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First propagation step

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Second propagation step

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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.

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**(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)**

**Q19.**          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 MnO2 and concentrated sulfuric acid.

(i)      Give the oxidation state of manganese in MnO2

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**(1)**

(ii)     Write a half-equation for the reaction of MnO2 in acid to form Mn2+ 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.

Cl2(aq) + H2O(I) H+(aq) + Cl–(aq) + HClO(aq)

(i)      Give the oxidation state of chlorine in Cl2 and in HClO

Cl2 …....................................................................................................

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– + H2SO4  Br2 + SO2 + 2H2O

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)**

**Q20.**          The following pairs of compounds can be distinguished by observing what happens in test-tube reactions.  
For each pair, give a suitable aqueous reagent that could be added separately to each compound.  
Describe what you would observe in each case.

(a)     NaF(aq) and NaCl(aq)

Reagent ......................................................................................................

Observation with NaF(aq) ...........................................................................

Observation with NaCl(aq) ..........................................................................

**(3)**

(b)     BaCl2(aq) and MgCl2(aq)

Reagent .......................................................................................................

Observation with BaCl2(aq) ..........................................................................

Observation with MgCl2(aq) ..........................................................................

**(3)**

(c)     AgCl(s) and AgI(s)

Reagent .......................................................................................................

Observation with AgCl(s) .............................................................................

Observation with AgI(s) ...............................................................................

**(3)**

(d)     Butan-2-ol(l) and 2-methylpropan-2-ol(l)

Reagent …...................................................................................................

Observation with butan-2-ol(l) .....................................................................

Observation with 2-methylpropan-2-ol(l) .....................................................

**(3)**

**(Total 12 marks)**

**Q21.**          (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** |
| 12C | 12.00000 |
| 1H | 1.00794 |
| 16O | 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)**

**Q22.**          (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)**

**Q23.**Iodine reacts with concentrated nitric acid to produce nitrogen dioxide (NO2).

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

I2 .......................................................................

HIO3..................................................................

**(2)**

(ii)     Complete the balancing of the following equation.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| l2 | + | 10HNO3 |  | ..........HIO3 | + | ..........NO2 | + | ..........H2O |

**(1)**

(b)     In industry, iodine is produced from the NalO3 that remains after sodium nitrate has been crystallised from the mineral Chile saltpetre.  
The final stage involves the reaction between NalO3 and Nal in acidic solution.  
Half-equations for the redox processes are given below.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| IO3– | + | 5e– | + | 6H+ |  | 3H2O | + | l2 |
|  |  |  |  | l – |  | l2 | + | e– |

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

Overall ionic equation

The oxidising agent .......................................................................................

**(2)**

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

(i)      Identify the black solid.

...............................................................................................................

**(1)**

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

...............................................................................................................

**(1)**

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

........................................................................................................................

**(1)**

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

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

...............................................................................................................

**(1)**

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

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...............................................................................................................

**(1)**

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

...............................................................................................................

...............................................................................................................

**(1)**

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

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Cl2(aq) | + | 2I–(aq) |  | I2(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)* ........................................................................................

...............................................................................................................

**(2)**

**(Total 15 marks)**

**Q24.**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– | + | H2SO4 |  | 4I2 | + | H2S | + | 4H2O |

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.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Br2(I) | + | H2O(I) |  | 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)**

**Q25.**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)**

**Q26.**Concentrated sulfuric acid reacts with solid potassium iodide as shown in the equation.

8KI + 9H2SO4   4l2 + 8KHSO4 + H2S + 4H2O

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 H2S and deduce the half-equation for the conversion of H2SO4 into H2S

**(Total 5 marks)**

**Q27.**(a)    Chlorine displaces iodine from aqueous potassium iodide.

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

...............................................................................................................

**(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)**

**Q28.**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)...............................................................................

........................................................................................................................

Observation with AgI(s) .................................................................................

........................................................................................................................

**(3)**

(b)     HCl(aq) and HNO3(aq)

Reagent .........................................................................................................

Observation with HCl(aq) ...............................................................................

........................................................................................................................

Observation with HNO3(aq) ..........................................................................

........................................................................................................................

**(3)**

(c)     Cyclohexane and cyclohexene

Reagent .........................................................................................................

Observation with cyclohexane .......................................................................

........................................................................................................................

Observation with cyclohexene ......................................................................

........................................................................................................................

**(3)**

(d)     Butanal and butanone

Reagent .........................................................................................................

Observation with butanal ...............................................................................

........................................................................................................................

Observation with butanone ............................................................................

........................................................................................................................

**(3)**

**(Total 12 marks)**

**Q29.**Sulfuric acid is manufactured by the Contact Process.

(a)     In this process, sulfur dioxide reacts with oxygen.  
The equation for the equilibrium that is established is

SO2(g) + O2(g)       SO3(g) *ΔH* = −98 kJ mol−1

(i)      State and explain the effect of a **decrease** in temperature on the equilibrium yield of SO3.

Effect of a decrease in temperature on yield .......................................

Explanation ...........................................................................................

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*(Extra space)* ........................................................................................

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**(3)**

(ii)     Give **two** features of a reaction at equilibrium.

Feature 1 ...............................................................................................

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Feature 2 ..............................................................................................

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**(2)**

(b)     Write an equation for the reaction of concentrated sulfuric acid with potassium bromide to form potassium hydrogensulfate and hydrogen bromide.

...............................................................................................................

**(1)**

(c)     Bromine is one of the products formed when concentrated sulfuric acid reacts with hydrogen bromide.

Write an equation for this reaction.  
State the role of sulfuric acid in this reaction.

Equation

........................................................................................................................

Role of sulfuric acid .......................................................................................

**(3)**

(d)     Concentrated sulfuric acid is used in a two-stage process to convert 2-methylpropene into 2-methylpropan-2-ol.

Stage **1** (CH3)2C=CH2 + H2SO4         (CH3)2C(OSO2OH)CH3

Stage **2**  (CH3)2C(OSO2OH)CH3 + H2O        (CH3)2C(OH)CH3 + H2SO4

(i)      Name and outline a mechanism for Stage **1** of this conversion.

Name of mechanism .........................................................................

Mechanism

**(5)**

(ii)     Deduce the type of reaction in Stage **2** of this conversion.

...............................................................................................................

**(1)**

(iii)    State the overall role of sulfuric acid in this conversion.

...............................................................................................................

**(1)**

**(Total 16 marks)**

**M1.**          (a)     (i)      Halides:-              Fluoride  
                             Chloride **(1)**Equation:-            H+ + F– → HF *(or molecular / for a correct halide)* **(1)**

(ii)     Halides:-              Bromide and iodide **(1)**Equation:-            H2SO4 *(or 2H+ + SO42-)*+ 2H+ +2e– → SO2 + 2H2O **(1)**                             2Br– → Br2 + 2e– **(1)** H2SO4 + 2H+ + 2Br – (or 2HBr) → Br2 + SO2 + 2H2O **(1)**

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

(iii)     Products              Sulphur (or S8 not S4) **(1)**                             Hydrogen sulphide **(1)**Equation:-            H2SO4 *(or 2H+ + SO42-)* +6H+ + 6e– → S + 4H2O **(1)  
                             OR** H2SO4 *(or 2H+ + SO42-)* + 8H+ + 8e– → H2S + 4H2O

**9**

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

(b)     Addition of silver nitrate  
                                      Chloride gives white precipitate / solid **(1)**                                      Bromide gives cream precipitate / solid **(1)**                                      Iodide gives yellow precipitate / solid **(1)**Addition of ammonia  
                                      Chloride precipitate soluble in dilute **(1)**                                      Bromide precipitate soluble in concentrated **(1)** Iodide precipitate insoluble **(1)**

*Do not allow halogen or sodium halide*

**6**

**[15]**

**M2.**          (a)     Moles = mv / 1000 **(1)**          = 0.36 × 28.2 / 1000 = 0.010(2) **(1)**

*NB An answer of 0.01 scores one*

**2**

(b)     I2 + 2S2O32– → S4O62– + 2I– **(1)**

*Allow multiples*

**1**

(c)     (Mole ratio = 1:2) Answer from (a) ÷ 2 = 0.005 **(1)** moles I2

**1**

(d)     2 KI + Cl2 → 2KCl + I2 **(1)**

*Or ionic or a multiple  
Ignore state symbols and incorrect use of caps*

**1**

(e)     Mass Cl2 = (moles from (c)) 0.0051 **(1)** × (35.5 × 2) **(1)**

*If moles not from (c) then max one if Mr chlorine given as 71*

              = 0.360 g **(1)**

*Allow 0.36  0.005  
If Ar of chlorine used score max 1   
If Mr chlorine = 70, penalise as A.E.*

**3**

(f)      *Indicator:* Starch **(1)**

*Colour change:* Blue (or black or blue / black) to colourless **(1)**

*NOT to straw coloured  
If an indicator given it must be correct for second mark to  
be awarded*

**2**

**[10]**

**M3.**          (a)     To kill bacteria or sterilize water**(1)**

*Or micro-organisms, microbes or germs, disinfect water or as a germicide Not to purify water  
Not to kill organisms*

**1**

(b)     *Equation:* Cl2 + H2O  HClO + HCl **(1)**

*Allow ionic products  
Identity of substance:* (Free) chlorine or Cl2

**2**

(c)     2NaOH +Cl2 → NaCl +NaClO + H2O **(1)**

*OR 2OH– + Cl2 → Cl– + ClO– (or OCl–) + H2O  
Both products must be salts*

**1**

(d)     (i)      Cl2 + 2 KI → 2 KCl +I2 **(1)**

*OR ionic equation*

(ii)     I2 + 2Na2S2O3 → 2NaI + Na2S4O6**(1)**

*Or ionic equation*

(iii)     Moles thio =  = 1.08 × 10–4 **(1)**

*Penalise missing 1000 as AE – 1*

         Moles of I2 = moles of Cl2 =  = 5.4 × 10–5 **(1)**

         Mass of Cl2 = moles of Cl2 × Mr = 5.4 × 10–5 × 71 **(1)**

                   = 3.8(34) × 10–3 g dm–3 **(1)**

*Allow 3.8(0) to 3.85 × 10–3 g dm–3*

**6**

**[10]**

**M4.**          (a)     (i)      HNO3 or CH3COOH **(1)**

*CE in (a) if incorrect acid given*

(ii)     2HNO3 + Na2CO3 → 2NaNO3 + CO2 +H2O **(1)**   
OR 2H +  + CO32- → H2O + CO2   
Not H2CO3

**2**

(b)     (i)      I– or At– not elements, atoms or molecules **(1)**

(ii)     F– not elements, atoms or molecules **(1)**

**2**

(c)     (i)      Cl– **(1)**

*Allow AgCl Not element, atoms or molecules*

(ii)     Br– **(1)**

*Allow AgBr Not element, atoms or molecules*

**2**

**[6]**

**M5.**          (a)     (i)      –2 OR 2–

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

*Not atoms or molecules*

(iii)     Smell of bad eggs **(1)**

*Allow PbAc2 goes black and K2Cr2O7/H+ goes  
cloudy green*

(iv)    8 e– + 8 H+ + H2SO4 → H2S + 4H2O **(1)**

*OR 10 H+ +SO42–*

**4**

(b)     (i)      HF or HCl **(1)**

*CE = 0 if redox answer given*

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

*If NaF or NaCl, or F– or Cl– given lose mark in (i)*

*Mark on if X is e.g. HF2 or H2F*

(ii)     NaF or NaCl or F– or Cl– **(1)**

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

(iv)    H+ +F– → HF

*OR H2SO4 + NaF → NaHSO4 + HF*

*OR H2SO4 + 2 NaF → Na2SO4 + 2 HF*

*OR for chloride*

**4**

**[8]**

**M6.**          (a)     *Trend*: decrease **(1) C.E if wrong***Explanation*: number of shells increases (or atomic radius increases) **(1)**increased nuclear shielding **(1)**or less attraction for bond (pair electrons)

**3**

(b)     (i)      *Observation*: brown solution or black solid **(1)**

*purple wrong*

*Equation*: Br2 + 2I– → I2 + 2Br– **(1)**

*Allow NaI, KI*

(ii)     Br2 is a weaker oxidising agent than Cl2 **(1) (or converse)**

**3**

*OR Br2 is less reactive than Cl2penalise Cl, Br, Cl–, Br– etc*

(c)     *Observation with KF (aq)*: no change **(1) (or colourless)***Observation with KBr(aq)*: cream/off white ppt **(or solid) (1)**

**2**

(d)     KF + H2SO4 → KHSO4 + HF **(1)**

*or 2 KF + H2SO4 → K2HSO4 + 2 HF   
Allow ions*

**1**

(e)     2 H2SO4 + 2 Br– → SO2 + Br2 + 2 H2O + SO42–**(1)**Balanced equation **(1)**

*Allow 2 H2SO4 + 2 NaBr → SO2 + Br2 + 2 H2O + Na2SO4H2SO4 + 2 HBr → 2 H2O + Br2 + SO2 etc*

**2**

**[11]**

**M7.**(a)     increases from fluorine to iodine **(1)**

sizes of molecules increase **(1)**(or molecules have more electrons or mass of molecules increases)

*QoL mark*

Magnitude of intermolecular forces or vdW forces increase **(1)** (or more vdW forces)

More energy required to separate molecules (or particles) **(1)**(or more energy to break intermolecular forces)  
or intermolecular forces difficult to break

**4**

(b)     with NaCl           white ppt **(1)**                          soluble in ammonia **(1)**

*note, if ppt clearly refers to wrong substance   
e.g. NaCl then C.E = 0*

with NaBr          cream (or off white or biege) ppt **(1)**                 partially soluble (or insoluble) in ammonia **(1)**

*ignore references to conc ammonia*

*if obviously added silver nitrate mixed with ammonia allow:  
NaCl: no change* ***(2)****NaBr: cream ppt* ***(2)***

**4**

(c)     oxidising ability decreases from chlorine to iodine (or down the Group) **(1)**

          Cl2 + 2Br– → 2Cl– + Br2 **(1)**

*allow use of NaBr, HBr etc*

          Br2 red brown (or yellow or orange) liquid (or solution but not solid) **(1)**

          Cl2 + 2I– → 2Cl– + I2 **(1)**

*allow use of NaBr etc, penalise HI once only*

          I2 brown solution / black solid **(1)**

*do not allow any reference to purple*

          Br2 + 2I– → 2Br– + I2 **(1)**

          Yellow/orange/red-brown/brown solution goes brown/darker  
brown solution/black solid **(1)**

**7**

**[15]**

**M8.**          (a)     Fluorine or F2 or F **(1)**

*NOT Fl*

**1**

(b)     I– (or At–) **(1)**

*allow +e– but not equation*

**1**

(c)     *Observation with NaF(aq):* no change OR colourless solution  
                                         OR remains colourless **(1)**

*Observation with NaI (aq)*: yellow solid / percipitate **(1)**

*Equation*: I–(aq) + Ag+(aq) → AgI(s) **(1)** or NaI (aq) + AgNO3 (aq) → NaNO3(aq) + AgI(s)

*no ss no marks*

**3**

(d)     *Observation*: steamy / white / misty fumes **(1)**

*NOT smoke / gas*

*Equation*: NaCl + H2SO4 → NaHSO4 + HCl

**2**

*Ignore ss*

(e)     *Observation 1*: black / grey solid  
                        lilac / purple gas  
                        pungent / steamy / choking fumes / steam

*Observation 2*: yellow solid / smell bad eggs / stink bombs **(2)**

*any two mark first one on each line*

*Equation*: 2NaI + 2H2SO4 → Na2SO4 + 2H2O + I2 + SO2two reduction products from  
Na2SO4 e.g. H2S or S or SO2 + I2(s) **(1)**

**4**

*balanced equation* ***(1)***

(f)      *Observation*: (Starts) blue or black **(1)** → colourless **(1)**

*Equation*: I2 + 2Na2S2O3 → 2NaI + Na2S4O6 **(1)** (or I2 + 2S2O32– → 2I– + S4O62–)

**3**

**[14]**

**M9.**(a)     Increase

**1**

Van der Waal’s forces between molecules

**1**

Increase with size (or *M*r or surface area etc)

**1**

More energy needed to break (overcome) these forces

*(Note max 2 from last three marks if no mention of molecules or ‘molecular’)*

**1**

(b)     (i)      Brown solution (or yellow or orange)

**1**

         Cl2 + 2Br → 2C1– + Br2

**1**

(ii)     cream precipitate

**1**

         Br– + Ag+ → AgBr

**1**

         Precipitate dissolves

**1**

(iii)     orange (brown) fumes (gas), White fumes (or misty fumes),  
choking gas (any 2)

**2**

(c)     2H+ + H2SO4+ 2Br– → SO2 + Br2 + 2H2O (SO2 and Br2 (1),  
equation (1))

**2**

**[13]**

**M10.**          (a)     decreases;

**1**

increase in shielding ;

**1**

*(or atomic radius)*less attraction for bonding *(or shared)* electrons;

**1**

(b)     brown solution;

**1**

(or black solid)  
Cl2 + 2KI → 2KCl +I2;

(or ionic equation)

**1**

(c)     SO2;

**1**

****;

**1**

S (also H2S);

**1**

****)

**1**

(d)     Cl2 + 2NaOH → NaCl + NaOCl + H2O;

**1**

sodium chloride;

**1**

–1;

**1**

sodium chlorate(I) (or bleach etc);

**1**

+1;

**1**

**[14]**

**M11.**          (a)     decreases

**1**

number of shells increases/ shielding increases /atomic  
size increases

weaker attraction (by nucleus) on bonding electrons / weaker  
attraction (by nucleus)

**1**

on electron pair in a covalent bond

**1**

(b)     (i)      increases

**1**

(ii)     concentrated sulphuric acid

**1**

(c)     white ppt

**1**

soluble in ammonia

**1**

cream ppt

**1**

partially soluble /insoluble in ammonia

**1**

(d)     Cl2 + 2NaOH → NaCl + NaOCl +H2O

**1**

bleach

**1**

disinfectant /steriliser/kills bacteria

**1**

**[12]**

**M12.**          (a)     Reduction involves gain of electrons (1)

A reducing agent loses (donates) electrons (1)

**2**

(b)     (i)      Sulphur dioxide (1)

oxidation state +4 (1)

Sulphur (1)

oxidation state 0 (1)

Hydrogen sulphide (1)

oxidation state – 2 (1)

**6**

(ii)     Sulphur dioxide is a choking gas or has a pungent odour (1)

Sulphur is a yellow solid (1)

Hydrogen sulphide has a smell of bad eggs (1)

*Any 2 marks*

**2**

(iii)     SO42– + 4H+ + 2e–  → SO2 + 2H2O (1)

SO42– + 8H+ + 6e– → S + 4H2O (1)

SO42– + 10H+ + 8e– → H2S + 4H2O (1)

*Any 2 marks*

*(Allow equations with H2SO4)*

**2**

(c)     Cl2 + H2O → H+ + Cl– + HOCl

or Cl2 + H2O → 2H+ + Cl– + OCl–

or Cl2 + H2O → HCl + HOCl         (1)

Water is not oxidised (1)

The oxidation states of O (–2) and H (+1) remain unchanged (1)

**3**

**[15]**

**M13.**

|  |  |
| --- | --- |
| **Mark Range** | The marking scheme for this part of the question includes an overall assessment for the Quality of Written Communication (QWC). There are no discrete marks for the assessment of QWC but the candidates’ QWC in this answer will be one of the criteria used to assign a level and award the marks for this part of the question  **Descriptor** an answer will be expected to meet most of the criteria in the level descriptor |
| 4-5 | –    claims supported by an appropriate range of evidence  –    good use of information or ideas about chemistry, going beyond those given in the question  –    argument well structured with minimal repetition or irrelevant points  –    accurate and clear expression of ideas with only minor errors of grammar, punctuation and spelling |
| 2-3 | –    claims partially supported by evidence  –    good use of information or ideas about chemistry given in the question but limited beyond this  –    the argument shows some attempt at structure  –    the ideas are expressed with reasonable clarity but with a few errors of grammar, punctuation and spelling |
| 0-1 | –    valid points but not clearly linked to an argument structure  –    limited use of information or ideas about chemistry  –    unstructured  –    errors in spelling, punctuation and grammar or lack of fluency |

(a)     Kills bacteria / prevents bacterial diseases QWC

**1**

          Chlorine is a toxic substance

**1**

          Cl2 + H2O → HCl + HClO

**1**

(b)     Cl2(aq) to Br–(aq);        yellow-orange or yellow-red or QWC  
                                   yellow-brown solution

**1**

                                             2Br– + Cl2 → 2Cl– + Br2                                   or molecular equation

**1**

Cl2(aq) to I–(aq);           brown/black solution formed or QWC  
                                   black/brown/grey ppt/solid

**1**

                                   2I– + Cl2 → 2Cl– + I2

*or molecular equation*

**1**

(c)     Bromide:                     Brown/orange fumes

**1**

                                             Bromine produced

**1**

                                             Sulphur dioxide produced

**1**

Iodide:                         Purple fumes or black/brown/grey solid QWC  
                                   or smell of bad eggs

**1**

                                             Iodine produced

**1**

                                             SO2, S, H2S produced (one mark each)

**3**

Half-equations            2Br– → Br2 + 2e–1  
                                   OR 2I– →I2 + 2e–

**1**

                                   H2SO4 + 2e– + 2H+ → SO2 + 4H2O  
                                   OR H2SO4 + 6e– + 6H+ → S + 4H2O  
                                   OR H2SO4 + 8e– + 8H+ → H2S + 4H2O

**1**

          Overall equation Any correct equation based on half-equations QWC

**1**

**[18]**

**M14.**          (a)     **M1**    MnO2 + 4H+ + 2e– → Mn2+ + 2H2O

**1**

*OR multiples*

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

*Ignore state symbols*

*M2 NOT an “electron pair acceptor”*

**1**

**M3**    MnO2 is the oxidising agent

*Ignore “takes electrons” or “takes away electrons”*

**1**

(b)     **M1**    Formation of SO2 and Br2 (could be in an equation)

**1**

**M2**    Balanced equation  
**Several possible equations  
2**KBr + **3**H2SO4 → **2**KHSO4 + Br2 + SO2 + **2**H2O  
**OR  
2**KBr + 2H2SO4 → K2SO4 + Br2 + SO2 + **2**H2O

**1**

**M3**    **2**KBr + Cl2 → **2**KCl + Br2

*M2 Could be ionic equation with or without K+****2****Br– +* ***6****H+ +* ***3****SO42– → Br2 +* ***2****HSO4– + SO2 +* ***2****H2O  
(****3****H2SO4)*

***2****Br– +* ***4****H+ + SO42– → Br2 + SO2 +* ***2****H2O  
(****2****HBr + H2SO4)*

*Accept HBr and H2SO4 in these equations as shown or mixed variants that balance.  
Ignore equations for KBr reacting to produce HBr  
M3 Could be ionic equation with or without K+****2****Br– + Cl2 →* ***2****Cl– + Br2*

**1**

**M4**    % atom economy of bromine

          = 

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

*M4 Ignore greater number of significant figures*

**1**

**M5**    One from:

•        High atom economy

•        Less waste products

•        Cl2 is available on a large-scale

•        No SO2 produced

•        Does not use concentrated H2SO4

•        (Aqueous) KBr or bromide (ion) in seawater.

•        Process 3 is simple(st) or easiest to carry out

*M5 Ignore reference to cost  
Ignore reference to yield*

**1**

(c)     **M1**    HBr        **–1**

**1**

**M2**    HBrO     **(+)1**

**1**

**M3**    Equilibrium will shift to the right  
***OR***L to R  
***OR***Favours forward reaction  
***OR***Produces more HBrO

**1**

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

**1**

**[12]**

**M15.**          (a)     Hydrochloric acid contains chloride ions / Cl–***OR***Chloride ions / Cl– (in the acid) would react  
***OR***Chloride ions / Cl– would interfere with the test  
***OR***Would form a (white) precipitate  
***OR***Would form insoluble AgCl

*QoL*

*If a precipitate colour is given it must be white*

**1**

(b)     **M1**    No precipitate  
***OR***Colourless solution  
***OR***No change.

**1**

*Ignore “nothing”*

**M2**    Silver fluoride / AgF is soluble (in water)

*Do not penalise the spelling “flouride”*

**1**

(c)     **M1**    Yellow precipitate  
***OR***Yellow solid

*Both words needed for M1  
Ignore “pale” as a prefix before “yellow”*

**1**

**M2**    Ag+ + I– → AgI

*Ignore state symbols  
Allow crossed out nitrate ions, but penalise if not crossed out*

**1**

**[5]**

**M16.**          (a)     **M1** Cl2 (provides the pale green colour)

*M1 requires the formula*

**M2** NaOH reacts with the acid(s)/the HCl/the HClO/H+

*Ignore “reacts with the products”*

*Ignore “reacts with chloride ion”  
Ignore “reacts with chlorine”*

**M3 requires a correct answer in M2**Equilibrium shifts (from left ) to right ***OR*** wtte

**3**

(b)     **M1** A reducing agent is an electron donor OR (readily) loses/  
gives away electrons

*Penalise M1 if “electron pair donor”*

**M2** Cl2 + **2**e– → **2**Cl–

For M3 and M4, **i**odide ions are stronger reducing agents than  
chloride ions, because

*Ignore state symbols in M2 Accept no charge on the electron  
Credit the electrons being lost on the RHS*

**M3 Relative size of ions/atomic radius/ionic radius**Iodide ions are larger/have more (electron) shells/levels than  
chloride ions (or converse for chloride ion) OR electron(s) to be  
lost/outer shell/level is further from the nucleus (or converse for  
chloride ion) OR greater/more shielding

*For M3 insist on “iodide ions”*

**M4 Strength of attraction for electron(s) being lost**Electron(s) lost from an iodide ion is less strongly held by the nucleus  
compared with that lost from a chloride ion

*M3 and M4 must be comparative and should refer to electrons.*

(assume argument refers to iodide ions but accept converse argument  
for chloride ions)

**4**

(c)     **M1 2**Cl2 + **2**H2O → **4**HCl + O2

*Or multiples*

**M2** silver chloride ONLY

*M2 requires a name*

**M3** The solid/precipitate would dissolve  
***OR*** is soluble  
***OR*** (It) forms a (colourless) solution

*Mark M3 independently*

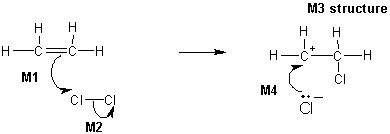
*Ignore “disappears”*

**3**

(d)     Electrophilic addition

**1**

Mechanism:



*M2 Penalise partial charges if wrong way around, otherwise ignore*

*Max 3 marks* ***for the mechanism*** *for wrong reactant and/or “sticks” (wrong reactant could be HBr or Br2 or incorrect alkene)*

**M1** must show an arrow from the double bond towards one of the  
Cl atoms on a Cl–Cl molecule.

**M2** must show the breaking of the Cl–Cl bond.

**M3** is for the structure of the carbocation with Cl substituent.

**M4** must show an arrow from the lone pair of electrons on a negatively  
charged chloride ion towards the positively charged carbon atom.

**4**

**[15]**

**M17.**          (a)     NaBr ONLY

*Penalise incorrect case or additional formulae.  
Ignore names*

**1**

(b)     NaF ONLY

*Penalise incorrect case or additional formulae.  
Ignore names*

**1**

(c)     ONLY one from either  
NaF

***OR***

NaCl

*Penalise incorrect case or additional formulae.  
Ignore names*

**1**

(d)     NaI ONLY

*Penalise incorrect case or additional formulae.  
Ignore names*

**1**

**[4]**

**M18.**          (a)     (i)      **M1    Initiation**Cl2  2Cl•

**M2    First propagation**

Cl• + CH3CH3  •CH2CH3 + HCl  
C2H6

**M3**    **Second propagation**

Cl2 + •CH2CH3  CH3CH2Cl + Cl•  
                          C2H5Cl

**M4**    **Termination (must make C4H10)**

2 •CH2CH3  C4H10 or CH3CH2CH2CH3

*Penalise absence of dot once only.*

*Penalise + or – charges every time*

*Penalise incorrect position of dot on ethyl radical once only.*

*Penalise C2H5• once only*

*Accept CH3CH2 • with the radical dot above/below/to the side of the CH2*

*Mark independently*

**4**

(ii)     **M1** ultra-violet/uv/sun light  
OR (very) high temperature OR 500 °C ≥ T ≤1000 °C

**M2**    (free-)radical substitution

*Ignore “heat” for M1*

*Both words needed for M2*

*For M2, ignore the word “mechanism”*

**2**

(b)     (i)      Cl2 + H2O  HClO + HCl

***OR***

Cl2 + H2O  2H+ + ClO– + Cl–

*Accept HOCl or ClOH*

*Accept other ionic or mixed representations*

*Ignore state symbols*

**1**

(ii)     **M1**    Any one from

•        in swimming pools

•        in drinking water

•        to sterilise/disinfect/sanitise water

•        in water treatment

*Ignore the manufacture of bleach  
Ignore “to clean water”  
Ignore “water purification”*

**M2**    The (health) benefit outweighs the risk or wtte  
OR a clear statement that once it has done its job,  
little of it remains OR used in (very) dilute concentrations/  
small amounts/low doses

*Mark independently but M1 can score from (M2) explanation*

**2**

(iii)     Sodium chlorate(I) or sodium hypochlorite

*Must be named*

*Ignore (in)correct formulae*

*Insist on the (I) in the name*

**1**

(c)     (i)      Cl2 + **2**Br–  Br2 + **2**Cl–

*Or half this equation*

*Ignore state symbols*

**1**

(ii)     **M1    The relative size (of the molecules/atoms)**Bromine is larger than chlorine OR has more  
electrons/electron shells  
***OR*** It is larger/It has a larger atomic radius/it is a   
larger molecule/atom

**M2**    **How size of the intermolecular force affects  
energy needed**   
The forces between bromine/Br2 molecules are  
stronger (than the forces between chlorine/Cl2molecules leading to more energy needed to  
separate the molecules) (or converse)  
***OR*** bromine/Br2 has stronger/more (VdW) intermolecular  
forces.  
(or converse)

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

*CE = 0 for reference to (halide) ions*

*Ignore molecular mass*

***QoL*** *for clear reference to the difference in size of the force between molecules*

*Penalise M2 if covalent bonds are broken*

**2**

**[13]**

**M19.**          (a)     (i)      MnO2 (+) 4

**1**

(ii)     MnO2 + **4**H+ + **2**e–  Mn2+ + **2**H2O

*Or multiples*

*Ignore state symbols*

*Credit electrons subtracted from RHS*

*Ignore absence of charge on e*

**1**

(iii)     Iodide ion(s) is/are oxidised because they have lost electron(s)

*Do not penalise reference to iodine; the mark is for electron loss*

**1**

(b)     (i)      **M1**       Cl2         0

**M2** HClO   (+) 1

**2**

(ii)     **M1**    Equilibrium will shift/move to the right

OR    L to R

OR    to favour the forward reaction

OR    to produce more HClO

**M2**    **Consequential on correct** **M1**

          To oppose the loss of HClO

OR    replaces the HClO (that has reacted)

*for M2*

*NOT just “to oppose the change”*

**2**

(c)     (i)      The answers can be in **either order**

**M1**    **2**Br–  Br2 + **2**e–

**M2    4**H+ + SO42– + **2**e–  SO2 + **2**H2O

OR

**2**H+ + H2SO4 + **2**e–  SO2 + **2**H2O

*NOT multiples*

*Ignore state symbols*

*Credit electrons subtracted from incorrect side*

*Ignore absence of charge on e*

**2**

(ii)     KCl + H2SO4  KHSO4 + HCl

OR

**2**KCl + H2SO4  K2SO4 + **2**HCl

*Credit ionic equations*

**1**

(iii)     For M1 and M2, chloride ions are weaker reducing agents  
than bromide ions, because

**M1    Relative size of ions**

Chloride ions are smaller than bromide ions OR  
chloride ion electron(s) are closer to the nucleus  
OR chloride ion has fewer (electron) shells/levels  
OR chloride ion has less shielding (or converse for  
bromide ion)

**M2    Strength of attraction for electron being lost**

Outer shell/level electron(s) OR electron(s) lost  
from a chloride ion is more strongly held by the  
nucleus compared with that lost from a bromide  
ion (or converse for bromide ion)

*If the forces are described as intermolecular or Van der Waals then CE = 0*

*Ignore general reference to Group 7 trend*

*For M1 accept reference to chlorine/bromine or reference to atoms of these but NOT “chloride/bromide atoms” or “chlorine/bromine molecules”*

*For M2 insist on reference to the correct ions*

*This is the expected answer, but award credit for a candidate who gives a correct explanation in terms of hydration enthalpy, electron affinity and atomisation enthalpy.*

**2**

**[12]**

**M20.**          (a)     **M1** AgNO3 OR silver nitrate OR any soluble silver salt

**M2** remains colourless or no reaction or no (observed)  
change or no precipitate

**M3** white precipitate or white solid/white suspension

*An insoluble silver salt OR Tollens’ OR ammoniacal silver nitrate or HCl/AgNO3 is CE = 0 for the clip*

*For M1*

*Credit acidified (or HNO3) silver nitrate for M1 and mark on*

*If silver ions or incorrect formula for silver nitrate, penalise M1 but mark M2 and M3*

*If no reagent or incorrect reagent in M1, then no marks for M2 or M3*

*For M2*

*Ignore “nothing”*

*Ignore “no observation”*

*Ignore “clear”*

*Ignore “dissolves”*

*For M3*

*Ignore “cloudy solution” OR “suspension”*

**3**

(b)     **M1** any soluble sulfate by name or formula e.g. sodium sulfate  
or sulfuric acid.

**M2** white precipitate or white solid/white suspension

**M3** remains colourless or no reaction or no (observed) change  
or no precipitate

***OR*** as an alternative

**M1** NaOH/KOH

**M2** remains colourless or no reaction or no (observed) change

**M3** white precipitate or white solid/white suspension

*An insoluble sulfate OR conc H2SO4 is CE = 0 for the clip*

*If no reagent or incorrect reagent in M1, then no marks for M2 or M3*

*For the M1 soluble sulfate*

*If sulfate ions or incorrect formula for the chosen sulfate, penalise M1 but mark M2 and M3*

*For the M1 NaOH/KOH*

*If ammonia, then CE = 0*

*If hydroxide ions or incorrect formula for the chosen hydroxide, penalise M1 but mark M2 and M3*

*For no (observed) change in both alternatives*

*Ignore “nothing”*

*Ignore “no observation”*

*Ignore “clear”*

*Ignore “dissolves”*

*For the white precipitate in both alternatives*

*Ignore “cloudy solution” OR “suspension”*

**3**

(c)     **M1** ammonia (can be dilute or concentrated)

**M2** dissolves OR soluble OR (forms a) colourless  
solution OR goes colourless

**M3** does not dissolve OR not soluble OR remains as a solid  
OR no (observed) change OR no reaction OR yellow solid remains

OR if concentrated ammonia has been used, accept yellow  
solid turns white.

OR as an alternative using conc sulfuric acid

**M1**    concentrated sulfuric acid OR c(onc) H2SO4

**M2** misty/white fumes/gas

OR remains white

OR no change (in colour)

**M3** turns black (solid)

OR purple fumes/gas

OR correct reference to H2S observation (e.g. bad egg smell)

*For M1*

*If incorrect formula or “ammonium”, penalise M1 but mark M2 and M3*

*If no reagent or incorrect reagent in M1, then no marks for M2 or M3*

*For M3*

*Ignore “nothing”*

*Ignore “no observation”*

*For the alternative using sulfuric acid*

*If dilute sulfuric acid or “aq” (alone) or the idea of concentrated not included CE = 0*

*If incorrect formula, penalise M1 but mark M2 and M3*

*If no reagent or incorrect reagent in M1, then no marks for M2 or M3*

**3**

(d)     **M1** acidified potassium dichromate or K2Cr2O7/H2SO4

OR K2Cr2O7/H+ OR acidified K2Cr2O7

**M2**    (orange to) green solution OR goes green

**M3**    (solution) remains orange or no reaction or no (observed) change

Alternative using KMnO4/H2SO4

**M1** acidified potassium manganate(VII) or KMnO4/H2SO4

OR KMnO4/H+ OR acidified KMnO4

**M2**    colourless solution OR goes colourless

**M3** (solution) remains purple or no reaction or no (observed) change

*If no reagent or incorrect reagent in M1, then no marks for M2 or M3*

*For M1*

*If “dichromate” or “dichromate(IV)” or incorrect formula or no acid, penalise M1 but mark M2 and M3*

*For M2 ignore dichromate described as “yellow” or “red”*

*For M3*

*Ignore “nothing”*

*Ignore “no observation”*

*For M1*

*If “manganate” or “manganate(IV)” or incorrect formula or no acid, penalise M1 but mark M2 and M3*

*Credit alkaline KMnO4 for possible full marks but M2 gives brown precipitate or solution goes green*

**3**

**[12]**

**M21.**          (a)     (i)      **M1** (yellow precipitate is) silver iodide OR AgI (which  
may be awarded from the equation)

**M2** Ag+ + I– → AgI (Also scores M1 unless contradicted)

**M3** sodium chloride OR NaCl

*For M2*

*Accept multiples*

*Ignore state symbols*

*Allow crossed out nitrate ions, but penalise if not crossed out*

**3**

(ii)     The silver nitrate is acidified to

•        react with / remove ions that would interfere with the test

•        prevent the formation of other silver precipitates / insoluble silver compounds that would interfere with the test

•        remove (other) ions that react with the silver nitrate

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

*Ignore reference to “false positive”*

**1**

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

**M1** Fluoride (ion) OR F–

**M2**    •    Silver fluoride / AgF is soluble / dissolves (in water)

         •    no precipitate would form / no visible /observable change

*Do not penalise the spelling “fluoride”,*

*Penalise “fluride” once only*

*Mark M1 and M2 independently*

**2**

(b)     **M1** Ba2+ + SO42- → BaSO4

(or the ions together)

**M2** white precipitate / white solid / white suspension

**M3** Barium meal or ( internal ) X-ray or to block X-rays

**M4** BaSO4 / barium sulfate is insoluble (and therefore not toxic)

*For M1, ignore state symbols*

*Allow crossed out sodium ions, but penalise if not crossed out*

*For M2, ignore “milky”*

*If BaSO3 OR BaS used in M1 and M4, penalise once only*

*For M3 Ignore radio-tracing*

*For M4 NOT barium ions*

*NOT barium*

*NOT barium meal*

*NOT “It” unless clearly BaSO4*

**4**

(c)     **M1 2**(12.00000) + **4**(1.00794) = 28.03176

**M2** Ethene and CO or “they” have an imprecise **M*r*** of 28.0 / 28

OR

Ethene and CO or “they” have the same *M*r to one d.p.

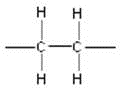
OR

These may be shown by two clear, simple sums identifying  
both compounds

**M3** C2H4 + **2**O2 → **2**CO + **2**H2O

(H2C=CH2)

**M4** Displayed formula



**M5** Type of polymer = Addition (polymer)

*M1 must show working using 5 d.p.for hydrogen*

*Penalise “similar” or “close to”, if this refers to the imprecise value in M2, since this does not mean “the same”*

*For M3, accept CH2=CH2 OR CH2CH2*

*For M4, all bonds must be drawn out including those on either side of the unit.*

*Penalise “sticks”*

*Ignore brackets around* ***correct*** *repeating unit but penalise “n”*

*Penalise “additional”*

**5**

**[15]**

**M22.**          (a)     Ca(OH)2 OR Mg(OH)2

*Ignore name*

*Could be ionic*

**1**

(b)     NaF or sodium fluoride

OR

NaCl or sodium chloride

*Either formula or name can score*

*Do not penalise the spelling “fluoride”*

*When both formula and name are written,*

*•    penalise contradictions*

*•    if the attempt at the correct* ***formula*** *is incorrect, ignore  
     it and credit* ***correct name*** *for the mark unless  
     contradictory*

*•    if the attempt at the correct name is incorrect, ignore it  
     and credit* ***correct formula*** *for the mark unless contradictory*

**1**

(c)     NaClO OR NaOCl

*Ignore name (even when incorrect)*

*The correct formula must be clearly identified if an equation is written*

**1**

(d)     **Br2** (ONLY)

*Only the correct formula scores;*

*penalise lower case “b”, penalise upper case “R”, penalise superscript*

*Ignore name*

*The correct formula must be clearly identified if an equation is written*

**1**

(e)     **M1** S OR S8 OR S2

**M2** I2 (ONLY)

*Ignore names*

*penalise lower case “i” for iodine,*

*penalise superscripted numbers*

*Mark independently*

*The correct formula must be clearly identified in each case if an equation is written*

**2**

(f)      (i)      CH3CH2CH=CH2

*Structure of but-1-ene. Ignore name*

*Credit “sticks” for C-H bonds*

**1**

(ii)     CH3CH2CH2CH2OH

*Structure of butan-1-ol. Ignore name*

*Credit “sticks” for C-H bonds*

**1**

(iii)     CH3CH2CH3

*Structure of propane. Ignore name*

*Ignore calculations and molecular formula*

*Credit “sticks” for C-H bonds*

*Ignore the molecular ion*

**1**

(iv)    CH3CH2Br OR C2H5Br

*Structure of bromoethane.*

*Ignore name and structure of nitrile*

*Credit “sticks” for C-H bonds*

**1**

**[10]**

**M23.**(a)      (i)     **M1     0**

**M2     (+) 5**

*Accept Roman V for M2*

**2**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (ii) | I2 | + | 10HNO3 |  | **2**HIO3 | + | **10**NO2 | + | **4**H2O |

*Accept multiples*

**1**

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| (b) | **M1** | IO3– | + | **6**H+ | + | **5**I – |  | **3**I2 | + | **3**H2O |

*For M1, ignore state symbols*

*Credit multiples*

*Accept 2½I2 + ½I2 as alternative to 3I2*

*Electrons must be cancelled*

**M2**    NaIO3 ***OR*** IO3– ***OR*** iodate ions ***OR*** iodate(V) ions etc.

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

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

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

**2**

(c)     (i)     Iodine ***OR*** I2

*Insist on correct name or formula*

**1**

(ii)     H2SO4   +   **6**H+   +   **6**e–      S   +   **4**H2O

*Ignore state symbols*

SO42–   +   **8**H+   +   **6**e–      S   +   **4**H2O

*Credit multiples*

*Do not penalise absence of charge on the electron*

**1**

(d)     hydrogen sulfide

***OR*** H2S

***OR*** hydrogen sulphide

**1**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| (e)    (i) | Ag+ | + | I – |  | AgI | ONLY |

*Ignore state symbols*

*No multiples*

**1**

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

*ignore “nothing (happens)”*

***OR*** turns to a white solid

*ignore “no observation”*

***OR*** stays the same

***OR*** no (visible/ observable) change

***OR*** no effect / no reaction

**1**

(iii)    The silver nitrate is acidified to

•    react with / remove (an)ions that would interfere with the test

*Ignore reference to “false positive”*

•    prevent the formation of other silver precipitates / insoluble silver  
     compounds that would interfere with the test

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

•    remove (other) ions that react with the silver nitrate

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

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

**1**

(f)     (i)     An electron donor

*Penalise “electron pair donor”*

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

*Penalise “loss of electrons” alone*

*Accept “electron donator”*

**1**

(ii)     Cl2    +    **2**e–        **2**Cl–

*Ignore state symbols*

*Do not penalise absence of charge on electron*

*Credit Cl2 * ***2****Cl – –* ***2****e –*

*Credit multiples*

**1**

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

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

**M1   Relative size of ions**

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

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

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

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

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

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

***OR*** converse for chloride ion

**M2   Strength of attraction for electron(s)**

*Must be comparative in both M1 and M2*

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

***OR*** converse for a chloride ion

**2**

**[15]**

**M24.**         (a)      (i)     **M1**    iodine ***OR*** I2 OR I3–

*Ignore state symbols*

*Credit* ***M1*** *for “iodine solution”*

**M2**    Cl2 + **2**I –  **2**Cl – + I2***OR***½ Cl2 + I –  Cl – + ½ I2

*Penalise multiples in M2 except those shown*

***M2*** *accept correct use of I3–*

**M3**    redox or reduction-oxidation or displacement

**3**

(ii)     **M1**    (the white precipitate is) silver chloride

***M1*** *must be named and for this mark ignore incorrect formula*

**M2**    Ag+ + Cl –  AgCl

*For* ***M2*** *ignore state symbols*

*Penalise multiples*

**M3**    (white) precipitate / it dissolves

***OR***    colourless solution

*Ignore references to “clear” alone*

**3**

(b)     (i)      **M1**    H2SO4 + **2**Cl –  **2**HCl + SO42–

*For* ***M1*** *ignore state symbols*

***OR***    H2SO4 + Cl–  HCl + HSO4–

*Penalise multiples for equations and apply the list principle*

***OR***    H+ + Cl–  HCl

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

**2**

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

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

**M1    2**I –  **I**2 + **2**e –

***OR***

**8**I –  **4**I2 + **8e –**

***Do not penalise absence of charge on the electron***

***Credit electrons shown correctly on the other side of each equation***

**M2    H2SO4 + 8H+ + 8e –  H2S + 4H2O**

**OR**

**SO42– + 10H+ + 8e –  H2S + 4H2O**

***Additional equations should not contradict***

**M3    oxidising agent / oxidises the iodide (ions)**

***OR***

**electron acceptor**

**M4    sulfur *OR* S *OR* S2 *OR* S8 *OR* sulphur**

**4**

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

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

***Ignore reference to NaOH reacting with bromide ions***

***Ignore reference to NaOH reacting with HBrO alone***

**M2    Requires a correct statement for M1**

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

**•        to replace the H+ / acid / HBr that has been removed / lost**

**•        *OR*  to increase the H+ / acid / HBr concentration**

**•        *OR* to make more H+ / acid / HBr / product(s)**

**•        *OR* to oppose the loss of H+ / loss of product(s)**

**•        *OR* to oppose the decrease in concentration of product(s)**

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

**M3    The (health) benefit outweighs the risk or wtte**

***OR***

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

***OR***

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

**3**

**[15]**

**M25.(a)     M1 Cl2 + 2Br−  2Cl− + Br2**

***Accept a correct equation using ½ Cl2 but no other multiples***

**M2 solution goes orange / yellow ( from colourless)**

***Ignore reference to brown colour***

***Penalise incorrect observations eg fumes, precipitates***

**2**

**(b)     M1 Cl2 + 2NaOH   NaClO + NaCl + H2O**

**(NaOCl)**

***Or a correct ionic equation***

***Ignore reference to “swimming pools” and to “disinfectant”***

**M2 bleach or kills bacteria / bacteriacide / micro-organisms / microbes**

**M3 sodium chlorate(I) ONLY**

**3**

**(c)     M Cl2 + H2O   HClO + HCl**

**(HOCl)**

***Equilibrium symbol required in M1***

***Accept ionic RHS***

**M2**

**The (health) benefit outweighs the risk or wtte**

***OR***

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

***OR***

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

**2**

**(d)     M1 Silver nitrate OR AgNO3 (with or without nitric acid)**

***For M1***

***If only the formula is written then it must be correct***

***If both the formula and the name are written then ignore incorrect attempt at the formula, but penalise an incorrect name***

**M2 (depends on M1)**

**white precipitate / white solid**

***If the reagent is incomplete eg Ag+ ions, penalise M1 and mark on***

**M3 Ag+ + Cl−  AgCl**

***Penalise both M1 and M2 for alkaline AgNO3 OR for the use of HCl to acidify the silver nitrate OR for Tollens’ reagent***

**3**

**[10]**

**M26.M1 and M2 (either order)**

**Any two from**

**•        purple vapour / gas**

**•        (white solid goes to) black or black / grey or black / purple   
solid**

**•        bad egg smell or words to this effect**

***Ignore misty white fumes  
Ignore yellow solid  
Ignore purple solid  
Ignore “goes (dark) brown”***

**M3**

***Or multiples for possible equation in M3***

**The iodide ion(s) / they lose (an) electron(s)**

***OR***

**2I− I2 + 2e−**

**M4**

***Accept “changes by − 8”***

**Oxidation state of S changes from +6 to −2 or changes by 8**

**M5**

**H2SO4 + 8H+ + 8e− H2S + 4H2O**

***OR***

**SO42− + 10H+ + 8e− H2S + 4H2O**

**[5]**

**M27.(a)     (i)      ½Cl2 + I −   ½ I2 + Cl−**

***Only these two equations.***

**OR**

**Cl2 + 2I−   I2 + 2Cl−**

**1**

**(ii)     (Solution turns from colourless to) brown / red-brown solution**

***Allow grey / black solid.***

***Ignore “purple”.***

**1**

**(b)     2Cl2 + 2H2O   4HCl + O2(4H+ + 4Cl−)**

***Credit multiples.***

**1**

**(c)     M1 The relative size (of the molecules / atoms)  
Chlorine is smaller than bromine OR has fewer electrons / electron shells  
*OR* It is smaller / It has a smaller atomic radius / it is a smaller molecule / or has smaller Mr(or converse for bromine)**

***Ignore general Group 7 statements.***

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

**M2 How size of the intermolecular force affects energy needed  
The forces between chlorine / Cl2 molecules are weaker (than the forces between bromine / Br2 molecules leading to less energy needed to separate the molecules)  
(or converse for bromine)  
*OR* chlorine / Cl2 has weaker / less / fewer forces between molecules *OR* chlorine / Cl2 has weaker / less / fewer intermolecular forces  
(or converse for bromine)**

***CE=0 for reference to (halide) ions.***

***QoL for clear reference to the difference in size of the force between molecules.***

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

**2**

**[5]**

**M28.(a)     M1 concentrated sulfuric acid OR c(onc) H2SO 4**

***If no reagent or incorrect reagent in M1, CE= 0 and no marks for M2 or M3***

**M2 (cream solid) turns orange  
*OR* orange / red / brown fumes / gas / vapour**

***If dilute sulfuric acid OR “aq” (alone) CE=0***

**M3 (yellow solid) turns black  
OR purple fumes / gas / vapour  
*OR* correct reference to H2S observation (eg bad egg smell)**

***If H2SO4 / sulfuric acid given but not stated whether dilute or concentrated, penalise M1 and mark on for M2 and M3  
If incorrect formula for the acid, penalise M1 but mark M2 and M3***

***OR* as an alternative**

**M1 concentrated ammonia *OR* c(onc) NH3**

***If NH3 / ammonia / aq ammonia given, but not stated as concentrated OR if dilute ammonia given, penalise M1 but mark on for*** **M2** and **M3**Ignore “partially” and ignore “clear” in **M2**

M2 (cream solid) dissolves / solution formed

M3 precipitate remains / does not dissolve / insoluble  
***OR*** no reaction / no change / (yellow solid) turns to white solid

*If incorrect formula for ammonia, penalise* ***M1*** *but mark* ***M2*** *and* ***M3***

*In* ***M3*** *for ammonia.  
ignore “nothing (happens)”.  
ignore “no observation”.*

**3**

(b)     M1 AgNO3 ***OR*** silver nitrate ***OR*** any soluble silver salt

*If no reagent* ***OR*** *incorrect reagent in* ***M1****,* ***CE= 0*** *and no marks for* ***M2******OR******M3***

M2 white precipitate or white solid / white suspension

*An insoluble silver salt OR Tollens’* ***OR*** *Ag* ***OR*** *ammoniacal silver nitrate or HCl / AgNO3* ***CE= 0*** *for the clip.*

M3 remains colourless ***OR*** no reaction ***OR*** no (observed) change ***OR*** no precipitate

*For* ***M1****Credit acidified (****OR*** *HNO3) silver nitrate for* ***M1*** *and mark on.  
If silver ions or incorrect formula for silver nitrate, penalise* ***M1*** *but mark* ***M2*** *and* ***M3***

Credit alternative test for nitrate ions

*For* ***M2****Ignore “cloudy solution”* ***OR*** *“suspension”.*

*For* ***M3****Ignore “nothing (happens)”.  
Ignore “no observation”.  
Ignore “clear”.  
Ignore “dissolves”.*

**3**

(c)     M1 Br2 ***OR*** bromine (water) ***OR*** bromine (in CCl4 / organic solvent)

*If no reagent or incorrect reagent in* ***M1****,* ***CE= 0*** *and no marks for* ***M2*** *or* ***M3***

**Either Order**

M2     (stays) Orange / red / yellow / brown / the same  
***OR*** no reaction ***OR*** no (observed) change  
***OR*** reference to colour going to cyclohexane layer

*No credit for combustion observations;* ***CE=0****For* ***M2 in every case****.  
Ignore “nothing (happens)”.  
Ignore “no observation”.  
Ignore “clear”.*

M3 decolourised / goes colourless / loses its colour

***With bromine (water)  
For M1****, it must be a whole reagent and / or correct formula.  
If oxidation state given in name, it must be correct.****For M1*** *penalise incorrect formula, but mark* ***M2*** *and* ***M3***

***OR* as an alternative**

**Use KMnO4/H2SO4**M1 acidified potassium manganate(VII) or KMnO4/H2SO4***OR***    KMnO4/ H+ ***OR*** acidified KMnO4M2 (stays) purple or no reaction or no (observed) change

***With potassium manganate(VII)  
For M1***

M3 purple to colourless solution ***OR*** goes colourless

*If “manganate” or “manganate(IV)” or incorrect formula or no acid, penalise* ***M1*** *but mark* ***M2*** *and* ***M3***

Credit alternative test using **iodine** (for **M1**)  
M2 (brown) to purple or accept no change, M3 colourless  
Credit alternative test using concentrated H2 SO4M2 no change, M3 brown

*Credit alkaline / neutral KMnO4 for possible full marks but* ***M3*** *gives brown precipitate or solution goes green.*

**3**

(d)     M1 Tollens’ (reagent) OR ammoniacal silver nitrate OR a description of making Tollens’  
(Ignore either AgNO3 or [Ag(NH3)2+] or “the silver mirror test” on their own, but mark M2 and M3)  
M2 silver mirror  
***OR*** black solid / precipitate (Ignore silver precipitate)  
M3 (stays) colourless or no reaction or no (observed) change

*If no reagent or incorrect reagent in* ***M1****,* ***CE= 0*** *and no marks for* ***M2*** *or* ***M3***

***For M3 in every case****Ignore “nothing (happens)”.  
Ignore “no observation”.*

Alternative using Fehling’s (solution)  
M1 Fehling’s (solution) or Benedict’s solution  
(Ignore Cu2+(aq) or CuSO4 on their own, but mark M2 and M3)  
M2 Red solid / precipitate (Credit Orange or brown solid)  
M3 (stays) blue or no reaction or no (observed) change

***With potassium dichromate(VI)  
For M1****If “dichromate” or “(potassium) dichromate(IV)” or incorrect formula or no acid, penalise* ***M1*** *but mark* ***M2*** *and* ***M3***

Alternative using K2Cr2O7/H2 SO4M1 acidified potassium dichromate or K2Cr2O7/H2SO4***OR*** K2Cr2O7/H+ ***OR*** acidified K2Cr2O7M2 (Orange to) green solution OR goes green  
M3 (stays) Orange or no reaction or no (observed) change

*For* ***M3****Ignore dichromate described as “yellow” or “red”.*

**With potassium manganate(VII)  
For M1**If “manganate” or “(potassium manganate(IV)” or incorrect formula or no acid, penalise M1 but mark M2 and M3

Alternative using KMnO4 /H2 SO4M1 acidified potassium manganate(VII) or KMnO4 /H2 SO 4***OR*** KMnO 4 /H + ***OR*** acidified KMnO 4M2 purple to colourless solution OR goes colourless  
M3 (stays) purple or no reaction or no (observed) change

*Credit alkaline / neutral KMnO4 for possible full marks but* ***M2*** *gives brown precipitate or solution goes green.*

**3**

**[12]**

**M29.**(a)     (i)      M1 (Yield) increases / goes up / gets more

*If* ***M1*** *is blank, mark on and seek to* ***credit the correct information in the explanation.****If* ***M1*** *is incorrect CE=0 for the clip.*

M2  
The (forward) reaction / to the right is exothermic or gives out / releases heat   
***OR*** The reverse reaction / to the left is endothermic or takes in / absorbs heat

***M3*** *depends on a correct statement for* ***M2***

**M3 depends on correct M2 and must refer to temperature / heat**The (position of ) equilibrium shifts / moves left to right to oppose the  
decrease in temperature

*For* ***M3****, the equilibrium shifts / moves  
to release heat* ***OR****to raise the temperature* ***OR****to heat up the reaction.*

**3**

(ii)     M1    *Concentration(s)* (of reactants and products) remain or stay constant /  
         the same

*For* ***M1*** *credit [ ] for concentration.*

M2    Forward rate = reverse / backward rate

*Not “equal concentrations”.  
Not “concentrations is / are the same”.  
Not “amount”.*

*Ignore “dynamic” and ignore “speed”.*

*Ignore “closed system”.*

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

**2**

(b)     KBr + H2SO4   KHSO4 + HBr

*Credit this equation in its ionic form.*

*Ignore state symbols.*

*Credit multiples.*

**1**

(c)     M1 SO2 identified

**M2 correctly balanced equation (would also gain M1)**

*Credit* ***M2*** *equation in its ionic form.*

*Ignore state symbols.*

**2**HBr + H2SO4   Br2 + SO2 + **2**H2O

*Credit multiples.*

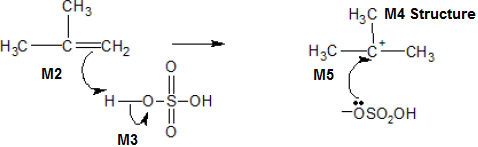
*Not H2SO3 on the right-hand side.*

**Mark M3 independently**M3 Oxidising agent ***OR*** electron acceptor ***OR*** oxidant  
***OR*** to oxidise the bromide (ion) / HBr

***M3*** *Not “electron pair acceptor”.*

**3**

(d)    (i)      **M1 Electrophilic addition**



***M1*** *both words required.*

***For the mechanism  
M3*** *Penalise incorrect partial charges on O − H bond and penalise formal charges  
Ignore partial negative charge on the double bond.*

***M5*** *Not HSO4 –*

*For* ***M5****, credit as shown or −:OSO3H ONLY with the negative charge anywhere on this ion****OR*** *correctly drawn out with the negative charge placed correctly on oxygen.*

M2 must show an arrow from the double bond towards the H atom of the H − O bond / HO on a compound with molecular formula for H2SO4M2 could be to an H+ ion and M3 an independent O − H bond break on a compound with molecular formula for H2SO4

*Max any 3 of 4 marks* ***for a correct mechanism*** *using the wrong organic reactant or wrong organic product (if shown) or a primary carbocation.*

M3 must show the breaking of the O − H bond on H2SO4

*Penalise once only in any part of the mechanism for a line and two dots to show a bond.*

M5 must show an arrow from the lone pair of electrons on the correct oxygen of the negatively charged ion towards the positively charged carbon atom on their carbocation

*Credit the correct use of “sticks”.*

*For* ***M5****, credit attack on a partially positively charged carbocation structure, but penalise* ***M4***

**NB The arrows here are double-headed**

**5**

(ii)     Hydrolysis

*Credit “(nucleophilic) substitution” but do not accept any other prefix.*

*Credit phonetic spelling.*

**1**

(iii)    Catalyst

**1**

**[16]**