PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 2: INORGANIC CHEMISTRY OF GROUP 7 (LIMITED TO CHLORINE, BROMINE AND IODINE)

SCORE	PERCENTAGE
/153	%

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Q1.

Answer the questions with a cross in the boxes you think are correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

A white solid, **X**, gives a red colour in the flame test and a cream precipitate forms when acidified silver nitrate solution is added to a solution of **X**.

(a) What is the white solid, **X**?

(1)

☒ **A** lithium chloride

☒ **B** calcium chloride

☒ **C** strontium bromide

☒ **D** barium bromide

(b) What causes the flame colour to be red?

(1)

☒ **A** electrons absorb blue and green light as they are promoted

☒ **B** electrons emit red light as they are promoted

☒ **C** blue and green light is absorbed as electrons return to lower energy levels

☒ **D** red light is emitted as electrons return to lower energy levels

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 2 marks)

Q2.

This question is about the forces between molecules and ions.

*(a) Some data for three small molecules are shown.

Molecule	M_r	Boiling temperature / °C
Fluorine	38.0	−188
Hydrogen chloride	36.5	−85
Methanol	32.0	65

Explain the large variation in boiling temperatures, given the small range in M_r values.

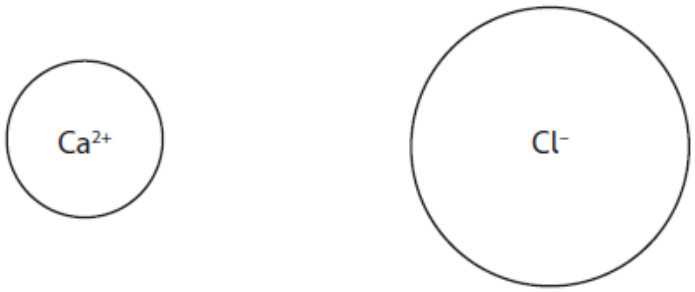
Detailed descriptions of the forces involved are not required.

(6)

(b) Calcium chloride is soluble in water.

Complete the diagram to show how water molecules interact with each ion.
You may use  to represent a water molecule.

(2)



(c) Explain why bromine is a liquid but iodine is a solid at room temperature.

Detailed explanations of the forces involved are not required.

(2)

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(Total for question = 10 marks)

Q3.

This question is about bicycles.

Bicycle frames have been made from steel and aluminium for many years but more recently titanium has been used.

Titanium is a metal that is extracted from its ore, impure titanium oxide (TiO_2), in a two-step process.

Step **1**

The titanium oxide reacts with chlorine in the presence of carbon to form titanium(IV) chloride ($TiCl_4$) and carbon monoxide.

Step **2**

The titanium(IV) chloride reacts with magnesium.

$$TiCl_4 + 2Mg \rightarrow Ti + 2MgCl_2$$

(a) (i) Write the equation for Step **1**.

State symbols are not required.

(1)

(ii) Explain why Step **2** is a redox reaction.

Refer to relevant oxidation numbers in your answer.

(2)

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(b) Titanium(IV) chloride is a liquid that reacts violently with water, producing white smoke. This reaction has been used to produce naval smoke screens to hide ships.

Suggest the type of reaction taking place **and** the compound producing the white smoke.

(2)

Type of reaction

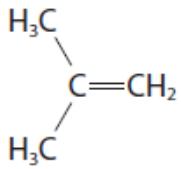
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Compound

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(c) Many bicycles use an inner tube inside the tyre.

A common material used for inner tubes is the addition polymer formed from 2-methylpropene.

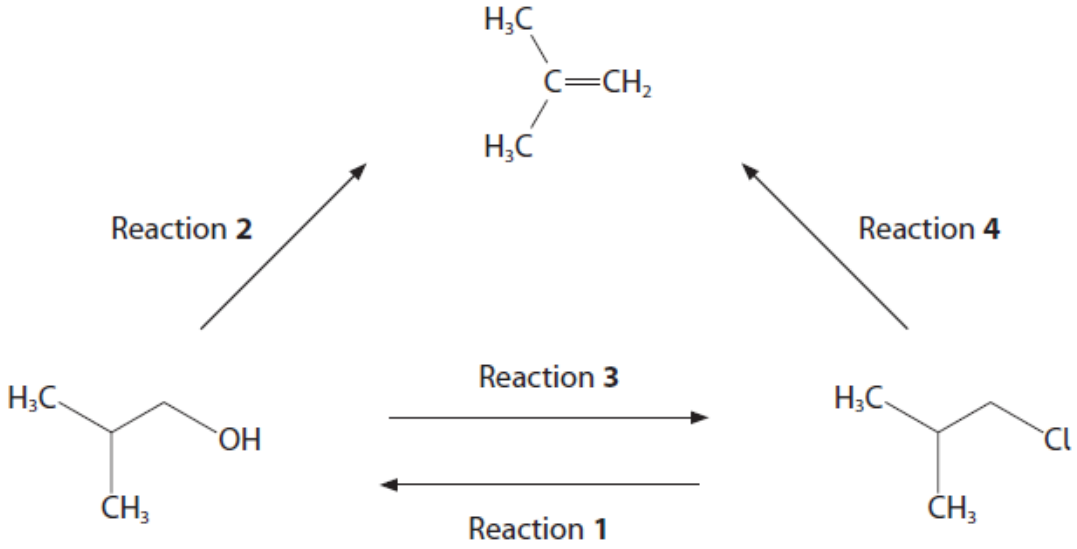


2-methylpropene

Draw a section of the polymer showing two repeat units.

(2)

(d) A reaction scheme involving 2-methylpropene is shown.



(i) For Reaction **1**, give the name or formula of a suitable reagent, stating the conditions for the reaction.

(2)

Reagent

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Conditions

.....

(ii) For Reaction **2**, give the name or formula of a suitable reagent, stating the type of reaction taking place.

(2)

Reagent

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Type of reaction

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(iii) For Reaction **3**, give the name or formula of a suitable reagent, writing an equation for the reaction taking place.

(2)

Reagent

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Equation

(iv) For Reaction **4**, the reagent used is potassium hydroxide (KOH).

Give the conditions required for this reaction, stating the role of the hydroxide ions in this reaction.

(2)

Conditions

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Role of hydroxide ions

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(e) Many cyclists carry a small cylinder of carbon dioxide to inflate their inner tube if it is punctured. The carbon dioxide is stored under pressure.



(Source: © Douglas Sacha/Getty Images)

A gas cylinder contains 16.0 g of carbon dioxide (CO_2).
The cylinder has a volume of 20 cm^3 .

Calculate the pressure in the cylinder at 25 °C. Include units in your answer.
Assume that all the CO_2 in the cylinder is a gas.

[$pV = nRT$ $R = 8.31$ J mol^{-1} K^{-1}]

(5)

(Total for question = 20 marks)

Q4.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which sequence shows the molecules in order of **increasing** boiling temperature?

☐ **A** $H_2O < Br_2 < Cl_2 < CH_4$

☐ **B** $Br_2 < CH_4 < Cl_2 < H_2O$

☐ **C** $Cl_2 < CH_4 < H_2O < Br_2$

☐ **D** $CH_4 < Cl_2 < Br_2 < H_2O$

(Total for question = 1 mark)

Q5.

Iodine can be extracted from seaweed. The seaweed is heated strongly to burn off the organic matter. The resultant ash is boiled in water to dissolve the iodide ions, and the mixture is filtered.

(a) Acidified hydrogen peroxide (H_2O_2) is added to the filtrate.

A redox reaction takes place with iodine and water as the only products.

(i) Write half-equations for the oxidation and reduction reactions that take place.

State symbols are not required.

(2)

(ii) Use your answers to (a)(i) to write the overall equation for this redox reaction.

State symbols are not required.

(1)

(b) The iodine is separated from the aqueous solution using solvent extraction.

The aqueous solution is mixed with cyclohexane in a separating funnel, forming two layers.

The mixture is then shaken gently and left until the layers separate.

Most of the iodine dissolves in the cyclohexane layer.

(i) State the colour of each layer **after** separation.

(2)

Aqueous layer
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Cyclohexane layer
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(ii) Explain why iodine is very soluble in cyclohexane but only slightly soluble in water.

(2)

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(c) The cyclohexane layer is then removed from the separating funnel and dried.

Identify, by name or formula, a suitable drying agent.

(1)

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(Total for question = 8 marks)

Q6.

Which statement is **not** correct?

(1)

☒ **A** chlorine is more electronegative than bromine

☒ **B** chlorine is more reactive than bromine

☒ **C** chloride ions are stronger reducing agents than bromide ions

☒ **D** chloride ions are stronger reducing agents than fluoride ions

(Total for question = 1 mark)

Q7.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Aqueous chlorine is added to an aqueous solution of potassium iodide.
A non-polar organic solvent is then added and the mixture is shaken.
The layers are allowed to separate.

What colour is seen in the organic layer?

☒ **A** brown

☒ **B** green

☒ **C** orange

☒ **D** violet

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q8.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of these is a disproportionation reaction?

☒ **A** $2NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2H_2O$

☒ **B** $6NaOH + 3Br_2 \rightarrow 5NaBr + NaBrO_3 + 3H_2O$

☒ **C** $2NaOH + 2Al + 2H_2O \rightarrow 2NaAlO_2 + 3H_2$

☒ **D** $NaOH + CO_2 \rightarrow NaHCO_3$

(Total for question = 1 mark)

Q9.

What are the gaseous products formed, other than water vapour, when concentrated sulfuric acid is added to potassium bromide?

(1)

☒ **A** bromine and sulfur dioxide only

☒ **B** bromine, hydrogen bromide and hydrogen sulfide only

☒ **C** bromine, hydrogen bromide and sulfur dioxide only

☒ **D** bromine, hydrogen bromide, sulfur dioxide and hydrogen sulfide only

(Total for question = 1 mark)

Q10.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which statement about the Group 7 elements chlorine, bromine and iodine is **not** correct?

☒ **A** boiling temperature increases down the group

☒ **B** reactivity increases down the group

☒ **C** first ionisation energy decreases down the group

☒ **D** electronegativity decreases down the group

(Total for question = 1 mark)

Q11.

This question is about the elements in Group 7.

(a) Use your knowledge of the trends in the properties of Group 7 elements to predict the colour and physical state of astatine at room temperature.

(1)

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(b) (i) State the meaning of the term electronegativity.

(1)

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(ii) Explain the trend in electronegativity down Group 7.

(2)

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*(c) Compare and contrast the reactions of chlorine with

- water
- cold, dilute aqueous alkali

- hot, concentrated aqueous alkali

Include an equation for each reaction, stating the type of reaction and the oxidation numbers of the chlorine involved. State symbols are not required.

(6)

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(Total for question = 10 marks)

Q12.

A white solid **X** produces a red colour in a flame test.

When aqueous silver nitrate and nitric acid are added to a solution of **X**, a cream precipitate is formed which dissolves in concentrated aqueous ammonia.

What is the formula of **X**?

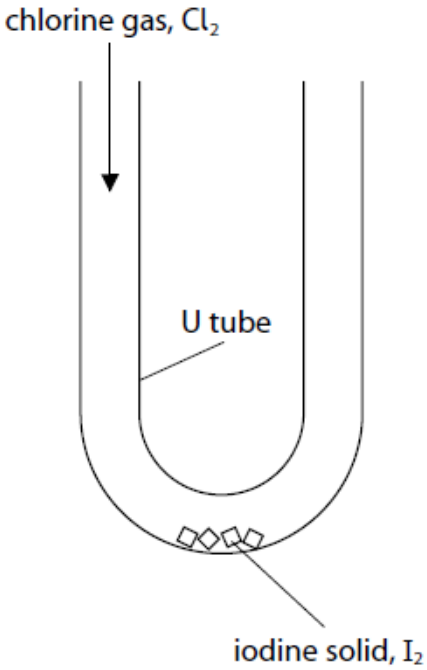
- ☒ **A** $SrBr_2$
- ☒ **B** NaBr
- ☒ **C** LiCl
- ☒ **D** BaI_2

(Total for question = 1 mark)

Q13.

Iodine monochloride, ICl, is a covalent compound produced by the reaction of iodine with chlorine. Iodine monochloride is a dark brown liquid at room temperature.

The equipment shown can be used to pass chlorine over solid iodine to produce iodine monochloride.



When excess chlorine is passed through the U tube, the iodine monochloride reacts to produce iodine trichloride in an equilibrium reaction.

(a) Write a chemical equation for the reaction of iodine with chlorine to produce iodine monochloride. Include state symbols.

(2)

(b) The iodine monochloride molecule has a permanent dipole. Complete the following table using the electronegativity data from your Data Booklet and hence show the dipole on the diagram of the iodine monochloride molecule.

(1)

Element	Electronegativity
Cl	
I	

I — Cl

(c) Iodine monochloride reacts with propene to form two isomeric products. This is an addition reaction that is similar to the reaction of propene with hydrogen halides.

(i) Draw the skeletal formulae of both isomers.

(2)

(ii) Explain which of these isomers is the major product.

(3)

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(d) The equation for the reaction between iodine monochloride and chlorine is:

$$\underset{\text{brown liquid}}{ICl(l)} + Cl_2(g) \rightleftharpoons \underset{\text{yellow solid}}{ICl_3(s)}$$

(i) State and justify **one** precaution that must be taken when preparing iodine trichloride.

(2)

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(ii) Give the oxidation number of iodine in both iodine-containing compounds in the equilibrium.

(1)

I in ICl

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I in ICl_3

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(iii) Iodine trichloride can also be made by reacting potassium chlorate(V) with iodine in hydrochloric acid. The equation for the reaction is

$$KClO_3 + I_2 + 6HCl \rightarrow KCl + 2ICl_3 + 3H_2O$$

By considering oxidation numbers for chlorine, explain whether or not this reaction is a disproportionation.

(2)

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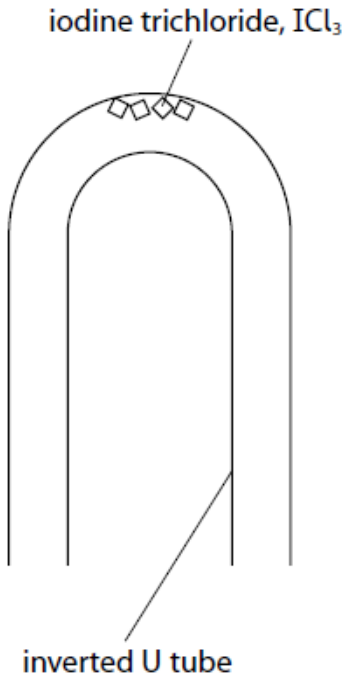
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(e) Chlorine gas has a molar volume of 24 000 cm^3 mol^{-1} under the conditions used in this reaction.

(i) Show that the density of chlorine gas is approximately 3 g dm^{-3}.

(2)

(ii) Air has an average density of 1.25 g dm^{-3}. If the U-tube used in part (d) is inverted, as shown in the diagram, the solid yellow iodine trichloride produced in the equilibrium reaction turns to a brown liquid.



Explain this observation.

(3)

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(f) A mass of 0.64 g of iodine reacted with fluorine to form 1.31 g of a fluoride of iodine.

Calculate the empirical formula of this compound of iodine and fluorine.

(2)

(Total for question = 20 marks)

Q14.

When chlorine is reacted with hot concentrated potassium hydroxide, the chlorine undergoes disproportionation.

What are the oxidation states of chlorine in the products?

(1)

☒ **A** –1 and +3

☒ **B** –1 and +5

☒ **C** +1 and –1

☒ **D** +1 and +5

(Total for question = 1 mark)

Q15.

Potassium chlorate(V), $KClO_3$, is a crystalline solid used in fireworks.

It is produced by the Liebig Process in two stages.

Stage **1** Chlorine gas is passed through hot calcium hydroxide solution forming calcium chlorate(V), $Ca(ClO_3)_2$.

$$6Ca(OH)_2(aq) + 6Cl_2(g) \rightarrow Ca(ClO_3)_2(aq) + 5CaCl_2(aq) + 6H_2O(l)$$

Stage **2** Potassium chloride solution is then added to form potassium chlorate(V).

$$Ca(ClO_3)_2(aq) + 2KCl(aq) \rightarrow 2KClO_3(aq) + CaCl_2(aq)$$

The solution is heated to reduce its volume and then allowed to crystallise.
The crystals are filtered off.
The remaining filtrate is evaporated further to obtain more crystals.

(a) (i) Write the **overall** equation for the Liebig Process.
State symbols are not required.

(1)

(ii) Calculate the **overall** atom economy by mass for the production of potassium chlorate(V), $KClO_3$, using your equation in (a)(i).

(3)

(b) Explain the type of reaction that takes place in Stage 1 of the Liebig Process, using oxidation numbers.

$$6Ca(OH)_2(aq) + 6Cl_2(g) \rightarrow Ca(ClO_3)_2(aq) + 5CaCl_2(aq) + 6H_2O(l)$$

(3)

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(c) The crystals of potassium chlorate(V) formed also contain some halide ion impurities.

(i) Describe a chemical test on a solution of these crystals to **confirm** that the impurities present are chloride ions rather than bromide ions. Include the expected results.

(3)

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(ii) 1.52 g of impure potassium chlorate(V), formed in the Liebig Process, was heated until the mass of solid remaining was constant at 1.02 g.

The reaction that occurred was

$$2KClO_3(s) \rightarrow 2KCl(s) + 3O_2(g)$$

The impurities present did not decompose on heating.

Calculate the percentage purity of the sample.
Give your answer to an appropriate number of significant figures.

(5)

(d) In fireworks, potassium chlorate(V) decomposes. This thermal decomposition takes place in two stages with a solid catalyst.

$$4KClO_3 \rightarrow KCl + 3KClO_4$$

$$KClO_4 \rightarrow KCl + 2O_2$$

(i) Give the systematic name of $KClO_4$.

(1)

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(ii) A student investigated the role of the catalyst in this reaction.

Procedure

Step **1** Heat a sample of $KClO_3$, in a test tube, with a known mass of insoluble catalyst until the mass remains constant.

Step **2** Mix the contents of the test tube with water.

Step **3** Filter the mixture and rinse with deionised water.

Step **4** Dry the remaining solid.

Step **5** Measure the mass of the dry solid.

Explain how each of the steps in this procedure is needed to show that the catalyst is **not** used up in this reaction.

(4)

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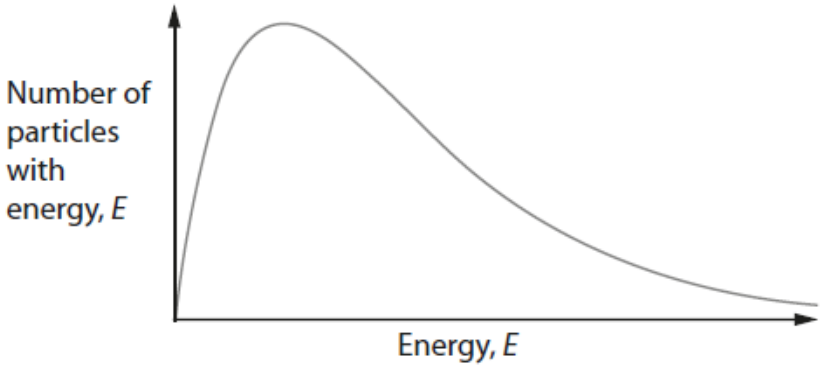
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(e) Explain, using the diagram, how a catalyst speeds up a chemical reaction.

(2)



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(Total for question = 22 marks)

Q16.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Potassium chloride reacts with concentrated sulfuric acid, producing misty fumes.
It can be deduced that

☒ **A** sulfuric acid is acting as an oxidising agent

☒ **B** chloride ions are acting as an oxidising agent

☒ **C** hydrogen chloride is formed in the reaction

☒ **D** chlorine is formed in the reaction

(Total for question = 1 mark)

Q17.

Which of these products are formed when chlorine is passed through cold, dilute aqueous sodium hydroxide?

(1)

☒ **A** NaCl and NaClO

☒ **B** NaClO and $NaClO_3$

☒ **C** NaCl and $NaClO_3$

☒ **D** NaClO and $NaClO_4$

(Total for question = 1 mark)

Q18.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Solid potassium bromide reacts with concentrated sulfuric acid.

Which of these substances does **not** form?

☒ **A** bromine

☒ **B** hydrogen bromide

☒ **C** hydrogen sulfide

☒ **D** sulfur dioxide

(Total for question = 1 mark)

Q19.

Potassium iodide reacts with concentrated sulfuric acid.

Which of the following is **not** a product?

(1)

☒ **A** H_2S

☒ **B** I_2

☒ **C** S

☒ **D** SO_3

(Total for question = 1 mark)

Q20.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which reaction is **not** a disproportionation?

☒ **A** $3Cl_2(g) + 6NaOH(aq) \rightarrow NaClO_3(aq) + 5NaCl(aq) + 3H_2O(l)$

☒ **B** $2H_2O_2(l) \rightarrow 2H_2O(l) + O_2(g)$

☒ **C** $Cl_2(g) + H_2O(l) \rightarrow HCl(aq) + HClO(aq)$

☒ **D** $Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$

(Total for question = 1 mark)

Q21.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

When iodine is dissolved in a non-polar organic solvent, the solution formed is

☒ **A** purple

☒ **B** orange

☒ **C** colourless

☒ **D** brown

(Total for question = 1 mark)

Q22.

(a) Silver ions have anti-microbial properties and are used in some wound dressings. Silver nitrate can be made
by warming a mixture of silver metal and concentrated nitric acid.

$$Ag(s) + 2HNO_3(aq) \rightarrow AgNO_3(aq) + NO_2(g) + H_2O(l)$$

Show, by reference to oxidation numbers, that this is a redox reaction.

(2)

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(b) Two students used different methods to determine the concentration of a silver nitrate solution.

(i) Student A used a calorimetric method, reacting a 50.0 cm^3 sample of the solution with excess powdered zinc.

$$AgNO_3(aq) + \tfrac{1}{2}Zn(s) \rightarrow \tfrac{1}{2}Zn(NO_3)_2(aq) + Ag(s) \quad \Delta_r H = -36.1\ kJ\ mol^{-1}$$

The student recorded a maximum rise in temperature of 5.2 °C.

Calculate the concentration of the silver nitrate solution in mol dm^{-3}.

[Assume the specific heat capacity of the solution is 4.18 J g^{-1} $°C^{-1}$ and the density of the solution is 1.00 g cm^{-3}.]

(3)

(ii) Student B used a gravimetric method, which involved weighing a product of a reaction.

A 50.0 cm^3 sample of the same silver nitrate solution was mixed with excess potassium bromide solution.
The precipitate was filtered and weighed.

$$AgNO_3(aq) + KBr(aq) \rightarrow AgBr(s) + KNO_3(aq)$$

The mass of the precipitate was found to be 5.96 g.

Calculate the concentration of the silver nitrate solution, in mol dm^{-3}, from this gravimetric method.

(2)

(iii) The students' values were different from the data book value.

Student A's value was lower and student B's value was higher.
Give a possible reason for each difference.

(2)

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(Total for question = 9 marks)

Q23.

The products of the reaction of sodium fluoride with concentrated sulfuric acid can be predicted by considering the trends for the other sodium halides.

Which gas or gases form when sodium fluoride reacts with concentrated sulfuric acid?

☒ **A** hydrogen fluoride only

☒ **B** hydrogen fluoride and fluorine only

☒ **C** hydrogen fluoride and sulfur dioxide only

☒ **D** hydrogen fluoride, fluorine and sulfur dioxide only

Use this space for any rough working. Anything you write in this space will gain no credit.

(Total for question = 1 mark)

Q24.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which silver halides are soluble in **concentrated** aqueous ammonia?

☒ **A** AgBr and AgI

☒ **B** AgCl and AgI

☒ **C** AgCl and AgBr

☒ **D** AgCl only

(Total for question = 1 mark)

Q25.

This question is about sulfuric acid.

(a) Sulfuric acid is manufactured in a three-step process.

Step **1** $S(s) + O_2(g) \rightarrow SO_2(g)$

Step **2** $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

Step **3** $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(l)$

(i) At room temperature and pressure, sulfur is a solid and oxygen a gas.

Explain why sulfur and oxygen exist in different states by referring to the intermolecular forces involved.

(2)

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(ii) Step **2** is a reversible reaction.

$$2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g) \qquad \Delta H = -196\,kJ\,mol^{-1}$$

State the effect on the position of equilibrium when the temperature and pressure are increased. Justify your answers.

(4)

Increasing temperature at constant pressure

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Increasing pressure at constant temperature

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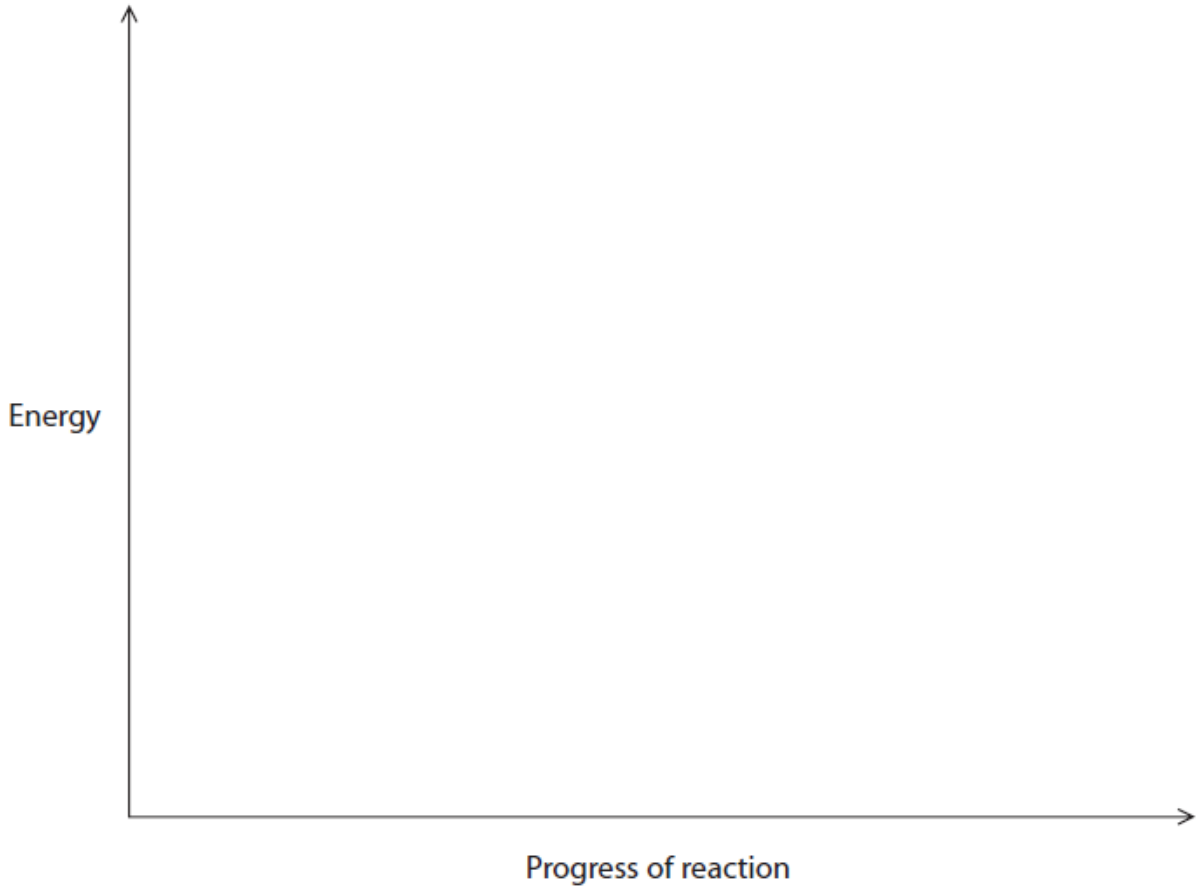
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(iii) Vanadium(V) oxide, V_2O_5, is used to catalyse the reaction in Step **2**.

Complete the reaction profile to show both the catalysed and uncatalysed reactions.

Label the activation energy and the enthalpy change. Your diagram does not have to be to scale.

(4)



(iv) Explain how the use of a catalyst makes this reaction more sustainable.

(2)

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* (b) Concentrated sulfuric acid reacts with solid potassium chloride and with solid potassium iodide.

Compare and contrast these reactions to show the difference in reducing ability of these two halide ions.
In your answer describe what would be observed and identify the products formed.

(6)

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(c) Dilute sulfuric acid is used in many laboratories. It is often supplied as concentrated sulfuric acid and then diluted.

A technician makes 500 cm^3 of 1.5 mol dm^{-3} sulfuric acid by adding 40.5 cm^3 of concentrated sulfuric acid to distilled water.

Calculate the concentration of the **concentrated** sulfuric acid, in mol dm^{-3} .

(2)

(Total for question = 20 marks)

Q26.

Which test is used to show that sodium chloride solution contains chloride ions?

(1)

☒ **A** damp blue litmus paper turns red

☒ **B** damp blue litmus paper is bleached

☒ **C** dilute hydrochloric acid followed by silver nitrate solution gives a white precipitate

☒ **D** dilute nitric acid followed by silver nitrate solution gives a white precipitate

(Total for question = 1 mark)

Q27.

For each question, select one answer from A to D and put a cross in the box ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Four tests used to identify ions are shown:

1 flame test

2 addition of acidified barium nitrate solution

3 addition of acidified silver nitrate solution

4 addition of sodium hydroxide solution, then testing any gas with indicator paper

Which tests could be used to positively identify the ions in ammonium chloride?

☒ **A** 1 and 2

☒ **B** 1 and 3

☒ **C** 2 and 4

☒ **D** 3 and 4

(Total for question = 1 mark)

Q28.

This question is about the halogens and some of their compounds.

(a) Descending the group from fluorine to iodine, the electronegativity of the atoms decreases even though their nuclear charge increases.

Explain the trend in electronegativity.

(2)

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(b) Iodate(V) ions, IO_3^-, react with iodide ions in acid solution.

$$IO_3^- + 5I^- + 6H^+ \rightarrow 3I_2 + 3H_2O$$

Explain, in terms of the oxidation numbers of iodine in the three species, why this is **not** a disproportionation reaction.

(2)

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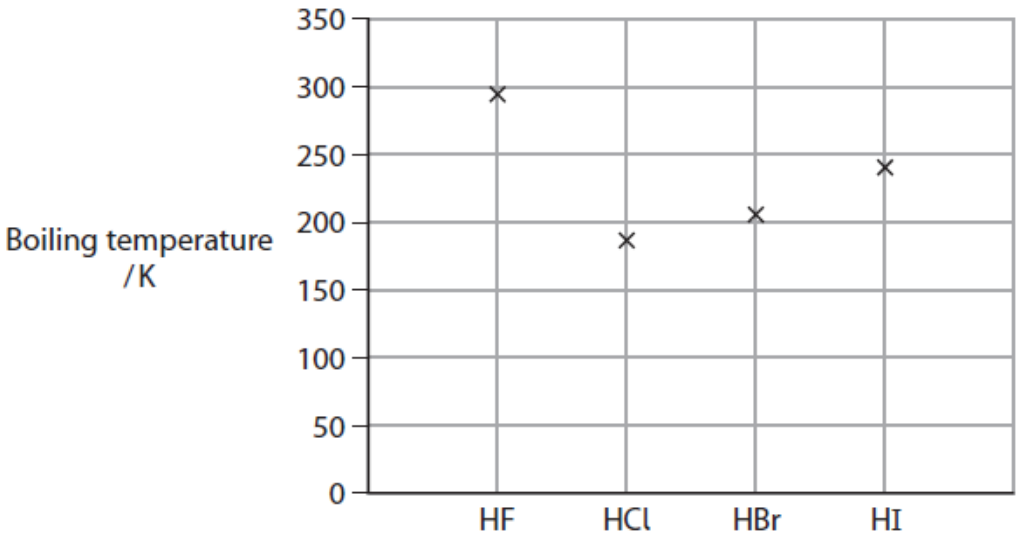
(c) Hydrogen bromide and hydrogen iodide reduce sulfuric acid.

Identify, by name or formula, the **compound** produced containing sulfur with its lowest oxidation number in that reaction.

(1)

Hydrogen halide	Compound produced with the lowest oxidation number of sulfur
HBr	
HI	

(d) The graph shows the boiling temperatures of the hydrogen halides.



Explain the trend in the boiling temperatures of the hydrogen halides.

(4)

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(e) A sample of seawater was evaporated to dryness.

The solid residue was weighed, then dissolved completely in deionised water.

Excess aqueous silver nitrate was added to the solution.
All the chloride ions in the seawater formed a precipitate of silver chloride.

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

The precipitate was filtered, washed, dried and weighed.

Results:

Mass of solid residue from seawater = 0.098 g

Mass of silver chloride precipitate = 0.226 g

Calculate the percentage, by mass, of chloride ions in the solid residue.

[Assume silver chloride is the only precipitate.]

(3)

(Total for question = 12 marks)

Q29.

Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which trend is **not** correct as Group 7 is descended?

☒ **A** atomic radius of the elements increases

☒ **B** boiling temperature of the elements increases

☒ **C** electronegativity of the elements decreases

☒ **D** reactivity of the elements increases

(Total for question = 1 mark)

Use this space for any rough working. Anything you write in this space will gain no credit.

Q30.

Answer the question with a cross in the box you think is correct ☒ . If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒ .

Which of these **increases** as Group 7 is descended?

☒ **A** oxidising ability of the molecular halogens

☒ **B** reducing ability of the halide ions

☒ **C** electrostatic attraction between the nucleus and outer shell of electrons

☒ **D** electronegativity of the halogen atoms

(Total for question = 1 mark)

Mark Scheme

Q1.

Question number	Answer	Mark
(a)	**The only correct answer is C** (strontium bromide) *A is not correct because the chloride will give a white precipitate* *B is not correct because the chloride will give a white precipitate* *D is not correct because the barium will give a green flame*	**(1)**

Question number	Answer	Mark
(b)	**The only correct answer is D** (red light is emitted as electrons return to lower energy levels) *A is not correct because the electrons absorb heat as they are promoted* *B is not correct because the electrons emit light when they return to ground state* *C is not correct because light energy is emitted when the electrons return to the ground state*	**(1)**

Q2.

<table>
<tr><th>Q</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(a)*</td><td>
This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr>
<tr><td>6</td><td>4</td></tr>
<tr><td>5-4</td><td>3</td></tr>
<tr><td>3-2</td><td>2</td></tr>
<tr><td>1</td><td>1</td></tr>
<tr><td>0</td><td>0</td></tr>
</table>
The following table shows how the marks should be awarded for structure and lines of reasoning
<table>
<tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr>
<tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr>
<tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr>
<tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr>
</table>
</td><td>
Guidance on how the mark scheme should be applied.

The mark for indicative content should be added to the mark for lines of reasoning.
For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning).

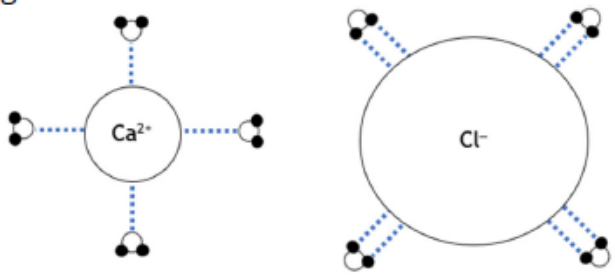
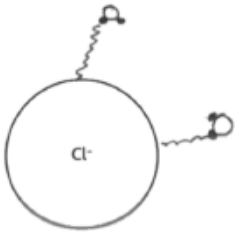
If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).

In general, it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning.

If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s).

Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.
</td><td>6</td></tr>
</table>

Indicative content: • IP1: fluorine molecules **only** have London forces (instantaneous dipole-induced dipole) between them (as it has a symmetrical electron cloud/is a symmetrical/non-polar molecule.)	Allow dispersion forces / van der Waals forces Allow no dipole-dipole forces in place of "only"
• IP2: hydrogen chloride is a polar molecule as chlorine is more electronegative than hydrogen.	Allow H and Cl have different electronegativities
• IP3: HCl forms permanent dipole-permanent dipole interactions in addition to London forces.	Allow just "permanent dipole interactions"
• IP4: methanol contains a hydrogen attached to a small electronegative element so can form hydrogen bonds (in addition to permanent dipole-permanent dipole interactions and London Forces).	Allow oxygen in place of the small electronegative element
• IP5: hydrogen bonds are the strongest intermolecular forces so take the most energy to break.	
• IP6: London forces are the weakest intermolecular forces, so fluorine has the lowest boiling temperature.	Energy and boiling temperature need only be referenced once each in relation to H-bonds and/or London forces in order to gain IP5 and IP6 Allow reverse arguments for IP5 and IP6 Ignore references to shapes, sizes and surface areas

Q	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • the oxygen is closest to the calcium ion **(1)** • the hydrogen is closest to the chloride ion **(1)**	(A minimum of two water molecules should be drawn for each ion – penalise once only) E.g.  Allow displayed formula of water Allow diagrams without dotted lines Allow only one hydrogen of each water molecule closest to the chloride e.g.  A singular water molecule correctly orientated between the ions scores 1 Dipoles are not required but if shown they must be correct Incorrectly labelled dipoles as charges should be penalised once, whether on water (or conversely on ions) Do not award O_2H, but if molecules are unshaded assume they are H_2O	**2**

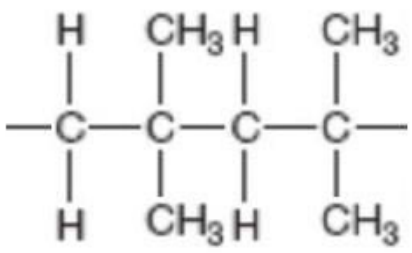
Q	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points: • Iodine has more electrons (per molecule) (than bromine) **(1)** • so stronger London forces between molecules / I_2 (mean a higher melting temperature for iodine) **(1)**	Accept reverse arguments. If numbers of electrons are given they must be correct for molecules, not the atoms. Accept stronger van der Waals/induced dipole-induced dipole forces / dispersion forces Do not award between atoms Allow "between iodine"	**2**
			(Total for Question = 10 marks)

Q3.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	$TiO_2 + 2Cl_2 + 2C \rightarrow TiCl_4 + 2CO$	Ignore state symbols even if incorrect Allow multiples	1

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	• Ti is reduced **and** from +4 to 0 (1) • Mg is oxidised **and** from 0 to +2 (1)	Four correct oxidation numbers with no or incorrect mention of reduced or oxidised scores (1) Ti is reduced as it gains electrons and Mg is oxidised as it loses electrons with no or incorrect oxidation numbers scores (1)	2

Question Number	Answer	Additional Guidance	Mark
(b)	• hydrolysis (1) • titanium((IV)) oxide/TiO_2 (1)	Do not award hydration Ignore hydrogen chloride/HCl Allow titanium((IV))hydroxide/$Ti(OH)_4$	2

Question Number	Answer	Additional Guidance	Mark
(c)	 • correct repeating unit (1) • two repeating units and extension (1) Note M2 depends on M1 or near miss eg missing a H	Allow adjacent pairs of methyl groups Ignore square brackets and subscript n/2 Ignore connectivity of CH_3	2

Question Number	Answer	Additional Guidance	Mark
(d)(i)	An answer that makes reference to the following points: • reagent: potassium hydroxide / KOH (1) • conditions: aqueous/water (1) M2 dependent on M1or near miss e.g. OH^- will not score M1 but will allow access to M2.	Allow sodium hydroxide / NaOH Ignore any reference to concentration or heat Allow dilute	2

Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to the following points: • reagent: (concentrated) phosphoric((V)) acid / H_3PO_4 (1) • reaction type: elimination/dehydration (1) Independent marks	Allow (concentrated) sulfuric acid Ignore heat Do not award H_3PO_3 Allow passing vapour over porous pot / alumina or any surface catalyst **and** heat	2

Question Number	Answer	Additional Guidance	Mark
(d)(iii)	An answer that makes reference to the following points: • reagent: phosphorus(V) chloride/ phosphorus pentachloride/PCl_5 (1) • equation: $C_4H_9OH + PCl_5 \rightarrow C_4H_9Cl + HCl + POCl_3$ (1)	Allow thionyl chloride / $SOCl_2$ Allow phosphorus (III) chloride / phosphorus trichloride / PCl_3 Allow $C_4H_9OH + SOCl_2 \rightarrow C_4H_9Cl + HCl + SO_2$ $3C_4H_9OH + PCl_3 \rightarrow 3C_4H_9Cl + H_3PO_3$ Allow skeletal, structural, displayed or molecular formulae	2

Question Number	Answer	Additional Guidance	Mark
(d)(iv)	An answer that makes reference to the following points: • conditions: alcoholic (1) • role of the hydroxide ions: base (1) Note answers may be given on either line	Allow ethanol/ethanolic Ignore heat and concentration Allow proton acceptor/reacts with H^+	2

Question Number	Answer	Additional Guidance	Mark
(e)	An answer that makes reference to the following points: • moles of carbon dioxide (1) • conversion of cm^3 to m^3 (1) • conversion of °C to K (1) • rearrangement of the ideal gas equation (1) • calculation of pressure and correct units given (1)	Examples of calculation 16 ÷ 44 = 0.36364 (mol)/ 4÷11(mol) 20 ÷ 1000000 = 2×10^{-5} / 0.00002 (m^3) 273 + 25 = 298 (K) $p = \frac{nRT}{V}$ $\frac{0.3636 \times 8.31 \times 298}{2 \times 10^{-5}}$ = 45025000 Pa / 45025 kPa 4.5 x 10^7 Pa / 45MPa Ignore SF except 1 Allow TE for answers to M1, M2 and M3 But no TE on wrong rearrangement of gas equation Correct answer, including units with or without working scores (5)	5

Q4.

Question Number	Answer	Mark
	The only correct answer is D ($CH_4 < Cl_2 < Br_2 < H_2O$) ***A*** *is incorrect because the sequence is reversed* ***B*** *is incorrect because methane has the lowest boiling temperature* ***C*** *is incorrect because methane has the lowest boiling temperature*	**(1)**

Q5.

Question Number	Answer	Additional guidance	Mark
(a)(i)	• $2I^- \rightarrow I_2 + 2e^{(-)}$ **(1)** • $2H^+ + 2e^- + H_2O_2 \rightarrow 2H_2O$ **(1)**	Allow $2I^- - 2e^{(-)} \rightarrow I_2$ Ignore state symbols, even if incorrect Allow multiples Allow equations in either order	**(2)**

Question Number	Answer	Additional guidance	Mark
(a)(ii)	$2I^- + 2H^+ + H_2O_2 \rightarrow I_2 + 2H_2O$ OR $2HI + H_2O_2 \rightarrow I_2 + 2H_2O$	Ignore state symbols, even if incorrect Allow multiples No TE from (a)(i) Do not award uncancelled electrons	**(1)**

Question Number	Answer	Additional guidance	Mark
(b)(i)	An answer that makes reference to the following points: (pale) yellow aqueous layer **(1)** Pink cyclohexane layer **(1)**	Do not award just 'brown' / colourless / orange allow light brown / pale brown / yellowbrown / straw Allow purple / violet Do not award red / grey	**(2)**

Question Number	Answer	Additional guidance	Mark
(b)(ii)	An explanation that makes reference to the following points: Cyclohexane and iodine form London forces (between molecules) **(1)** Hydrogen bonds between water molecules are stronger than London forces (between iodine and water molecules so less soluble in aqueous layer) **(1)**	Allow 'van der Waals' / dispersion forces / instantaneous dipole – induced dipole forces Allow 'Hydrogen bonds in water are strong' Allow one mark for answers that compare type of attraction without any reference to magnitude or answers based solely on polarity e.g. Just 'iodine forms London forces with cyclohexane but cannot form hydrogen bonds with water' scores 1 mark 'iodine and cyclohexane are non-polar, but water is polar' scores 1 e.g. 'Intermolecular forces formed by iodine and water are weaker than intermolecular forces in water' scores 1	**(2)**

Question Number	Answer	Additional guidance	Mark
(c)	(Anhydrous) sodium sulfate / Na_2SO_4 / magnesium sulfate / $MgSO_4$ / calcium chloride / $CaCl_2$ / calcium sulfate / $CaSO_4$ / calcium oxide / CaO	Allow silica gel Do not award concentrated sulfuric acid / phosphoric acid Do not award $CuSO_4$ / $CaCO_3$	**(1)**

Q6.

Question Number	Answer	Mark
	The only correct answer is C (chloride ions are stronger reducing agents than bromide ions) *A is incorrect because chlorine is more electronegative than bromine* *B is incorrect because chlorine is more reactive than bromine* *D is incorrect because chloride ions are stronger reducing agents than fluoride ions*	**(1)**

Q7.

Question number	Answer	Mark
	The only correct answer is D (violet) ***A*** *is incorrect because iodine is produced in the reaction and it is brown in aqueous solution but violet in a non-polar organic solvent* ***B*** *is incorrect because chlorine gas is green* ***C*** *is incorrect because bromine is orange in a non-polar organic solvent*	**(1)**

Q8.

Question number	Answer	Mark
	The only correct answer is B ($6NaOH + 3Br_2 \rightarrow 5NaBr + NaBrO_3 + 3H_2O$) ***A*** *is not correct because it is a neutralisation reaction* ***C*** *is not correct because only Al is oxidised and only H is reduced* ***D*** *is not correct because no oxidation numbers change*	**(1)**

Q9.

Question number	Answer	Mark
	C bromine, hydrogen bromide and sulfur dioxide only	1

Q10.

Question Number	Answer	Mark
	The only correct answer is B (reactivity increases down the group) ***A** is not correct because boiling temperature does increase down the group* *C is not correct because first ionisation energy does decrease down the group* ***D** is not correct because electronegativity does decrease down the group*	**(1)**

Q11.

Question Number	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • (dark) grey / black **and** solid	Ignore shiny / metallic	**(1)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• the ability of an atom to attract a bonding/shared pair of electrons (in a covalent bond)	Allow "ability of an atom to attract electron**s** in a covalent bond"	**(1)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	An explanation that makes reference to the following points: • elements become less electronegative (down the group) **(1)** • the outer electron(s)/shell is further away from the (positive) nucleus (so the bonding electrons are less strongly attracted) **(1)**	Allow decreases Allow descriptions using names of elements Allow increased repulsion (from inner electrons) Allow more shielding (by inner electrons) Allow more (inner) shells of electrons Allow effective nuclear charge is lower Ignore other comments about nuclear charge Ignore size/radius of atom increases Allow reverse argument Marks are independent	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)*	This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content.	Guidance on how the mark scheme should be applied. The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	**(6)**

Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points
6	4
5-4	3
3-2	2
1	1
0	0

Question Number	Answer	Additional Guidance	Mark
	The following table shows how the marks should be awarded for structure and lines of reasoning Number of marks awarded for structure of answer and sustained lines of reasoning Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout — 2 Answer is partially structured with some linkages and lines of reasoning — 1 Answer has no linkages between points and is unstructured — 0	In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning, and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning.	

	Indicative content: **IP1** all are disproportionation reactions (because chlorine is both oxidised and reduced)	Allow for a description, including the name, of disproportionation if a reaction type is not given for all three equations Allow disproportional/disproportion reaction
	IP2 chlorine changes/is reduced from 0 to –1 (in Cl^- in all reactions)	
	IP3 $Cl_2 + H_2O \rightleftharpoons HCl + HOCl$	Allow $Cl_2 + H_2O \rightarrow H^+ + Cl^- + HOCl$ Allow single arrow instead of equilibrium sign Allow HClO or ClOH
	IP4 $Cl_2 + 2NaOH \rightarrow NaClO + NaCl + H_2O$	Allow $Cl_2 + 2OH^- \rightarrow ClO^- + Cl^- + H_2O$
	IP5 $3Cl_2 + 6NaOH \rightarrow NaClO_3 + 5NaCl + 3H_2O$	Allow $3Cl_2 + 6OH^- \rightarrow ClO_3^- + 5Cl^- + 3H_2O$
	IP6 chlorine oxidised to +1, +1 and +5 shown in the appropriate reaction	Allow oxidation numbers shown next to a combination of correct names and formulae even if the equations are not balanced Ignore state symbols even if incorrect

Q12.

Question Number	Answer	Mark
	The only correct answer is A ($SrBr_2$) *B is incorrect because sodium produces a yellow flame test* *C is incorrect because although the flame test would be red the silver halide ppt would be white* *D is incorrect because the flame test would be green and the silver halide ppt would be yellow and insoluble in concentrated ammonia*	(1)

Q13.

Question number	Answer	Additional guidance	Mark
(a)	• balanced equation (1) • all states correct (1)	$I_2(s) + Cl_2(g) \rightarrow 2ICl(l)$ Accept multiples	2

Question number	Answer	Additional guidance	Mark
(b)	• correct electronegativity values and correct dipole diagram	Cl = 3.0 **and** I = 2.5 δ+ I — Cl δ- Do not award full charges	1

Question number	Answer	Additional guidance	Mark
(c)(i)	• 1 mark each correct formula	 Allow 1 mark for 2 correct non-skeletal formulae	2

Question number	Answer	Additional guidance	Mark
(c)(ii)	An explantion that makes reference to the following points: • identification of correct isomer (1) • iodine is δ+ and is attacked by the π electrons (1) • more stable secondary carbocation formed. (1)	2-chloro-1-iodopropane	3

Question number	Answer	Additional guidance	Mark
(d)(i)	An answer that makes reference to the following points: • carry out in fume cupboard (1) • chlorine is toxic. (1)	Allow fume hood or similar description Do not allow 'harmful'	2

Question number	Answer	Additional guidance	Mark
(d)(ii)	• I in ICl = +1 I in ICl_3 = +3	Both needed for the mark	1

Question number	Answer		Additional guidance	Mark
(d)(iii)	• +5 **and** -1 to -1 (and -1)	(1)		2
	• not disproportionation because the chlorine has not undergone both oxidation and reduction	(1)		

Question number	Answer		Additional guidance	Mark
(e)(i)	• correct method	(1)	$Cl_2 = 2 \times 35.5 = 71$ $71 \div 24000$	2
	• answer with units	(1)	$= 0.0029583$ g cm^{-3} $= 3$ g dm^{-3}	

Question number	Answer		Additional guidance	Mark
(e)(ii)	An explanation that makes reference to the following points:			3
	• chlorine (gas) is more dense than air	(1)		
	• chlorine (gas) removed (from the equilibrium)	(1)		
	• position of equilibrium moves to the LHS (more brown liquid/ICl).	(1)		

Question number	Answer		Additional guidance	Mark
(f)	• calculation of mols of iodine and fluorine	(1)	Mols of iodine = $0.64 \div 126.9 = 5.04 \times 10^{-3}$ Mols of fluorine = $(1.31–0.64) \div 19 = 3.53 \times 10^{-2}$	2
	• calculation of whole number ratio and formula	(1)	Ratio 1:7 therefore formula IF_7	

Q14.

Question number	Answer	Mark
	B -1 and +5	1

Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	$3Ca(OH)_2 + 3Cl_2 + KCl \rightarrow KClO_3 + 3CaCl_2 + 3H_2O$ OR $6Ca(OH)_2 + 6Cl_2 + 2KCl \rightarrow 2KClO_3 + 6CaCl_2 + 6H_2O$	Allow multiples If multiple used allow '$CaCl_2$ +5$CaCl_2$' Ignore state symbols	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	• calculation of M_r of $KClO_3$ **(1)** • calculation of M_r of all products / reactants **(1)** • calculation of overall atom economy **(1)**	<u>Example of calculation</u> 39.1 + 35.5 + 48 (= 122.6) 122.6 + (3 ×18) + ((71+40.1) × 3) = 509.9 Value for M2 should be consistent with numerator of atom economy expression (122.6 ÷509.9) ×100 = 24.044 = 24.0 % Ignore SF except 1 SF Use of 39 for K or 40 for Ca is acceptable Allow TE from (a)(i) using either M_r of all products or reactants Allow TE throughout calculation But TE for M3 must give a value of less than 100 %	3

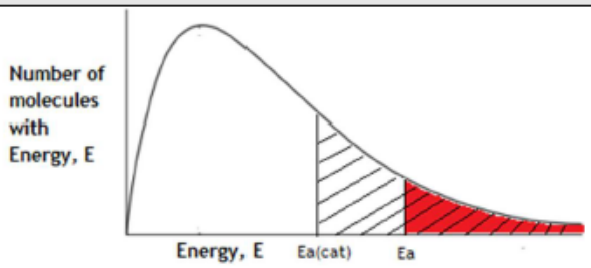
Question Number	Acceptable Answers	Additional Guidance	Mark
(b)	An explanation that makes reference to the following points: • disproportionation reaction **(1)** • as chlorine (atoms) are oxidised from 0 (in chlorine) to (+) 5 (in calcium chlorate) **(1)** • and reduced (from 0) to −1 (in calcium chloride) **(1)**	Allow incorrect spellings of disproportionation if the word is recognisable and could not be confused with another chemical term Ignore redox Mark independently of M2 and M3 If initial oxidation state of 0 is not referenced at least once in either M2 or M3, then allow 1 for Cl is oxidised to +5 and reduced to -1 Changes in oxidation number can be shown above equation If no reference to oxidation and reduction then allow 1 mark for correct changes in oxidation number	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)	An answer that makes reference to the following points: • add (dilute) nitric acid and silver nitrate (solution) **(1)** • white precipitate forms / precipitate forms whose colour is difficult to distinguish (between white and cream) **(1)** • which dissolves in dilute ammonia / dilute NH_3 / $NH_3(aq)$**(1)**	Throughout the question if formulae are given they must be correct Allow acidified silver nitrate / $AgNO_3$ and H^+ Allow $AgNO_3$ Allow HNO_3 Do not award hydrochloric acid / sulfuric acid Allow white solid / white crystals / white ppt Allow aqueous ammonia Allow 'disappears' for dissolves Do not award **just** 'dissolves in concentrated NH_3' M2 and M3 dependent on reference to silver nitrate / $AgNO_3$	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	• calculation of mass of oxygen **(1)** • calculation of moles of oxygen **(1)** • deduction of moles of potassium chlorate /calculation of mass of KCl **(1)** • calculation of mass of potassium chlorate in impure sample **(1)** • calculation of % purity of sample to 2 or 3 SF **(1)**	<u>Example of calculation</u> 1.52 − 1.02 = 0.50 (g) 0.50 ÷ 32 = 0.015625 (mol) 0.015625 × (2÷3) = 0.010417 (mol) / 0.015625 x (2/3) x 74.6 = 0.777 (g) 0.010417 × (39.1 + 35.5 + 48) = 1.2771 (g) / 0.777 + 0.5 = 1.277 (g) = (1.2771 ÷ 1.52) × 100 = 84.019 = 84 / 84.0 (%) Penalise incorrect rounding once only in M1-M4 Allow TE at each step, but TE for M5 must give a value less than 100% and based on 1.52 Allow alternative methods based on finding x where x = mass of impurity	**5**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(i)	potassium chlorate(VII) OR chlorate(VII) potassium	Allow pottassium chlorate(VII) Do not award just potassium chlorate	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
(d)(ii)	An explanation that makes reference to any four of the following points: • heat to constant mass so all of the potassium chlorate(V) decomposes **(1)** • the solid product or potassium chloride dissolves (when the water is added) **(1)** • the rinsing removes potassium chloride (solution, which would otherwise add to the mass of the solid when it dries **(1)** • drying ensures the final mass recorded is only that of that catalyst **(1)** • the mass (of solid) recorded (at the end of the procedure) should be the same of that of the catalyst at the start **(1)**	Allow so all $KClO_3$ reacts / so reaction goes to completion Allow the catalyst does not dissolve (when the water is added) Ignore KCl reacts with the water / catalyst does not react with the water Allow to remove soluble impurities (from catalyst) Allow 'to remove water from the catalyst' / 'ensure the catalyst is dry' Allow 'to compare to the mass of catalyst' Allow 'to check the mass (of catalyst) hasn't changed'	4

Question Number	Acceptable Answers	Additional Guidance	Mark
(e)	An explanation that makes reference to the following points: • activation energies shown and labelled for both catalysed and uncatalysed reaction **(1)** • number of molecules with $E > E_a$ shown on diagram **(1)**	 M2 can be awarded by written description	2

Q16.

Question number	Answer	Mark
	The only correct answer is C (hydrogen chloride is formed in the reaction) ***A*** *is not correct because chlorine does not increase oxidation state when HCl (misty fumes) forms* ***B*** *is not correct because sulfur does not increase oxidation state when HCl (misty fumes) forms* ***D*** *is not correct because chlorine will not be evident as misty fumes and does not form in the reaction*	**(1)**

Q17.

Question Number	Answer	Mark
	The only correct answer is A (NaCl and NaClO) *B is incorrect because both products are the result of oxidation* *C is incorrect because the reaction is not heated and the solution is not concentrated* *D is incorrect because both products are the result of oxidation*	**(1)**

Q18.

Question Number	Answer	Mark
	The only correct answer is C (hydrogen sulfide) ***A*** *is not correct because bromine is formed* ***B*** *is not correct because hydrogen bromide is formed* ***D*** *is not correct because sulfur dioxide is formed*	**(1)**

Q19.

Question Number	Answer	Mark
	The only correct answer is D (SO_3) *A is incorrect because H_2S is a product* *B is incorrect because I_2 is a product* *C is incorrect because S is a product*	**(1)**

Q20.

Question Number	Answer	Mark
	The only correct answer is D ($Zn(s) + CuSO_4(aq) \rightarrow ZnSO_4(aq) + Cu(s)$) ***A** is not correct because Cl has undergone disproportionation* ***B** is not correct because O has undergone disproportionation* ***C** is not correct because Cl has undergone disproportionation*	**1**

Q21.

Question Number	Answer	Mark
	The only correct answer is A (purple) ***B** is not correct because this is the colour of bromine in water* ***C** is not correct because the solution is not colourless* ***D** is not correct because the solution is not brown*	**(1)**

Q22.

Question Number	Answer	Additional Guidance	Mark
(a)	• Silver is oxidised from 0 to +1 **(1)** • Nitrogen is reduced from +5 to +4 **(1)**	These may be shown on the equation ALLOW one mark for silver is oxidised **and** nitrogen is reduced or all oxidation numbers correct ALLOW 1 or 1+ for +1	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• calculation of energy change **(1)** • calculation of no of moles **(1)** • calculation of concentration **(1)**	Examples of calculation Q = 50.0 ÷ 1000 x 4.18 x 5.2 = 1.0868 (kJ)/1086.8(J) 1.0868 ÷ 36.1 = 0.030105/3.0105 x10^{-2} (moles) 0.030105 ÷ 50 x 1000 = 0.602105(mol dm^{-3}) = 0.602/0.60/0.6 (mol dm^{-3}) Ignore SF	**(3)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• calculation of moles of ppt **(1)** • calculation of concentration **(1)**	Example of calculation 5.96 ÷ 187.8 = 0.0317359 (moles) 0. 00317359 ÷ 50 x 1000 = 0.634718(mol dm^{-3}) Ignore SF except 1 SF ALLOW use of 188 as M_r Penalise incorrect rounding once only	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An explanation that makes reference to: • the calorimetry method (student A) is lower because heat may be lost to the surroundings /absorbed by the container or apparatus **(1)** • the gravimetric method (student B) is higher because the product may have been wet/ have impurities **(1)**	Do not award: non-standard conditions, just "incomplete reaction", human error, incorrect solution density/heat capacity ALLOW: not all the **solution** reacted	**(2)**

Q23.

Question Number	Answer	Mark
	The only correct answer is A (hydrogen fluoride only) ***B*** *is incorrect because sulfuric acid is not a strong enough oxidising agent to oxidise the fluoride ion* ***C*** *is incorrect because the fluoride ion is not a strong enough reducing agent to reduce sulfuric acid* ***D*** *is incorrect because the fluoride ion is not a strong enough reducing agent to reduce sulfuric acid and sulfuric acid is not a strong enough oxidising agent to oxidise the fluoride ion*	**(1)**

Q24.

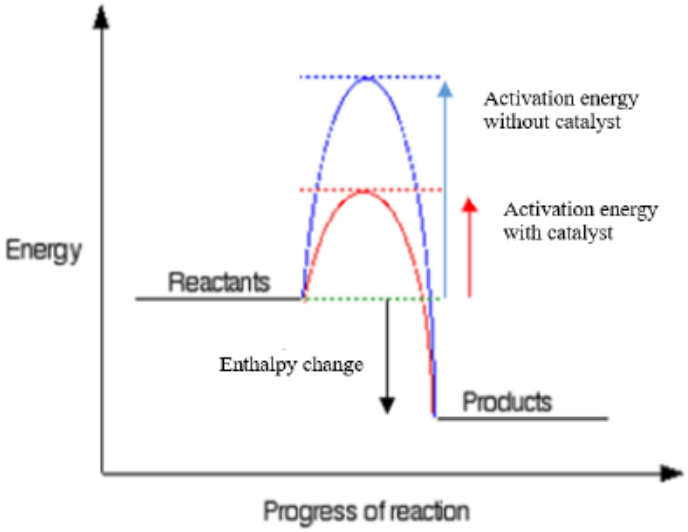
Q	Answer	Mark
	The only correct answer is C (AgCl and AgBr) ***A*** *is incorrect because AgBr will be soluble but not AgI* ***B*** *is incorrect because AgCl will be soluble but not AgI* ***D*** *is incorrect because AgBr will also be soluble*	**1**

Q25.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: • **both** have London forces (only) **(1)** • S molecules have more electrons / S is a larger molecule (than oxygen) / S electrons are more easily polarised **(1)** Independent marks	Accept dispersion forces Accept instantaneous dipole-induced dipoles Allow van der Waals' forces Note any mention of other intermolecular forces being present e.g. dipole-dipole negates M1 Allow S_8, rather than O_2 Allow just S has more electrons Allow just S is larger Allow reverse argument Ignore electron density Do not award a S atom has more electrons than an oxygen molecule	

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: Increasing temperature **(1)** • equilibrium shifts to the LHS/backwards **(1)** • in the endothermic direction (in order to reduce the temperature) Increasing pressure **(1)** • equilibrium shifts to the RHS/forward **(1)** • to the side with fewer (gaseous) molecules/moles (in order to reduce the pressure) Independent marks	Ignore any reference to yield Allow reaction is exothermic Allow favours endothermic direction Allow favours RHS/forward direction Allow 3 moles (of gas) on the LHS (forms) 2 moles(of gas) on the RHS. If numbers of moles are quoted they must be correct. Allow reverse argument Ignore any reference to rate	**4**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An answer that makes reference to the following points: Increasing temperature • equilibrium shifts to the LHS/backwards (1) • in the endothermic direction (in order to reduce the temperature) (1) Increasing pressure • equilibrium shifts to the RHS/forward (1) • to the side with fewer (gaseous) molecules/moles (in order to reduce the pressure) (1) Independent marks	Ignore any reference to yield Allow reaction is exothermic Allow favours endothermic direction Allow favours RHS/forward direction Allow 3 moles (of gas) on the LHS (forms) 2 moles(of gas) on the RHS. If numbers of moles are quoted they must be correct. Allow reverse argument Ignore any reference to rate	4

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	• reactants/(2)SO_2 + O_2 higher than products/(2)SO_3 (1) • non-catalysed activation energy correctly labelled and arrow going up (1) • catalysed activation energy correctly labelled and arrow going up (1) • enthalpy change labelled and arrow going down If just one curve is drawn max (3) MB distribution scores (0) If endothermic reaction TE available for M2. M3 and M4 Double-headed arrows or no arrow heads penalise once	 Allow energy for enthalpy Allow E_a and E_{cat} Allow intermediates in the activation energy curves Ignore sign and units of energy even if incorrect	4

Question Number	Answer	Additional Guidance	Mark
(a)(iv)	An explanation that makes reference to the following points: • (operates at) a lower temperature (1) • less energy required (for the reaction to proceed at an acceptable rate) or less burning of fossil fuels / less greenhouse gas evolved / less CO_2 evolved (1)	Allow lower temperature Allow less energy costs Ignore just cheaper Ignore less time/faster rate Allow less pollution	2

Question Number	Answer	Additional Guidance	Mark
* (b)	This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. Number of indicative marking points seen in answer / Number of marks awarded for indicative marking points 6 / 4 5-4 / 3 3-2 / 2 1 / 1 0 / 0 The following table shows how the marks should be awarded for structure and lines of reasoning Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout / 2 Answer is partially structured with some linkages and lines of reasoning / 1 Answer has no linkages between points and is unstructured / 0	Guidance on how the mark scheme should be applied. The mark for indicative content should be added to the mark for lines of reasoning. For example, a response with five indicative marking points that is partially structured with some linkages and lines of reasoning scores 4 marks (3 marks for indicative content and 1 mark for partial structure and some linkages and lines of reasoning). If there were no linkages between the points, then the same indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages). In general it would be expected that 5 or 6 indicative points would get 2 reasoning marks, and 3 or 4 indicative points would get 1 mark for reasoning and 0, 1 or 2 indicative points would score zero marks for reasoning. If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). Comment: Look for the indicative marking points first, then consider the mark for the structure of the answer and sustained line of reasoning	6

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	Indicative content <u>Potassium chloride</u> IP1 (misty/steamy fumes of) HCl/hydrogen chloride <u>Potassium iodide</u> IP2 purple vapour/black solid **and** I_2 /iodine IP3 bad eggs **and** H_2S/ hydrogen sulfide OR yellow solid **and** S/ sulfur OR Choking gas **and** SO_2/sulfur dioxide IP4 KCl is **not** a redox reaction and KI is a redox reaction / KCl cannot reduce sulfuric acid but KI can IP5 iodide stronger reducing agent than chloride IP6 (because) S is reduced from +6 to – 2 in H_2S OR S is reduced from +6 to 0 in S OR S is reduced from +6 to + 4 in SO_2 OR Any balanced equation making H_2S, SO_2, or S showing electrons eg $8H^+ + H_2SO_4 + 8e^- \longrightarrow H_2S + 4H_2O$ $2H^+ + H_2SO_4 + 2e^- \longrightarrow SO_2 + 2H_2O$ $6H^+ + H_2SO_4 + 6e^- \longrightarrow S + 4H_2O$	Note observation is not required for IP This can be seen in an equation Ignore any reference to hydrogen iodide/HI/misty fumes The two parts of this answer may often be seen in different places. Allow hydrogen iodide or potassium iodide is a stronger reducing agent than hydrogen chloride or potassium chloride. Allow reducing ability (of the halides) increases down the group Or reverse argument Do not award iodine/I is a stronger reducing agent than chlorine/Cl Allow just correct stated product and oxidation number eg – 2 in H_2S or 0 in S or + 4 in SO_2 Ignore I_2 oxidation number = 0	

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Question Number	Answer	Additional Guidance	Mark
(c)	• number of moles of sulfuric acid in 40.5 cm^3 (1) • concentration of the concentrated sulfuric acid (1)	Example of calculation $1.5 \times 500 \div 1000 = 0.75$ (mol) $0.75 \times 1000 \div 40.5 = 18.519$ (mol dm^{-3}) Allow TE on incorrect moles Units not required but if given they must be correct Correct answer with or without working scores (2) Ignore SF except 1 SF	2

Q26.

Question number	Answer	Mark
	D dilute nitric acid followed by silver nitrate solution gives a white precipitate	1

Q27.

Question Number	Answer	Mark
	The only correct answer is D (3 and 4) ***A*** *is incorrect because a flame test will not positively identify ammonium ions and barium nitrate will not positively identify chloride ions* ***B*** *is incorrect because a flame test will not positively identify ammonium ions* ***C*** *is incorrect because barium nitrate will not positively identify chloride ions*	**(1)**

Q28.

Question Number	Answer	Additional Guidance	Mark
(a)	An explanation that makes reference to the following points: • atomic radius increases **or** distance between the nucleus and outer electrons increases **or** there are more shells / energy levels of inner electrons between the nucleus and the outer shell electrons **(1)** • so there is less attraction (by the nucleus with a higher charge) for the bonding electrons / shared pair of electrons **(1)**	Allow size of atoms increases / gets bigger Allow just 'more shells of electrons' Allow effective nuclear charge decreases Do not award nuclear charge decreases Do not award reference to ions / ionic radius for M1 only Allow greater shielding between the nucleus and the bonding electrons / shared pair of electrons **Note** – bonding / shared pair can be mentioned anywhere in the answer	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • three oxidation numbers of I: IO_3^- = (+)5 I^- = −1 I_2 = 0 (1) • two different species / ions / compounds (of iodine) are oxidised and reduced (to form the same species) **or** there is not one species / ion / compound that is being oxidised and reduced **or** 2 different oxidation states are not produced from one oxidation state (of iodine) **or** only one species / oxidation state of iodine is formed (1)	Allow oxidation numbers written near species in the equation Ignore oxidation numbers of H and O Do not award O.N. I_2 is neutral / I^- is −5 Allow I_2 / iodine is oxidised and reduced in the reverse reaction Allow (iodine in) IO_3^- is only being reduced **or** (iodine in) I^- is only being oxidised Ignore just 'the reaction is only oxidation / reduction' Ignore just 'comproportionation' Ignore just 'I / iodine is not simultaneously oxidised and reduced'	(2)

Question Number	Answer	Additional Guidance	Mark
(c)	• sulfur dioxide / sulfur (IV) oxide / SO_2 produced from HBr **and** hydrogen sulfide / H_2S produced from HI	Example of table: Hydrogen halide | Compound produced with the lowest oxidation number of sulfur (HBr) | sulfur dioxide / SO_2 (HI) | hydrogen sulfide / H_2S Ignore Br_2 and I_2 **Note** - If name and formula are given, both must be correct	(1)

Question Number	Answer	Additional Guidance	Mark
(d)	An explanation that makes reference to the following points:	Allow van der Waals' forces / dispersion forces / attractions between instantaneous dipoles and induced dipoles for London forces or a description of London forces	(4)
	• all hydrogen halides have London forces (and dipole-dipole forces between molecules) (1)	Ignore London forces omitted from HF Do not award this mark if ions mentioned in answer Do not award this mark if breaking H-Cl, H-Br or H-I bonds	
	• the strength of the London forces increases as the number of electrons increases (so the boiling temperature increases from HCl to HI) **or** the strength of the London forces increases as the polarisability of the molecules increases from HCl to HI (1)	Ignore the strength of the London forces increases as the size of the molecule / M_r increases	
	• (only) HF has hydrogen bonding (between molecules) (1)	Do not award M3 if hydrogen bonding in any other hydrogen halide	
	• hydrogen bonding is (much) stronger than London forces / dipole-dipole forces (so HF has the highest boiling temperature) (1)	Allow more heat energy is needed to overcome hydrogen bonding than London forces Allow hydrogen bonding is the strongest intermolecular force / bond	

Question Number	Answer	Additional Guidance	Mark
(e)	An answer that makes reference to the following point: • calculation of mol of AgCl (1) • calculation of mass of Cl^- (1) • calculation of percentage of Cl^- (1) **OR** • calculation of % by mass of Cl in AgCl (1) • calculation of mass of Cl in residue (1) • calculation of percentage of Cl^- (1)	Example of calculation: **Method 1** mol AgCl = $\frac{0.226}{143.4}$ = 0.0015760 / 1.5760 x 10^{-3} mass Cl^- = 1.5760 x 10^{-3} x 35.5 = 0.055948 (g) % Cl^- = $\frac{0.055948}{0.098}$ x 100 = 57.09 / 57.1 / 57 (%) **Method 2** % by mass of Cl in AgCl = $\frac{35.5}{143.4}$ x 100 = 24.756 (%) mass of Cl = 24.756 x 0.226 = 0.055948 (g) % by mass of Cl^- in residue = $\frac{0.055948}{0.098}$ x 100 = 57.09 / 57.1 / 57 (%) Correct answer with no working scores (3) Allow TE at each stage Allow alternative methods Ignore SF except 1 SF Accept fractions / correct working not evaluated for M1 and M2	(3)

Q29.

Question Number	Answer	Mark
	The only correct answer is D (reactivity of the elements increases) *A is not correct because atomic radius increases down the group* *B is not correct because the boiling temperature increases down the group* *C is not correct because electronegativity decreases down the group*	1

Q30.

Question Number	Correct Answer	Mark
	The only correct answer is B (reducing ability of the halide ions) ***A*** *is incorrect as the oxidising ability of the molecular halogens decreases down the group* ***C*** *is incorrect as the electrostatic attraction between nucleus and outer shell of electrons decreases down the group* ***D*** *is incorrect as electronegativity decreases down the group*	**1**