PEARSON EDEXCEL IAL CHEMISTRY · YCH11

CHEMISTRY



EXAM QUESTION PACK

UNIT 2: INTERMOLECULAR FORCES

SCORE	PERCENTAGE
/209	%

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Q1.

Which alkane has the highest boiling temperature?

(1)

☒ **A** 2,2-dimethylpropane

☒ **B** 2-methylbutane

☒ **C** butane

☒ **D** pentane

(Total for question = 1 mark)

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.

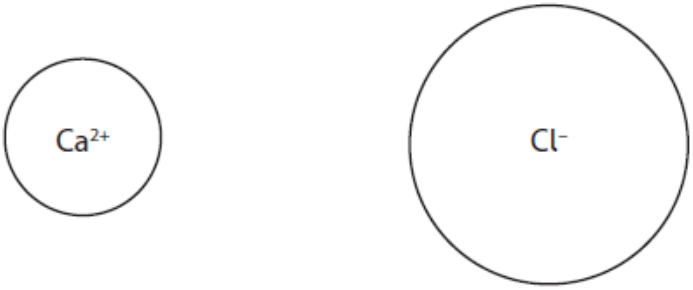
Detailed descriptions of the forces involved are not required.

(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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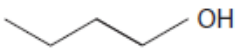
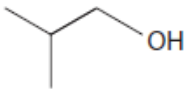
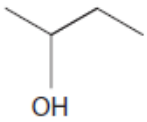
(Total for question = 10 marks)

Q3.

Biobutanol is a possible alternative to bioethanol as an additive to petrol.

(a) (i) Complete the table for the four isomers of C_4H_9OH which are alcohols.

(3)

Skeletal formula	Name	Classification	Boiling temperature / °C
	butan-1-ol	primary	117
			108
			99
	2-methylpropan-2-ol		82

(ii) Explain the difference in boiling temperature between butan-1-ol and 2-methylpropan-2-ol.

(2)

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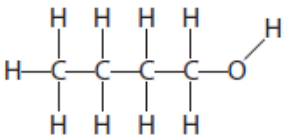
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(iii) The displayed formula of butan-1-ol is shown.

Complete the diagram to show the strongest intermolecular force between **two** molecules of butan-1-ol. Include the intermolecular bond angle.

(2)



(b) (i) Complete the equation for the combustion of butan-1-ol.

State symbols are not required.

(1)



(ii) Calculate a value for the enthalpy change of combustion of butan-1-ol using the equation in (b)(i) and the mean bond enthalpies in the table.

(3)

Bond	C—C	C—O	C═O	C—H	O—H	O═O
Mean bond enthalpy/kJ mol^{-1}	347	358	805	413	464	498

(iii) A data book value of the molar enthalpy change of combustion of butan-1-ol is −2670 kJ mol^{-1}

Give **two** reasons for the difference between this value and the value calculated in (b)(ii).

(2)

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(c) Biobutanol has some advantages over bioethanol.

(i) The combustion of bioethanol releases 23 MJ dm^{-3} compared to petrol which releases 32 MJ dm^{-3}.

Calculate the energy released in MJ dm^{-3} for the combustion of biobutanol.

Biofuel	Formula	$\Delta_c H$/kJ mol^{-1}	Density/g cm^{-3}
biobutanol	C_4H_9OH	−2670	0.810

(2)

(ii) Biobutanol can be mixed with petrol in any proportion whereas bioethanol cannot.

Petrol is a mixture of liquid alkanes.

Explain why petrol is more miscible with biobutanol than with bioethanol.

(2)

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(Total for question = 17 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.

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 ☒.

This question is about alkanes.

(a) Which of these alkanes has the highest boiling temperature?

(1)

☒

A butane

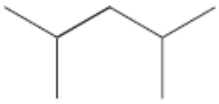
☒ **B** hexane

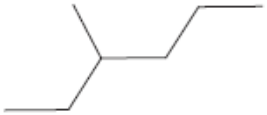
☒ **C** pentane

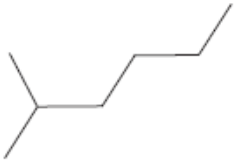
☒ **D** propane

(b) Which of these alkanes has the lowest boiling temperature?

(1)

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for question = 2 marks)

Q6.

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 isomers with the formula C_8H_{18} has the lowest boiling temperature?

☒ **A** $CH_3CH(CH_3)CH_2CH_2CH(CH_3)CH_3$

☒ **B** $CH_3CH(CH_3)CH_2CH_2CH_2CH_2CH_3$

☒ **C** $CH_3C(CH_3)_2CH_2CH(CH_3)CH_3$

☒ **D** $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

(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 ☒.

Which of these compounds would be expected to have the **highest** boiling temperature?

☒ **A** $(CH_3)_3COH$

☒ **B** $CH_3CH_2CH_2CH_2OH$

☒ **C** $CH_3CH_2CH(CH_3)_2$

☒ **D** $CH_3CH_2CH_2CH_2CH_3$

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

(Total for question = 1 mark)

Q8.

Which row shows the hydrogen halides in order of **increasing** boiling temperature?

	Lowest ⟶			Highest
☒ **A**	HF	HCl	HBr	HI
☒ **B**	HI	HBr	HCl	HF
☒ **C**	HCl	HBr	HI	HF
☒ **D**	HF	HI	HBr	HCl

(Total for question = 1 mark)

Q9.

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 ☒.

Why is the boiling temperature of hydrogen iodide higher than that of hydrogen bromide?

☒ **A** hydrogen iodide has stronger London forces than hydrogen bromide

☒ **B** hydrogen iodide has a larger permanent dipole than hydrogen bromide

☒ **C** hydrogen iodide has stronger hydrogen bonds than hydrogen bromide

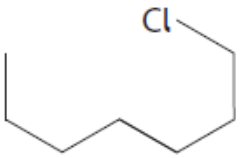
☒ **D** the H—I bond is stronger than the H—Br bond

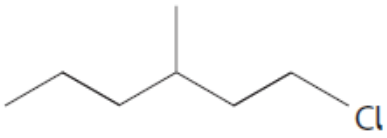
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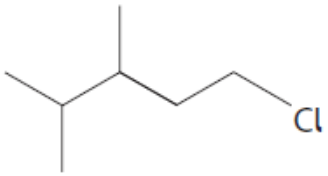
Q10.

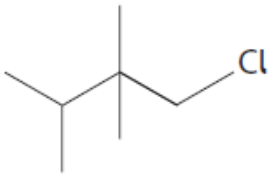
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of these isomers has the **highest** boiling temperature?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

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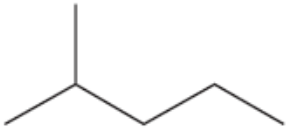
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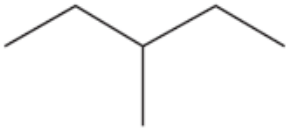
Q11.

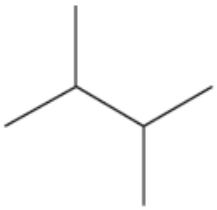
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which of these isomers has the **highest** boiling temperature?

☒ **A** 

☒ **B** 

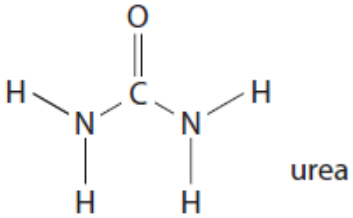
☒ **C** 

☒ **D** 

(Total for question = 1 mark)

Q12.

Some diesel cars contain an extra catalytic converter for the reduction of nitrogen oxides (NO_x) in exhaust gases.
A solution of urea is used for this process.



urea

(a) Urea has a melting temperature of 133 °C.

Explain why this value is higher than expected for a relatively small molecule.

(3)

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(b) A saturated solution of urea has a concentration of 9.07 mol dm^{-3} at 25°C.

Calculate the mass of urea in 150 cm^3 of a saturated solution.

(2)

(c) State why NO_x emissions are harmful to the environment.

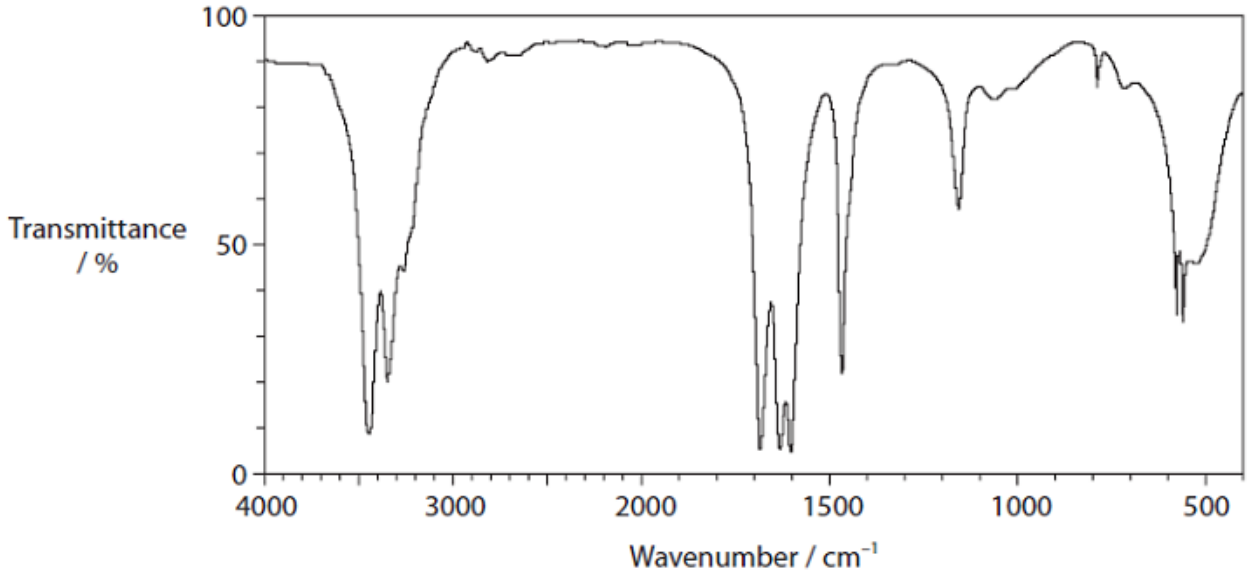
(1)

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(d) An infrared spectrum of urea is shown.

Refer to your Data Booklet.



(i) Draw a circle around an absorption in the spectrum that could be due to the stretching of the N—H bond.

(1)

(ii) Identify the bond responsible for the absorption at 1683 cm^{-1}.

.....

(1)

(e) In a diesel car exhaust system, the urea reacts with water to form ammonia and carbon dioxide. The enthalpy change for this reaction is +133 kJ mol^{-1}.

(i) Complete the equation for this **reversible** reaction.

State symbols are not required.

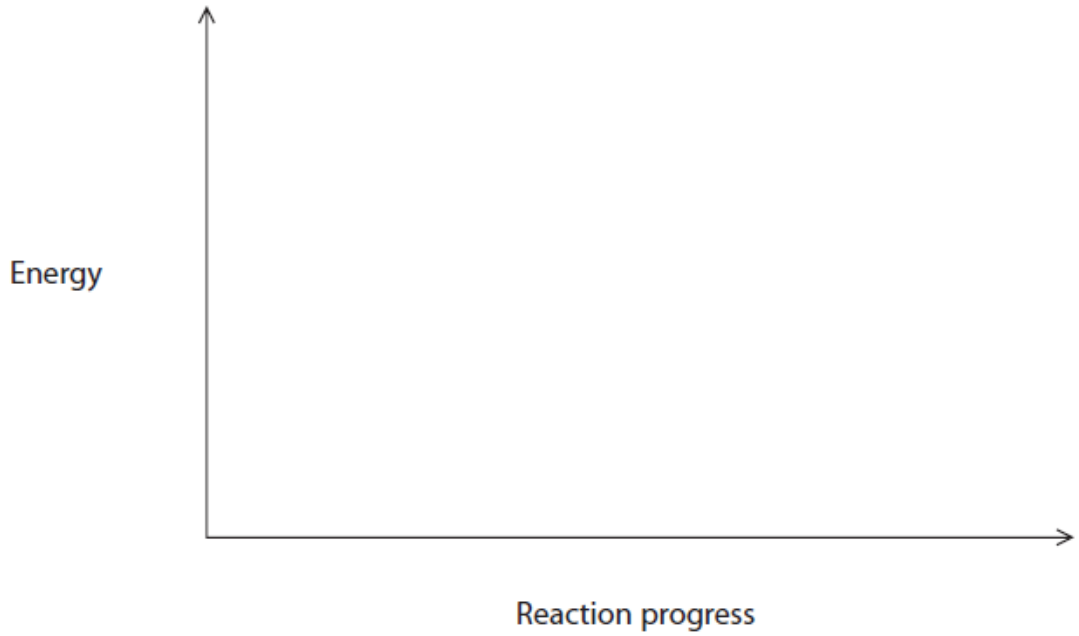
(1)

$(NH_2)_2CO + H_2O$

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(ii) Sketch the reaction profile for the forward reaction on the axes provided.

Include labels for ΔH and the activation energy (E_a).



(3)

(f) The catalytic converter contains metal oxides. When the exhaust gases pass through the catalytic converter, ammonia reacts with NO_x gases to form nitrogen and water.

(i) Explain why it is **not** correct to state that urea is acting as a catalyst in the reaction.

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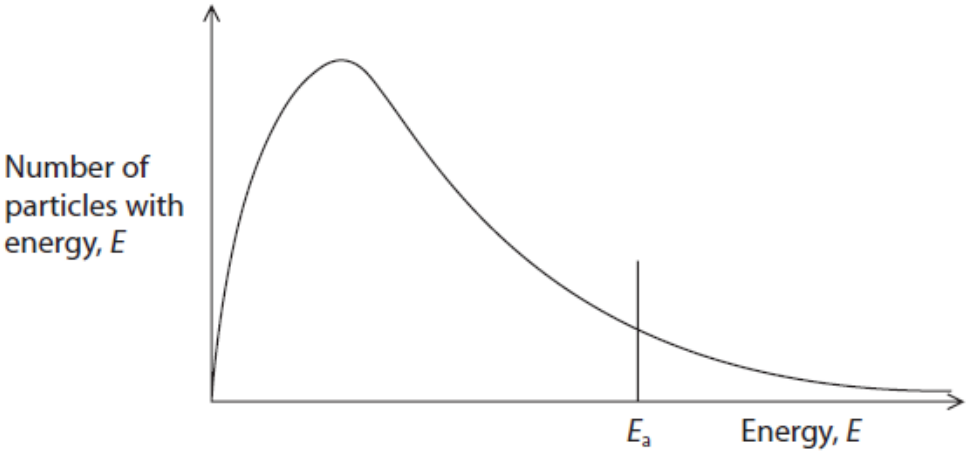
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(1)

(ii) Explain how a catalyst increases the rate of a chemical reaction.

Use the Maxwell-Boltzmann distribution shown and refer to the collision theory.

(3)



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(g) The catalytic converter works best at a temperature of around 350 °C.

(i) Suggest how the catalytic converter reaches this temperature.

(1)

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(ii) The chemical reactions in the exhaust system of a diesel car, using a catalytic converter, form 89.3 m^3 of nitrogen per hour.

Calculate the number of molecules of nitrogen formed per hour.

[Molar volume at 350 °C = 51.1 dm^3 mol^{-1}

Avogadro constant, $L = 6.02 \times 10^{23}$ mol^{-1}]

(3)

(Total for question = 20 marks)

Q13.

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
.....

Cyclohexane layer
.....

(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)

Q14.

This question is about compounds containing Group 2 elements.

(a) Hydrated magnesium nitrate has the formula $Mg(NO_3)_2.xH_2O$.

A student devised an experiment to determine the value of **x** by leaving 5.12 g of hydrated magnesium nitrate for several hours in a warm oven. After this time, the solid remaining had a mass of 2.97 g.

(i) State why the student used a warm oven to remove the water from the

hydrated salt, rather than direct heating with a Bunsen burner.

(1)

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(ii) Use the data obtained by the student to calculate the value of **x**.

You **must** show your working.

(4)

(b) Magnesium carbonate, MgCO3, is a white solid used as an additive in foods.

(i) Explain, in terms of energy changes, why magnesium carbonate is insoluble in water.

(2)

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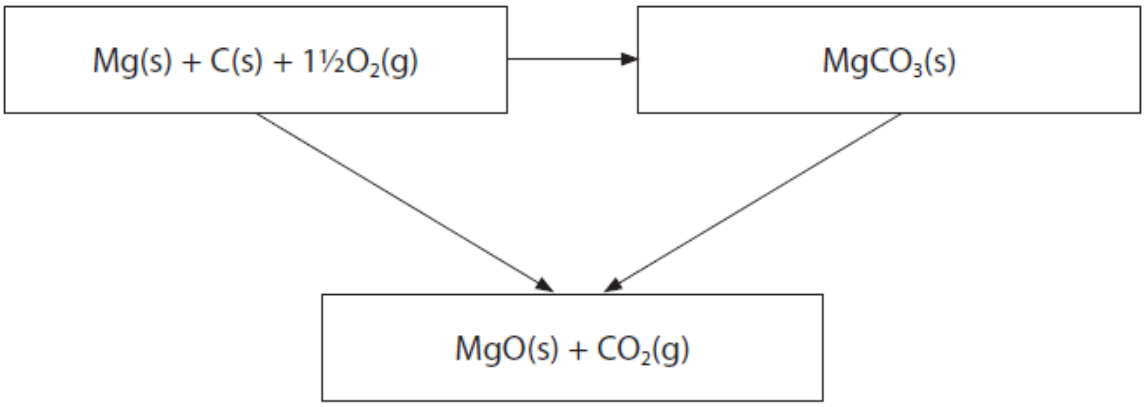
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(ii) The Hess cycle and data to calculate the enthalpy change for the thermal decomposition of MgCO3 are shown.



Compound	$\Delta_f H^{\ominus}$ / kJ mol^{-1}
$CO_2(g)$	−394
MgO(s)	−602
$MgCO_3(s)$	−1096

Calculate the enthalpy change for the thermal decomposition of $MgCO_3$.

(2)

(iii) Explain the trend in thermal stability of Group 2 carbonates.

(4)

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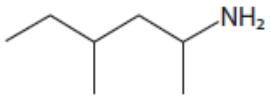
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(Total for question = 13 marks)

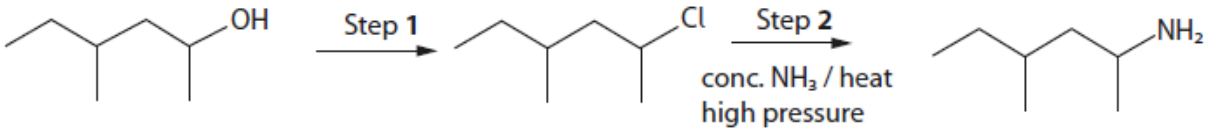
Q15.

The compound DMAA was originally synthesised as a decongestant.



DMAA

A suggested synthetic route for DMAA is shown.



compound **A**

(a) (i) Give the systematic name of compound **A**.

(1)

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(ii) Identify, by name or formula, a suitable reagent for Step **1**.

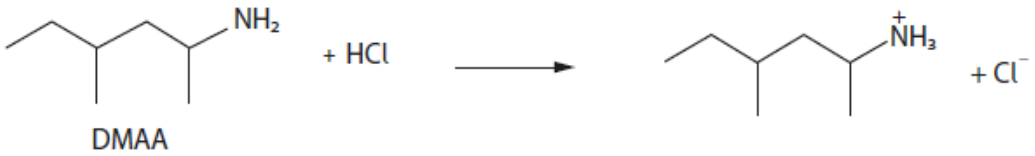
(1)

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(iii) Give the mechanism for the reaction in Step **2**.
Include curly arrows, and any relevant dipoles and lone pairs.

(4)

(b) DMAA is only slightly soluble in water but dissolves readily in hydrochloric acid to form an aqueous solution.



DMAA

(i) Explain the type of bonding that occurs between the nitrogen atom and the hydrogen ion, when the positive ion forms.

(3)

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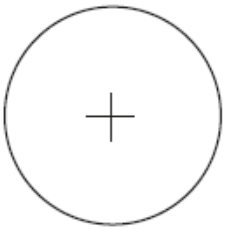
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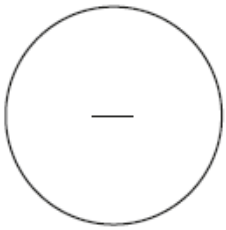
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(ii) Complete the diagrams to show how the ions formed in the reaction between DMAA and hydrochloric acid interact with water molecules.

(3)





(Total for question = 12 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 ☒.

Which compound does **not** form hydrogen bonds between its molecules?

☒ **A** HCl

☒ **B** H_2O

☒ **C** HF

☒ **D** NH_3

(Total for question = 1 mark)

Q17.

Ethanol can be made in industry by the reaction of ethene with steam, using a phosphoric(V) acid catalyst.

$$CH_2{=}CH_2(g) + H_2O(g) \rightleftharpoons CH_3CH_2OH(g) \quad \Delta_rH = -45 \text{ kJ mol}^{-1}$$

The reaction is carried out at 300°C and 60 atm. An initial yield of 5 % is achieved when the ethene and steam first pass through the reactor.

*(a) Explain the chemical reasons for the conditions used and why such a low initial yield is acceptable in the industrial process.

(6)

(b) The product of the reaction is a mixture of ethanol and water.

Explain why ethanol and water mix together fully.

You may find it helpful to draw a diagram.

(3)

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(c) Ethanol can be oxidised using a solution of acidified potassium dichromate(VI), $K_2Cr_2O_7(aq)$.

Ethanoic acid and another organic compound, **Y**, are both possible products.

(i) Draw the structure of **Y**.

(1)

(ii) State the conditions needed to maximise the yield of each product.

(2)

Conditions for maximum yield of **Y**

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Conditions for maximum yield of ethanoic acid

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(Total for question = 12 marks)

Q18.

This question is about ethanol and bioethanol.

The main fuel used as a petrol substitute is bioethanol. Bioethanol is ethanol that has been produced by fermentation. The starting material is usually some form of plant material rich in starch, such as wheat, maize or potatoes. Enzymes in yeast convert this material to simple carbohydrates such as glucose ($C_6H_{12}O_6$) and then to ethanol and carbon dioxide.

$$C_6H_{12}O_6 \rightarrow 2CH_3CH_2OH + 2CO_2$$

The mixture is left for several days until fermentation is complete.
The percentage of ethanol is never greater than 15 % because higher concentrations of ethanol kill the yeast.

A common blend of fuel is 95 % petrol and 5 % bioethanol. The engine does not need to be modified for this mixture.

(a) Give **one** advantage and **one** disadvantage of using bioethanol in petrol.

(2)

Advantage

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Disadvantage

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(b) Suggest why this fermentation must be carried out in the absence of air.

(1)

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(c) Suggest how the ethanol can be obtained, after filtering the fermentation mixture.

(1)

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(d) Ethanol is hygroscopic, which means it readily absorbs water from the air.

(i) Give a possible reason why ethanol is able to absorb water.

(1)

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(ii) Suggest a problem arising from the hygroscopic nature of ethanol when using this fuel in a motor vehicle.

(1)

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(e) Ethanol can also be produced by the hydration of ethene.

$$CH_2 = CH_2(g) + H_2O(g) \leftrightarrow CH_3CH_2OH(g) \qquad \Delta H = -45 \text{ kJ mol}^{-1}$$

*(i) Typical conditions are 300 °C and 60 atm with a catalyst of phosphoric acid.

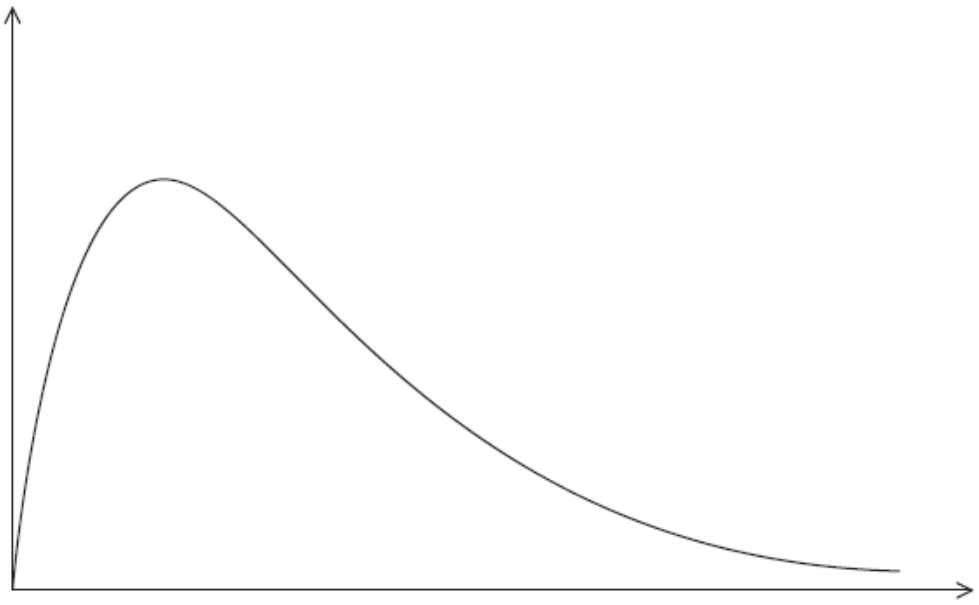
Explain why these conditions are used, by describing the effect of changing the temperature and pressure on rate of reaction, equilibrium yield and cost.

(6)

(ii) The rate of this reaction is increased by using a catalyst of phosphoric acid.

Label the axes on the Maxwell–Boltzmann distribution curve and use it to explain how a catalyst increases the rate of reaction.

(4)



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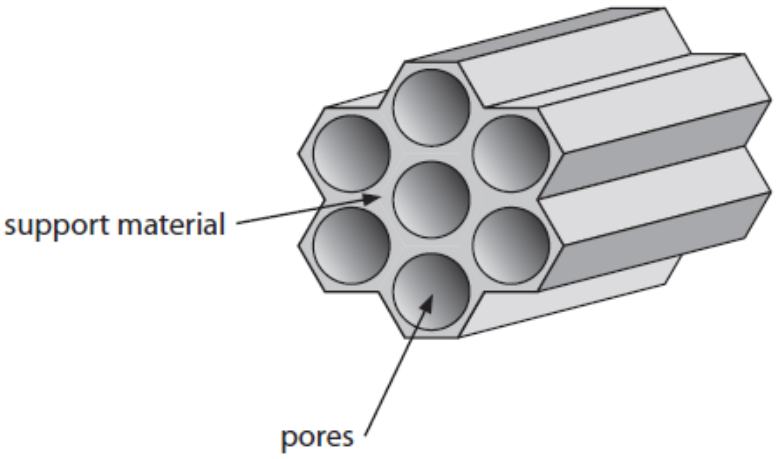
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(f) Catalysts such as phosphoric acid are bonded to a support material that contains lots of pores.



(i) Suggest the advantage of using support materials containing lots of pores.

(1)

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(ii) Under these conditions, only about 5 % of the ethene is converted into ethanol as it passes over the catalyst.

Suggest how the overall yield of this process can be improved to make it economically viable.

(2)

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(Total for question = 19 marks)

Q19.

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 ☒.

This question is about hydrogen bonding.

(a) Which property is **not** due to hydrogen bonding?

(1)

☒ **A** ice has a lower density than water at 0°C

☒ **B** hydrogen fluoride has a higher boiling temperature than hydrogen chloride

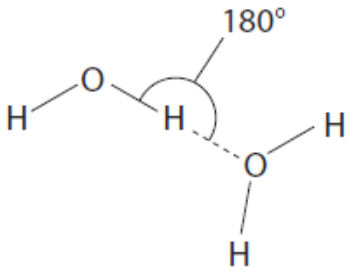
☒ **C** H—H bond enthalpy is greater than Si—H bond enthalpy

☒ **D** alcohols are less volatile than alkanes with a similar molar mass

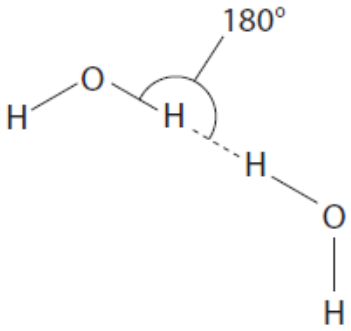
(b) Which diagram best represents a hydrogen bond between two water molecules?

(1)

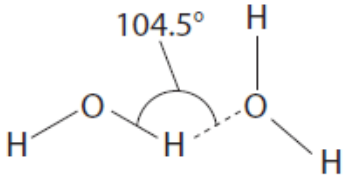
☒ **A**



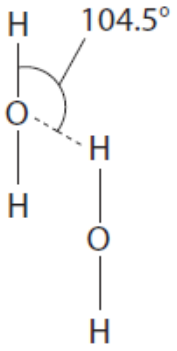
☒ **B**



☒ **C**



☒ **D**



(Total for question = 2 marks)

Q20.

Which statement is **not** explained by hydrogen bonding?

(1)

☒ **A** all Group 1 hydroxides are soluble in water

☒ **B** many simple alcohols are soluble in water

☒ **C** the density of ice is less than the density of liquid water at 0 °C

☒ **D** the melting temperature of water is abnormally high

(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 ☒ .

Which of these pure compounds has hydrogen bonding in the liquid state?

☒ **A** 1,1,1-trichloroethane, CH_3CCl_3

☒ **B** trimethylamine, $(CH_3)_3N$

☒ **C** hydrogen fluoride, HF

☒ **D** hydrogen sulfide, H_2S

(Total for question = 1 mark)

Q22.

What are the strongest interactions **between** molecules in solid hydrogen iodide, HI?

(1)

☒ **A** covalent bonds

☒ **B** hydrogen bonds

☒ **C** ionic bonds

☒ **D** London forces

(Total for question = 1 mark)

Q23.

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 intermolecular forces exist **between** the molecules of the compound shown?



☒ **A** hydrogen bonding and London forces only

☒ **B** hydrogen bonding and permanent dipole-permanent dipole forces only

☒ **C** London forces and permanent dipole-permanent dipole forces only

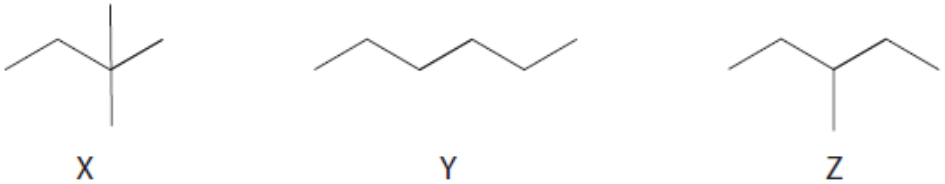
☒ **D** hydrogen bonding, permanent dipole-permanent dipole forces and London forces

(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 ☒.

The skeletal formulae of three isomers are shown.



Which series shows the correct order of **increasing** boiling temperatures?

☒ **A** Y, X, Z

☒ **B** X, Y, Z

☒ **C** Y, Z, X

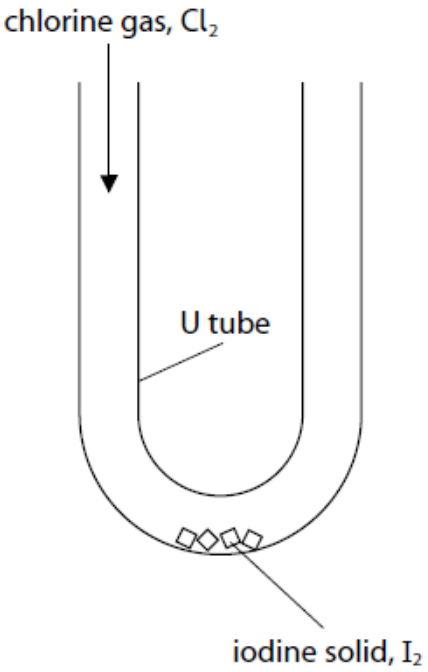
☒ **D** X, Z, Y

(Total for question = 1 mark)

Q25.

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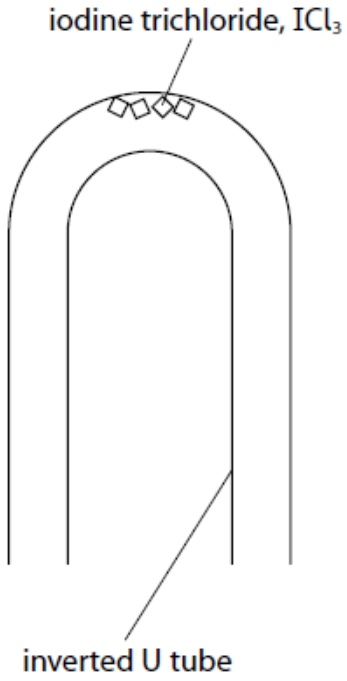
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(e) Chlorine gas has a molar volume of 24 000 cm^3 mol^{-1} under the conditions used in this reaction.

(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.

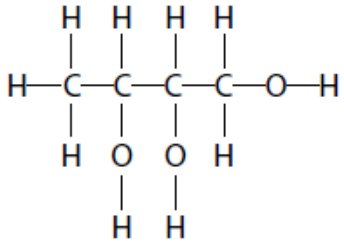
(2)

(Total for question = 20 marks)

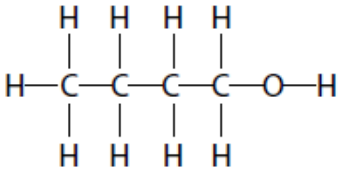
Q26.

Which is the order of **increasing** boiling temperature?

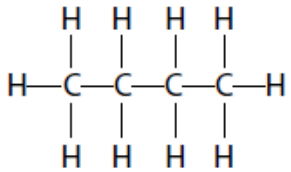
W =



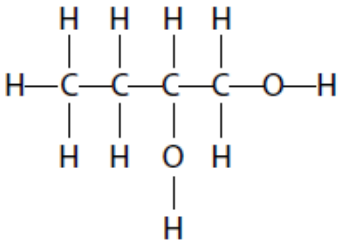
X =



Y =



Z =



(1)

☒ **A** Y Z X W

☒ **B** Y X Z W

☒ **C** W X Z Y

☒ **D** X W Y Z

(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 ☒.

Which is **not** correct about ice?

☒ **A** ice has a lower density than water

☒ **B** H_2O molecules are further apart in ice than in water

☒ **C** the H—O—H bond angle is the same in ice and in water

☒ **D** H_2O molecules in ice are held together by hydrogen bonds

(Total for question = 1 mark)

Q28.

This question is about halogenoalkanes.

(a) The rates of hydrolysis of 1-chloropropane, 1-bromopropane and 1-iodopropane in reactions with aqueous silver nitrate solution were compared.

(i) State what would be measured in the experiment to compare the rates of hydrolysis.

(1)

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(ii) State which of these halogenoalkanes would hydrolyse the fastest.

Justify your answer.

(2)

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(b) The equation for the hydrolysis of 1-chloropropane by aqueous hydroxide ions is shown.

$$CH_3CH_2CH_2Cl + OH^- \rightarrow CH_3CH_2CH_2OH + Cl^-$$

Give the mechanism for this hydrolysis.
Include curly arrows, and relevant dipoles and lone pairs.

(2)

(c) The boiling temperatures of some halogenoalkanes are shown.

Halogenoalkane	Boiling temperature / °C
1-chloropropane	47
1-bromopropane	71
1-iodopropane	103

Explain the trend in boiling temperature of these halogenoalkanes by comparing the intermolecular forces involved.

Detailed explanations of the forces involved are not required.

(4)

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(d) In another experiment, 2-bromobutane is heated with ethanolic potassium hydroxide and an elimination reaction occurs.

Draw the **skeletal** formulae of the three possible organic products, giving their names.

(3)

Skeletal formula	Name

(Total for question = 12 marks)

Q29.

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 solvent dissolves the greatest amount of hydrocarbon $C_{35}H_{72}$?

☒ **A** butan-1-ol

☒ **B** ethanoic acid

☒ **C** hexane

☒ **D** water

(Total for question = 1 mark)

Q30.

Enthalpy changes of formation are often difficult to determine directly.

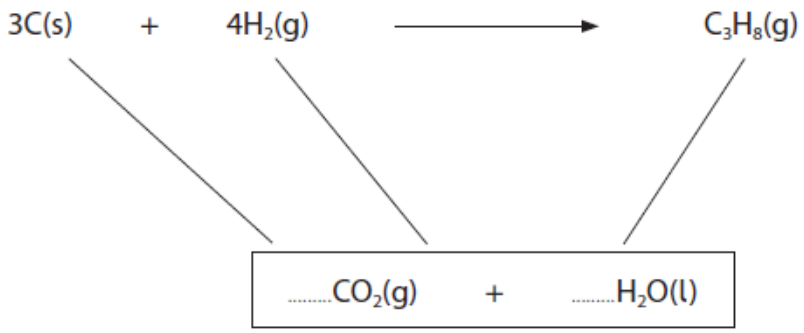
Some enthalpy data are shown.

Compound	Standard enthalpy change of formation, $\Delta_f H^{\ominus}$ / kJ mol^{-1}
$H_2O(l)$	−285.8
$CO_2(g)$	−393.5

Standard enthalpy change of combustion of propane $(\Delta_c H^{\ominus}(C_3H_8)) = -2219\,\text{kJ mol}^{-1}$.

(a) (i) Add arrowheads and stoichiometric coefficients to the Hess's Law diagram.

(1)



(ii) Use the data at the start of the question and your Hess's Law diagram to calculate the standard
enthalpy change of formation of propane.
Include a sign and units in your answer.

(2)

(b) The values for the boiling temperatures and the standard enthalpies of combustion of a series of straight-chain alkanes
are shown in the table.

Alkane	Boiling temperature / °C	Standard enthalpy change of combustion, $\Delta_c H^{\ominus}$ / kJ mol^{-1}	Increase in $\Delta_c H^{\ominus}$ / kJ mol^{-1}
C_2H_6	–88.5	–1560	–
C_3H_8	–42.0	–2219	659
C_4H_{10}	–0.5	–2877	658
C_5H_{12}	36.1	–3509	632
C_6H_{14}	68.8	–4163	654
C_7H_{16}	98.4	–4817	654

(i) Explain why the increases in the values of $\Delta_c H^{\ominus}$ are similar.

(2)

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(ii) The increase in the value of $\Delta_c H^{\ominus}$ from butane to pentane is smaller than any other increase.

Suggest an explanation for this.

(2)

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(iii) Explain, with reference to their intermolecular forces, why the boiling temperatures of **alkanes** increase as the number of carbon atoms increases. A detailed description of the intermolecular forces is not required.

(3)

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(Total for question = 10 marks)

Q31.

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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(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} .

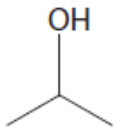
(2)

(Total for question = 20 marks)

Q32.

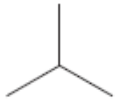
Answer the question with a cross in the box you think is correct ☒. If you change your mind about an answer, put a line through the box ☒ and then mark your new answer with a cross ☒.

Which compound has the **highest** boiling temperature?

☒ **A** 

☒ **B** 

☒ **C** 

☒ **D** 

(Total for question = 1 mark)

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

Q33.

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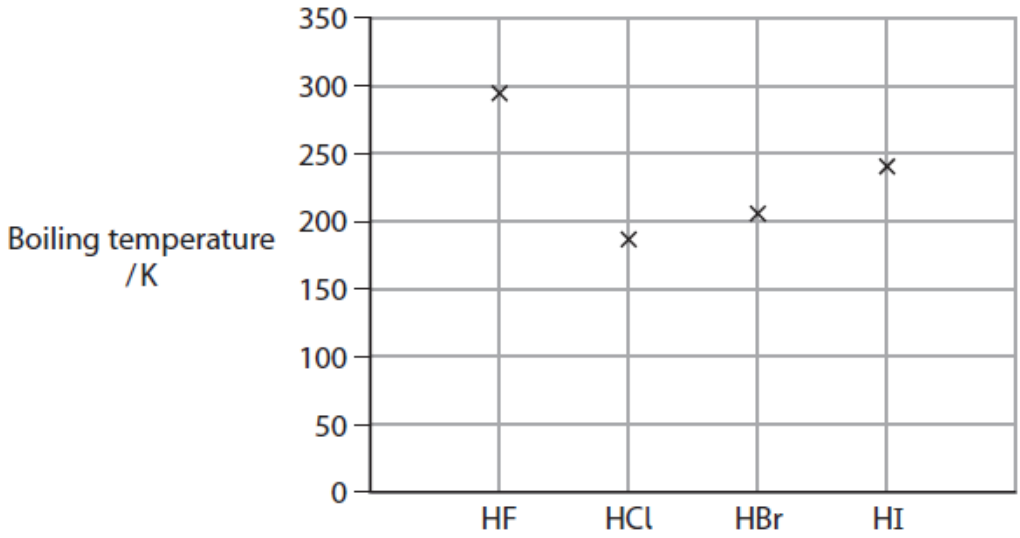
(c) Hydrogen bromide and hydrogen iodide reduce sulfuric acid.

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.]

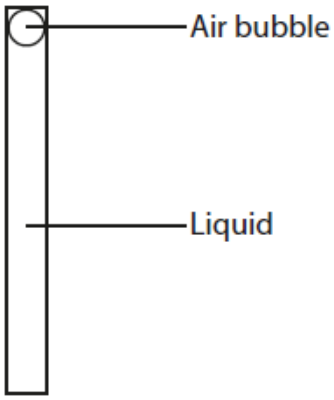
(3)

(Total for question = 12 marks)

Q34.

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 ☒ .

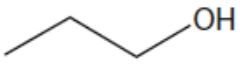
The viscosities of four liquid organic compounds are compared by placing the liquids in separate identical tubes, each with an air bubble at the top.



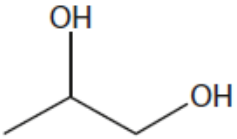
The tubes are inverted, and the times measured for the air bubble to travel the length of the tube.

For which compound does the air bubble take the longest time?

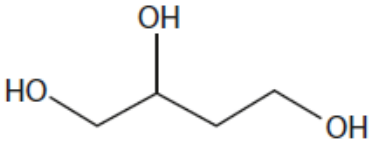
☒ **A**



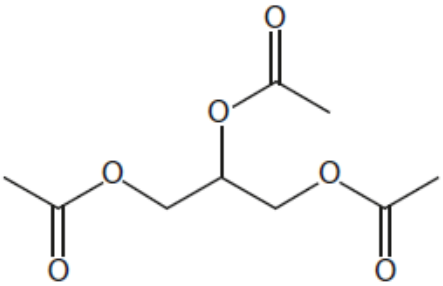
☒ **B**



☒ **C**



☒ **D**



(Total for question = 1 mark)

Q35.

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 the following statements about water is **not** due to hydrogen bonding?

☒ **A** water has a less open structure than ice

☒ **B** ice cubes float in a glass of iced water

☒ **C** when water freezes its volume increases

☒ **D** water is a good solvent for ionic compounds

(Total for question = 1 mark)

Mark Scheme

Q1.

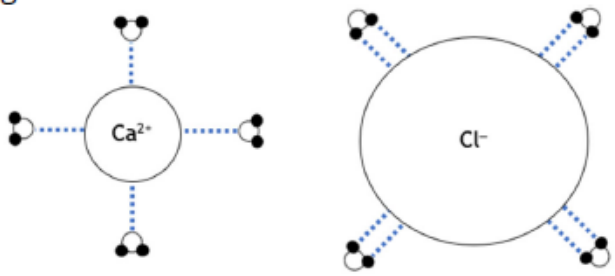
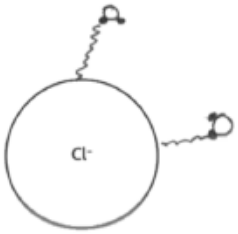
Question number	Answer	Mark
	D pentane	1

Q2.

Q	Answer	Additional Guidance	Mark
(a)*	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 **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	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**

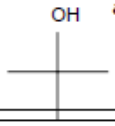
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Indicative content: • IP1: fluorine molecules **only** have London forces (instantaneous dipole-induced dipole) between them (as it has a symmetrical electron cloud/is a symmetrical/non-polar molecule.)	Allow dispersion forces / van der Waals forces 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

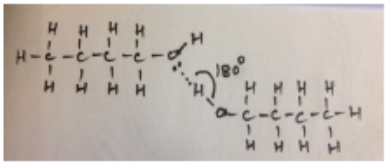
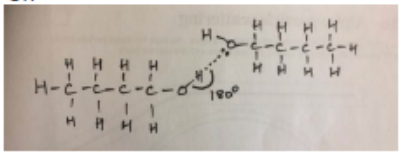
Q	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • the oxygen is closest to the calcium ion **(1)** • the hydrogen is closest to the chloride ion **(1)**	(A minimum of two water molecules should be drawn for each ion – penalise once only) E.g.  Allow displayed 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**

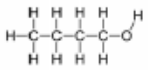
Q	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points: • Iodine has more electrons (per molecule) (than bromine) **(1)** • so stronger London forces between molecules / I_2 (mean a higher melting temperature for iodine) **(1)**	Accept reverse arguments. If numbers 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)	• (2)-methylpropan-1-ol and primary	(1)	All 6 correct scores 3 4 or 5 correct scores 2 2 or 3 correct scores 1	(3)
	• butan-2-ol and secondary	(1)		
	•  and tertiary	(1)	Ignore bond lengths and bond angles Do not award displayed formula	

Question Number	Answer		Additional Guidance	Mark
(a)(II)	An explanation that makes reference to the following points:		Accept reverse argument (butan-1-ol has a higher boiling temperature than 2-methylpropan-2-ol because)	(2)
	• Identification of (at least) one of the intermolecular forces and a comparison of its strength in the two molecules	(1)	the instantaneous dipoles-induced dipoles / London forces / dispersion forces / van der Waals forces are stronger between straight chains Allow There are more London forces OR the hydrogen bonding is stronger between straight chain molecules	
	• an explanation for this difference	(1)	the straight chain molecule/ butan-1-ol has greater surface area / more points of contact OR as the -OH group is more exposed / less hindered (so less energy is needed to break the intermolecular forces) If the explanation is in terms of London forces, ignore 'hydrogen bonding is similar / same' Ignore 'references to"longer carbon chain" Do not award Any reference to longer carbon bonds/breaking covalent bonds	

Question Number	Answer	Additional Guidance	Mark
(a)(iii)	• O---H—O (1) • bond O-H-O must be shown as (approximately) linear (1) **and** angle labelled as 180°	Example of diagrams:  OR  Do not penalise omission of lone pair on the oxygen or errors in the carbon chain e.g. missing Hs Do not award hydrogen bond shown as a solid line (M1) H—O---H bond shown as 180° (M2) Incorrect -OH attachment to chain (M2) ignore bond lengths	(2)

Question Number	Answer	Additional Guidance	Mark
(b)(i)	• balanced equation	 + 6 O=O ⟶ 4 O=C=O + 5 H−O−H	(1)

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	• calculation or working of energy needed to break bonds (1) • calculation or working of energy released when bonds are made (1) • calculation of energy change and give a sign (1)	Here, and throughout the paper do not penalise mol⁻ for mol^{-1} Energy to break all bonds: (3x347) + (9x413) + 358 + 464 + (6x498) = 8568 (kJ mol^{-1}) Energy released when all bonds made: (10x464) + (8x805) = 11080(kJ mol^{-1}) −11080 + 8568 = −2512 (kJ mol^{-1}) Do not award incorrect units TE on incorrect balancing of equation and TE at each stage of calculation Ignore SF except 1SF Correct answer no working scores (3) Comment Common error is the use of 6.5 x 498 (forgets about the alcohol oxygen). This gives −2263 kJ mol^{-1} scores 2.	(3)

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An answer that makes reference to the following points: • mean bond enthalpies do not refer to specific compounds such as butan-1-ol/ mean bond enthalpies are averages/mean for different molecules/bonds in different environments/compounds **(1)** • butan-1-ol is a liquid and bond enthalpies refer to gases OR mean bond enthalpy calculations do not include changes of state **(1)**	Ignore just "mean bond enthalpies are an average" Ignore references to standard conditions Just 'different states'	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)(i)	• calculation of energy produced per gram **(1)** • calculation of energy produced per cm^3 **(1)** OR • calculation of moles in 1 cm^3 **(1)** • calculation of energy produced per cm^3 **(1)**	Example of calculations: (–)2670 ÷ 74 = (–)36.081/36.1 / 36 ($kJ\ g^{-1}$) 36.1 x 0.81= 29.226/29.2 / 29 ($MJ\ dm^{-3}$) 0.81 / 74 = 0.010946 (moles) 0.010946 x (–)2670 = 29.226/29.2 / 29 ($MJ\ dm^{-3}$) Units, if given, must be correct in $MJ\ dm^{-3}$ Correct answer with no working scores (2) Ignore sign and SF except 1SF	**(2)**

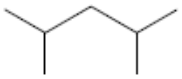
Question Number	Answer	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following points: • biobutanol has a longer hydrocarbon / alkane chain/ more electrons than bioethanol **(1)** • so more/stronger London forces / dispersion forces / Van der Waals forces between biobutanol and petrol (than bioethanol and petrol) **(1)**	Ignore references to polarity, non-polar parts Allow London forces in biobutanol and petrol are similar Do not award just "biobutanol has stronger London forces than bioethanol"	**(2)**

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	Mark
(a)	**The only correct answer is B** (hexane) ***A*** *is incorrect because this has a shorter chain length* ***C*** *is incorrect because this has a shorter chain length* ***D*** *is incorrect because this has a shorter chain length*	**(1)**

Question Number	Answer	Mark
(b)	**The only correct answer is A** () ***B*** *is incorrect because this only has one branch* ***C*** *is incorrect because this only has one branch* ***D*** *is incorrect because this is unbranched*	**(1)**

Q6.

Question Number	Correct Answer	Mark
	The only correct answer is C ($CH_3C(CH_3)_2CH_2CH(CH_3)CH_3$) ***A*** *is incorrect as this structure has less branching* ***B*** *is incorrect as structure has less branching* ***D*** *is incorrect as structure has no branching*	**1**

Q7.

Question number	Answer	Mark
	The only correct answer is B ($CH_3CH_2CH_2CH_2OH$) ***A*** *is incorrect because branching in the carbon chain reduces the boiling temperature of isomeric alcohols* ***C*** *is incorrect because alkanes do not have hydrogen bonding and have lower boiling temperatures than alcohols with a similar number of electrons* ***D*** *is incorrect because alkanes do not have hydrogen bonding and have lower boiling temperatures than alcohols with a similar number of electrons*	**(1)**

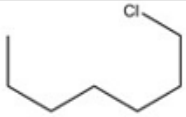
Q8.

Question Number	Answer	Mark
	The only correct answer is C (HCl, HBr, HI, HF) ***A*** *is not correct because HF is the highest* ***B*** *is not correct because HI is not the lowest* ***D*** *is not correct because HF is the highest and the rest of the order is wrong*	**(1)**

Q9.

Question Number	Answer	Mark
	The only correct answer is A (hydrogen iodide has stronger London forces than hydrogen bromide) ***B*** *is not correct because hydrogen iodide has a smaller permanent dipole than hydrogen bromide* ***C*** *is not correct because neither HBr or HI can form hydrogen bonds* ***D*** *is not correct because the H–I bond is weaker than the H–Br bond*	1

Q10.

Question number	Answer	Mark
	 **The only correct answer is A** ***B*** *is not correct because it is an isomer with 1 branch, so lower London forces* ***C*** *is not correct because it is an isomer with 2 branches, so lower London forces* ***D*** *is not correct because it is an isomer with 3 branches, so lower London forces*	**(1)**

Q11.

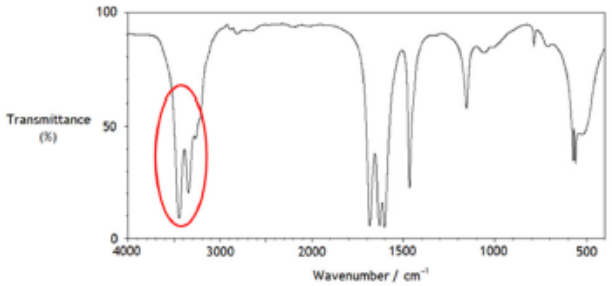
Question Number	Answer	Mark
	The only correct answer is A  ***B*** *is not correct because the molecule is branched so has weaker London Forces* *C is not correct because the molecule is branched so has weaker London Forces* ***D*** *is not correct because the molecule is branched so has weaker London Forces*	**(1)**

Q12.

Question Number	Answer	Additional Guidance	Mark
(a)	An answer that makes reference to the following points: • urea forms hydrogen bonds **(1)** • urea forms (permanent) dipole-dipole forces **(1)** • these forces are stronger than London forces **(1)**	Ignore references to number of hydrogen bonds Allow a correct diagram Allow hydrogen bonds are the strong**est** intermolecular forces Allow dispersion forces/van der Waals for London forces Do not award M3 if breaking covalent bonds is referenced	**(3)**

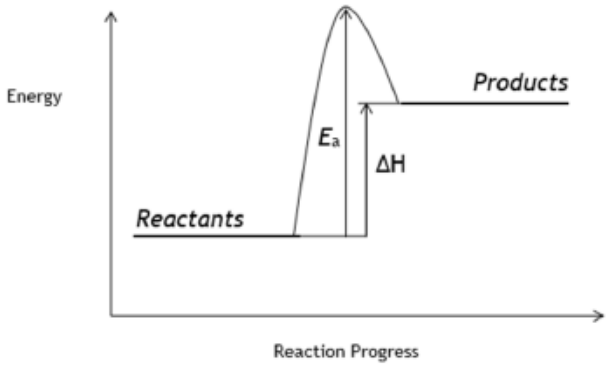
Question Number	Answer	Additional Guidance	Mark
(b)	An answer that makes reference to the following points: • M_r of urea **(1)** OR moles of urea • mass of urea required **(1)**	M_r = 60 (9.07 ÷ 1000) × 150 = 1.36(05) (9.07 ÷ 1000) × 150 × 60 = 81.63 (g) / 81.6 (g) Ignore SF except 1 SF Correct answer scores (2) No M2 if units other than grams are used	**(2)**

Question Number	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following point: • (oxides of nitrogen lead to the formation of) acid rain	Allow formation of photochemical smog Allow "NO can react with ozone" Allow descriptions of acid rain formation e.g. forms HNO_3 Do not award greenhouse effect / global warming Do not award depletes the ozone layer without reference to nitrogen(II) oxide/NO	**(1)**

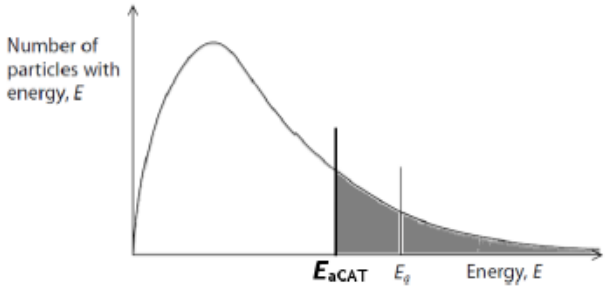
Question Number	Answer	Additional Guidance	Mark
(d)(i)	An answer that makes reference to the following point • correct peak circled	Example of completed spectra:  Allow any number of the three peaks in the region to be circled individually Extra circles negate the mark	**(1)**

Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to the following point • C=O		**(1)**

Question Number	Answer	Additional Guidance	Mark
(e)(i)	An answer that makes reference to the following points • products **and** reversible arrow	Example of balanced equation: $\rightleftharpoons 2NH_3 + CO_2$ Accept products in any order Allow multiples if equation is balanced Allow 2 full headed arrows, one in either direction	**(1)**

Question Number	Answer	Additional Guidance	Mark
(e)(ii)	An answer that makes reference to the following points: • line labelled products higher than line labelled reactants and to the right **(1)** • ΔH labelled correctly **(1)** • E_a labelled correctly **(1)**	 Accept actual reactants and products labelled on diagram (even if slightly incorrect names or formulae are used) Ignore state symbols even if incorrect Allow ΔH given as +133 Double-headed arrows penalised once only Arrows in wrong direction or missing heads penalised each time M2 and M3 can be given as a TE on exothermic reaction if arrows are consistent	**(3)**

Question Number	Answer	Additional Guidance	Mark
(f)(i)	An explanation that makes reference to the following points: • the urea is a reactant and forms a new product (that leaves the catalytic converter)	Allow "catalysts are not used up in the reaction" Allow "urea is used up in the reaction" Allow "the amount/mass of urea changed" Allow "urea is not reformed" Allow "the catalyst is a metal oxide" Ignore references to activation energy / rate / reusable Do not award "catalysts do not react"	**(1)**

Question Number	Answer	Additional Guidance	Mark
(f)(ii)	An explanation that makes reference to the following points: • catalyst decreases the activation energy required **(1)** • more particles have the energy required for the reaction to take place **(1)** • increases the number of successful collisions per unit time / frequency of successful collisions **(1)**	Example of a completed diagram  Accept M1 shown on the diagram Allow "Ea moves to the left" Allow area under the curve above Ea increases for M2 NOTE: Shading is not required, but incorrect shading would negate M2	**(3)**

Question Number	Answer	Additional Guidance	Mark
(g)(i)	• hot gases from the engine warm up the catalytic converter	Allow uses the (heat) energy from the engine Allow energy from combustion of fuel Allow the reactions that occur in the catalytic converter are exothermic	**(1)**

Question Number	Answer	Additional Guidance	Mark
(g)(ii)	• conversion of m^3 to dm^3 **(1)** • moles of nitrogen **(1)** • number of molecules of nitrogen **(1)**	<u>An example of a calculation:</u> $89.3 \times 1000 = 89300\ dm^3$ $89300 \div 51.1 = 1747.6 / 1748$ mol $1748 \times 6.02 \times 10^{23} = 1.052 \times 10^{27} / 1.05 \times 10^{27} / 1.1 \times 10^{27}$ Allow TE throughout Ignore SF except 1SF Ignore units even if incorrect $1.052 \times 10^{24} / 1.05 \times 10^{24} / 1.1 \times 10^{24}$ scores 2 $1.052 \times 10^{21} / 1.05 \times 10^{21} / 1.1 \times 10^{21}$ scores 2 $2.747 \times 10^{30} / 2.75 \times 10^{30} / 2.8 \times 10^{30}$ scores 2 Correct answer with some working scores (3)	**(3)**

Q13.

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)

Q14.

Question Number	Answer	Additional guidance	Mark
(a)(i)	• magnesium nitrate decomposes / breaks down (when heated with a Bunsen burner)	Ignore references to evaporation Do not award 'reacts with oxygen' Do not award **just** the idea that magnesium nitrate reacts Ignore products of decomposition even if incorrect Ignore 'spitting' / any references to removing water too quickly	(1)

Question Number	Answer	Additional guidance	Mark
(a)(ii)	• calculate mass of water removed **(1)** calculates moles of water removed **(1)** • calculates moles of anhydrous magnesium nitrate **(1)** • deduces x **(1)** **OR** • calculates moles of anhydrous magnesium nitrate **(1)** • Calculates Mr of hydrated salt **(1)** • Writes expression to find x in terms of mass and *M* **(1)** • deduces **x** **(1)**	Example of calculation 5.12 – 2.97 = 2.15 g 2.15 / 18 = 0.11944 (mol) M1 could be subsumed in M2 2.97/148.3 = 0.0200 (mol) 0.11944:0.0200 = 6:1 so x = 6 (must be integer) 2.97/148.3 = 0.0200 (mol) 5.12/0.0200 = 256 148.3 + 18x = 256 x = 6 (must be integer) Allow TE at each step Correct answer with no working scores M4 only Ignore SF apart from M4, which must be 1SF	**(4)**

Question Number	Answer	Additional guidance	Mark
(b)(i)	An explanation that makes reference to the following points: • large(r) amount of energy required to break **ionic** bonds (in lattice / $MgCO_3$ / solid) **(1)** • small(er) amount of energy released during hydration (of ions) / when ions form bonds to water **(1)** **OR** Lattice energy is **more exothermic** **(1)** than the hydration enthalpies **(1)**	Do not award molecules / atoms / London forces Ignore references to H bonds If no other mark is awarded allow 1 for 'lattice energy is **greater** than hydration enthalpy'	**(2)**

Question Number	Answer	Additional guidance	Mark
(b)(ii)	• application of Hess's Law **(1)** • calculation of $\Delta_f H^\circ$ **(1)**	Example of calculation: +(–394 –602) + 1096 **(+)** 100 (kJ mol^{-1}) Correct answer with no working scores 2 marks – 100 (kJ mol^{-1}) scores 1 mark (+) 702 (kJ mol^{-1}) scores 1 mark (+) 494 (kJ mol^{-1}) scores 1 mark – 2092 (kJ mol^{-1}) scores 1 mark (+) 2092 (kJ mol^{-1}) scores 1 mark Ignore units even if incorrect	**(2)**

Question Number	Answer	Additional guidance	Mark
(b)(iii)	An explanation that makes reference to the following points • Group 2 carbonates increase in (thermal) stability as you go down the group **(1)** • size of the (metal) **ion** increases / charge density (of ion) decreases **(1)** • so metal ion is less polarising or (electron cloud of) anion less distorted **(1)** • so weakens (covalent) bonds in carbonate ion less / more energy needed to break (covalent) bonds in carbonate **(1)**	Accept reverse argument Each marking point is independent Ignore 'atomic radius'' Allow C-O or C=O as alternative for 'bonds in carbonate'	**(4)**

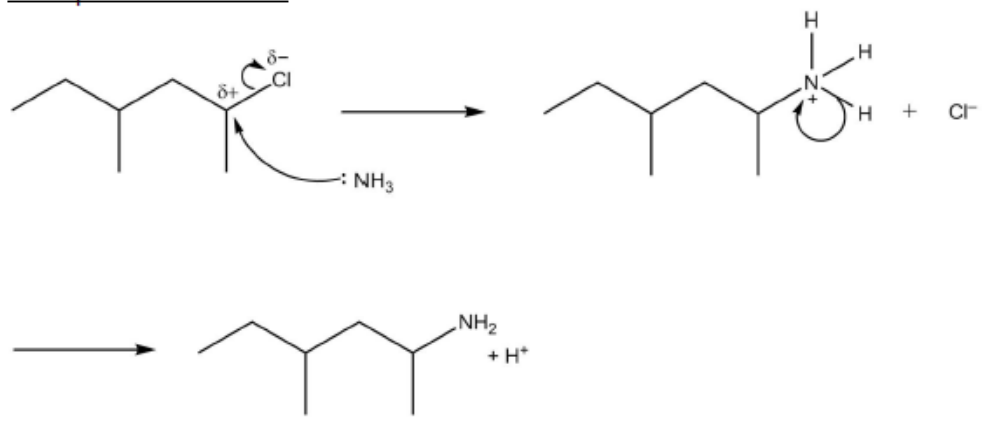
Q15.

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(i)	• 4-methylhexan-2-ol	Allow 4-methyl-2-hexanol Allow 4-methylhexane-2-ol Ignore incorrect punctuation Do not award 4-methylhex-2-ol	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(ii)	• PCl_5 / phosphorus(V) chloride / phosphorus pentachloride	Allow **concentrated** hydrochloric acid / conc.HCl or thionyl chloride / $SOCl_2$ Allow PCl_3 / phosphorus(III) chloride / phosphorus trichloride Allow conc.H_2SO_4 and KCl If name and the formula are given, both must be correct Ignore just HCl / hydrochloric acid	1

Question Number	Acceptable Answers	Additional Guidance	Mark
(a)(iii)	A mechanism that includes the following points • arrow from lone pair on nitrogen atom in ammonia to carbon atom **(1)** • dipole shown and arrow from C–Cl bond to Cl or just beyond **(1)** • formula of intermediate including the + charge on the N atom **and** Cl^- **(1)** • arrow from N-H bond of the intermediate to N(+ and formulae of products) **(1)**	See example mechanism below M1 and M2 can be awarded if shown in 2 steps, via a carbocation Ignore any bases Ignore missing H^+ Ignore errors in hydrocarbon chain	4

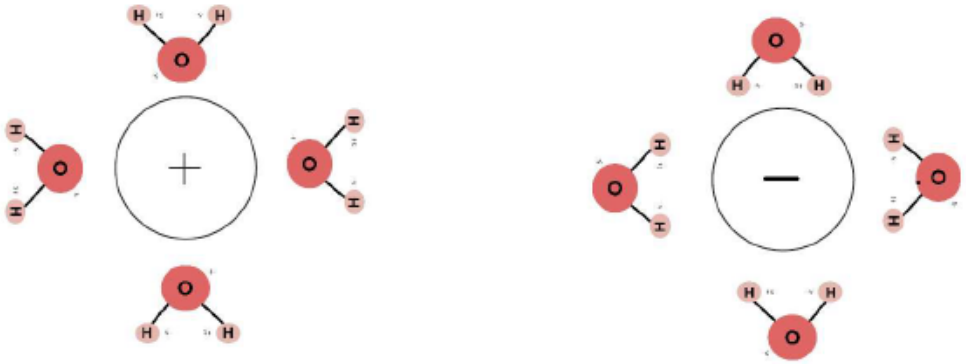
Example of mechanism



Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(i)	An explanation that makes reference to the following points: • (the bond formed is a) dative (covalent) / coordinate bond **(1)** • As the (lone) pair of electrons on the nitrogen (atom) **(1)** • (form the bond) as hydrogen (ion) has an empty orbital / no electrons **(1)**	Allow 'two electrons from the nitrogen' Ignore 'lone pair on the ammonia' Allow can be donated to / shared with the hydrogen (ion) Do not award hydrogen atom	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(b)(ii)	A diagram that includes the following points: • dipole on at least one of the water molecules **(1)** • DMAA ion is attracted to slightly negative oxygen atoms (in water) **(1)** • chloride ion is attracted to slightly positive hydrogen atoms (in water) **(1)**	must be at least 2 water molecules surrounding an ion Ignore lone pairs on oxygen Allow orientation showing only 1 H attracted to ion Allow slight positive charge shown on only 1 H atom Correct diagram but with missing dipoles loses M1 but can score M2 and M3 Ignore attempts to show 'force' or 'bond' e.g. with dashes / arrows Ignore any additions to the circles	**3**

Example of diagram for Qbii



Q16.

Question Number	Answer	Mark
	The only correct answer is A (HCl) ***B*** *is not correct because hydrogen bonds form between molecules of* H_2O ***C*** *is not correct because hydrogen bonds form between molecules of HF* ***D*** *is not correct because hydrogen bonds form between molecules of* NH_3	**1**

Q17.

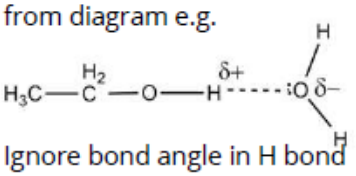
<table>
<tr><th>Q</th><th>Acceptable Answers</th><th>Additional Guidance</th><th>Mark</th></tr>
<tr><td>(a)</td><td>
This question assesses the student's ability to show a coherent and logically structured answer with linkages and fully sustained reasoning.

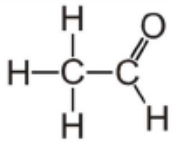
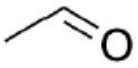
Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning.

The following table shows how the marks should be awarded for indicative content.
<table>
<tr><td>Number of indicative marking points seen in answer</td><td>Number of marks awarded for indicative marking points</td></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><td></td><td>Number of marks awarded for structure of answer and sustained lines of reasoning</td></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>
Indicative Points
</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 four 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 and overall score of 3 marks (3 marks for indicative content and zero marks for linkages).

Note – allow reverse arguments where appropriate
e.g. IP1 and IP5
</td><td>6</td></tr>
</table>

• **IP1** High temperature increases rate as more particles have $E \geq E_a$		
• **IP2** Catalyst increases rate by providing alternative mechanism / catalysts lower activation energy	May be shown on a labelled diagram	
• **IP3** but high temperature reduces yield / moves eqm to LHS as reaction is exothermic		
• **IP4** so (high) temperature (of 300°) is a compromise (between rate and yield)	Allow compromise between temperature or pressure and energy costs / equipment to withstand pressure/ costs to maintain temperature / costs to maintain pressure	
• **IP5** high pressure increases the yield as reaction / equilibrium moves to side of fewest particles / high pressure increases rate as more particles in the same volume		
• **IP6** (low yield acceptable) as unconverted reactants can be recycled / passed through reactor again	Allow (low yield acceptable) as ethanol is removed as it forms to move equilibrium to RHS Ignore any references to environmental effects / atom economy	

Q	Acceptable Answers	Additional Guidance	Mark
(b)	An explanation that makes reference to the following points: • when they mix can form hydrogen bonds (to each other) **(1)** • as both compounds have hydrogen bonds (between their molecules) OR forces that form are similar in strength or stronger than hydrogen bonds in water / ethanol **(1)** • from the lone pair / slight negative charge on an oxygen (atom in one molecule) to a slightly positive hydrogen (atom in the other molecule) (on OH group or water) **(1)**	Ignore references to other intermolecular forces Allow ethanol-water forces can overcome ethanol-ethanol / water-water forces M1 and M3 can be awarded from diagram e.g.  Ignore bond angle in H bond diagram Ignore hydrocarbon structure on ethanol	**3**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(i)		Allow  Allow CH_3CHO Allow 'hybrid' structure e.g. skeletal but with some parts of the structure displayed Ignore bond angles Ignore correct molecular formulae Ignore attempts to write a balanced equation Ignore names even if incorrect Note Look out for structures drawn above the stem If 2 structures shown, e.g. skeletal and displayed, but one is incorrect then award 0 marks	**1**

Question Number	Acceptable Answers	Additional Guidance	Mark
(c)(ii)	An answer that makes reference to the following points: • Y - Distil (off Y from reaction mixture as it forms) **(1)** • Ethanoic acid – (heat under) reflux **(1)**	Note if both answers given but the wrong way round allow 1 mark If no other mark is awarded, controlling the amount of oxidising agent in either case scores (1) Ignore temperatures if given	**2**

Q18.

Question Number	Answer	Additional Guidance	Mark
(a)	A description that makes reference to the following points: • advantage: (it is produced from) renewable / sustainable (resources) **or** it produces fewer emissions (of CO_2 / greenhouse gases) **(1)** • disadvantage: it uses up land (that could be used for food production)/uses a food crop that could be eaten **or** it produces less energy (per mole / g) **(1)**	Do not award no greenhouse gases Ignore cleaner fuel/ more efficient combustion Ignore reference to engine modifications/carbon neutrality/using less oil/good for the environment Ignore just ' it uses lots of crops' Ignore references to time to grow crops/time to carry out fermentation/cost Ignore produces CO_2 Do not award any references to ozone depletion	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)	• **ethanol** can be oxidised	Allow **ethanol** can react with oxygen Allow possible (organic) products of oxidation e.g. carboxylic acid / ethanoic acid / aldehyde / ethanal Ignore just 'oxidation takes place' or 'it can be oxidised' Allow to ensure only anaerobic respiration takes place. Allow aerobic respiration would take place (in the air) (producing water and carbon dioxide) Do not award yeast reacts with oxygen Do not award to prevent combustion/ethanol would burn	(1)

Question Number	Answer	Additional Guidance	Mark
(c)	• (fractional) distillation	Allow distil the mixture	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(i)	• ethanol forms hydrogen bonds (with water)	Ignore both are polar/ they are miscible Ignore comments about solubility/like dissolves like	(1)

Question Number	Answer	Additional Guidance	Mark
(d)(ii)	An answer that makes reference to one of the following points: • (water can cause) corrosion / rusting • reduce the energy efficiency of the engine/fuel/ethanol • causes phase separation of the fuel	Ignore damages the engine Allow water does not burn/ fewer km per l / miles per gallon Allow just 'reduced efficiency' Ignore references to ethanol being diluted	(1)

<table>
<tr><th>Question Number</th><th>Answer</th><th>Additional Guidance</th><th>Mark</th></tr>
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Marks are awarded for indicative content and for how the Answer is structured and shows lines of reasoning.
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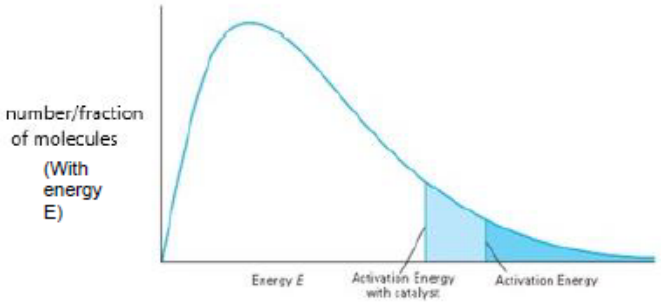
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If there were no linkages between the points, then the same indicative Marking points would yield an overall score of 3 Marks (3 Marks for indicative content and no Marks for linkages).</td><td>(6)</td></tr>
</table>

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	Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout	2		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).	
	Answer is partially structured with some linkages and lines of reasoning	1			
	Answer has no linkages between points and is unstructured	0			
	Indicative content **IP1** if temperature increases, **rate** increases (because more particles have energy greater than E_a) **IP2** if temperature increases, yield decreases (because forward reaction is exothermic/ reaction moves in the endothermic direction) **IP3** if pressure increases, rate increases (because particles are more crowded and) collision frequency increases) **IP4** if pressure increases, yield increases(as there are fewer particles on the RHS of the equation)				

	IP5 the catalyst allows the use of lower temperature/less energy (for the same rate) **IP6** high pressure (and temperature) are very expensive	Allow reaction shifts to the left as an alternative to decreases yield Allow reaction shifts to the right as an alternative to increase yield Ignore fewer atoms on the RHS Ignore any reference to how the catalyst works and the effect of catalyst on rate and yield Allow conditions used are compromise between yield **and** cost / rate **and** cost Allow reverse argument for all points	

Question Number	Answer	Additional Guidance	Mark
(e)(ii)	An explanation that makes reference to the following points: (1) • correct labelling of both axes. (1) • activation energy labelled (1) • activation energy with a catalyst shown to the left of the uncatalysed activation energy. (1)	 M1, M2 and M3 shown on the diagram Both Ea and the catalysed Ea must be to the right of the peak and on the same curve if another temp curve is drawn M4 can be shown on the diagram with labelled shading Allow more particles have activation energy Do not award catalyst increases yield / particles have more energy/ particles move faster/ greater collision frequency Ignore more frequent successful collisions	(4)

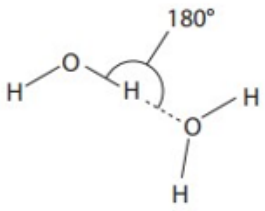
	• more particles have energy greater than the activation energy with the catalyst / more particles to the right of the activation energy / greater area to the right of the activation energy		

Question Number	Answer	Additional Guidance	Mark
(f)(i)	• large(r) surface area (so faster rate of reaction)	Accept more (active) sites Allow more / greater surface Ignore greater area / area of contact	(1)

Question Number	Answer	Additional Guidance	Mark
(f)(ii)	A description that makes reference to the following points: • remove the ethanol (1) • recycle the (unused) reactants (1)	Accept condense the ethanol Allow remove the ethanol to shift the eqm to the right scores (2) Ignore any reference to temperature, pressure or catalyst Ignore any reference to adding more reactants	(2)

Q19.

Question number	Answer	Mark
(a)	**The only correct answer is C** (H-H bond enthalpy is greater than Si-H bond enthalpy) *A is not correct because hydrogen bonding does explain why ice has a lower density than water* *B is not correct because hydrogen bonding does explain why HF has a higher boiling temperature then HCl* *D is not correct because hydrogen bonding does explain why alcohols are less volatile than similar alkanes*	(1)

Question number	Answer	Mark
(b)	**The only correct answer is A**  *B is not correct because the 2 water molecules do not form a hydrogen bond between two hydrogen atoms* *C is not correct because the hydrogen bond angle is not 104.5˚* *D is not correct because the angle between 2 water molecules should be 180˚ and water molecules should not have a bond angle of 180˚*	(1)

Q20.

Question number	Answer	Mark
	A all Group 1 hydroxides are soluble in water	1

Q21.

Question Number	Correct Answer	Mark
	The only correct answer is C (hydrogen fluoride, HF) ***A*** *is incorrect as it does not contain an O, N or F atom* ***B*** *is incorrect as it does not contain an electropositive H atom* ***D*** *is incorrect as it does not contain an O, N or F atom*	**1**

Q22.

Question Number	Answer	Mark
	The only correct answer is D (London forces) *A is incorrect because covalent bonds are between atoms not molecules* *B is incorrect because there are no hydrogen bonds as electronegativity of iodine is low* *C is incorrect because there are no ions present*	**(1)**

Q23.

Question Number	Answer	Mark
	The only correct answer is D (hydrogen bonding, permanent dipole-permanent dipole forces and London forces) ***A*** *is incorrect because there are also permanent dipole-permanent dipole interactions* ***B*** *is incorrect because there are also London forces* ***C*** *is incorrect because there are also hydrogen bonds*	**(1)**

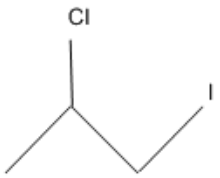
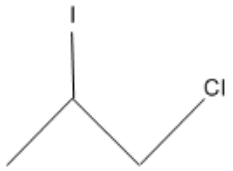
Q24.

Question Number	Answer	Mark
	The only correct answer is D (X,Z,Y) ***A*** *is incorrect because Y has the highest boiling temperature and X will have a boiling temperature below that of the singly branched chain alkane Z* ***B*** *is incorrect because although X has the lowest boiling temperature, Y will have a boiling temperature above that of the singly branched chain alkane, Z* ***C*** *is incorrect because Y has the highest boiling temperature and X has the lowest boiling temperature*	**(1)**

Q25.

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:			3
	• identification of correct isomer	(1)	2-chloro-1-iodopropane	
	• iodine is δ+ and is attacked by the π electrons	(1)		
	• more stable secondary carbocation formed.	(1)		

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

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: • 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)		3

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

Q26.

Question number	Answer	Mark
	B Y X Z W	1

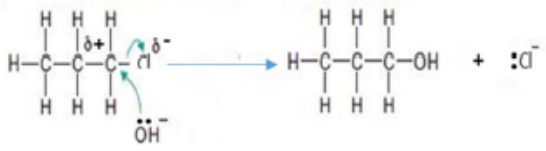
Q27.

Question Number	Answer	Mark
	The only correct answer is C (the H–O–H bond angle is the same in ice and in water) ***A** is incorrect because ice does have a lower density than water* ***B** is incorrect because H_2O molecules are further apart in ice than in water* ***D** is incorrect because the molecules in ice are held together by hydrogen bonds*	**(1)**

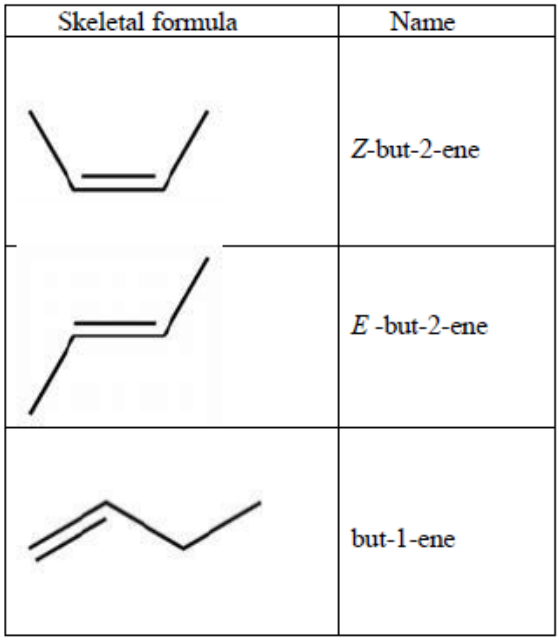
Q28.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	• time taken for the (first appearance of the)precipitate (of silver halide) to form	Allow ppt / ppte for precipitate / cloudy/ silver halide Allow how fast / how quickly / rate for time	(1)

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	An explanation that makes reference to the following points: • 1-iodopropane (1) • C–I bond weakest/lowest bond enthalpy (1)	Allow any correct formula Do not award for simply saying the iodine /1-iodopropane bond is weakest M2 depends on M1 Ignore reference to bond length Ignore any references to reactivity, electronegativity/size	(2)

Question Number	Answer	Additional Guidance	Mark
(b)	A mechanism that shows: • dipole on C-Cl bond and curly arrow from bond to Cl or just beyond (1) • curly arrow from lone pair on OH^- ion to δ+ carbon (1) 	Ignore S_N2 transition state Do not award curly arrow from negative charge on OH Do not award M2 if a metal hydroxide e.g. KOH has a covalent bond Ignore products Penalise use of half arrows once only in M1 and M2 If S_N1 mechanism M1 as above and then M2 awarded for curly arrow from lone pair on OH^- ion to C+ of carbocation	(2)

Question Number	Answer	Additional Guidance	Mark
(c)	An answer that makes reference to the following points: • London forces (and (permanent) dipole-(permanent) dipole forces) (1) • iodine atoms are more polarisable (than chlorine or bromine)/ 1-iodopropane has more electrons (than 1-chloropropane and 1-bromopropane) (1) • (resulting in) stronger / more London Forces (so more energy required to overcome these forces) (1) • (despite) 1-iodopropane having the weakest (permanent) dipole / (permanent) dipole forces	Accept dispersion forces / instantaneous dipole-(induced) dipole Allow van der Waals' Allow iodine has more electrons than chlorine/ bromine Ignore it is a larger molecule / larger molar mass Do not award iodine has stronger/more London forces. Allow van der Waals / dispersion forces Ignore just stronger intermolecular forces Do not award M3 if any indication that covalent bonds are being broken. Allow 1-chloropropane has the strongest (permanent) dipole / (permanent) dipole forces Ignore abbreviations such as id-id and pd-pd	(4)

Question Number	Answer	Additional Guidance	Mark
(d)		Allow any order Allow *cis* Allow *trans* If only one but-2-ene isomer is given the *E/Z* does not have to be identified Penalise displayed formulae only once All 6 correct scores **(3)** 4-5 correct scores **(2)** 2-3 correct scores **(1)** No TE of names of incorrect formulae	**(3)**

Q29.

Question Number	Answer	Mark
	The only correct answer is C (hexane) ***A*** *is incorrect because butan-1-ol contains polar bonds* ***B*** *is incorrect because ethanoic acid contains polar bonds* ***D*** *is incorrect because water contains polar bonds*	**(1)**

Q30.

Question Number	Answer	Additional Guidance	Mark
(a)(i)	All three arrowheads down at any point in/on the line **(1)** AND coefficients are 3 for CO_2 **and** 4 for H_2O		**(1)**

Question Number	Answer	Additional Guidance	Mark
(a)(ii)	• calculation for enthalpy change on LHS **(1)** • correct application of Hess's Law and answer with correct sign **(1)**	Example of calculation; (3 x −393.5) + (4 x−285.8) = (−1180.5) + (− 1143.2) = −2323.7(kJ mol^{-1}) +2219 -2323.7 = -104.7/-105 (kJ mol^{-1}) Correct answer with sign (2)	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(i)	An explanation that makes reference to the following points: • each alkane differs from the next by -CH_2/one carbon atom and two hydrogen atoms/same number of C-C bonds and same number of C-H bonds/ forms a homologous series/ has a general formula C_nH_{2n+2} **(1)** • bonds broken and/or made increase regularly/ each -CH_2 combusted adds almost the same amount of energy/ bond energies are very similar **(1)**	Ignore references to intermolecular forces/boiling points	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(ii)	An explanation that makes reference to **two** of the following points: • butane is a gas and pentane is a liquid (at 298 K / under standard conditions) **(1)** • liquids vaporise before burning/combustion **(1)** • (pentane is a liquid so) some of the energy released by combustion is used to vaporise / vaporisation is endothermic **(1)** OR More energy is needed to break intermolecular forces in pentane or reverse argument	Pentane vaporises before combustion **and** butane is (already) a gas would score M1 and M2	**(2)**

Question Number	Answer	Additional Guidance	Mark
(b)(iii)	An explanation that makes reference to the following points: • the intermolecular forces are London / dispersion forces / instantaneous dipole - induced dipole forces **(1)** • these forces depend on the number of electrons which increase (as the number of carbon atoms increase) **(1)** • more **energy** is needed to break these intermolecular forces/to separate the molecules (so the boiling temperature increases) **(1)**	Any reference to hydrogen bonding or permanent dipole interaction loses M1 and M2 ALLOW: Van der Waals forces for London forces ALLOW: increase in surface area/more points of contact (as the number of carbon atoms increase) Any reference to breaking of covalent bonds loses M3	**(3)**

Q31.

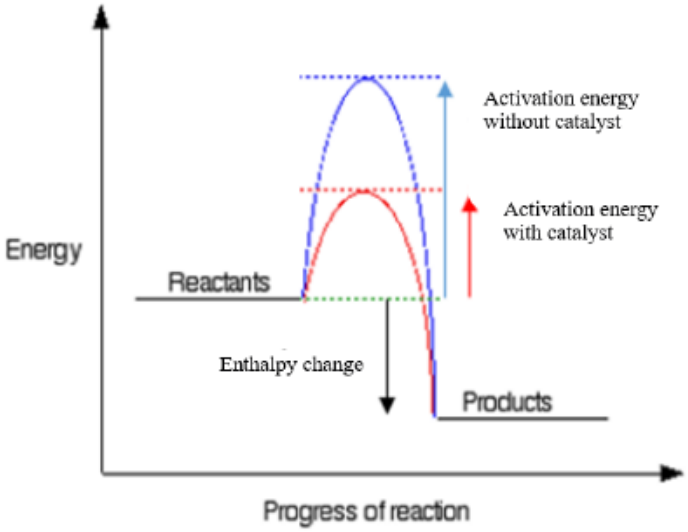
Question Number	Answer	Additional Guidance	Mark
(a)(i)	An answer that makes reference to the following points: • **both** have London forces (only) **(1)** • S molecules have more electrons / S is a larger molecule (than oxygen) / S electrons are more easily polarised **(1)** Independent marks	Accept 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	

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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 (1) • equilibrium shifts to the RHS/forward • 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)(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

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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

Q32.

Question Number	Answer	Mark
	The only correct answer is B  ***A** is not correct because propan-2-ol has a lower boiling temperature as the alcohol is branched* ***C** is not correct because butane has a lower boiling temperature as it does not form hydrogen bonds* ***D** is not correct because 2-methylpropane has a lower boiling temperature as it does not form hydrogen bonds*	1

Q33.

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)**

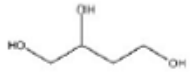
Question Number	Answer	Additional Guidance	Mark
(c)	• sulfur dioxide / sulfur (IV) oxide / SO_2 produced from HBr **and** hydrogen sulfide / H_2S produced from HI	Example of table: Hydrogen halide | Compound produced with the lowest oxidation number of sulfur (HBr) | sulfur dioxide / SO_2 (HI) | hydrogen 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	

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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)

Q34.

Question Number	Correct Answer	Mark
	The only correct answer is C () ***A*** *is incorrect as the liquid only contains one OH group so less hydrogen bonding forms* ***B*** *is incorrect as the liquid only contains two OH groups so less hydrogen bonding forms* ***D*** *is incorrect as the liquid does not form hydrogen bonds*	**1**

Q35.

Question Number	Answer	Mark
	The only correct answer is D (water is a good solvent for ionic compounds) ***A*** *is incorrect because the less open structure of water compared to ice is due to hydrogen bonding* ***B*** *is incorrect because the reduction in density of ice compared to water is due to hydrogen bonding* ***C*** *is incorrect because the expansion of volume of ice compared to water is due to hydrogen bonding*	**(1)**