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EDEXCEL A LEVEL CHEMISTRY: QUESTIONS BY TOPIC

Bonding and Structure (2)

A Level Chemistry Topic 2

20 questions · 185 marks · Mark schemes included

Pearson Edexcel A Level Chemistry (9CH0), June 2017 - June 2025

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HOW TO USE THIS BOOKLET

Questions are grouped by specification sub-topic; within each sub-topic they run from the lowest mark tariff to the highest.

Click any sub-topic heading or question row below to jump straight to it.

On every question page, click ANSWER in the top-right corner to jump to its mark scheme.

Diagrams, graphs, tables and data are printed exactly as they appeared in the original papers.

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QUESTIONS

20 questions · 185 marks · grouped by sub-topic



SUB-TOPIC 2(a)

IONIC BONDING

1 question in this sub-topic · 12 marks · lowest tariff first



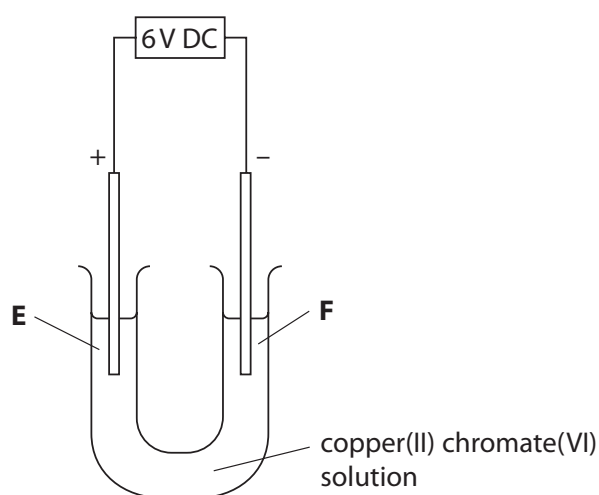
4 This question is about structure and bonding.

(a) Ionic bonding is the strong electrostatic attraction between

(1)

- ☐ A anions and cations
- ☐ B atoms and delocalised electrons
- ☐ C cations and delocalised electrons
- ☐ D two nuclei and a shared pair of electrons

(b) An aqueous solution of copper(II) chromate(VI) was electrolysed using the apparatus shown in the diagram.



Deduce the colours of the solutions in regions **E** and **F** after the electrolysis has occurred.

(2)

Colour in region **E**

Colour in region **F**

(c) Some ionic radii are given in the table.

Ion	Ionic radius / nm
Na^+	0.102
Mg^{2+}	0.072
Cl^-	0.180
Br^-	0.195

Deduce the **formula** of the compound, formed from the ions in the table, that has the strongest ionic bonding.

(1)

(d) The names of four substances are given.

Substance	Name
P	copper
Q	iodine
R	silicon(IV) oxide
S	sodium chloride

(i) Which of these substances exists at room temperature as a giant lattice of oppositely charged ions?

(1)

- ☐ **A** Substance **P**
- ☐ **B** Substance **Q**
- ☐ **C** Substance **R**
- ☐ **D** Substance **S**



(ii) Which of these substances has a high melting temperature, **and** conducts electricity when solid and when molten?

(1)

- ☐ **A** Substance **P**
- ☐ **B** Substance **Q**
- ☐ **C** Substance **R**
- ☐ **D** Substance **S**



(Total for Question 4 = 12 marks)



SUB-TOPIC 2(c)

SHAPES OF MOLECULES AND IONS

3 questions in this sub-topic · 35 marks · lowest tariff first



1 A phosphorus atom has mass number 31.

(a) How many of each sub-atomic particle are present in the phosphide ion, P^{3-} ?

(1)

	Number of protons	Number of neutrons	Number of electrons
☐ A	15	16	12
☐ B	15	16	18
☐ C	16	15	12
☐ D	16	15	18

(b) Phosphorus(III) chloride molecules are pyramidal with a bond angle less than 109.5° .



(i) Explain why a phosphorus(III) chloride molecule has this shape and bond angle.

(2)

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(ii) Which describes the polarity of the P—Cl bond and the polarity of the phosphorus(III) chloride molecule?

(1)

	Polarity of P—Cl bond	Polarity of molecule
☐ A	non-polar	non-polar
☐ B	non-polar	polar
☐ C	polar	non-polar
☐ D	polar	polar

(c) Phosphorus has one naturally occurring isotope with mass number 31. Chlorine exists as two isotopes with mass numbers 35 and 37.

Give the formulae and mass/charge ratio of the ions responsible for the molecular ion peaks in the mass spectrum of phosphorus(III) chloride, PCl_3 .

(2)

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(Total for Question 1 = 6 marks)



3 This question is about compounds of Group 5 elements.

(a) Phosphorus forms two chlorides with the formulae PCl_3 and PCl_5 .

(i) Explain the shape of the PCl_3 molecule. The bond angle is not required.

(3)

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(ii) Draw a diagram to show the three-dimensional shape of the PCl_5 molecule in the gas phase.

Include bond angles and the name of the shape.

(3)

(iii) Explain why phosphorus forms PCl_5 but nitrogen does not form NCl_5 .

(2)

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- (b) Nitrogen trichloride, NCl_3 , has a boiling temperature of 344 K, and nitrogen trifluoride, NF_3 , has a boiling temperature of 144 K.

Explain this difference in boiling temperatures, by referring to all the intermolecular forces present.

(5)

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- (c) Which of these compounds produces hydrogen chloride when it reacts with PCl_5 ?

(1)

- ☒ A propanal
- ☒ B propan-1-ol
- ☒ C propanone
- ☒ D propyl propanoate

(Total for Question 3 = 14 marks)



4 This question is about nitrogen and some nitrogen compounds.

(a) A study of one brand of crisps found that each packet contained 0.420 g of nitrogen gas at a pressure of 120 kPa and a temperature of 20 °C.

(i) Calculate the volume of nitrogen gas, in **cm³**, in one packet of crisps.

$$[R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}]$$

(4)

(ii) Give a possible reason why nitrogen gas and not air is used in packets of crisps.

(1)

(b) Draw dot-and-cross diagrams for a molecule of nitrogen gas and for the nitride ion, N^{3-} , in sodium nitride, Na_3N .

Use dots (•) for nitrogen electrons and crosses (X) for electrons from sodium.

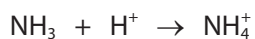
(2)

Nitrogen molecule

Nitride ion



(c) Ammonia accepts a proton to form an ammonium ion.



Explain why the ammonia molecule and the ammonium ion have different shapes and different bond angles.

(4)

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(d) Butylamine, $\text{C}_4\text{H}_9\text{NH}_2$, reacts with ethanoyl chloride.



Explain how this equation illustrates that butylamine acts as a nucleophile and as a base.

(4)

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(Total for Question 4 = 15 marks)



SUB-TOPIC 2(e)

INTERMOLECULAR FORCES

9 questions in this sub-topic · 90 marks · lowest tariff first



2 This is a question about hydrocarbons.

(a) State what is meant by the term **hydrocarbon**.

(1)

(b) Explain why 2,2-dimethylpropane has a much lower boiling temperature than its isomer pentane.

Detailed descriptions of the forces involved are not required.

(2)

(c) The **heterolytic** bond fission of a sigma (σ) bond in an alkane would produce

(1)

- ☐ A only carbocations
- ☐ B only free radicals
- ☐ C free radicals and ions
- ☐ D ions

(Total for Question 2 = 4 marks)



5 Ice has a density of 0.92 g cm^{-3} and water has a density of 1.00 g cm^{-3} .

- (a) About 200 cm^3 of water and 200 cm^3 of cooking oil were placed in a large beaker and two layers formed. The cooking oil formed the upper layer.

An ice cube made from water with a water-soluble blue food dye was added.

Initially the ice cube floated on top of the cooking oil but on melting the blue-coloured water sank into the bottom layer of water.

Give a possible value for the density of the cooking oil. Justify your answer.

(2)

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- (b) Calculate how many **more** molecules there are in 5.00 cm^3 of water compared to 5.00 cm^3 of ice.

(3)

(Total for Question 5 = 5 marks)



1 This question is about methanol, CH_3OH .

- (a) Draw a dot-and-cross diagram to show the bonding in a molecule of methanol. Show outer shell electrons only.

(2)

- (b) Predict which bond has the shortest bond length in a molecule of methanol.

(1)



(c) Methanol is soluble in water.

- (i) State the strongest type of intermolecular force that occurs between molecules of methanol and water.

(1)

- (ii) Draw a labelled diagram to show the interaction named in (c)(i) between one molecule of methanol and one molecule of water. Include any relevant lone pairs and dipoles in your diagram.

(3)

(Total for Question 1 = 7 marks)

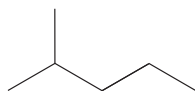


2 This question is about the intermolecular forces in organic compounds.

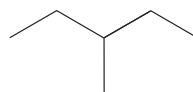
The structures of four isomeric alkanes are shown.



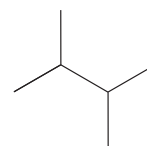
compound **A**



compound **B**



compound **C**



compound **D**

The only significant intermolecular forces between molecules of these compounds are London forces.

(a) Explain how London forces arise.

(3)

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(b) Explain which of the compounds **A–D** will have the highest boiling temperature.

(2)

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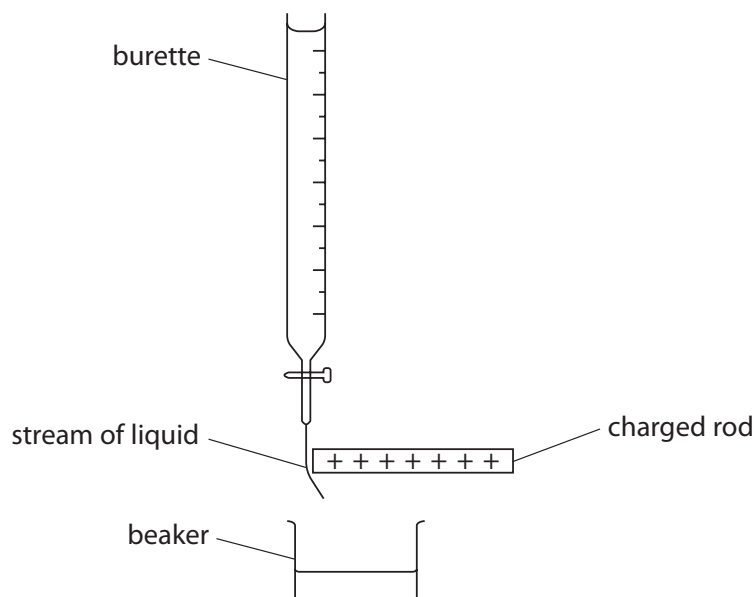
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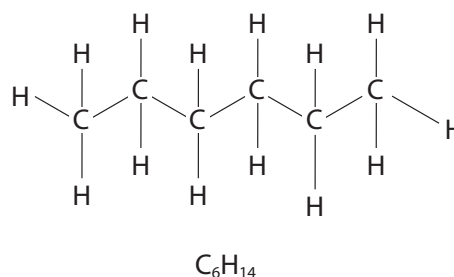
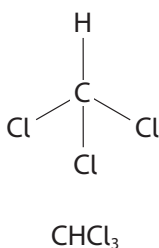
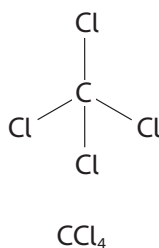
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- (c) The apparatus shown may be used in an experiment to compare how far, if at all, a charged rod deflects different liquids.



The structures of three liquids are shown.



Explain whether or not each of these liquids will be deflected in this experiment.

(3)

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(Total for Question 2 = 8 marks)

2 Intermolecular forces affect the physical properties of compounds.

- (a) Which of these isomers, with the formula C_8H_{18} , will have the **lowest** boiling temperature?

(1)

- ☐ **A** $(CH_3)_2CHCH_2C(CH_3)_3$
- ☐ **B** $(CH_3)_2CHCH_2CH(CH_3)CH_2CH_3$
- ☐ **C** $CH_3CH_2CH_2C(CH_3)_2CH_2CH_3$
- ☐ **D** $CH_3CH_2CH_2CH_2CH_2CH_2CH_2CH_3$

- (b) Pentan-1-ol and hexane have the same number of electrons but pentan-1-ol is much less volatile than hexane.

Explain this difference in volatility.

(2)

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- (c) Iodine is a solid at room temperature but on gentle heating it vaporises.

What bonds or forces are being broken?

(1)

- ☐ **A** covalent bonds
- ☐ **B** ionic bonds
- ☐ **C** London forces
- ☐ **D** permanent dipole-dipole forces

- (d) The boiling temperature of boron trichloride is 13°C while that of phosphorus trichloride is 76°C .

Explain, in terms of the shapes of the molecules, why phosphorus trichloride has a much higher boiling temperature, although both compounds have polar bonds.

Do not consider differences in London forces.

(4)

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(Total for Question 2 = 8 marks)



1 This question is about some halogens and their compounds.

(a) The intermolecular attractions between halogen molecules are London forces.

(i) Describe how London forces form between halogen molecules.

(3)

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(ii) The boiling temperatures of chlorine and bromine are shown in the table.

Halogen	Boiling temperature / °C
chlorine	–34
bromine	59

Explain why bromine has a higher boiling temperature than chlorine.

(2)

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(b) A student carries out experiments to determine the order of reactivity of three halogens: bromine, chlorine and iodine.

The student is provided with aqueous solutions of the following five substances:

- bromine
- iodine
- potassium chloride
- potassium bromide
- potassium iodide.

The student has **no** access to chlorine gas or chlorine water.

The student uses cyclohexane, an organic solvent, to identify the halogen present at the end of each experiment.

The student carries out the **smallest** number of experiments required to determine the order of reactivity of the halogens.

Describe the experiments and the expected observations.

Include in your answer **ionic** equations for any reactions that occur.

State symbols are **not** required.

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(Total for Question 1 = 10 marks)



6 This is a question about water.

- (a) Water might be expected to have a lower boiling temperature than hydrogen sulfide but it actually has a higher boiling temperature.

Comment on this statement by referring to the intermolecular forces in both these substances.

A detailed description of how the intermolecular forces arise is not required.

(4)

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- (b) Explain why both water and carbon dioxide molecules have polar bonds but only water is a polar molecule.

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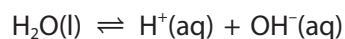
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- (c) Pure water ionises to form H_3O^+ and OH^- ions, although only to a very small extent. Draw the dot-and-cross diagrams of these ions. Use dots (•) for the hydrogen electrons and crosses (×) for the oxygen electrons.

(2)



(d) An equation for the ionisation of water is



The expression for the ionic product of water is

$$K_w = [\text{H}^+(\text{aq})][\text{OH}^-(\text{aq})]$$

The value of K_w at 310K is $2.40 \times 10^{-14} \text{ mol}^2 \text{ dm}^{-6}$

(i) Calculate the pH of water at 310K.

Give your answer to **two** decimal places.

(2)

(ii) Predict, with a reason, whether water is acidic, alkaline or neutral at 310K.

(2)

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(iii) Predict, with a reason, the sign of the enthalpy change for the ionisation of water.

(1)

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(Total for Question 6 = 15 marks)



10 Manganese compounds can be used to determine the amounts of dissolved molecular oxygen in water samples.

- (a) Draw the dot-and-cross diagram for an oxygen molecule, O_2 .
Show outer shell electrons only.

(1)

- (b) The solubility of oxygen in water under standard conditions is $1.22 \times 10^{-3} \text{ mol dm}^{-3}$.

Comment on this value by considering the type and strength of the intermolecular forces in

- pure water
- pure oxygen
- a mixture of water and oxygen.

Detailed descriptions of the forces involved are not required.

(4)

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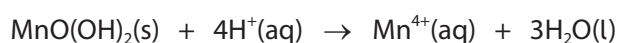


(c) The amount of dissolved oxygen in a sample of river water was found using the process outlined.

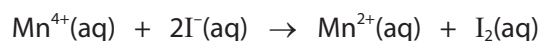
- excess alkaline manganese(II) sulfate, MnSO_4 , was added to a 150 cm^3 sample of river water
- the Mn^{2+} ions reacted with the dissolved oxygen forming a precipitate of manganese(IV) oxide hydroxide



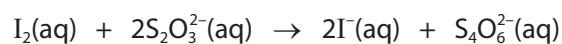
- the precipitate was then dissolved using excess sulfuric acid, forming $\text{Mn}^{4+}(\text{aq})$ ions



- excess potassium iodide solution was then added, forming iodine



- the liberated iodine was then titrated with sodium thiosulfate solution, $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$, of concentration $0.00518\text{ mol dm}^{-3}$



- the mean volume of the titre of $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ was 34.20 cm^3 .
- (i) Calculate the concentration of dissolved oxygen in the sample of river water, in g dm^{-3} .

(5)



You may use this space to continue your answer to 10(c)(i).

- (ii) The concentration of oxygen in water is often expressed in parts per million (ppm), where 1 ppm equals 1 g of solute dissolved in 1×10^6 g of solvent.

Calculate the concentration of the oxygen in the sample of river water in ppm. Assume the density of the river water is 1.00 g cm^{-3} .

(1)



(d) Some data is shown for electrode systems involving the $\text{Mn}^{3+}(\text{aq})$ ion.

Half-cell	Electrode system	$E^\ominus / \text{V}$
A	$\text{MnO}_2(\text{s}) + 4\text{H}^+(\text{aq}) + \text{e}^- \rightleftharpoons \text{Mn}^{3+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l})$	+0.95
B	$\text{Mn}^{3+}(\text{aq}) + \text{e}^- \rightleftharpoons \text{Mn}^{2+}(\text{aq})$	+1.51

Explain why Mn^{3+} ions are unstable in aqueous solution.
Include an equation and the type of reaction that occurs.

(4)

(Total for Question 10 = 15 marks)



7 This question is about carbonyl compounds.

- (a) Ethanal, CH_3CHO , and ethanoic acid, CH_3COOH , are both soluble in water but ethanoic acid has a much higher boiling temperature than ethanal.

Explain these physical properties of ethanal and ethanoic acid in terms of intermolecular forces.

Include a labelled diagram to show why ethanal is soluble in water.

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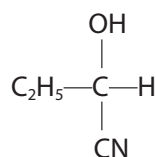
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- (b) Propanal reacts with hydrogen cyanide in the presence of potassium cyanide to form 2-hydroxybutanenitrile.



- (i) Draw the mechanism for this reaction.
Include curly arrows and any relevant lone pairs and dipoles.

(4)

- (ii) Explain whether or not the 2-hydroxybutanenitrile formed will be a racemic mixture.

(3)

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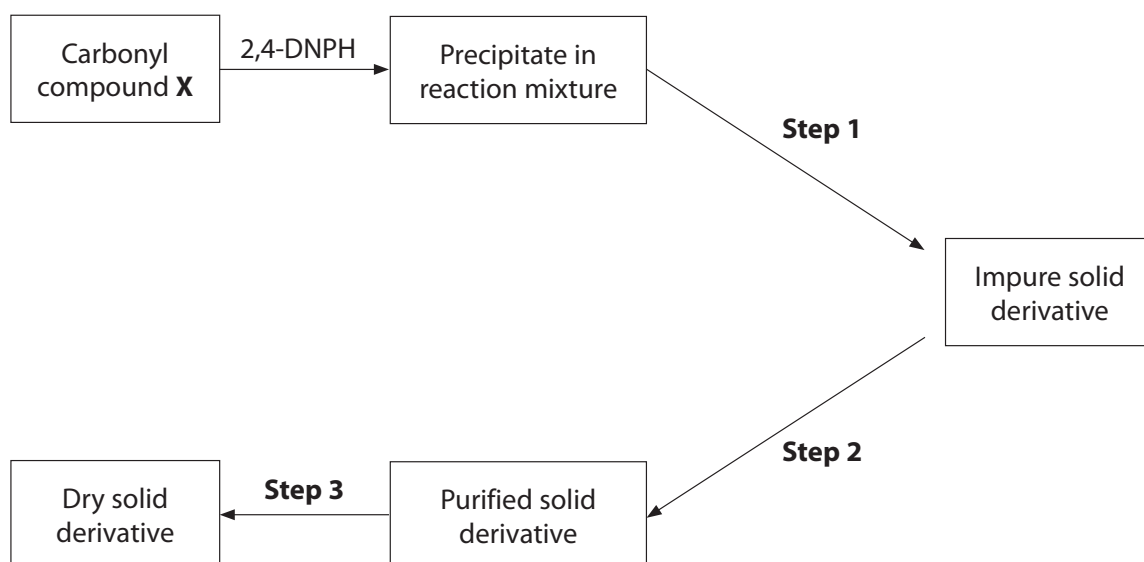
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(c) Carbonyl compounds can be identified by reacting them with 2,4-dinitrophenylhydrazine (2,4-DNPH) to form a solid derivative. These derivatives have characteristic melting temperatures.

(i) Identify the steps required to prepare a sample of a pure, dry derivative of a carbonyl compound **X**.

(3)



Step 1

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Step 2

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Step 3

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- (ii) The melting temperature ranges of the derivatives of some carbonyl compounds that could be **X** are shown in the table.

Carbonyl compound	Melting temperature range of derivative / °C
ethanal	165 – 168
propanal	154 – 156
propanone	127 – 129
cyclohexanone	158 – 160

The melting temperature of the derivative of carbonyl compound **X** is 156–158°C and **X** has an absorption at 1717 cm^{-1} in its infrared spectrum.

Deduce the identity of **X**. Justify your answer.

(2)

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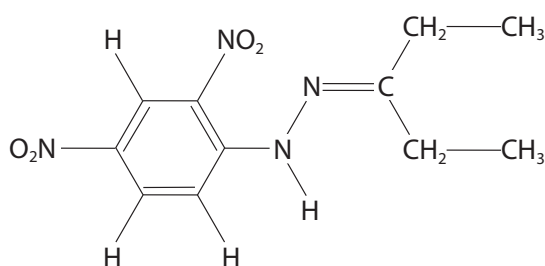
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- (iii) These carbonyl compounds may also be identified using modern methods such as proton NMR spectroscopy.
The structure of the pentan-3-one derivative formed with 2,4-DNPH is shown.



Label the different proton environments that would give rise to the peaks in the low resolution proton NMR spectrum.

(2)

(Total for Question 7 = 18 marks)



SUB-TOPIC 2(f)

METALLIC BONDING AND GIANT STRUCTURES

1 question in this sub-topic · 3 marks · lowest tariff first



2 Diamond, graphene and graphite are different forms of carbon.

(a) The structural feature that graphene and graphite have in common is that the carbon atoms are arranged in

(1)

- ☐ **A** layers with each atom bonded to four others
- ☐ **B** hexagonal and pentagonal rings within a layer
- ☐ **C** hexagonal rings within a layer
- ☐ **D** a three-dimensional structure

(b) The bond angles within a layer of graphene and a layer of graphite are

(1)

- ☐ **A** 90° and 109.5°
- ☐ **B** all 109.5°
- ☐ **C** 109.5° and 120°
- ☐ **D** all 120°

(c) One way in which diamond differs from graphene and graphite is that only diamond has

(1)

- ☐ **A** a high melting temperature
- ☐ **B** a precise molecular formula
- ☐ **C** poor electrical conductivity
- ☐ **D** a giant structure

(Total for Question 2 = 3 marks)



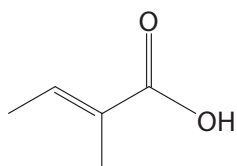
TOPIC 2

SYNOPTIC AND MIXED QUESTIONS

6 questions in this sub-topic · 45 marks · lowest tariff first



3 What is the systematic name for tiglic acid?



tiglic acid

- ☐ A *E*-2-methylbut-2-enoic acid
- ☐ B *Z*-2-methylbut-2-enoic acid
- ☐ C *E*-3-methylbut-2-enoic acid
- ☐ D *Z*-3-methylbut-2-enoic acid

(Total for Question 3 = 1 mark)

2 This question is about Grignard reagents.

A Grignard reagent is formed by reacting bromoethane with magnesium under reflux.



(a) The most suitable solvent for this reaction is

(1)

- ☐ A cyclohexane
- ☐ B ether
- ☐ C ethyl ethanoate
- ☐ D hexane

(b) State the use of Grignard reagents in organic synthesis.

(1)

(c) In their reactions, the Grignard reagent is best described as

(1)

- ☐ A a carbocation
- ☐ B an electrophile
- ☐ C a nucleophile
- ☐ D a radical

(d) Grignard reagents must be kept dry.

Predict the **organic** product that forms when $\text{CH}_3\text{CH}_2\text{MgBr}$ reacts with water.
Justify your answer by considering the polarity of both $\text{CH}_3\text{CH}_2\text{MgBr}$ and water.

(2)

(e) Which compound will form a **tertiary** alcohol when it reacts with a Grignard reagent, followed by acid hydrolysis?

(1)

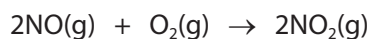
- ☐ A CO_2
- ☐ B HCHO
- ☐ C CH_3CHO
- ☐ D CH_3COCH_3

(Total for Question 2 = 6 marks)



(Total for Question 4 = 6 marks)

5 Nitrogen monoxide reacts with oxygen to form nitrogen dioxide.



The rate is proportional to the concentration of oxygen and to the square of the concentration of nitrogen monoxide.

(a) The rate of this reaction can be determined by measuring the change in the total gas pressure.

(i) Give a reason why this method can be used in this reaction.

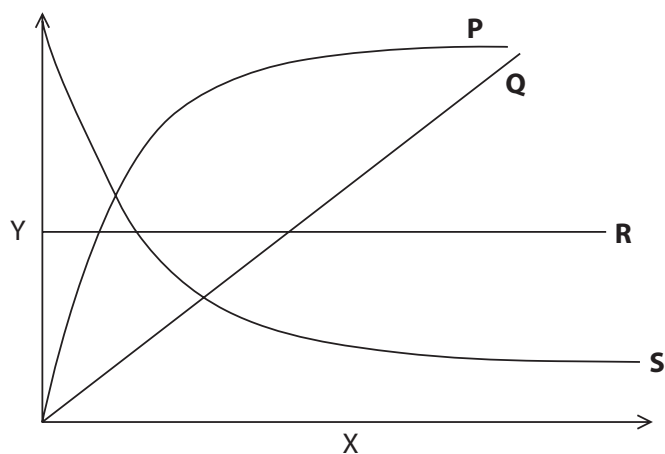
(1)

(ii) State **two** factors, other than initial amounts of reactants, that must be kept constant for this method to work.

(1)



(b) The graph shows four lines of a quantity Y plotted against a quantity X.



(i) Which line shows the relationship between the concentration of nitrogen monoxide (Y) and time (X)?

(1)

- ☐ A line P
- ☐ B line Q
- ☐ C line R
- ☐ D line S

(ii) Which line shows the relationship between rate (Y) and concentration of oxygen (X)?

(1)

- ☐ A line P
- ☐ B line Q
- ☐ C line R
- ☐ D line S

(c) The rate of this reaction is $z \text{ mol dm}^{-3} \text{ s}^{-1}$ under certain conditions.

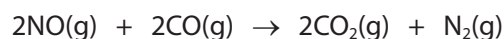
The concentration of nitrogen monoxide is doubled and the concentration of oxygen is halved. All other conditions remain the same.

What will be the new rate of reaction in $\text{mol dm}^{-3} \text{ s}^{-1}$?

(1)

- ☐ A $z/2$
- ☐ B z
- ☐ C $2z$
- ☐ D $4z$

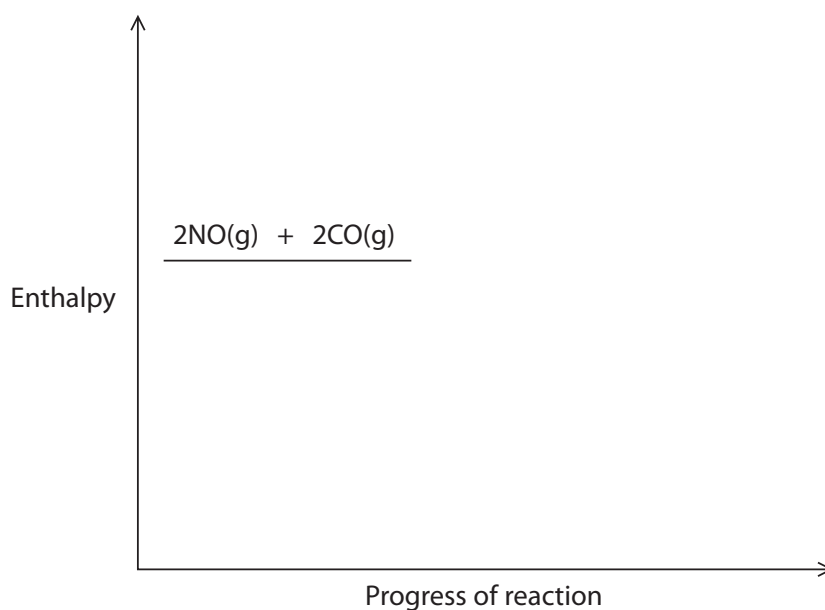
- (d) Nitrogen monoxide is formed in car engines. It is removed by the catalytic converter in the car exhaust.



The reaction is exothermic and the most active catalyst is platinum.

- (i) Complete the labelled reaction profile for the **catalysed** reaction.

(3)



- (ii) Catalysts, such as platinum, are very expensive.

Explain an economic benefit of using a catalyst in an industrial process.

(2)

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(Total for Question 5 = 10 marks)



7 Boric acid, H_3BO_3 , is a weak acid with antiseptic properties.

- (a) Boric acid can be prepared by reacting borax, $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$, with hydrochloric acid.

Write the equation for this reaction. State symbols are not required.

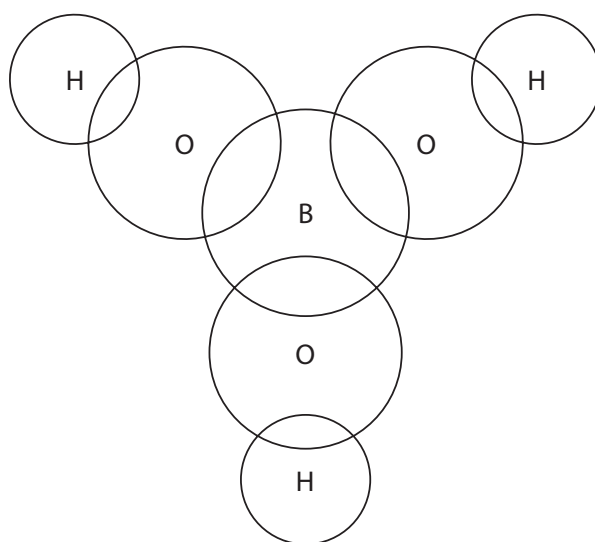
(1)

- (b) The formula of boric acid can also be written as $\text{B}(\text{OH})_3$.

- (i) Complete the dot-and-cross diagram of a molecule of boric acid. Show the outer shell electrons only.

Use dots (•) for the hydrogen electrons, crosses (x) for the oxygen electrons and triangles (Δ) for the boron electrons.

(2)



- (ii) What are the $\text{O}-\text{B}-\text{O}$ and $\text{B}-\text{O}-\text{H}$ bond angles in a molecule of boric acid?

(1)

	$\text{O}-\text{B}-\text{O}$ bond angle	$\text{B}-\text{O}-\text{H}$ bond angle
☐ A	109.5°	104.5°
☐ B	109.5°	180°
☐ C	120°	104.5°
☐ D	120°	180°

(c) Boric acid is a solid with melting temperature 171 °C.

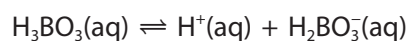
What are the strongest interactions between the molecules in solid boric acid?

(1)

- ☐ **A** covalent bonds
- ☐ **B** hydrogen bonds
- ☐ **C** ionic bonds
- ☐ **D** London forces

(d) In aqueous solution, boric acid dissociates into ions in three stages.

The equation for the first dissociation is



$\text{p}K_{\text{a}}$ for this dissociation is 9.24

- (i) Calculate the pH of a $0.0500 \text{ mol dm}^{-3}$ solution of boric acid from the $\text{p}K_{\text{a}}$ value for the first dissociation.

(3)



(ii) State any assumptions you made in your calculation in (d)(i).

(2)

(e) Boric acid can undergo further dissociation.

Which is the conjugate acid of the HBO_3^{2-} ion?

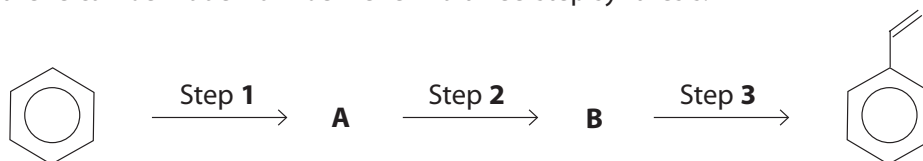
(1)

- ☐ A BO_3^{3-}
- ☐ B H_2BO_3^-
- ☐ C H_3BO_3
- ☐ D H_3O^+

(Total for Question 7 = 11 marks)



- 7 Phenylethene, commonly known as styrene, is an important substance in the production of polystyrene which is used for some types of plastic packaging. Phenylethene can be made from benzene in a three-step synthesis.



- (a) Some of the following compounds can be used to make phenylethene from benzene.

Aluminium chloride	Chloroethane	Ethanal	Ethanol
Ethanoic acid	Ethanoyl chloride	Ethene	Ether
Hydrochloric acid, concentrated	Lithium tetrahydridoaluminate(III)	Phosphoric acid, concentrated	Sulfuric acid, concentrated

Selecting **only** from these compounds, devise a synthetic pathway for converting benzene into phenylethene, clearly identifying compounds **A** and **B** and stating the appropriate conditions for each step.

(5)

(b) Which reagent could produce a diol from phenylethene?

(1)

- ☒ A acidified potassium dichromate(VI)
- ☒ B acidified potassium manganate(VII)
- ☒ C aqueous sodium hydroxide
- ☒ D steam

(c) Draw a section of the polymer, polystyrene, showing **two** repeat units.

(1)



(d) Give one advantage and one disadvantage of the disposal of polystyrene by incineration.

(2)

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(e) Calculate the percentage by mass of carbon in phenylethene, giving your answer to an appropriate number of significant figures.

(2)

(Total for Question 7 = 11 marks)

MARK SCHEMES

official Pearson Edexcel mark schemes



Question number	Answer	Mark
4(a)	The only correct answer is A (anions and cations) <i>B is incorrect because ionic bonding involves positive ions and negative ions</i> <i>C is incorrect because there are no delocalised electrons in ionic bonding</i> <i>D is incorrect because this is a description of covalent bonding</i>	(1)

Question Number	Answer	Additional Guidance	Mark
4(b)	- region E: yellow (1) - region F: blue (1)	Ignore additional descriptions of colours e.g. pale, bright Do not award any other colours e.g. blue-green	(2)



Question Number	Answer	Additional Guidance	Mark
4(c)	MgCl₂	Ignore names Do not award MgCl	(1)

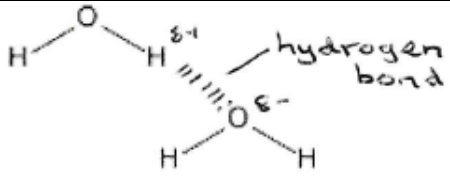
Question number	Answer	Mark
4(d)(i)	The only correct answer is D (Substance S) <i>A is incorrect because copper exists as a giant metallic lattice</i> <i>B is incorrect because iodine exists as a simple molecular lattice</i> <i>C is incorrect because silicon(IV) oxide exists as a giant covalent lattice</i>	(1)

Question number	Answer	Mark
4(d)(ii)	The only correct answer is A (Substance P) <i>B is incorrect because iodine has a low melting temperature and does not conduct electricity</i> <i>C is incorrect because silicon(IV) oxide does not conduct electricity</i> <i>D is incorrect because sodium chloride does not conduct electricity when solid</i>	(1)



Question Number	Acceptable Answers	Additional Guidance	Mark												
4(e)*	This question assesses a 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.	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	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, an answer 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 are no linkages between points, the same five indicative marking points would yield an overall score of 3 marks (3 marks for indicative content and no marks for linkages).	(6)
Number of indicative marking points seen in answer	Number of marks awarded for indicative marking points														
6	4														
5–4	3														
3–2	2														
1	1														
0	0														

		Number of marks awarded for structure of answer and sustained line of reasoning		
	Answer shows a coherent and 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		
	Comment: Look for the indicative marking points first, then consider the mark for structure of answer and sustained line of reasoning			
	General points to note If there is any incorrect chemistry, deduct mark(s) from the reasoning. If no reasoning mark(s) awarded do not deduct mark(s). Example of incorrect chemistry Reference to ionic bonding/ions Ignore reference to intermolecular forces other than London forces in H₂S			

Indicative content • IP1 – lone pair and dipole lone pair on oxygen in hydrogen bond and dipole shown with $\delta+$ on any one H and $\delta-$ on any one O • IP2 – shape hydrogen bond labelled / or shown as a dotted line and hydrogen bond(s) shown as approximately linear or O-H-O bond angle labelled 180° • IP3 – London forces hydrogen sulfide has stronger London forces/ dispersion forces / van der Waals' forces (because it has more electrons) • IP4 – comparison hydrogen bonding is stronger than London forces / is the strongest intermolecular force / requires more energy to break/ requires more energy to overcome • IP5 – ice at 0°C (water molecules are arranged) in a lattice / hexagon or hydrogen bonds are longer than covalent bonds • IP6 – water at 0°C (water) molecules get closer / have less distance between them / more molecules in the same volume	 <u>Example of diagram</u> Comment: allow bond angles drawn between 170° and 190° if labelled 180° If multiple hydrogen bonds are drawn the majority must be within this tolerance Allow / attractions between temporary dipoles and induced dipoles / instantaneous dipole - induced dipole for London forces Do not award breaking of covalent bonds Allow hydrogen bonds take a lot of energy to break as long as hydrogen bonds are only mentioned as being present in the water Allow this shown in a diagram Allow rings (of 6 for hexagonal) Allow there are spaces / air / gaps in the structure Allow (water) molecules fill the spaces/gaps Allow reverse argument
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(Total for Question 4 = 12 marks)

Question Number	Answer	Mark
1(a)	The only correct answer is B <i>A is not correct because incorrect electrons</i> <i>C is not correct because incorrect protons, neutrons and electrons</i> <i>D is not correct because incorrect protons and neutrons</i>	(1)



Question Number	Answer	Additional Guidance	Mark
1(b)(i)	An explanation that makes reference to the following points: (pyramidal / this shape) because there are 4 pairs / 3 bond pairs and one lone pair of electrons (around central / P atom) and these are arranged to minimise repulsion (1) (bond angle less than 109.5°) as lone pair-bond pair repulsion is greater than bond pair-bond pair repulsion (1)	'ions' scores (0) overall Allow the electron pairs are arranged to minimise repulsion Allow (4) pairs of electrons with maximum separation / as far apart as possible Ignore reference to 'bonds' Ignore wrong shape Ignore repel equally Ignore repulsion between electrons There must be a comparison in M2 Allow lone pairs have greater repulsion than bond pairs Ignore just 'the lone pairs repel more' Ignore repetition of the question e.g. 'reduces the bond angle' Ignore incorrect bond angle stated (Data book value is 100.1°) Do not allow bond angle $>109.5^\circ$	(2)

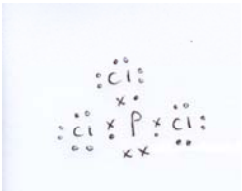
Question Number	Answer	Mark
1(b)(ii)	The only correct answer is D <i>A is not correct because both incorrect</i> <i>B is not correct because non-polar bond is incorrect</i> <i>C is not correct because non-polar molecule is incorrect</i>	(1)

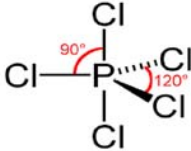


Question Number	Answer	Additional Guidance	Mark										
1(c)	- all 4 ion formulae (1) - all 4 m/z values (1) or - any two m/z values with corresponding ion formulae (1) - the other two m/z values with corresponding ion formulae (1)	Example of answer: <table><tr><td>ions</td><td>m/z</td></tr><tr><td>$\text{P}^{(35}\text{Cl})_3^+$</td><td>136</td></tr><tr><td>$\text{P}^{(35}\text{Cl})_2^{37}\text{Cl}^+$</td><td>138</td></tr><tr><td>$\text{P}^{35}\text{Cl}^{(37}\text{Cl})_2^+$</td><td>140</td></tr><tr><td>$\text{P}^{(37}\text{Cl})_3^+$</td><td>142</td></tr></table> Allow any other unambiguous way of representing the formulae e.g. with brackets or in words Positive charge only needs to be shown on one of the ions Ignore mass number on P	ions	m/z	$\text{P}^{(35}\text{Cl})_3^+$	136	$\text{P}^{(35}\text{Cl})_2^{37}\text{Cl}^+$	138	$\text{P}^{35}\text{Cl}^{(37}\text{Cl})_2^+$	140	$\text{P}^{(37}\text{Cl})_3^+$	142	(2)
ions	m/z												
$\text{P}^{(35}\text{Cl})_3^+$	136												
$\text{P}^{(35}\text{Cl})_2^{37}\text{Cl}^+$	138												
$\text{P}^{35}\text{Cl}^{(37}\text{Cl})_2^+$	140												
$\text{P}^{(37}\text{Cl})_3^+$	142												

(Total for Question 1 = 6 marks)



Question Number	Answer	Additional Guidance	Mark
3(a)(i)	An explanation that makes reference to • M1 PCl_3 is (trigonal) pyramidal • M2 has 3 bond pairs and 1 lone pair (around central P atom) • M3 electron pairs repel to positions of minimum repulsion / maximum separation	Marking points 1 and 2 may be shown on diagrams (see below) (1) Award M1 for correct name of shape even if diagram(s) incorrect (1) Ignore lone pair – bond pair repulsions > bond pair – bond pair repulsions (1) Answer must state or imply somewhere that (electron) pairs repel Do not award if specifically stated that ‘bonds repel’ or ‘atoms repel’ Ignore any references to bond angles even if incorrect	(3)
Example of diagram for award of M1 (a lone pair may also be shown on the P atom)  Example of diagram for award of M2 (must show 3 bond pairs and 1 lone pair) 			

Question Number	Answer	Additional Guidance	Mark
3(a)(ii)	M1 Diagram showing trigonal bipyramidal shape, with 3D emphasised by use of two wedges or one hatch and one wedge in the central plane (1) M2 90° and 120° angles labelled (1) M3 trigonal bipyramidal (1)	 M2 dependent on correct M1 Ignore 180° Do not award M2 if any incorrect bond angle is shown M3 stand alone mark Both words required Award "trigonal bipyramid"	(3)

Question Number	Answer	Additional Guidance	Mark
3(a)(iii)	An answer that makes reference to the following points: - phosphorus can expand its octet / can expand its (outer) shell / can accommodate more than 8 electrons / can accommodate 10 electrons / has available (3d-) orbitals (for promotion of electrons) (1) - nitrogen does not have (2)d-orbitals / can only accommodate eight electrons (in its outer shell) (1)	Comment Award reference to P accommodating 18 electrons Ignore comparisons of size / radius of P and N atoms	(2)



Question Number	Answer	Additional Guidance	Mark
3(b)	An explanation that makes reference to the following points: • M1 London forces are greater in NCl_3 (1) • M2 as NCl_3 has more electrons / as Cl (atom) has more electrons (than F atom) (1) • M3 (permanent) dipole-dipole forces / "permanent dipoles" / "dipole forces" stronger in NF_3 (than NCl_3) (1) • M4 as F is more electronegative than Cl (1) • M5 either London forces predominate / London forces are more significant or more (heat) energy needed to overcome the intermolecular forces between NCl_3 molecules (than NF_3 molecules) (1)	Allow reverse arguments Award van der Waals' / induced dipole etc Award NCl_3 has 58 electrons whereas NF_3 has 34 electrons Ignore comparisons of M_r Do not award M2 if comparison of "ionic radii" Award for M3 (permanent) dipole-dipole forces only in NF_3 Electronegativity difference 1.0 between N and F / No electronegativity difference between N and Cl / N-F is a more polar bond than N-Cl Award (0) for M5 if any mention of: Ionic bonds breaking in either NF_3 or NCl_3 Breaking of N-F and / or N-Cl covalent bonds scores (0) for M5 Note If hydrogen bonding mentioned, can only award M1, M2 and M5 max Ignore polarisation of ions	(5)



Question Number	Answer	Mark
3(c)	The only correct answer is B (propan-1-ol) A is not correct because it does not give hydrogen chloride when PCl_5 is added C is not correct because it does not give hydrogen chloride when PCl_5 is added D is not correct because it does not give hydrogen chloride when PCl_5 is added	(1)

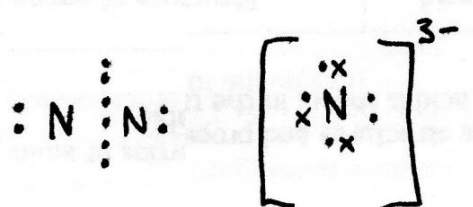
(Total Question 3 = 14 marks)



Question Number	Answer	Additional Guidance	Mark
4(a)(i)	- evaluation of number of moles of nitrogen (1) - conversion of pressure and temperature to correct units (1) - rearrangement of ideal gas equation so $V = nRT \div P$ and evaluation of volume (1) - answer converted into cm^3 (1)	<u>Example of calculation:</u> $n = 0.42 \div 28 = 0.015 \text{ (mol)}$ $120 \text{ kPa} = 120\,000 \text{ Pa}$, $20^\circ\text{C} = 293 \text{ K}$ $V = \frac{0.015 \times 8.31 \times 293}{120\,000}$ $= 3.0435 \times 10^{-4} \text{ (m}^3\text{)}$ $= 3.0435 \times 10^{-4} \times 10^6$ $= 304 \text{ (cm}^3\text{)}$ Ignore SF except 1SF TE throughout Correct answer without working scores (4)	(4)

Question Number	Answer	Additional Guidance	Mark
4(a)(ii)	An answer that makes reference to prevents oxidation (of the crisps)	Allow answers such as 'keep the crisps fresh' or 'prevents the crisps from going off/stale' Allow reference to 'crisps not reacting with nitrogen but will with air' Ignore reference to gas prevents crisps from getting squashed/broken Ignore nitrogen is less reactive than air/oxygen or nitrogen is inert Ignore reference to effects of moisture	(1)



Question Number	Answer	Additional Guidance	Mark
4(b)	- dot-and-cross diagram of nitrogen gas (1) - dot-and-cross diagram of nitride ion (1)	<u>Example of dot-and-cross diagrams</u>  Nitrogen molecule Nitride ion Allow electrons to be paired horizontally Allow the crosses to be paired in any way Allow representation of inner shell with two electrons Allow any pairing of dots and crosses Ignore lines representing covalent bonds Ignore missing circles Ignore absence of brackets and charge on nitride ion Ignore any diagram of the sodium ion	(2)

Question Number	Answer	Additional Guidance	Mark
4(c)	An explanation that makes reference to the following points: - the lone pair (of electrons) in ammonia repels more than the bonded pairs (of electrons) (1) The further three marks are scored as follows: Six of the following scores (3) four or five scores (2) and two or three scores (1) - the ammonia molecule has three bond pairs and one lone pair - the ammonium ion has four bond pairs - the ammonia molecule is (trigonal) pyramidal - ammonium ion is tetrahedral - the bond angle in ammonia is $107(^{\circ})$ - the bond angle in the ammonium ion is $109.5(^{\circ})$	Standalone mark Accept points made on labelled diagrams	(4)

Question Number	Answer	Additional Guidance	Mark
4(d)	An explanation that makes reference to the following points: - nucleophiles are electron pair donors / attack areas of low electron density / the nitrogen donates its lone pair of electrons (1) - so the amine group attacks as a (nucleophile) by attacking the $C^{\delta+}$ of the acyl chloride (1) - which produces hydrogen chloride (1) - it's a base because amine group reacts with the acid / protons (to produce the salt / $C_4H_9NH_3Cl$) (1)	Allow the N/ butylamine for 'the amine group' Allow shown in a mechanism Do not award attacks carbocation Allow hydrochloric acid Allow the N/ butylamine for 'the amine group' Allow base is a proton acceptor Do not award just 'hydrogen' for proton Do not award reference to ethanoyl chloride as an acid/donating a proton	(4)

(Total Question 4 = 15 marks)



Question Number	Answer	Additional Guidance	Mark
2(a)	An answer which makes reference to: • a compound of hydrogen and carbon only	Allow absence of 'only' Allow substance/molecule/chain/species for compound Do not award reference to a carbon and/or a hydrogen Do not award 'an element made of carbon and hydrogen' Do not award a mixture of carbon and hydrogen Do not award contains carbon and hydrogen molecules	(1)

Question Number	Answer	Additional Guidance	Mark
2(b)	An explanation which makes reference to the following points: - branching results in fewer/weaker London forces (1) - due to less surface area/points of contact (1)	Accept reverse argument Allow van der Waals / instantaneous dipole-induced dipole / dispersion forces Ignore just intermolecular forces Do not award 'fewer electrons' Do not award if covalent bonds broken Allow reference to less close packing of molecules together	(2)

Question Number	Answer	Mark
2(c)	The only correct answer is D (ions) <i>A is not correct because both anions and cations are produced</i> <i>B is not correct because homolytic fission produces free radicals</i> <i>C is not correct because homolytic fission produces free radicals and heterolytic fission also produces anions</i>	(1)

(Total Question 2 = 4 marks)



Question Number	Answer	Additional Guidance	Mark
5(a)	An answer which makes reference to the following points: - density between 0.92 and 1.00 (g cm^{-3}) (1) - because water is the bottom layer so more dense and ice floats on oil so is less dense (1)	Accept any value or range between 0.92 – 1.00 Ignore units even if incorrect Accept reverse arguments Reference to the layers is required	(2)

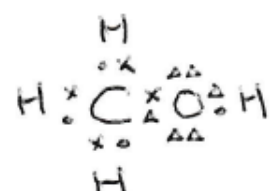


Question Number	Answer	Additional Guidance	Mark
5(b)	An answer that give evidence of the following: • use of both densities to get two masses and division by 18 to give moles (1) • subtraction to give either mass or moles or number of molecules (1) • multiplication by Avogadro constant to give number of molecules (1)	Multiple correct methods are possible which process the data in different sequences. The correct final answer is 1.34×10^{22} / 1.338×10^{22} which can be awarded (3) regardless of working If this answer is not given then look for evidence of each of the given mathematical processes and give one mark for each The use of both densities must be carried out first Note that the use of 5 for the mass of water implies the use of a density of 1.00 g cm^{-3} Depending on the method used this can be done at the beginning, the middle or at the end of the calculation but must be of (water – ice) This must be evidenced after moles have been calculated Allow TE throughout Ignore SF except 1SF for the final answer Allow use of 6×10^{23} which gives 1.33×10^{22} for (3) Correct answer without working scores (3) Do not allow a number of molecules <1	(3)

	Marking points		<u>Example of calculation vs1</u>
	Subtraction	(1)	$m(\text{water}) = (5 \times 1.00) - (5 \times 0.92) = 0.40 \text{ (g)}$
	Use of both densities and division by 18 to give moles	(1)	$n(\text{H}_2\text{O}) = (0.40 \div 18) = 0.022222 / 2.2222 \times 10^{-2} \text{ (mol)}$
	Multiplication by Avogadro constant	(1)	$N = (2.2222 \times 10^{-2} \times 6.02 \times 10^{23}) = 1.34 \times 10^{22} / 1.338 \times 10^{22}$
	or		<u>Example of calculation vs2</u>
	Multiplication by Avogadro constant	(1)	$N(\text{water molecules}) = ((5 \times 1) \div 18) \times 6.02 \times 10^{23} = 1.667 \times 10^{23}$
	Use of both densities and division by 18 to give moles	(1)	$N(\text{ice molecules}) = ((5 \times 0.92) \div 18) \times 6.02 \times 10^{23} = 1.533 \times 10^{23}$
	Subtraction	(1)	$N(\text{Extra}) = 1.667 \times 10^{23} - 1.533 \times 10^{23} = 1.34 \times 10^{22}$
or			<u>Example of calculation vs3</u>
	Use of both densities and division by 18 to give moles	(1)	$n(\text{water}) = ((1.00 \times 5.00) \div 18) = 0.27778 \text{ (mol)}$ $n(\text{ice}) = ((0.92 \times 5.00) \div 18) = 0.25556 \text{ (mol)}$
	Subtraction	(1)	Difference in mol = $(0.27778 - 0.25556) = 0.022222 \text{ (mol)}$
	Multiplication by Avogadro constant	(1)	Extra molecules = $0.022222 \times 6.02 \times 10^{23} = 1.34 \times 10^{22}$

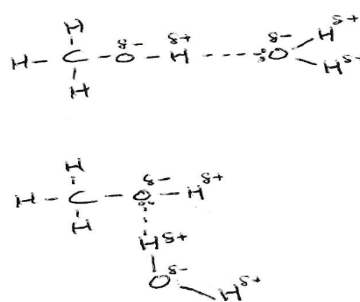
(Total Question 5 = 5 marks)



Question Number	Answer	Additional Guidance	Mark
1(a)	- all bonding pairs of electrons correct (1) 2 lone pairs of electrons on oxygen (1)	<u>Example of diagram</u>  Allow any symbols for electrons, including all dots or all crosses Allow electrons either side of a line for a bond e.g. $\underline{x}$ • Electrons can be in overlapping circles, on the lines, inside the lines or in the gaps between the lines Non-bonding electrons on O can be shown as 2 pairs, all 4 together or as 3 and 1 Ignore inner shell electrons	(2)

Question Number	Answer	Additional Guidance	Mark
1(b)	O-H	Allow this shown on diagram in (a) Allow OH Do not award -O-H	(1)

Question Number	Answer	Additional Guidance	Mark
1(c)(i)	hydrogen bonding		(1)

Question Number	Answer	Additional Guidance	Mark
1(c)(ii)	- at least one lone pair shown on the oxygen atom in water or methanol and involved in the hydrogen bond (1) - hydrogen bond shown between an H in one molecule and an O on the other molecule and O-H...O / O...H-O bond angle at (about) 180° (1) - at least one δ^+ shown on either H atom in water or attached to O in methanol and at least one δ^- shown on any O atom (1)	<u>Examples of diagrams</u>  Any bond angle labelled as 180° must be between the correct bonds 180° must be drawn at about 180°, not just labelled Ignore all other bond angles Only 1 correct dipole needs to be shown No TE on c(i) If 2 hydrogen bonds shown, 1 with correct bond angle and 1 incorrect, do not award M2	(3)

(Total for Question 1 = 7 marks)

Question Number	Answer	Additional Guidance	Mark
2(a)	An explanation that makes reference to the following points: (Setting up of the dipole) (random) movement of electrons / (temporary) uneven distribution of electrons / Fluctuation of electrons (Type of dipole) (this results in an) instantaneous/temporary dipole (in the first molecule) (Induction of a second dipole) (which) causes/induces a (second) dipole in a neighbouring/adjacent molecule	Allow reference to atoms throughout but for M3 a second/different atoms should be clear Allow reference to electron density (1) Allow oscillating dipole Do not award reference to permanent dipole (1) Allow in/on another molecule for adjacent Do not award reference to permanent dipole M3 is consequential on M2 or a near miss Allow a labelled diagram for evidence of these marks Ignore any reference to attraction stated thereafter Penalise reference to electronegativity once only	(3)

Question Number	Answer	Additional Guidance	Mark
2(b)	An answer that makes reference to the following points: - compound A as London forces increase as branching decreases or compound A is unbranched and has greater/more London forces - so surface area/points of contact (of molecules) increases	(1) Allow van der Waals'/dispersion forces/ induced dipole – dipole forces for London forces Allow 'least branching'/ 'longer chain' for unbranched (1) Allow reference to packing of molecules more closely/closer together Allow compound for molecule Ignore A molecules are more compact Do not award 'more electrons' Do not award M2 if clear reference to covalent bonds being broken/decomposition Accept reverse argument e.g. - compound A, as the other compounds have less London forces as branching increases - so surface area/points of contact (of molecules) decreases	(2)



Question Number	Answer	Additional Guidance	Mark																
2(c)	An explanation that makes reference to the following points: - effect on the stream of liquid by CCl_4, CHCl_3 and C_6H_{14} (1) (because of) bond polarity in CCl_4, CHCl_3 and C_6H_{14} (1) (resulting in) molecular non-polar /polarity due to shape (1)	Allow differences in electronegativities for references to polar/non-polar bonds <table border="1"> <tr> <td></td><td>CCl_4,</td><td>CHCl_3</td><td>C_6H_{14}</td></tr> <tr> <td>Deflection</td><td>X</td><td>✓</td><td>X</td></tr> <tr> <td>Bond polarity</td><td>✓</td><td>✓</td><td>*X</td></tr> <tr> <td>Molecular polarity</td><td>X because symmetrical</td><td>✓ because non-symmetrical</td><td>*(X)</td></tr> </table> Score either rows or columns, awarding the higher score * For hexane only, allow reference to non-polar bonds to imply non-polar molecule but not vice versa Allow no dipole moment/vectors cancel for symmetry Allow reference to dipoles cancel for symmetry		CCl_4 ,	CHCl_3	C_6H_{14}	Deflection	X	✓	X	Bond polarity	✓	✓	*X	Molecular polarity	X because symmetrical	✓ because non-symmetrical	*(X)	(3)
	CCl_4 ,	CHCl_3	C_6H_{14}																
Deflection	X	✓	X																
Bond polarity	✓	✓	*X																
Molecular polarity	X because symmetrical	✓ because non-symmetrical	*(X)																

(Total for Question 2 = 8 marks)



Question Number	Answer	Mark
2(a)	The only correct answer is A $((\text{CH}_3)_2\text{CHCH}_2\text{C}(\text{CH}_3)_3)$ <i>B is not correct because this is not the most branched isomer as it only has two branches</i> <i>C is not correct because this is not the most branched isomer as it only has two branches</i> <i>D is not correct because this unbranched isomer will have the highest boiling temperature</i>	(1)

Question Number	Answer	Additional Guidance	Mark
2(b)	An explanation that makes reference to the following points: (only) pentan-1-ol has hydrogen bonds (1) (Intermolecular forces in pentan-1-ol) are stronger and require more energy to break (hence the lower volatility) (1)	Can be shown on a diagram for M1 Do not award reference to covalent bonding Accept answers referring to higher boiling temperature instead of lower volatility of pentan-1-ol Allow reverse argument: hexane only has London forces which are weaker than Hydrogen bonds and so require less energy to break scores 2 (Allow VdW/dispersion forces/instantaneous induced dipoles) Ignore references to permanent dipole-dipole forces	(2)



Question Number	Answer	Mark
2(c)	The only correct answer is C (London forces) <i>A is not correct because covalent bonds are not broken when iodine vaporises</i> <i>B is not correct because ionic bonds are not broken when iodine vaporises</i> <i>D is not correct because iodine does not have permanent dipole-dipole forces</i>	(1)

Question Number	Answer	Additional Guidance	Mark
2(d)	An explanation that makes reference to the following points: - boron trichloride has a trigonal planar shape - phosphorus trichloride has a pyramidal shape (because) in boron trichloride molecules the dipoles/vectors cancel / boron trichloride molecules have no dipole moment and Phosphorous trichloride is polar molecule/has an overall dipole (which means) phosphorus trichloride has permanent dipole-dipole forces (between the molecules to give the higher boiling temperature)	Allow 3D diagrams for M1 and M2 (1) Ignore references to VSEPR and lone pairs (1) If name and diagram given, both must be correct (1) If diagram shown, net dipole must be clear for M3 Allow discussion about the difference in symmetry of the boron trichloride and phosphorus trichloride Do not award the charges cancel (1) Allow permanent dipole forces Ignore references to London forces	(4)

(Total for Question 2 = 8 marks)



Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(i)	An answer that makes reference to the following points: setting up of the dipole - uneven distribution of electrons / (random) movement of electrons / (random) fluctuations of electrons (1) type of dipole (results in an) instantaneous dipole / temporary dipole (in the first molecule) (1) induction of a second dipole - causes/induces a (second) dipole on another molecule (1)	M1 & M3 could be scored for an appropriate diagram Allow "Change in electron density" Allow "transient dipole" / "oscillating dipole" Do not award for "permanent dipole" Allow neighbouring molecule / adjacent molecule Do not award for "permanent dipole"	(3)



Question Number	Acceptable Answers	Additional Guidance	Mark
1(a)(ii)	An explanation that makes reference to the following points: relative number of electrons - bromine has more electrons (than chlorine) / bromine has one more shell of electrons (than chlorine) (1) relative strength of intermolecular forces (so) bromine has stronger (London) forces (between molecules) / more (heat) energy is needed to overcome the London forces between bromine molecules / greater temporary dipole – induced dipole forces (1)	Allow reverse arguments Allow correct formulae Bromine has 35/70 electrons and chlorine has 17/34 electrons Ignore comments about protons, molecular mass etc Do not award “more outer shells” Ignore comments about ‘points of contact’ Allow more (London) forces Allow “bonds between molecules” Award (0) marks overall if any implication that covalent bonds are broken (on boiling)	(2)



Question Number	Acceptable Answers	Additional Guidance	Mark
1(b)	An answer that makes reference to the following points: mixing of 1st pair of solutions • mix Br₂ with KCl (1) mixing of 2nd pair of solutions • mix Br₂ with KI or • mix I₂ with KBr (1) colours of halogen (in cyclohexane) • colour seen for experiment 1/ bromine is orange / yellow and • colour seen for experiment 2/ iodine is purple / pink / violet / lilac (1) correct ionic equation • Br₂ + 2I⁻ → 2Br⁻ + I₂ (1) • use of ONLY two correct experiments as above (1)	Ignore any reference to any additional reactions, e.g. with silver nitrate Award mark if correct ionic equation is given Ignore colours before the addition of cyclohexane Do not award brown Do not award red Allow multiples Ignore state symbols even if incorrect	(5)

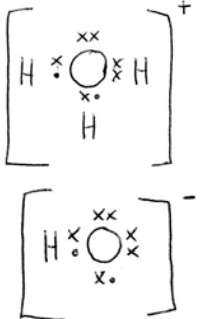
(Total for Question 1 = 10 marks)

Question Number	Answer	Additional Guidance	Mark
6(a)	An answer that makes reference to the following points: • (M1) (a lower boiling temperature is expected) because water has fewer electrons than hydrogen sulfide (1) • (M2) water has weaker/less London forces (1) • (M3) (a higher boiling temperature occurs because) water has hydrogen bonding (1) • (M4) hydrogen bonding is stronger than London forces and requires more energy to break (and results in a higher boiling temperature) (1)	Accept water has 10 electrons but hydrogen sulfide has 18 electrons (per molecule) Ignore reference to Mr/size of atom Allow van der Waals'/dispersion forces/ instantaneous dipole-induced dipole Accept reverse arguments Ignore references to permanent dipole-dipole forces	(4)



Question Number	Answer	Additional Guidance	Mark
6(b)	An explanation that makes reference to the following points: • (M1) oxygen is more electronegative than hydrogen and carbon (1) • (M2) which results in a polar bond with oxygen δ^- so carbon and hydrogen δ^+ (1) • (M3) carbon dioxide is a symmetrical/linear molecule and so the dipole moments/vectors cancel (1) • (M4) the lone pairs of electrons of oxygen/ the V-shape of the water molecule mean that the dipole moments/vectors do not cancel (1)	Accept supporting diagrams which illustrate the following: Accept electronegativity values stated Allow oxygen has a greater force of attraction for the bonded electron pairs than hydrogen or carbon Penalise the failure to refer to carbon and hydrogen once only Allow 'symmetrical so dipoles/ polar bonds cancel' Allow angular/bent for V-shape Penalise reference to just 'charges' once only in M3 and M4 if dipoles not stated or shown in the answer	(4)



Question Number	Answer	Additional Guidance	Mark
6(c)	Two diagrams • oxonium ion (1) • hydroxide ion (1)	Examples of suitable diagrams  Ignore inner 'shell' of two electrons Ignore missing brackets Ignore covalent circles Penalise all dots or all crosses or use of other symbols for electrons once only Penalise omission of charges once only	(2)

Question Number	Answer	Additional Guidance	Mark
6(d)(i)	- square root of K_w at 310K to get $[H^+]$ (1) - calculation of pH to 2 decimal places (1)	Example of calculation: $[H^+] = (\sqrt{2.40 \times 10^{-14}}) = 1.549 \times 10^{-7} \text{ (mol dm}^{-3}\text{)}$ $pH = (-\log 1.549 \times 10^{-7})$ $= (6.809894379) = 6.81$ Correct answer with no working scores (2) Allow TE from incorrect $[H^+]$ as long as answer is in the pH range 6.00 – 7.00 inclusive	(2)

Question Number	Answer	Additional Guidance	Mark
6(d)(ii)	An answer that makes reference to the following points: (M1) neutral (1) (M2) because $[H^+(aq)] = [OH^-(aq)]$ /equal amounts of H^+ and OH^- ions (1)	Acidic or alkaline scores (0) Allow both $[H^+]$ and $[OH^-]$ have increased equally (from 298 K to 310 K) M2 dependent on M1	(2)



Question Number	Answer	Additional Guidance	Mark
6(d)(iii)	An answer that makes reference to the following point: positive / + sign because K_w increases as the temperature increases	Allow 'positive because' bond breaking requires energy or equilibrium shifts to the right or there is greater/more ionisation/dissociation Ignore 'endothermic'	(1)

(Total Question 6 = 15 marks)



Question Number	Answer	Additional guidance	Mark
10(a)	An answer that makes reference to the following points dot-and-cross diagram for oxygen	Allow diagram without circles Allow all dots or all crosses Allow bond pairs shown axially X X O O If circles are drawn, allow electrons anywhere in the overlap region / on the lines in the overlap region Ignore inner shells	(1)

Question Number	Answer	Additional Guidance	Mark
10(b)	An answer that makes reference to the following points - the oxygen is only sparingly soluble (in water) (1) - oxygen has (only weak) London forces (between molecules) (1) - water has (London forces, dipole- dipole attractions and strong) hydrogen bonds (between molecules) (1) - the (intermolecular) forces between oxygen and water would be London forces and which are weaker than the hydrogen bonds (in water) (1)	Allow abbreviations such as LDF / VDW as this has been penalised in q4 Allow H-bonds for hydrogen bonds Allow not very soluble / slightly soluble / low solubility / doesn't dissolve very well Do not award any additional forces / bonds between O₂ molecules Allow this shown on a diagram Allow the resultant forces between them would be London forces, which are not strong enough to overcome the hydrogen bonds (in water) Allow oxygen molecules are not able to disrupt the hydrogen bonds between water molecules Allow dispersion / temporary dipole-induced dipole / instantaneous dipole / van der Waals as alternatives to London forces throughout Ignore just 'results in fewer hydrogen bonds between water molecules' Ignore hydrogen bonds between oxygen and water	(4)



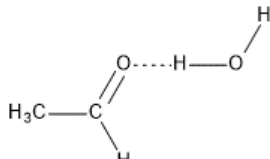
Question Number	Answer	Additional Guidance	Mark
10(c)(i)	- calculation of amount of $\text{Na}_2\text{S}_2\text{O}_3(\text{aq})$ (1) - calculation of amount of $\text{I}_2(\text{aq})$ (1) - calculation of amount of $\text{O}_2(\text{aq})$ (1) - calculation of concentration of O_2 in $\text{mol dm}^{-3}(\text{aq})$ (1) - calculation of concentration of O_2 in $\text{g dm}^{-3}(\text{aq})$ (1)	<u>Example of calculation</u> $(34.2 \div 1000) \times 0.00518 = 1.7716 \times 10^{-4} (\text{mol})$ $= (1.7716 \times 10^{-4}) \div 2 = 8.8578 \times 10^{-5} (\text{mol})$ $= (8.8578 \times 10^{-5}) \div 2 = 4.4289 \times 10^{-5} (\text{mol})$ $= 4.4289 \times 10^{-5} \times (1000/150) = 2.9526 \times 10^{-4} (\text{mol dm}^{-3})$ $= 2.9526 \times 10^{-4} \times 32 = 9.4483 \times 10^{-3} / 0.0094483 (\text{g dm}^{-3})$ Allow steps in different orders Allow TE throughout Allow intermediate values quoted as fractions Ignore SF except 1 SF Ignore units even if incorrect Correct answer, with or without working, scores (5) Penalise incorrect rounding / truncation once only	(5)

Question Number	Answer	Additional Guidance	Mark
10(c)(ii)	calculation of concentration of O_2 in ppm	<u>Example of calculation</u> $9.4483 \times 10^{-3} \times (1000000 \div 1000)$ $= 9.4483 (\text{ppm})$ Allow TE from (i) Ignore SF except 1 SF	(1)

Question Number	Answer	Additional Guidance	Mark
10(d)	An answer that makes reference to the following points (some) Mn^{3+} (ions from half-cell B) will oxidise (other) Mn^{3+} (ions from half-cell A) and (some) Mn^{3+} (ions) will reduce (other) Mn^{3+} ions (1) - as E° for half-cell B is more positive / higher than E° for half-cell A or as $E^\circ_{\text{cell}} = (+)0.56 \text{ V}$ (1) $2\text{Mn}^{3+}(\text{aq}) + 2\text{H}_2\text{O}(\text{l}) \rightarrow \text{Mn}^{2+}(\text{aq}) + \text{MnO}_2(\text{s}) + 4\text{H}^+(\text{aq})$ (1) - disproportionation (reaction) (1)	Allow use of oxidation numbers instead of formulae of ions / molecules Allow Mn^{4+} to represent manganese(IV) in MnO_2 Allow Mn^{3+} is oxidised in one (half) equation and reduced in the other Allow Mn^{3+} is an oxidising agent in one (half) equation and a reducing agent in the other M2 can be shown by anti-clockwise rule, eg in table Ignore just E°_{cell} is positive so reaction is feasible Allow reversible arrow Ignore state symbols Ignore just redox	(4)

(Total for Question 10 = 15 marks)

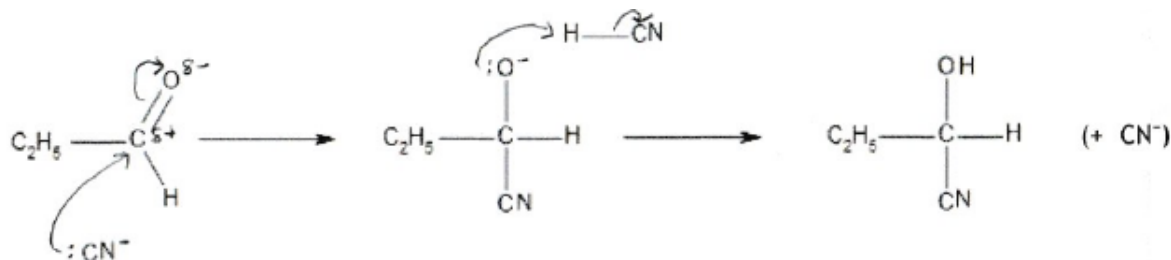


Question Number	Answer	Additional Guidance	Mark
7(a)	An explanation that makes reference to the following points: - ethanal and ethanoic acid (are both soluble because they) can form hydrogen bonds (with water) (1) - diagram to show hydrogen bonding between ethanal and water (1) - ethanal (has a lower boiling temperature because it only) has (weak) London forces and dipole-dipole forces between molecules (1) (ethanoic acid has a higher boiling temperature) because it forms intermolecular hydrogen bonds / hydrogen bonds between molecules and more energy is needed to overcome these / hydrogen bonds are the strongest intermolecular force / stronger than London Forces and dipole - dipole (1)	<u>Example of diagram</u> Allow H-bond for hydrogen bond  O--H--O bond angle should be about 180° Allow skeletal formulae Ignore dipoles and lone pair Do not award hydrogen bond from H of CHO to O of H₂O Allow van der Waals' / dispersion forces / attractions between temporary dipole and induced dipoles for London forces Allow less energy is needed to overcome intermolecular forces in ethanal (then ethanoic acid) for the 'and' statement	(4)



Question Number	Answer	Additional Guidance	Mark
7(b)(i)	- curly arrow from lone pair on C of CN^- to C of $\text{C}=\text{O}$ (1) - dipole on $\text{C}=\text{O}$ and curly arrow from double bond to, or just beyond, O (1) - structure of intermediate (1) - curly arrow from lone pair on O to H of HCN and curly arrow from H–CN bond to anywhere on CN or curly arrow from lone pair on O^- to H^+ (1)	Allow correct skeletal formulae throughout. Allow CN^- to attack $\text{C}=\text{O}$ from any angle Allow CN bond displayed Ignore arrows showing the formation of CN^- from HCN, attack must be by CN^- Negative charge on O must be present. Allow if lone pair (s) on O missing. Do not award δ^- on O. This mark can be awarded if no / incorrect charge on O (as already penalised above)	(4)

Example of mechanism:

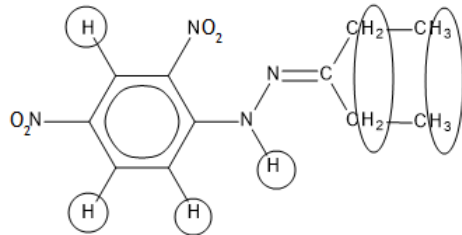


Question Number	Answer	Additional Guidance	Mark
7(b)(ii)	An explanation that makes reference to the following points: a racemic mixture will form because - the compound is planar around C=O / carbonyl group / $\text{C}\delta^+$ (1) - and the CN^- ion / nucleophile can attack either side / above and below (the plane) (1) - so equal amounts / chance of the two isomers / enantiomers (1)	Do not allow just the molecule / propanal / intermediate is planar for M1 Allow CN without the negative charge as this has been assessed in 7bi Award one mark only for a statement that a racemic mixture will not form (because) a single enantiomer will form	(3)

Question Number	Answer	Additional Guidance	Mark
7(c)(i)	An answer that makes reference to the following points: - filter (under suction) (1) - recrystallise (1) - suitable method of drying (1)	Allow answers on the diagram Ignore filter while hot Comment Allow gravity filtration Allow description of recrystallisation to include dissolving in hot solvent and filtering (whether hot or cold) Allow to dry in a (warm) oven, on a radiator, sunny windowsill, dry between filter / tissue paper / desiccator Do not award use of a drying agent except with desiccator Do not award dry to constant mass Do not award dehydration No TE on points made against the incorrect step	(3)



Question Number	Answer	Additional Guidance	Mark
7(c)(ii)	An answer that makes reference to the following points: X is cyclohexanone (1) 156-8°C is just below / close to / within range of the melting temperature range of cyclohexanone and the IR absorption of 1717 is in the range (1720 – 1700 cm⁻¹) for (alkyl) ketones (1)	Allow 156-8°C / the melting point of the compound is close to the range of both cyclohexanone and propanal If the range of IR absorption is quoted it must be correct	(2)

Question Number	Answer	Additional Guidance	Mark
7(c)(iii)	- benzene protons and nitrogen proton identified (1) - carbon protons identified (1)	Example of labelling  Allow any clear way of labelling the proton environments e.g. numbers 1 to 6 or letters A to F Do not award M1 if the nitrogen is circled as well as the hydrogen.	(2)

(Total for Question 7 = 18 marks)



Question Number	Answer	Mark
2(a)	The only correct answer is C (hexagonal rings within a layer) <i>A is not correct because in the layers of graphite and graphene the carbon atoms are bonded to three other carbon atoms and not four</i> <i>B is not correct because graphite and graphene do not have pentagonal rings within their layers</i> <i>D is not correct because graphene is a two-dimensional structure consisting of a single layer</i>	(1)

Question Number	Answer	Mark
2(b)	The only correct answer is D (all 120°) <i>A is not correct because the angles within a layer of graphite and graphene are neither 90° nor 109.5° but are all 120°</i> <i>B is not correct because the angles within a layer of graphite and graphene are not 109.5° but are all 120°</i> <i>C is not correct because there are no angles within a layer of graphite and graphene that are 109.5° but they are all 120°</i>	(1)

Question Number	Answer	Mark
2(c)	The only correct answer is C (poor electrical conductivity) <i>A is not correct because both graphene and graphite are similar to diamond in having a high melting temperature</i> <i>B is not correct because neither graphene nor graphite nor diamond have a precise molecular formula since they are giant molecular structures</i> <i>C is not correct because graphene, graphite and diamond are all giant molecular structures</i>	(1)

(Total for Question 2 = 3 marks)



Question Number	Answer	Mark
3	The only correct answer is A (<i>E</i>-2-methylbut-2-enoic acid) <i>B is incorrect because the two high priority groups are on opposite sides</i> <i>C is incorrect because the methyl group is on carbon 2</i> <i>D is incorrect because the two high priority groups are on opposite sides and the methyl group is on carbon 2</i>	(1)

Question Number	Answer	Additional Guidance	Mark
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Question Number	Answer	Mark
2(a)	The only correct answer is B (ether) <i>A is not correct because cyclohexane is not a good solvent for Grignard reagents as it is not polar</i> <i>C is not correct because ethyl ethanoate would react with Grignard reagents</i> <i>D is not correct because hexane is not a good solvent for Grignard reagents as it is not polar</i>	(1)

Question Number	Answer	Additional Guidance	Mark
2(b)	An answer that makes reference to the following point: to increase the length of a carbon chain (in a molecule) / extend the carbon chain	Accept to form a (new) carbon- carbon (single) bond Allow to increase the number of carbon(s) (atoms) (in the starting material) / Ignore to increase chain length / add to the carbon chain Ignore adding alkyl groups	(1)

Question Number	Answer	Mark
2(c)	The only correct answer is C (a nucleophile) <i>A is not correct because the reactive carbon has a partial negative charge</i> <i>B is not correct because the reactive carbon has a partial negative charge</i> <i>D is not correct because the reactive carbon has a partial negative charge</i>	(1)



Question Number	Answer	Additional Guidance	Mark
2(d)	An answer that makes reference to the following points: - ethane (1) (partially) negative carbon (in Grignard reagents) is attracted to / reacts with the (partially) positive hydrogen (in water) (1)	Accept CH_3CH_3 / C_2H_6 Allow use of symbols e.g. $\delta^- \text{C}$, $\delta^+ \text{H}$ Allow use of full negative charges on C and H	(2)

Question Number	Answer	Mark
2(e)	The only correct answer is D (CH_3COCH_3) <i>A is not correct because CO_2 would form a carboxylic acid with a Grignard reagent</i> <i>B is not correct because HCHO would form a primary alcohol with a Grignard reagent</i> <i>C is not correct because CH_3CHO would form a secondary alcohol with a Grignard reagent</i>	(1)

(Total for Question 2 = 6 marks)



Question Number	Answer	Additional Guidance	Mark																				
*4	This question assesses the student’s ability to show a coherent and logically structured answer with linkages and fully sustained reasoning. Marks are awarded for indicative content and for how the answer is structured and shows lines of reasoning. The following table shows how the marks should be awarded for indicative content. <table><tr><th>Number of indicative marking points seen in answer</th><th>Number of marks awarded for indicative marking points</th></tr><tr><td>6</td><td>4</td></tr><tr><td>5-4</td><td>3</td></tr><tr><td>3-2</td><td>2</td></tr><tr><td>1</td><td>1</td></tr><tr><td>0</td><td>0</td></tr></table> The following table shows how the marks should be awarded for structure and lines of reasoning. <table><tr><th></th><th>Number of marks awarded for structure of answer and sustained lines of reasoning</th></tr><tr><td>Answer shows a coherent logical structure with linkages and fully sustained lines of reasoning demonstrated throughout</td><td>2</td></tr><tr><td>Answer is partially structured with some linkages and lines of reasoning</td><td>1</td></tr><tr><td>Answer has no linkages between points and is unstructured</td><td>0</td></tr></table>	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		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)
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																						
	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																						



	Indicative content Treatment of waste polymers IP1 (waste) polymers can be (sorted and) recycled IP2 (waste) polymers can be incinerated to release energy / generate electricity IP3 (waste) polymers can be cracked / thermally decomposed (to (re)form monomers) Limiting problems caused by disposal IP4 (chemists) develop / invent (new) biodegradable polymers IP5 (chemists can help develop techniques to) minimise emission of harmful / toxic / acidic gases from incineration (of waste polymers) IP6 by neutralising HCl / SO₂ / NO_x	Allow re-use / repurpose (objects made from) polymers Allow polymers can be incinerated to release heat / used as a fuel Allow polymers can be used as a feedstock/raw material for cracking Allow polymers can converted into smaller / more useful molecules (to be used as a feedstock) Allow use /develop / invent (new) polymers that decompose Ignore use of alternative non-synthetic materials Ignore biofuels Allow minimise emissions of named pollutants from incineration e.g. HCl / SO₂ / NO_x / CO₂ / CO / dioxins Ignore comments on greenhouse gases / global warming Allow by carbon capture of CO₂ Allow by ensuring complete combustion to minimise CO / by converting CO to CO₂	
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(Total for Question 4 = 6 marks)



Question Number	Answer	Additional Guidance	Mark
5(a)(i)	An answer that makes reference to the following point: there is a change / decrease in the number of (gas) molecules / moles (so there will be a change in the total gas pressure)	If numbers are given, they must be correct (3 to 2) Ignore there is a change in the total volume of gas Ignore references to partial pressure	(1)

Question Number	Answer	Additional Guidance	Mark
5(a)(ii)	An answer that includes: temperature and volume	Do not award 'pressure'. Do not award 'heat' for temperature. Allow 'volume of container' Do not award 'volume of reactants'. Ignore catalyst Do not award if more than two factors given	(1)

Question number	Answer	Mark
5(b)(i)	The only correct answer is D (line S) <i>A is incorrect because $[NO(g)]$ is decreasing during the reaction</i> <i>B is incorrect because $[NO(g)]$ is decreasing during the reaction</i> <i>C is incorrect because $[NO(g)]$ is decreasing during the reaction</i>	(1)



Question number	Answer	Mark
5(b)(ii)	The only correct answer is B (line Q) <i>A is incorrect because rate is directly proportional to $[O_2(g)]$</i> <i>C is incorrect because rate is directly proportional to $[O_2(g)]$</i> <i>D is incorrect because rate is directly proportional to $[O_2(g)]$</i>	(1)

Question number	Answer	Mark
5(c)	The only correct answer is C (2z) <i>A is incorrect because this is the rate if only the concentration of oxygen is halved</i> <i>B is incorrect because this is the rate if the concentration of nitrogen monoxide is doubled, the concentration of oxygen is halved and the reaction is first order with respect to nitrogen monoxide</i> <i>D is incorrect because this is the rate if only the concentration of nitrogen monoxide is doubled</i>	(1)



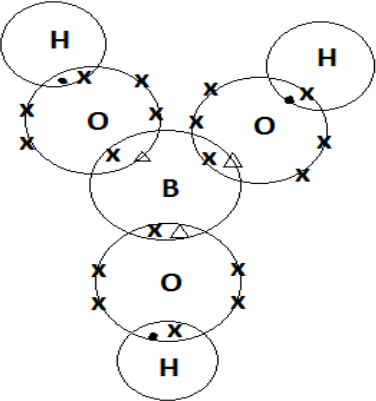
Question Number	Answer	Additional Guidance	Mark
5(d)(i)	- products line to the right and lower than reactants line and labelled - single - headed arrow downwards and labelled - two curves to show enthalpy with a catalyst	<u>Example of reaction profile</u> Allow (unbalanced) formula of product or just 'product' Ignore missing state symbols Allow other labels, e.g. enthalpy change / energy change Do not award $-\Delta H$ but ΔH negative is awarded Do not award double-headed arrow Arrow should be close to the reactant line and finish close to the product line Ignore activation energy arrows Both curves must be above the reactants line Ignore missing line and / or label for intermediate	(3)

Question Number	Answer	Additional Guidance	Mark
5(d)(ii)	An explanation that makes reference to the following points: - a lower temperature can be used / no need for high(er) temperature (as the forward reaction is exothermic) there will be a higher equilibrium yield at lower temperature (1) - this reduces the cost of the energy / fuel needed (1)	Ignore reference to decreased pressure Ignore environmental issues (e.g. greenhouse gases) Ignore less heat. Ignore just 'to reduce cost' If no other mark is awarded, allow (1) for 'even though they are expensive, they are not used up so last a long time' / 'catalysts reduce the activation energy and speed up the reaction'	(2)

(Total for Question 5 = 10 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
7(a)	correct equation	<u>Examples of equation</u> $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O} + 2\text{HCl} \rightarrow 4\text{H}_3\text{BO}_3 + 2\text{NaCl} + 5\text{H}_2\text{O}$ or $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O} + 2\text{HCl} \rightarrow 4\text{B}(\text{OH})_3 + 2\text{NaCl} + 5\text{H}_2\text{O}$ Allow multiples Allow reversible arrow provided the equation is written in the direction shown. Ignore state symbols, even if incorrect	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(b)(i)	- all 6 bonding pairs correct (1) 2 lone pairs on each O and no additional electrons on boron or hydrogen (1)	<u>Example of diagram</u>  Non-bonding electrons on O can be shown as pairs, all 4 together or as 3 and 1 Electrons in overlap regions can be on the lines or the gaps between the lines Allow (1) for electrons in correct places but incorrect symbols for electrons Ignore inner shell electrons shown on B and/or O Note If any double bonds are shown the answer scores (0)	(2)

Question Number	Answer	Mark
7(b)(ii)	The only correct answer is C <i>A is incorrect because 109.5° is incorrect</i> <i>B is incorrect because 109.5° and 180° are incorrect</i> <i>D is incorrect because 180° is incorrect</i>	(1)

Question Number	Answer	Mark
7(c)	The only correct answer is B <i>A is incorrect because covalent bonds are within molecules not between molecules</i> <i>C is incorrect because there are no ionic bonds</i> <i>D is incorrect because London forces are not the strongest force</i>	(1)



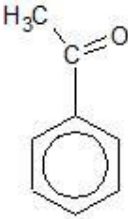
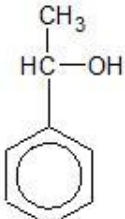
Question Number	Acceptable Answer	Additional Guidance	Mark
7(d)(i)	- calculation of K_a - calculation of $[H^+]$ - calculation of pH	<u>Example of calculation</u> $K_a = 10^{-pK_a} = 10^{-9.24} = 5.7544 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$ $[H^+] = \sqrt{K_a[H_3BO_3]} = \sqrt{5.7544 \times 10^{-10} \times 0.05}$ $= 5.364 \times 10^{-6} \text{ (mol dm}^{-3}\text{)}$ TE on K_a pH = $-\log_{10} [H^+] = -\log_{10} 5.364 \times 10^{-6}$ $= 5.2705 / 5.271 / 5.27 / 5.3$ TE on $[H^+]$ provided pH is >2 and <7 Accept alternative methods, for example $[H^+] = \sqrt{K_a[H_3BO_3]}$ pH = $\frac{1}{2}pK_a - \frac{1}{2}\log[H_3BO_3]$ (1) $= \frac{1}{2}9.24 - \frac{1}{2}\log 0.05$ (1) $= 5.2705 / 5.271 / 5.27 / 5.3$ (1) Alternative method: $K_a = 10^{-pK_a} = 10^{-9.24} = 5.7544 \times 10^{-10} \text{ (mol dm}^{-3}\text{)}$ (1) $[H^+]^2 = K_a ([H_3BO_3] - [H^+])$ $= 5.7544 \times 10^{-10} \times (0.05 - [H^+])$ $[H^+] = 5.135 \times 10^{-6}$ (1) pH = 5.29 (1) Ignore SF except 1SF Correct answer without working scores 3 marks	(3)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(d)(ii)	An answer that makes reference to the following points: $[H^+] = [H_2BO_3^-]$ or no H^+ from the (ionisation of) water / ionisation of water is negligible or H^+ is only from the acid or no H^+ from ionisation of $H_2BO_3^-$ (1) - ionisation / dissociation of the acid is negligible / very small / insignificant or $[H_3BO_3]_{initial} = [H_3BO_3]_{equilibrium}$ or $[H_3BO_3]_{equilibrium} = 0.05 \text{ (mol dm}^{-3}\text{)}$ or $[H^+]/[H_2BO_3^-] \ll [H_3BO_3]$ or $[H_3BO_3]$ / acid concentration remains constant or $[H_3BO_3]_{equilibrium} = [H_3BO_3]_{initial} - [H^+]$ used in calculation in (i) (1)	Allow $[A^-]$ for $[H_2BO_3^-]$ / $[HA]$ for $[H_3BO_3]$ Allow any of the expressions described in words Allow approximately equal to for $=$ (in symbols or words) Ignore reference to standard conditions Do not award two marks from the same marking point Allow the effect of the third ionisation is negligible Ignore partial dissociation / not completely dissociated Do not award H_3BO_3 / $[HA]$ is completely dissociated	(2)

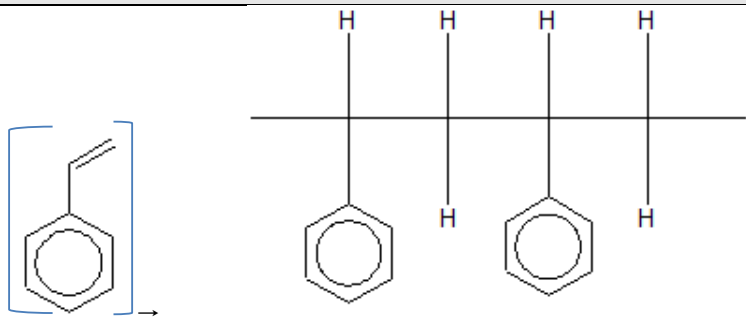
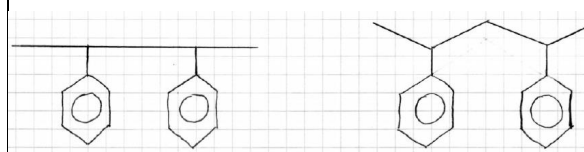
Question Number	Answer	Mark
7(e)	The only correct answer is B <i>A is not correct because it is the conjugate base not acid</i> <i>C is not correct because it is not the conjugate acid</i> <i>D is not correct because it is not the conjugate acid</i>	(1)

(Total for Question 7 = 11 marks)



Question Number	Acceptable Answer	Additional Guidance	Mark
7(a)	An answer that makes reference to the following: synthetic pathway that consists of: (Step 1) (acylation of benzene) using ethanoyl chloride (1) - use of aluminium chloride (and heat) (1) (Step 2) (reduction of) A with LiAlH_4 in ether (dry) (1) (Step 3) (dehydration of) B with (conc.) phosphoric acid/H_3PO_4 (1) (Intermediates) - identification of A as phenylethanone and B as (1-)phenylethanol $\text{H}_3\text{C}-\text{C}(=\text{O})-\text{C}_6\text{H}_5$  $\text{CH}_3-\text{CH}(\text{OH})-\text{C}_6\text{H}_5$  (1)	The compounds used can be stated or given within equations. Only award if part of a Friedel-Crafts reaction Only award if given to reduce an aromatic carbonyl or carboxylic acid Allow (conc.) sulfuric acid/ H_2SO_4 Only award if given to dehydrate an aromatic alcohol Accept formulae for names, but if both given, then both must be correct This also applies to reagents Do not award use of other reagents not in the table.	(5)

Question Number	Acceptable Answer	Mark
7(b)	The only correct answer is B <i>A is incorrect because this is an oxidising agent for alcohols not alkenes</i> <i>C is incorrect because this would not react</i> <i>D is incorrect because this would only produce an alcohol</i>	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(c)		Accept skeletal, structural or displayed formulae Accept any orientation of benzene ring Ignore brackets Ignore 'n' / '2n' / 'n/2' Allow syndiotactic and atactic forms Allow more than two units, as long as all correct. Neither of these diagrams scores Both have missing CH₂ 	(1)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(d)	An answer that makes reference to the following: An advantage - release of energy/avoids landfill (1) A disadvantage - release of toxic fumes (of polycyclic aromatics) (1)	Allow used to generate electricity Allow Release of benzene/carbon monoxide Release of carbon dioxide because of global warming / it's a greenhouse gas/ reduces recycling Release of carbon particulates increases respiratory problems Do not award damages the ozone layer Do not award references to acid rain Ignore just 'harmful' fumes	(2)

Question Number	Acceptable Answer	Additional Guidance	Mark
7(e)	- calculation of M_r of phenylethene (1) - answer converted into percentage to 2 or 3 SF (1)	<u>Example of calculation:</u> (M_r of phenylethene = 104 % = $(96 \div 104 \times 100 = 92.30769.. \%)$ =92 (%)/92.3 (%) Allow TE on incorrect M_r as long as answer not >100% Correct answer without working scores (2)	(2)

(Total for Question 7 = 11 marks)