Answer **all** the questions.

1 Benzene is an important industrial chemical and is used in a wide range of manufacturing processes. Over time our understanding of the structure and bonding of benzene has changed and various models have been proposed.

(a) In 1865, Kekulé proposed a model for the structure and bonding of benzene, but there is considerable evidence to suggest that Kekulé's model may not be correct. Scientists have proposed alternative models for the structure and bonding of benzene.

Explain the evidence that led scientists to doubt the model proposed by Kekulé.

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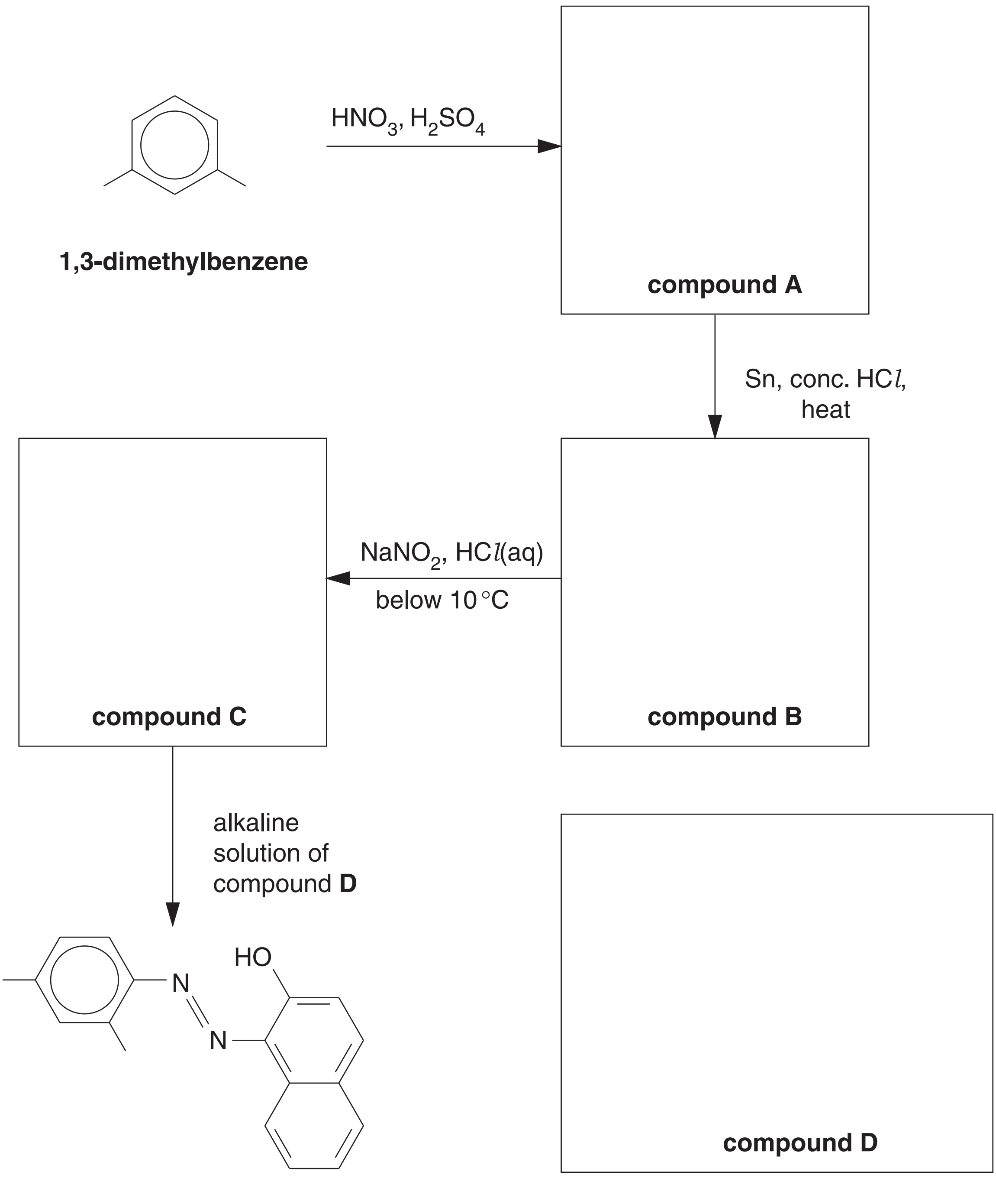
.... **[3]**

Turn over

(b) Sudan II is an azo dye which was used as a colourant in chilli powder. However, scientists advised the Food Standards Agency that Sudan II was linked to an increased risk of cancer and it is now no longer used as a food colourant.

The flowchart below shows how Sudan II could be prepared in the laboratory from 1,3-dimethylbenzene.

(i) Draw the structures of the organic compounds **A**, **B**, **C** and **D** in the boxes below. Display the functional group in compound **C**.



Sudan II

[4]

(ii) Compound **A** is formed by reacting 1,3-dimethylbenzene with HNO_3 and H_2SO_4.

Explain, with the aid of curly arrows, the mechanism for the formation of compound **A**.

Your answer should clearly show the role of H_2SO_4 as a catalyst.

[5]

(iii) Deduce how many **other** structural isomers of compound **A** could have been formed from the mononitration of 1,3-dimethylbenzene.

.... **[1]**

[Total: 13]

2 A student was researching the development of polymers and discovered three polyesters, PET, PEN and PGA, that are used in the manufacture of plastic bottles.

(a) The student discovered that the first polyester developed was Terylene which is also known as poly(ethylene terephthalate) or PET.

PET can be made by reacting benzene-1,4-dicarboxylic acid with ethane-1,2-diol.

(i) Draw the **displayed** formula of the repeat unit in PET.

[2]

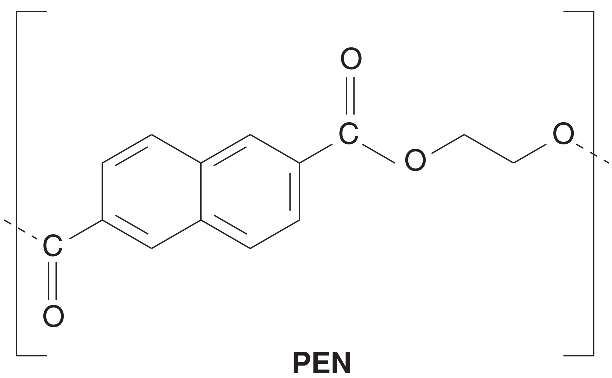
(ii) The industrial manufacture of PET involves two main stages. The first stage, known as 'pre-polymerisation', forms compound **F** with molecular formula $C_{12}H_{14}O_6$.

Draw the structure of compound **F**.

[1]

(b) PEN is a new kind of polyester. PEN is rigid at high temperature whereas PET readily softens.

The repeat unit of PEN is shown below.



PEN

(i) What is the empirical formula of the repeat unit in PEN?

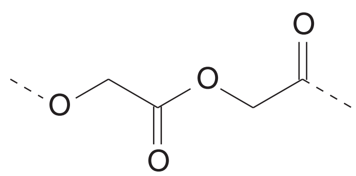
.... **[1]**

(ii) Draw the structures of **two** monomers that could be used to make PEN.

[2]

(c) Polyglycolic acid, PGA, is a polymer that is being developed as an inner coating for PET bottles.

A short section of PGA is shown below.



PGA

(i) Compared with other synthetic polymers, PGA can be easily hydrolysed.

Draw the skeletal formula of the organic product formed from the complete hydrolysis of PGA by NaOH(aq).

[2]

(ii) Explain why scientists now think that polymers such as PGA are better for the environment than hydrocarbon-based polymers.

In your answer, you should use appropriate technical terms, spelt correctly.

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.... **[1]**

[Total: 9]

Turn over

3 A student was given three compounds, an aldehyde, a ketone, and a carboxylic acid.

(a) The student carried out the same two chemical tests on each compound. This allowed her to distinguish between all three compounds.

- Describe two suitable tests that the student could have used.
- Show how the observations would allow her to distinguish between the compounds.

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.... **[4]**

(b) Explain how the student could use infrared spectroscopy to confirm which compound is a carboxylic acid.

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.... **[1]**

(c) The aldehyde has the molecular formula $C_5H_{10}O$.

The ^1H NMR spectrum of the aldehyde contains a doublet at $\delta = 0.9$ ppm with a relative peak area of six compared with the aldehyde proton.

Analyse this information to deduce the structure of the aldehyde. Explain your reasoning.

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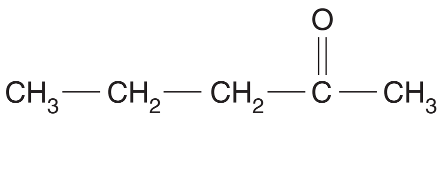
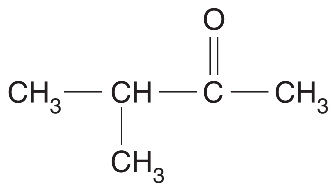
.... **[3]**

(d) The ketone also has the molecular formula $C_5H_{10}O$. There are three structural isomers of this formula that are ketones.

(i) Two of these isomers are shown below.

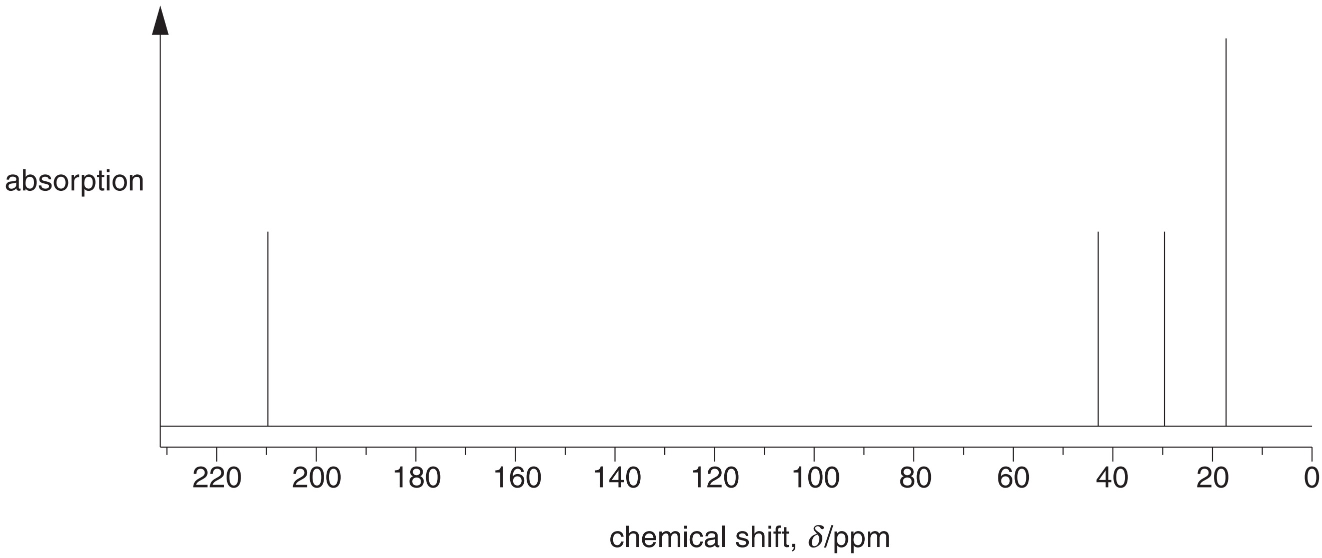
Draw the structural formula of the third structural isomer in the box below.

		
ketone 1	**ketone 2**	**ketone 3**

[1]

(ii) The ^{13}C NMR spectrum of the ketone given to the student is shown below.

- Use the spectrum to identify the ketone. Explain your reasoning.
- Identify the carbon responsible for the peak at δ = 210 ppm.



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.... **[3]**

[Total: 12]

Turn over

4 Two esters, $CH_3(CH_2)_2COO(CH_2)_3CH_3$ and $CH_3(CH_2)_2COOCH_2CH_3$, contribute to the odour of pineapple. A food scientist analysed a sample of pineapple essence by separating the two esters using gas chromatography, GC, and measuring their retention times.

(a) **(i)** State what is meant by *retention time*.

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.... **[1]**

(ii) Explain the possible limitations of GC in separating the two esters.

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.... **[1]**

(iii) Give the systematic name for the ester $CH_3(CH_2)_2COO(CH_2)_3CH_3$.

.... **[1]**

(b) The unsaturated ester, ethyl deca-2,4-dienoate contributes to the flavour of pears.

(i) Draw the structure of this ester.

[2]

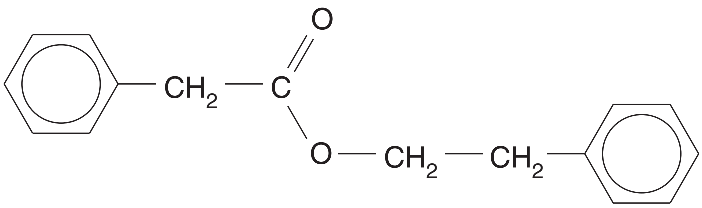
(ii) When pears ripen, ethyl deca-2,4-dienoate is formed following the breakdown of triglycerides.

Draw the general structure of a triglyceride with any functional groups fully displayed.

You can use 'R' to represent the carbon chains.

[1]

(c) The food scientist decided to synthesise the ester shown below, for possible use as a flavouring.



The **only** organic compound available to the food scientist was phenylethanal ($C_6H_5CH_2CHO$).

Explain how the food scientist was able to synthesise this ester using only phenylethanal and standard laboratory reagents.

In your answer, you should use appropriate technical terms, spelt correctly.

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.... **[7]**

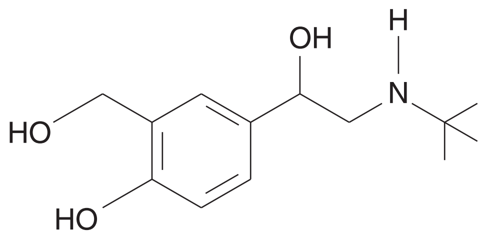
[Total: 13]

Turn over

5 Hydroxyamines are organic compounds containing hydroxyl and amino functional groups.

(a) Salbutamol is a hydoxyamine used in the treatment of asthma and bronchitis. Salbutamol is an example of a chiral drug.

(i) Draw a circle around the chiral carbon in the structure of salbutamol shown below.



salbutamol

[1]

(ii) Suggest possible problems of making a chiral drug such as salbutamol and describe **two** ways that the pharmaceutical industry might overcome these problems.

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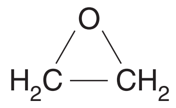
.... **[4]**

(b) Monoethanolamine, MEA, $H_2NCH_2CH_2OH$, is a hydroxyamine that is used in aqueous solution as a gas scrubber to remove acidic gases from emissions in incinerators.

MEA is prepared industrially by reacting ammonia with epoxyethane.



epoxyethane

(i) Write an equation for the industrial preparation of MEA.

[1]

(ii) During the manufacture of MEA, a compound with molecular formula $C_4H_{11}NO_2$ is also formed.

Draw the structure of the compound with molecular formula $C_4H_{11}NO_2$.

[1]

(c) The combustion of some polymers produces emissions containing toxic acidic gases such as HCl and H_2S. MEA can remove HCl and H_2S from the emissions.

Give the formula of the organic salts formed when MEA removes:

(i) HCl,

[1]

(ii) H_2S.

[1]

TURN OVER FOR QUESTION 5 PARTS (d) AND (e)

Turn over

(d) MEA, $H_2NCH_2CH_2OH$, can be oxidised to form an α-amino acid.

(i) Explain what is meant by an α-amino acid.

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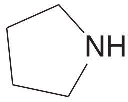
.... **[1]**

(ii) Write an equation for the oxidation of MEA to form an α-amino acid.

Use [O] to represent the oxidising agent.

.... **[1]**

(e) Isomers **F** and **G** are hydroxyamines each with the molecular formula $C_4H_{11}NO$.

- Isomer **F** can be dehydrated to form the cyclic compound 

- Isomer **G** has two chiral centres.

Identify and draw the structural isomers **F** and **G**.

isomer F	**isomer G**

[2]

[Total: 13]

END OF QUESTION PAPER