1 Mandelic acid (2-phenyl-2-hydroxyethanoic acid), $C_6H_5CH(OH)COOH$, is used in some skin creams and can be converted into a condensation polymer.

The addition polymer of ethyl methacrylate (ethyl 2-methyl-2-propenoate), $CH_2C(CH_3)COOC_2H_5$, is used to make some artificial fingernails.

(a) Explain what is meant by the term *condensation polymerisation*.

Your answer should use appropriate technical terms, spelled correctly.

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..... **[1]**

(b) Draw **two** repeat units of a polymer that is formed when,

(i) mandelic acid, $C_6H_5CH(OH)COOH$, polymerises

[2]

(ii) ethyl methacrylate, $CH_2C(CH_3)COOC_2H_5$, polymerises.

[1]

(c) When ethyl methacrylate, $CH_2C(CH_3)COOC_2H_5$, is heated under reflux with aqueous dilute acid, a hydrolysis reaction takes place forming compound **C** and ethanol.

When compound **C** is heated with steam in the presence of an acid catalyst, an addition reaction takes place forming two organic products **D** and **E**.

Compounds **D** and **E** are structural isomers with the molecular formula $C_4H_8O_3$.

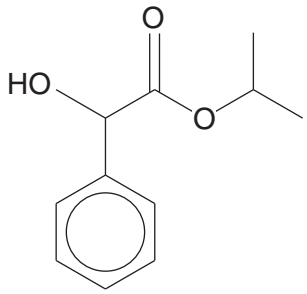
Draw the structures of compounds **C**, **D** and **E**.

compound **C**
compound **D**
compound **E**

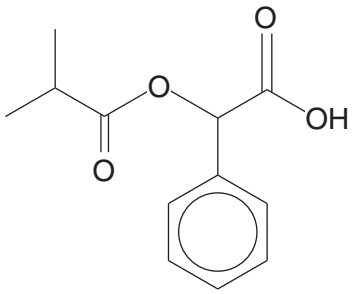
[3]

TURN OVER FOR PART (d)

(d) Mandelic acid has anti-bacterial properties and is used in some skin creams. A cosmetic chemist used mandelic acid to prepare two different esters that might be suitable for new skin creams. The structures of the two esters are shown below.



ester 1



ester 2

(i) Draw the structure of an organic compound that could react with mandelic acid, $C_6H_5CH(OH)COOH$, to produce **ester 1**.

[1]

(ii) Identify an organic compound that could react with mandelic acid to produce **ester 2.**

[1]

(iii) **Ester 1** is less soluble in water than mandelic acid, $C_6H_5CH(OH)COOH$.

Explain the difference in water solubility of mandelic acid and **ester 1**.

You may use a labelled diagram in your answer.

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..... **[3]**

(iv) Before any skin cream can be sold to the public, it must be tested to ensure it is safe to use.

Suggest why.

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..... **[1]**

[Total: 13]

2 'Methylglyoxal', CH_3COCHO, is formed in the body during metabolism.

Describe **one** reduction reaction and **one** oxidation reaction of methylglyoxal that could be carried out in the laboratory.

Your answer should include reagents, equations and observations, if any.

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..... **[5]**

[Total: 5]

3 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]

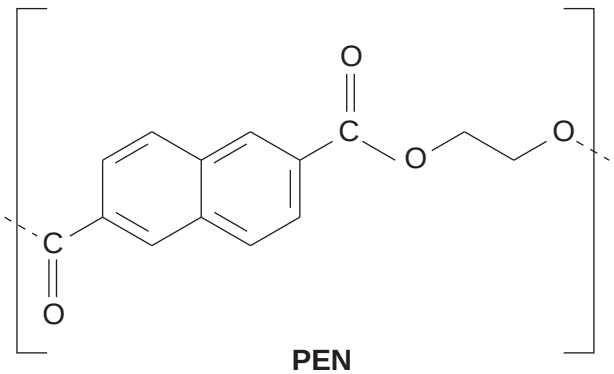
(ii) The industrial manufacture of PET involves two main stages. The first stage, known as 'pre-polymerisation', forms compound **F** with molecular formula $C_{12}H_{14}O_6$.

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?

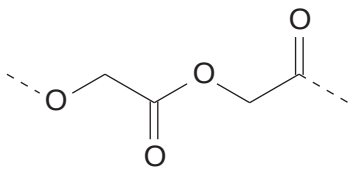
..... **[1]**

(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]

4 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 δ = 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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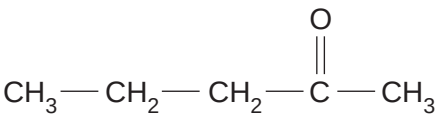
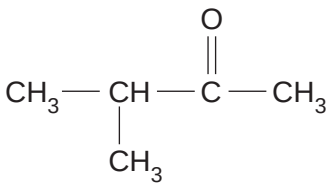
..... **[3]**

(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.

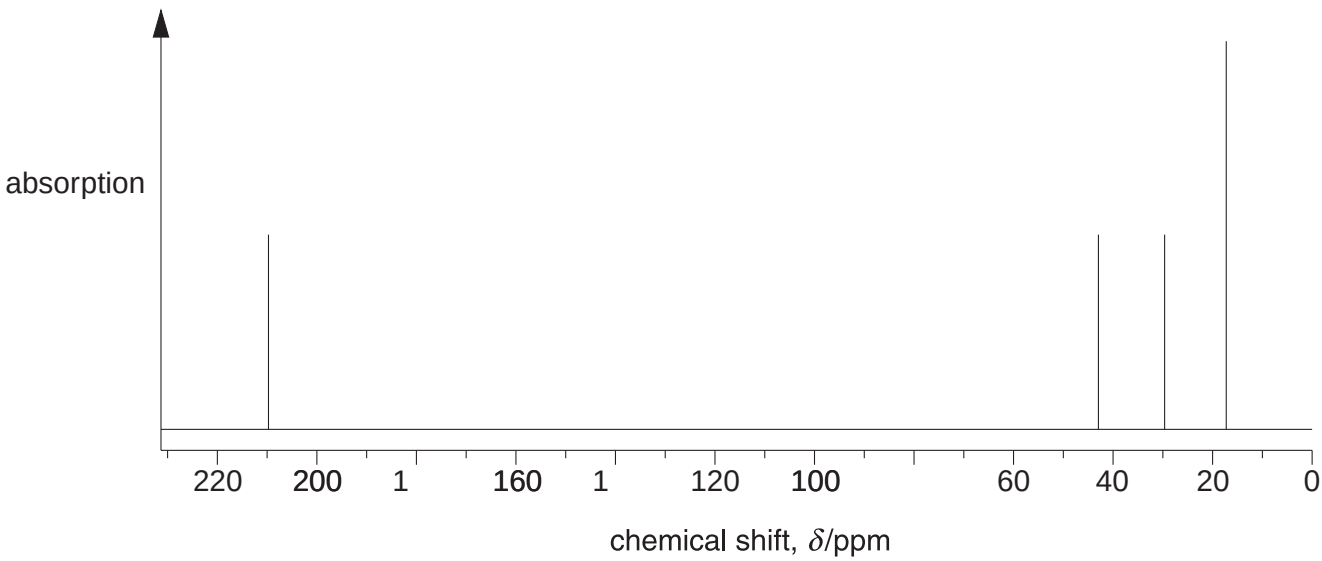
Draw the structural formula of the third structural isomer in the box below.

		
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]**

5 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.

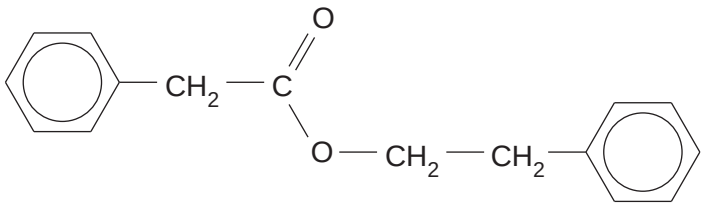
[2]

(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.

(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]

6 This question is about different organic compounds containing C, H and O.

(a) A technician found an unlabelled bottle in a chemical store cupboard. The technician thinks that the bottle contains pentan-2-one, pentan-3-one or pentanal.

(i) Describe a series of chemical tests that the technician could use to confirm that the compound in the bottle is a ketone. Include appropriate reagents and any relevant observations.

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..... **[2]**

(ii) Describe how the technician could use the product of one of the tests in **(i)** to show whether the bottle contains pentan-2-one or pentan-3-one.

The method used should **not** involve spectroscopy.

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..... **[2]**

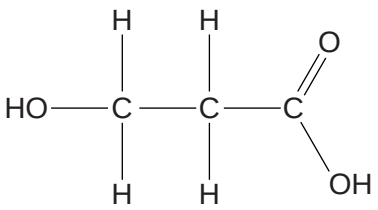
(b) 3-Hydroxypropanoic acid, $HOCH_2CH_2COOH$, can be produced microbiologically from sugars in corn. $HOCH_2CH_2COOH$ can be used as a 'green' starting material for the synthesis of many organic compounds including some important polymers.

Three synthetic routes are shown below for converting $HOCH_2CH_2COOH$, **A**, into different polymers.

The names of the processes for each synthetic step are given.

(i) In the boxes below, give the structures of the organic compounds formed.

Synthesis 1

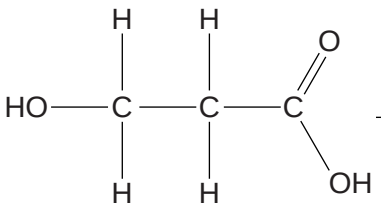


A

polymerisation

one repeat unit

Synthesis 2

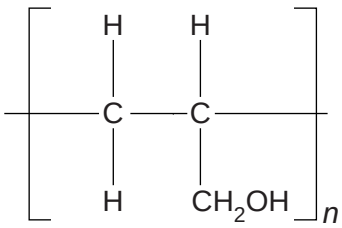


A

elimination of H_2O

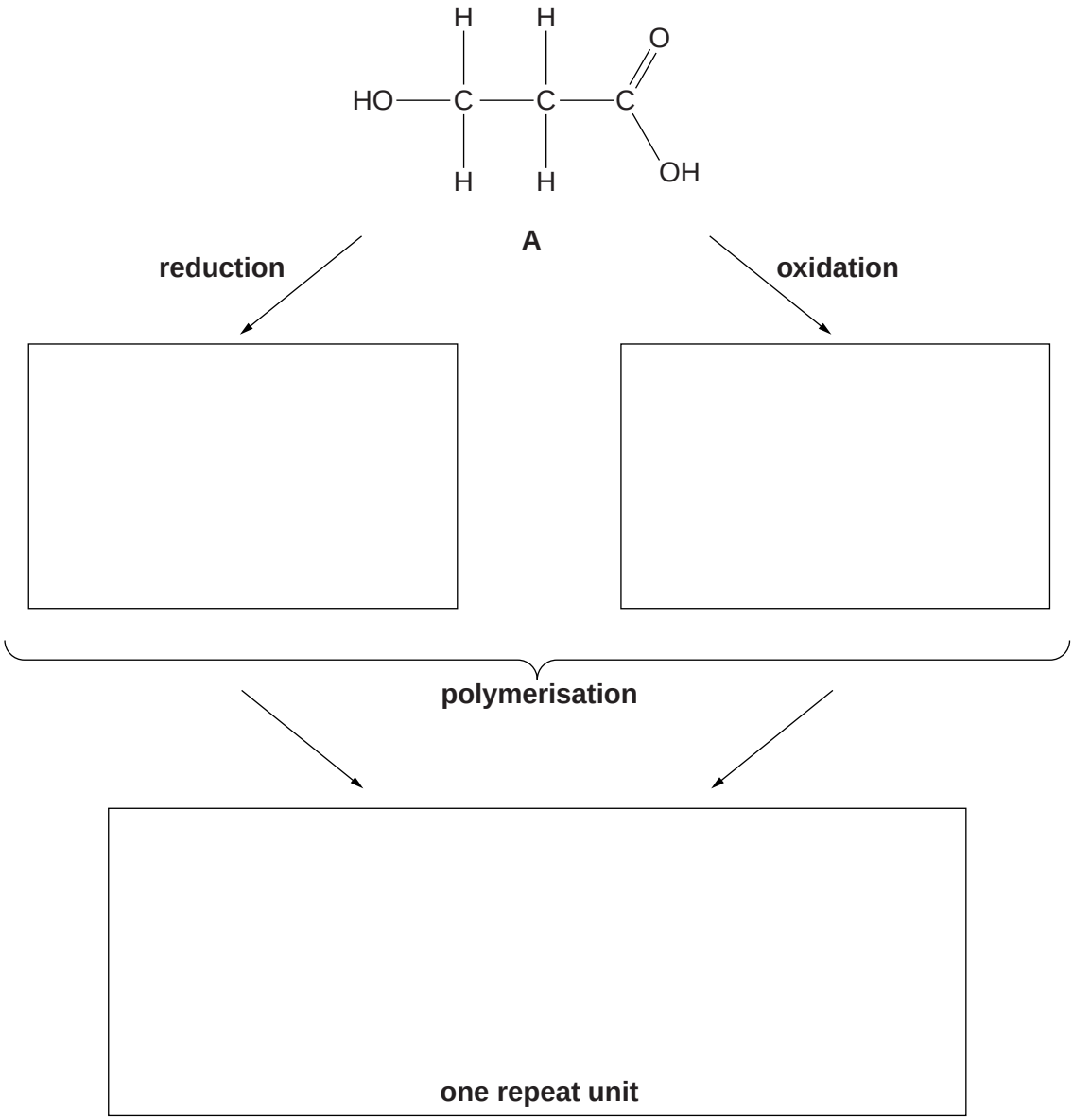
reduction

polymerisation



PVA, used in adhesives

Synthesis 3



[6]

(ii) State the type of polymerisation taking place in each synthetic route.

Synthesis 1: .....

Synthesis 2: .....

Synthesis 3: .....

[1]

[Total: 11]