For Examiner's Use

Answer **all** the questions.

1 Leucine (2-amino-4-methylpentanoic acid) is a naturally occurring α-amino acid that is often used in protein supplements.

Leucine has a structural formula of $(CH_3)_2CHCH_2CH(NH_2)COOH$.

(a) **(i)** State the general formula of an α-amino acid.

..... [1]

(ii) Draw a displayed formula of leucine.

[1]

(b) Leucine can exist as a zwitterion.

(i) State what is meant by the term *zwitterion*.

.....

..... [1]

(ii) Explain with the aid of a diagram how the zwitterion is formed from the functional groups in leucine.

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..... [2]

c) Leucine can be obtained from a source of protein such as meat.

(i) State suitable reagents and conditions to break down a protein into amino acids.

.....

..... [2

(ii) State the type of reaction occurring.

..... [1

d) Leucine can also be synthesised in the laboratory from simpler compounds.

(i) One reaction in this synthesis converts 2-chloro-4-methylpentanoic acid $(CH_3)_2CHCH_2CHClCOOH$, into leucine.

State the reagents and conditions needed for this reaction.

..... [1

(ii) Explain how a purified sample of leucine synthesised in the laboratory would diffe from a sample of leucine purified from meat.

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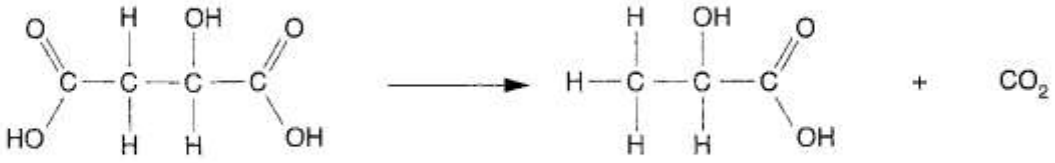
..... [3

[Total: 12

2 One of the final stages in winemaking involves the fermentation of malic acid to lactic acid.

An equation for the reaction is shown below.



malic acid **lactic acid**

(a) Both acids contain a chiral centre.

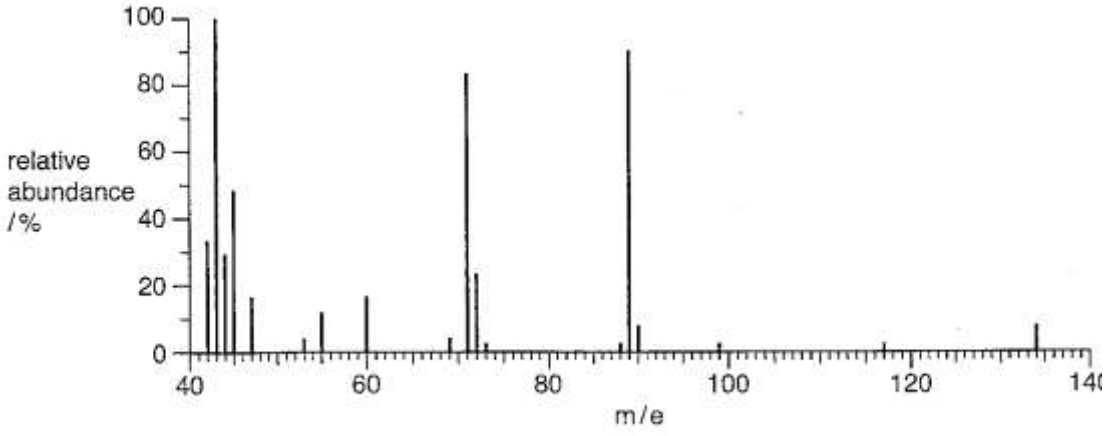
(i) Identify the chiral centre on the structure of **malic acid** above using an asterisk *. [1]

(ii) Draw a diagram to show the 3-D arrangement of groups around the chiral centre in malic acid.

[1]

(b) Wine can be analysed for the presence of these acids by mass spectrometry.

The mass spectrum of **malic acid** is shown below.



(i) Draw a circle around the molecular ion peak on this spectrum of malic acid. [1

(ii) Deduce the m/e value of the molecular ion peak of **lactic acid**.

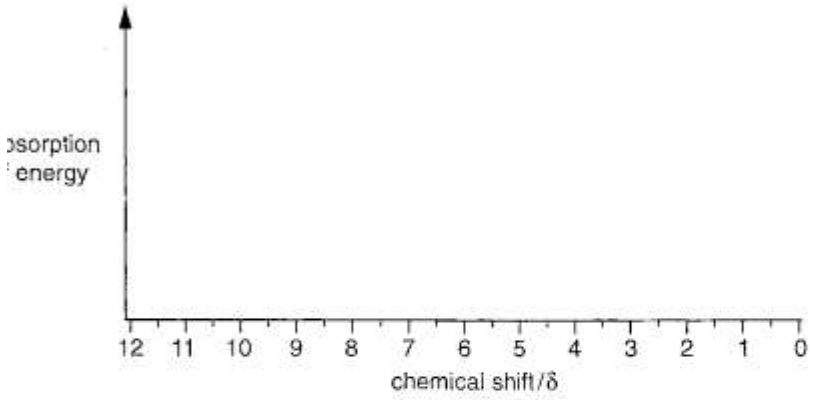
.....

..... [1]

(c) Lactic acid produces an n.m.r. spectrum in D_2O with peaks at chemical shift values of 1.4 ppm and 4.3 ppm.

(i) On the axes below, sketch the high resolution n.m.r. spectrum of lactic acid in D_2O.

Show any splitting patterns and state the relative areas of the two peaks. [4]



(ii) How many peaks would you expect if the n.m.r. spectrum of lactic acid was run in an inert solvent rather than in D_2O? Explain your answer.

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..... [2]

(d) As a wine ages, some of the acids slowly react with ethanol in the wine to produce esters.

(i) Draw a displayed formula to show the structure of the ester formed when **lactic acid** reacts with ethanol.

[1]

(ii) Suggest what effect this process might have on the flavour of the wine. Explain your reasoning.

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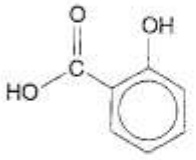
..... [1]

[Total: 12]

For Examiner's Use

3 Salicylic acid is used in the manufacture of aspirin tablets. In the UK around 3500 tonnes of salicylic acid are manufactured per year.



salicylic acid

Salicylic acid is manufactured from phenol in three stages.

(a) Phenol is first converted to sodium phenoxide, $C_6H_5O^-\ Na^+$.

(i) State a reagent that could be used for this reaction.

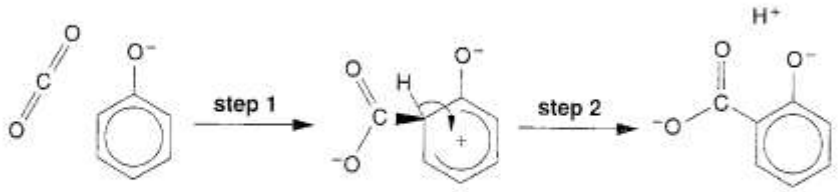
..... [1]

(ii) Write a balanced equation for this reaction.

[1]

(b) The phenoxide ion is then combined with carbon dioxide under high pressure to form the salicylate ion.

This reaction is an electrophilic substitution reaction, which occurs by the incomplete mechanism shown below. Carbon dioxide acts as the electrophile.



intermediate

(i) Add partial charges δ^+ and δ^- to show the polarisation of the C=O bonds in the carbon dioxide molecule above. [1]

(ii) Complete the mechanism by adding curly arrows to show the movement of electron pairs in **step 1** to give the intermediate shown. [2]

(iii) Carbon dioxide is normally a very poor electrophile. However, this reaction does occur because the benzene ring in the phenoxide ion is activated.

Explain how the benzene ring in the phenoxide ion is activated.

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..... [3]

c) In the final stage of this process, the salicylate ion is acidified to give salicylic acid.

Assuming an overall yield by mass of 45% for this three stage process, calculate the mass of phenol that is needed to produce the annual UK output of 3500 tonnes of salicylic acid.

M_r of phenol = 94.0; 1 tonne = 10^6 g

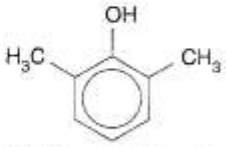
mass of phenol = ... tonnes [4]

[Total: 12]

For Examiner's Use

4 A dye can be made from 4-methylphenylamine and 2,6-dimethylphenol, shown below.

4-methylphenylamine



2,6-dimethylphenol

4-Methylphenylamine is dissolved in ice-cold hydrochloric acid and sodium nitrite is added. This mixture is then slowly added to an alkaline solution of the phenol to form the dye.

(a) **(i)** Identify the inorganic nitrogen-containing compound formed by the mixture of hydrochloric acid and sodium nitrite.

..... [1]

(ii) Draw the structure of the organic compound formed in the ice-cold acidic mixture, showing a displayed formula of the nitrogen-containing group.

[1]

(iii) State the name of the type of organic compound drawn in **(ii)**.

..... [1]

(iv) Suggest why the mixture must be kept at a low temperature.

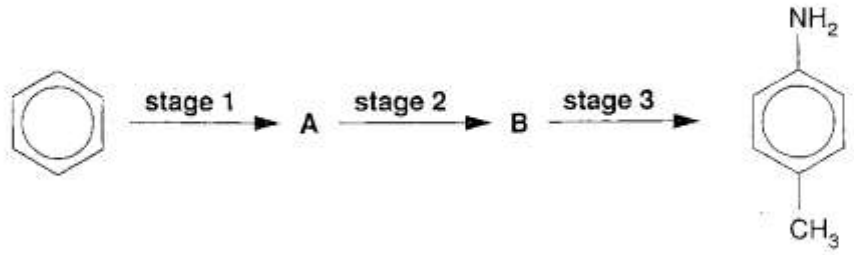
.....

..... [1]

(v) Suggest the structure of the dye.

) In this question, one mark is available for the quality of use and organisation of scientific terms.

4-Methylphenylamine can be manufactured from benzene in three stages.



benzene **4-methylphenylamine**

Describe how benzene could be converted by these three stages into 4-methylphenylamine.

Include the structures of the intermediate compounds **A** and **B**. State the reagents and conditions. Give a balanced equation for each stage.

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Quality of Written Communication [1]

[Total: 18]

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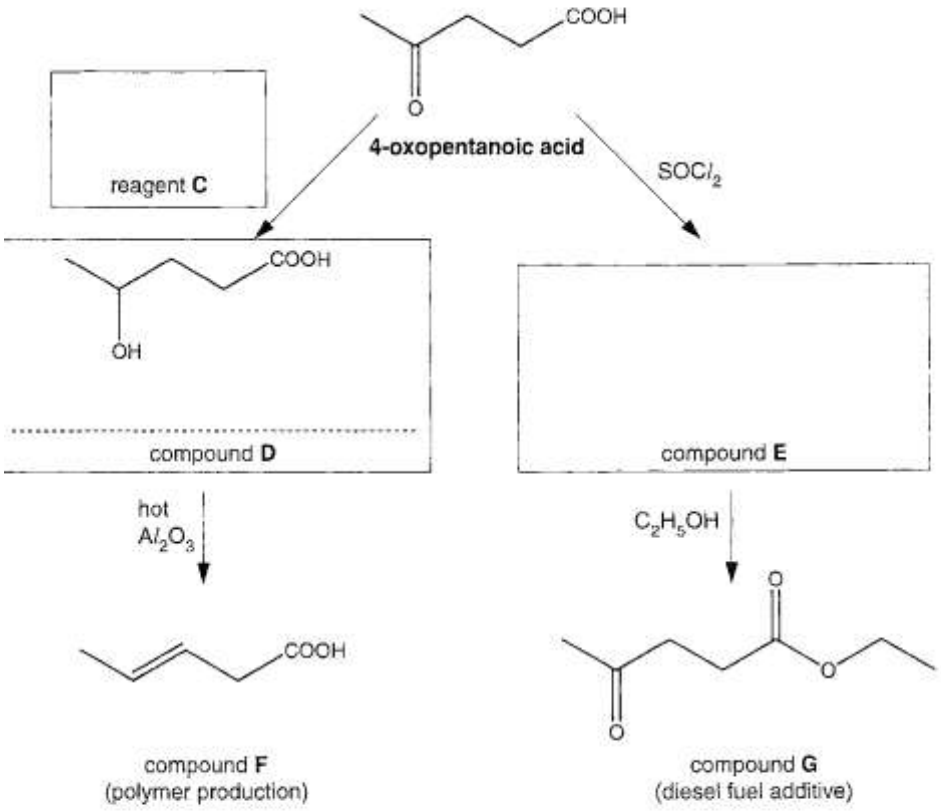
Examiner's Use

Chemists are currently developing renewable sources of organic chemicals to replace diminishing crude oil reserves.

One process involves the conversion of plant material to 4-oxopentanoic acid. This can then be converted to other useful organic compounds, including those shown below.



(a) Complete the scheme by filling in the boxes to:

(i) identify reagent **C** [1]

(ii) state the name of compound **D** [1]

(iii) draw the structure of compound **E** [1]

b) Compound **F** can be used to form a polymer.

(i) Draw a short section of this polymer showing at least three repeat units.

[1]

(ii) Draw a circle round one repeat unit on your structure. [1]

c) Compound **G** can be added to diesel fuel to reduce the amount of soot formed when the fuel burns.

(i) Deduce the molecular formula of compound **G**.

..... [1]

(ii) Write a balanced equation for the complete combustion of compound **G**.

[2]

(iii) Suggest how compound **G** reduces the amount of soot when the fuel burns.

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..... [1]

d) If compound **G** is accidentally spilt, it is broken down rapidly in the environment by reactions such as alkaline hydrolysis.

(i) State the reagents and conditions that would normally be used for alkaline hydrolysis in the laboratory.

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..... [2]

(ii) Explain why compound **G** is able to be hydrolysed.

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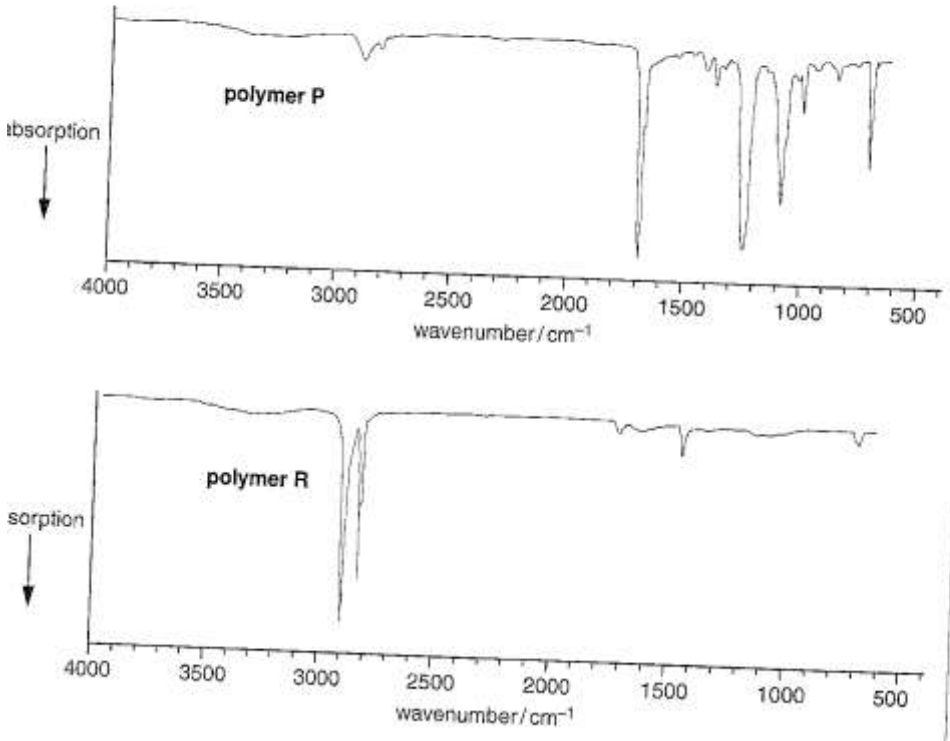
..... [1]

[Total: 12]

For Examiner's Use

6 Forensic scientists often use infra-red spectroscopy to identify very small fragments of polymers left at a crime scene.

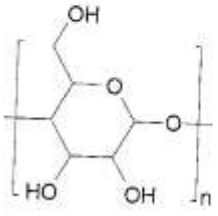
The infra-red spectra of two polymer samples **P** and **R** found at the scene of a crime are shown below.



The possible polymers are:

- a hydrocarbon polymer
- *Terylene*
- cellulose.

The repeat unit below shows the structure of cellulose.



cellulose

(a) *Terylene* and cellulose are condensation polymers used as fibres in clothing.

(i) State the type of condensation polymer used to make *Terylene*.

..... [1]

(ii) Draw the repeat unit of *Terylene* and describe how it is formed from its monomers.

[3]

(b) Identify polymer **P** and polymer **R**.

Explain your reasoning and comment on the presence or absence of any relevant peaks.

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..... [3]

(c) Two hydrocarbon polymers commonly used for household items and packaging are poly(ethene) and poly(propene).

Name the other hydrocarbon polymer in common use for packaging.

..... [1]

Examiner's Use

f) Poly(propene) used in disposable packaging is usually *atactic*. For more specialist uses, a *syndiotactic* form of the same polymer has been produced.

Describe how the structure of atactic poly(propene) differs from syndiotactic poly(propene). Use diagrams to illustrate your answer.

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[5]

[Total: 13]

7 In this question, one mark is available for the quality of spelling, punctuation and grammar.

The π-bond in carbonyl compounds reacts readily with nucleophiles, but not with electrophiles.

- Describe the π-bond in a carbonyl group and explain why this π-bond does **not** react readily with electrophiles. [4]

- Explain why carbonyl compounds react with nucleophiles and illustrate your answer by showing the mechanism for the reaction of methanal with a suitable nucleophile. [6]

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Quality of Written Communication [1]

[Total: 11]

END OF QUESTION PAPER