Question 1: N/A
Question 2: N/A

3 Esters are produced by the reaction of alcohols with other esters and by the reaction of alcohols with carboxylic acids.

3 (a) The esters which make up biodiesel are produced industrially from the esters in vegetable oils.

3 (a) (i) Complete the equation for this formation of biodiesel.

....

(2 marks)

3 (a) (ii) Write an equation for the complete combustion of $C_{17}H_{35}COOCH_3$

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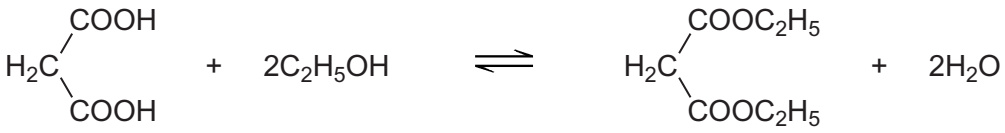
(2 marks)

3 (b) The ester commonly known as diethyl malonate (**DEM**) occurs in strawberries and grapes. It can be prepared from acid **A** according to the following equilibrium.



A **DEM**

3 (b) (i) A mixture of 2.50 mol of **A** and 10.0 mol of ethanol was left to reach equilibrium in an inert solvent in the presence of a small amount of concentrated sulfuric acid. The equilibrium mixture formed contained 1.80 mol of **DEM** in a total volume, V dm^3, of solution.

Calculate the amount (in moles) of **A**, of ethanol and of water in this equilibrium mixture.

Moles of **A** .....

Moles of ethanol .....

Moles of water.....

(3 marks)

3 (b) (ii) The total volume of the mixture in part **(b) (i)** was doubled by the addition of more of the inert solvent.

State and explain the effect of this addition on the equilibrium yield of **DEM**.

Effect .....

Explanation .....

.....

(2 marks)

3 (b) (iii) Using **A** to represent the acid and **DEM** to represent the ester, write an expression for the equilibrium constant K_c for the reaction.

.....

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(1 mark)

3 (b) (iv) In a second experiment, the equilibrium mixture was found to contain 0.85 mol of **A**, 7.2 mol of ethanol, 2.1 mol of **DEM** and 3.4 mol of water.

Calculate a value of K_c for the reaction and deduce its units.

Calculation.....

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Units.....

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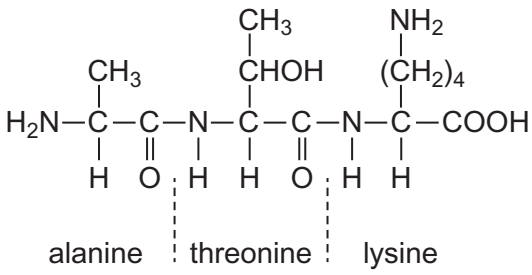
(3 marks)

13

4 (a) The tripeptide shown is formed from the amino acids alanine, threonine and lysine.



4 (a) (i) Draw a separate circle around **each** of the asymmetric carbon atoms in the tripeptide.

(1 mark)

4 (a) (ii) Draw the zwitterion of alanine.

(1 mark)

4 (a) (iii) Give the IUPAC name of threonine.

.....

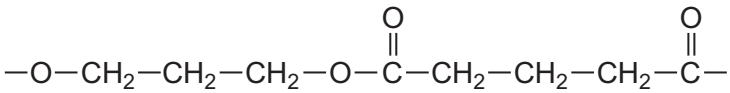
(1 mark)

4 (a) (iv) Draw the species formed by lysine at low pH.

(1 mark)

Question 4 continues on the next page

4 (b) The repeating unit shown represents a polyester.



4 (b) (i) Name this type of polymer.

.....

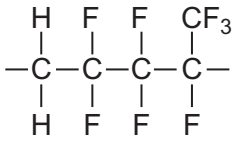
(1 mark)

4 (b) (ii) Give the IUPAC name for the alcohol used to prepare this polyester.

.....

(1 mark)

4 (c) The repeating unit shown represents a polyalkene co-polymer. This co-polymer is made from two different alkene monomers.



4 (c) (i) Name the type of polymerisation occurring in the formation of this co-polymer.

.....

(1 mark)

4 (c) (ii) Draw the structure of each alkene monomer.

Alkene monomer 1 Alkene monomer 2

(2 marks)

Do not write outside the box

4 (d) One of the three compounds shown in parts **(a)**, **(b)** and **(c) cannot** be broken down by hydrolysis.

Write the letter **(a)**, **(b)** or **(c)** to identify this compound and explain why hydrolysis of this compound does **not** occur.

Compound .....

Explanation .....

.....

.....

(2 marks)

11

Turn over for the next question

5 This question concerns isomers of $C_6H_{12}O_2$ and how they can be distinguished using n.m.r. spectroscopy.

5 (a) The non-toxic, inert substance TMS is used as a standard in recording both ^1H and ^{13}C n.m.r. spectra.

5 (a) (i) Give **two** other reasons why TMS is used as a standard in recording n.m.r. spectra.

Reason 1 .....

.....

Reason 2 .....

.....

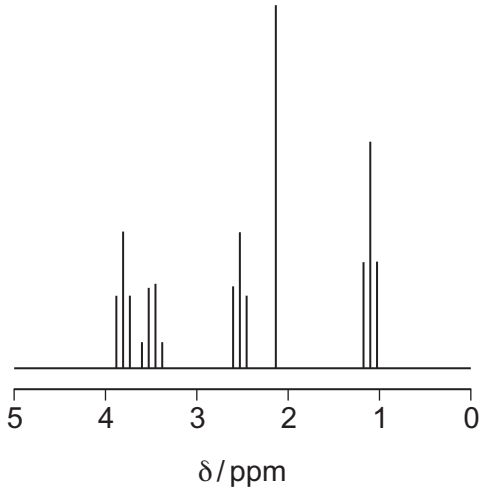
(2 marks)

5 (a) (ii) Give the structural formula of TMS.

(1 mark)

5 (b) The proton n.m.r. spectrum of compound **P** ($C_6H_{12}O_2$) is represented in **Figure 1**.

Figure 1



The integration trace gave information about the five peaks as shown in **Figure 2**.

Figure 2

δ / ppm	3.8	3.5	2.6	2.2	1.2
Integration ratio	2	2	2	3	3

5 (b) (i) Use **Table 2** on the Data Sheet, **Figure 1** and **Figure 2** to deduce the structural fragment that leads to the peak at δ 2.2

(1 mark)

5 (b) (ii) Use **Table 2** on the Data Sheet, **Figure 1** and **Figure 2** to deduce the structural fragment that leads to the peaks at δ 3.5 and 1.2

(1 mark)

5 (b) (iii) Use **Table 2** on the Data Sheet, **Figure 1** and **Figure 2** to deduce the structural fragment that leads to the peaks at δ 3.8 and 2.6

(1 mark)

5 (b) (iv) Deduce the structure of **P**.

(1 mark)

Question 5 continues on the next page

5 (c) These questions are about different isomers of **P** ($C_6H_{12}O_2$).

5 (c) (i) Draw the structures of the two esters that both have only two peaks in their proton n.m.r. spectra. These peaks both have an integration ratio of 3:1

Ester 1

Ester 2

(2 marks)

5 (c) (ii) Draw the structure of an optically active carboxylic acid with five peaks in its ^{13}C n.m.r. spectrum.

(1 mark)

5 (c) (iii) Draw the structure of a cyclic compound that has only two peaks in its ^{13}C n.m.r. spectrum and has no absorption for C = O in its infrared spectrum.

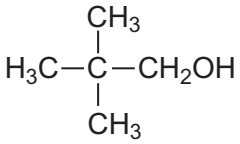
(1 mark)

11

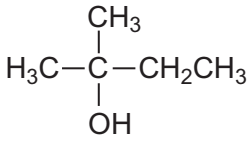
6 Describe how you could distinguish between the compounds in the following pairs using **one** simple test-tube reaction in each case.

For each pair, identify a reagent and state what you would observe when both compounds are tested separately with this reagent.

6 (a)



R



S

Reagent .....

Observation with **R** .....

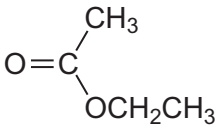
.....

Observation with **S** .....

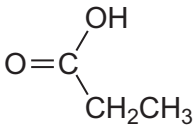
.....

(3 marks)

6 (b)



T



U

Reagent .....

Observation with **T** .....

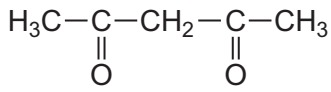
.....

Observation with **U** .....

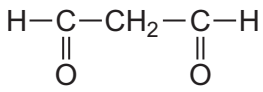
.....

(3 marks)

6 (c)



V



W

Reagent .....

Observation with **V** .....

.....

Observation with **W** .....

.....

(3 marks)

9

Turn over for the next question

Section B

Answer **all** questions in the spaces provided.

7 Each of the following conversions involves reduction of the starting material.

7 (a) Consider the following conversion.

Identify a reducing agent for this conversion.

Write a balanced equation for the reaction using molecular formulae for the nitrogen-containing compounds and [H] for the reducing agent.

Draw the repeating unit of the polymer formed by the product of this reaction with benzene-1,4-dicarboxylic acid.

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(5 marks)

(Extra space) .....

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7 (b) Consider the following conversion.

Identify a reducing agent for this conversion.

State the empirical formula of the product.

State the bond angle between the carbon atoms in the starting material and the bond angle between the carbon atoms in the product.

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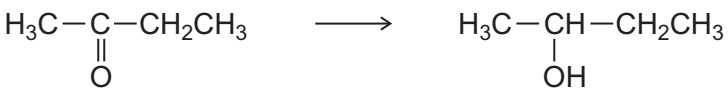
(4 marks)

Question 7 continues on the next page

7 (c) The reducing agent in the following conversion is $NaBH_4$



7 (c) (i) Name and outline a mechanism for the reaction.

Name of mechanism .....

Mechanism

(5 marks)

7 (c) (ii) By considering the mechanism of this reaction, explain why the product formed is optically inactive.

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(3 marks)

17

8 Acyl chlorides such as CH_3COCl are useful compounds in synthesis.

8 (a) The acyl chloride CH_3COCl reacts with benzene.

8 (a) (i) Write an equation for this reaction and name the organic product.

Identify a catalyst for the reaction.

Write an equation to show how this catalyst reacts with CH_3COCl to produce a reactive intermediate.

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(4 marks)

8 (a) (ii) Name and outline a mechanism for the reaction of benzene with the reactive intermediate in part **(a) (i)**.

Name of mechanism .....

Mechanism

(4 marks)

Question 8 continues on the next page

8 (b) Nucleophiles such as alcohols can react with CH_3COCl
The ion CH_3COO^- can act as a nucleophile in a similar way.

State the meaning of the term *nucleophile*.

Draw the structure of the organic product formed by the reaction of CH_3COO^- with CH_3COCl

Name the functional group produced in this reaction.

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(3 marks)

11

Question 9: N/A

Section B

Answer **all** questions in the spaces provided.

10 The reactions of molecules containing the chlorine atom are often affected by other functional groups in the molecule.

Consider the reaction of CH_3CH_2COCl and of $CH_3CH_2CH_2Cl$ with ammonia.

10 (a) For the reaction of CH_3CH_2COCl with ammonia, name and outline the mechanism and name the organic product.

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(6 marks)

(Extra space) .....

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10 (b) For the reaction of $CH_3CH_2CH_2Cl$ with an **excess** of ammonia, name and outline the mechanism and name the organic product.

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(6 marks)

(Extra space) .....

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Question 10 continues on the next page

10 (c) Suggest **one** reason why chlorobenzene (C_6H_5Cl) does **not** react with ammonia under normal conditions.

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(1 mark)

(Extra space) .....

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13