

Carboxylic Acids & Derivatives

Question Paper 4

Level	International A Level
Subject	Chemistry
Exam Board	CIE
Topic	Carboxylic Acids & Derivatives
Sub-Topic	
Paper Type	Theory
Booklet	Question Paper 4

Time Allowed: 72 minutes

Score: /60

Percentage: /100

Grade Boundaries:

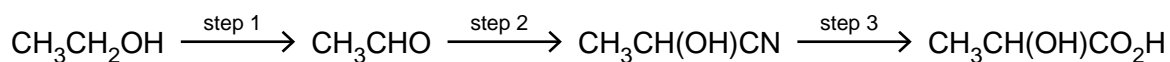
A*	A	B	C	D	E	U
>85%	77.5%	70%	62.5%	57.5%	45%	<45%

- 1 Lactic acid, 2-hydroxypropanoic acid, $\text{CH}_3\text{CH}(\text{OH})\text{CO}_2\text{H}$, occurs naturally in sour milk and in our muscles when we take hard exercise.
Lactic acid is chiral and shows stereoisomerism.

- (a) Draw fully displayed structures of the two optical isomers of lactic acid.
Indicate with an asterisk (*) the chiral carbon atom in the lactic acid molecule.

[3]

- (b) Lactic acid may be synthesised from ethanol by the following route.



Give the reagent(s) and essential condition(s) for **each** step.

	reagent(s)	condition(s)
step 1		
step 2		
step 3		

[6]

During exercise, lactic acid is produced in our muscles from pyruvic acid, $\text{CH}_3\text{COCO}_2\text{H}$. This reaction occurs in the presence of the enzyme lactic acid dehydrogenase.

(c) (i) What type of chemical compound is the enzyme lactic acid dehydrogenase?

.....

(ii) How would you detect a small quantity of pyruvic acid in a sample of lactic acid?

State the reagent(s) you would use and what would be seen in your test.

reagent(s)

observation

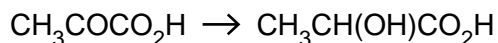
(iii) How would you detect a small quantity of lactic acid in a sample of pyruvic acid?

State the reagent(s) you would use and what would be seen in your test.

reagent(s)

observation

(iv) What chemical reagent would be used to convert pyruvic acid into lactic acid?



.....

[6]

[Total: 15]

2 A range of modern analytical techniques has made the identification of molecules, and atoms in compounds, much more rapid than traditional laboratory analysis.

(a) One instrumental technique is NMR spectroscopy, which uses the fact that under certain conditions protons can exist in two different energy states.

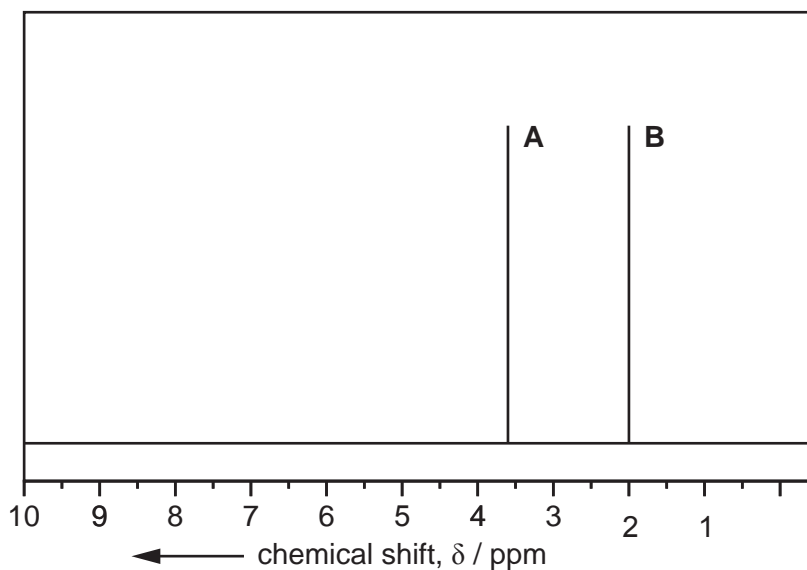
Explain how these different energy states arise.

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

(b) When methanol, CH_3OH , is examined using NMR spectroscopy, it absorbs at two different frequencies. Explain why, and predict the relative areas of the two peaks.

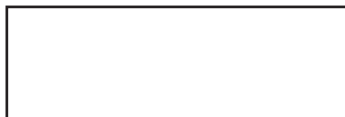
.....
.....
..... [2]

(c) The NMR spectrum below is that of one of three possible isomers of molecular formula $\text{C}_3\text{H}_6\text{O}_2$.

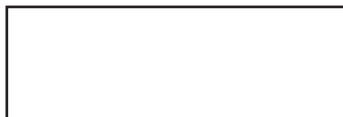


The compound could be propanoic acid, methyl ethanoate or ethyl methanoate.

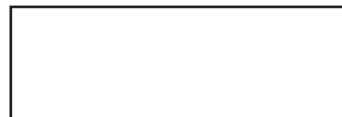
(i) In the boxes provided, draw the structures of the three compounds.



propanoic acid



methyl ethanoate



ethyl methanoate

(ii) Explain which compound produced the spectrum shown, indicating which protons are responsible for each of the peaks **A** and **B**.

.....
.....
.....

(iii) The NMR spectrum of another of the compounds has a peak at $\delta 11.0$. State which compound this would be, and identify the proton(s) responsible for this peak.

compound

proton(s)

[4]

(d) X-ray crystallography is a technique used to identify the relative positions of atoms in a crystal of a compound.

(i) What further information about organic macromolecules can be deduced by the use of X-ray crystallography?

.....
.....

(ii) Which atoms cannot be located by X-ray crystallography?

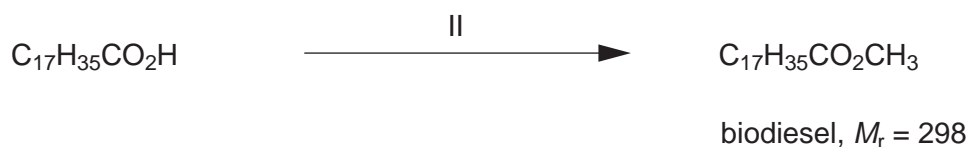
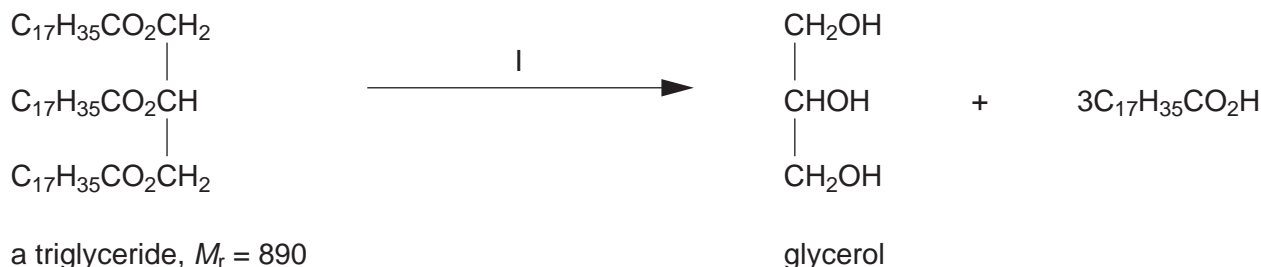
.....

[2]

[Total: 10]

- 3 Recently much interest has been shown in the production of the fuel *biodiesel* from algae. Up to 55% of the mass of the dried algae is composed of lipids, the majority of which are triglycerides.

To convert triglycerides into biodiesel, the following processes are carried out.



- (a) Name the functional group present in triglycerides.

..... [1]

- (b) Suggest reactants and conditions for

reaction I,

.....

reaction II.

.....

[4]

- (c) Suggest the structural formula of the compound formed when glycerol is reacted with

- (i) an excess of HBr(aq),

.....

- (ii) an excess of hot acidified $\text{K}_2\text{Cr}_2\text{O}_7(\text{aq})$.

.....

[2]

- (d) Calculate the mass of biodiesel that can be produced from 1000kg of dried algae, assuming that 50% of the algal mass is triglycerides.

mass = kg [2]

- (e) (i) Construct an equation for the complete combustion of biodiesel.

.....

- (ii) Use your equation to calculate the mass of CO₂ produced when 10kg of biodiesel is burned.

.....

.....

[3]

- (f) The production of biodiesel is at present an expensive process.

Suggest a reason why the development of biodiesel as an alternative to fossil fuels is important.

.....

..... [1]

[Total: 13]

4 An organic ester, **B**, has the empirical formula C_2H_4O . An experiment by a student in a college gave a value of 87.5 for M_r of **B**.

(a) What is the molecular formula of **B**?

.....

[1]

(b) In the boxes below, draw the structural formulae of **four** isomers of **B** that are esters.

W	X
Y	Z

[4]

The student hydrolysed his sample of **B** by heating with aqueous mineral acid and then separating the alcohol, **C**, that was formed. He heated the alcohol **C** under reflux with acidified dichromate(VI) ions and collected the product **D**.

A sample of **D** gave an orange precipitate with 2,4-dinitrophenylhydrazine reagent. A second sample of **D** gave no reaction with Tollens' reagent.

(c) (i) What group does the reaction with 2,4-dinitrophenylhydrazine reagent show to be present in **D**?

.....

(ii) What does the result of the test with Tollens' reagent show about **D**?

.....

(iii) What is the structural formula of the alcohol **C**?

(iv) Which of your esters, **W**, **X**, **Y**, or **Z** has the same structure as that of the ester **B**?

.....

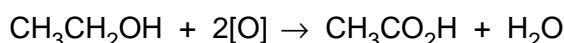
(d) Which, if any of your esters, **W**, **X**, **Y**, or **Z** is chiral? Explain your answer.

.....

..... [1]

[Total: 10]

- 5 Ethanoic acid, CH₃CO₂H, is formed as vinegar by the bacterial oxidation of ethanol present in wine and other solutions.



Ethanoic acid can also be formed in the laboratory by the oxidation of ethanol.

- (a) (i) What oxidising agent is used for this laboratory reaction?

.....

- (ii) What colour change would be observed?

from to

[2]

When ethanoic acid is prepared in this way in the laboratory, the reagents are heated under reflux for some time before the ethanoic acid is separated.

- (b) (i) Why is the reaction carried out by heating under reflux?

.....

.....

- (ii) What would be the main organic compound formed if, instead of heating under reflux, the reagents were heated together and the products immediately distilled off?

.....

[2]

- (c) Ethanoic acid is manufactured from methanol, CH₃OH, by reacting it with carbon monoxide in the presence of a catalyst containing rhodium metal and iodide ions.



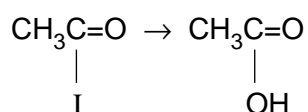
The reaction proceeds in a number of stages.

- (i) One stage in this process is the reaction of methanol with hydrogen iodide.

What organic compound is formed in this reaction?

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- (ii) A later stage involves the conversion of an intermediate compound.

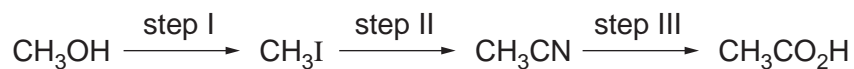


What type of reaction is this?

.....

[2]

- (d) Methanol can be converted into ethanoic acid in the laboratory in a three-stage process.



What reagent(s) and conditions are used in each step of the conversion?

step I

reagent(s)

conditions

step II

reagent(s)

conditions

step III

reagent(s)

conditions

[6]

[Total: 12]