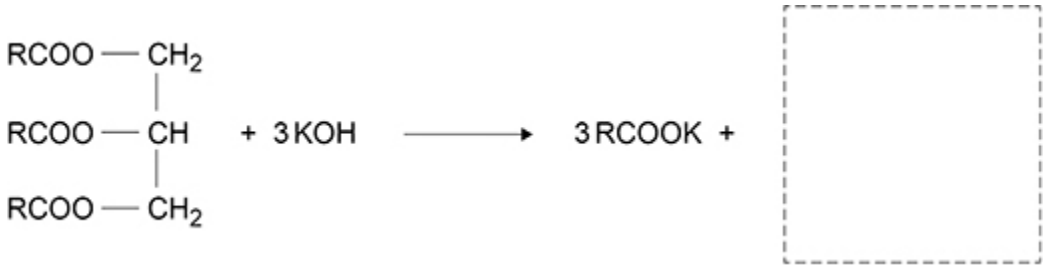
# A-Level Chemistry

## Carboxylic Acids and Esters

### Question Paper

**Time available: 61 minutes**
**Marks available: 57 marks**

**1.** Coconut oil contains a triester with three identical R groups.
This triester reacts with potassium hydroxide.




(a) Complete the equation by drawing the structure of the other product of this reaction in the box.

Name the type of compound shown by the formula RCOOK

Give **one** use for this type of compound.

Type of compound _____

Use _____

**(3)**

(b) The triester in coconut oil has a relative molecular mass, $M_r$ = 638.0
In the equation shown at the start of this question, R represents an alkyl group that can be written as $CH_3(CH_2)_n$

Deduce the value of n in $CH_3(CH_2)_n$
Show your working.

n _____

**(3)**

(c) A 1.450 g sample of coconut oil is heated with 0.421 g of KOH in aqueous ethanol until all of the triester is hydrolysed.
The mixture is cooled.
The remaining KOH is neutralised by exactly 15.65 $cm^3$ of 0.100 mol $dm^{-3}$ HCl

Calculate the percentage by mass of the triester ($M_r$ = 638.0) in the coconut oil.

Percentage by mass _____

**(6)**

(d) Suggest why aqueous ethanol is a suitable solvent when heating the coconut oil with KOH.

Give a safety precaution used when heating the mixture.
Justify your choice.

Reason _____

_____

Safety precaution _____

_____

Justification _____

_____

**(3)**

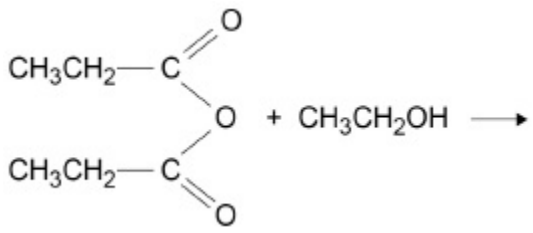
**(Total 15 marks)**

**2.** This question is about esters including biodiesel.

(a) An ester is formed by the reaction of an acid anhydride with $CH_3CH_2OH$

Complete the equation. In your answer show clearly the structure of the ester.
Give the IUPAC name of the ester.

Equation




Name of ester _____

**(3)**

(b) In a reaction to form biodiesel, one mole of a vegetable oil reacts with an excess of methanol to form two moles of an ester with molecular formula $C_{19}H_{34}O_2$ and one mole of an ester with molecular formula $C_{19}H_{36}O_2$

Draw the structure of the vegetable oil showing clearly the ester links.

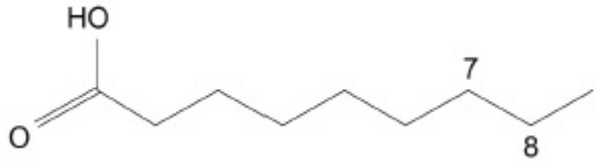
You should represent the hydrocarbon chains in the form $C_xH_y$ where *x* and *y* are the actual numbers of carbon and hydrogen atoms.

**(2)**

(c) The compound $C_{19}H_{34}O_2$ is the methyl ester of Z,Z-octadeca-9,12-dienoic acid.

Part of the structure of the acid is shown.

Complete the skeletal formula to show the next part of the hydrocarbon chain to carbon atom number 14.
In your answer, show the Z stereochemistry around both C=C double bonds.



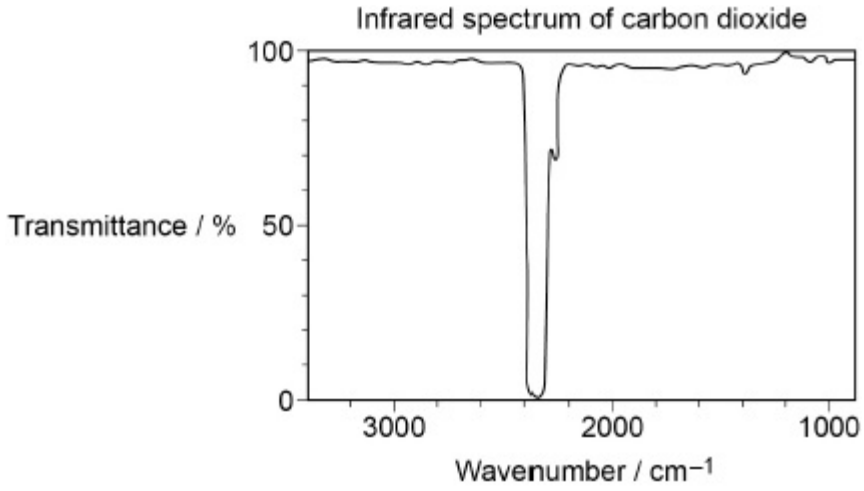

**(2)**

(d) Give an equation for the complete combustion of the ester $C_{19}H_{34}O_2$

_____

**(1)**

(e) Combustion of biodiesel produces greenhouse gases such as carbon dioxide that cause global warming.
Part of the infrared spectrum of carbon dioxide is shown in the diagram.




State how the infrared spectrum of carbon dioxide in the diagram above is **not** what you might predict from the data provided in **Table A** in the Data Booklet.

_____

_____

_____

**(1)**

(f) Explain how carbon dioxide causes global warming.

_____

_____

_____

_____

_____

_____

**(2)**

**(Total 11 marks)**

**3.** Esters are used as raw materials in the production of soaps and biodiesel.

(a) A student prepared an ester by two different methods.

Method **1** alcohol + acid anhydride

Method **2** alcohol + acyl chloride

(i) An ester was prepared using method **1**, by reacting $(CH_3)_2CHOH$ with $(CH_3CO)_2O$

Write an equation for this reaction and give the IUPAC name of the ester formed.

Equation

_____

IUPAC name of the ester _____

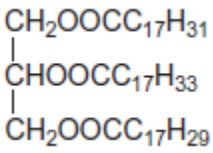
**(2)**

(ii) The same ester was prepared using method **2** by reacting $(CH_3)_2CHOH$ with $CH_3COCl$

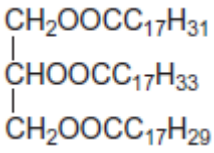
Outline a mechanism for this reaction.

**(4)**

(b) The ester shown occurs in vegetable oils.
It can be hydrolysed to make soap and can also be used to produce biodiesel.



(i) Write an equation for the reaction of this ester with sodium hydroxide to form soap.



**(2)**

(ii) Give the formula of the biodiesel molecule with the highest $M_r$ that can be produced by reaction of this ester with methanol.

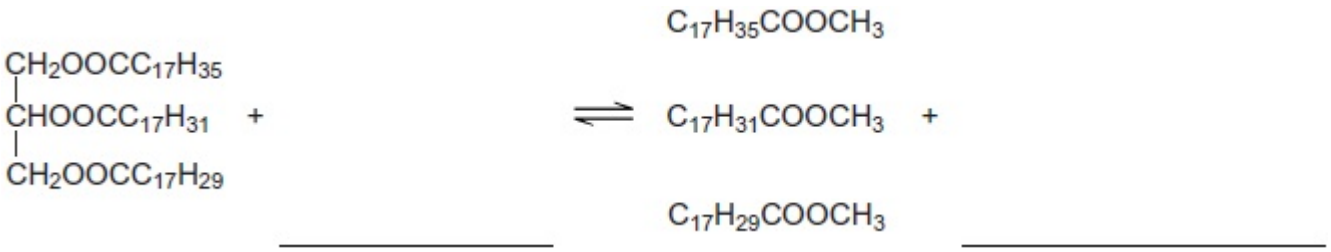
**(1)**

**(Total 9 marks)**

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

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

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

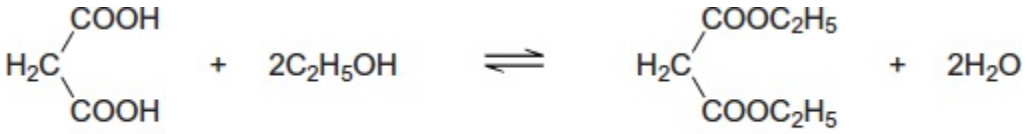


**(2)**

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

**(2)**

(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**

(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)**

(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)**

(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.

_____

_____

**(1)**

(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 _____

_____

_____

_____

_____

_____

_____

_____

Units _____

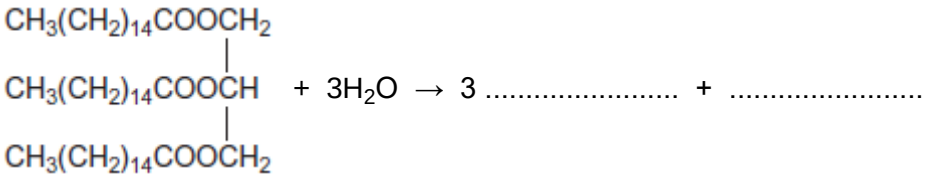
_____

**(3)**

**(Total 13 marks)**

**5.** The slowing down of chemical processes is important in food storage. Over time, fats may become rancid. This involves the formation of compounds that have unpleasant odours and flavours within the food.
Hydrolysis of fats is one way in which rancid flavours are formed. Fats break down to long-chain carboxylic (fatty) acids and glycerol.

(a) Complete the right-hand side of the equation below to show how hydrolysis affects the molecule of fat shown.




**(2)**

(b) Other than by cooling, suggest **one** method that would decrease the rate of hydrolysis of fats.

_____

_____

_____

**(1)**

(c) Food can also acquire unpleasant flavours when the fatty acids, produced by hydrolysis of fats, are oxidised by air. This oxidation occurs by a free-radical mechanism.
Chemicals called anti-oxidants can be added to food to slow down the oxidation.
Suggest why anti-oxidants are **not** regarded as catalysts.

**(2)**

(d) A student investigated the extent of hydrolysis in an old sample of the fat in part (a).
The carboxylic acid extracted from a 2.78 g sample of this fat ($M_r$ = 806.0) reacted with 24.5 $cm^3$ of a 0.150 mol $dm^{-3}$ solution of NaOH.
Calculate the percentage of the fat that had hydrolysed.
Show your working.

**(4)**

**(Total 9 marks)**