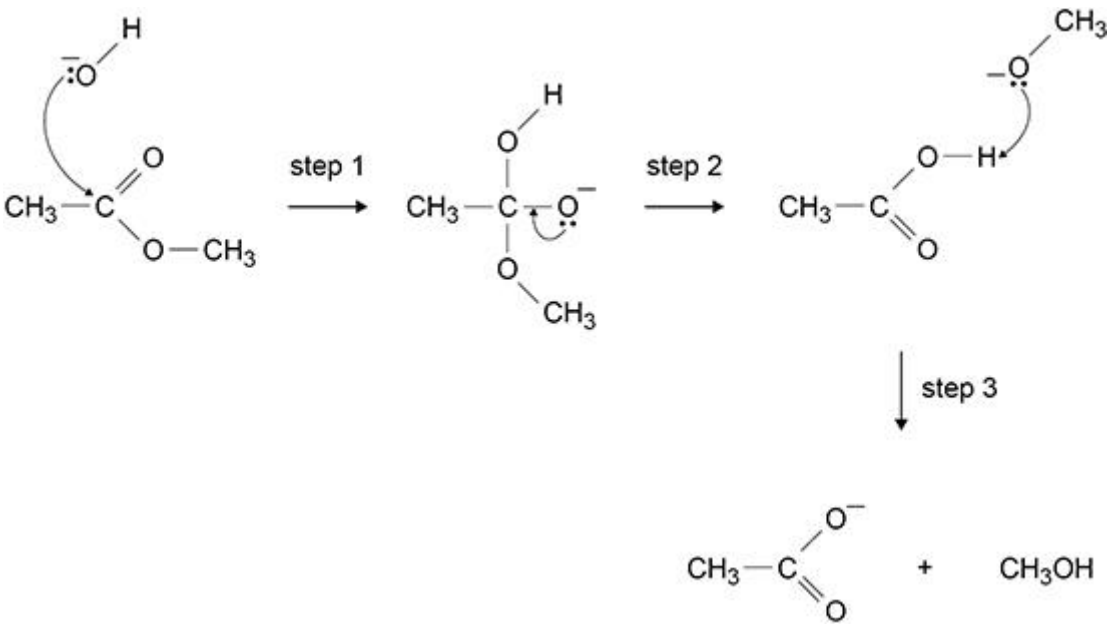
Q1.

This question is about esters.

The diagram below shows an incomplete mechanism for the reaction of an ester with aqueous sodium hydroxide.



(a) Add **three** curly arrows to complete the mechanism in above diagram.

(3)

(b) Name the type of reaction shown in the diagram above.

(1)

(c) Deduce the role of the CH_3O^- ion in step **3** shown in the diagram above.

(1)

(d) A triester in vegetable oil reacts with sodium hydroxide in a similar way.

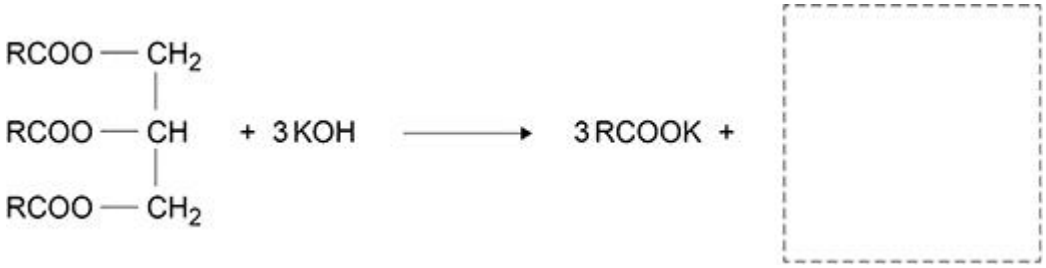
Give a use for a product of this reaction.

(1)

(Total 6 marks)

Q2.

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)

Q3.

Which compound reacts with warm dilute aqueous sodium hydroxide?

A C_6H_6 ⬭

B $CH_3CH=CH_2$ ⬭

C $CH_3CH_2CH_2NH_2$ ⬭

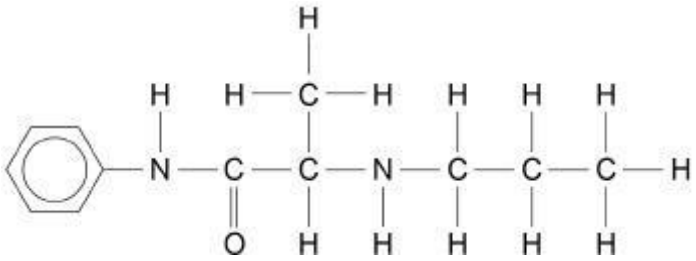
D $(CH_3CO)_2O$ ⬭

(Total 1 mark)

Q4.

Prilocaine is used as an anaesthetic in dentistry.
Figure 1 shows the structure of prilocaine.

Figure 1



(a) Draw a circle around any chiral centre(s) in **Figure 1**.

(1)

(b) Identify the functional group(s) in the prilocaine molecule.

Tick (✓) the box(es) corresponding to the functional group(s).

Amide	Amine	Ester	Ketone

(1)

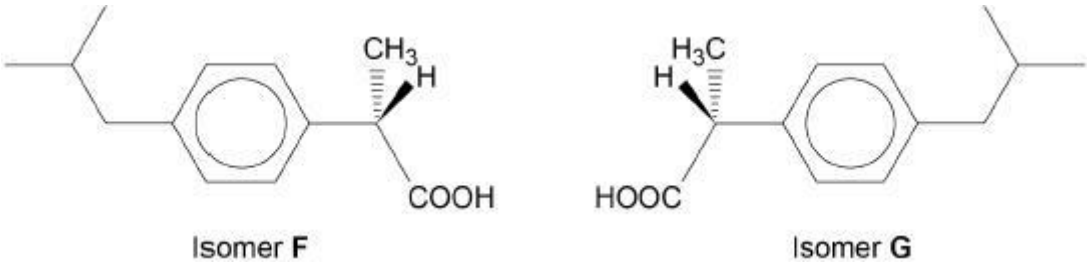
(c) Prilocaine is completely hydrolysed in the human body to give a mixture of products.

Draw the structures of the two organic products formed in the complete hydrolysis of prilocaine in acidic conditions.

(3)

(d) **Figure 2** shows optical isomers **F** and **G**.

Figure 2



Isomer **F** Isomer **G**

Isomer **F** is the active compound in the medicine ibuprofen.

In the manufacture of ibuprofen both isomers **F** and **G** are formed. An enzyme is then used to bind to isomer **G** and catalyse its hydrolysis.

After the products of hydrolysis of **G** are removed, a pure sample of isomer **F** is collected.

Explain how a structural feature of this enzyme enables it to catalyse the hydrolysis of isomer **G** but not the hydrolysis of isomer **F**.

_____

_____

_____

_____

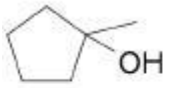
(2)

(Total 7 marks)

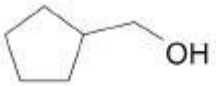
Q5.

This question is about the structural isomers shown.

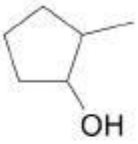
P



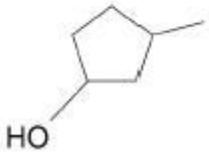
Q



R

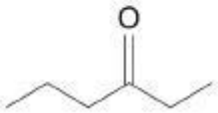


S



T

U



(a) Identify the isomer(s) that would react when warmed with acidified potassium dichromate(VI).

State the expected observation when acidified potassium dichromate(VI) reacts.

Isomer(s) _____

Expected observation _____

_____

(2)

(b) Identify the isomer(s) that would react with Tollens' reagent.

State the expected observation when Tollens' reagent reacts.

Isomer(s) _____

Expected observation _____

_____

(2)

(c) Separate samples of each isomer are warmed with ethanoic acid and a few drops of concentrated sulfuric acid. In each case the mixture is then poured into a solution of sodium hydrogencarbonate.

Identify the isomer(s) that would react with ethanoic acid.

Suggest a simple way to detect if the ethanoic acid reacts with each isomer.

Give a reason why the mixture is poured into sodium hydrogencarbonate solution.

Isomer(s) _____

Suggestion _____

_____

_____

Reason _____

_____

(3)

(d) State the type of structural isomerism shown by isomers **P**, **Q**, **R** and **S**.

_____

(1)

(e) Describe fully how infrared spectra can be used to distinguish between isomers **R**, **S** and **T**.
Use data from **Table A** in the Data Booklet in your answer.

_____

_____

_____

_____

_____

_____

_____

(4)

(f) State why mass spectrometry using electrospray ionisation is **not** a suitable method to distinguish between the isomers.

_____

_____

(1)

(Total 13 marks)

Q6.

Which compound is formed when phenyl benzenecarboxylate is hydrolysed under acidic conditions?

A $C_6H_5CH_2OH$ ⬭

B C_6H_5CHO ⬭

C $C_6H_5COCH_3$ ⬭

D C_6H_5COOH ⬭

(Total 1 mark)

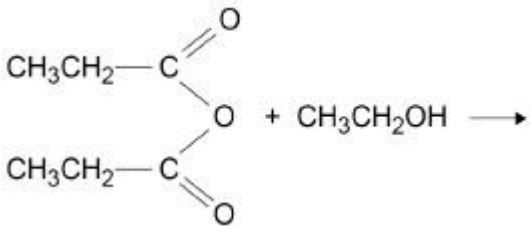
Q7.

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.

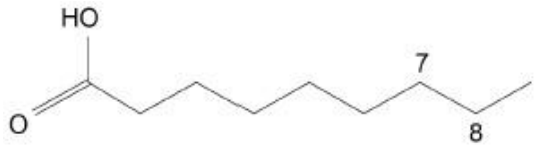
You should represent the hydrocarbon chains in the form C_xH_y where *x* and *y* are the actual numbers of carbon and hydrogen atoms.

(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.



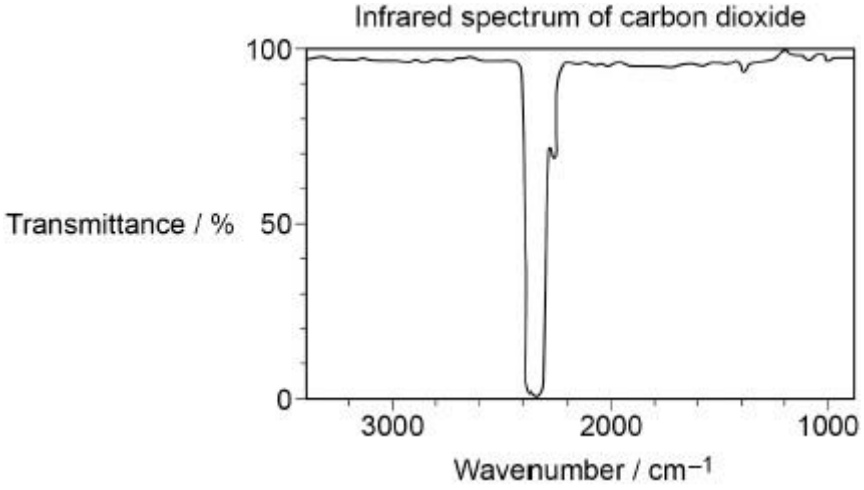
(2)

(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)

Q8.

Which compound is formed by acid hydrolysis of phenylmethyl ethanoate?

A $C_6H_5CH_2OH$ ⬭

B C_6H_5CHO ⬭

C $C_6H_5COCH_3$ ⬭

D C_6H_5COOH ⬭

(Total 1 mark)

Q9.

A student is required to dry a liquid sample of pentanoic acid.

Which drying agent is suitable?

A Calcium oxide ⬭

B Calcium sulfate ⬭

C Potassium hydroxide ⬭

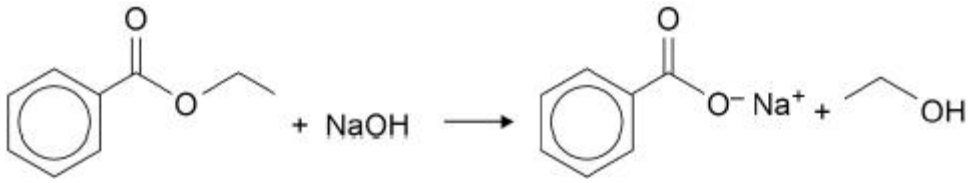
D Potassium carbonate ⬭

(Total 1 mark)

Q10.

Benzoic acid can be prepared from ethyl benzoate.

Ethyl benzoate is first hydrolysed in alkaline conditions as shown:



A student used the following method.

Add 5.0 cm^3 of ethyl benzoate (density = 1.05 g cm^{-3}, M_r = 150) to 30.0 cm^3 of aqueous 2 mol dm^{-3} sodium hydroxide in a round-bottomed flask.

Add a few anti-bumping granules and attach a condenser to the flask. Heat the mixture under reflux for half an hour. Allow the mixture to cool to room temperature.

Pour 50.0 cm^3 of 2 mol dm^{-3} hydrochloric acid into the cooled mixture.

Filter off the precipitate of benzoic acid under reduced pressure.

(a) Suggest how the anti-bumping granules prevent bumping during reflux.

_____

_____

_____

(1)

(b) Show, by calculation, that an excess of sodium hydroxide is used in this reaction.

(2)

(c) Suggest why an excess of sodium hydroxide is used.

_____

_____

(1)

(d) Suggest why an electric heater is used rather than a Bunsen burner in this hydrolysis.

(1)

(e) State why reflux is used in this hydrolysis.

(1)

(f) Write an equation for the reaction between sodium benzoate and hydrochloric acid.

(1)

(g) Suggest why sodium benzoate is soluble in cold water but benzoic acid is insoluble in cold water.

(2)

(h) After the solid benzoic acid has been filtered off, it can be purified.

Describe the method that the student should use to purify the benzoic acid.

(6)

(i) In a similar experiment, another student used 0.040 mol of ethyl benzoate and obtained 5.12 g of benzoic acid.

Calculate the percentage yield of benzoic acid.

Suggest why the yield is not 100%.

Percentage yield _____ %

Suggestion _____

_____

_____

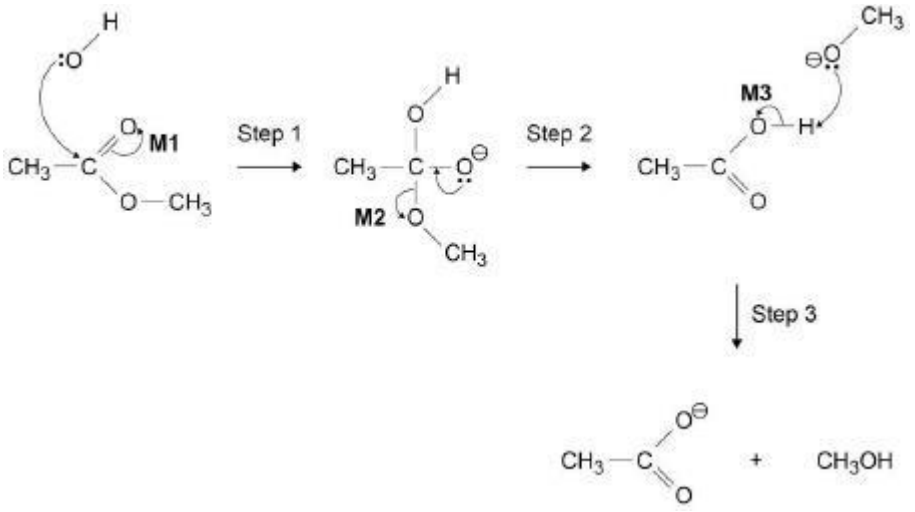
(3)

(Total 18 marks)

Mark schemes

Q1.

(a)



M1: Arrow from C=O bond to O
M2: Arrow from correct C-O bond to O
M3: Arrow from O-H bond to O

3

(b) (Alkaline/base) hydrolysis

1

(c) Base

Allow proton acceptor
Ignore ref to Bronsted Lowry

1

(d) Soap only

1

[6]

Q2.

(a) $CH_2OHCH(OH)CH_2OH$

1

(Potassium) Carboxylate salt

Allow fatty acid salt / salt
Salt of a carboxylic acid

1

Soap

Allow detergent / surfactant

1

(b) $638 = 173 + 3(15 + 14n)$
M_r ester fragment = 173

M1

Show subtract 638 – (M1 + 45)

M2

Division of M2 by 42
n = 10

n must be an integer

M3

(c) Amount HCl = 0.100 × 0.01565 = 1.565 ×10^{-3} mol

M1

Initial amount KOH = $\frac{0.421}{56.1}$ = 7.50 ×10^{-3} mol

M2

Amount KOH used = M2 – M1 = 5.939 ×10^{-3} mol

M3

Amount ester = $\frac{5.935 \times 10^{-3}}{3}$ = 1.980 ×10^{-3} mol (M3 / 3)

M4

Mass ester = (1.980 ×10^{-3}) × 638 = 1.263 g (M4 x 638)

M5

%age by mass = $\frac{1.263}{1.45}$ × 100 = 87.1 % ((M5 / 1.45) x 100)

Allow 87.0 to 87.1

Allow 2 sf

Don't allow M6 for an answer >100%

M6

(d) Allow to dissolve both oil and KOH

*To act as a mutual solvent **OR** To ensure reactants are miscible*

M1

Precaution must be linked to heating
e.g. Use a water bath for heating mixture

Allow electrical heater / mantle

Allow sand bath

M2

Prevents risk of fire / Ethanol is flammable

Allow KOH is corrosive/caustic/damages eyes if matches alternative precaution given

M3

[15]

Q3.

D

$(CH_3CO)_2O$

[1]

Q4.

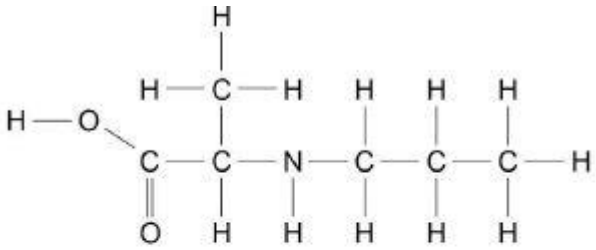
(a) One circled C atom only – The C attached to CH_3/C=O/ H and NH

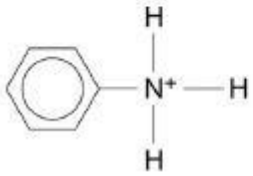
1

(b) Two ticks only for amine and amide

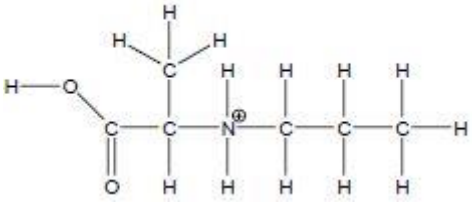
1

(c)





M1 *for choosing the correct bond to hydrolyse*
M2 *and* ***M3*** *for the correct structures of the products*
Allow protonated amino acid for M2



Allow $C_6H_5NH_3^+$ *or + outside a square bracket*

3

(d) **M1** Enzyme has an <u>active site</u>

1

M2
The G-Enantiomer / Enzyme has the correct stereo chemistry / stereospecific
Or
The G-Enantiomer / Enzyme has the complementary shape
For M2 allow opposite argument for F-Enantiomer

1

[7]

Q5.

(a) **M1** Q, R, S, T
M1 Allow the mark for candidates who correctly name or draw the isomers.

1

M2 (Orange solution) turns green
Independent

1

(b) **M1** T

As above

1

M2 Silver mirror

Allow grey/black ppt

1

(c) **M1** P, Q, R, S

As above

1

M2 Sweet smelling (liquid)

1

M3 To react with (remove excess) acid / neutralise

Allow easier to identify the smell

1

(d) Position

Allow positional

1

(e) **M1** R & S have an O-H alcohols peak at 3230-3550 cm^{-1}

Allow value within the range

1

M2 T has C=O peak at 1680-1750 cm^{-1}

1

M3 R & S (unique) fingerprint region or below 1500 cm^{-1}

1

M4 Compare to a database / known spectra (and look for an exact match)

1

(f) All have the same M_r

Allow

same (molecular) ion M/Z peak

same molecular formula

1

[13]

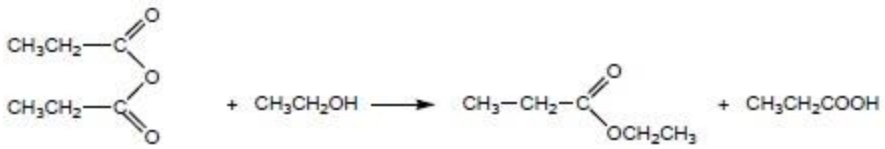
Q6.

D

[1]

Q7.

(a)



Ethyl propanoate only

M1 *Structure of ester (allow $C_2H_5CO_2C_2H_5$)*

1

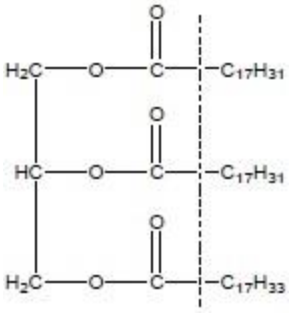
M2 *propanoic acid formula (allow $C_2H_5CO_2H$) and correctly balanced equation*

1

M3 *Ethyl propanoate only*

1

(b)



M1 for all except $C_{17}H_{3x}$ (i.e. all to the left of the dotted line)

Allow $–O_2C–$, $–OOC–$, $–OCO–$

Not $–CO_2–$, $–COO–$

1

M2 for two $C_{17}H_{31}$ and one $C_{17}H_{33}$ in any order top to bottom

1

(c)

M1 for skeleton

1

M2 for both Z correct
Independent marks

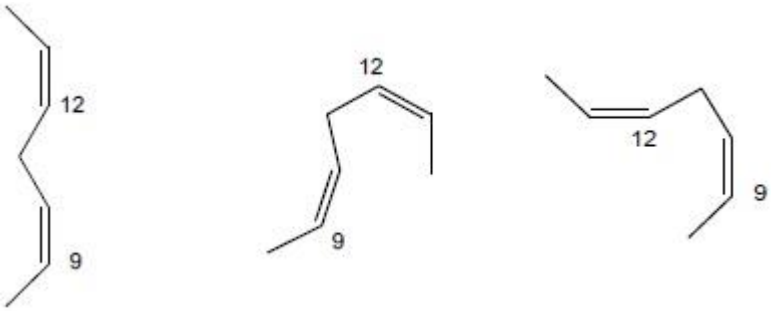
1

C9 – C14 shown with double bonds in the correct place

Ignore structure beyond carbon 14

*If hydrogens shown or not skeletal can only score **M2***

Other representations include



(d) $C_{19}H_{34}O_2 + 26½\ O_2 \longrightarrow 19\ CO_2 + 17\ H_2O$

Allow 53/2 or all doubled

1

(e) Absorption in spectrum at 2350 cm^{-1} does not correspond to data booklet value of 1680 – 1750 cm^{-1} or for C=O bonds in organic compounds)

Allow would expect a peak at 1680 – 1750 cm^{-1}

1

(f) C=O Bonds in CO_2 absorb infrared radiation (of 2350 cm^{-1})

1

IR radiation emitted by the earth does not escape (from the atmosphere)
OR
This energy is transferred to other molecules in the atmosphere by collisions (so all atmosphere is warmed)

Ignore IR reflected

1

[11]

Q8.

A

[1]

Q9.

B

[1]

Q10.

(a) allows smaller bubbles to form / prevents the formation of (very) large bubbles

ALLOW provides large surface area for bubbles to form on

IGNORE 'air'

NOT no bubbles form / prevents bubbles forming

1

(b) (Mass of ester = 1.05 × 5.0 = 5.25g)
amount of ester = 5.25 / 150.0 = 0.0350 mol

1

amount of NaOH = 30 × 2 / 1000 = 0.06 mol

1

OR

(Mass of ester = 1.05 × 5.0 = 5.25g)
amount of ester = 5.25 / 150.0 = 0.0350 mol

1

Vol of 0.035 mol of NaOH = (0.035/2) × 1000 = 17.5 cm^3
(so 30 cm^3 used is an excess)

1

OR

amount of NaOH = 30 × 2 / 1000 = 0.06 mol

1

0.06 mol of ester = 9 g = 8.57 cm^3
(only 5 cm^3 used so NaOH in excess)

1

Mark independently

Max 2

(c) To ensure that the ester is completely hydrolysed / to ensure all the ester reacts

ALLOW to ensure the other reagent has completely reacted

1

(d) Many organic compounds / the ester / ethanol are flammable

ALLOW prevent ignition of any flammable vapours formed

1

(e) Reflux allows reactant vapours (of volatile organic compounds) to be returned to the reaction mixture / does not allow any reactant vapour to escape

IGNORE reference to products

1

(f) $C_6H_5COONa + HCl \longrightarrow C_6H_5COOH + NaCl$

Allow ionic equation.

ALLOW molecular formulae ($C_7H_5O_2Na$ and $C_7H_6O_2$)

ALLOW skeletal benzene ring

1

(g) Sodium benzoate soluble because it is ionic

IGNORE polar

1

Benzoic acid insoluble because: despite the polarity of the COOH group / ability of COOH to form H-bonds, the benzene ring is non-polar.

ALLOW 'part of molecule' or 'one end' for COOH

1

(h) Dissolve crude product in <u>hot</u> solvent/water

ALLOW ethanol

If no M1 max = 4

1

of minimum volume

ALLOW reference to saturated soln as alternative to 'min vol'

1

Filter (hot to remove insoluble impurities)

IGNORE use of Buchner funnel here

1

Cool to recrystallise

apply list principle for each additional process in an incorrect method but IGNORE additional m.pt determination

1

Filter under reduced pressure / with Buchner/Hirsch apparatus

1

wash (with cold solvent) **and** dry

1

(i) 5.12 / 122 (= 0.042 mol)

method mark

1

(0.042/0.04) × 100 = 105 %

ecf for M1/0.04

or calculation that 0.04 mol of benzoic = 4.88 g (M1) so

% yield = (5.12/4.88) × 100 = 105%

1

Product not dried / impurities present in product

Only allow M3 if M2>100%

1

[18]