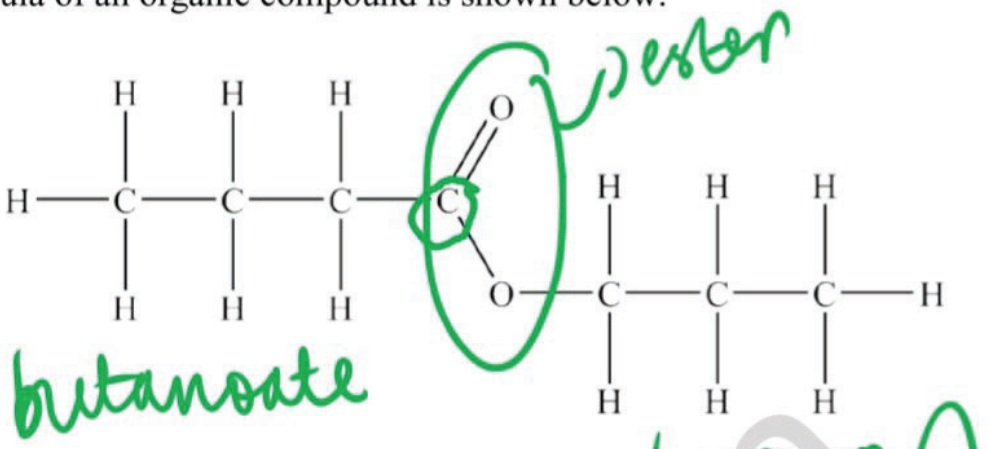
1. The displayed formula of an organic compound is shown below.



What is the systematic name of this organic compound?

A Propyl propanoate

B Propyl butanoate

C Butyl propanoate

D Butyl butanoate

Your answer B

2. Which alcohol could be used to prepare $HCOOCH(CH_3)_2$?

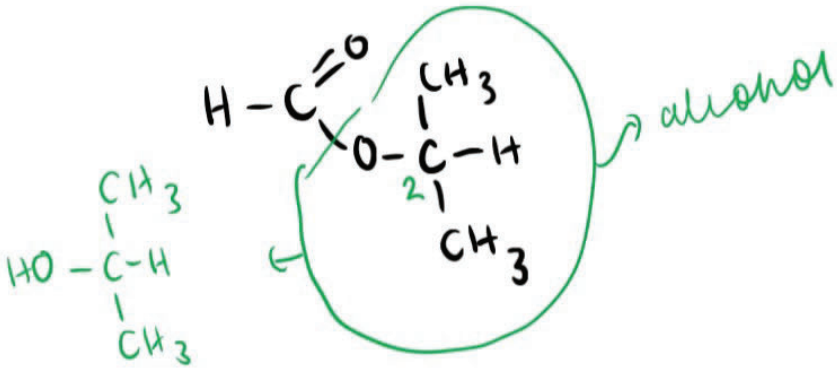
ester → c. acid + alcohol

A Propan-1-ol

B Propan-2-ol

C 2-Methylpropan-2-ol

D Methanol



Your answer **B**

[1]

3. Equal amounts of the four compounds are added to the same volume of water.

   Which compound would produce the most acidic solution?

   A CH_3CONH_2

   B CH_3COOH

   C CH_3COOCH_3

   D CH_3COCl $+H_2O \longrightarrow CH_3COOH + HCl$ both acids

   Your answer D

[1]

4. Which compound(s) is a/are structural isomer(s) of $C_6H_{12}O_2$?

    1 hexanoic acid

    2 ethyl butanoate

    3 propyl propanoate

    A 1, 2 and 3

    B Only 1 and 2

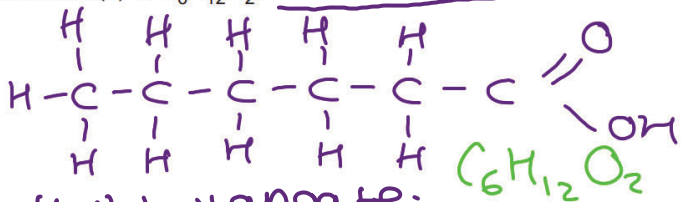
    C Only 2 and 3

    D Only 1

    Your answer A

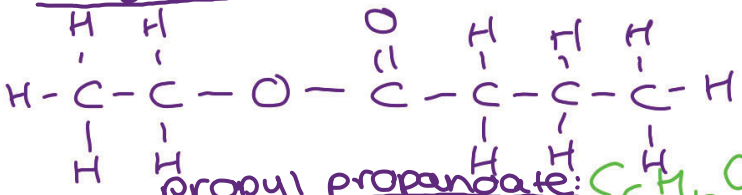
    [1]

hexanoic acid:

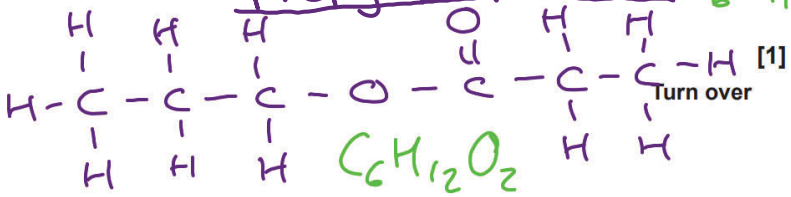


$C_6H_{12}O_2$

ethyl butanoate:



propyl propanoate: $C_6H_{12}O_2$



$C_6H_{12}O_2$

5. This question is about weak acids.

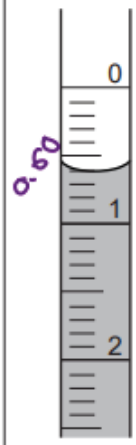
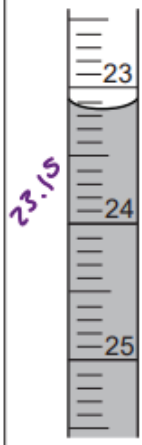
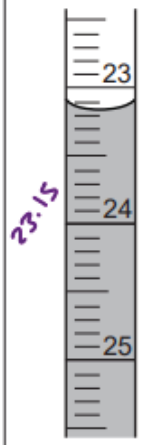
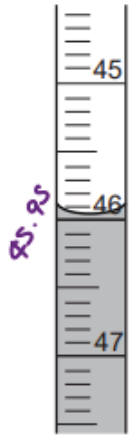
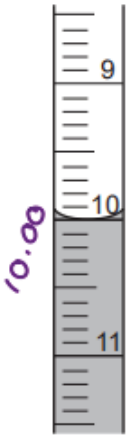
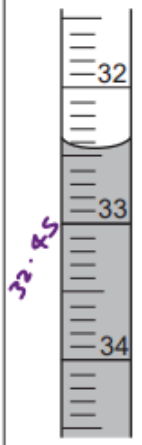
(a) Compound **A** is a weak monobasic acid.

A student is supplied with a 250.0 cm^3 solution prepared from 2.495 g of **A**.

The student titrates 25.0 cm^3 samples of this solution with 0.0840 mol dm^{-3} NaOH in the burette.

The student carries out a trial, followed by the three further titrations. The diagrams show the initial burette readings and the final burette readings for the student's three **further** titrations.

All burette readings are measured to the nearest 0.05 cm^3.

Titration 1		Titration 2		Titration 3	
Initial reading	Final reading	Initial reading	Final reading	Initial reading	Final reading
					

2dp.

(i) Record the student's readings and the titres in an appropriate format.

Calculate the mean titre that the student should use for analysing the results.

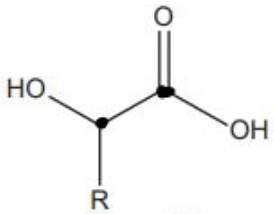
final (cm^3)	initial (cm^3)	titre (cm^3)
23.15	0.60	22.55
45.95	23.15	22.80
32.45	10.00	22.45

concordant within ± 0.10 cm^3

$\frac{22.55 + 22.45}{2} = 22.50$

mean titre = 22.50 cm^3 **[4]**

(ii) The structure of compound **A** is shown below.



compound A

C : 2
H : 3
O : 3

$(2 \times 12) + 3 + (16 \times 3)$
$= 75 + R = 131.7$

Compound **A** has four optical isomers.

Using this information and the student's results, answer the following.

- Determine the molar mass of **A** and the formula of the alkyl group R.
- Draw the structure of compound **A** and label any chiral carbon atoms with an asterisk*.

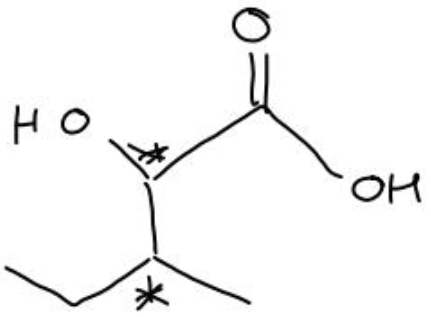
Show all your working.

mol of NaOH : $0.084 \times 22.5 \times 10^{-3} = 1.89 \times 10^{-3}$ mol

$250 cm^3$: $1.89 \times 10^{-3} \times 10 = 1.89 \times 10^{-2}$ mol

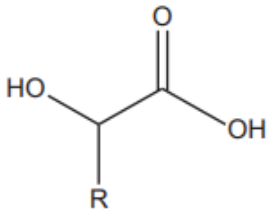
$$\frac{2.495}{1.89 \times 10^{-2}} = 131.7$$

$131.7 - 75 = 56.7 = 57 = C_4H_9$



[6]

(b) The structural formula of compound **A** is repeated below.



compound A

Two reactions of compound **A** are carried out.

Suggest an equation for each reaction and state the type of reaction.

In your equations, draw structures for organic compounds.
You can use R for the alkyl group.

(i) Magnesium ribbon is added to a solution of compound **A**.
Gas bubbles are seen and the magnesium slowly dissolves.

salt

Equation

$$2HOCH(R)COOH + Mg \rightarrow 2HOCH(R)COO^{-}Mg^{2+} + H_2$$

Type of reaction redox ..... **[3]**

(ii) Compound **A** is heated with a few drops of concentrated sulfuric acid as a catalyst.
A cyclic 'dimer' of compound **A** forms.

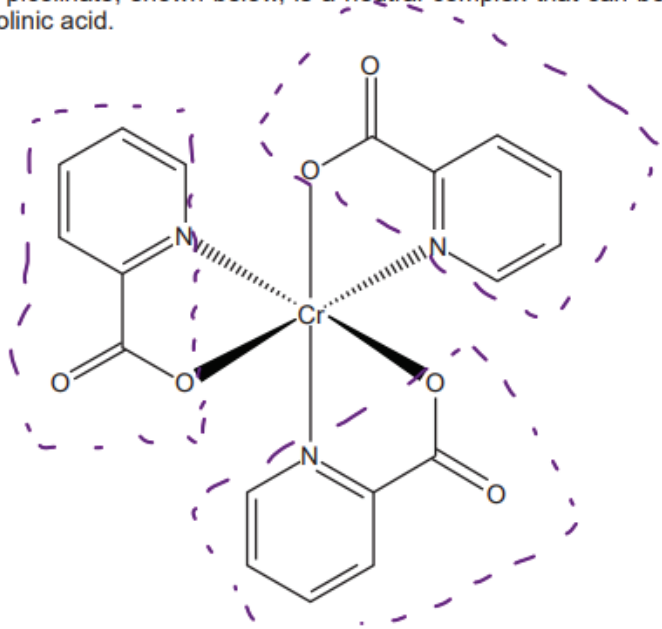
Equation

$$2HOCH(R)COOH \rightarrow \text{(cyclic dimer)} + 2H_2O$$

compound consisting of 2 identical parts

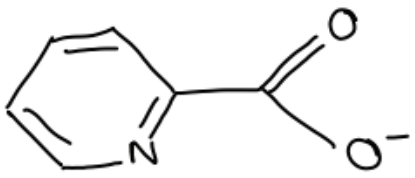
Type of reaction esterification ..... **[3]**

(c) Chromium(III) picolinate, shown below, is a neutral complex that can be prepared from the weak acid, picolinic acid.



Chromium(III) picolinate is used in tablets as a nutritional supplement for chromium.

(i) Draw the structure of the ligand in chromium(III) picolinate.



[1]

(ii) A typical tablet of chromium(III) picolinate contains 200 μg of chromium.

Calculate the mass, in g, of chromium(III) picolinate in a typical tablet.
1 μg = 10^{-6} g.

Give your answer to **three** significant figures.

C:6
H:4
O:2
N:1
} RFM = (12×6) + 4 + 14 + (16×2) = 122

(122 × 3) + 52 = 418 RFM of Chromium (III) picolinate

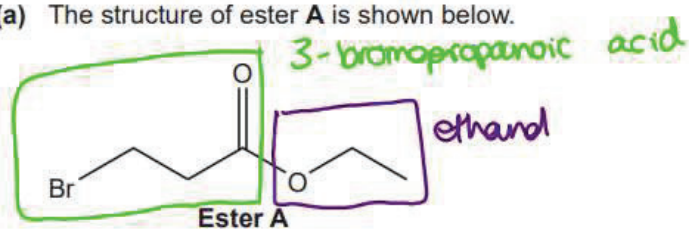
$\frac{200\times10^{-6}}{52} = 3.85\times10^{-6}$

$3.85\times10^{-6} \times 418 = 1.6\times10^{-3}$

mass = 1.6×10^{-3} g **[2]**

6. This question is about esters.

(a) The structure of ester **A** is shown below.



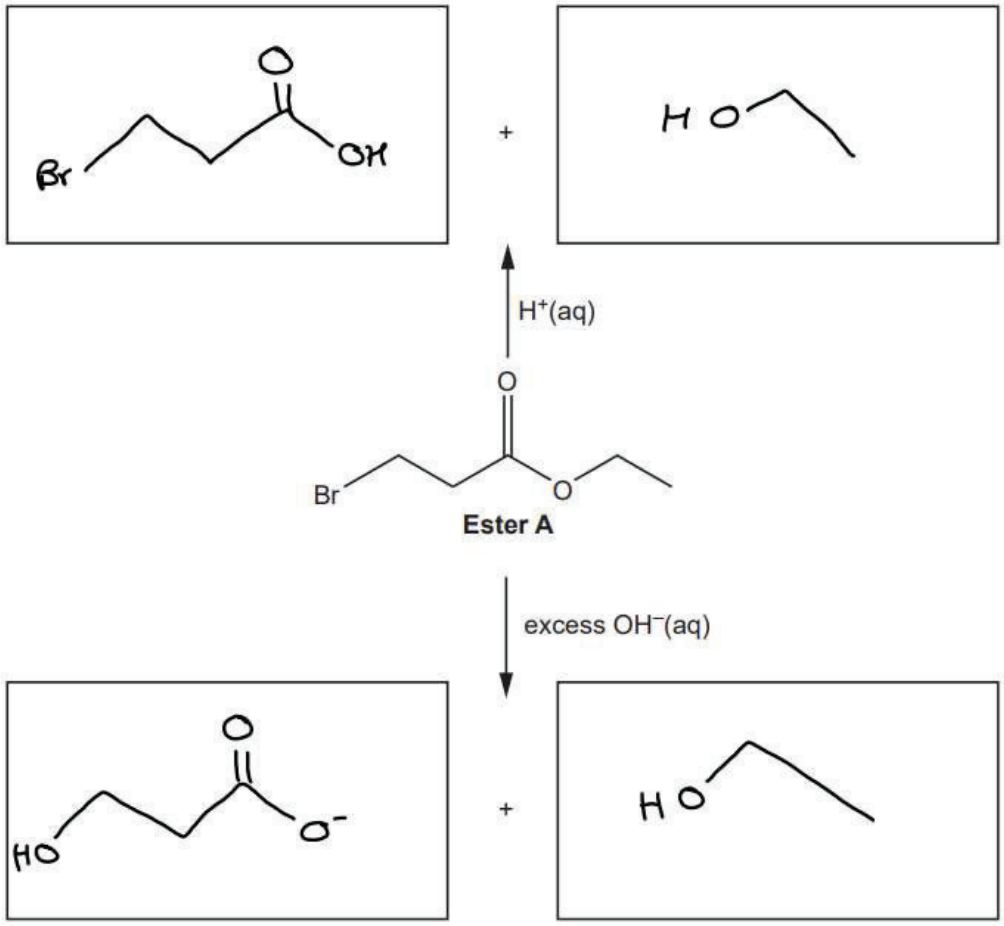
Ester A

(i) What is the systematic name of ester **A**?

ethyl 3-bromopropanoate ..... **[1]**

(ii) In the boxes, draw the organic products for the reactions of the functional groups in ester **A** shown below.

Each reaction forms two organic products.

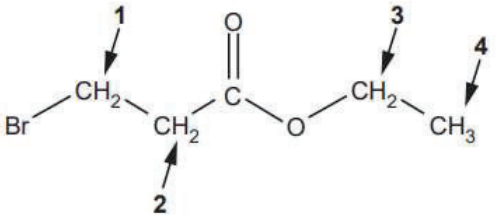


[5]

(iii) Name the type of reactions of ester **A** shown in **(ii)**.

hydrolysis ..... **[1]**

(b) The protons in ester **A** are in four different environments, labelled **1–4** on the structure below.



Complete the table to predict the **proton** NMR spectrum of ester **A**.

Proton environment	Chemical shift	Splitting pattern
1	3.0-4.3	triplet
2	2.0-3.0	triplet
3	3.0-4.3	quartet
4	0.5-1.9	triplet

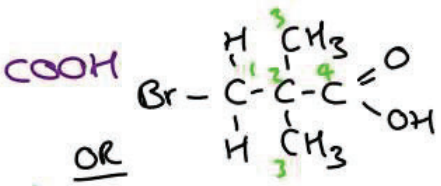
[4]

$C_5H_9O_2Br$

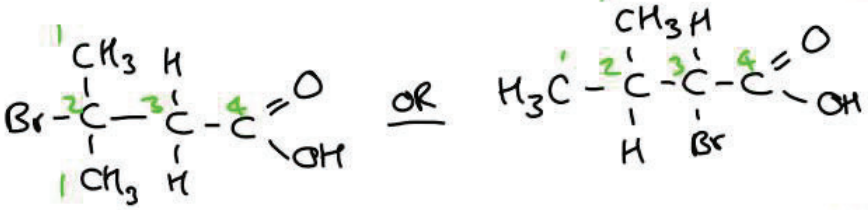
(c) Compound **B** is a structural isomer of ester **A**.

- Compound **B** reacts with aqueous sodium carbonate.
- The ^{13}C NMR spectrum of **B** has 4 peaks.

Draw a possible structure for compound **B**.

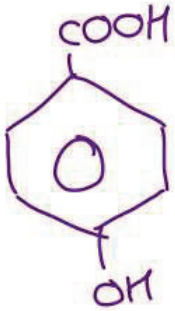


OR



[1]

(d) A polyester is formed from 200 molecules of 4-hydroxybenzoic acid.



What is the relative molecular mass, M_r, of the polyester?

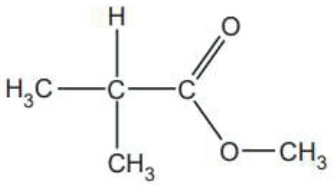
$(12 \times 7) + 6 + ((16 \times 3) = 138 \text{ g mol}^{-1}$

$138 \times 200 = 27600 \text{ g mol}^{-1}$

$27600 - ((99 \times 18) = 24018$

M_r = ... 24018 ..... g mol^{-1} **[2]**

(e)* A student intends to synthesise ester **C**.



Ester C

(i) Plan a two-stage synthesis to prepare 12.75g of ester **C** starting from 2-methylpropanal, $(CH_3)_2CHCHO$. Assume the overall percentage yield of ester **C** from 2-methylpropanal is 40%.

In your answer include the mass of 2-methylpropanal required, reagents, conditions and equations where appropriate.

Purification details are **not** required. **[6]**

$\frac{12.75}{(12\times5)+10+(16\times2)} = 0.125$ mol of ester C

$0.125 \times \frac{100}{40} = 0.3125$ mol of 2methyl-propanal

$((12\times4)+8+16) \times 0.3125 = 22.50$g of 2-methyl propanal

1: $(CH_3)_2CHCHO + [O] \rightarrow (CH_3)_2CHCOOH$

$[O]$: $Cr_2O_7^{2-}/H^+$ and reflux

2: $(CH_3)_2CHCOOH + CH_3OH \xrightarrow[\text{reflux}]{H^+} (CH_3)_2CHCOOCH_3 + H_2O$

Additional answer space if required

.....

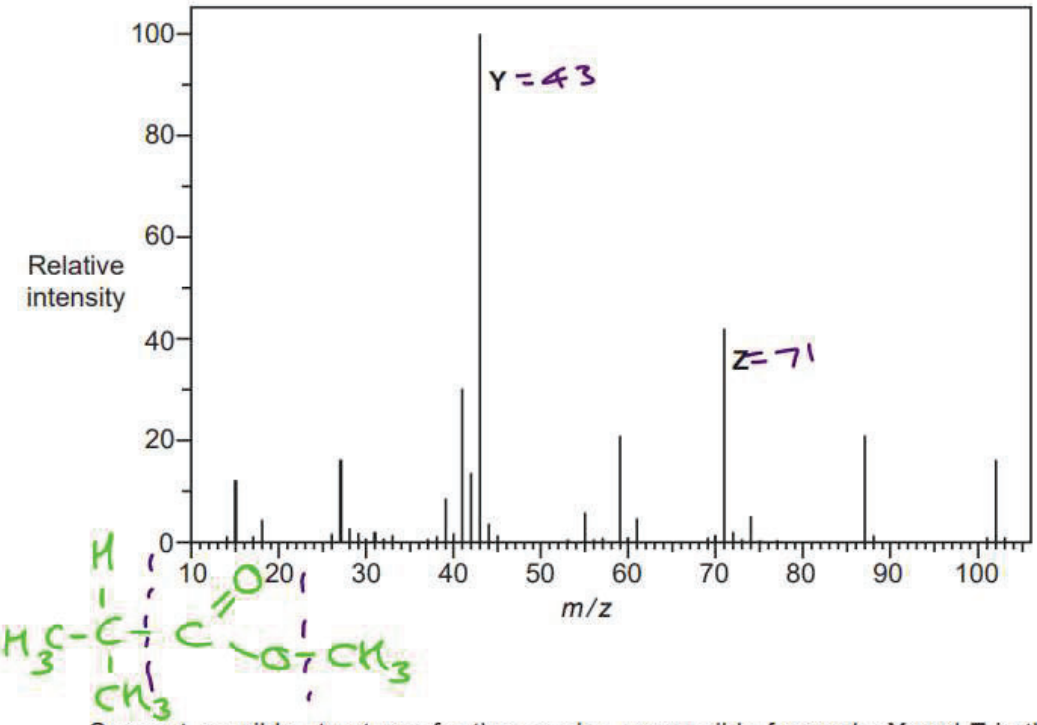
.....

.....

.....

.....

(ii) The mass spectrum of ester **C** is shown below.



Suggest possible structures for the species responsible for peaks **Y** and **Z** in the mass spectrum.

$(CH_3)_2CH^+$	$(CH_3)_2CHCO^+$
Y	**Z**

[2]

7. Which of these reagent(s) will **not** react with $HOCH_2CH_2CH_2COOH$?

alcohol carboxylic acid

A NaCN in ethanol reagents for haloalkane → nitrile

B C_2H_5OH in the presence of an acid catalyst esterification with COOH

C $(CH_3CO)_2O$ = acid anhydride + OH → ester

D concentrated H_2SO_4 OH → alkene

Your answer A

[1]

8. Which one of the following reacts with ethanoic acid **and** with phenol?

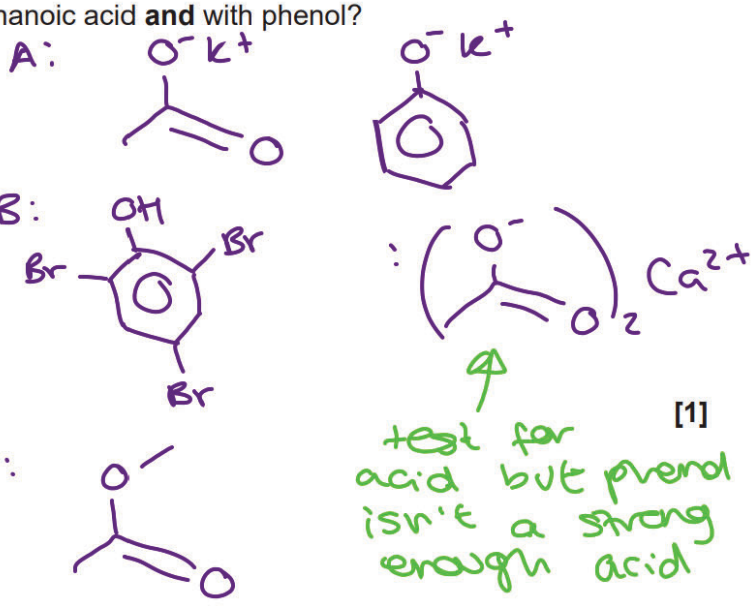
(A) Aqueous potassium hydroxide

~~B~~ Bromine only reacts with phenol

~~C~~ Calcium carbonate only reacts with CH_3COOH

~~D~~ Methanol and an acid catalyst only reacts with ethanoic acid (CH_3COOH)

Your answer A



test for acid but phenol isn't a strong enough acid

[1]

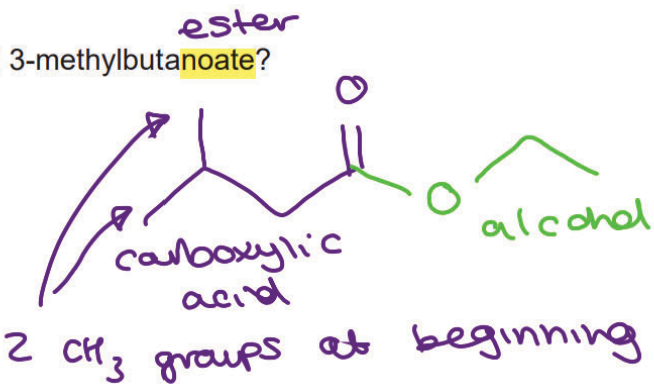
9. What is the structural formula of ethyl 3-methylbutanoate?

A $CH_3CH_2COOCH_2CH_2CH(CH_3)_2$

B $CH_3CH_2COOCH(CH_3)CH_2CH_3$

C $CH_3CH_2CH(CH_3)COOCH_2CH_3$

D $(CH_3)_2CHCH_2COOCH_2CH_3$



Your answer D

[1]

10. Alcohols can be used to prepare organic compounds with different functional groups.

(a) $HO(CH_2)_4OH$ can be oxidised to form $HOOC(CH_2)_2COOH$.

(i) State the reagents and conditions and write an equation for this oxidation.

In the equation, use [O] for the oxidising agent.

Reagents and conditions: $K_2Cr_2O_7$, H^+ (acidified) and reflux distillation would form an aldehyde

Equation:

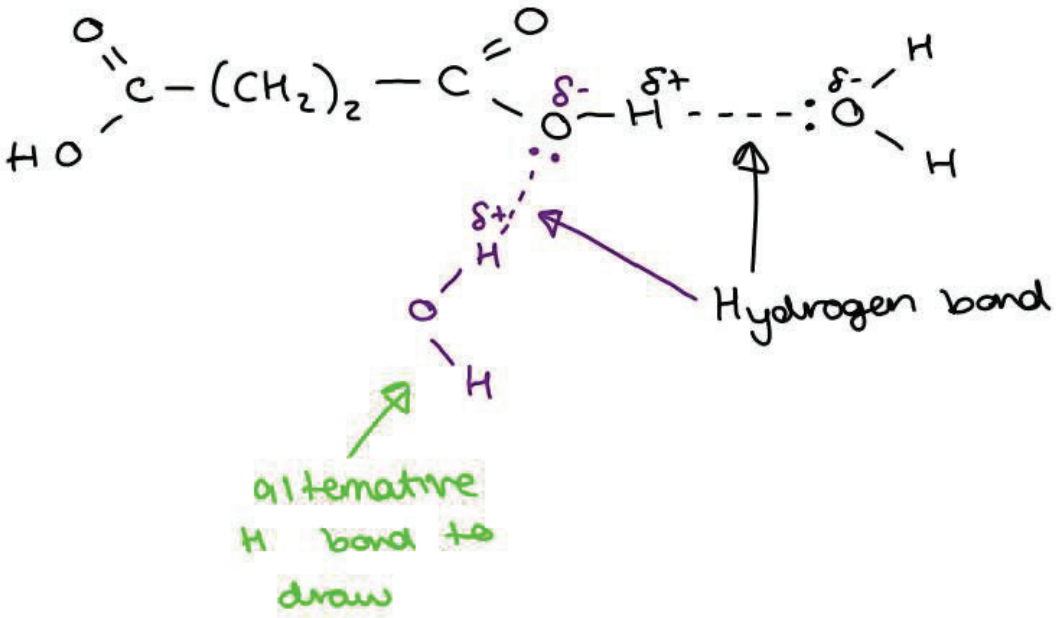
$$HO(CH_2)_4OH + 4[O] \longrightarrow HOOC(CH_2)_2COOH + 2H_2O$$

balance the lost H's in H_2O

[3]

(ii) $HOOC(CH_2)_2COOH$ is soluble in water.

Explain, using a labelled diagram, why $HOOC(CH_2)_2COOH$ is soluble in water.



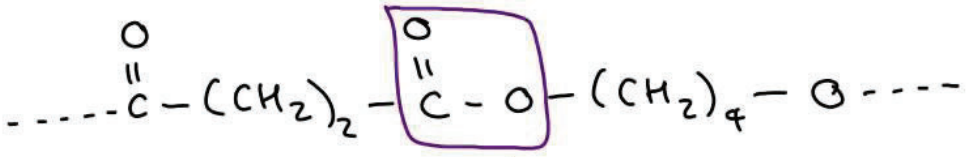
[2]

(b) $HOOC(CH_2)_2COOH$ and $HO(CH_2)_4OH$ react together to form polymer **E**.

alcohol + carboxylic acid → ester + water

(i) Draw **one** repeat unit of polymer **E**.

The functional groups should be clearly displayed.



ester link (one repeat unit = one ester link)

[2]

(ii) Governments are encouraging the development of biodegradable polymers to reduce dependency on persistent plastic waste derived from fossil fuels.

Polymer **E** is a biodegradable polymer.

Suggest why polymer **E** is able to biodegrade.

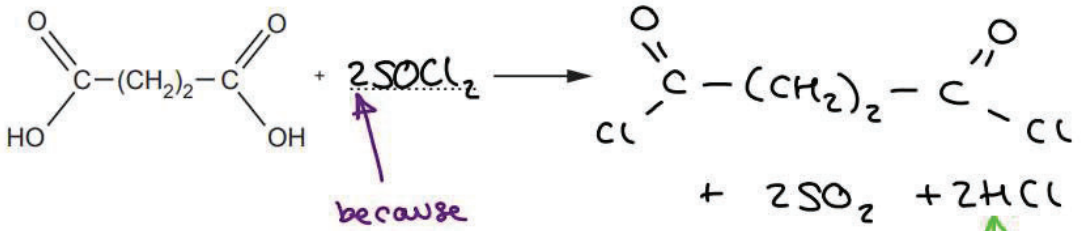
ester group can be broken down via hydrolysis **[1]**

(iii) A large yield of polymer **E** can be obtained by reacting a diacyl dichloride with $HO(CH_2)_4OH$.

The diacyl dichloride is prepared from $HOOC(CH_2)_2COOH$.

reaction map shows this

Complete the equation for the formation of a diacyl dichloride from $HOOC(CH_2)_2COOH$.



because diacyl dichloride

$+ 2SO_2 + 2HCl$

OH's lost from carboxylic acid and balanced here

[3]

11. This question is about two different types of acid found in organic compounds, carboxylic acids and sulfonic acids, as shown in **Fig. 6.1**.

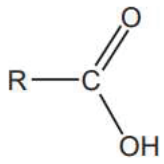
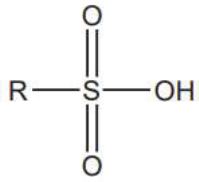
	
Carboxylic acid	Sulfonic acid

Fig. 6.1

(a) Complete **Table 6.1** to predict bond angles ***a*** and ***b*** and name the shapes which makes these bond angles in the functional groups of carboxylic acids and sulfonic acids.

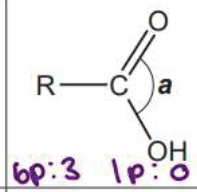
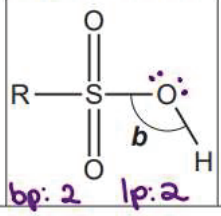
Type of acid	Acid	Bond angle	Name of shape
Carboxylic acid	 bp: 3 lp: 0	120°	trigonal planar
Sulfonic acid	 bp: 2 lp: 2	109.5°	non-linear

Table 6.1

[2]

lone pairs repel more than bonded pairs

(b) Ethanoic acid, CH_3COOH, and methanesulfonic acid, CH_3SO_2OH, are both monobasic acids. The pK_a values are shown in the table.

pka = pH

Acid		pK_a
Ethanoic acid	CH_3COOH	4.76
Methanesulfonic acid	CH_3SO_2OH	–1.90

A student suggests that 1.0 mol dm^{-3} CH_3SO_2OH should have a lower pH value than 1.0 mol dm^{-3} CH_3COOH.

Write an equation, showing conjugate acid–base pairs, for the equilibrium of CH_3SO_2OH with water and explain, with reasons, whether the student is correct.

Label the conjugate acid–base pairs: **A1**, **B1** and **A2**, **B2**.

CH_3SO_2OH + H_2O $\rightleftharpoons$ $CH_3SO_2O^-$ + H_3O^+

A1 B2 B1 A2

acids: proton donors

bases: proton acceptors

CH_3SO_2OH is a stronger acid / dissociates more

student is correct CH_3SO_2OH has a lower [4]

pka / pH / higher ka / $[H^+]$

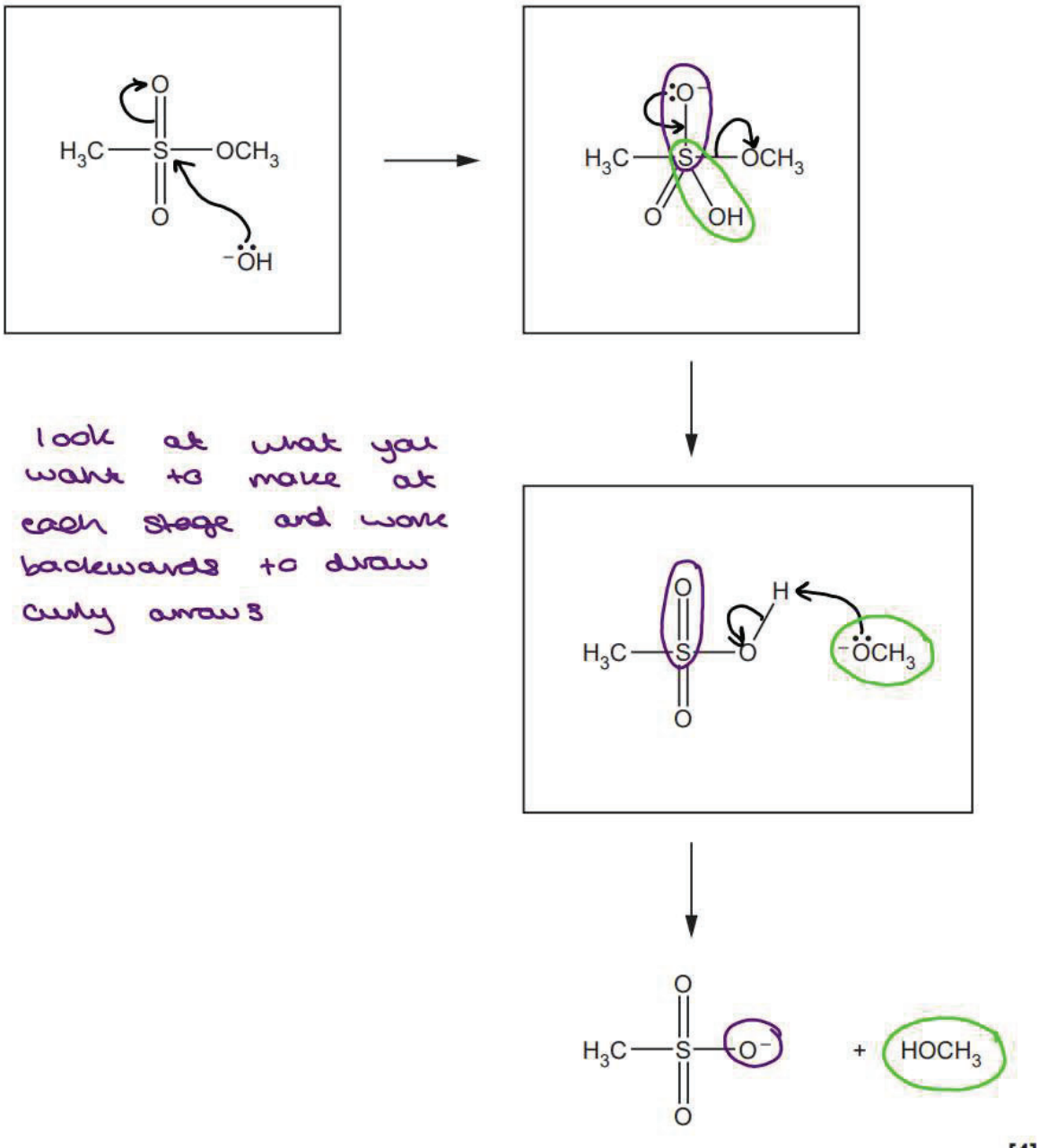
(c) Carboxylic acids and sulfonic acids both form esters.

Sulfonic acid esters can be hydrolysed by aqueous alkali.
The equation shows the alkaline hydrolysis of a sulfonic acid ester.

$CH_3SO_2OCH_3 + OH^- \rightarrow CH_3SO_2O^- + CH_3OH$

In the **3 boxes below**, add curly arrows to show the mechanism for this reaction.

In the first box, the hydroxide ion acts as a nucleophile.



look at what you want to make at each stage and work backwards to draw curly arrows

[4]