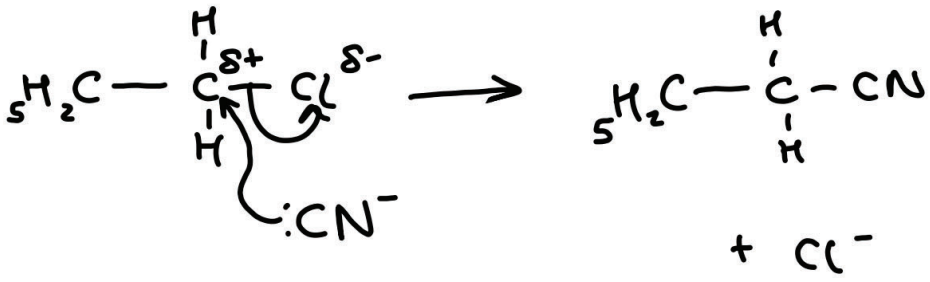
1. This question is about organic compounds containing nitrogen.

(a) Sodium cyanide, NaCN, can be reacted with many organic compounds to increase the length of a carbon chain.

(i) 1-Chloropropane, $CH_3CH_2CH_2Cl$, reacts with ethanolic sodium cyanide by nucleophilic substitution.

Outline the mechanism for this reaction.

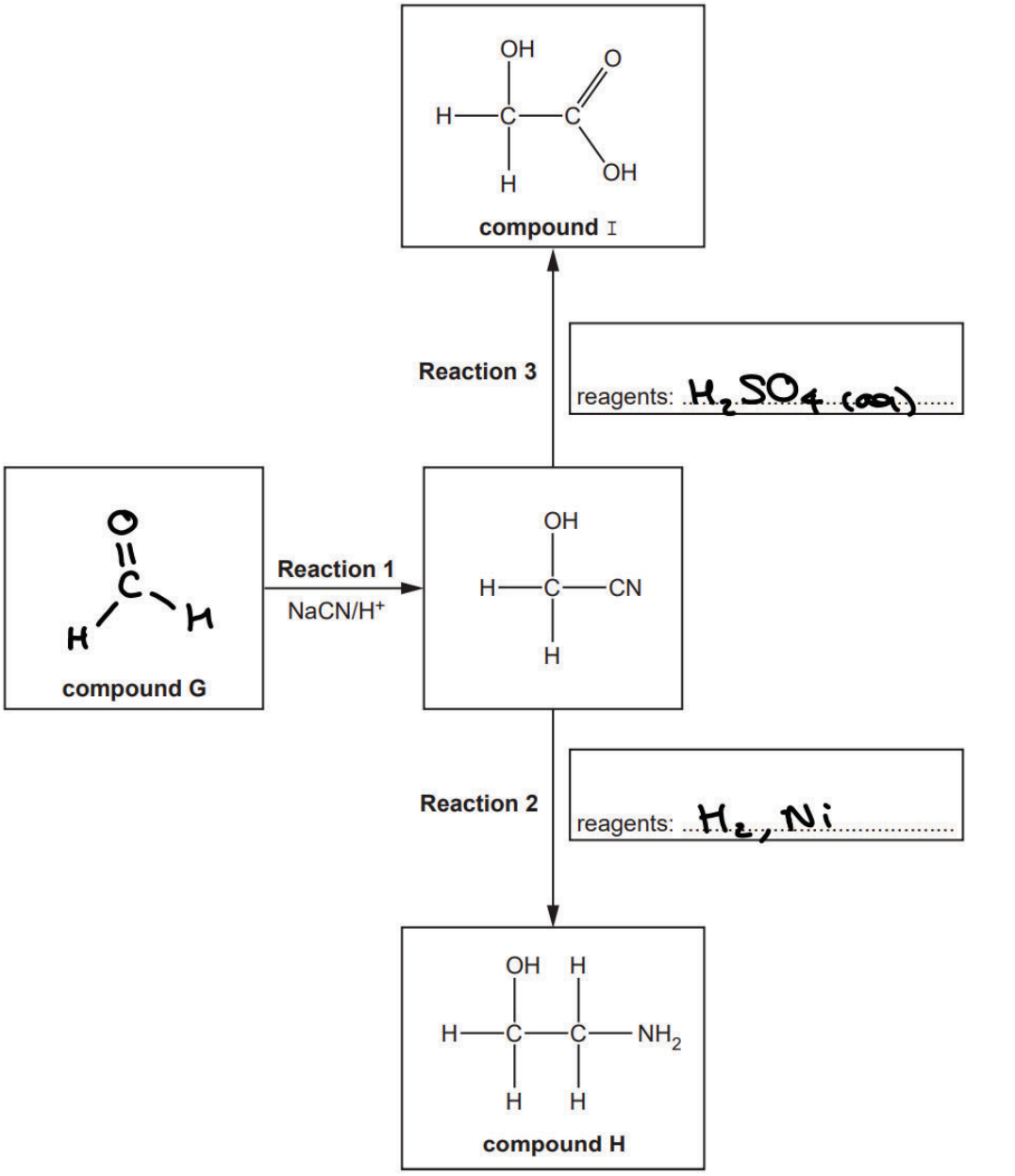
Include curly arrows, relevant dipoles and the structure of the organic product.



[3]

(ii) Compound **G** is used to synthesise compounds **H** and I as shown in the flowchart below.

Complete the flowchart showing the structure of compound **G** and the **formulae** of the reagents for **Reaction 2** and **Reaction 3**.



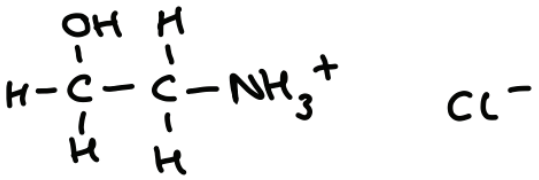
[3]

(iii) Compound **H** reacts with dilute hydrochloric acid to form a salt.

Explain why compound **H** can react with dilute hydrochloric acid and suggest a structure for the salt formed.

Explanation Nitrogen lone pair accepts a proton (H^+)

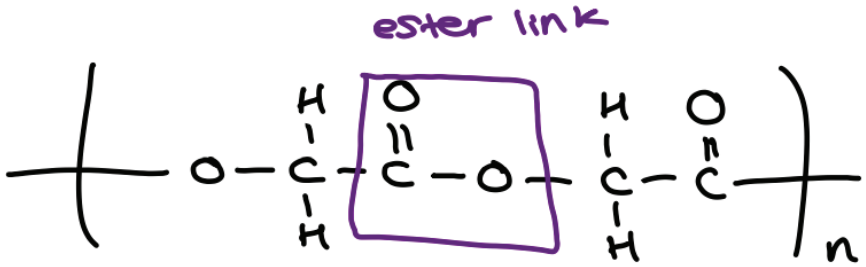
Structure



[2]

(iv) Compound I is the monomer for the biodegradable polymer **J**.

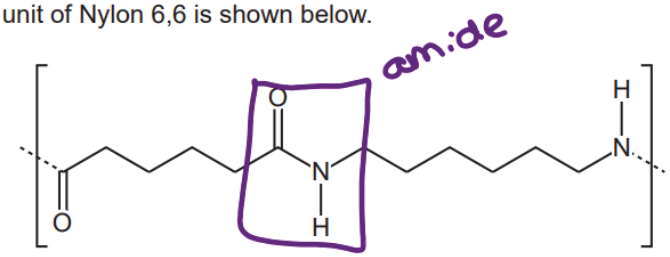
Draw **two** repeat units of polymer **J** and suggest a reason why it is biodegradable.



ester group can undergo hydrolysis

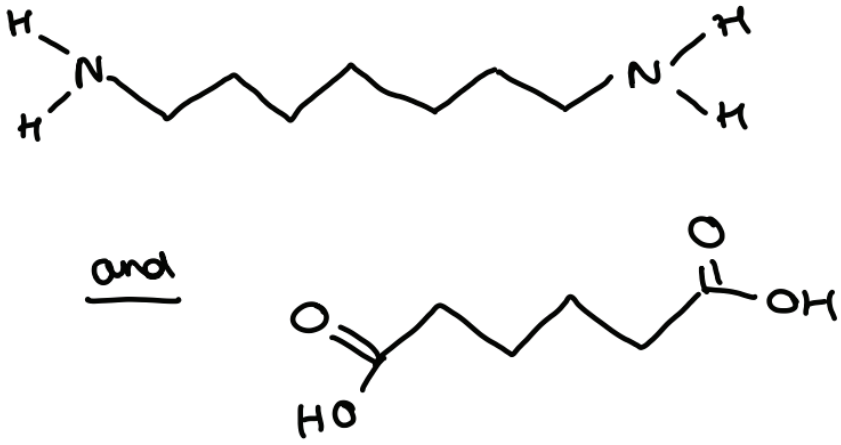
[3]

(b) The repeat unit of Nylon 6,6 is shown below.



Nylon 6,6

(i) Draw the structures of **two** monomers that can be used to form Nylon 6,6.



[2]

(ii) A sample of Nylon 6,6 has a relative molecular mass of 21500.

Estimate the number of repeat units in the sample.

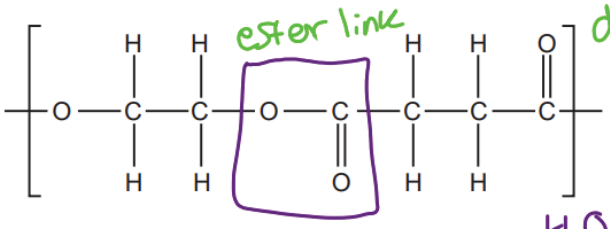
Give your answer as a **whole** number.

$$\frac{21500}{226} = 95.1$$

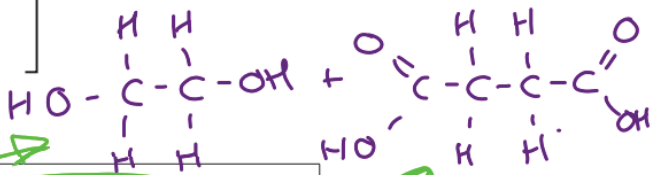
RFM = relative formula mass of repeat unit: $(12\times12)+(6\times2)+(14\times2)+22 = 226$

number of repeat units = 95 **[1]**

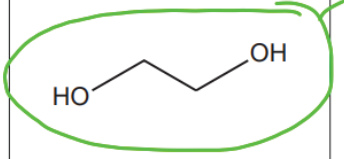
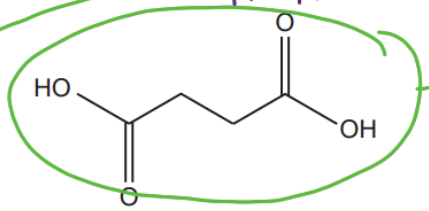
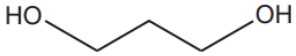
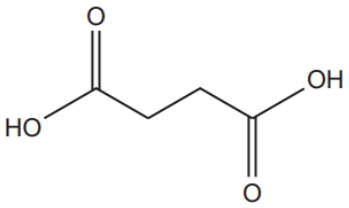
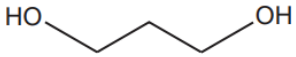
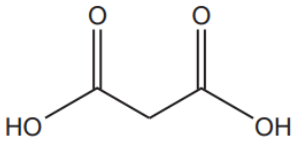
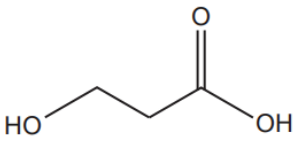
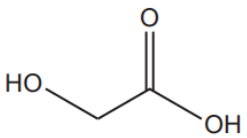
2. The repeat unit of a polymer is shown below.



di alcohol + di carboxylic acid



Which monomers could form this polymer?

A		
B		
C		
D		

Your answer A

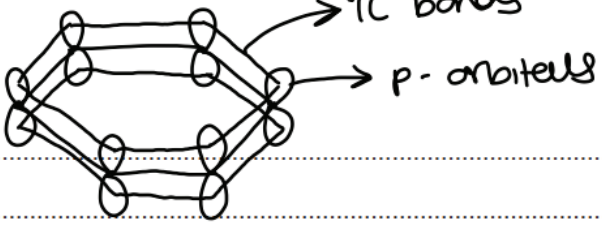
[1]

3. This question is about benzene.

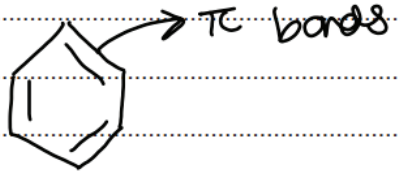
(a) Over time, the Kekulé and delocalised models have been used to describe the bonding and structure of a benzene molecule.

(i) Describe, in terms of orbital overlap, the similarities and differences between the bonding in the Kekulé model and the delocalised model of benzene.

delocalised model:



Kekulé:



differences:

Kekulé has 3 π bonds and the delocalised model has a π ring system

[3]

(ii) Experimental evidence led to the general acceptance of the delocalised model over the Kekulé model.

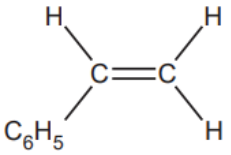
Describe **two** pieces of evidence to support the delocalised model of benzene.

- benzene is less reactive than alkenes
- all C–C bond lengths are the same

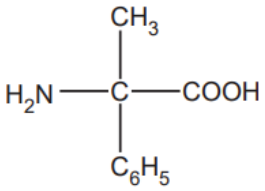
[2]

(b) Benzene can be used as the starting material for the synthesis of compounds **D** and **E**, shown below.

In the diagrams C_6H_5 is a phenyl group.



compound D



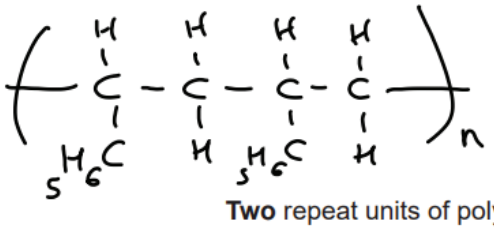
compound E

addition C=C → C-C

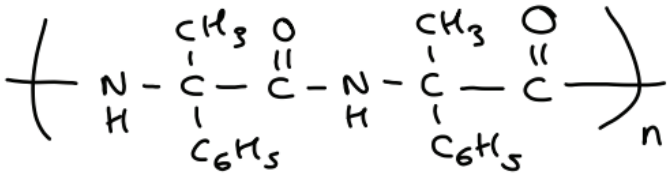
condensation forms $R_2N-\overset{H}{\underset{}{}}-\overset{O}{\overset{\|}{C}}-R_1$

Compounds **D** and **E** can be converted into polymers. amide

(i) Draw **two** repeat units of these polymers.



Two repeat units of polymer formed from **D**



Two repeat units of polymer formed from **E**

[3]

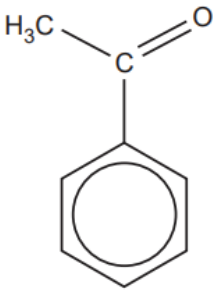
(ii) State the **type** of polymer formed from compounds **D** and **E**.

From compound **D** addition

From compound **E** condensation

[1]

(iii) In the synthesis of compounds **D** and **E**, benzene is first reacted with ethanoyl chloride, CH_3COCl, to form phenylethanone, shown below.



electrophilic substitution

phenylethanone

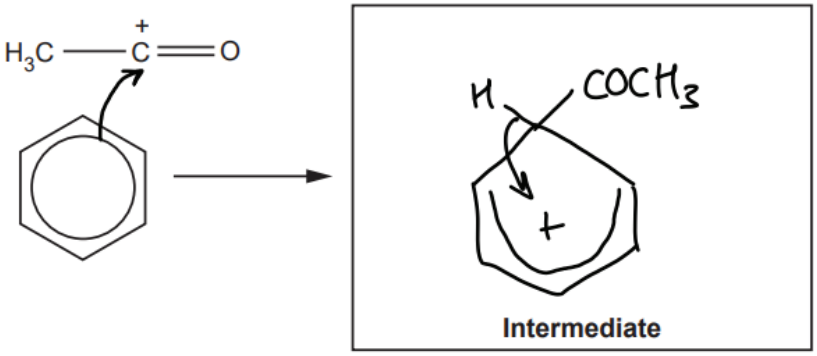
The reaction takes place in the presence of aluminium chloride, $AlCl_3$, which acts as a catalyst.

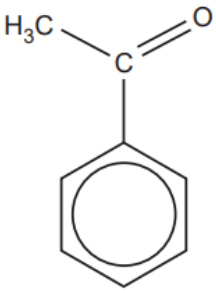
In the mechanism for this reaction,
- ethanoyl chloride first reacts with aluminium chloride to form the $CH_3–C^+=O$ cation
- the $CH_3–C^+=O$ cation then behaves as an electrophile.

Complete the mechanism for the reaction.

Include equations to show the role of the $AlCl_3$ catalyst, relevant curly arrows and the structure of the intermediate.

Formation of electrophile $CH_3COCl + AlCl_3 \rightarrow CH_3-C^+=O + AlCl_4^-$



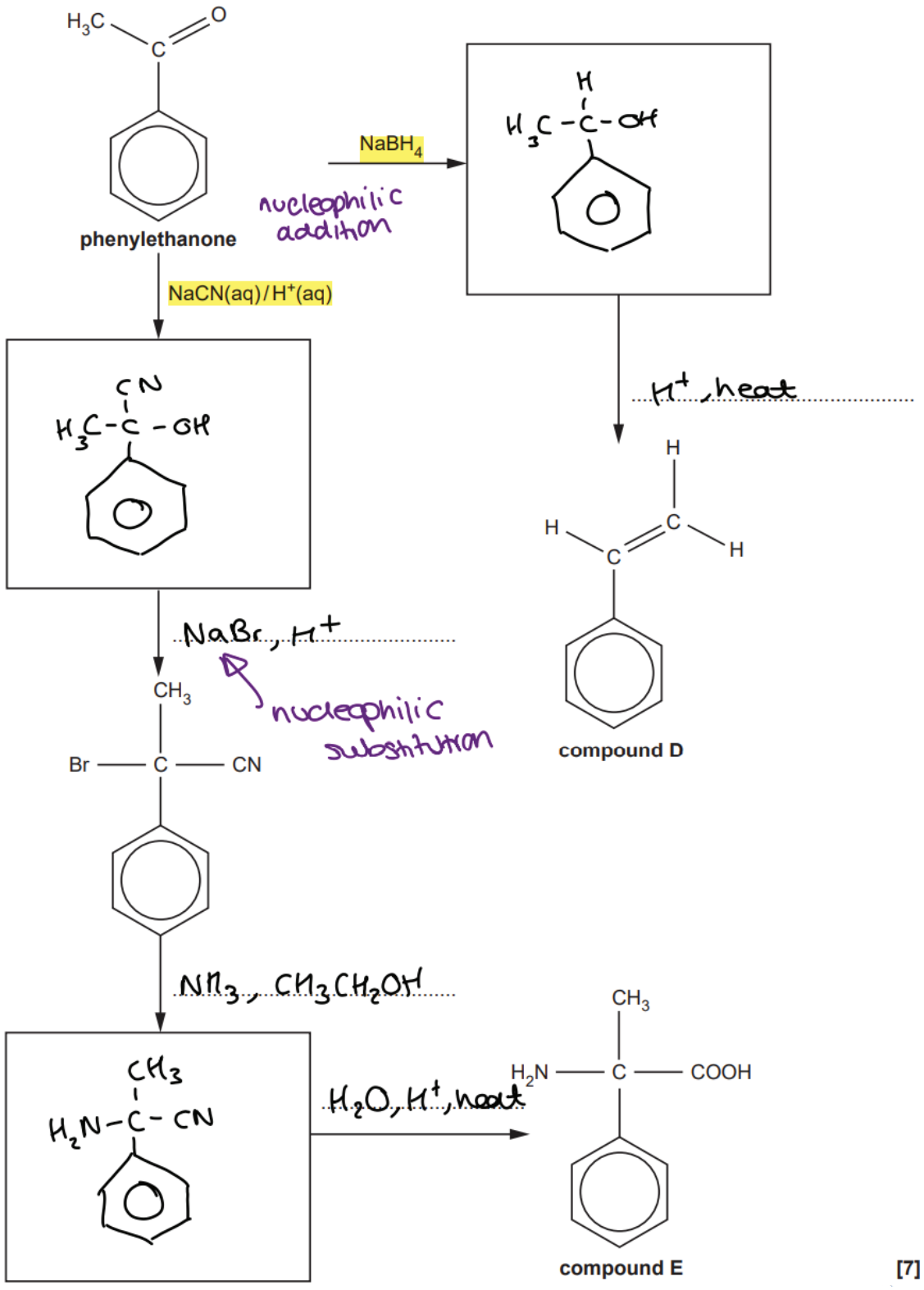


+ H^+

Regeneration of catalyst $H^+ + AlCl_4^- \rightarrow AlCl_3 + HCl$

[5]

(iv) Complete the flowchart for the synthesis of compounds **D** and **E** from phenylethanone.



[7]

4. 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:

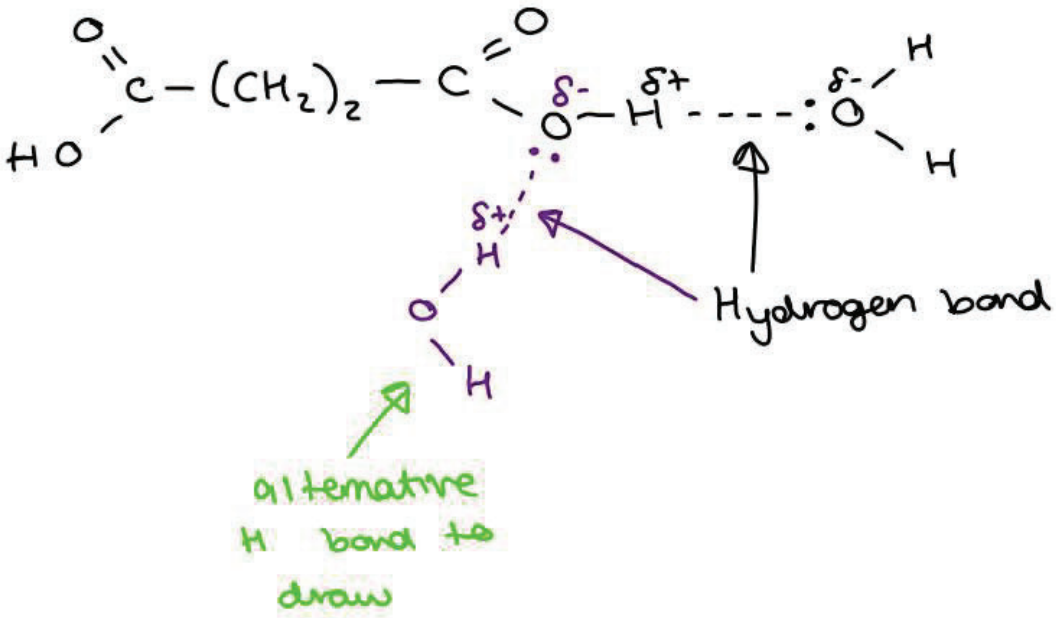
$$HO(CH_2)_4OH + 4[O] \longrightarrow HOOC(CH_2)_2COOH + 2H_2O$$

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.



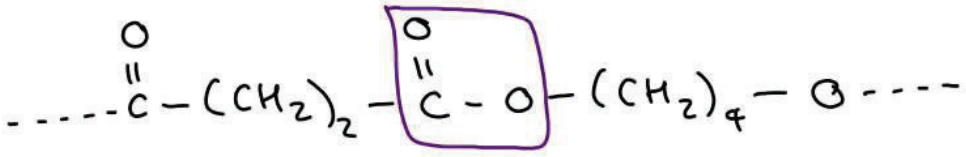
[2]

(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.

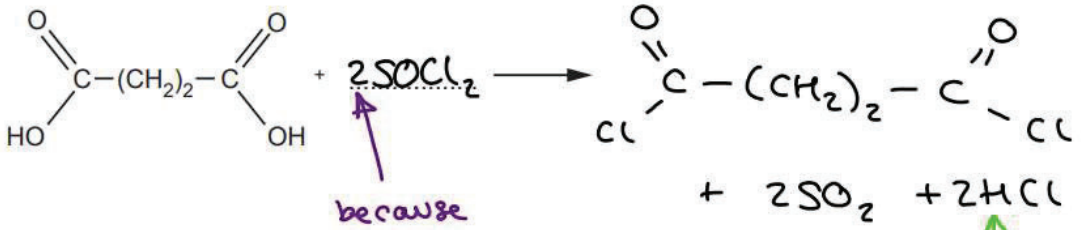
ester group can be broken down via hydrolysis **[1]**

(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

OH's lost from carboxylic acid and balanced here

[3]