

20 POLYMERIZATION

Learning outcomes

Candidates should be able to:

1. describe addition polymerisation as exemplified by poly(ethene) and poly(chloroethene), PVC
2. deduce the repeat unit of an addition polymer obtained from a given monomer
3. identify the monomer(s) present in a given section of an addition polymer molecule
4. recognise the difficulty of the disposal of poly(alkene)s, i.e. non-biodegradability and harmful combustion products

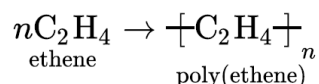
Introduction

Addition polymerisation

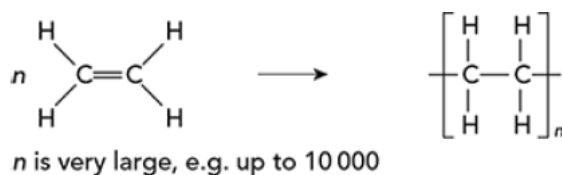
Probably the most important addition reaction of the alkenes forms the basis of much of the plastics industry. Molecules of ethene, as well as other unsaturated compounds, can react with each other under the right conditions to form polymer molecules.

A **polymer** is a long-chain molecule made up of many repeating units. The small, reactive molecules that react together to make the polymer are called **monomers**. Up to 10,000 ethene monomers can bond together to form the polymer chains of poly(ethene). Poly(ethene) is commonly used to make carrier bags.

We can show the polymerisation reaction of ethene as:



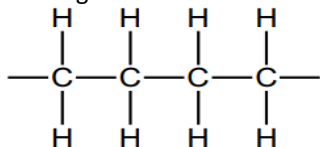
or by using the displayed formulae:



Remember that:

- the section of the polymer chain shown inside the square brackets by its structural or displayed formula is called its **repeat unit**
- addition polymerisation is characterised by:
 - unsaturated monomers, e.g. contain a C=C double bond
 - the polymer being the only product of the reaction.

1. The diagram shows a short length of an addition polymer chain.



The polymer has a relative molecular mass of approximately 10000.

Approximately how many monomer units are joined together in each polymer molecule?

- A 180 B 360 C 625 D 710

2. Which feature is present in both ethene and poly(ethene)?

- A bond angles of 109.5°
B π covalent bonds
C σ covalent bonds
D sp^3 orbitals

1. **D2** forms polymer **Z** when heated gently.



(i) Identify the type of polymer that forms from **D2**. [1]

(ii) Draw one repeat unit of polymer **Z**. [2]

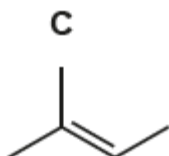
2. **C2** forms a polymer when heated gently.



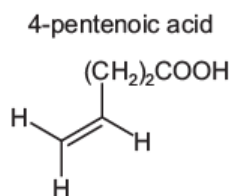
(i) Identify the type of polymer that forms from **C2**. [1]

(ii) Draw one repeat unit of the polymer formed from **C2**. [2]

3. **C** can form an addition polymer.
Draw the structure of one repeat unit of this addition polymer. [1]



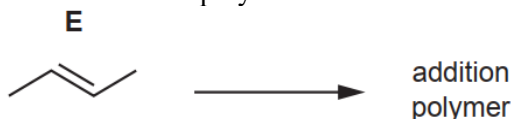
4. Fats are compounds made from glycerol and unsaturated carboxylic acids.
4-pentenoic acid is an example of an unsaturated carboxylic acid.



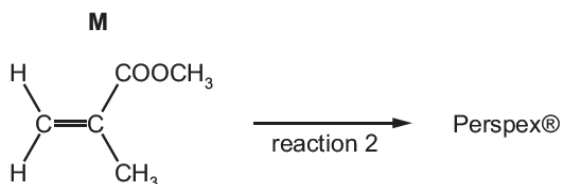
Draw the repeat unit of the addition polymer that can be formed from 4-pentenoic acid. [1]

5. Compound **W**, $\text{CH}_2=\text{CHCN}$, is used to make an addition polymer which is present in carbon fibres.
Draw **one** repeat unit of the addition polymer of **W**. [1]

6. Draw the structure of **one** repeat unit of the addition polymer that forms from **E**. [1]



7. Draw one repeat unit of the addition polymer Perspex®.



3. In polymer G every carbon atom in the polymer chain is bonded to one hydrogen atom and one methyl group. Which alkene could be polymerised to make polymer G?

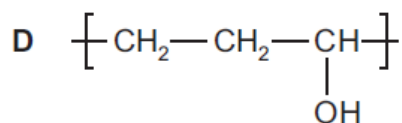
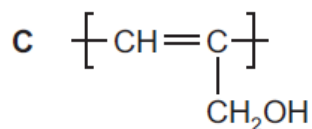
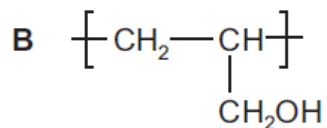
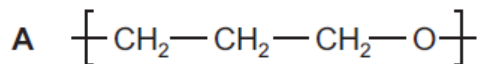
A but-1-ene

B but-2-ene

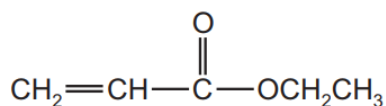
C methylpropene

D propene

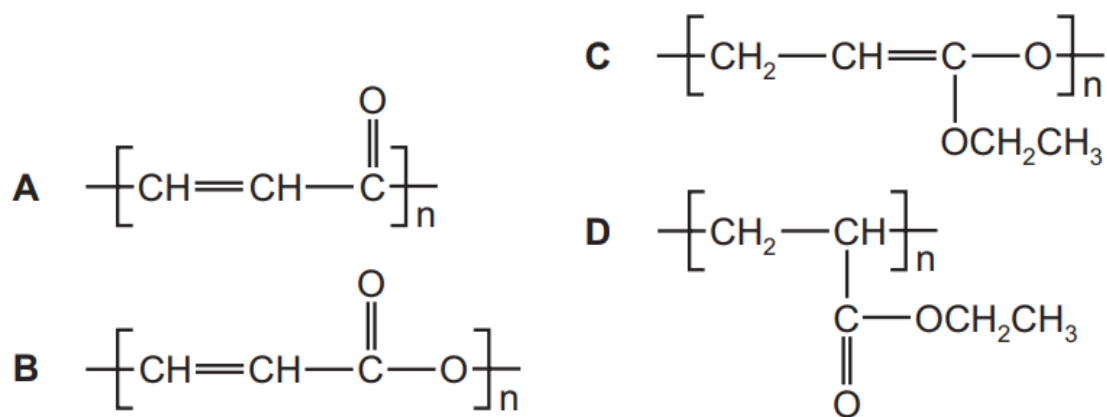
4. Synthetic resins can be made by polymerisation of a variety of monomers including prop-2-en-1-ol, $\text{CH}_2=\text{CHCH}_2\text{OH}$. Which structure represents the repeat unit in the polymer poly(prop-2-en-1-ol)?



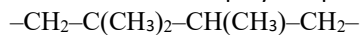
5. An addition polymer is made from monomer Z.
monomer Z



What is the structure of the polymer made from this monomer?



6. A small section of a polymer produced from two monomers is shown.



What are the two monomers?

- A but-1-ene and propene
 B but-2-ene and propene
 C ethene and pent-2-ene
 D methylpropene and propene

7. One molecule of an addition polymer containing 2000 repeat units has an M_r of 112 000.

The polymer molecule contains chiral centres.

What is a possible monomer for this polymer?

- A** $\text{CH}_2=\text{CHCH}_3$ **B** $\text{CH}_2=\text{C}(\text{CH}_3)_2$ **C** $\text{CH}_2=\text{CHCH}_2\text{CH}_3$ **D** $\text{CH}_2=\text{CHCH}_2\text{CH}_2\text{CH}_3$

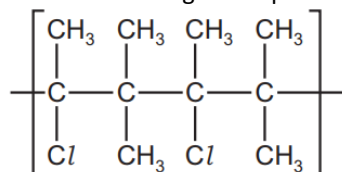
8. The formula shows the repeat unit of an addition polymer.



What is the correct name of the monomer from which this polymer is made?

- A** 1-methyl-2-ethylethene **B** 1-ethylprop-1-ene **C** pent-2-ene **D** pent-1-ene

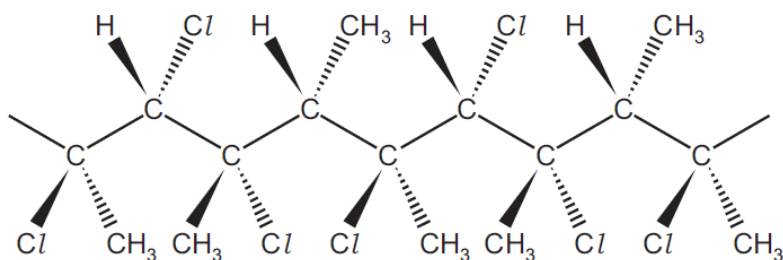
9. A section showing two repeat units of an addition polymer is shown.



What is the identity of the monomer that produced this polymer?

- A** 2-chloro-3-methylbutane
B 2-chloro-3-methylbut-2-ene
C 2-chloropent-2-ene
D 2,4-dichloro-3,3,4,5-tetramethylhexane

10. The diagram shows a section of an addition polymer. The polymer is made using two different monomers.



What are the names of the two monomers needed to make this polymer?

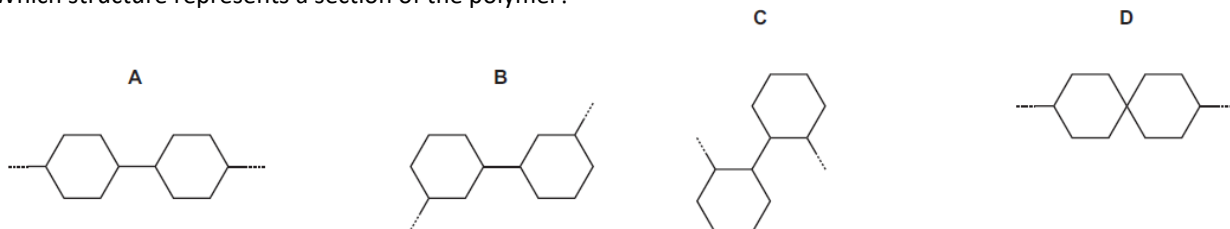
- A 1,2-dichloropropene and 2-chlorobut-2-ene
- B 2,3-dichlorobut-2-ene and chloropropene
- C 1,2-dichloropropene and chloroethene
- D chloropropene and 2-chlorobut-2-ene

11. Cyclohexene, as shown in the diagram, can form an addition polymer.

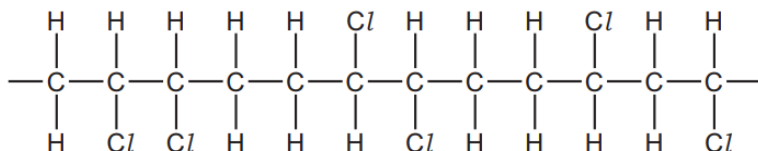
cyclohexene



Which structure represents a section of the polymer?



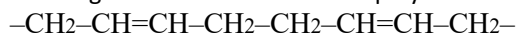
12. A molecule of a polymer contains the sequence shown.



Which monomer could produce this polymer by addition polymerisation?

- A $\text{CHCl}=\text{CHCl}$
- B $\text{CH}_2=\text{CHCl}$
- C $\text{CH}_3\text{CCl}=\text{CHCl}$
- D $\text{CH}_3\text{CCl}=\text{CH}_2$

13. The diagram shows a section of a polymer molecule.

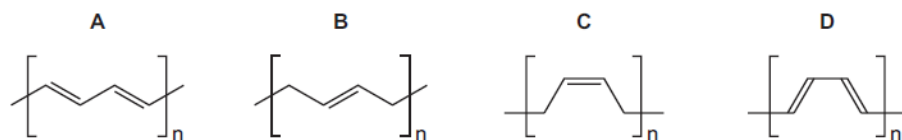


Which monomer will produce this polymer?

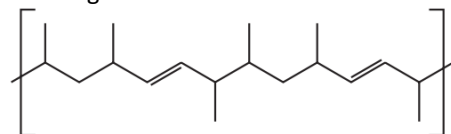
- A $\text{CH}_2=\text{CH}_2$
- B $\text{CH}_3\text{CH}=\text{CH}_2$
- C $\text{CH}_3\text{CH}=\text{CHCH}_3$
- D $\text{CH}_2=\text{CH}-\text{CH}=\text{CH}_2$

14. The monomer buta-1,3-diene can undergo addition polymerisation in various ways. Two of the polymers that can be made are called *cis*-poly(buta-1,3-diene) and *trans*-poly(buta-1,3-diene). In these names *cis* and *trans* have their usual meanings.

What is the structure of the repeat unit of *cis*-poly(buta-1,3-diene)?

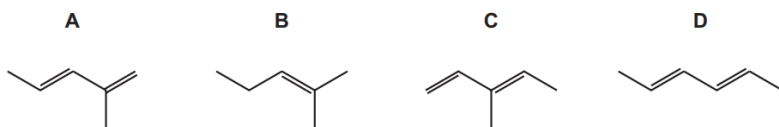


15. The diagram shows a section of an addition polymer formed from two different monomers.



One of the monomers is propene.

What is the other monomer?



Disposal of poly(alkene) plastics

Plastics are widely used in many aspects of everyday life. However, the large-scale use of poly(alkene)s has created a problem when we come to dispose of them. During their life, one of the most useful properties of poly(alkene)s is their lack of reactivity.

As poly(alkene)s are effectively huge alkane molecules, they are resistant to chemical attack. So they can take hundreds of years to decompose when dumped in landfill sites, taking up valuable space. They are non-biodegradable. Therefore, throwing away poly(alkenes) creates rubbish that will pollute the environment for centuries

Burning plastic waste

One way to solve this problem would be to burn the poly(alkene)s and use the energy released to generate electricity. As we have seen, if hydrocarbons burn in excess oxygen, the products are carbon dioxide and water. This solution would not help combat global warming, but would help to conserve our supplies of fossil fuels that currently generate most of our electricity. However, we have also seen that toxic carbon monoxide is produced from the incomplete combustion of hydrocarbons.

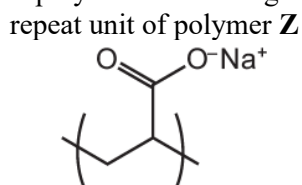
Another problem is the difficulty recycling companies have in separating other plastic waste from the poly(alkene)s. This happens when objects have just been thrown away and not been sorted according to their recycling code. Also, if poly(chloroethene) waste is burnt, acidic hydrogen chloride gas will be given off, as well as toxic compounds called dioxins. Acidic gases should be neutralised before releasing the waste gases into the atmosphere. Very high temperatures should be used in incinerators to break down any toxins.

16. Which statement about PVC is correct?

- A Combustion products of PVC are very alkaline and harmful to breathe in.
- B The empirical formula of PVC is the same as the empirical formula of the monomer.
- C Molecules of PVC are unsaturated.
- D The repeat unit of PVC is $(\text{CH}_2\text{CCl}_2)$.

8. X reacts with another reagent to form Y.

Molecules of Y react together to form addition polymer Z. The diagram shows the repeat unit of polymer Z.



(a) Draw the structural formula of monomer Y.

[1]

(b) Polymer **Z** is useful because it absorbs large amounts of water. However, there are problems associated with the disposal of products containing polymer **Z**.

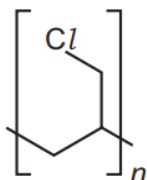
Combustion is not an appropriate method to dispose of pure **Z** because the process releases harmful gases. Some of these gases contribute to the enhanced greenhouse effect.

(i) Identify a gas released during the combustion of **Z** which contributes to the enhanced greenhouse effect. [1]

(ii) Identify another gas which could be produced during the combustion of pure **Z**. Describe a consequence, other than the enhanced greenhouse effect, of its release into the atmosphere.[1]

9. **X is an addition polymer.**

X



i) Draw the monomer of **X**. [1]

ii) Suggest **one** reason why the disposal of items made from **X** is difficult. [1]

10. Under suitable conditions, propene polymerises to form poly(propene).

Poly(propene) exhibits stereoisomerism.

(i) Identify the type of polymerisation that forms poly(propene) from propene.

..... [1]

(ii) Define stereoisomerism.

.....

..... [2]

(iii) Draw a section of poly(propene), showing two repeat units.

Use your diagram to identify the type of stereoisomerism shown by poly(propene).

Explain your answer.

section of poly(propene)

.....

.....

.....

.....

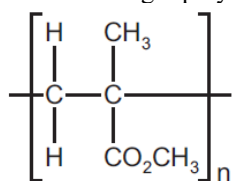
[3]

(iv) State two difficulties associated with the disposal of poly(propene).

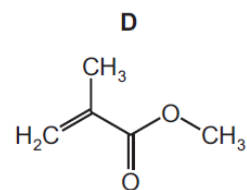
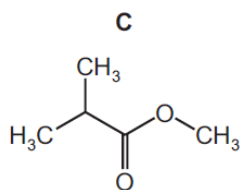
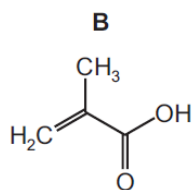
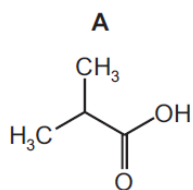
1.

2. [2]

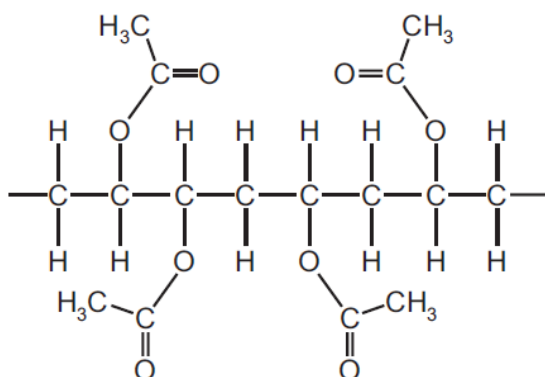
3. PMMA is a rigid polymer. The repeat unit of PMMA is shown.



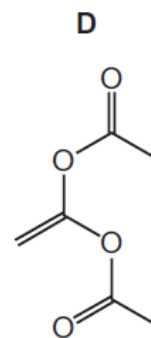
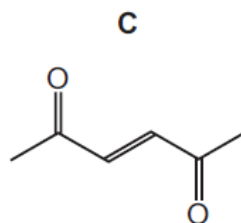
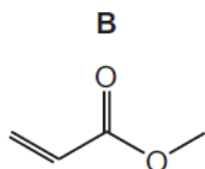
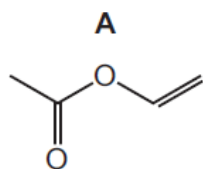
Which monomer is used to make PMMA?



4. A section of an addition polymer is shown



Which monomer is used to make this polymer?



***This is not a complete note. It is just to guide you. It is recommended to study prescribed textbooks along with this material. ***