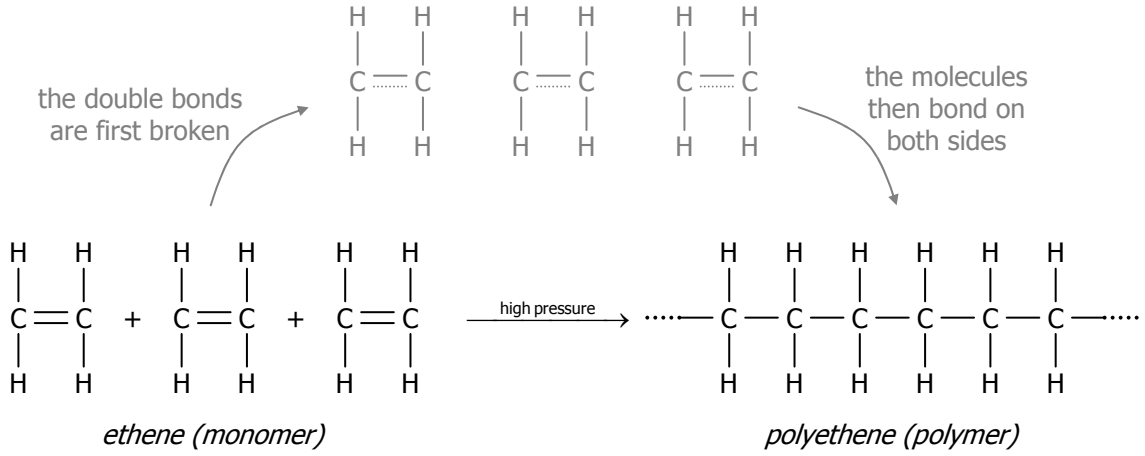
Topic 20D: **Answers**
Addition Polymerisation

SYLLABUS RELEVANCE & TEXTBOOK CHAPTERS		
O-LEVEL PURE (5072)	✓	Chapter 25
O-LEVEL SCIENCE (5116)	✓	Chapter 20
N-LEVEL SCIENCE (5155)	✖	

Lesson Package & Accompanying Slides Designed by Alex Lee (2011)
Last Modified by Alex Lee (2011)

1. **Addition Polymerisation: Polyethene**

Under extreme pressure (about 1000 atm), ethene molecules can undergo addition reactions with itself. This is known as **addition polymerisation**. The product of this reaction is **polyethene**.

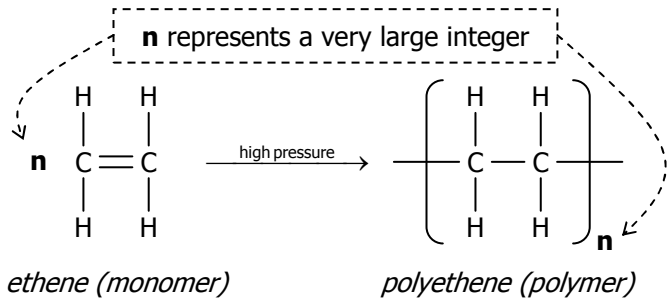


Polyethene is commonly found in the household, made into plastic bags or clingfilm.

'**Polymerisation**' refers to a reaction in which many small organic molecules combine to form a macromolecule (known as a polymer).

'**Addition polymerisation**' refers to a reaction in which many small unsaturated organic molecules combine to form a macromolecule as the only product.

In the above diagram, we had represent the polymer as a segment showing three repeating units. To represent the polymer in its entirety, we should use brackets as shown:

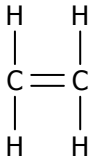


We only consider a molecule to be a polymer when an uncountable number of monomers have been joined together. If only two or three monomers have been joined, we do not consider it to be a polymer. Since the number of monomers (or repeating units) is uncountable, we simply represent this by the letter '**n**'.

We have to be careful of the terminology:

"MONOMER"

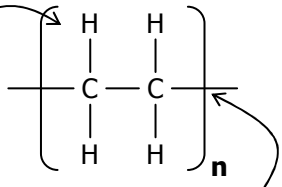
The small organic molecule before polymerisation takes place, i.e. ethene. In the case of addition polymerisation, the C=C bond will still be present.



"POLYMER"

The macromolecule formed after polymerisation takes place; brackets and 'n' are used to represent a very large number of repeating units.

only one repeating unit can be drawn in the brackets



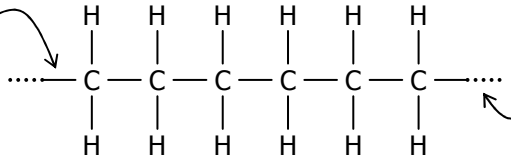
'continuation lines' must exceed the brackets

POLYETHENE

THREE "REPEATING UNITS"

Represents a segment of the polymer chain; do not draw brackets since this represents a definite number of repeating units. However, 'continuation lines' and 'continuation dots' must still be shown clearly on each end.

'continuation lines' must be drawn on both ends



'continuation dots' must also be drawn on both ends

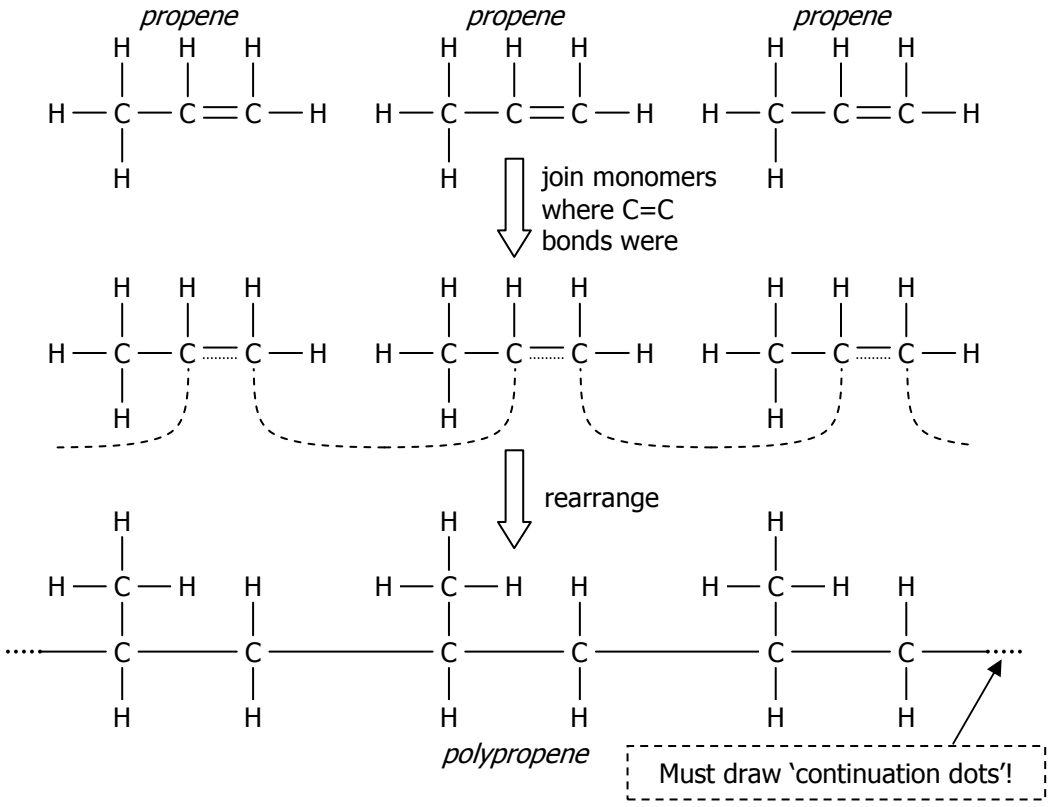
A **polymer** refers to a large molecule consisting of repeating structural units formed by the reaction of many small molecules joining together.

A **monomer** refers to a small organic molecule which is able to join with many other small organic molecules to form a macromolecule.

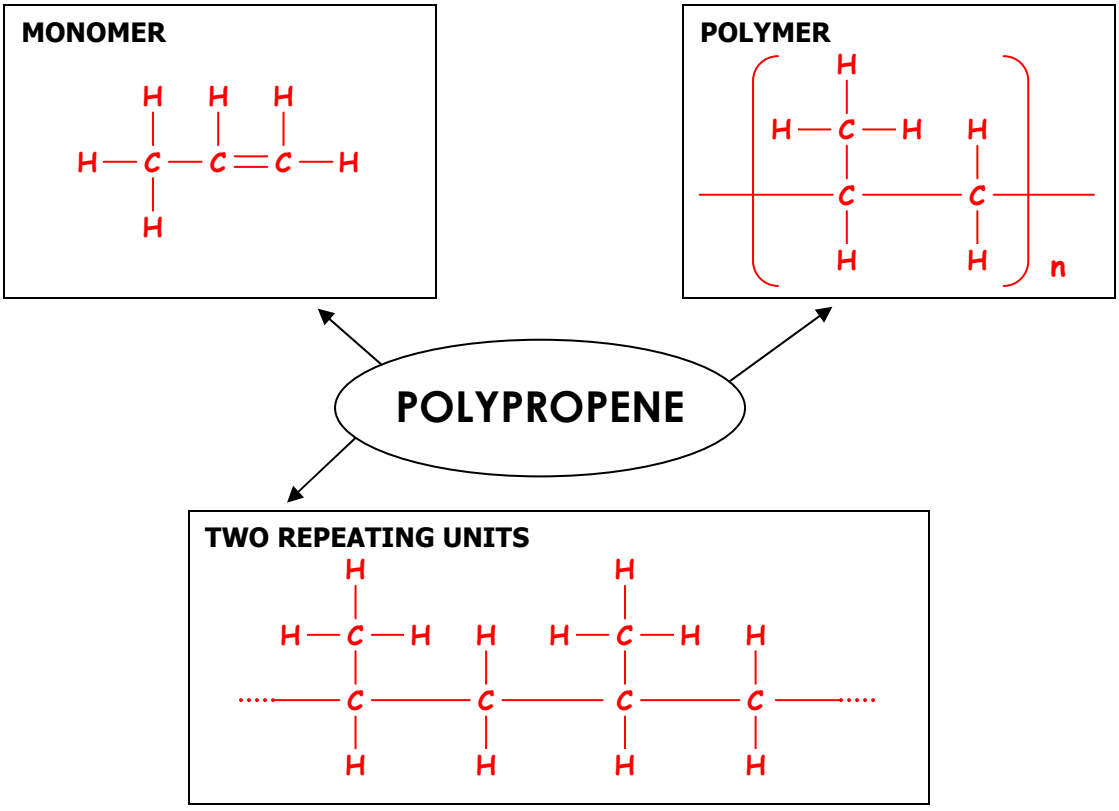
Polymers take on the names of their monomers, with the prefix 'poly' in front. As we have seen in the previous page, the polymer of ethene is simply known as polyethene or poly(ethene). (Writing the brackets in the polymer name is optional).

2. **Drawing Addition Polymers from Given Monomers**

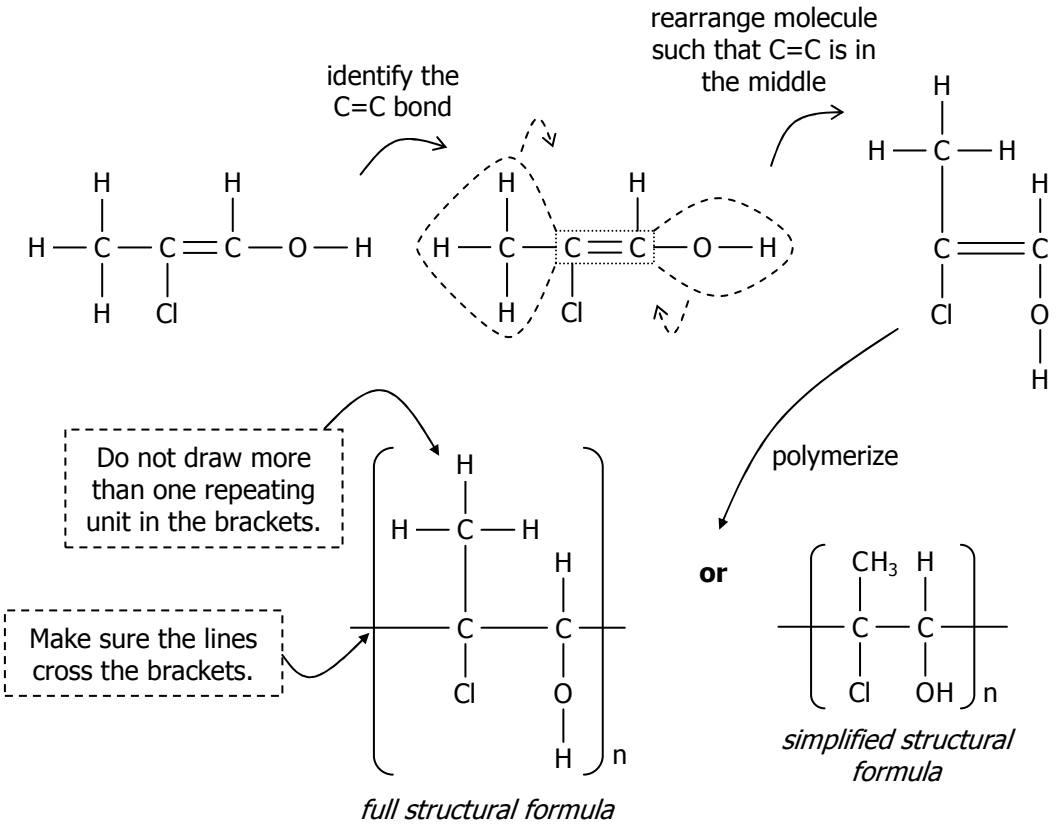
Like all other unsaturated compounds, propene can also undergo addition polymerisation.



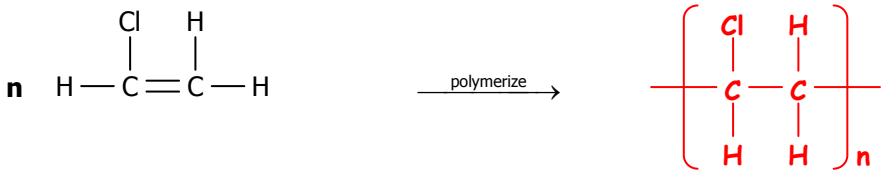
(a) Fill in the boxes below with the appropriate full structural formulae.

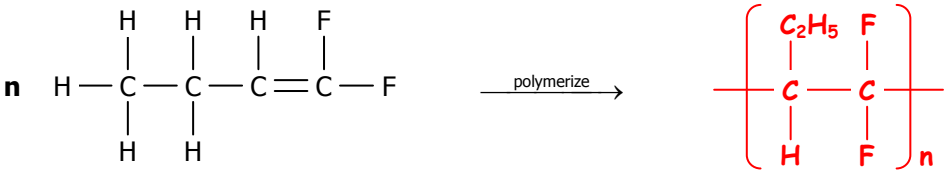


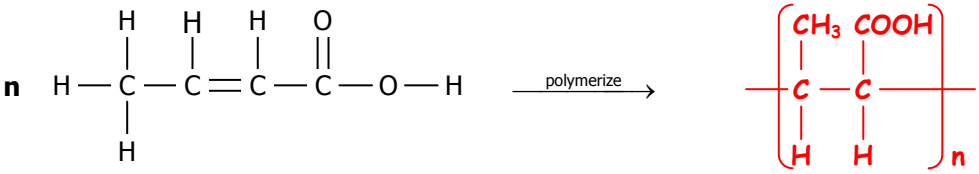
To determine the structure of an addition polymer from its monomer, we follow these steps:



(b) Draw the structural formula of the polymers formed from the monomers below.



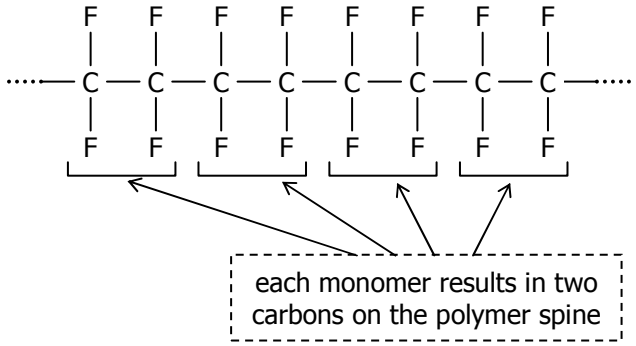




3. **Drawing Monomers from Given Addition Polymers**

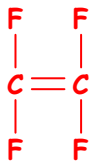
Since the spine of an addition polymer chain is made from the joining of C=C bonds, each monomer unit will eventually occupy two carbon units on the polymer spine.

To identify the monomer, we simply 'slice up' the polymer into pairs of carbon atoms, and replace the C=C bond that was originally broken during polymerisation.

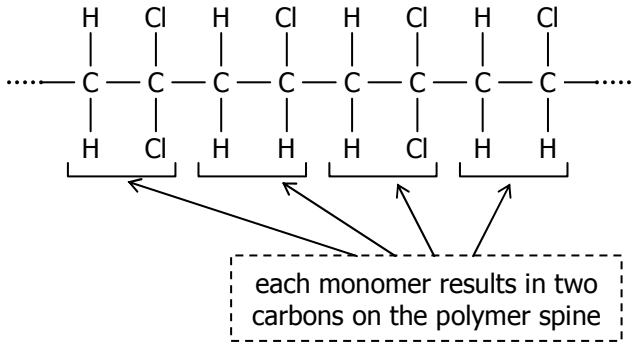


Number of repeating units represented in this segment: **4**

Structural formula of monomer(s):

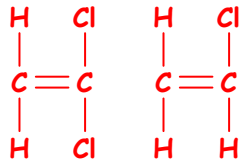


It is not uncommon for an addition polymer to be synthesized from two or more monomers. These polymers, which are made from multiple reactants, are referred to as 'copolymers'. One such example is the plastic *saran*:

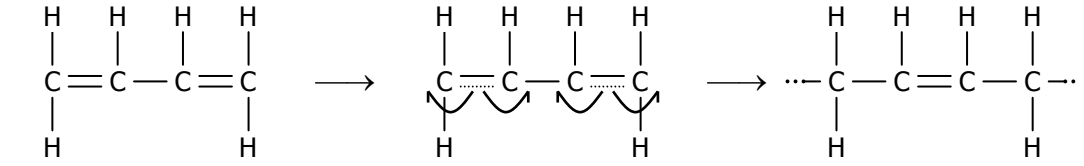


Number of repeating units represented in this segment: **2**

Structural formula of monomer(s):



However, one special exception is the polymerisation of but-1,3-diene, which forms natural rubber. In this special monomer, two C=C bonds are present in each molecule, with one C–C bond between them.



Each monomer contains two C=C bonds, both of which are involved in polymerisation.

Each C=C breaks, giving an electron to the next molecule, and an electron to the C–C bond.

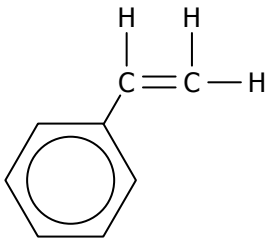
The C–C bond has become a C=C bond, while the C=C bonds have become C–C bonds.

This is unusual as each monomer results in four carbons on the polymer spine, instead of two!

4. **Review Questions**

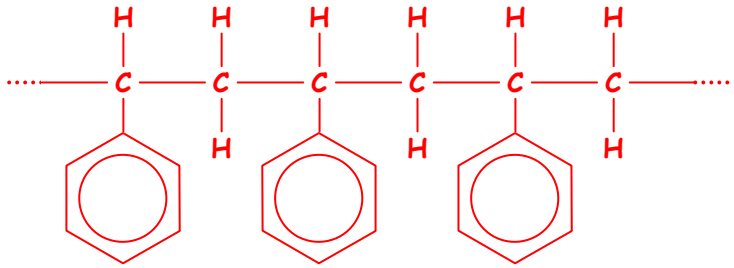
(a) Styrofoam is a useful material in packaging due to its good heat insulation properties, low density and relatively soft texture. It is made from a polymer known as polystyrene.

The monomer for polystyrene, molecule **X**, is shown below.



molecule **X**

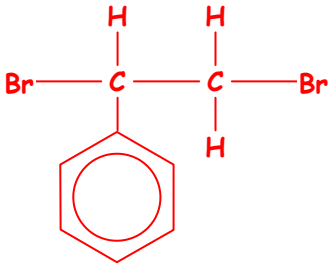
(i) Draw the structure of polystyrene, showing three repeating units.



(ii) Suggest the name for molecule **X**.

Styrene

(iii) Draw the product formed when **X** reacts with bromine at room conditions.



(b) Indicate if the following statements are **true** or **false**.

Polyethene is an unsaturated hydrocarbon. false

Polyethene has no effect on aqueous bromine. true

For addition polymerisation to occur, the reactants must have a C=C bond. true

During addition polymerisation, there is no change in total mass. true

During addition polymerisation, there is no change in percentage composition. true

A polymer is formed when two or three monomers join together. false

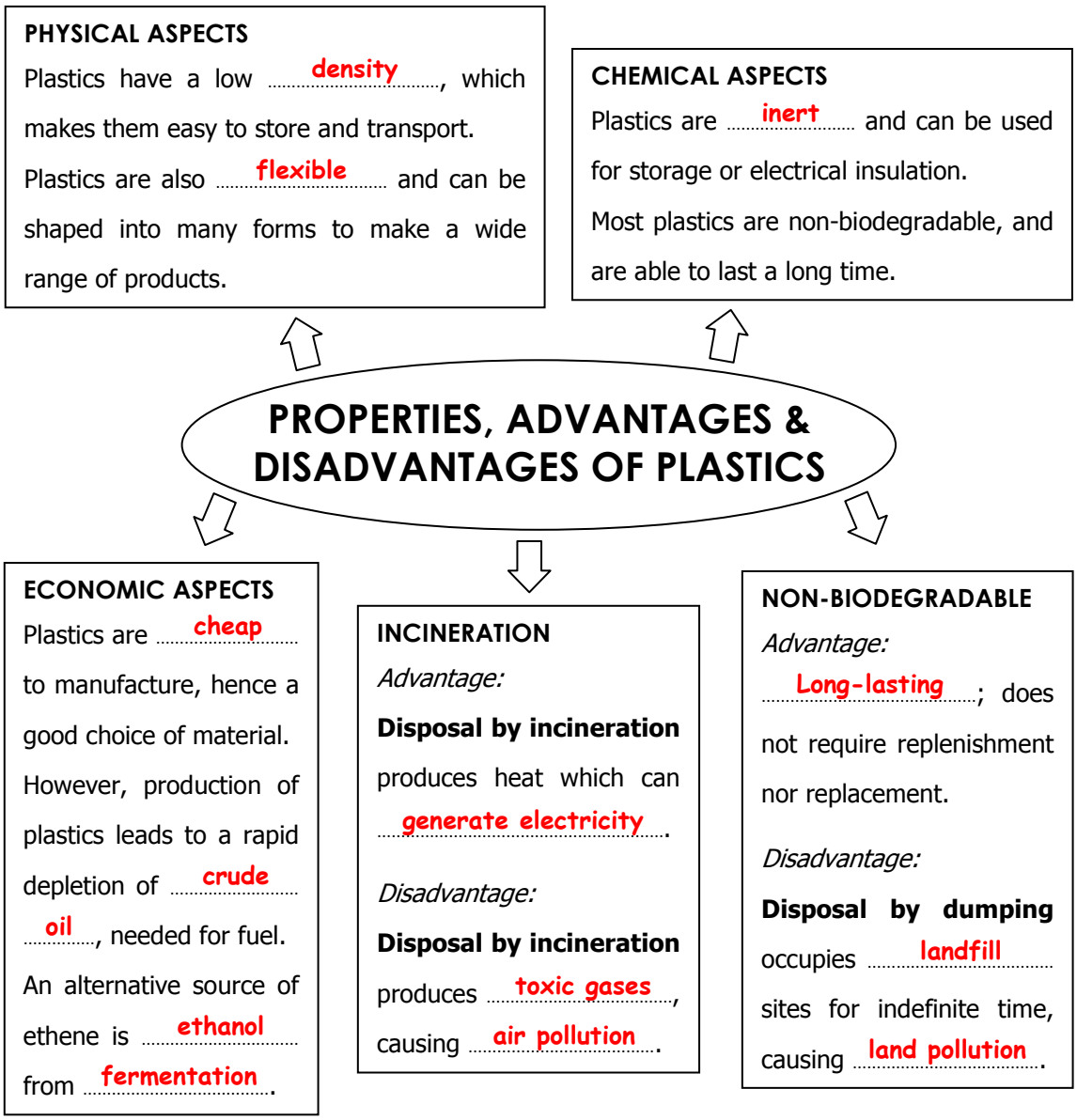
5. **Plastics & The Environment**

Most synthetic polymers are made into plastics, which serve a wide range of uses. Plastics are cheap, light-weight and can be made into many forms – be it storage boxes, electrical insulators, vehicle parts or even stationery and clothing!

While some **biodegradable** plastics have been found, most plastics are **non-biodegradable**.

'**Biodegradable**' refers to the ability of a substance to be broken down naturally by the action of bacteria.

Complete the diagram below which discusses the various properties of plastics.



As you have observed, the main disadvantages in the use of plastics is in their disposal; disposal by dumping leads to land pollution while disposal by incineration leads to air pollution.

6. **Review Questions**

(a) Polystyrene is an example of a polymer which is non-biodegradable.

(i) Explain what is meant by the term 'non-biodegradable'.

It means that the substance is not able to break down naturally by the action of bacteria.

(ii) Outline an advantage and a disadvantage of using non-biodegradable plastics.

Advantage: Able to last a long/indefinite time and does not require frequent replacement or replenishment (except from physical damage).

Disadvantage: Disposal by dumping will occupy landfill sites for a long/indefinite time, leading to land pollution.

(b) Two means of disposing of plastics are by dumping or by incineration.

(i) State an advantage of disposing of plastics by dumping over disposing by incineration.

Reduces air pollution caused by the poisoneous gases formed during incineration.

(i) State two advantages of disposing of plastics by incineration over disposing by dumping.

1. Reduces land pollution caused by the landfill sites occupied by dumping.

2. Heat produced from incineration can be used to generate electricity.

(c) Briefly explain why, upon being dumped at landfill sites,

(i) a piece of plastic lasts longer than a piece of wood,

The plastic is non-biodegradable and may not be broken down by bacteria in the soil, while the wood is biodegradable can can be broken down by bacteria.

(ii) a piece of plastic lasts longer than a piece of metal.

The plastic is non-biodegradable and may not be broken down by bacteria in the soil, while metal can react/oxidize in the air and dissolve to form compounds.

(d) Polyethene is a common plastic found in the household. State two uses for polyethene.

To manufacture clingfilm and plastic bags.

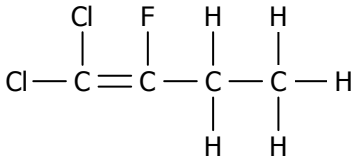
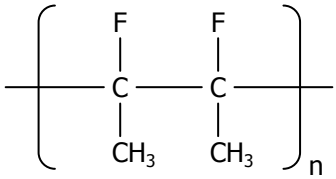
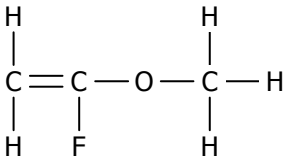
Self-Designed Summary

Supplementary Questions

1. Polyethene is the most common example of an addition polymer. It is manufactured by addition polymerisation of ethene molecules under high pressure.
   (a) Define 'polymerisation' and 'addition polymerisation'.
   (b) Draw the full structural formula for the monomer of polyethene.
   (c) State two uses of polyethene.

2. The most pertinent problem associated with the use of plastics is the fact that most plastics are non-biodegradable. This often poses a dilemma when these plastics are disposed of.
   (a) Explain what is meant by 'biodegradable'.
   (b) State the advantages of disposing of plastics by incineration, rather than by dumping.
   (c) State the advantages of disposing of plastics by dumping, rather than by incineration.

3. Complete the table below.

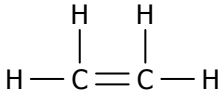
monomer	polymer
	
	
	

Supplementary Questions (Answers)

Question 1

(a) 'Polymerisation' is a reaction in which many small organic molecules (known as monomers) combine to form a macromolecule (known as a polymer).
'Addition polymerisation' is a reaction in which many small unsaturated organic molecules (known as monomers) combine to form a macromolecule (known as a polymer) as the only product.

(b)



(c) used as plastic bags; clingfilm

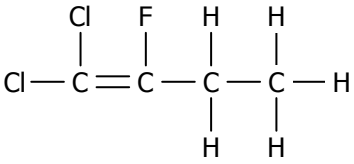
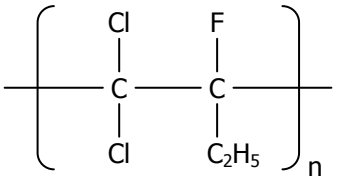
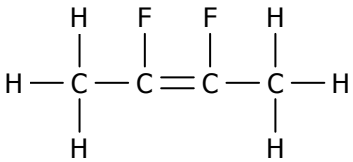
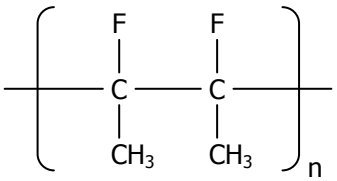
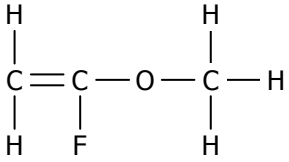
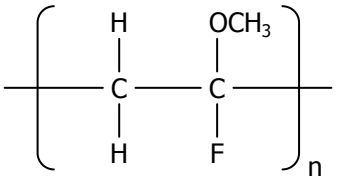
Question 2

(a) 'Biodegradable' refers to the ability of a substance to be broken down naturally by the action of bacteria.

(b) Incineration reduces the need for landfill sites caused by dumping and hence reduces land pollution; incineration can also be used to generate heat and electricity.

(c) Dumping does not produce harmful/toxic gases, unlike incineration, hence does not contribute to air pollution.

Question 3

monomer	polymer
	
	
	

Lecture Slides

Addition Polymerisation

Anglo-Chinese School (Barker Road)

CHEMISTRY
Prepared by Alex Lee

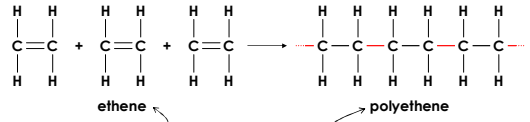
Chapter Overview

In This Chapter, We Will Learn …

1. Addition Polymerisation
2. Advantages & Disadvantages of Plastics

Addition Polymerisation: Polyethene

- Under extreme pressure (about 1000 atm), ethene molecules can undergo addition reactions with itself.
- This is known as **addition polymerisation**.

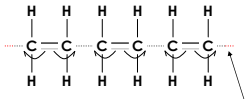


The reactant that undergoes addition polymerisation is known as the monomer.

The product of addition polymerisation is known as the polymer.

Addition Polymerisation: Polyethene

- Addition polymerisation occurs because the molecule **breaks its C=C bond** and joins adjacent molecules.



Since this reaction connects a extremely large number of molecules, dotted lines are drawn at the sides to represent an indefinite continuation.

Addition Polymerisation: Polyethene

- The product of polymerisation is known as a **polymer**.
- Polymers are named after their monomers. For example, the polymer of 'ethene' is just 'polyethene'.
- *Other examples of addition polymers:*
  - 'polyvinylchloride' (PVC) is made from 'vinylchloride'
  - 'polystyrene' is made from 'styrene'
- Polymers are considered to be **macromolecules**.

Addition Polymerisation: Polyethene

- **Polyethene** is a commonly-available plastic.
- In the household, it is often made into **plastic bags** or **cling film**.

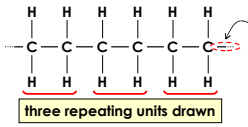
Images: http://www.regalpolythene.com/img/black-polythene-refuse-sack.jpg (Black Polythene Bags)
http://www.chuan-hwang.com.tw/img/ch-300h2.gif (Cling Film)

Addition Polymerisation: Definitions

- **Polymerisation** refers to a reaction in which many small organic molecules combine to form a macromolecule (known as a polymer).
- **Addition polymerisation** refers to a reaction in which many small *unsaturated* organic molecules combine to form a macromolecule *as the only product*.

Addition Polymerisation: Notation

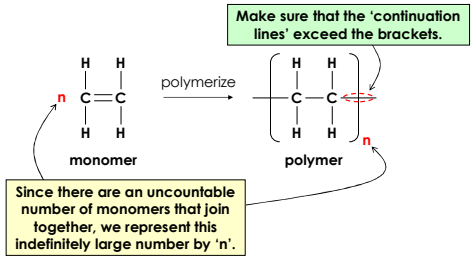
- In the earlier slides, we had represented the structure of a polymer as **three repeating units**:



- A polymer can be represented using any number of repeating units – one, two, three or even more!
- However, we must always use a whole number of repeating units – never draw half a repeating unit!

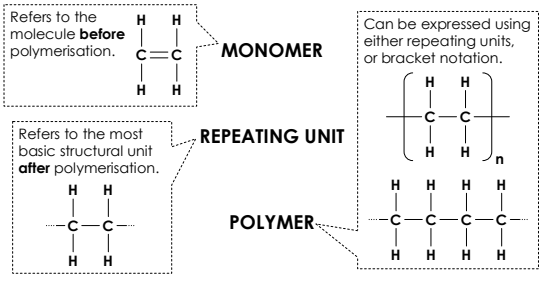
Addition Polymerisation: Notation

- A polymer can also be represented in its entirety by using the **bracket notation**:



Addition Polymerisation: Notation

- We must be careful of the terminology:



Addition Polymerisation: Definitions

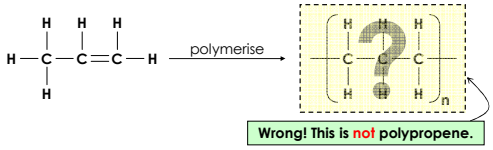
- A **polymer** refers to a large molecule consisting of repeating structural units, formed from the reaction of many small molecules joining together.
- A **monomer** refers to a small organic molecule which is able to join with many other small organic molecules to form a macromolecule.

Avoid using the terms 'monomer' and 'polymer' to define each other, e.g. "a polymer is a large molecule formed when many monomers join together".

Polypropene

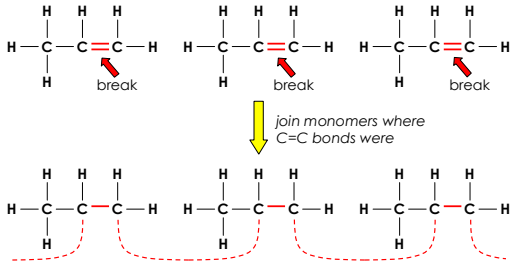
- Like ethene, **all unsaturated organic compounds can undergo addition polymerisation**.
- Propene polymerises to form polypropene.

What is the structure of polypropene?



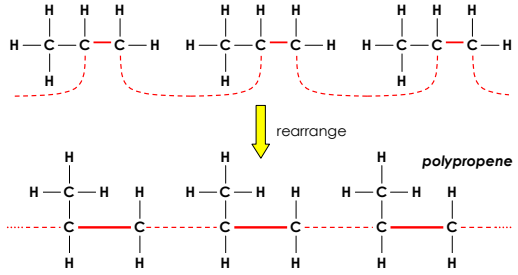
Polypropene

Polymerisation of Propene



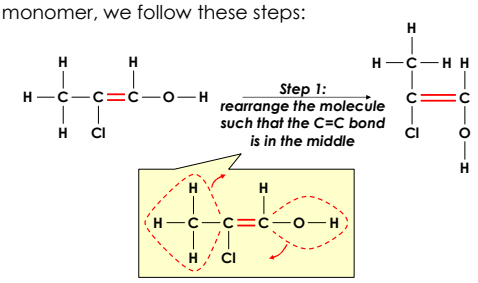
Polypropene

Polymerisation of Propene

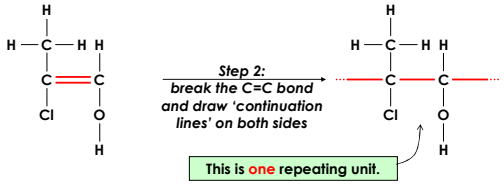


Drawing Addition Polymers

- To determine the structure of a polymer from a given monomer, we follow these steps:

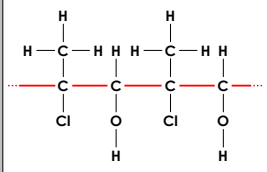
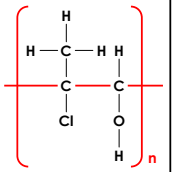
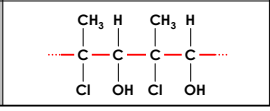
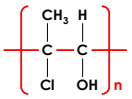


Drawing Addition Polymers



- We can then express the polymer using either the bracket notation, or as a chain of repeating units.

Different Ways to Represent Polymers

	Two Repeating Units	Bracket Notation
Full Structural Formula		
Simplified Structural Formula		

Different Ways to Represent Polymers

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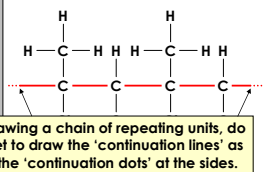
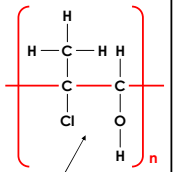
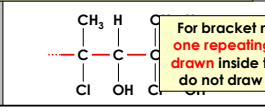
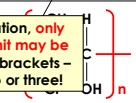
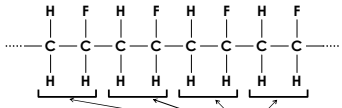
Full Structural Formula		
Simplified Structural Formula		

When drawing a chain of repeating units, do not forget to draw the 'continuation lines' as well as the 'continuation dots' at the sides.

For bracket notation, only one repeating unit may be drawn inside the brackets – do not draw two or three!

Deducing the Structure of Monomers

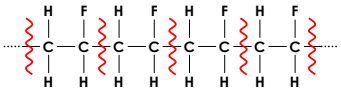
- Since we can deduce the structure of a polymer from its monomer, we can also deduce the structure of a monomer from the polymer it forms.
- Firstly, we should note that each monomer results in two carbon atoms on the spine of the polymer chain.



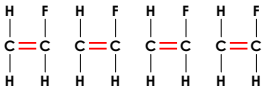
each monomer results in two carbons on polymer spine

Deducing the Structure of Monomers

- To identify the monomer, we should 'slice' the polymer spine into pairs of carbon atoms.



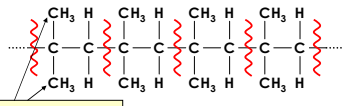
- Next, we **replace the C=C bond** that was originally present between each pair of carbon atoms.



Done! We have found the monomer.

Deducing the Structure of Monomers

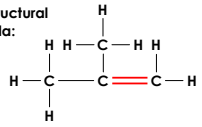
- Only **carbon atoms on the spine** of the polymer chain are counted – 'branches' are not split up.



The carbon atoms which are not on the spine are ignored.

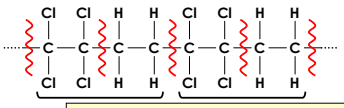
Hence the monomer is:

Full structural formula:



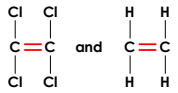
Deducing the Structure of Monomers

- It is also possible for an addition polymer to be made from **two or more types of monomers**:



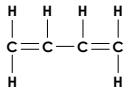
In this segment, although four monomer molecules were bonded, it only forms two repeating units.

Hence the monomers are:



But-1,3-diene: A Special Exception

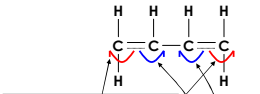
- The molecule ***but-1,3-diene*** contains two C=C bonds.



- This molecule is unusual because, when it undergoes addition polymerisation, **both** C=C bonds react!

But-1,3-diene: A Special Exception

- Each C=C bond breaks, giving an electron to the next molecule and another electron to the C–C bond in the middle of the molecule.



One electron goes towards bonding with adjacent monomers.

The other electron is added to the existing C–C bond.

This is unusual because each monomer results in four carbons on the polymer spine instead of two.

This is also unusual because the polymer contains C=C bonds along its spine.

Plastics & The Environment: An Overview

- Polymers can generally be classified into two types – biological polymers (naturally-occurring) and synthetic polymers (man-made).
- Synthetic polymers are often treated with additives, such as colourings, and moulded into various shapes for commercial use.
- These end-products are known as **plastics**.

Plastics & The Environment: An Overview

- Most plastics are **not biodegradable**, although recent research have led to the development of some biodegradable plastics.
- **'Biodegradable' refers to the ability of a substance to be broken down naturally by the action of bacteria**.
- This can be both an advantage and a disadvantage.

Properties of Plastics

Physical Aspects

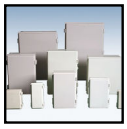
- Plastics have a **low density** which makes them easy to store and transport.
- Plastics are also **flexible** and can be shaped into many forms to make a wide range of products.

Images: http://www.vintageplasticsllc.com/About_Recycling_Plastic_Types.html

Properties of Plastics

Chemical Aspects

- Plastics are **inert** and can be used for storage or electrical insulation.
- Most plastics are non-biodegradable, and are **able to last a long time**.

Images: http://www.usplasticcoatings.com/plastic_coatings_services.htm (Plastic-Coated Tools)
http://www.directindustry.com/prod/ningbo-dayang-enclosures/plastic-box-55518-367057.html (Plastic Storage Boxes)

Properties of Plastics

Economic Aspects

- Plastics are **cheap** to manufacture, hence a good choice of material.
- However, production of plastics leads to a **rapid depletion of crude oil**, needed for fuel.
  - An alternative source of ethene is **ethanol**, made from **fermentation of sugar**.

Properties of Plastics

Incineration of Plastics (Environmental Aspects)

- ***Advantage:***
  Disposal of plastics by incineration produces heat which can **generate electricity**.
- ***Disadvantage:***
  Disposal of plastics by incineration produces toxic gases, causing **air pollution**.

Properties of Plastics

Non-Biodegradable Nature (Environmental Aspects)

- ***Advantage:***
  Long-lasting, does not require replenishment nor replacement, except from physical damage.
- ***Disadvantage:***
  Disposal by dumping occupies **landfill sites** for indefinite time, causing **land pollution**.

Avoid using the term 'durable' as it may be confused with mechanical strength.

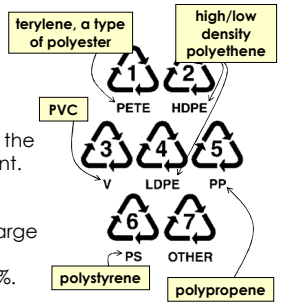
Disposal of Plastics

- As you would have seen, the main disadvantages of plastics is in the **competing use for crude oil** and the **pollution caused upon disposal**.

Method	Problems
Dumping	Uses **landfill sites** for indefinite periods of time, leading to **land pollution**.
Incineration	Produces **toxic gases** upon burning, leading to **air pollution**.
Recycling	Costly process; furthermore, not all plastics can be recycled.

Recycling of Plastics

- Most disposable plastic products have **recycling codes** imprinted on them.
- These plastic codes help recycling plants determine the **type of plastic** that is present.
- Generally, **only Type 1 and Type 2 are recycled** on a large scale – and even then, the return rate is low, about 20%.



Images: http://bsalert.com/f-store/plastic_recycle_code_legend.jpg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THE BEST IS YET TO BE