Organic Chemistry

Macromolecules

Organic Chemistry

What do I need to know about *macromolecules*?

Organic Chemistry

Macromolecules

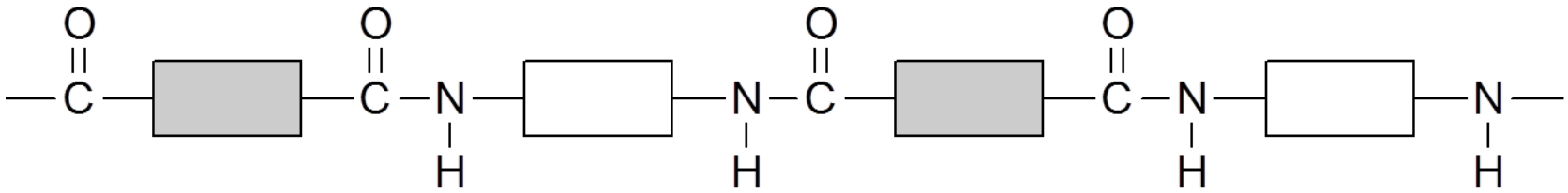
a) Describe macromolecules as large molecules built up from small units, different macromolecules having different units and/or different linkages.

b) Describe the formation of poly(ethene) as an example of addition polymerisation of ethene as the monomer.

c) State some uses of poly(ethene) as a typical plastic, *e.g.* plastic bags; clingfilm.

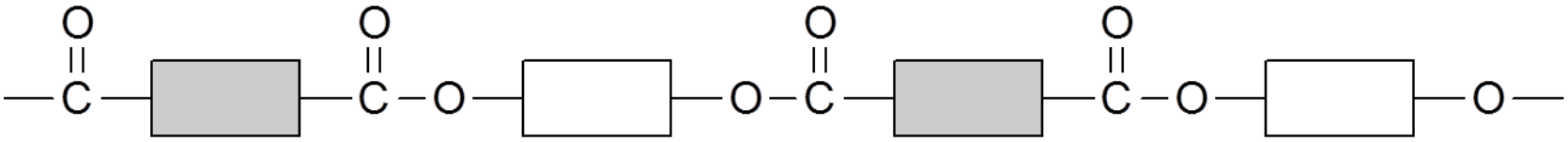
d) Deduce the structure of the polymer product from a given monomer and vice versa.

e) Describe nylon, a polyamide, and *Terylene*, a polyester, as condensation polymers, the partial structure of nylon being represented as:



Organic Chemistry

And the partial structure of *Terylene* as:



(Details of manufacture and mechanisms of these polymerisations are not required).

f) State some typical uses of man-made fibres such as nylon and *Terylene*, *e.g.* clothing; curtain materials; fishing line; parachutes; sleeping bags.

g) Describe the pollution problems caused by the disposal of non-biodegradable plastics.

Organic Chemistry

Macromolecules and Polymer Chemistry

Main Menu

Organic Chemistry

What are *macromolecules* or *polymers*?

- In everyday life we encounter macromolecules or polymers in the form of *plastics*.

• Return to Main Menu

Organic Chemistry

Uses of Polymers

Organic Chemistry

Uses of Polymers

Organic Chemistry

Uses of Polymers

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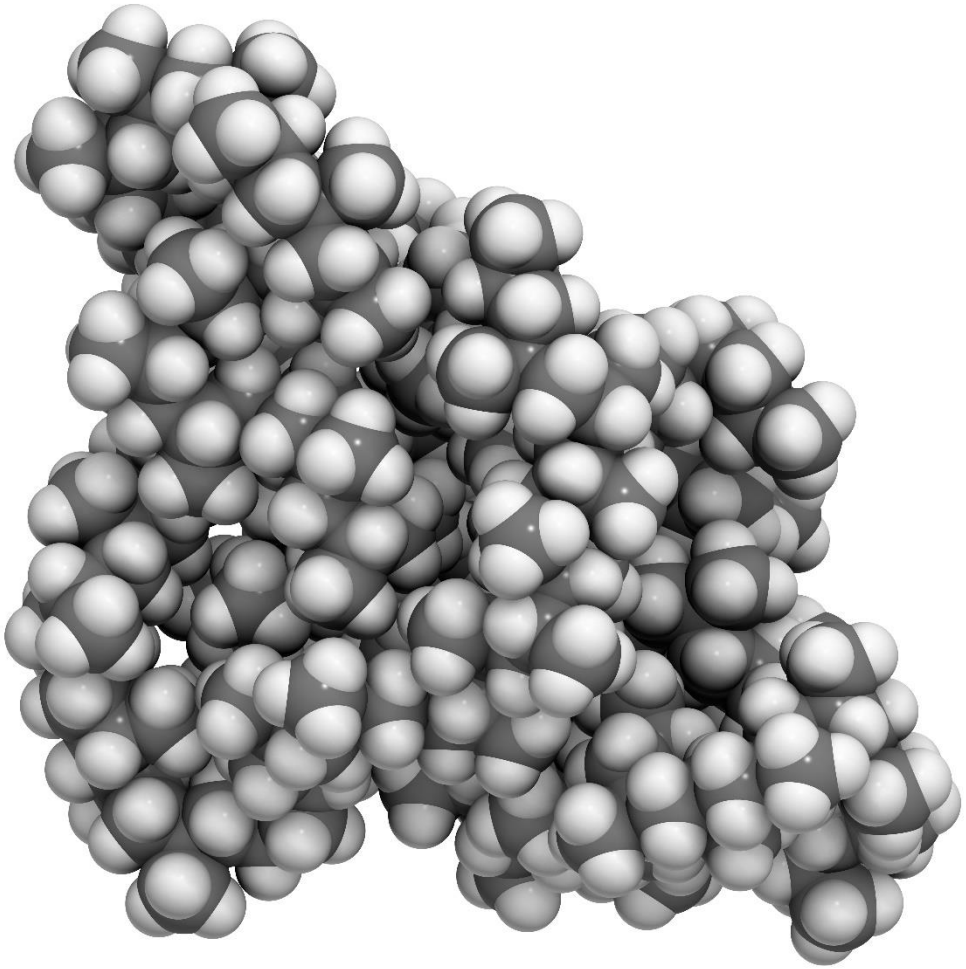
Uses of Polymers

Organic Chemistry

Uses of Polymers

Organic Chemistry

Uses of Polymers



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Uses of Polymers

- Polymers are macromolecules (giant covalent structure).
- Polymers are good electrical and thermal insulators.
- Polymers are resistant to corrosion.
- Polymers are insoluble in polar solvents such as water.
- Polymers can be molded into different shapes.
- Polymers are durable.
- Polymers have a high strength to weight ratio.
- Polymers are low cost and easy to manufacture.

Organic Chemistry

Uses of Polymers

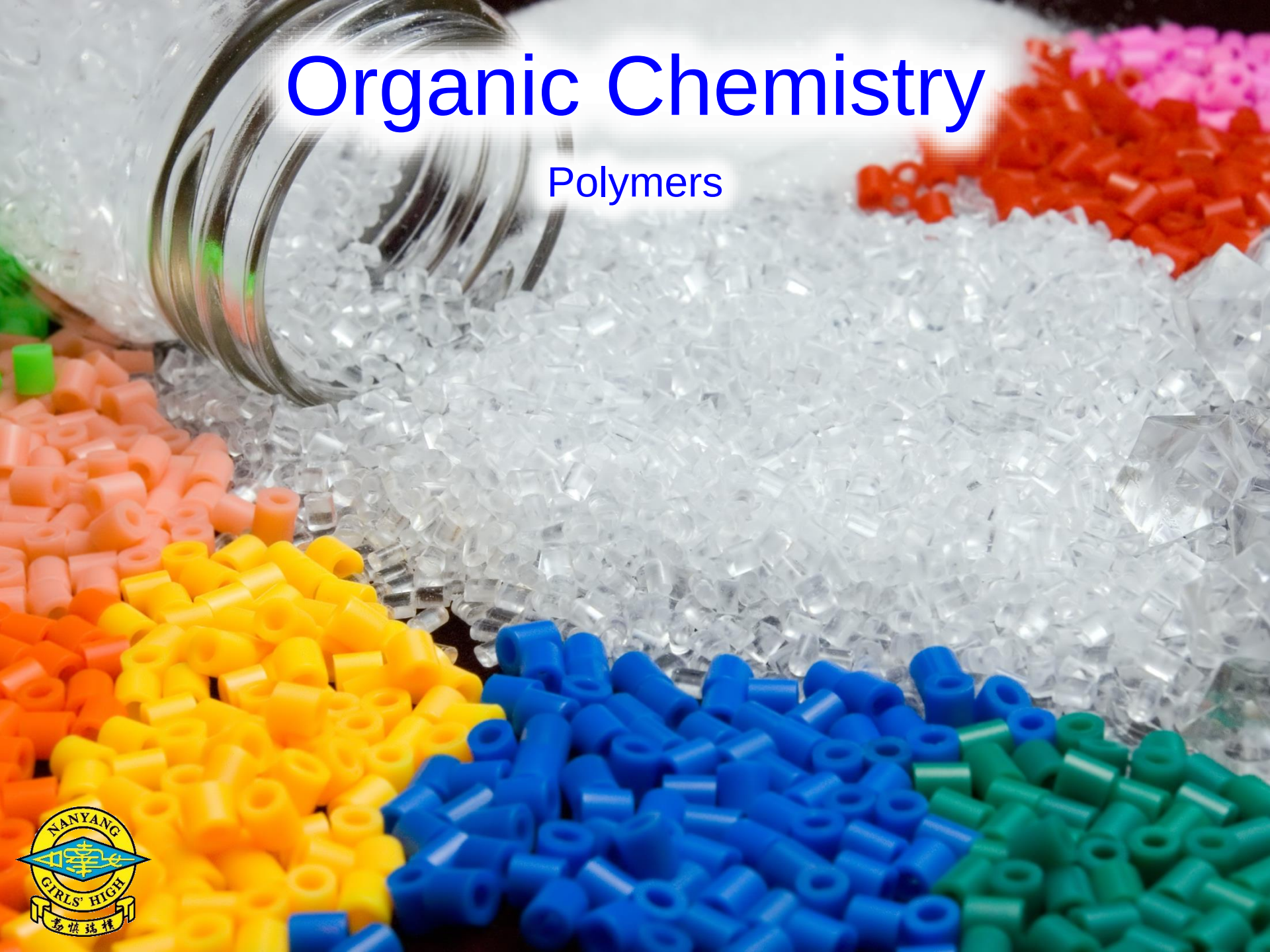
Organic Chemistry

Uses of Polymers

- **Uses of Plastics:** Describe some of the various everyday uses of plastics.
- **Thinking of Alternatives:** Instead of using plastic, what other material could be used for the same application?
- **Compare and Contrast:** Which is the better material for the given application? What are the advantages and disadvantages of using a plastic?
- **Final Thoughts:** Are there any applications which only a plastic is suitable for?

Organic Chemistry

Polymers



Organic Chemistry

Polymers

- A *macromolecule* or *polymer* is a chemical compound, consisting of many repeating units, that has been created through the process of *polymerisation*.

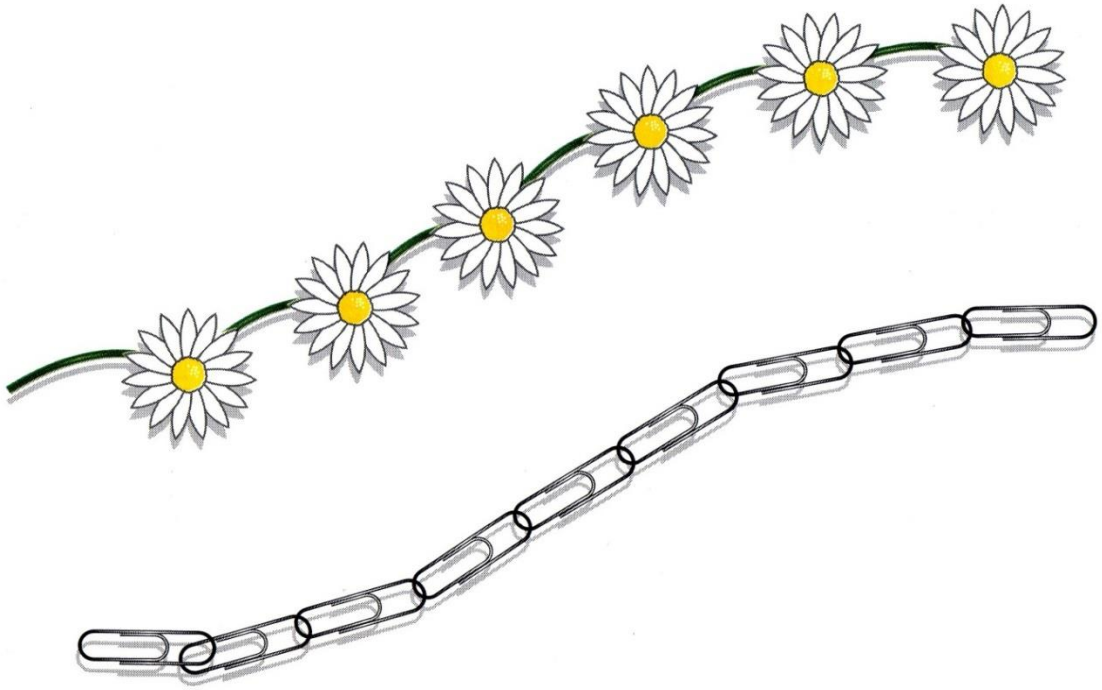
- During *polymerisation*, many thousands of small molecules, called *monomers*, join together to form a *polymer*.

- The word polymer is derived from the ancient Greek words *polus* (meaning many) and *meros* (meaning parts). Hence the term polymer literally means *many parts*.

- Polymers have very high relative molecular masses.

Organic Chemistry

Polymers



- How do these two *models* represent the concept of *polymer*?

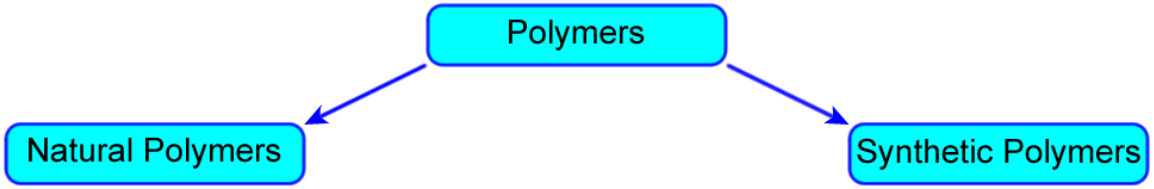
Organic Chemistry

Classification of Polymers

Polymers

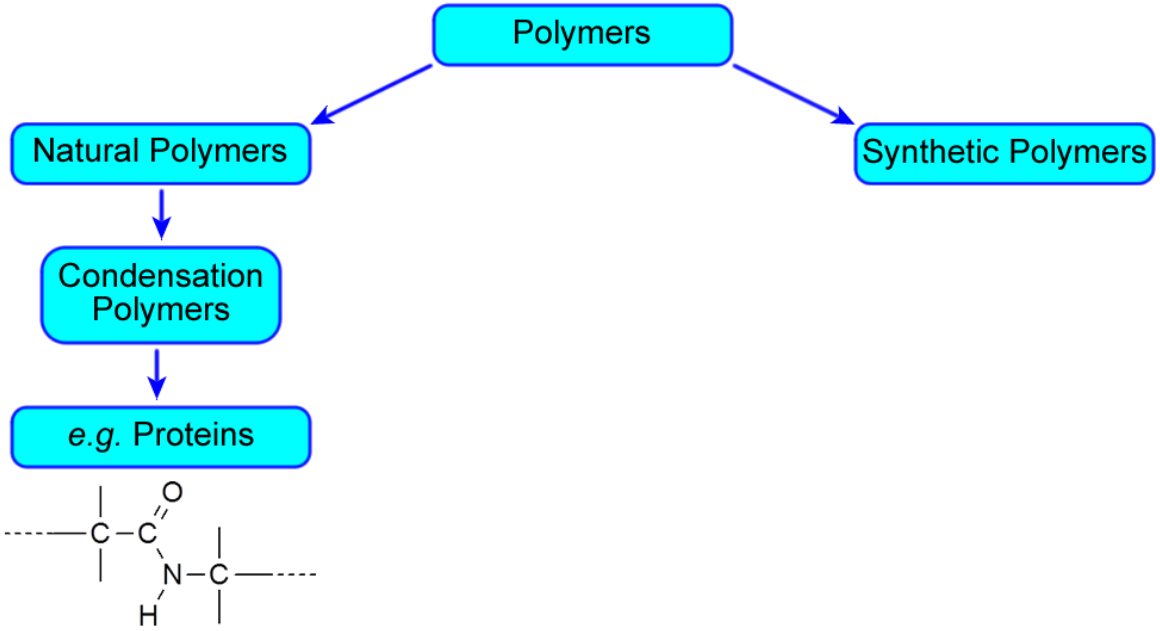
Organic Chemistry

Classification of Polymers



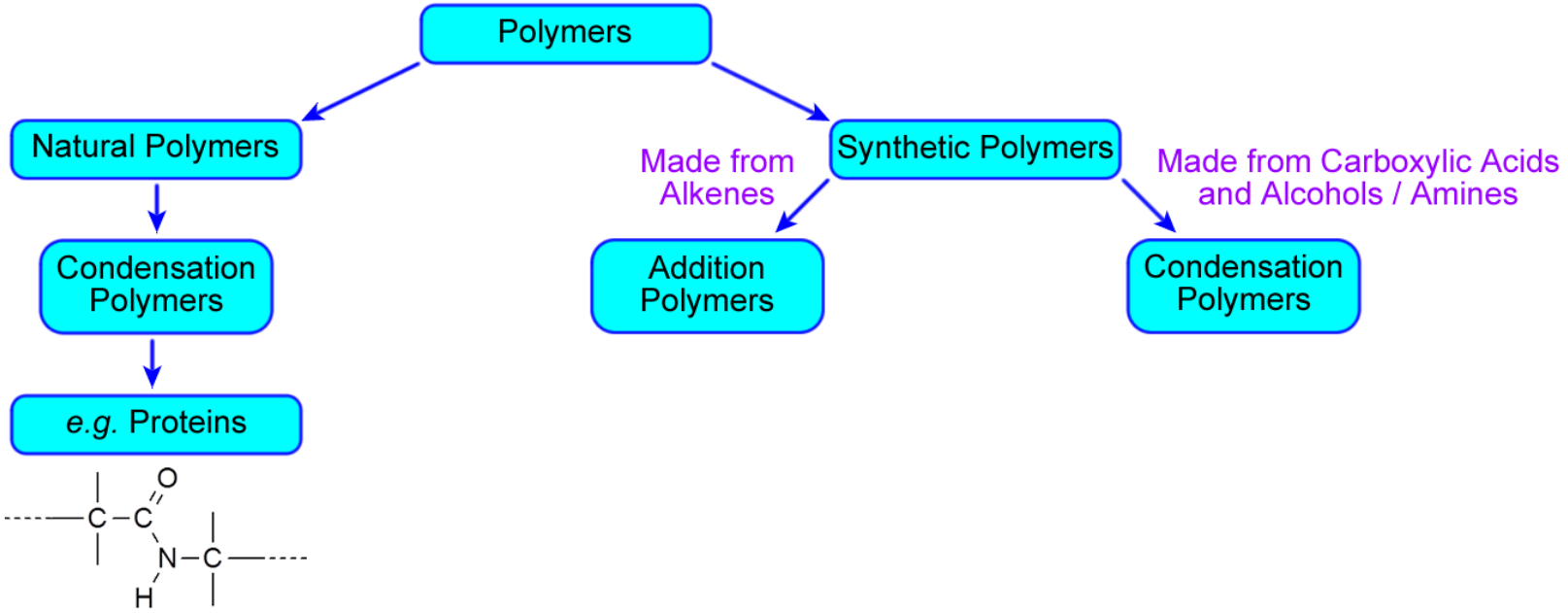
Organic Chemistry

Classification of Polymers



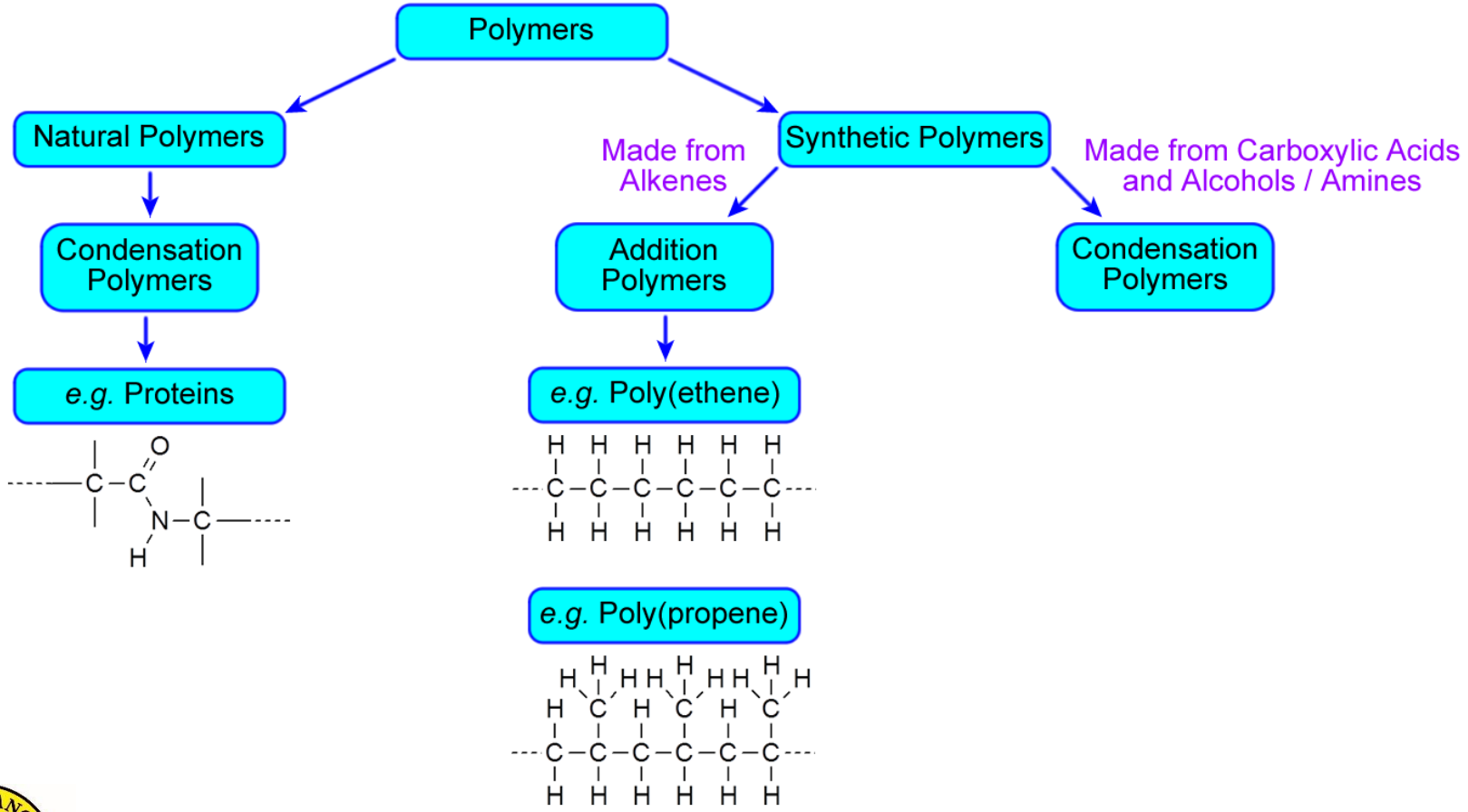
Organic Chemistry

Classification of Polymers



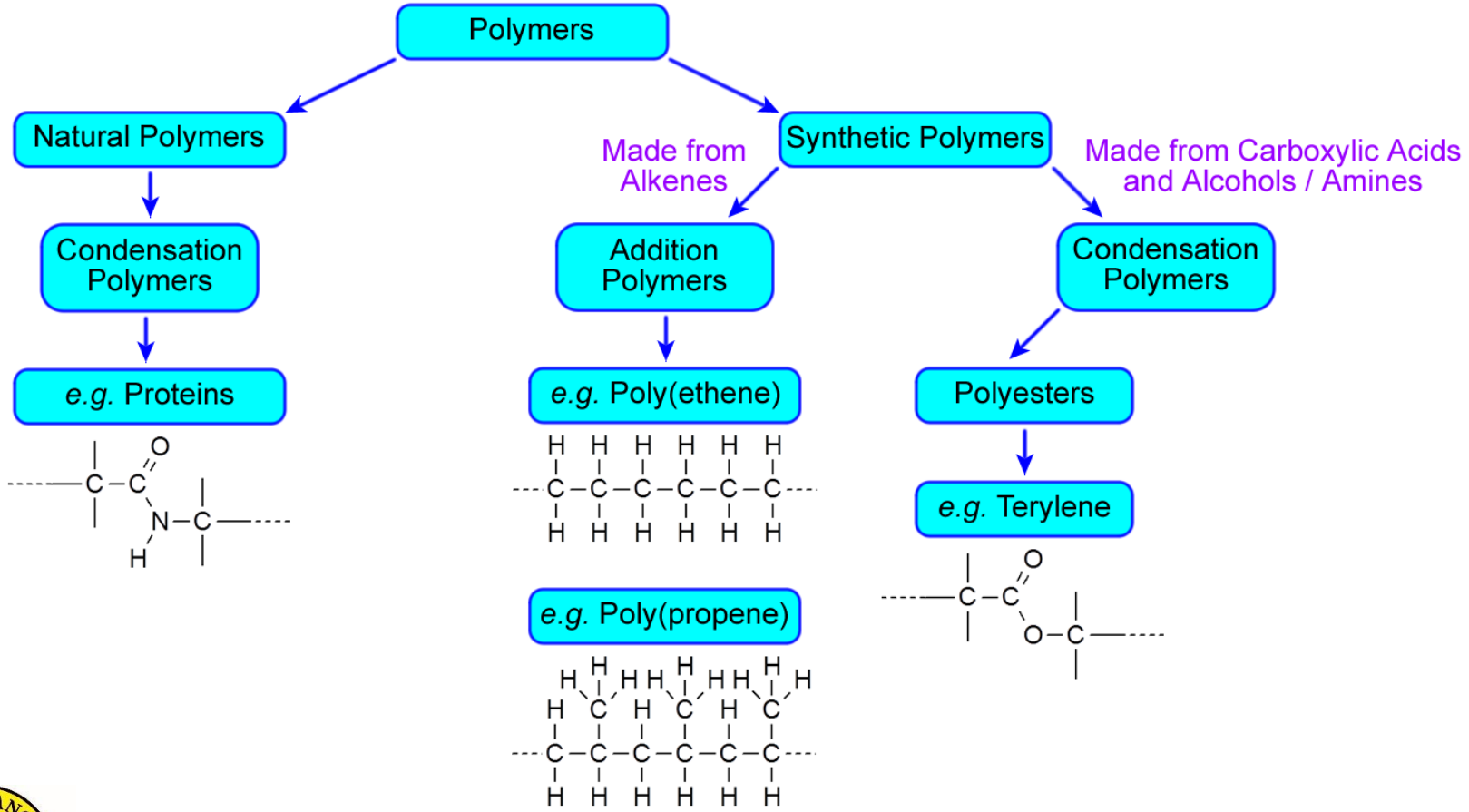
Organic Chemistry

Classification of Polymers



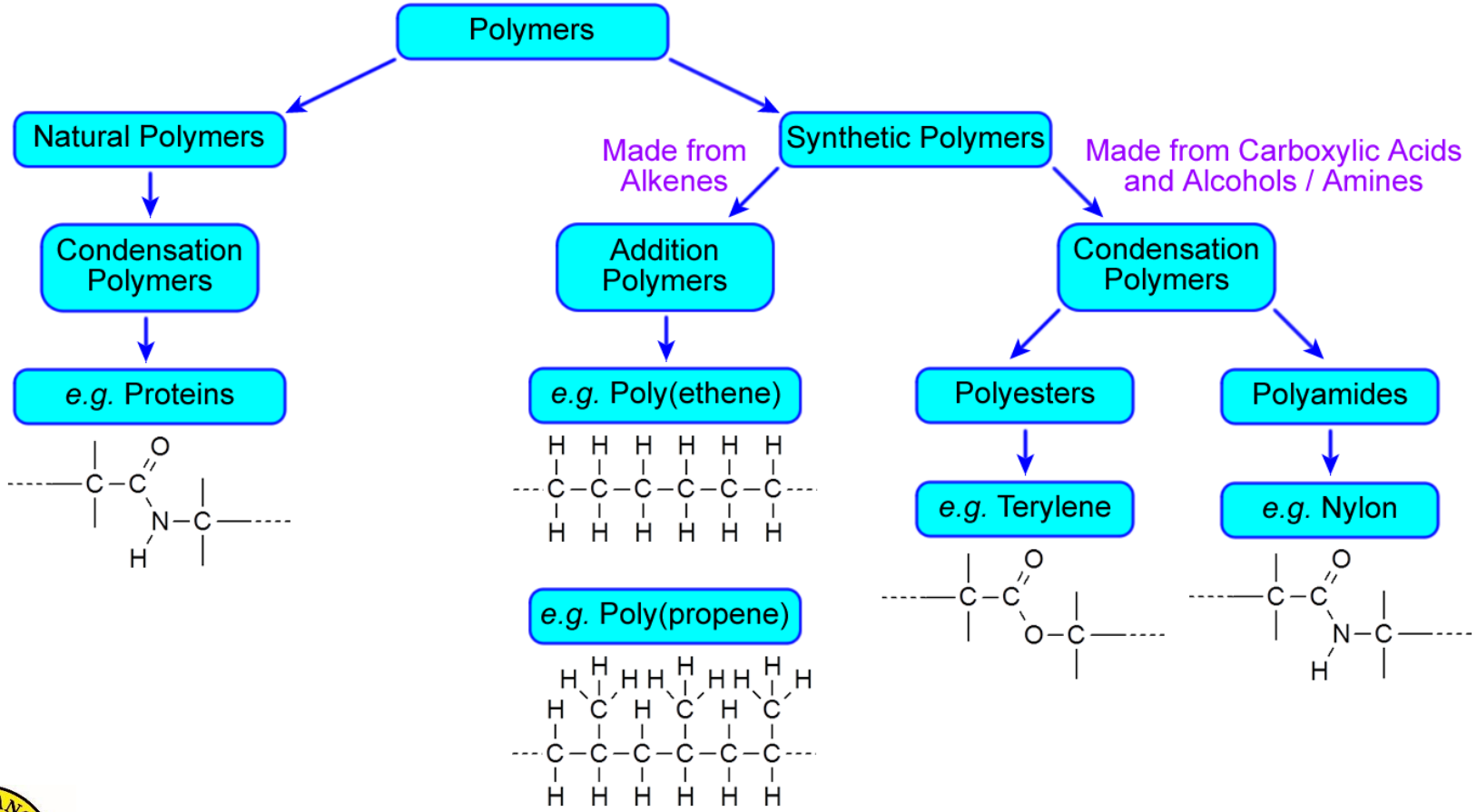
Organic Chemistry

Classification of Polymers



Organic Chemistry

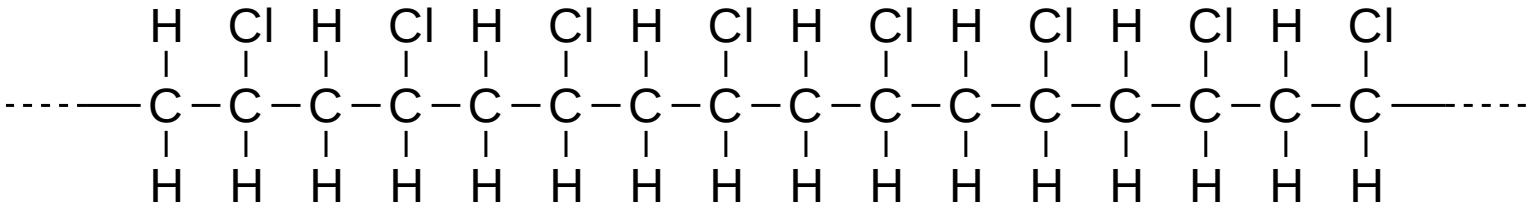
Classification of Polymers



Organic Chemistry

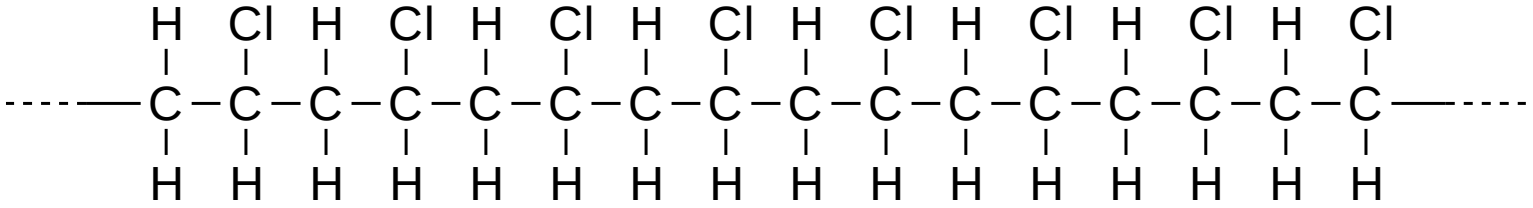
Organic Chemistry

Addition Polymers – Made from Alkenes



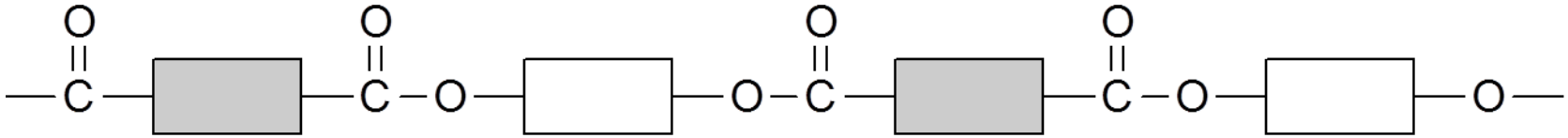
Organic Chemistry

Addition Polymers – Made from Alkenes

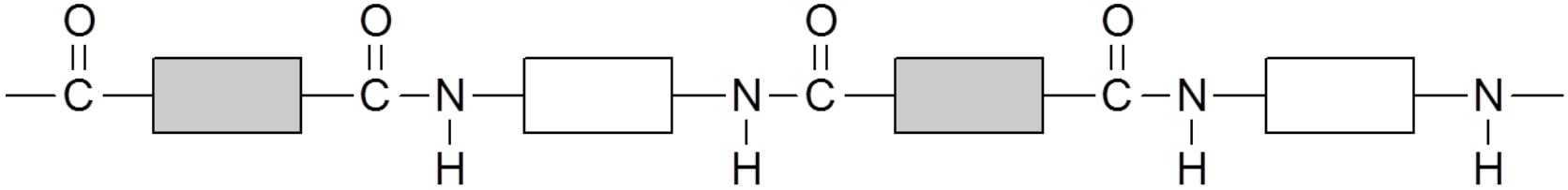


Condensation Polymers

Polyester – Made from a Carboxylic Acid and Alcohol



Polyamide – Made from a Carboxylic Acid and Amine



Organic Chemistry

Addition Polymers

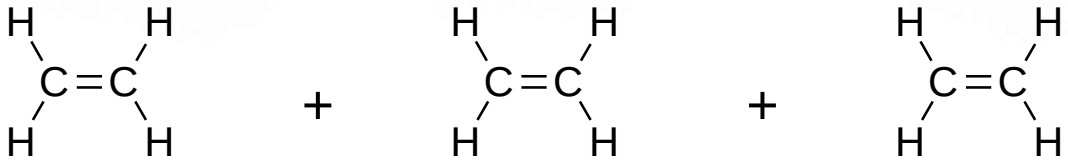
• Return to Main Menu

Organic Chemistry

Addition Polymers

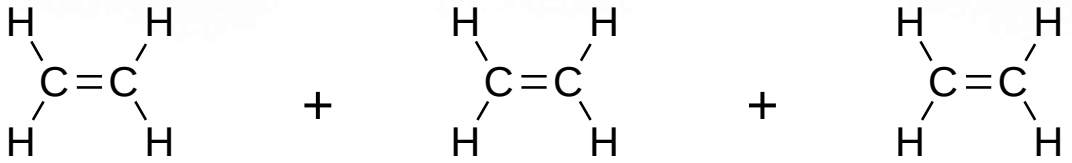
- When the alkene *ethene* polymerises, the polymer that is formed is *poly(ethene)*.
- Poly(ethene) is used to make products such as *clingfilm* and *plastic bags*.

Organic Chemistry



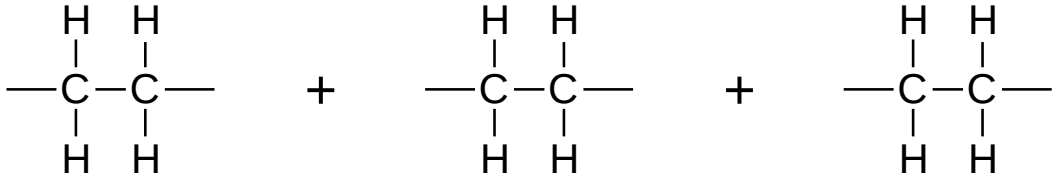
Ethene

Organic Chemistry

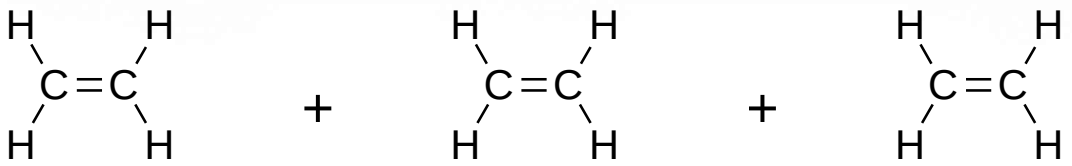


Ethene

The C=C bond breaks open..



Organic Chemistry



Ethene

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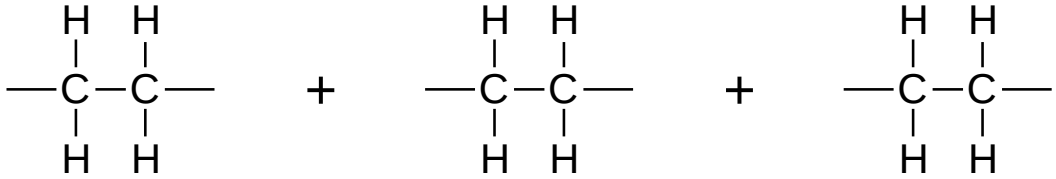
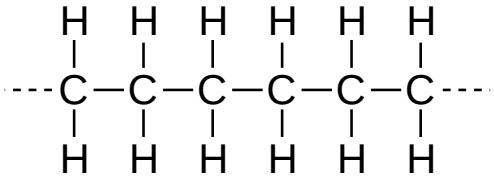


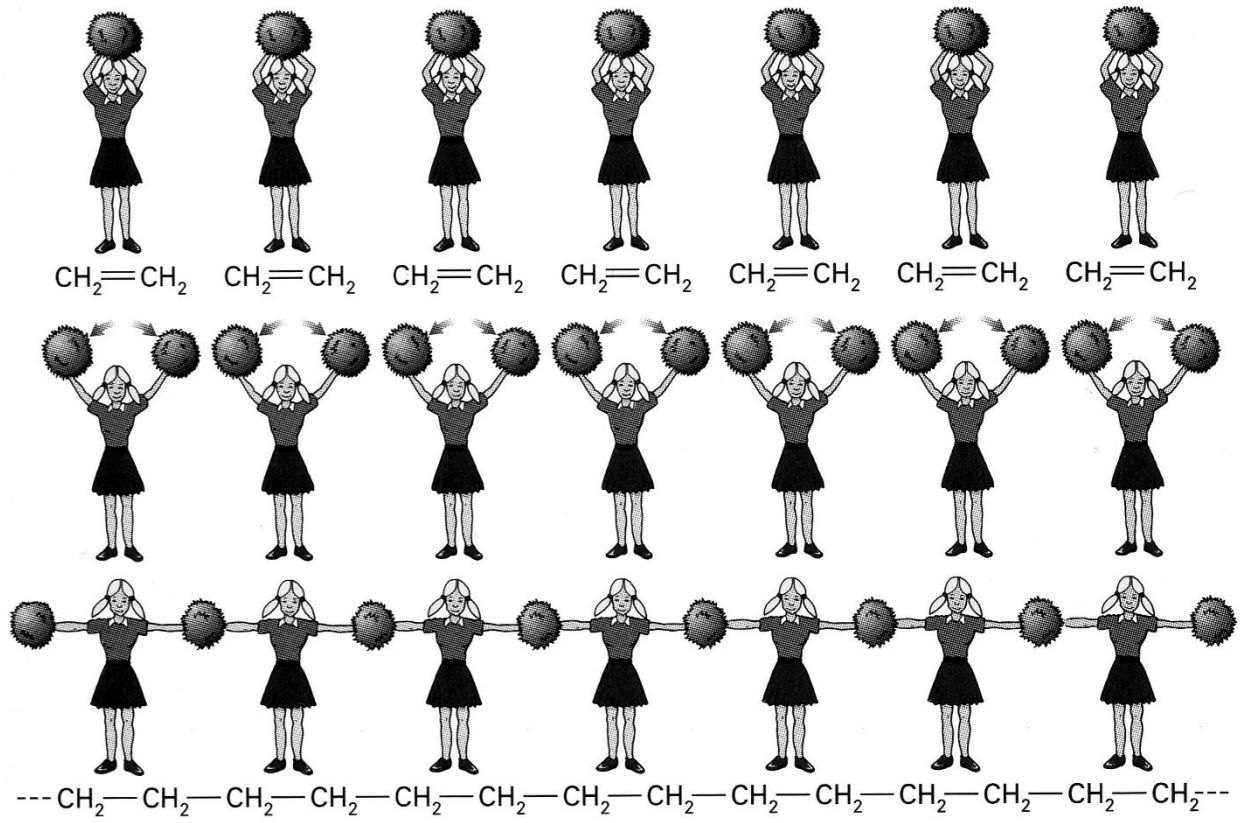
...and the fragments join together to form the polymer.



Poly(ethene)

Organic Chemistry

Addition Polymers



Organic Chemistry

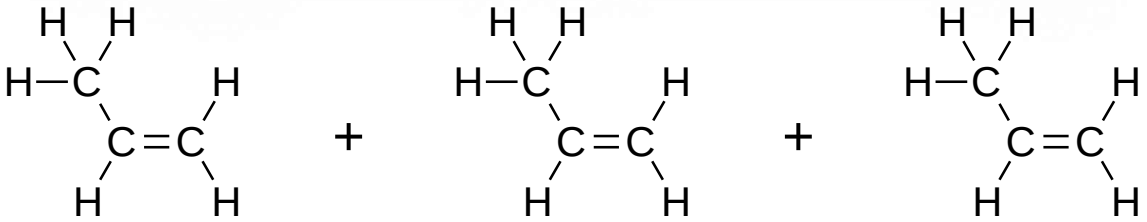
Addition Polymers

Organic Chemistry

Addition Polymers

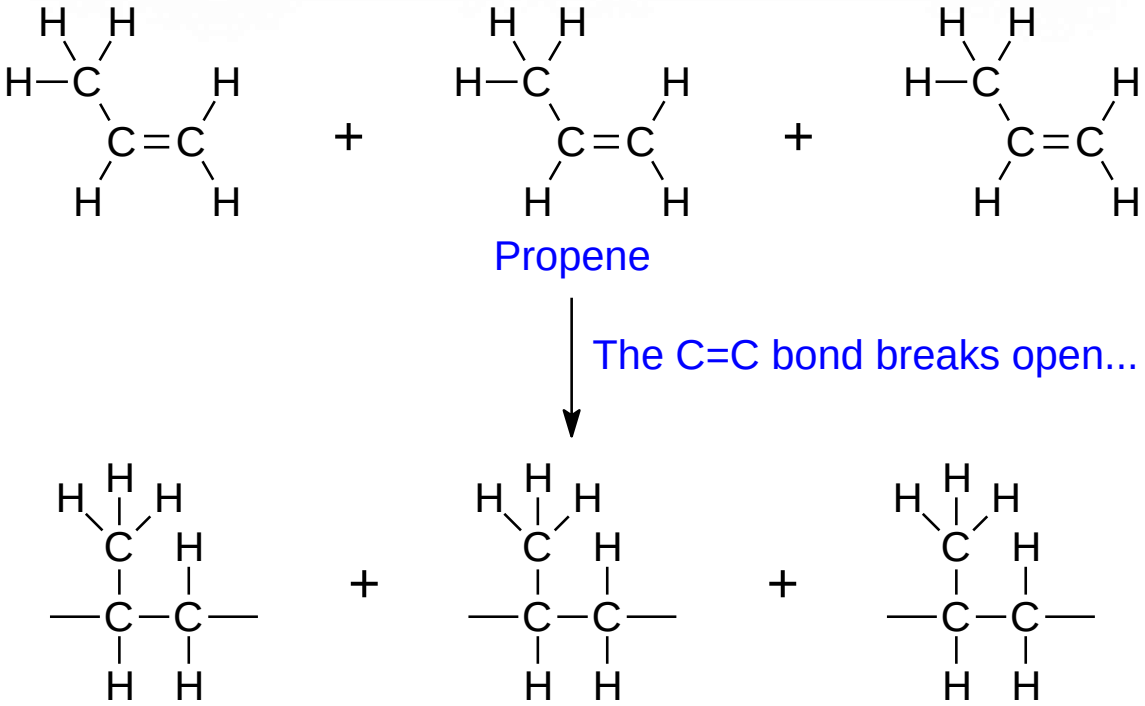
- When the alkene *propene* polymerises, the polymer that is formed is *poly(propene)*.
- Poly(propene) is used to make products such as *plastic bottles*.

Organic Chemistry

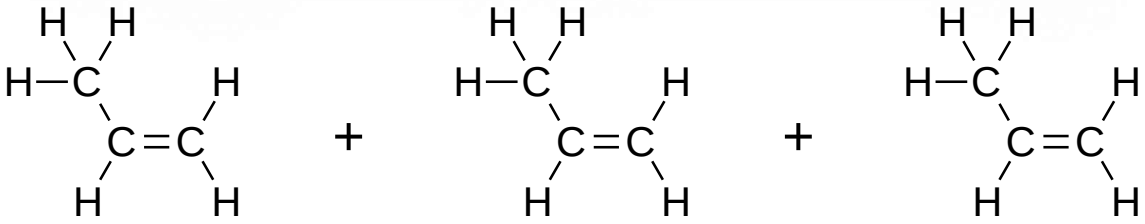


Propene

Organic Chemistry

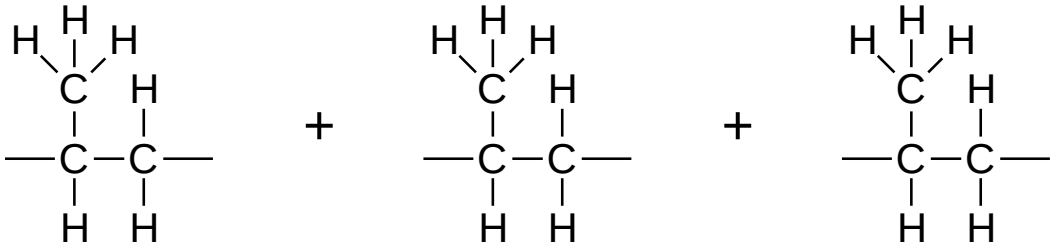


Organic Chemistry

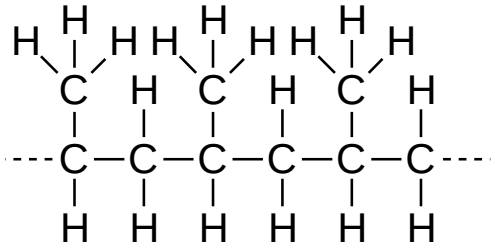


Propene

The C=C bond breaks open...

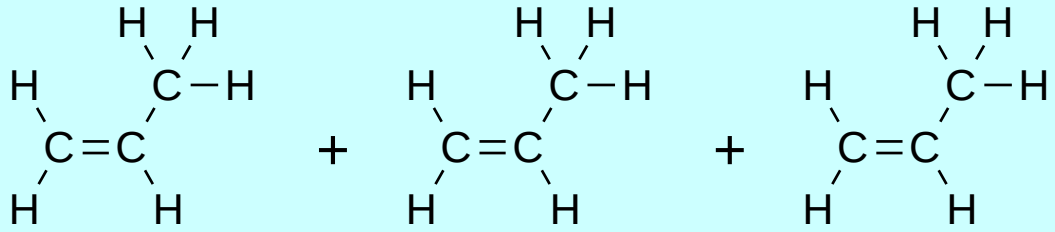


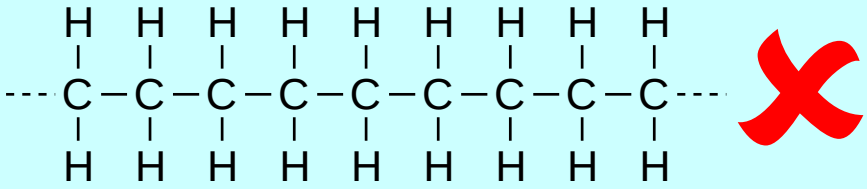
...and the fragments join together to form the polymer.

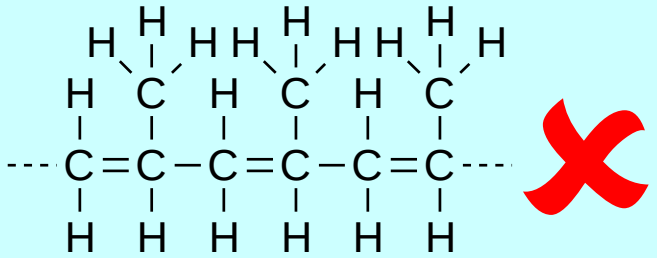


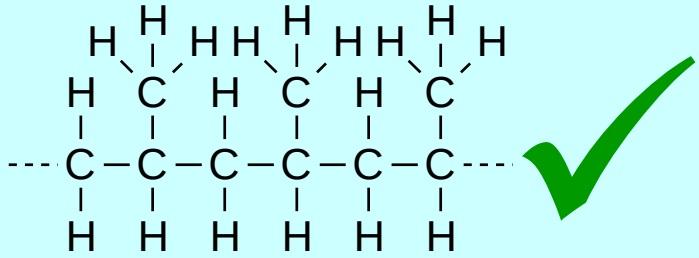
Poly(propene)

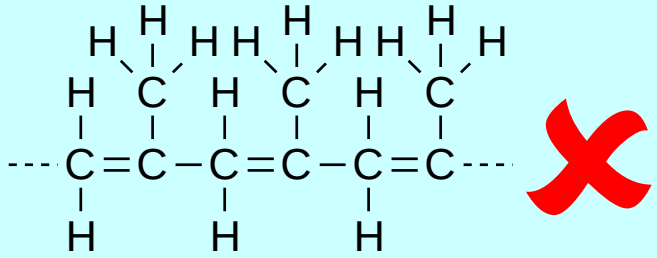
Organic Chemistry

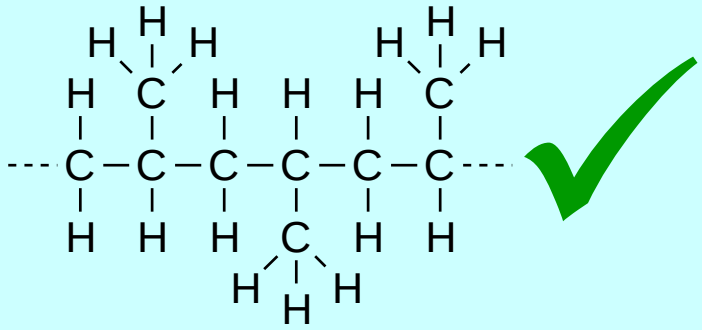


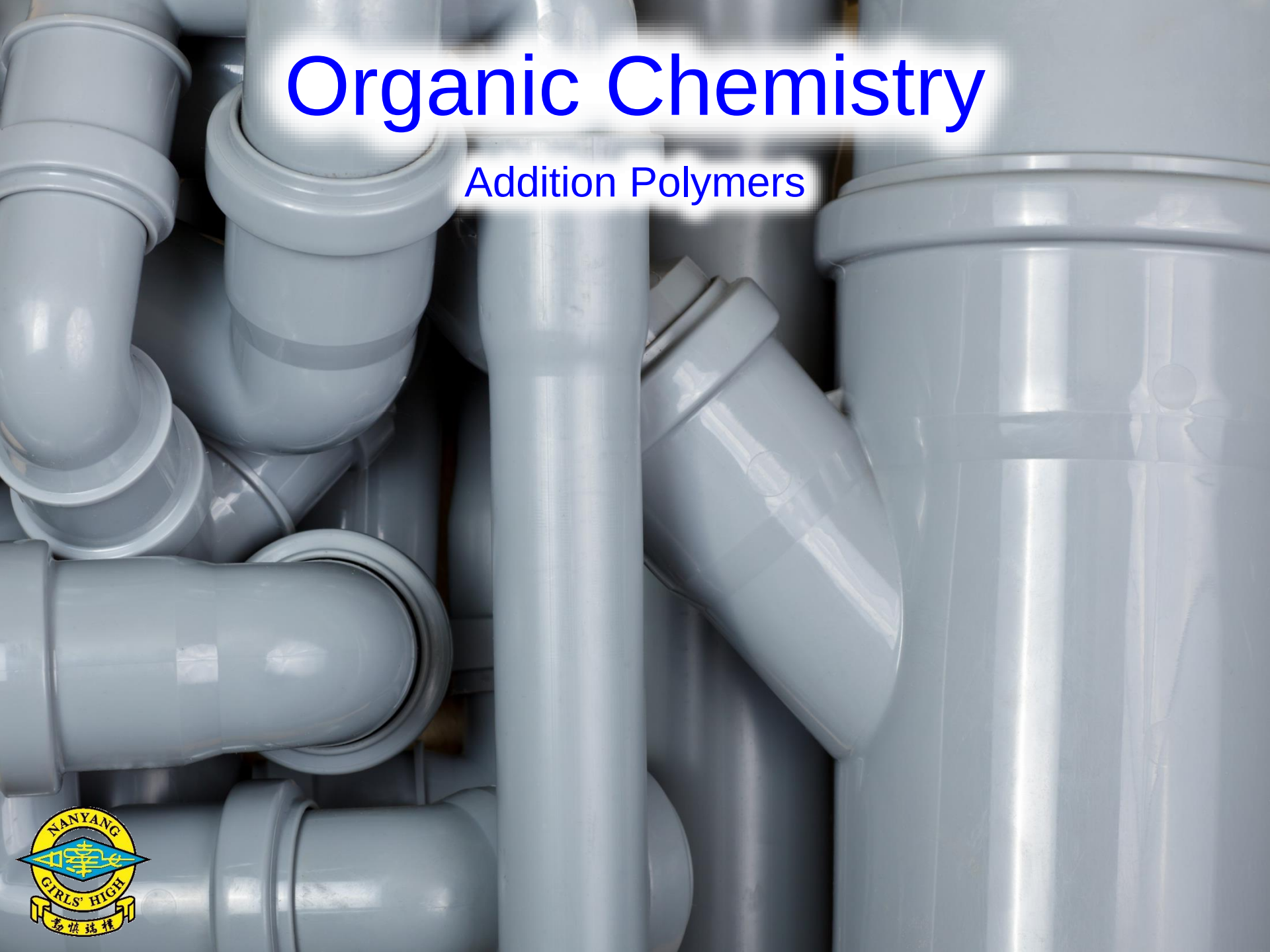












Organic Chemistry

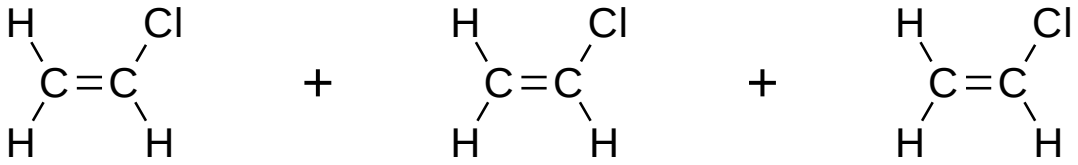
Addition Polymers

Organic Chemistry

Addition Polymers

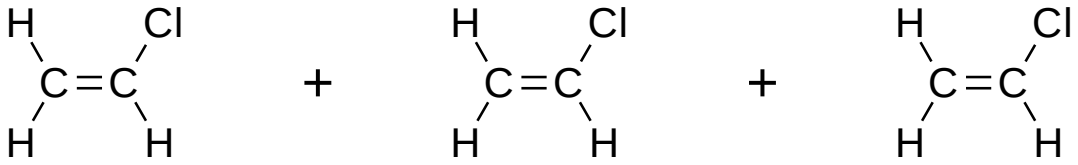
- When the alkene *chloroethene* polymerises, the polymer that is formed is *poly(chloroethene)*.
- Poly(chloroethene) is used to make products such as *plastic water pipes*.

Organic Chemistry



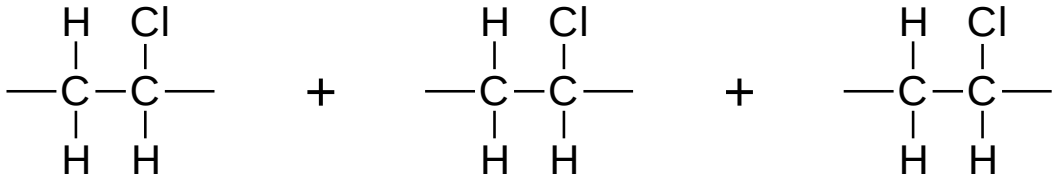
Chloroethene

Organic Chemistry

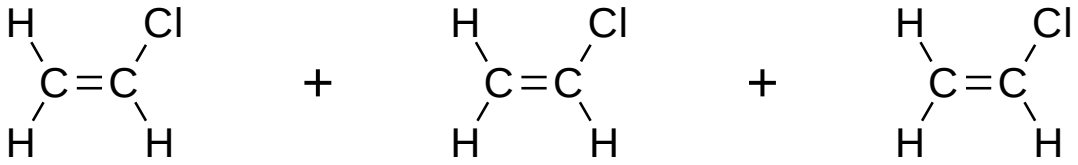


Chloroethene

The C=C bond breaks open..



Organic Chemistry



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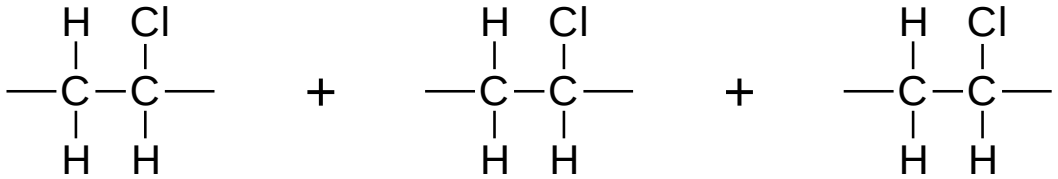
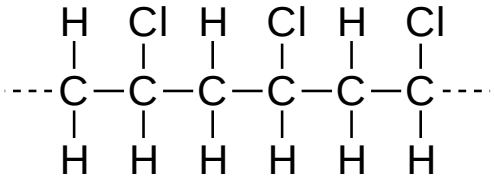


...and the fragments join together to form the polymer.



Poly(chloroethene)

Organic Chemistry

- What chemical test can be done to determine whether or not the addition polymerisation reaction is complete?

- The starting material (monomer) is *unsaturated*, *i.e.* it contains a carbon-to-carbon double covalent bond, C=C.

- The product (polymer) is *saturated*, *i.e.* it only contains carbon-to-carbon single covalent bonds, C–C.

- Test for unsaturation by adding a few drops of bromine dissolved in water (or an inert organic solvent) to the reaction:

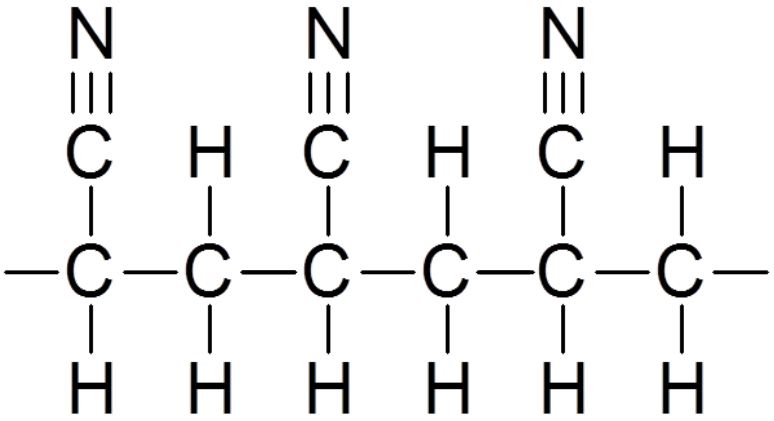
a) If the colour of the bromine fades from reddish-brown to colourless, then the reaction is *incomplete*, *i.e.* C=C present.

b) If the reddish-brown colour of the bromine remains, then the reaction is *complete*, *i.e.* C=C absent.

Organic Chemistry

Addition Polymers

- Which monomer is used to make the addition polymer shown below?



Organic Chemistry

Addition Polymers

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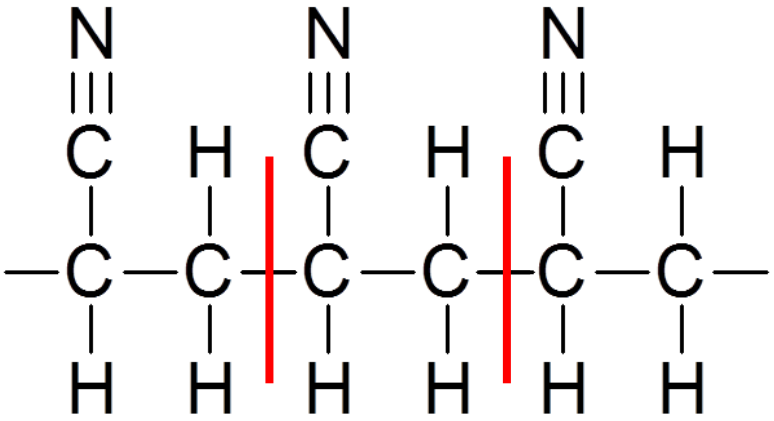
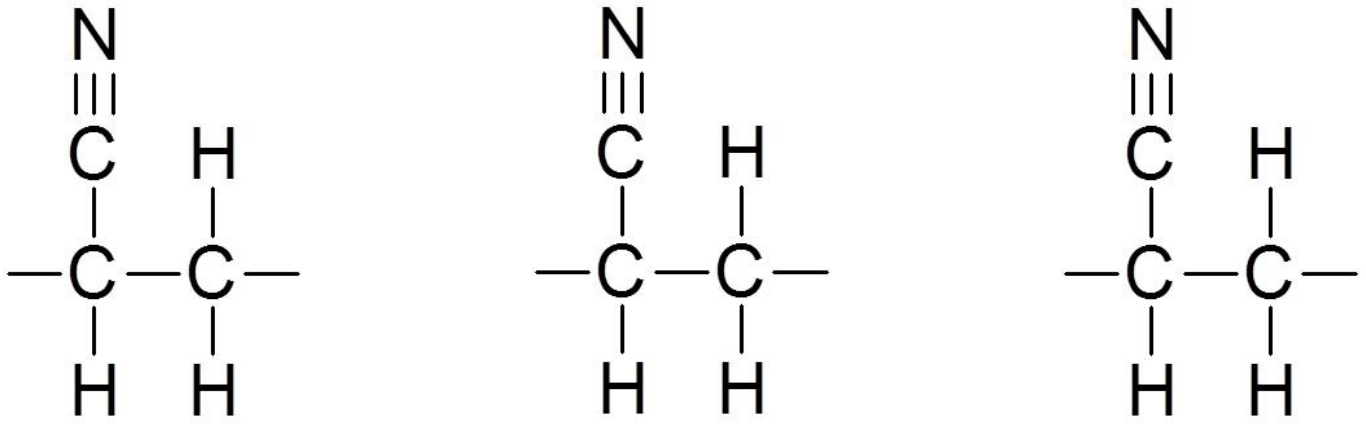


Step 1: Break the carbon chain into groups of *two* carbon atoms.

Organic Chemistry

Addition Polymers

- Which monomer is used to make the addition polymer shown below?



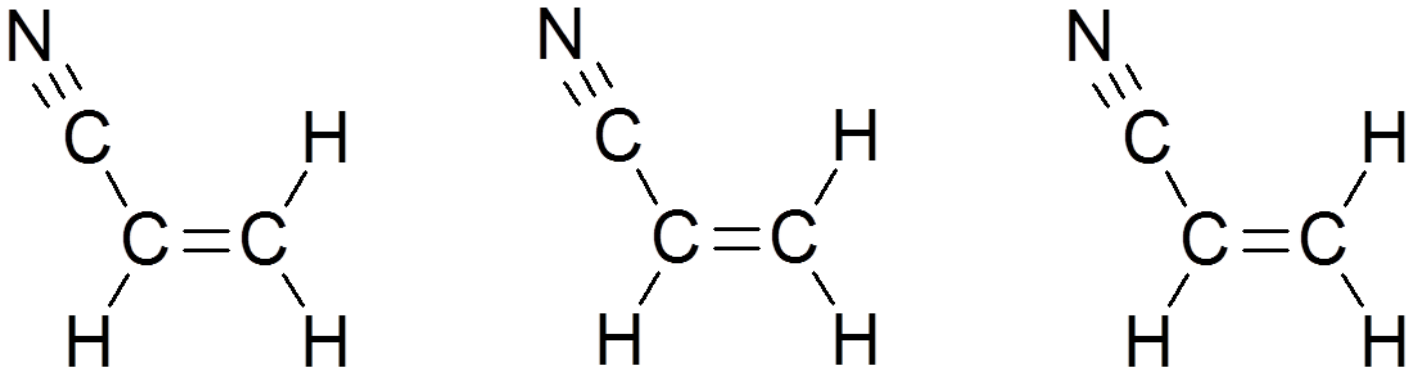
Step 1: Break the carbon chain into groups of *two* carbon atoms.

Step 2: Draw the fragments that are produced.

Organic Chemistry

Addition Polymers

- Which monomer is used to make the addition polymer shown below?

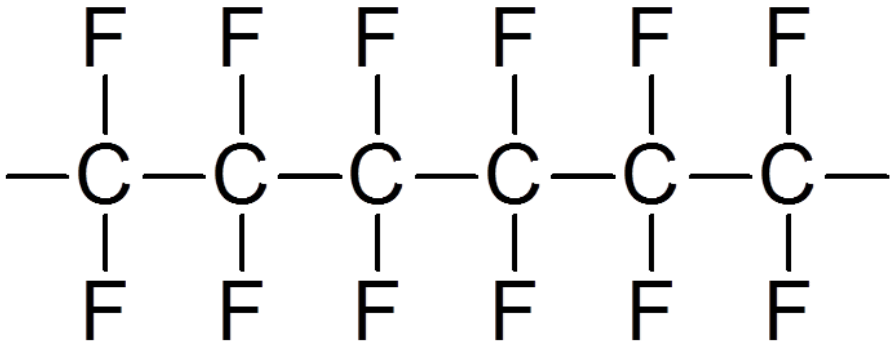


Step 3: Join the two carbon atoms, that were originally part of the carbon chain, together with a *double covalent bond*.

Organic Chemistry

Addition Polymers

- Which monomer is used to make the addition polymer shown below?



Organic Chemistry

Addition Polymers

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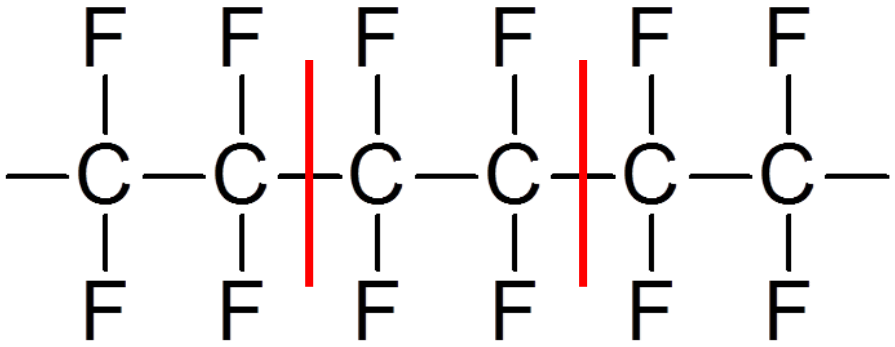

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Organic Chemistry

Addition Polymers

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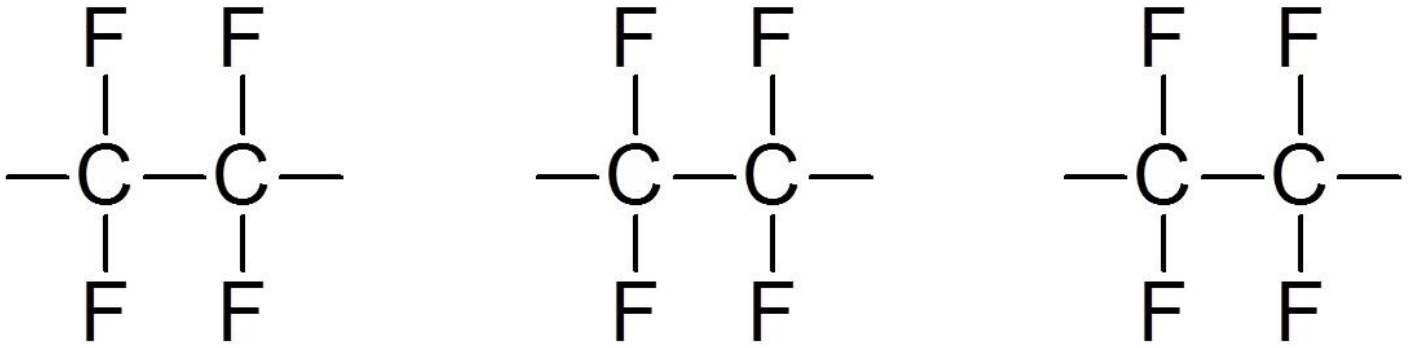

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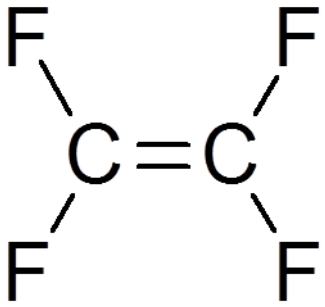
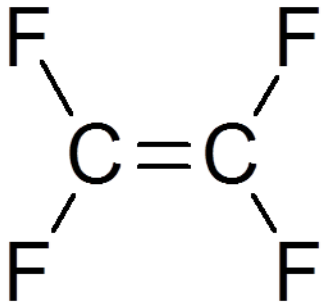
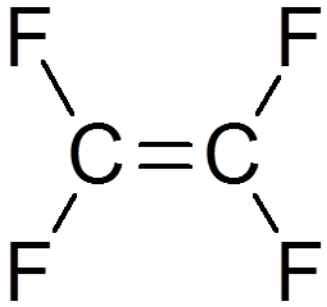
Organic Chemistry

Addition Polymers

- Which monomer is used to make the addition polymer shown below?







Step 3: Join the two carbon atoms, that were originally part of the carbon chain, together with a *double covalent bond*.

Organic Chemistry

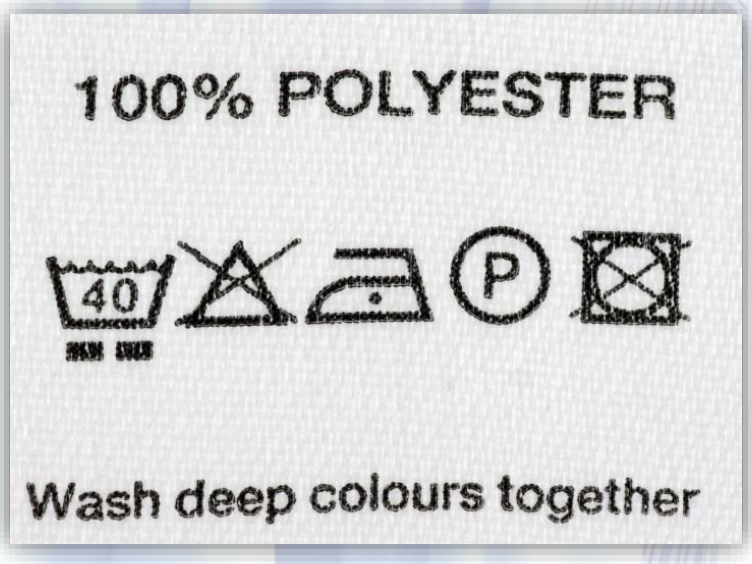
Condensation Polymers – Polyesters

- Return to Main Menu

Organic Chemistry

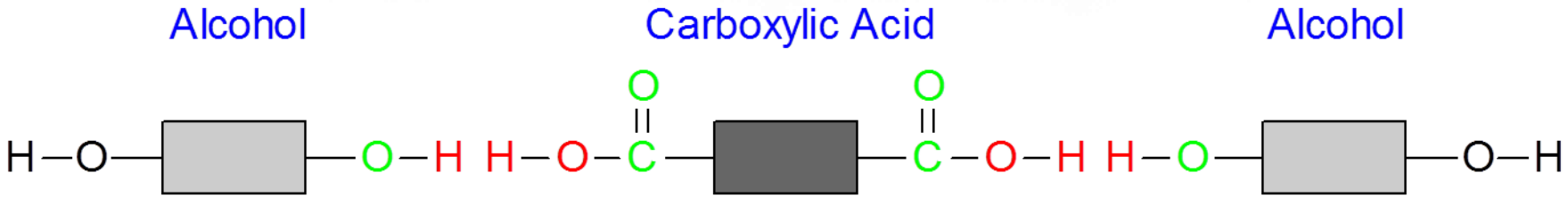
Condensation Polymers – Polyesters

- *Terylene* is an example of a polyester.
- *Terylene* is used for making clothing and curtains.



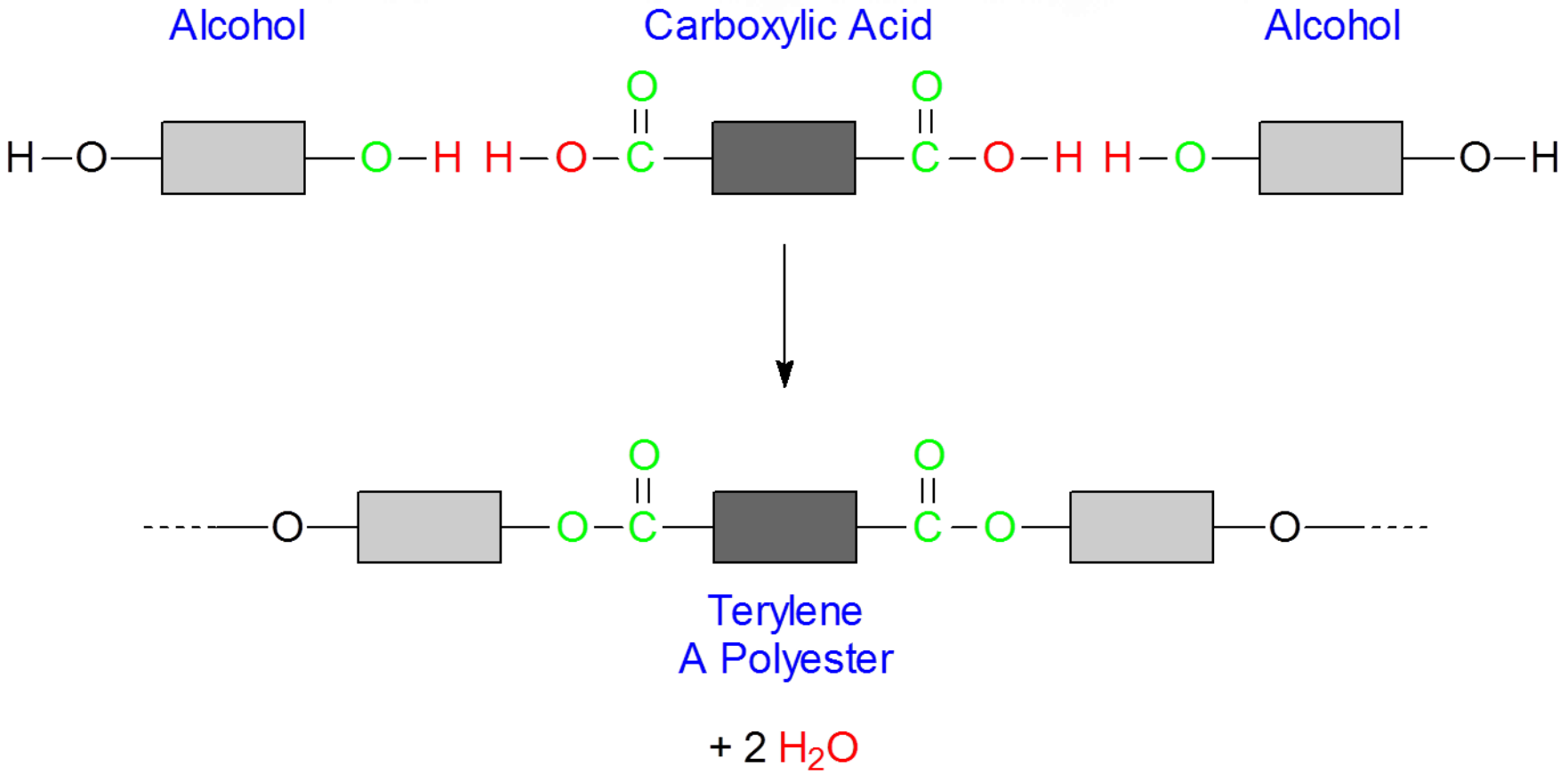
Organic Chemistry

Condensation Polymers – Polyesters



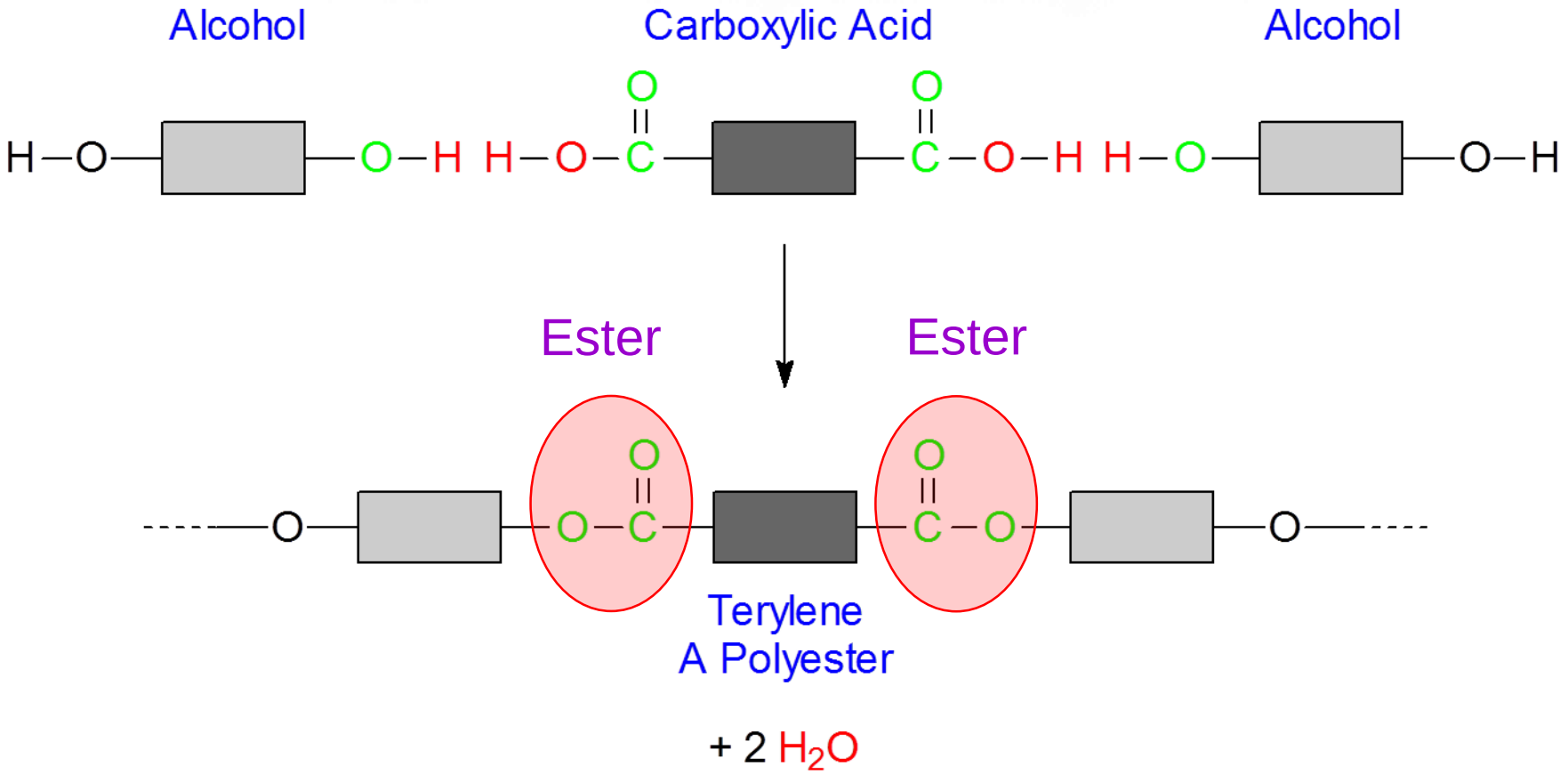
Organic Chemistry

Condensation Polymers – Polyesters



Organic Chemistry

Condensation Polymers – Polyesters



Organic Chemistry

Hydrolysis of a Polyester

- Polyesters can be *hydrolysed* (broken down by water) to form the original monomers. This is done by *warming* the polyester with a *dilute aqueous acid* or *alkali*.

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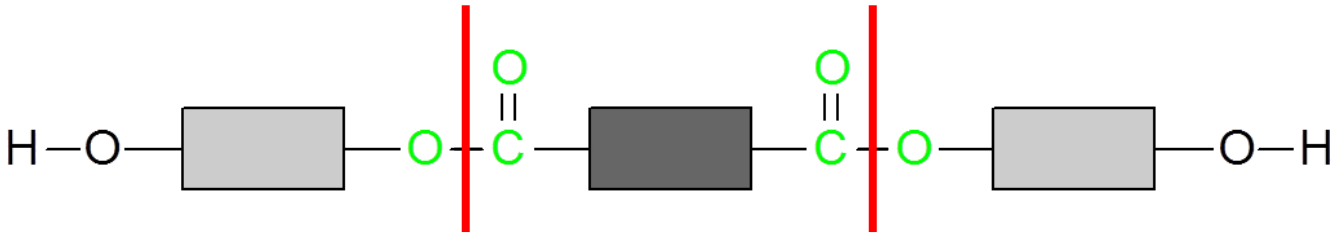

Step 1: Break the C–O bond that is attached to the C=O group.

Organic Chemistry

Hydrolysis of a Polyester

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Step 2: Draw the fragments that are produced after the C–O bond has been broken.

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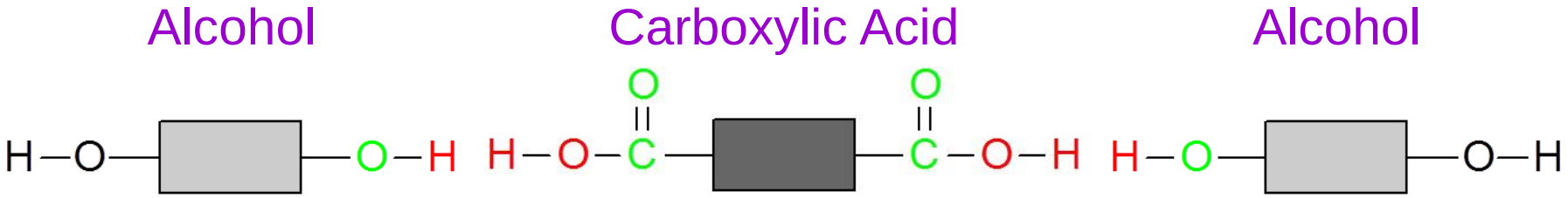


Step 3: Add water, H_2O, to the fragments that are formed.

→ O–H is bonded to the C=O group. This completes the carboxylic acid functional group, *–COOH*.

→ H is bonded to the single O. This completes the alcohol functional group, *–OH*.

Organic Chemistry

Condensation Polymers – Polyamides

• Return to Main Menu

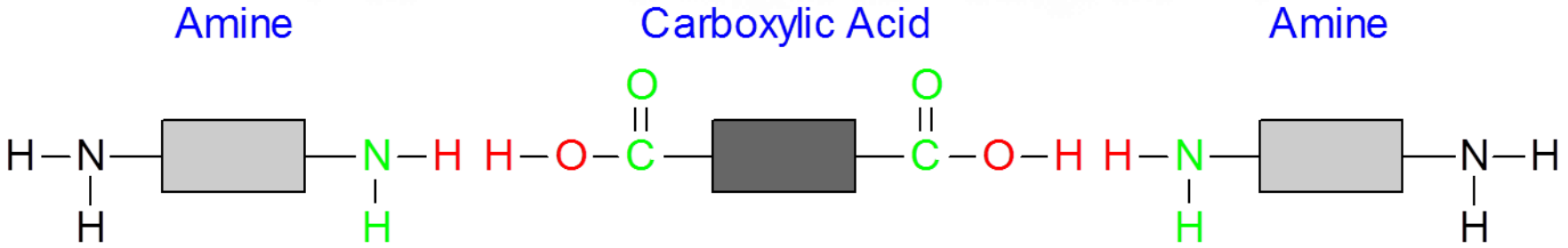
Organic Chemistry

Condensation Polymers – Polyamides

- Nylon is an example of a *polyamide*.
- Nylon is used for making fishing line, parachutes and sleeping bags.

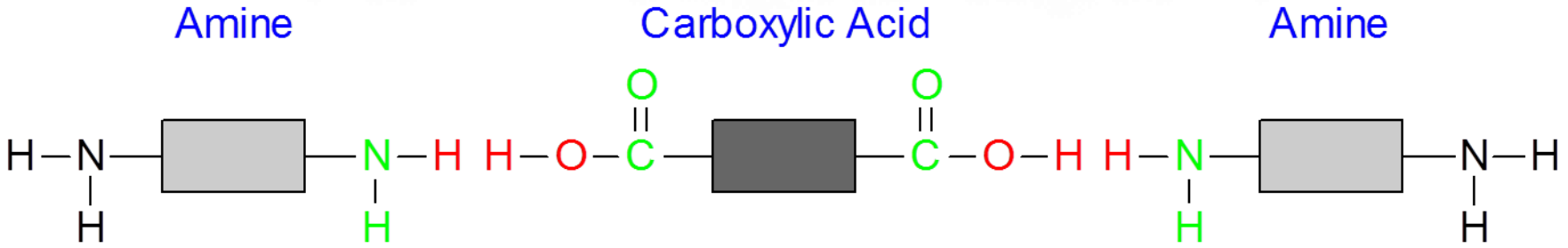
Organic Chemistry

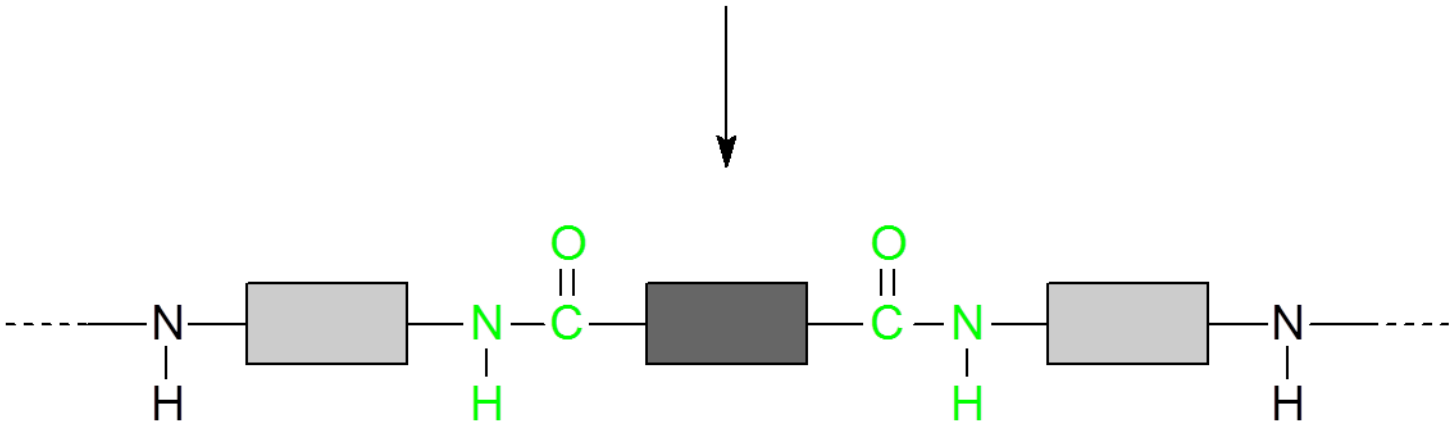
Condensation Polymers – Polyamides



Organic Chemistry

Condensation Polymers – Polyamides



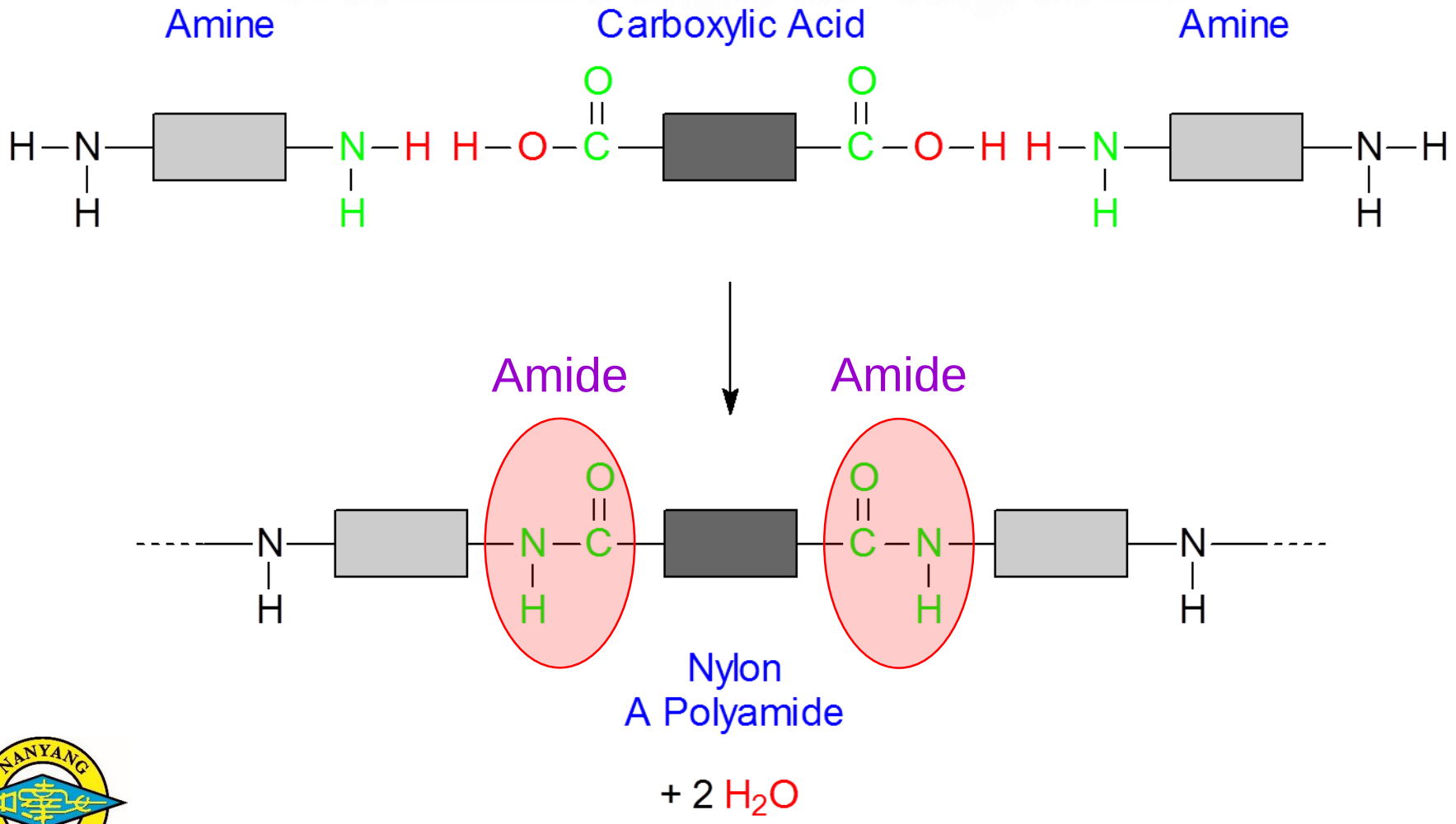


Nylon
A Polyamide

+ 2 H_2O

Organic Chemistry

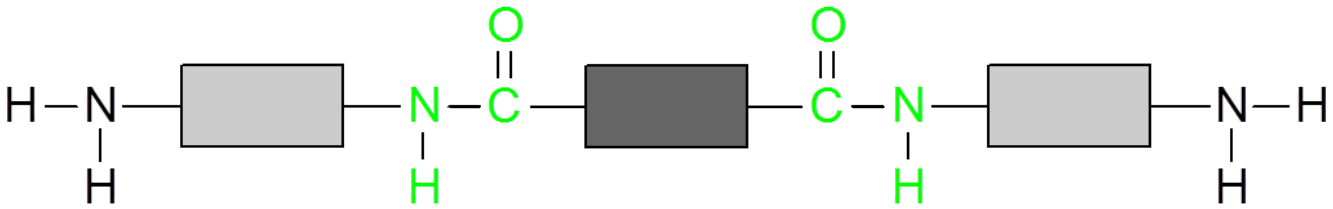
Condensation Polymers – Polyamides



Organic Chemistry

Hydrolysis of a Polyamide

- Polyamides can be *hydrolysed* (broken down by water) to form the original monomers. This is done by *warming* the polyamide with a *dilute aqueous acid* or *alkali*.



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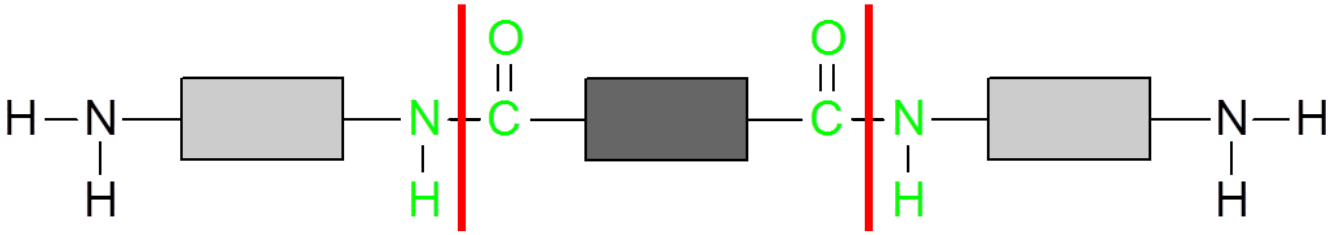

Step 1: Break the C–N bond that is attached to the C=O group.

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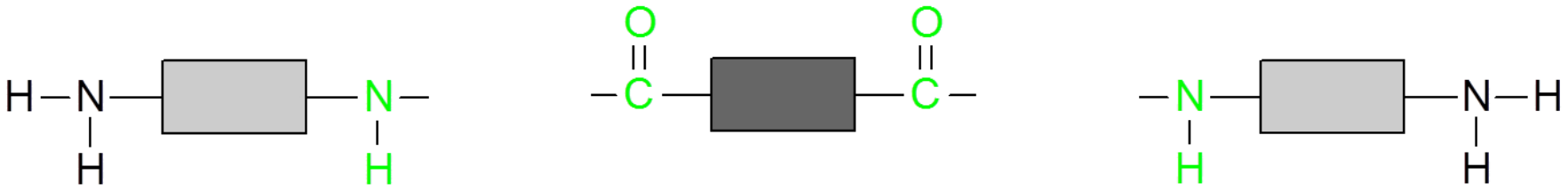

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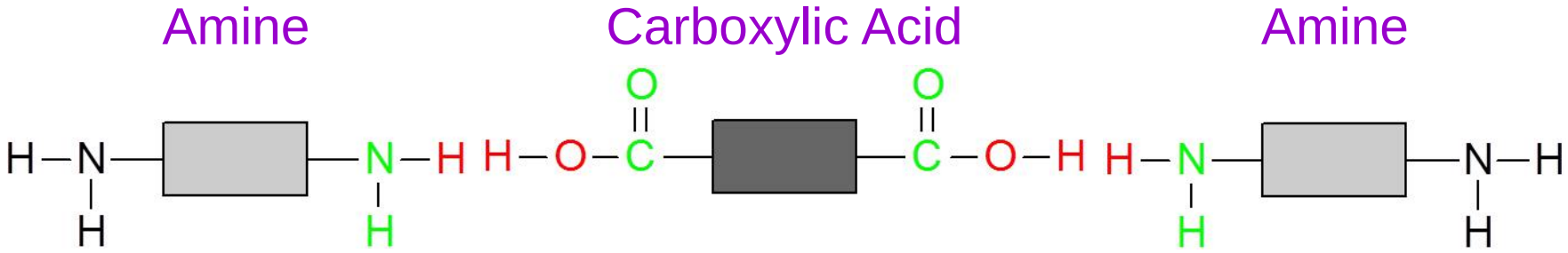


Step 3: Add water, H_2O, to the fragments that are formed.

→ O–H is bonded to the C=O group. This completes the carboxylic acid functional group, *–COOH*.

→ H is bonded to the N–H group. This completes the amine functional group, *–NH_2*.

Organic Chemistry

Compare Addition Polymers and Condensation Polymers

- Addition polymers are made from unsaturated alkenes.
- Condensation polymers are made from carboxylic acids and either alcohols or amines.
- Addition polymers are usually made from only one type of monomer, *i.e.* the alkene.
- Condensation polymers are usually made from two different monomers, *e.g.* carboxylic acid and alcohol.
- Addition polymerisation does not form any side-products.
- Condensation polymerisation forms side-products such as water or hydrogen chloride.

Organic Chemistry

Polymers – Pollution

- Return to Main Menu

Organic Chemistry

Polymers – Pollution

- Most synthetic polymers, or plastics, are *non-biodegradable*. This means that they do not break down or decompose *naturally* into simple compounds, but instead exist unaffected by the environment for very long periods of time. This causes plastics to *accumulate in the environment* where they can be unsightly to humans and dangerous to wild animals.

Organic Chemistry

Polymers – Pollution

Organic Chemistry

Polymers – Pollution

- Because they are *non-biodegradable*, plastics can only be disposed of through *incineration*, but this can release toxic fumes such as *carbon monoxide* (formula: CO) and *hydrogen cyanide* (formula: H−C≡N) into the environment.
- The most environmentally friendly and economic thing to do with a plastic once it has been used is to either *reuse it*, or *recycle it*.

Organic Chemistry

Polymers – Pollution

Organic Chemistry

Polymers – Pollution

- The *Great Pacific Garbage Patch* is estimated to be between 700 000 and 15 000 000 km^2 in area.
- It contains 335 000 plastic items / km^2 weighing a total of 5.1 kg / km^2.
- 20% of the plastic items are thought to be of marine origin, while 80% are thought to originate from land.

Organic Chemistry

Polymers – Pollution

- A recent study has discovered that 90% of sea birds have ingested some form of plastic, and have plastic in their digestive system.
  - In 1960, this figure was only 5%.
- By 2050, it is predicted that almost every sea bird – 99% – will have some form of plastic in its digestive system.

Organic Chemistry

Polymers – Pollution

Organic Chemistry

Polymers – Pollution

- Microbeads are non-biodegradable spheres of plastic, with diameters in the range of 0.5 to 500 μm, where 1 μm = 1×10^{-6} m.

- Microbeads are widely used in scientific research, but it is their use as exfoliants in cosmetics that is a growing concern.

- It is estimated that between *15 – 51 trillion* non-biodegradable microbeads have been washed into the Earth's oceans.

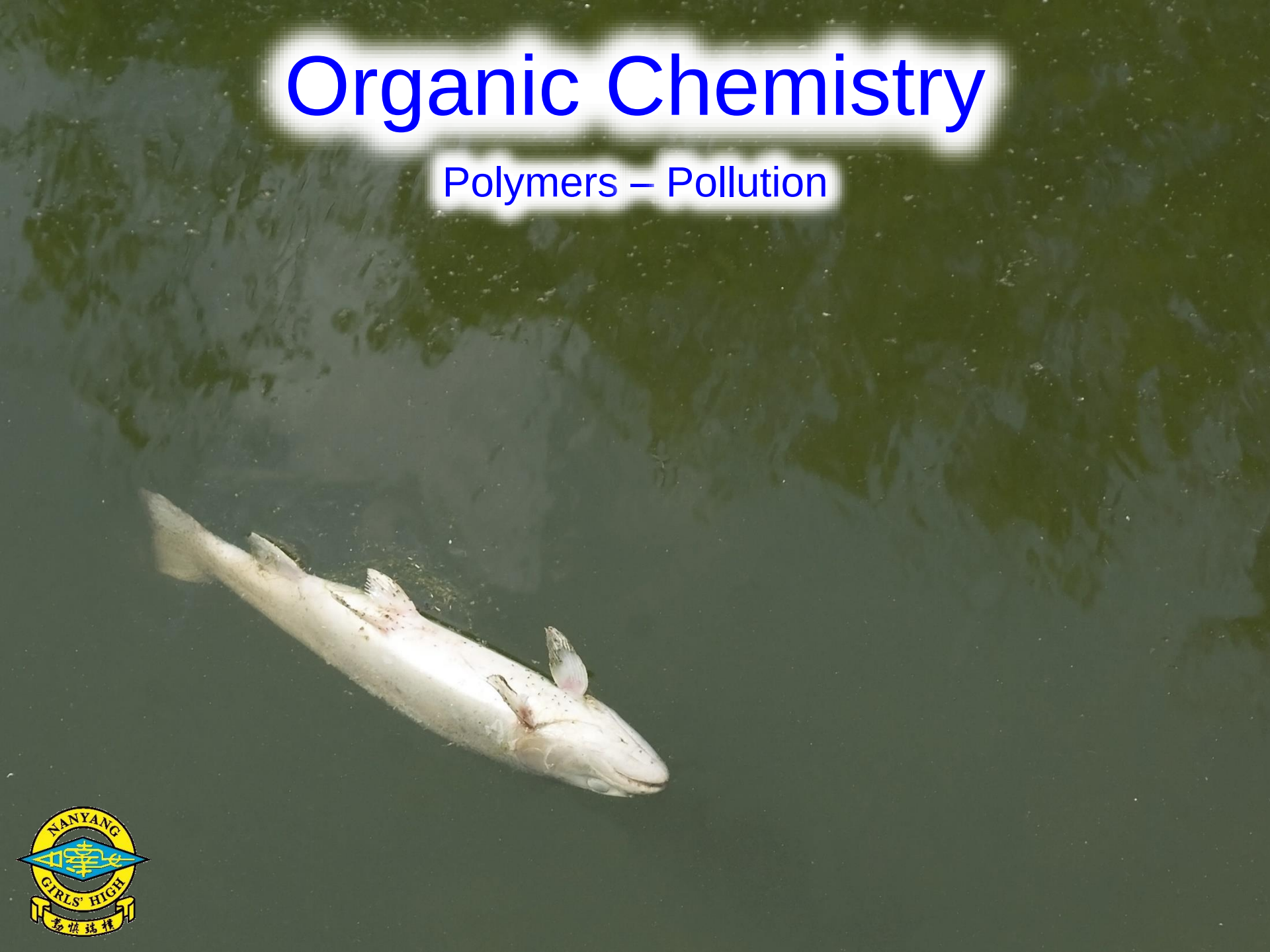
Organic Chemistry

Polymers – Pollution

- Microbeads in the seas and oceans enter the food-chain when they are consumed by aquatic microorganisms such as plankton. At the top of the food-chain are humans.
- The long term effects that microbeads have on human health are unknown.
- The use of microbeads in the manufacture of consumer products is being phased out, and their use will be completely banned by the end of 2017.

Organic Chemistry

Polymers – Pollution



Organic Chemistry

Polymers – Pollution

- In the Earth's oceans, the stresses of wind, waves and tides break plastics into microscopic fragments.
- These microscopic fragments are ingested by plankton and other small organisms which are eventually consumed by fish.
- Researchers at the University of Exeter (England) estimate that anyone consuming an average amount of seafood ingests about 11 000 plastic particles a year.

Organic Chemistry

Polymers – Pollution

Organic Chemistry

Presentation on

Macromolecules

by Dr. Chris Slatter

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10th February 2016