5.7: Polymers

Plastics are synthetic substances that can be moulded (often under heat and pressure) and retain the shape they are moulded into.

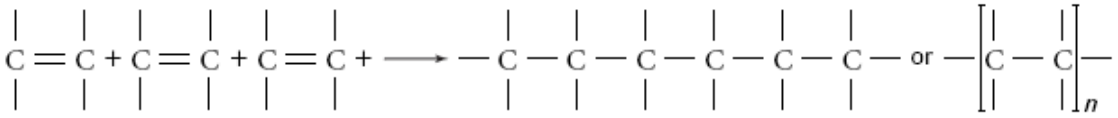
Polymers are large molecules that are made by linking together many smaller molecules (many repeating subunits), much like paper clips in a long chain.

Addition Polymers

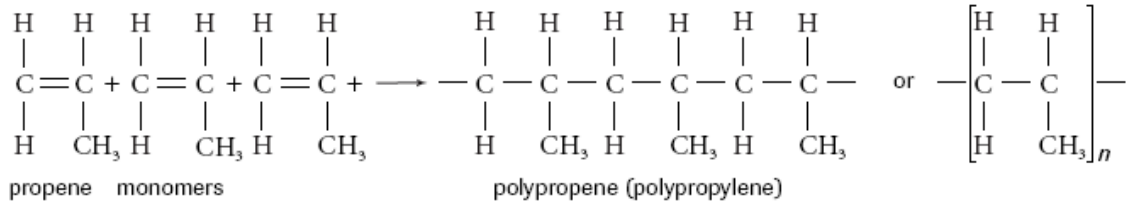
Addition polymers result from the *addition reactions* of small subunits that contain double or triple carbon-carbon bonds. The small subunits that make up a polymer are called **monomers**. The monomers in a polymer may all be identical, or two or more monomers may occur in a repeating pattern.

Examples:

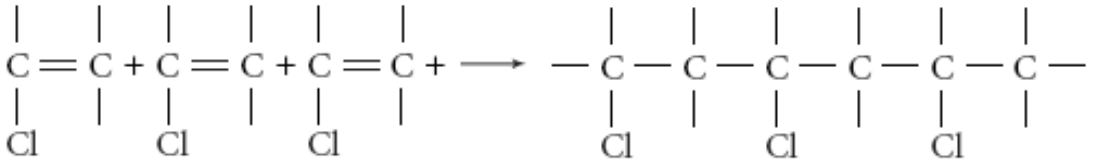
Polyethene (commonly called polyethylene) is used for insulating electrical wires and for making plastic containers. Its monomers are ethene molecules that undergo addition reactions with other ethene molecules. As a result, the double bond in each ethene monomer becomes a single bond. The **polymerization** reactions may continue until thousands of ethene molecules have joined the chain.



Propene also undergoes addition polymerization to produce polypropene, commonly called polypropylene, is used in things like rock climbing ropes.



Ethene molecules that have other substituted groups produce other polymers. For example, polyvinyl chloride (commonly known as PVC) is an addition polymer of chloroethene, C_2H_5Cl. PVC is used as insulation for electrical wires and drain pipes, and as a coating on raincoat and upholstery fabrics.



vinyl chloride monomers

polyvinyl chloride (PVC)

Properties of Addition Polymers

- They are chemically unreactive (ideal for containers)
- Generally they are flexible and mouldable

Some monomers have two double bonds. These monomers can therefore link to two separate polymer chains at the same time. As well as forming their regular polymer chain, they form strong covalent bonds, called **crosslinks**, between adjacent polymer chains. The more crosslinks there are, the more rigid the plastic is.

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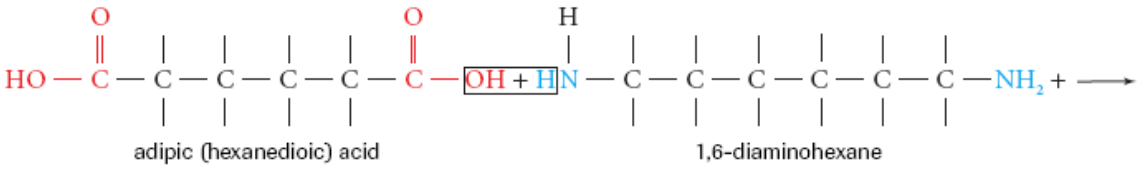
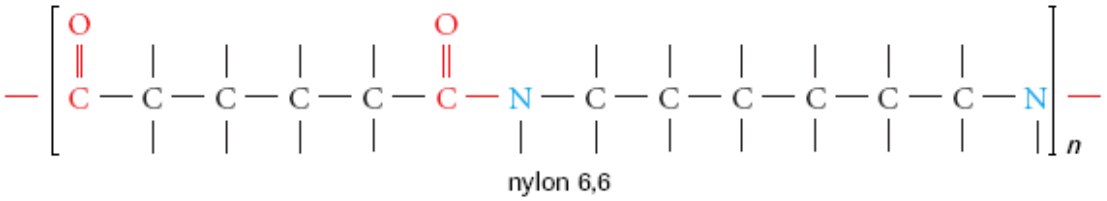
Condensation Polymers

Recall that carboxylic acids react with alcohols to form esters, and with amines to form amides. These reactions are called *condensation* reactions.When monomers can join, end to end, in ester or amide linkages, polymers called **polyesters** and **polyamides** are produced. Because polyesters and polyamides result from condensation reactions, these polymers are called **condensation polymers**.

To form a polyester or a polyamide, the monomer molecule must have *two functional groups*, one at each end of the molecule. The functional groups that meet end to end must be a carboxyl group (–COOH) and either a hydroxyl (−OH) group or an amine group (–NH2). For example, nylon is a polyamide formed from two different monomers: one with a carboxyl group at each end, and the other with another amine group at each end. This allows an amide to form at each junction of monomers, producing long chains of nylon.





You probably encounter many polyesters in your daily life. One of the most familiar polyesters is Dacron, which is found in clothing fabrics.

Properties of Condensation Polymers

Crosslinks play an important part in the properties of condensation polymers. Polyamide chains, such as nylon, have amine groups that can hydrogen-bond with the –C=O groups on other chains. As a result, polyamide chains form exceptionally strong fibres. Similarly, the strong attractive forces between polar groups in polyesters, such as Dacron, hold the separate polymer chains together, giving them considerable strength.

A polymer called Kevlar illustrates the effect of crosslinking in condensation polymers. Kevlar has very special properties. It is stronger than steel and heat resistant, yet it is lightweight enough to wear. Kevlar is used to make products such as aircraft parts, sports equipment, protective clothing for firefighters, and bulletproof vests for police officers.

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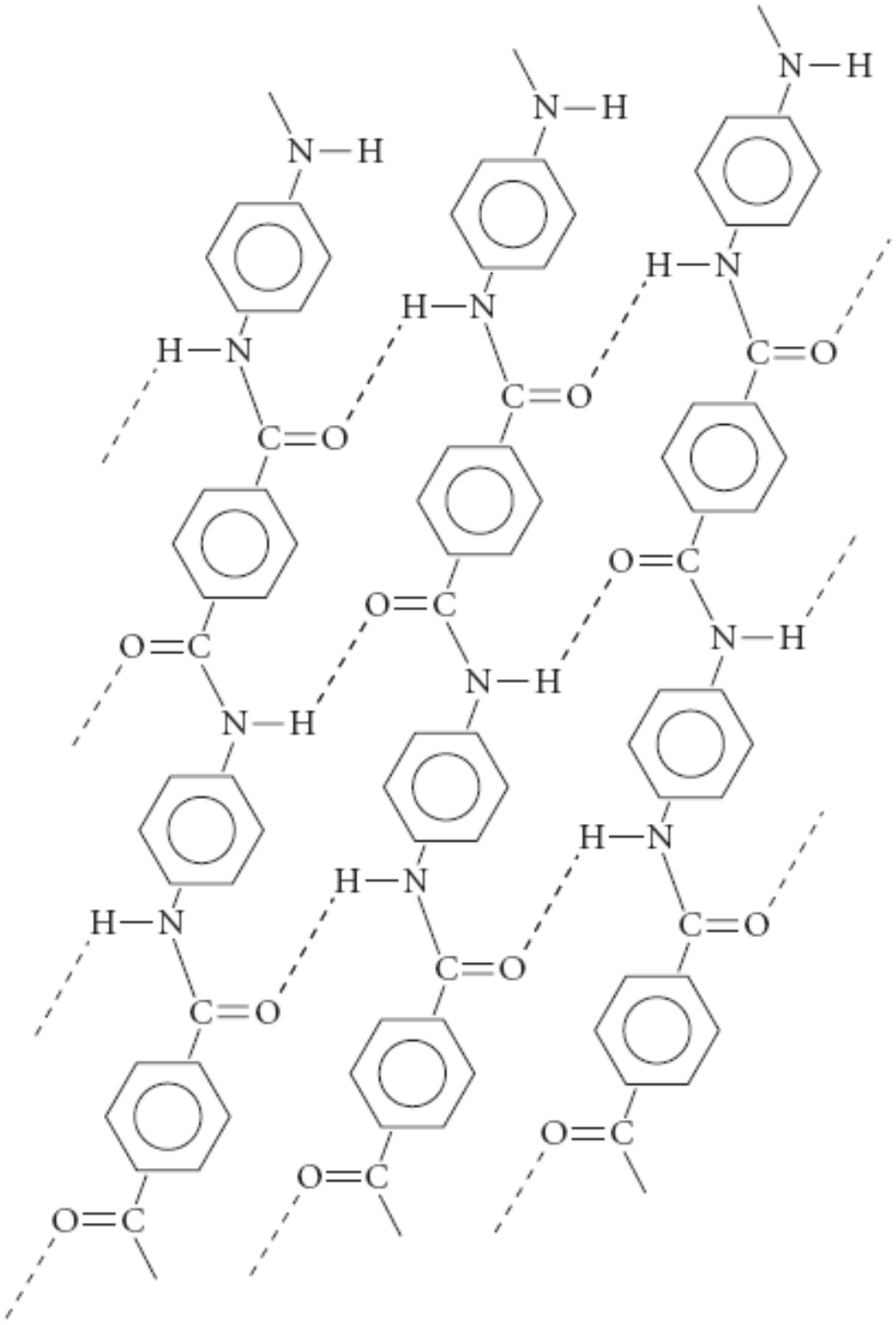
What gives Kevlar these special properties? The polymer chains form a strong network of hydrogen bonds, which hold adjacent chains together in a sheet-like structure. The sheets are stacked together to form extraordinarily strong fibres. When woven together, these fibres are resistant to damage, even the damage caused by a speeding bullet



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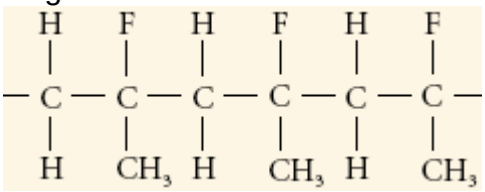
Worksheet 5.7: Polymers

1. Draw a structural diagram of three repeating units of a polymer of 1-butene.

2. Draw a structural diagram of the monomer of the following polymer.

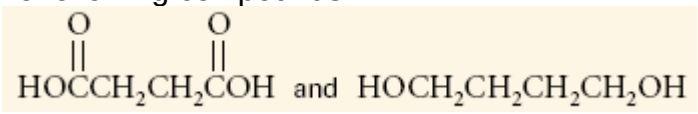


3. Draw a structural diagram of three repeating units of a polymer of vinyl fluoride.

4. What functional group(s), if any, must be present in a monomer that undergoes an addition polymerization reaction?

5. Addition polymers may be produced from two different monomers, called co-monomers. Saran, the polymer used in a brand of food wrap, is made from the monomer vinyl chloride and 1,1-dichloroethene. Draw structural diagrams for each monomer, and for three repeating units of the polymer, with alternating co-monomers.

6. Draw a structural diagram to show a repeating unit of a condensation polymer formed from the following compounds.



7. What functional group(s), if any, must be present in a monomer of a condensation polymer?

8. Describe the type of chemical bonding within a polyamide chain, and between adjacent polyamide chains.