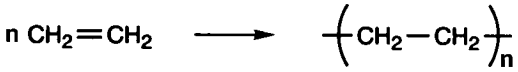
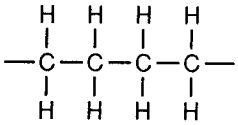
Advance warning

The following items needed for activities in this unit may not already be in your school, and might take a little time to obtain.

Activity	Item(s)	Essential/Optional	Typical quantity per experiment
PR2	Phenylethene (styrene) Di(dodecanoyl)peroxide (lauroyl peroxide)	Optional Optional	10 cm^3 0.2 g
PR3	Spaghetti	Essential	250 g
PR5.1	Cyclohexane and methylbenzene	Essential	50 cm^3 each
PR5.3	Poly(ethenol) film (hot-water soluble variety)	Essential	several small pieces (about 50 cm^2)
PR5.4	Poly(ethenol) (polyvinyl alcohol) (M_r 65 × 10^3 to 115 × 10^3; 96–98% hydrolysed)	Essential	2 g
PR6	Pyrrole Sodium 4-methylbenzenesulphonate (*p*-toluenesulphonic acid sodium salt)	Essential Essential	0.7 g 4.0 g

Storyline: answers to assignments

1 a 

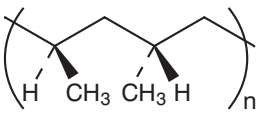
b 

c Oxygen acts as an initiator for the reaction. Too much oxygen causes too much reaction to happen all at once and, because the reaction is very exothermic, it goes out of control.

2 a No

b The chains are more closely packed in hdpe leading to stronger intermolecular forces.

c Hdpe is used where greater stiffness is required, especially when the plastic is warm. (Good quality washing up bowls are made from hdpe as this polymer stays stiff at temperatures up to 100 °C). Ldpe is cheaper and more easily stretched, and is therefore widely used in wrappings and packaging.

3 a 

b Syndiotactic polymers may not be able to pack so well as isotactic polymers (but much better than atactic polymers) leading to weaker intermolecular forces than in isotactic polymers. Thus syndiotactic polymers are, for example, likely to be a little more flexible and less dense than isotactic polymers

4 a Hydrogen bonding.

b The hydrogen bonding between chains is extensive and strong. Too much energy is required to break it down.

c A few randomly distributed ethanoate groups will cause extensive disruption to the hydrogen bonding.

d Increasing the number of ester groups decreases the extent of interchain bonding. Since hydrogen bonds to water molecules are formed when the polymer dissolves, this process becomes easier. However, too many ester groups will mean that hydrogen bonding to water becomes less extensive and the polymer becomes less soluble once more.

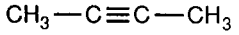
e The polymer must not dissolve when damp laundry is put in the bags.

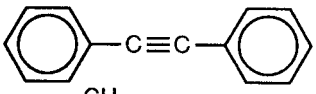
f For example, implantable capsules for the slow, continuous release of medicines into a patient, or coatings for seeds.

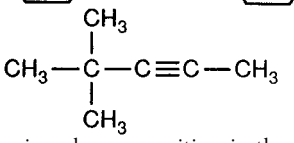
5 a i hex-3-yne

ii (2)-methylhex-3-yne

iii 1-phenylpropyne

b i 

ii 

iii 

(There is only one position in the molecule at which the methyl groups could be substituted, therefore it is not necessary to use numbers in the name.)

Activities: notes and answers to questions

PR1 Some important polymers: introductory data

It is a good idea to have samples of objects made from these polymers available for inspection by students.

This activity is designed to give students an overview of the production and uses of polymers in the UK and globally. It can be used to develop and practise data analysis and IT skills.

a Depending on their previous knowledge, students may want to leave completion of the table until later in the unit.

b **i** There is much for students to discuss here. The *proportion* of poly(chloroethene) and polystyrene made in the UK, compared with the other polymers, is higher. This may be due in part to their uses, for example, in the construction industry, for which proportionally more is needed in a developed country. It may also be in part due to the high level of integration needed in the chemical industry for the production of poly(chloroethene) and polystyrene, which require raw materials other than those derived from oil (ethene and propene).

ii Ldpe is used extensively in thin layer form as films and coatings. Hdpe is stronger and is moulded (blow moulded for bottles, etc, and injection moulded for tubes and pipes).

iii Both are extensively used for mouldings. Poly(propene) is also used as a fibre, particularly for carpets.

PR2 Making poly(phenylethene) (optional extension)

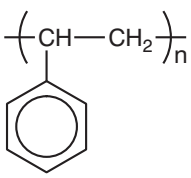
Safety note Information about hazardous chemicals is given on the activity sheet.

The activity **must** be carried out in a fume cupboard.

Satisfactory polymerisation should be achieved if fresh styrene is used.

a The monomer is an alkene and contains localised C=C double bonds; these are not present in the polymer. (The success of the bromine test depends on polymerising *all* the styrene. It may be better to test a sample of commercial polystyrene.)

b



c On heating, it forms RCOO•, radicals which decompose very rapidly to form R• and CO_2. The R• radicals initiate the chain reaction.

PR3 Using spaghetti to model polymer structure

Drain the spaghetti well before putting in the dish. Allow it to cool before attempting to turn the dish upside down. The best arrangement is usually seen on the base of the solid cake.

PR5.1 Deflecting jets

Safety note Information about hazardous chemicals is given on the activity sheet.

Students are warned in the activity that the liquids must be disposed of under the direction of the teacher.

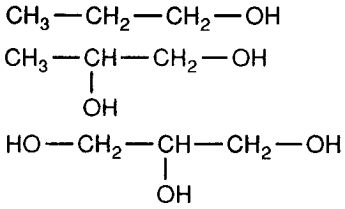
a Water, ethanol and propanone are dipolar and should be affected strongly by the charged rod.

b OH and C=O groups are responsible for the polarity.

PR5.2 Viscosity in alcohols

Safety note Information about hazardous chemicals is given on the activity sheet. Propan-1-ol and propane-1,2-diol are flammable.

a



b Students should realise that hydrogen bonding becomes more extensive, and hence the intermolecular forces become stronger, as the number of –OH groups per molecule increases.

PR5.3 Now you see it …

Safety note Information about hazardous chemicals is given on the activity sheet.

CARE Do not let students take the 'slime' out of the laboratory. It removes paint and sticks to carpets.

At 65 °C, the hot water soluble film starts to dissolve after about 10 s. The process is over after about 5 minutes. The water should be agitated with a glass rod. Washing powder does not affect dissolving.

PR5.4 Making 'slime'

Safety note Information about hazardous chemicals is given on the activity sheet. Avoid breathing poly(ethenol) dust.

The experiment works best with poly(ethenol) (polyvinyl alcohol) of high M_r (samples with M_r = 65 × 10^3 to 115 × 10^3; 96–98% hydrolysed work well).

Making a 4% poly(ethenol) solution

Bring 100 cm^3 of water to the boil in a 250 cm^3 beaker and add 4 g of poly(ethenol), a little at a time *while stirring*. (A magnetic stirrer is useful.) A colourless viscous solution should be obtained after 10–15 minutes. DO NOT BOIL: the poly(ethenol) degrades to give chains with lower M_r if heated too strongly.

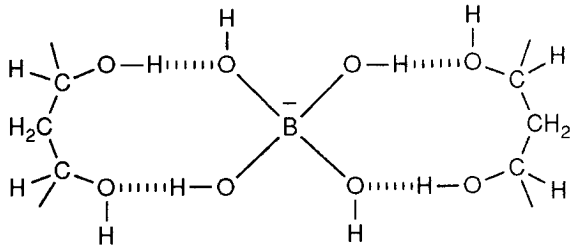
Properties of 'slime'

Can be stretched by slow pulling, but will break if pulled abruptly. Chunks of mechanically broken gel can be reworked into a single mass. Assumes shape of container; if suspended from hand will flow and stretch; self-siphons. If

placed on a flat surface, it flows to form a film. Bounces to a small extent. The 'slime' will keep several days if kept in a closed jar but mould will grow on it eventually.

Structure of 'slime'

The poly(ethenol) chains are linked by the borate groups through hydrogen bonding:



The cross-linking is not fixed, but can break and re-form easily.

Most of the space within the gel is taken up by water molecules held in the cross-linked structure. (Extreme dilution with water reverses the gelation process and disrupts the hydrogen bonding in the cross-links.)

'Fun extras' might include

- adding water soluble food colourings or fluorescent dyes before mixing the reagents;
- placing the 'slime' on something written or drawn in water soluble ink;
- watching lumps of 'slime' flow under the influence of gravity.

(**Note** A commercial product is made from guar gum and borax.)

PR6 Poly(pyrrole) – a conducting polymer

Safety note Information about hazardous chemicals is given on the activity sheet. Pyrrole is harmful, flammable and an irritant. Measure it out in a fume cupboard and avoid breathing the vapour. Wash off any skin contamination with lots of water. (Pyrrole darkens on exposure to air. Make sure the bottle is well sealed and stored in the dark.)

In some cases the light bulb might not glow in step **10**. However, a deflection should occur if a milliammeter is used.

a The polymer is a much poorer conductor than copper, but much better than familiar polymers such as nylon.

b and **c** The poly(pyrrole) should be purple/blue.

d It should start out golden/yellow and turn back to purple/blue.

e Reduced.

f Air oxidises the reduced form of the polymer.