This shows the relationship between the Storyline, the Activities and the Chemical Ideas. To aid planning, laboratory-based practical work is indicated by (P), activities involving IT skills are indicated by (IT) and those developing study skills by (S).

ACTIVITIES		CHEMICAL STORYLINE		CHEMICAL IDEAS
<b>PR1</b> Some important polymers: introductory data (IT)	PR1	THE START OF THE REVOLUTION		
PR2 Making poly(phenylethene) (optional extension) (P)	PR2	THE POLYTHENE STORY	12.2 5.3 5.5	Alkenes Forces between molecules: temporary and permanent dipoles The structure and properties of polymers (first part on addition polymers only)
<b>PR3</b> Using spaghetti to model polymer structure (P)	PR3	TOWARDS HIGH DENSITY POLYMERS		
	PR4	THE TEFLON MAN		
<b>PR5.1</b> Deflecting jets (P) <b>PR5.2</b> Viscosity in alcohols (P) <b>PR5.3</b> Now you see it (P) <b>PR5.4</b> Making 'slime' (P)	PR5	DISSOLVING POLYMERS	5.4	Forces between molecules: hydrogen bonding
<b>PR6</b> Poly(pyrrole) – a conducting polymer (P)	PR6	POLYMERS THAT SHINE IN THE DARK	3.5	Geometric isomerism
<b>PR7</b> Check your notes on <b>The Polymer Revolution</b> (S)	PR7	SUMMARY		

PR

AS

LEVEL

# THE POLYMER REVOLUTION

# Relation to other units

This is best taught as the fifth unit of the course, but it can be taught at any time between **From Minerals to Elements** and **What's in a Medicine?**, providing due attention is paid to the order in which the concepts are developed.

**Developing Fuels** introduces subjects such as hydrocarbons, isomerism, homologous series and organic nomenclature. **The Atmosphere** discusses bond polarity, bond fission and radicals, and introduces students to reaction mechanisms.

All these ideas are developed further in this unit, which also covers intermolecular forces in detail and provides more examples of the important relationship between the properties of a substance and its structure and bonding.

The study of polymers and polymerisation is continued in **Designer Polymers**. Ideas about shapes of molecules and isomerism in organic compounds are developed further in **Engineering Proteins**. The chemistry of alcohols is taken further in **What's in a Medicine?** The importance of intermolecular forces in determining the structure and properties of a substance is highlighted in several subsequent units. Ideas about the relationship between the properties of a substance and its structure and bonding are brought together in **Aspects of Agriculture**. The delocalisation of electrons in a benzene ring is explained in **Colour by Design**.

## Concept map

The concept map which follows shows how the major chemical ideas in this teaching unit develop throughout the course.

Concept	Introduced in unit	Developed in unit(s)	Assumed in unit(s)
Polymers and polymerisation	PR	DP	EP
Alkenes	PR	-	DP, CD, MD
Isomerism	DF	PR, EP	SS, AA, MD
Radicals	А	PR	MD
Reaction mechanisms	Α	PR, CD, MD	_
Electronegativity and bond polarity	EL	A, PR	several
Intermolecular forces	DF	PR	DP, EP, AA, CD, O, MD
Shapes of molecules	EL	DF, PR, EP, MD	A, WM, DP, SS, AA, CD, O
Relationship between properties, and bonding and structure	М	PR, DP, EP, AA, CD, O, MD	_
Alcohols	DF	PR, WM, DP, MD	CD
Delocalisation of electrons	PR	WM, CD	several

#### A note on the treatment of geometrical isomerism

We use *cis-trans* nomenclature throughout the course. However, students may come across the more general **Z**/**E convention** for naming geometric isomers, particularly if they look in more advanced textbooks.

Isomers are named *Z* (German: *zusammen*, together) or *E* (German: *entgegen*, across) according to whether substituents of *the higher priority* on each carbon atom are on the same or opposite sides of the double bond. Priority is decided by the relative atomic mass of the atom attached to the carbon of the double bond: the higher the relative atomic mass, the higher the priority (eg  $Cl > CH_3$ ). If these atoms are the same, the next atom is considered (eg  $CH_2Cl > CH_3$ ), and so on.

The order is:  $I > Br > Cl > OH > NH_2 > COOH > CONH_2 > CHO > C_6H_5 > C_2H_5 > CH_3 > H_3 > CHO > C_6H_5 > C_2H_5 > CH_3 > H_3 > CHO > C_6H_5 > C_2H_5 > CH_3 > H_3 > CHO > C_6H_5 > C_2H_5 >$ 

Using this convention, *cis*-but-2-ene becomes (*Z*)-but-2-ene and *trans*-but-2-ene becomes (*E*)-but-2-ene. The convention is particularly useful in cases such as the example below, where the *cis*-*trans* nomenclature cannot be used.

Br C=C

(*E*)-isomer (Br and I on opposite sides)

AS LEVEL



(Z)-isomer (Br and I on same side)

## 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 <sup>3</sup> 0.2 g
PR3	Spaghetti	Essential	250 g
PR5.1	Cyclohexane and methylbenzene	Essential	50 cm <sup>3</sup> each
PR5.3	Poly(ethenol) film (hot-water soluble variety)	Essential	several small pieces (about 50 cm <sup>2</sup> )
PR5.4	Poly(ethenol) (polyvinyl alcohol) ( $M_r$ 65 × 10 <sup>3</sup> to 115 × 10 <sup>3</sup> ; 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



- **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.



**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



(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.)