# *Map of the unit: Engineering Proteins*

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 |
|---|---|---|
| | **EP1** CHRISTOPHER'S STORY | |
| **EP2.1** Investigating amines and amino acids (P)<br>**EP2.2** What's in aspartame? (P)<br>**EP2.3** Using nuclear magnetic resonance (n.m.r.) spectroscopy for structure determination<br>**EP2.4** The shapes of α-amino acids (IT)<br>**EP2.5** A testing smell<br>**EP2.6** Taking note of proteins (S)<br>**EP2.7** Modelling DNA (IT)<br>**EP2.8** Life reveals its twisted secret | **EP2** PROTEIN BUILDING | ***13.3*** *Carboxylic acids and their derivatives (revision)*<br>***13.4*** *The –OH group in alcohols, phenols and acids (revision)*<br>***13.8*** *Amines and amides (revision)*<br>**13.9** Amino acids<br>**6.6** Nuclear magnetic resonance spectroscopy<br>***3.3*** *Shapes of molecules (revision)*<br>***3.5*** *Geometric isomerism (revision)*<br>**3.6** Optical isomerism |
| | **EP3** GENETIC ENGINEERING | |
| | **EP4** PROTEINS IN 3-D | ***5.3*** *Forces between molecules: temporary and permanent dipoles (revision)*<br>***5.4*** *Forces between molecules: hydrogen bonding (revision)* |
| | **EP5** GIVING EVOLUTION A PUSH | ***7.1*** *Chemical equilibrium (revision)*<br>**7.2** Equilibria and concentrations |
| **EP6.1** Testing for glucose (P)<br>**EP6.2** Succinate dehydrogenase (optional extension)<br>**EP6.3** The effect of enzyme and substrate concentration on the rate of a reaction (P)(IT)<br>**EP6.4** Using the iodine clock method to find the order of a reaction (P)(IT)<br>**EP6.5** Enzyme kinetics | **EP6** ENZYMES | ***10.2*** *The effect of temperature on rate (revision)*<br>***10.5*** *How do catalysts work? (revision)*<br>**10.3** The effect of concentration on rate |
| **EP7** Check your notes on **Engineering Proteins** (S) | **EP7** SUMMARY | |

**Note** Chemical Ideas shown in italics are revisited from earlier units.

# EP
# ENGINEERING PROTEINS

## *Relation to other units*

This teaching unit should come about the middle of the course or slightly later. It uses ideas from the earlier units: **The Elements of Life**, **Developing Fuels**, **The Atmosphere**, **What's in a Medicine?** and **Designer Polymers**. In particular, students will need to have been introduced to the organic chemistry of amines, amides and carboxylic acids, shapes of molecules, isomerism and intermolecular forces. They should have met chemical equilibrium and rates of reactions in a qualitative way.

Ideas about rates of reactions are taken further in **Aspects of Agriculture**. Equilibrium is taken further in **Aspects of Agriculture** and **The Oceans**. Enzymes and molecular recognition arise again in **Medicines by Design**. **Colour by Design** and **Medicines by Design** contain more organic chemistry. Students will use n.m.r. spectra (in conjunction with other spectroscopic techniques) for the structure determination of organic molecules in **Medicines 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) |
|---|---|---|---|
| Amines and amides | DP | EP | CD, MD |
| Carboxylic acids | WM | DP | EP, AA, CD, MD |
| Condensation reactions | DP | EP | MD |
| Intermolecular forces | DF | PR | DP, EP, AA, CD, O, MD |
| Isomerism | DF | PR, EP | SS, AA. MD |
| Shapes of molecules | EL | DF, PR, EP, MD | A, WM, DP, SS, AA, CD, O |
| Molecular recognition | EP | MD | – |
| Amino acids | EL | EP | MD |
| Proteins and enzymes | EL | EP | MD |
| DNA, protein synthesis and genetic engineering | EP | – | – |
| Chemical equilibrium | A | EP, AA, O | SS |
| Catalysis | DF | A, EP, SS, AA | several |
| Rates of reactions | A | EP, AA | – |
| Relationship between properties, and bonding and structure | M | PR, DP, EP, AA, CD, O, MD | – |
| Nuclear magnetic resonance spectroscopy | EP | – | MD |

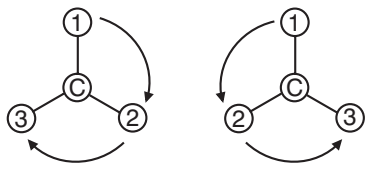
### *A note on the treatment of optical isomerism*

Students should be familiar with the two terms *optical isomer* and *enantiomer*. We have deliberately not referred to the rotation of plane-polarised light in this context, as it is difficult to explain at this level and often causes confusion. Students are usually happy to relate the term 'optical' to the idea of non-superimposable mirror images.

We use the **D/L** nomenclature throughout the course. However, students may come across the more general **R/S convention** for naming optical isomers, particularly if they look in more advanced textbooks.

According to the R/S convention, the groups attached to a chiral centre are listed in order of priority. Priority is decided by the relative atomic mass of the atom attached to the chiral centre: the higher the relative atomic mass, the higher the priority. This is the same system used for deciding priority in *Z*/*E* isomers (see page 47 for further details). For example, for the amino acid alanine, the order is: $NH_2$ > COOH > $CH_3$ > H.

The chiral carbon atom is viewed from the direction which places the –H atom (lowest priority) behind it, and the other three groups in front. These three groups are then numbered in descending order of priority; a clockwise path is given by the (*R*)-isomer (Latin: *rectus*, right); an anticlockwise path is given by the (*S*)-isomer (Latin: *sinister*, left). Using this convention, L-alanine becomes (*S*)-alanine.



(*R*)-isomer (*S*)-isomer

# *Advance warning*

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

| Activity | Item(s) | Essential/Optional | Typical quantity per experiment |
|---|---|---|---|
| EP2.2 | Searle 'Canderel' tablets | Essential | 1–3 tablets |
| | Aspartic acid | Essential | Small amounts for chromatography |
| | Phenylalanine | Essential | Small amounts for chromatography |
| EP2.5 | Spearmint chewing gum | Essential | Quarter of a piece |
| | Caraway seeds | Essential | 10 seeds |
| EP2.7 | * Plastic coated wire (eg Radio Spares 30 × 0.25 mm strand: code RS360239 to RS360295 depending on colour) | Essential | 1 m |
| | * 'Minit' molecular model peg type a: Ref 7–a–293 (white) to 7–a–300 (green) depending on colour | Essential | 30 |
| | * 21 cm plastic tubes: Ref 7–2–289 (red) | Essential | 8 |
| EP6.1 | * Glucose test strips (such as Clinistix™ or Diastix™) | Essential | 5–10 |
| EP6.4 | Potassium peroxodisulphate(VI) ($K_2S_2O_8$) | Essential | 100 mg |

* Current suppliers are listed on the **Salters Advanced Chemistry Web Site**.

## *Molecular modelling software*

The model-building activities in this unit will be greatly enhanced if students also have access to molecular modelling software (see **Salters Advanced Chemistry Web Site**).

## Storyline: answers to assignments

**1 a i** Amino acids with non-polar side-chains are
Gly Ala Val Leu Ile Phe Pro (Trp Met)

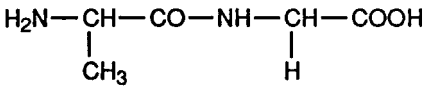
**ii** Amino acids with polar side-chains are
Ser Thr Cys Asp Glu Asn Gln Tyr His Lys Arg

**iii** Amino acids with ionisable groups on their side-chains are
Asp Glu His Lys Arg

**b** The side-chains in Leu and Ile cause them to be structural isomers.

**c i** Ser
**ii** Thr
**iii** Tyr
**iv** Either Asp or Glu

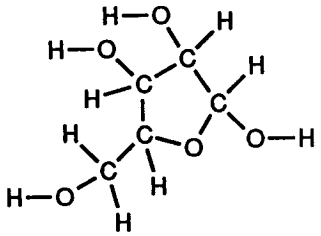
**2 a**



**b i** Ser **ii** Ala

**3 a i** Condensation **ii** Condensation

**b**



**4** Only two bases are important in coding for:
Ser Leu Pro Arg Thr Val Ala Gly
Three bases are important for:
Phe Tyr Cys Trp His Glu Ile Met Asn Lys Asp Gln

**5 a i** Lys Lys Lys …
**ii** Arg Ala Arg Ala …
**iii** Tyr Leu Thr
**b i** ACC **ii** CUA or CUG

**6 a** GUCA
**b** GTCA

**8** $K_c = \dfrac{[Ins_2]^3}{[Ins_6]}$ Units: $mol^2\ dm^{-6}$

## Activities: notes and answers to questions

### *EP2.1 Investigating amines and amino acids*

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

As preparation for this activity, it may help to ask students to think about how ammonia would behave in the four tests.

**a** Butylamine is soluble in water. It forms hydrogen bonds to water molecules.

**b** Butylamine solution is alkaline because of the reaction
$C_4H_9NH_2 + H_2O \rightleftharpoons C_4H_9NH_3^+ + OH^-$

**c** The smell of the amine is lost on addition of acid because the free amine is removed by the reaction
$C_4H_9NH_2 + H_3O^+ \rightarrow C_4H_9NH_3^+ + H_2O$

The amine is regenerated on addition of alkali
$C_4H_9NH_3^+ + OH^- \rightarrow C_4H_9NH_2 + H_2O$

**d** $[Cu(C_4H_9NH_2)_4(H_2O)_2]^{2+}$