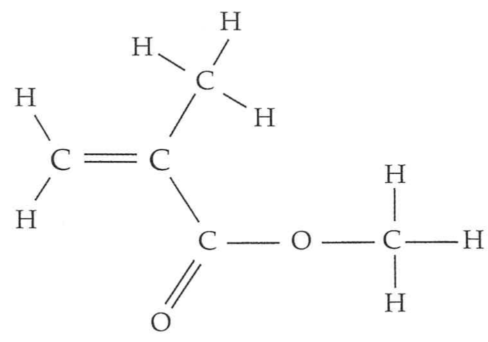
# Set 8. Polymers and amino acids

1. Perspex is a clear, colourless polymer. Methyl methacrylate, shown below, is the only monomer used in its synthesis.



(a) Would Perspex be an addition or condensation polymer?

(b) Draw a section of the Perspex polymer showing at least two repeating units.

2. Write an equation for the synthesis of polychloroethene (PVC) from its monomer chloroethene.

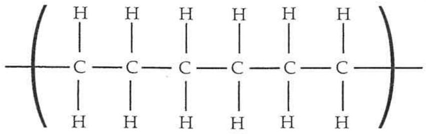
3. PVC is a hard, rigid polymer. Explain this with reference to the intermolecular forces present between polymer chains.

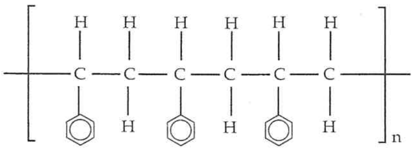
4. Which of the polymers below would be best suited for making:

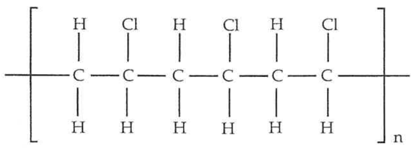
(a) a coffee cup.

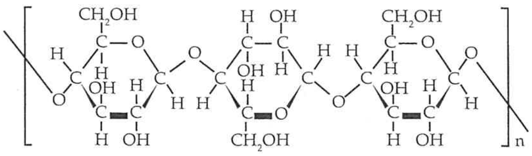
(b) a water bottle.

(c) gutter pipes.

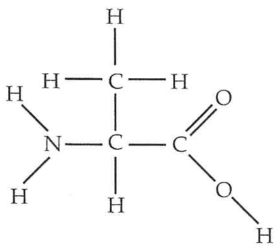
i) 

ii) 

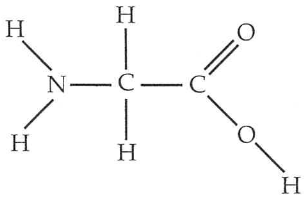
iii) 

iv) 

5. Silks produced by insects are natural protein fibres or polypeptides. They consist of amino acid residues. One such silk was found to consist mainly of alternating glycine and alanine residues.



alanine



glycine

(a) Draw a section of this natural protein fibre showing at least four amino acid residues.

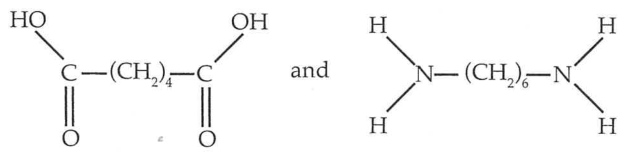
(b) What type of polymerisation reaction is this?

(c) What is the name of the link between each amino acid residue in the silk?

(d) State the bonding type that contributes to the α-helix structure of the silk.

6. The monomers below are used to produce Nylon 6,6.

(a) Name these monomers.




(b) Draw a section of Nylon 6,6 showing at least two repeating units.

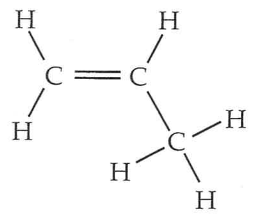
7. Cysteine is an α-amino acid found in many high protein foods. Its condensed chemical formula is:

$$HSCH_2CH(NH_2)COOH$$

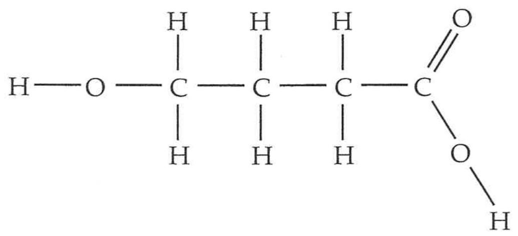
(a) Draw the structural formula of cysteine.

(b) Draw the structural formula of cysteine in its zwitterionic form.

8. Draw diagrams of an addition polymer and a condensation polymer which uses one of the monomers below. Show a minimum of two repeating units.



Monomer 1

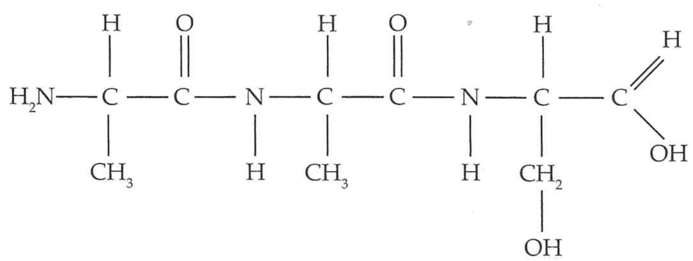


Monomer 2

(a) Addition polymer

(b) Condensation polymer

9. A tripeptide is a peptide consisting of three amino acids joined by peptide bonds.



(a) Circle the peptide bonds in the tripeptide shown above.

(b) Draw the structures of the two amino acid (peptide) monomers that produced this tripeptide.

(c) Using this tripeptide as an example, explain what determines its primary structure.

(d) Which parts of the tripeptide could contribute to α-helix structures or β-pleating secondary structures in a protein?

(e) Explain the difference between α-helix structures and β-pleating.

(f) The tertiary structure of proteins determines their shape and also function. Give examples of side chains and functional groups on polypeptides that can contribute to a protein's tertiary structure and name the type of bonding that occurs between each.

10. Carbonic anhydrases are enzymes that help maintain the pH balance in blood. The reversible reaction that they catalyse is shown below:

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq) \rightleftharpoons H^+(aq) + HCO_3^-(aq)$$

The forward reaction is fast but the reverse reaction takes about 15s without a catalyst.

(a) Explain why it is important that this reaction can move in either direction at a rapid rate.

(b) How do carbonic anhydrases catalyse this reaction?

# Set 9. Empirical and molecular formulae

1. An organic compound contains 40.67% of carbon, 8.54% of hydrogen, 27.09% of oxygen, and the rest is nitrogen. Determine its empirical formula.

2. An organic compound containing carbon, hydrogen, oxygen and chlorine gave on analysis 16.30% of carbon and about 0.68% of hydrogen. On reacting with $AgNO_3$, 0.295 g of the compound gave 0.861 g of silver chloride. Another sample of mass 0.295 g was heated and had a volume of 49.2 mL at 101.3 kPa pressure at 27.0°C.

   Determine the molecular formula of the compound.

3. An organic compound containing only carbon, hydrogen and oxygen is analysed by combusting a 2.323 g sample in excess oxygen. All the carbon in the compound is converted to carbon dioxide, and all the hydrogen it contains is converted to water.

(a) Given that the mass of carbon dioxide produced is 5.281 g and the mass of water is 2.162 g, calculate the empirical formula of the compound.

(b) When a 1.503 g sample of the compound is vaporised in the absence of air, the vapour occupies 579.7 mL at S.T.P. From this data, calculate the molecular formula of the compound.

(c) Further analysis shows the presence of a CHO group. From this information, draw the structural formula of the compound.

4. A sample of 4.121 g of a chlorofluorocarbon (a compound containing carbon, fluorine and chlorine only) was analysed as follows:

All the carbon in the sample was converted into carbon dioxide gas, and all its chlorine was converted into hydrochloric acid. The carbon dioxide weighed 1.320 g, and the hydrochloric acid formed required 85.70 mL of 1.050 mol $L^{-1}$ ammonia solution for complete neutralisation. Another sample of the same gaseous compound of mass 3.661 g occupied 0.6068 L at S.T.P.

(a) Determine the empirical formula of the compound.

(b) Determine the molecular formula of the compound.

(c) Name and draw a possible structure of the compound.

5. 15.00 g of an alkyl hydrogen sulfate containing only carbon, hydrogen, oxygen and sulfur was completely combusted to produce 10.50 g of carbon dioxide and 6.421 g of water. A second sample weighing 10.00 g was reacted with concentrated sodium hydroxide and all of its sulfur was reacted to form 9.980 g of sodium sulfite.

(a) Determine the empirical formula of the alkyl hydrogen sulfate.

(b) To deduce its molecular formula 2.000 g was heated to 220.0°C, beyond its boiling point at 100.0 kPa, and it had a volume of 0.651 L. What is its molecular formula?

(c) How might its formula be written in condensed form?

6. A chlorofluorocarbon (a compound containing only chlorine, fluorine and carbon) is analysed by preparing two identical samples of the compound of mass 2.320 g. The first sample is burnt in excess oxygen gas to convert all the carbon it contains into carbon dioxide. The second sample of the compound is chemically treated to convert all the chlorine it contains into hydrochloric acid.

(a) Given that the mass of carbon dioxide produced is 0.9267 g and the hydrochloric acid produced requires 17.20 mL of 3.062 mol $L^{-1}$ ammonia solution for complete neutralisation, calculate the empirical formula of the chlorofluorocarbon.

(b) When a 1.503 g sample of the compound is vaporised in the absence of air, the vapour occupies 152.8 mL at S.T.P. From this data, calculate the molecular formula of the compound.

(c) Draw full structural formula for the chlorofluorocarbon.

7. 0.450 g of an organic compound containing carbon, hydrogen, nitrogen and possibly oxygen was combusted to produce 0.792 g of carbon dioxide and 0.324 g of water. 0.240 g of the same compound was analysed to determine its nitrogen content. It was heated with sulfuric acid to produce ammonium sulfate and this was then distilled with sodium hydroxide to produce ammonia. The ammonia formed was absorbed into 50.0 mL of 0.100 M sulfuric acid. The excess acid required 76.5 mL of 0.100 M sodium hydroxide for complete neutralisation.

Determine the empirical formula of the compound.

8. An organic compound containing only carbon, hydrogen and oxygen is analysed by combusting a 3.605 g sample in excess oxygen. All the carbon in the compound is converted to carbon dioxide, and all the hydrogen it contains is converted to water.

(a) Given that the mass of carbon dioxide produced is 8.802 g and the mass of water is 3.603 g, calculate the empirical formula of the compound.

(b) When a 2.466 g sample of the compound is vaporised in the absence of air, the vapour occupies 441.8 mL at 22.0°C and 95.0 kPa. From this data, calculate the molecular formula of the compound.

(c) Further analysis shows the compound is an hydroxy aldehyde. From this information, draw a possible structural formula of the compound.

9. Hexamethylene glycol is an organic compound used in the production of polyesters and polyurethane. Elemental analysis of hexamethylene glycol has shown it to be composed of carbon, hydrogen and oxygen only.

In order to find the empirical formula of hexamethylene glycol, a 0.7870 g sample of the compound was burned in a plentiful supply of oxygen, causing the carbon and hydrogen to be converted into carbon dioxide and water respectively. The mass of carbon dioxide formed was 1.759 g, whilst the mass of water was 0.8436 g.

Further analysis of hexamethylene glycol showed that a 0.8980 g sample when heated to gaseous state occupied 198.0 mL at a pressure of 101.3 kPa and a temperature of 45.0°C.

(a) Calculate the empirical formula hexamethylene glycol.

(b) Determine the molecular formula of hexamethylene glycol.

(c) Given that hexamethylene glycol is a diol, or an alcohol with two hydroxyl groups (-OH), draw a possible structure showing all atoms and bonds.

(d) Hexamethylene glycol is not an IUPAC name. Give the IUPAC name for the structure that you have drawn above.

## Set 1. Chemical synthesis

1. $Mn_3O_4$ is found in nature as the mineral hausmannite. It can be reduced with carbon monoxide to produce MnO according to the equation:

$$Mn_3O_{4(s)} + CO_{(g)} \rightarrow 3MnO_{(s)} + CO_{2(g)}$$

If 2.62 tonnes of hausmannite is reacted with 871 kL of carbon monoxide at 100.0 kPa and 600.0°C determine the mass of manganese (II) oxide produced.

2. Chalcopyrite, $CuFeS_2$, is an ore of copper. The first step when extracting the copper is to roast the impure chalcopyrite in oxygen to produce copper (I) sulfide according to the equation:

$$2CuFeS_2(s) + 4O_2(g) \rightarrow 2FeO(s) + Cu_2S(s) + 3SO_2(g)$$

$1.25 \times 10^4$ tonnes of impure chalcopyrite is roasted in excess oxygen. The mass of copper (I) sulfide produced was found to be $5.10 \times 10^3$ tonnes. If the process is assumed to be 100% efficient, determine the percentage purity of the chalcopyrite.

3. The Bayer process is used to purify bauxite, $Al_2O_3$, prior to electrolysis in the production of aluminium. It proceeds via the following series of reactions:

$$Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2NaAl(OH)_4(aq)$$

$$NaAl(OH)_4(aq) \rightarrow Al(OH)_3(s) + NaOH(aq)$$

$$2Al(OH)_3(s) \rightarrow Al_2O_3(s) + 3H_2O(l)$$

The first reaction is 97.0% efficient. The second reaction is 83.0% efficient.

If $1.10 \times 10^4$ tonnes of ore are initially reacted and the final mass of bauxite produced is $7.50 \times 10^3$ tonnes, what is the efficiency of the final reaction?

4. Rutile, $TiO_2$, is the ore from which titanium is extracted. It is first heated with chlorine and coke at a temperature of about 900°C to produce titanium (IV) chloride. The titanium (IV) chloride is then reduced in a batch process to produce very pure titanium by reacting it with sodium metal.

$$TiO_2(s) + 2Cl_2(g) + 2C(s) \rightarrow TiCl_4(s) + 2CO(g)$$

$$TiCl_4(s) + 4Na(l) \rightarrow Ti(s) + 4NaCl(s)$$

In a small scale pilot plant operating at 95.0% efficiency chemists tested the purity of a sample of rutile. They reacted 10.0 kg of rutile with excess chlorine and coke, and then purified it through reduction with excess sodium. They produced 5.076 kg of pure titanium.

Determine the purity of their rutile sample.

5. The Solvay process is a multi-step synthesis for the production of sodium carbonate and calcium chloride from the raw materials sodium chloride, ammonia and calcium carbonate (limestone).

Step 1: $CaCO_3(g) \rightarrow CaO(s) + CO_2(g)$

Step 2: $NaCl(aq) + NH_3(g) + H_2O(l) + CO_2(g) \rightarrow NH_4Cl(aq) + NaHCO_3(aq)$

Step 3: $2NaHCO_3(s) \rightarrow Na_2CO_3(s) + CO_2(g) + H_2O(l)$

Step 4: $CaO(s) + H_2O(l) \rightarrow Ca(OH)_2(aq)$

Step 5: $2NH_4Cl(aq) + Ca(OH)_2(aq) \rightarrow 2NH_3(g) + CaCl_2(aq) + 2H_2O(l)$

(a) A company produces 325 000 tonnes per year of sodium carbonate. How many tonnes of calcium carbonate are needed to produce this?

(b) Salt is the raw material for the process and is mined from evaporative basins in salt lakes. This is purified, then dissolved to form a saturated brine solution that is pumped to the Solvay plant for Step 2. If 60.0% of the original salt is sodium chloride what mass of salt must be mined in order to maintain production?

(c) What mass of ammonia is required to ensure that all of the sodium chloride reacts?

(d) Calcium hydroxide is made from the calcium oxide produced in Step 1. This is then reacted with the ammonium chloride from Step 2 to produce calcium chloride. What mass of calcium chloride is produced if Step 4 is only 85.0% efficient?

6. An analytical chemist is required to determine the percentage by mass of methanol in a sample of methylated spirits (a mixture of ethanol and methanol). The chemist takes a 20.0 g sample of the methylated spirits, adds concentrated sulfuric acid and reacts the resulting liquid with excess pure ethanoic acid. After the resulting esterification reaction is complete, the chemist removes any residual ethanoic acid, dries the remaining liquid and finds it to be a mixture of methyl ethanoate and ethyl ethanoate. The mass of ethyl ethanoate was found to be 35.76 g. Assume that complete recovery of both organic compounds was achieved.

(a) Determine the percentage by mass of methanol in the sample of methylated spirits.

(b) Determine the mass of water produced during the complete esterification of the 20.0 g sample of methylated spirits.

7. Iron pyrites $FeS_2$ can be used to produce small quantities of sulfuric acid via the following sequence of reactions:

$$4FeS_2(s) + 11O_2(g) \rightarrow 2Fe_2O_3(s) + 8SO_2(g)$$

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$

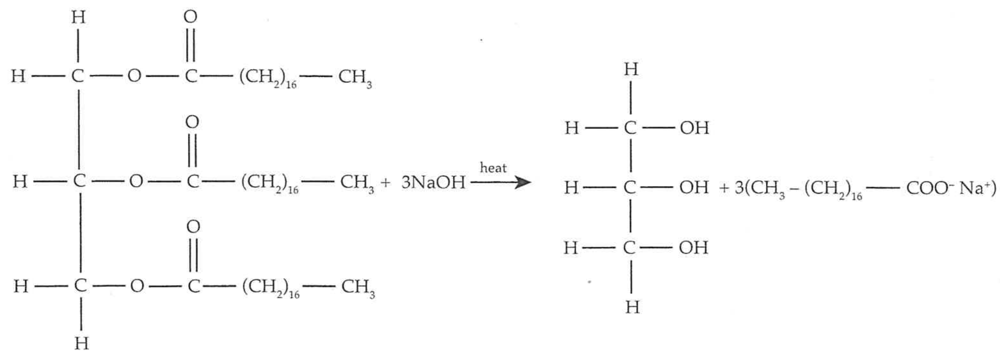
$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

Step 1 is 95.0% efficient, step 2 is 85.0% efficient and step 3 is only 67.0% efficient.

If 2.550 kg of impure iron pyrites is reacted in excess oxygen and 15.00 L of 1.500 mol $L^{-1}$ sulfuric acid is produced, what is the percentage purity of the original sample?

8. Some chemistry students decided to prepare some soap, $CH_3(CH_2)_{16}COO^-Na^+$, in the laboratory by the reaction between a pure vegetable oil and sodium hydroxide.

The reaction is:




The students weighed out 50.0 g of the vegetable oil.

(a) Calculate the mass of sodium hydroxide needed to react with the vegetable oil.

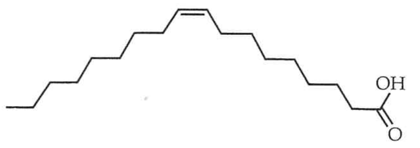
(b) Calculate the mass of glycerol produced as a by-product of this reaction.

(c) The soap which was prepared was then dissolved in excess 'hard' water containing $Ca^{2+}$ ions and $HCO_3^-$ ions. This produced a grey insoluble scum, $(CH_3(CH_2)_{16}COO^-)_2\ Ca^{2+}$.

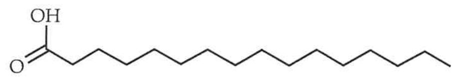
What mass of scum is formed by dissolving 10.0 g of the soap in excess 'hard' water?

9. Products from olive oil

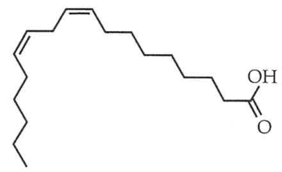
A sample of olive oil was found to consist of triglycerides containing the fatty acids oleic acid, palmitic acid and linoleic acid in various combinations.




oleic acid, $CH_3(CH_2)_7CHCH(CH_2)_7COOH$




palmitic acid, $CH_3(CH_2)_5CHCH(CH_2)_7COOH$




linoleic acid, $CH_3(CH_2)_4CHCHCH_2CHCH(CH_2)_7COOH$

(a) Which of these fatty acids is saturated?

(b) The most prevalent triglyceride in olive oil is the oleic-oleic-oleic (or OOO) triglyceride. Write a condensed formula for the methyl ester biodiesel molecule formed in the production of biodiesel from OOO triglyceride.

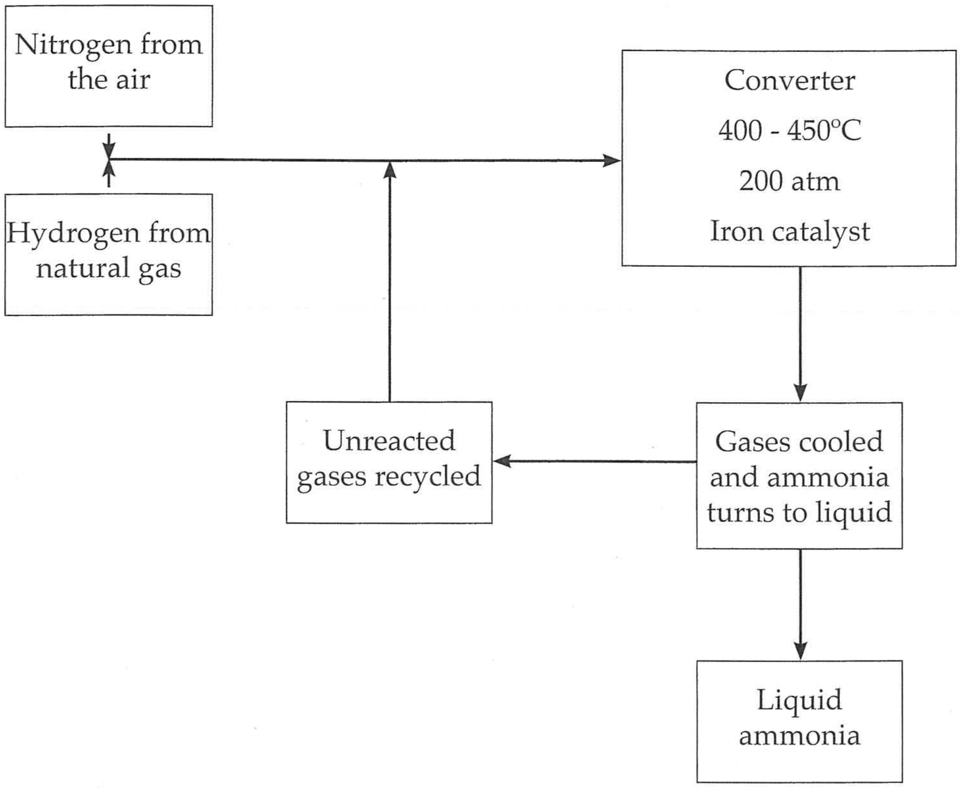
(c) If oleic-linoleic-palmitic (or OLP) triglyceride from olive oil was used to prepare soap, draw diagrams of the soap molecules formed, labelling their polar hydrophilic and the non-polar hydrophobic sections.

(d) Describe, with reference to the micelle, how soaps are able to lift oil and grease from fabrics.

(e) How are detergents different from soaps?

10. Describe how you might prepare ethylpropanoate in the laboratory starting with ethene and propan-1-ol. Give equations showing each step and include the reagents required for each step.

11. You have studied the Haber process from an equilibrium perspective. Examine the flowchart of the Haber process below:




(a) Does this process utilise local and renewable resources?

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(b) How is waste kept to a minimum?

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(c) Can you identify a part of the process where energy cycling or heat recovery could be implemented?

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(d) From your equilibrium studies what are the conditions that are employed to maximise yield? Is there a compromise in the chosen conditions?

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