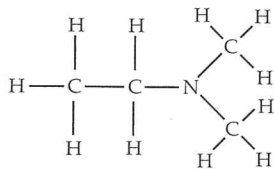
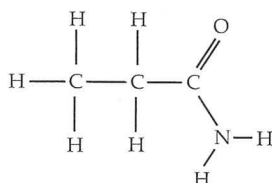


3.
 (a) butanamide
 (b) 4-aminobutan-2-ol
 (c) 2-aminoheptanoic acid
 (d) pentanamide
 (e) hexanamine
 (f) 2-aminobenzoic acid

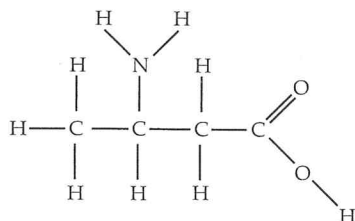
4.
 (a)



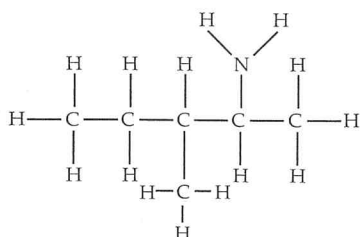
(b)



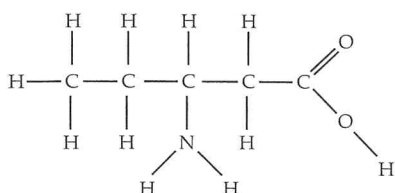
(c)



(d)



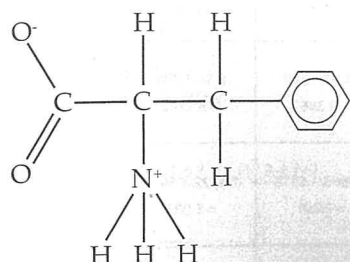
(e)



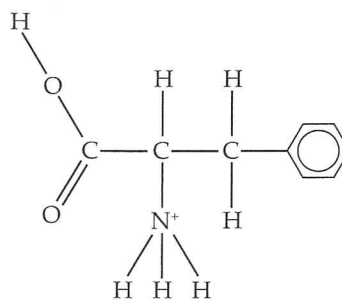
5. a, b and e are α -amino acids.

6.

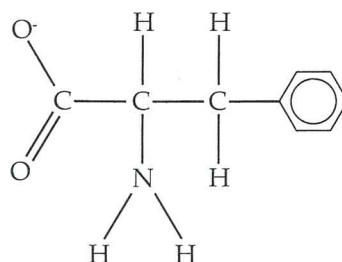
(a)



(b)



(c)

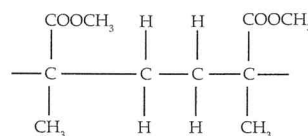


Set 8 Polymers and Amino Acids

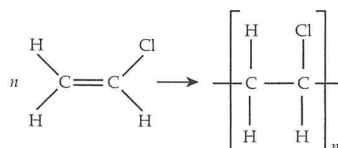
1.

(a) Perspex is an addition polymer.

(b)



2.



3. The PVC chain contains polar carbon to chlorine bonds which can form dipole-dipole interactions with neighbouring chains. These relatively strong intermolecular forces give PVC its strength.

4.

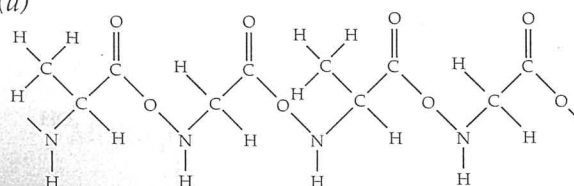
(a) (ii)

(b) (i)

(c) (iii)

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.

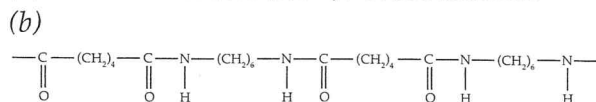
(a)



- (b) Condensation polymerisation.
 (c) A peptide link.
 (d) The α -helix structure of the silk is determined by hydrogen bonding between amide and carbonyl functional groups within a peptide chain.

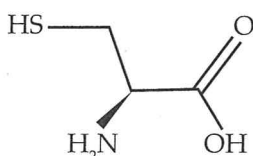
6. The monomers below are used to produce Nylon 6,6.

(a) hexanedioic acid and 1,6-hexanediamine

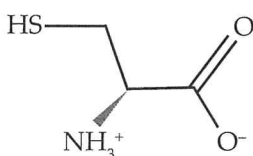


7.

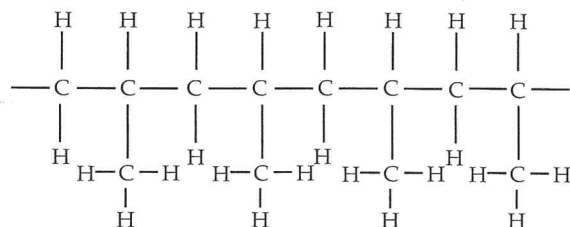
(a)



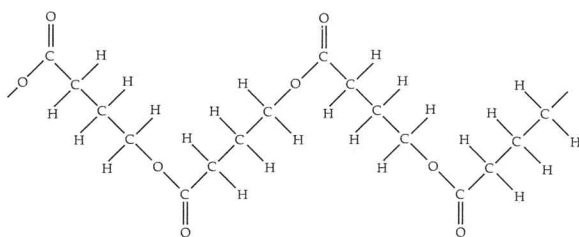
(b)



8.



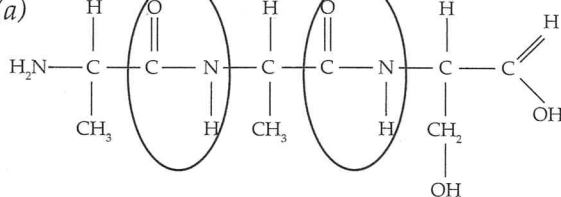
(a) Addition polymer



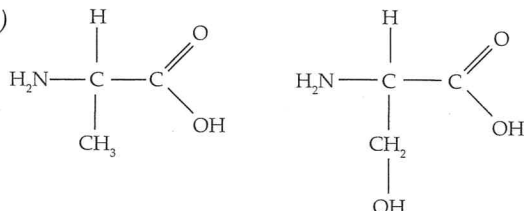
(b) Condensation polymer

9.

(a)



(b)



- (c) The sequence of amino acids in the polypeptide determines the primary structure of a tripeptide. Two of the first amino acids form a peptide bond and then the second amino acid forms a peptide bond with them.
- (d) The -NH amide functional group, the C=O carbonyl group and the -OH in CH_2OH can all hydrogen bond with one another and so could contribute to α -helix structures or β -pleating secondary structures in a protein.
- (e) α -helix structures form where hydrogen bonding between amide and carbonyl functional groups occur *within* a peptide chain. β -pleated sheets occur when hydrogen bonding happens *between* functional groups on adjacent polypeptide chains.
- (f) Disulphide bridges are covalent bonds between two sulphur containing side groups. Hydrogen bonding occurs between groups like -OH and -NH_2 . Dipole-dipole interactions occur between polar side groups. Dispersion forces are weak interactions between non-polar side groups like methyl, CH_3 . Ionic interactions are between charged side groups like CO_2^- and NH_3^+ .

10.

- (a) It is important that the reaction system shown can move easily and quickly in either direction as it is the blood buffer system and needs to be able to maintain the pH balance in blood efficiently as any changes in pH occur.
- (b) Carbonic anhydrases are catalysts and so provide an alternative reaction pathway with a lower activation energy.

Set 9 Impirical and Molecular Formulae

$$1. \quad \%N = 100 - 40.67 - 8.54 - 27.09 \\ = 23.7\%$$

	C	H	O	N
%	40.67	8.54	27.09	23.70
Mass in 100 g	40.67	8.54	27.09	23.70
Moles	$40.67/12.01$ $= 3.3863$	$8.54/1.008$ $= 8.4722$	$27.09/16.00$ $= 1.6931$	$23.70/14.01$ $= 1.6916$
Simplest Ratio	$3.3863/1.6916$ $= 2.001$	$8.4722/1.6916$ $= 5.008$	$1.6931/1.6916$ $= 1.001$	$1.6916/1.6916$ $= 1$
	2	5	1	1

$$\text{E.F.} = \text{C}_2\text{H}_5\text{NO}$$

$$\begin{aligned}
 2. \quad m(\text{AgCl}) &= 0.861 \text{ g} \\
 n(\text{AgCl}) &= 0.861/143.35 \\
 &= 6.006 \times 10^{-3} \text{ mol} \\
 n(\text{Cl}^-) &= 6.006 \times 10^{-3} \text{ mol} \\
 m(\text{Cl}^-) &= 6.006 \times 10^{-3} \times 35.45 \\
 &= 0.2129 \text{ g} \\
 \% \text{Cl} &= 0.2129/0.295 \times 100 \\
 &= 72.18\% \\
 \% \text{O} &= 100 - 16.30 - 0.68 - 72.18 \\
 &= 10.84\%
 \end{aligned}$$

	C	H	O	Cl
%	16.30	0.68	10.84	72.18
Mass in 100 g	16.30	0.68	10.84	72.18
Moles	40.67/12.01 = 1.3572	0.68/1.008 = 0.6746	10.84/16.00 = 0.6777	72.18/35.45 = 2.036
Simplest Ratio	1.3572/0.6746 = 2.012	0.6746/0.6746 = 1	0.6777/0.6746 = 1.005	2.036/0.6746 = 3.018
	2	1	1	3

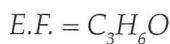


$$\begin{aligned}
 n(\text{MF}) &= PV/RT \\
 &= (101.3 \times 0.0492) / (8.314 \times 300.15) \\
 &= 1.997 \times 10^{-3} \text{ mol} \\
 M(\text{MF}) &= 0.295/1.997 \times 10^{-3} \\
 &= 147.705 \text{ g mol}^{-1} \\
 M(\text{EF}) &= (2 \times 12.01) + (3 \times 35.45) + 16.00 \\
 &\quad + 1.008 \\
 &= 147.378 \text{ g mol}^{-1} \\
 \text{Since } M(\text{MF}) &\approx M(\text{EF}) \text{ the molecular} \\
 \text{formula is } &\text{C}_2\text{Cl}_3\text{OH}
 \end{aligned}$$

3.

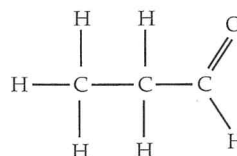
$$\begin{aligned}
 (a) \quad m(\text{CO}_2) &= 5.281 \text{ g} \\
 n(\text{CO}_2) &= 5.281/44.01 \\
 &= 0.1200 \text{ mol} \\
 n(\text{C}) &= 0.1200 \text{ mol} \\
 m(\text{C}) &= 0.1200 \times 12.01 \\
 &= 1.441 \text{ g} \\
 m(\text{H}_2\text{O}) &= 2.162 \text{ g} \\
 n(\text{H}_2\text{O}) &= 2.162/18.016 \\
 &= 0.1200 \text{ mol} \\
 n(\text{H}) &= 2 \times 0.1200 \\
 &= 0.2400 \text{ mol} \\
 m(\text{H}) &= 0.2400 \times 1.008 \\
 &= 0.2419 \text{ g} \\
 m(\text{O}) &= 2.323 - 1.441 - 0.2419 \\
 &= 0.6399 \text{ g} \\
 n(\text{O}) &= 0.6399/16.00 \\
 &= 0.0400 \text{ mol}
 \end{aligned}$$

	C	H	O
Moles	0.1200	0.2400	0.0400
Simplest ratio	0.1200/0.0400 = 3	0.2400/0.0400 = 6	0.0400/0.0400 = 1



$$\begin{aligned}
 (b) \quad n(\text{MF}) &= 0.5797/22.71 \\
 &= 0.02553 \text{ mol} \\
 M(\text{MF}) &= 1.503/0.02553 \\
 &= 58.88 \text{ g mol}^{-1} \\
 M(\text{EF}) &= (3 \times 12.01) + (6 \times 1.008) + 16.00 \\
 &= 58.078 \text{ g mol}^{-1} \\
 \text{Since } M(\text{MF}) &\approx M(\text{EF}) \text{ the molecular} \\
 \text{formula is } &\text{C}_3\text{H}_6\text{O}
 \end{aligned}$$

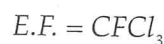
(c)



4.

$$\begin{aligned}
 (a) \quad m(\text{CO}_2) &= 1.320 \text{ g} \\
 n(\text{CO}_2) &= 1.320/44.01 \\
 &= 0.0300 \text{ mol} \\
 n(\text{C}) &= 0.0300 \text{ mol} \\
 m(\text{C}) &= 0.0300 \times 12.01 \\
 &= 0.3602 \text{ g} \\
 n(\text{NH}_3) &= 1.050 \times 0.08570 \\
 &= 0.0900 \text{ mol} \\
 n(\text{HCl}) &= 0.0900 \text{ mol} \\
 n(\text{Cl}^-) &= 0.0900 \text{ mol} \\
 m(\text{Cl}) &= 0.0900 \times 35.45 \\
 &= 3.190 \text{ g} \\
 m(\text{F}) &= 4.121 - 0.3602 - 3.190 \\
 &= 0.5708 \text{ g} \\
 n(\text{F}) &= 0.5708/19.00 \\
 &= 0.03004 \text{ mol}
 \end{aligned}$$

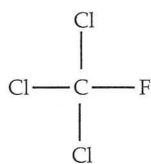
	C	F	Cl
Moles	0.0300	0.03004	0.0900
Simplest ratio	0.0300/0.0300 = 1	0.03004/0.0300 = 1.002	0.0900/0.0300 = 3.000
	1	1	3



$$\begin{aligned}
 (b) \quad n(\text{MF}) &= V/22.71 \\
 &= 0.6068/22.71 \\
 &= 0.02672 \text{ mol} \\
 M(\text{MF}) &= 3.661/0.02672 \\
 &= 137.016 \text{ g mol}^{-1} \\
 M(\text{EF}) &= 12.01 + 19.00 + (3 \times 35.45) \\
 &= 137.36 \text{ g mol}^{-1}
 \end{aligned}$$

Since $M(MF) \approx M(EF)$ the molecular formula is $CFCl_3$

(c) trichlorofluoromethane



5.

(a) Sample 1

$$m(\text{CO}_2) = 10.50 \text{ g}$$

$$n(\text{CO}_2) = 10.50/44.01$$

$$= 0.2386 \text{ mol}$$

$$n(\text{C}) = 0.2386 \text{ mol}$$

$$m(\text{C}) = 0.2386 \times 12.01$$

$$= 2.865 \text{ g}$$

$$m(\text{H}_2\text{O}) = 6.421 \text{ g}$$

$$n(\text{H}_2\text{O}) = 6.421/18.016$$

$$= 0.3564 \text{ mol}$$

$$n(\text{H}) = 2 \times 0.3564$$

$$= 0.7128 \text{ mol}$$

$$m(\text{H}) = 0.7128 \times 1.008$$

$$= 0.7185 \text{ g}$$

Sample 2

$$m(\text{Na}_2\text{SO}_3) = 9.980 \text{ g}$$

$$M(\text{Na}_2\text{SO}_3) = (2 \times \text{Na}) + (1 \times \text{S}) + (3 \times \text{O})$$

$$= 126.05 \text{ g mol}^{-1}$$

$$n(\text{Na}_2\text{SO}_3) = 9.980/126.05$$

$$= 0.07917 \text{ mol}$$

$$n(\text{S}) = 0.07917 \text{ mol}$$

$$m(\text{S}) = 0.07917 \times 32.07$$

$$= 2.5391 \text{ g}$$

$$m(\text{S})_{\text{Sample 1}} = 2.5391 \times 15.00/10.00$$

$$= 3.809 \text{ g}$$

$$m(\text{O}) = 15.00 - 2.8654 - 0.7185 - 3.809$$

$$= 7.607 \text{ g}$$

$$n(\text{O}) = 7.607/16.00$$

$$= 0.4755 \text{ mol}$$

$$n(\text{S}) = 3.809/32.07$$

$$= 0.1188 \text{ mol}$$

	C	H	O	S
Moles	0.2386	0.7128	0.4755	0.1188
Simplest ratio	0.2386/0.1188 = 2.009	0.7128/0.1188 = 6.002	0.4755/0.1188 = 4.003	0.1188/0.1188 = 1
	2	6	4	1

$$E.F. = \text{C}_2\text{H}_6\text{O}_4\text{S}$$

(b) $n(MF) = PV/RT$

$$= (100.0 \times 0.651) / (8.314 \times 493.15)$$

$$= 0.015877858 \text{ mol}$$

$$M(MF) = 2.000/0.015877858$$

$$= 125.962 \text{ g mol}^{-1}$$

$$M(EF) = (2 \times 12.01) + (6 \times 1.008) + (4 \times 16.00) + 32.07$$

$$= 126.138 \text{ g mol}^{-1}$$

Since $M(MF) \approx M(EF)$ the molecular formula is $\text{C}_2\text{H}_6\text{O}_4\text{S}$

(c) $\text{CH}_3\text{CH}_2\text{HSO}_4$

6.

$$(a) \quad m(\text{CO}_2) = 0.9267 \text{ g}$$

$$n(\text{CO}_2) = 0.9267/44.01$$

$$= 0.02106 \text{ mol}$$

$$n(\text{C}) = 0.02106 \text{ mol}$$

$$m(\text{C}) = 0.02106 \times 12.01$$

$$= 0.2529 \text{ g}$$

$$n(\text{NH}_3) = 3.062 \times 0.01720$$

$$= 0.05267 \text{ mol}$$

$$n(\text{HCl}) = 0.05267 \text{ mol}$$

$$n(\text{Cl}^-) = 0.05267 \text{ mol}$$

$$m(\text{Cl}) = 0.05267 \times 35.45$$

$$= 1.8670 \text{ g}$$

$$m(\text{F}) = 2.320 - 0.2529 - 1.8670$$

$$= 0.2001 \text{ g}$$

$$n(\text{F}) = 0.2001/19.00$$

$$= 0.01053 \text{ mol}$$

	C	F	Cl
Moles	0.02106	0.01053	0.05267
Simplest ratio	0.02106/0.01053 = 1.999	0.01053/0.01053 = 1	0.05267/0.01053 = 5.001
	2	1	5

$$E.F. = \text{C}_2\text{FCl}_5$$

$$(b) \quad n(MF) = V/22.71$$

$$= 0.1528/22.71$$

$$= 0.006728313 \text{ mol}$$

$$M(MF) = 1.503/0.006728313$$

$$= 223.384 \text{ g mol}^{-1}$$

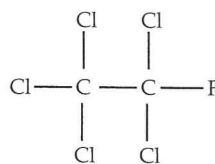
$$M(EF) = (2 \times 12.01) + 19.00 +$$

$$(5 \times 35.45)$$

$$= 220.27 \text{ g mol}^{-1}$$

Since $M(MF) \approx M(EF)$ the molecular formula is C_2FCl_5

(c)



7. Sample 1

$$m(\text{CO}_2) = 0.792 \text{ g}$$

$$n(\text{CO}_2) = 0.792/44.01$$

$$= 0.01800 \text{ mol}$$

$$\begin{aligned}
 n(\text{C}) &= 0.01800 \text{ mol} \\
 m(\text{C}) &= 0.01800 \times 12.01 \\
 &= 0.2161 \text{ g} \\
 m(\text{H}_2\text{O}) &= 0.324 \text{ g} \\
 n(\text{H}_2\text{O}) &= 0.324/18.016 \\
 &= 0.01798 \text{ mol} \\
 n(\text{H}) &= 2 \times 0.01798 \\
 &= 0.03597 \text{ mol} \\
 m(\text{H}) &= 0.03597 \times 1.008 \\
 &= 0.03626 \text{ g}
 \end{aligned}$$

Sample 2

$$\begin{aligned}
 n(\text{NaOH}) &= 0.100 \times 0.0765 \\
 &= 7.65 \times 10^{-3} \text{ mol} \\
 n(\text{H}_2\text{SO}_4) &= 0.100 \times 0.0500 \\
 &= 5.00 \times 10^{-3} \text{ mol} \\
 n(\text{H}^+) &= 2 \times 5.00 \times 10^{-3} \\
 &= 0.0100 \text{ mol} \\
 n(\text{NH}_3) &= 0.0100 - 7.65 \times 10^{-3} \\
 &= 2.35 \times 10^{-3} \text{ mol} \\
 n(\text{N}) &= 2.35 \times 10^{-3} \text{ mol} \\
 m(\text{N}) &= 2.35 \times 10^{-3} \times 14.01 \\
 &= 0.03292 \text{ g} \\
 m(\text{N})_{\text{Sample 1}} &= 0.03292 \times 0.450/0.240 \\
 &= 0.06173 \text{ g} \\
 m(\text{O}) &= 0.450 - 0.2161 - 0.03626 \\
 &\quad - 0.06173 \\
 &= 0.1359 \text{ g}
 \end{aligned}$$

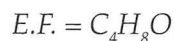
	C	H	N	O
Mass	0.2161	0.03626	0.06173	0.1359
Moles	0.2161/12.01 = 0.01800	0.03626/1.008 = 0.03597	0.06173/14.01 = 4.406 × 10 ⁻³	0.1359/16.00 = 8.493 × 10 ⁻³
Simplest ratio	$\frac{0.01800}{4.406 \times 10^{-3}}$ = 4.08	$\frac{0.03597}{4.406 \times 10^{-3}}$ = 8.16	$\frac{4.406 \times 10^{-3}}{4.406 \times 10^{-3}}$ = 1	$\frac{8.493 \times 10^{-3}}{4.406 \times 10^{-3}}$ = 1.92
	4	8	1	2



8.

$$\begin{aligned}
 (a) \quad m(\text{CO}_2) &= 8.802 \text{ g} \\
 n(\text{CO}_2) &= 8.802/44.01 \\
 &= 0.2000 \text{ mol} \\
 n(\text{C}) &= 0.2000 \text{ mol} \\
 m(\text{C}) &= 0.2000 \times 12.01 \\
 &= 2.402 \text{ g} \\
 m(\text{H}_2\text{O}) &= 3.603 \text{ g} \\
 n(\text{H}_2\text{O}) &= 3.603/18.016 \\
 &= 0.2000 \text{ mol} \\
 n(\text{H}) &= 2 \times 0.2000 \\
 &= 0.4000 \text{ mol} \\
 m(\text{H}) &= 0.4000 \times 1.008 \\
 &= 0.4032 \text{ g} \\
 m(\text{O}) &= 3.605 - 2.402 - 0.4032 \\
 &= 0.7998 \text{ g} \\
 n(\text{O}) &= 0.7998/16.00 \\
 &= 0.04999 \text{ mol}
 \end{aligned}$$

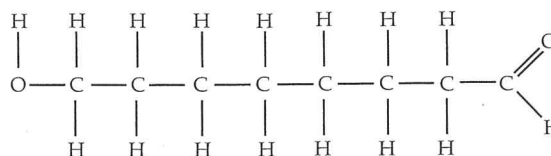
	C	H	O
Moles	0.2000	0.4000	0.04999
Simplest ratio	0.2000/0.04999 = 4.0009	0.4000/0.04999 = 8.0013	0.04999/0.04999 = 1
	4	8	1



$$\begin{aligned}
 (b) \quad n(\text{MF}) &= PV/RT \\
 &= (95.0 \times 0.4418)/ \\
 &\quad (8.314 \times 295.15) \\
 &= 0.017103953 \text{ mol} \\
 M(\text{MF}) &= 2.466/0.017103953 \\
 &= 144.1772 \text{ g mol}^{-1} \\
 M(\text{EF}) &= (4 \times 12.01) + (8 \times 1.008) \\
 &\quad + 16.00 \\
 &= 72.104 \text{ g mol}^{-1}
 \end{aligned}$$

Since $M(\text{MF}) \approx 2 \times M(\text{EF})$ the molecular formula is $\text{C}_8\text{H}_{16}\text{O}_2$

(c) hydroxy group can be on any but the terminal C.



9.

$$\begin{aligned}
 (a) \quad m(\text{CO}_2) &= 1.759 \text{ g} \\
 n(\text{CO}_2) &= 1.759/44.01 \\
 &= 0.03997 \text{ mol} \\
 n(\text{C}) &= 0.03997 \text{ mol} \\
 m(\text{C}) &= 0.03997 \times 12.01 \\
 &= 0.4800 \text{ g} \\
 m(\text{H}_2\text{O}) &= 0.8436 \text{ g} \\
 n(\text{H}_2\text{O}) &= 0.8436/18.016 \\
 &= 0.04683 \text{ mol} \\
 n(\text{H}) &= 2 \times 0.04683 \\
 &= 0.09365 \text{ mol} \\
 m(\text{H}) &= 0.09365 \times 1.008 \\
 &= 0.09440 \text{ g} \\
 m(\text{O}) &= 0.7870 - 0.4800 - 0.09440 \\
 &= 0.2126 \text{ g} \\
 n(\text{O}) &= 0.2126/16.00 \\
 &= 0.01329 \text{ mol}
 \end{aligned}$$

	C	H	O
Moles	0.039997	0.09365	0.01329
Simplest ratio	0.03997/0.01329 = 3.00	0.09365/0.01329 = 7.05	0.01329/0.01329 = 1
	3	7	1

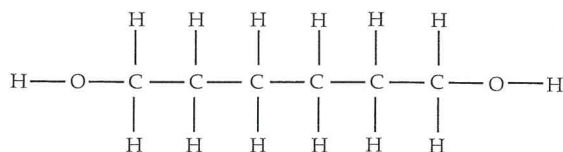


$$\begin{aligned}
 (b) \quad n(\text{MF}) &= PV/RT \\
 &= (101.3 \times 0.198) / (8.314 \times 318.15)
 \end{aligned}$$

$$\begin{aligned}
 &= 0.007582853 \text{ mol} \\
 M(\text{MF}) &= 0.8980/0.007582853 \\
 &= 118.425 \text{ g mol}^{-1} \\
 M(\text{EF}) &= (3 \times 12.01) + (7 \times 1.008) \\
 &\quad + 16.00 \\
 &= 59.086 \text{ g mol}^{-1}
 \end{aligned}$$

Since $M(\text{MF}) \approx 2 \times M(\text{EF})$ the molecular formula is $\text{C}_6\text{H}_{14}\text{O}_2$

(c) OH's can be on any carbon



(d) hexane-1,6-diol

Chapter 5. Chemical Synthesis

Set 1 Chemical Synthesis

- $$\begin{aligned}
 M(\text{Mn}_3\text{O}_4) &= (3 \times 54.94) + (4 \times 16.00) = 228.82 \text{ g mol}^{-1} \\
 n(\text{Mn}_3\text{O}_4) &= 2.62 \times 10^3 \times 10^3 / 228.82 \text{ g mol}^{-1} \\
 &= 11450 \text{ mol} \\
 n(\text{CO}) &= 100 \times 871 \times 10^3 / 8.314 \times 873.15 \\
 &= 11998 \text{ mol} \\
 \therefore \text{Mn}_3\text{O}_4 \text{ is L.R.} \\
 n(\text{MnO}) &= 3 \times n(\text{Mn}_3\text{O}_4) \\
 &= 34350 \text{ mol} \\
 M(\text{MnO}) &= 54.94 + 16.00 = 70.94 \text{ g mol}^{-1} \\
 m(\text{MnO}) &= 34350 \times 70.94 \\
 &= 2.44 \text{ tonnes}
 \end{aligned}$$
- $$\begin{aligned}
 M(\text{Cu}_2\text{S}) &= (2 \times 63.55) + 32.07 \\
 &= 159.17 \text{ g mol}^{-1} \\
 n(\text{Cu}_2\text{S}) &= 5.10 \times 10^3 \times 10^6 / 159.17 \\
 &= 3.204 \times 10^7 \text{ mol} \\
 n(\text{CuFeS}_2) &= 2 \times 3.204 \times 10^7 \\
 &= 6.408 \times 10^7 \text{ mol} \\
 M(\text{CuFeS}_2) &= 63.55 + 55.85 + (2 \times 32.07) \\
 &= 183.54 \text{ g mol}^{-1} \\
 m(\text{CuFeS}_2) &= 6.408 \times 10^7 \times 183.54 \\
 &= 1.176 \times 10^{10} \text{ g} \\
 \% \text{ purity} &= 1.176 \times 10^{10} / 1.25 \times 10^{10} \times 100 \\
 &= 94.1 \%
 \end{aligned}$$
- $$\begin{aligned}
 M(\text{Al}_2\text{O}_3) &= (2 \times 26.98) + (3 \times 16.00) \\
 &= 101.96 \text{ g mol}^{-1} \\
 n(\text{Al}_2\text{O}_3) &= 7.50 \times 10^3 \times 10^6 / 101.96 \\
 &= 7.356 \times 10^7 \text{ mol} \\
 n(\text{Al}(\text{OH})_3) &= 2 \times 7.356 \times 10^7 \\
 &= 1.471 \times 10^8 \text{ mol} \\
 n(\text{NaAl}(\text{OH})_4) &= 1.471 \times 10^8 \times 100/83 \\
 &= 1.772 \times 10^8 \text{ mol}
 \end{aligned}$$

- $$\begin{aligned}
 n(\text{Al}_2\text{O}_3) &= \frac{1}{2} \times 1.772 \times 10^8 \times 100/97 \\
 &= 9.137 \times 10^7 \text{ mol} \\
 m(\text{Al}_2\text{O}_3) &= 9.137 \times 10^7 \times 101.96 \\
 &= 9.316 \times 10^9 \text{ g} \\
 \% \text{ efficiency} &= 9.316 \times 10^9 / 1.1 \times 10^{10} \times 100 \\
 &= 84.7 \%
 \end{aligned}$$
- $$\begin{aligned}
 n(\text{Ti}) &= 5.076 \times 10^3 / 47.88 \\
 &= 106.0 \text{ mol} \\
 n(\text{TiCl}_4) &= n(\text{Ti}) \\
 &= 106.0 \text{ mol} \\
 n(\text{TiO}_2) &= n(\text{TiCl}_4) \\
 &= 106.0 \times 100/95 \\
 &= 111.6 \text{ mol} \\
 M(\text{TiO}_2) &= 47.88 + 2 \times 16.00 = 79.88 \text{ g mol}^{-1} \\
 m(\text{TiO}_2) &= 111.6 \times 79.88 \\
 &= 8914 \text{ g} \\
 \% \text{ purity} &= 8914 / 10000 \times 100 \\
 &= 89.1 \%
 \end{aligned}$$
 - $$\begin{aligned}
 M(\text{Na}_2\text{CO}_3) &= (2 \times 22.99) + 12.01 + (3 \times 16.00) \\
 &= 105.99 \text{ g mol}^{-1} \\
 n(\text{Na}_2\text{CO}_3) &= 325000 \times 10^6 / 105.99 \\
 &= 3.066 \times 10^9 \text{ mol} \\
 n(\text{NaHCO}_3) &= 2 \times n(\text{Na}_2\text{CO}_3) \\
 &= 6.133 \times 10^9 \text{ mol} \\
 n(\text{CO}_2) &= n(\text{NaHCO}_3) = 6.133 \times 10^9 \text{ mol} \\
 n(\text{CaCO}_3) &= n(\text{CO}_2) \\
 &= 6.133 \times 10^9 \text{ mol} \\
 M(\text{CaCO}_3) &= 40.08 + 12.01 + (3 \times 16.00) \\
 &= 100.09 \text{ g mol}^{-1} \\
 m(\text{CaCO}_3) &= 6.133 \times 10^9 \times 100.09 \\
 &= 6.138 \times 10^{11} \text{ g} \\
 &= 6.14 \times 10^5 \text{ tonnes}
 \end{aligned}$$
 - $$\begin{aligned}
 n(\text{NaCl}) &= n(\text{CO}_2) \\
 &= 6.133 \times 10^9 \text{ mol} \\
 M(\text{NaCl}) &= 22.99 + 35.45 = 58.44 \text{ g mol}^{-1} \\
 m(\text{NaCl}) &= 6.133 \times 10^9 \times 58.44 \\
 &= 3.584 \times 10^{11} \text{ g} \\
 m(\text{mined salt}) &= 3.584 \times 10^{11} \times 100/60 \\
 &= 5.97 \times 10^5 \text{ tonnes}
 \end{aligned}$$
 - $$\begin{aligned}
 n(\text{NH}_3) &= n(\text{NaCl}) \\
 &= 6.133 \times 10^9 \text{ mol} \\
 M(\text{NH}_3) &= 14.01 + (3 \times 1.008) \\
 &= 17.034 \text{ g mol}^{-1} \\
 m(\text{NH}_3) &= 6.133 \times 10^9 \times 17.034 \\
 &= 1.04 \times 10^5 \text{ tonnes}
 \end{aligned}$$
 - $$\begin{aligned}
 n(\text{CaO}) &= n(\text{CaCO}_3) \\
 &= 6.133 \times 10^9 \text{ mol} \\
 n(\text{Ca}(\text{OH})_2) &= n(\text{CaO}) \\
 &= 6.133 \times 10^9 \text{ mol}
 \end{aligned}$$

$$n(\text{NH}_4\text{Cl}) = 6.133 \times 10^9 \text{ mol}$$

	$n(\text{NH}_4\text{Cl})$	$n(\text{Ca}(\text{OH})_2)$
Stoichiometric ratio	2	1
Actual ratio	6.133×10^9	6.133×10^9
	1	1

\therefore L.R. is NH_4Cl

$$n(\text{CaCl}_2) = \frac{1}{2} \times n(\text{NH}_4\text{Cl})$$

$$= \frac{1}{2} \times 6.133 \times 10^9 \times 85/100$$

$$= 2.606 \times 10^9 \text{ mol}$$

$$M(\text{CaCl}_2) = 40.08 + (2 \times 35.45)$$

$$= 110.98 \text{ g mol}^{-1}$$

$$m(\text{CaCl}_2) = 2.606 \times 10^9 \times 110.98$$

$$= 2.89 \times 10^{11} \text{ g}$$

$$= 2.89 \times 10^5 \text{ tonnes}$$

6.

$$(a) M(\text{CH}_3\text{CH}_2\text{OOCCH}_3) = (8 \times \text{H}) + (2 \times \text{O}) + (4 \times \text{C})$$

$$= 88.104 \text{ g mol}^{-1}$$

$$n(\text{CH}_3\text{CH}_2\text{OOCCH}_3) = 35.76/88.104$$

$$= 0.4059 \text{ mol}$$

$$n(\text{CH}_3\text{CH}_2\text{OH}) = n(\text{CH}_3\text{CH}_2\text{OOCCH}_3)$$

$$= 0.4059 \text{ mol}$$

$$M(\text{CH}_3\text{CH}_2\text{OH}) = (2 \times \text{C}) + (6 \times \text{H}) + \text{O}$$

$$= 46.068 \text{ g mol}^{-1}$$

$$m(\text{CH}_3\text{CH}_2\text{OH}) = 0.4059 \times 46.068$$

$$= 18.7 \text{ g}$$

$$m(\text{CH}_3\text{OH}) = 20.0 - 18.7$$

$$= 1.302 \text{ g}$$

$$\% \text{CH}_3\text{OH} = 1.302/20.0 \times 100$$

$$= 6.51 \%$$

$$(b) n(\text{H}_2\text{O})_{\text{eth}} = 0.4059 \text{ mol}$$

$$m(\text{H}_2\text{O})_{\text{eth}} = 0.4059 \times 18.016$$

$$= 7.312 \text{ g}$$

$$M(\text{CH}_3\text{OH}) = (1 \times \text{C}) + (4 \times \text{H}) + \text{O}$$

$$= 32.042 \text{ g mol}^{-1}$$

$$n(\text{CH}_3\text{OH}) = 1.302/32.042$$

$$= 0.04063 \text{ mol}$$

$$n(\text{H}_2\text{O}) = 0.04063 \text{ mol}$$

$$m(\text{H}_2\text{O})_{\text{meth}} = 0.04063 \times 18.016$$

$$= 0.7319 \text{ g}$$

$$m(\text{H}_2\text{O})_{\text{total}} = m(\text{H}_2\text{O})_{\text{eth}} + m(\text{H}_2\text{O})_{\text{meth}}$$

$$= 8.04 \text{ g}$$

$$7. n(\text{H}_2\text{SO}_4) = 1.500 \times 15.00$$

$$= 22.50 \text{ mol}$$

$$n(\text{SO}_3) = 100/67 \times 22.50$$

$$= 33.58 \text{ mol}$$

$$n(\text{SO}_2) = 100/85 \times n(\text{SO}_3)$$

$$= 100/85 \times 33.58$$

$$= 39.51 \text{ mol}$$

$$n(\text{FeS}_2) = 4/8 \times 100/95 \times n(\text{SO}_2)$$

$$= 4/8 \times 100/95 \times 39.51$$

$$= 20.79 \text{ mol}$$

$$M(\text{FeS}_2) = \text{Fe} + (2 \times \text{S})$$

$$= 119.99 \text{ g mol}^{-1}$$

$$m(\text{FeS}_2) = 20.79 \times 119.99$$

$$= 2495 \text{ g}$$

$$\% \text{purity} = 2495/2550 \times 100$$

$$= 97.8 \%$$

8.

$$(a) M(\text{oil}) = (57 \times \text{C}) + (110 \times \text{H}) + (6 \times \text{O})$$

$$= 891.45 \text{ g mol}^{-1}$$

$$N(\text{oil}) = 50.0/891.45 = 0.05609 \text{ mol}$$

$$n(\text{NaOH}) = 3 \times 0.05609 = 0.1683 \text{ mol}$$

$$M(\text{NaOH}) = 22.99 + 16.00 + 1.008$$

$$= 39.998 \text{ g mol}^{-1}$$

$$m(\text{NaOH}) = 0.1683 \times 39.998$$

$$= 6.73 \text{ g}$$

$$(b) n(\text{glycerol}) = 0.05609 \text{ mol}$$

$$M(\text{glycerol}) = (3 \times \text{C}) + (3 \times \text{O}) + (8 \times \text{H})$$

$$= 92.094 \text{ g mol}^{-1}$$

$$m(\text{glycerol}) = 0.05609 \times 92.094$$

$$= 5.17 \text{ g}$$

$$(c) 2\text{CH}_3(\text{CH}_2)_{16}\text{COONa} + \text{Ca}^{2+} \rightarrow$$



$$M(\text{soap}) = (18 \times \text{C}) + (2 \times \text{O}) + (35 \times \text{H}) + \text{Na}$$

$$= 306.45 \text{ g mol}^{-1}$$

$$n(\text{soap}) = 10.0/306.45$$

$$= 0.03263 \text{ mol}$$

$$n(\text{scum})$$

$$= \frac{1}{2} \times 0.03263$$

$$= 0.01632 \text{ mol}$$

$$M(\text{scum}) = (36 \times \text{C}) + (4 \times \text{O}) + (70 \times \text{H}) + \text{Ca}$$

$$= 607 \text{ g mol}^{-1}$$

$$m(\text{scum}) = 0.01632 \times 607$$

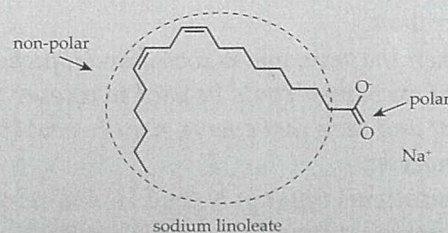
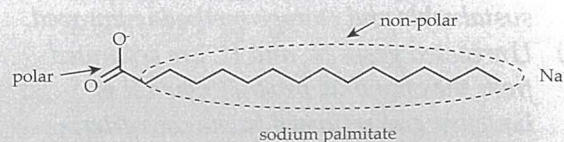
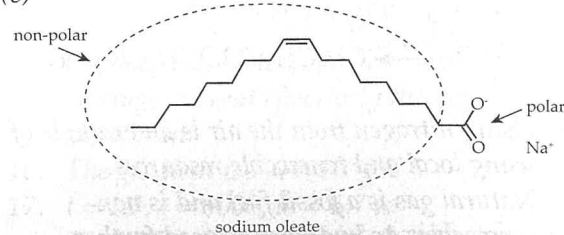
$$= 9.90 \text{ g}$$

9.

(a) palmitic acid

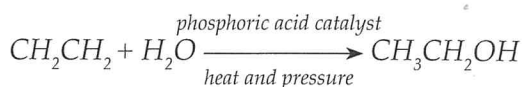


(c)

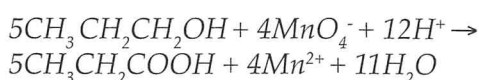


- (d) On agitation in water the soap molecules can surround small droplets of oil and grease forming micelles. The hydrophobic end dissolves in the oil and the hydrophilic end in water. These small droplets can now be washed away as they are effectively dissolved in water.
- (e) With soaps the non-polar end is a hydrocarbon chain and with anionic detergents the non-polar end is a hydrocarbon chain containing a benzene ring. With soaps the polar end is the carboxylate group -COO^- and with detergents it is the sulfonate group $\text{-SO}_2\text{O}^-$.
- Soaps are not effective in hard water as they form scum with calcium and magnesium ions. Detergents do not form scum with calcium or magnesium ions and so can be used in hard water.

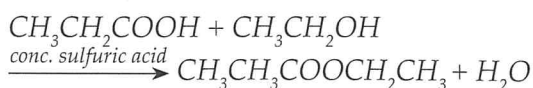
10. The first step is the hydration of ethene to produce ethanol.



The second step is the oxidation of 1-propanol to propanoic acid using an oxidising agent like potassium permanganate (shown) or potassium dichromate.



The final step is to react the ethanol from step one with the propanoic acid from step two to produce ethylpropanoate.



- 11.
- (a) Using nitrogen from the air is an example of using local and renewable resources. Natural gas is a fossil fuel and is non-renewable. As hydrogen is used further as a fuel production should become more sustainable and storage methods improved.
- (b) Unreacted gases N_2 and H_2 are separated from the ammonia product when it is liquefied and returned to the converter, shifting the equilibrium in the forward direction.
- (c) When the ammonia is cooled and liquefied a heat exchanger could be used to recover the heat and then that energy used to heat the converter.
- (d) Continuous input of N_2 and H_2 and removal of ammonia favours forward direction.

High pressures would favour the forward direction but safety and cost must be considered so a compromise is made and a moderate pressure is chosen.

High temperatures would improve the rate of the reaction, but since the reaction is exothermic in the forward direction this would shift the equilibrium in the reverse direction decreasing yield. A compromise is made and a moderate temperature is chosen. To offset the effect of lower pressure and temperature a catalyst is used to increase rate.

12.

- (a) $\text{S(l)} + \text{O}_2\text{(g)} \rightarrow \text{SO}_2\text{(g)}$
 $2\text{SO}_2\text{(g)} + \text{O}_2\text{(g)} \rightleftharpoons 2\text{SO}_3\text{(g)}$
 $\text{SO}_3\text{(g)} + \text{H}_2\text{SO}_4\text{(l)} \rightarrow \text{H}_2\text{S}_2\text{O}_7\text{(l)}$
 $\text{H}_2\text{S}_2\text{O}_7\text{(l)} + \text{H}_2\text{O(l)} \rightarrow 2\text{H}_2\text{SO}_4\text{(l)}$
- (b) Raw materials: Most sulfur is produced by removing contaminants from natural gas and petroleum. It is a sustainable use of the by-product of another process, which is favourable, although natural gas and petroleum are fossil fuels and non-renewable. There are natural sources of sulfur but it mostly occurs as sulfides and sulphates and would require processing. The oxygen for the process is obtained from air and so is local and renewable. Water is used in step 4, and whilst pure, clean water is in short supply in some locations, it is considered a local resource.

Energy and energy cycling: In step 1 energy is required to melt the sulfur and also to burn it in oxygen. Step 2 is carried out at $400\text{--}450^\circ\text{C}$ and so energy is required. Heat can be recovered from step 1 for use in step 2.

Recycling unused reactants: In step 1 an excess of oxygen is used so it is already available for step 2. Sulfur trioxide is the only product of step 2 and it is passed directly into step 3. Sulfuric acid is a reactant in step 3 and this can be obtained from the final product.

Toxic products/by products: The products of all steps are toxic and as such it is important that none escapes into the environment. Sulfurous oxides contribute to acid rain if released into the atmosphere.

Rate and equilibrium considerations: Step 1 utilises molten sulfur which is sprayed into excess oxygen (surface area) at high temperatures (increased collisions and collisions with greater energy) to maximise the rate of this step.

Step 2 is the equilibrium step. Ideally high pressures would be used to shift the equilibrium in the forward direction since