

Now test yourself answers

Chapter 1

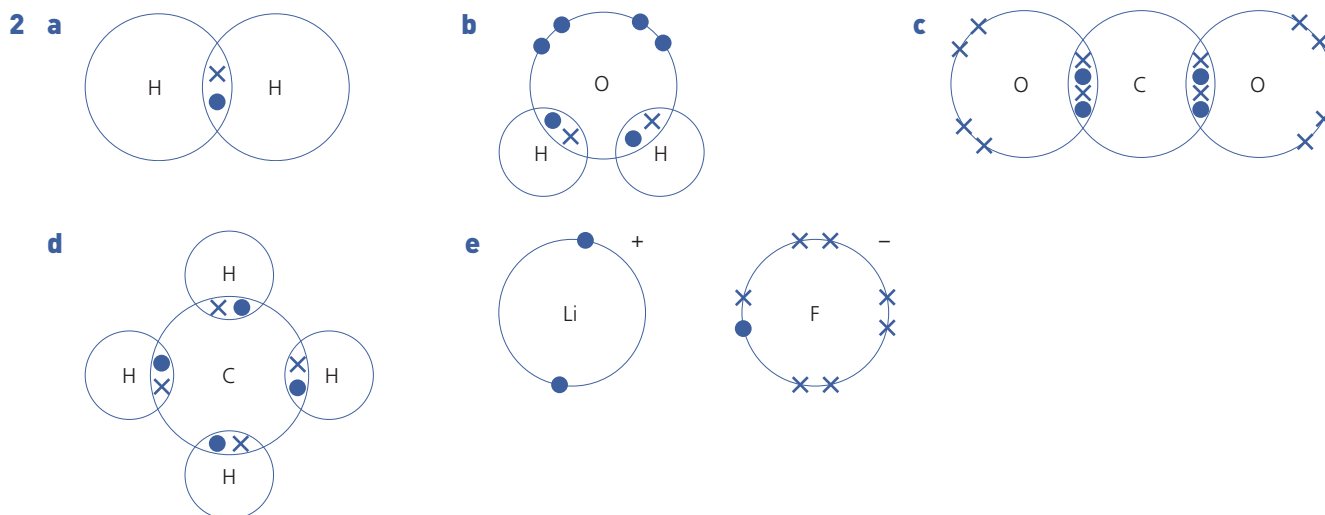
- 1 **A** $^{23}_{11}\text{Na}^+$ **B** $^{23}_{11}\text{Na}$
C $^{23}_{11}\text{Na}^-$ **D** $^{24}_{12}\text{Mg}$
E $^{25}_{12}\text{Mg}$ **F** $^{26}_{12}\text{Mg}$
- 2 **a** 12p, 13n, 10e
b $1s^2, 2s^2, 2p^6$
c This is an isotope of Mg.
- 3 Z is in Group 15.

Chapter 2

- 1 **b** $^{19}_9\text{F}$
c $^{32}_{16}\text{S}$
d $^{52}_{24}\text{Cr}$
e $^{38}_{18}\text{Ar}^+$ – Noble gases do not usually form ions.
- 2 **a** 0.5 mol
b 1.5 mol
c 0.25 mol
- 3 **a** 4 g
b 14 g
c 7 g
d 11 g
- 4 **a** RbO
b $\text{C}_3\text{O}_3\text{H}_8$
- 5 1.3 g
6 3.7 g
7 2.6 g
8 125 cm^3 of oxygen and 75 cm^3 of carbon dioxide
9 1.6 g
10 120 cm^3
11 0.110 mol dm^{-3} ; 6.19 g dm^{-3}
12 0.15 mol dm^{-3}

Chapter 3

1	Element	Charge on the ion	Electronic configuration
	Magnesium	+2	2,8
	Lithium	+1	2
	Oxygen	-2	2,8
	Aluminium	+3	2,8
	Fluorine	-1	2,8
	Sulfur	-2	2,8,8



- 3 a** linear **b** trigonal planar **c** octahedral

4 a Na_2O

b SO_2

Na and O have the largest difference in electronegativity whereas S and O have the smallest difference.

5

Material	Intermolecular force
Methanol, CH_3OH	Hydrogen bonding
Magnesium oxide, MgO	Ionic
Iodine chloride, ICl	Dipole-dipole/van der Waals'
Argon, Ar	van der Waals'
Aluminium, Al	Metallic

Chapter 4

- Dipoles exist in CO_2 but not in N_2 . This increases the attraction between adjacent molecules, making CO_2 easier to liquefy under high pressure.
- At the boiling point of the liquid, all the energy put in is used to overcome the enthalpy of vaporisation – the energy needed to break intermolecular bonds – rather than increasing the kinetic energy of the particles, so the temperature is unchanged.
- The third row is correct.
- Diamond has a giant molecular structure with strong covalent bonds throughout the structure and a tetrahedral arrangement of carbon atoms. Buckminsterfullerene has a simple molecular structure consisting of C_{60} spheres with sp^2 hybridised carbon atoms and weak bonds between the spheres.
- It has a low melting point, so bonds between the particles in X are weak. It is an electrical insulator both as a solid and when molten, so it cannot be a metal or have ionic bonds. It dissolves in cyclohexane, which is covalently bonded. So the data suggest that X has covalent bonds in its molecules, and probably van der Waals' forces or dipoles between molecules – for example, paraffin wax.

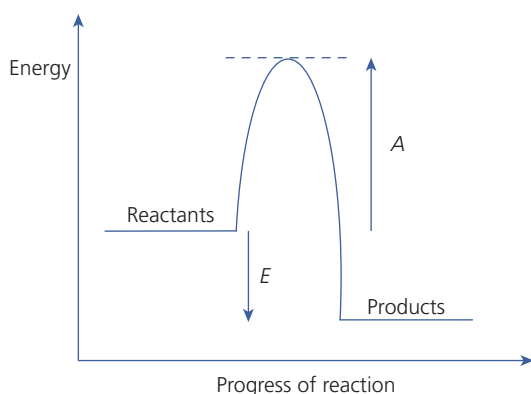
Chapter 5

- a** An explosion, e.g. the ignition of hydrogen

b Burning magnesium ribbon in air

c Putting two different metals into an electrolyte, e.g. dilute sulfuric acid, and connecting the metals with a wire.

2

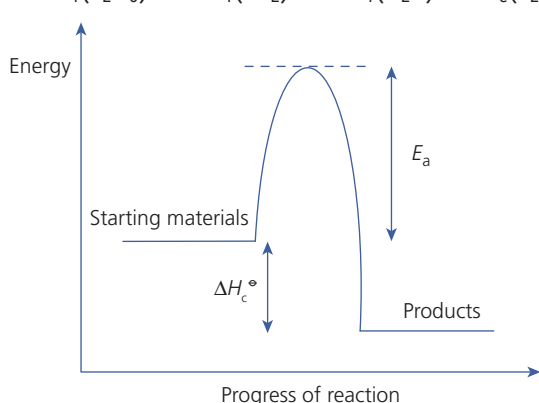


3 a A – enthalpy change of combustion of C_2H_6 ; B – y times the enthalpy change of formation of CO_2 ; C – z times the enthalpy change of formation of H_2O

b $x = 5$; $y = 2$; $z = 3$

c $\Delta H_f(C_2H_6) = 2\Delta H_f(CO_2) + 3\Delta H_f(H_2O) - \Delta H_c(C_2H_6)$

4



Chapter 6

1 a +3

b 0

c +6

2 +7, +4, +6

Chapter 7

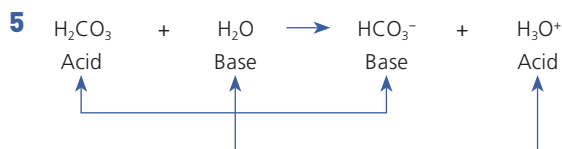
- 1 a i The reaction is exothermic; the equilibrium will move in the direction which absorbs energy, i.e. to the left.
 ii The reaction has fewer molecules on the right than on the left; increasing the pressure will favour a shift to the right.
 b i The reaction consumes CH_3CO_2H in moving from left to right, so this is favoured if the acid concentration is increased.
 ii The reaction produces water in moving from left to right; the removal of water will favour a shift in this direction.

$$2 \quad K_c = \frac{[Sn^{4+}][Fe^{2+}]^2}{[Sn^{2+}][Fe^{3+}]^2}$$

$$3 \quad K_p = \frac{p[PCl_3]p[Cl_2]}{p[PCl_5]}$$

- 4 a The equations show any changes in the number of molecules present and hence how pressure changes influence the position of equilibrium; the ΔH values indicate how temperature changes will influence the position of equilibrium.

- b** In industry the rate of production of product is critical if the process is to be economic, so sometimes compromises in the ideal conditions are made.



- 6 a** 5
b 3.5
c $K_w = 10^{-14}$, so solution contains $10^{-8.5} \text{ mol dm}^{-3} \text{ H}^+$, so its pH is 8.5

Chapter 8

- 1 Temperature:** At higher temperature, particles move faster causing more collisions in a given time; more of these collisions have sufficient energy to react.
Concentration: Greater concentration means that the likelihood of collisions between reactant particles is increased, giving more collisions in a given time.
Catalyst: A catalyst lowers the activation energy of the reaction. As a result, a greater proportion of collisions will exceed the activation energy.
- 2 a** A higher proportion of the molecules have energies greater than E_a at the higher temperature.
b E_a is lower in the catalysed reaction, so a higher proportion of the molecules have energies greater than E_a .

Chapter 9

- 1** Being a poor conductor means the element cannot be a metal. If it is a solid at room temperature, it cannot be chlorine or argon. Only phosphorus forms molecules containing four atoms.
- 2 a** The higher the nuclear charge, the stronger the attraction for the electrons.
b The further an electron is from the nucleus, the weaker the force of attraction.
- 3 a** From Table 9.1 and 9.2 we can see that X is sulfur and Y is aluminium.
b Al_2S_3
- 4** For the chlorides the first four elements have single oxidation states, corresponding to the loss of their outer electrons. Only phosphorus shows two oxidation states, losing 3 and 5 electrons respectively. Sulfur can lose 4, 2 or 1 electron when reacting with chlorine. Chlorine and argon do not react.

5 a

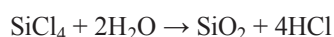
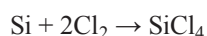
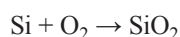
Element	Na	Mg	Al	Si	P	S	Cl
Difference in electronegativity	2.6	2.3	2.0	1.7	1.4	1.0	0.5

- b** The difference in electronegativity decreases from left to right.

c

Element	Na	Mg	Al	Si	P	S	Cl
Bonding	Ionic	Ionic	Ionic	Covalent	Covalent	Covalent	Covalent

- 6** J cannot be a gas because when it is in powdered form it reacts with oxygen. J forms a liquid chloride so it must be a non-metallic element. Only silicon tetrachloride hydrolyses to give an acidic solution and an insoluble solid.



Chapter 10

- 1 The increase in nuclear charge is counteracted by the increase in the number of inner electrons. The outer electrons are further from the nucleus, which reduces the electronegativity.
- 2 Strontium is so reactive that the surface of the metal is coated with an oxide layer which restricts the contact with oxygen until close to the melting point of strontium.
- 3 The small cation at the top of the group has a high charge density; so it can polarise the nitrate anion more.

Chapter 11

- 1 As you descend the group the van der Waals' forces between the molecules get stronger, and the halogens change from gases to a liquid and then to solid elements.
- 2 There would be no reaction because the H-F bond is stronger than the H-Cl bond.
- 3 Any suitable example in which an element in a compound is both oxidised and reduced.

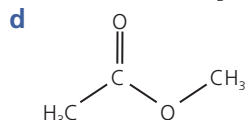
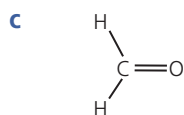
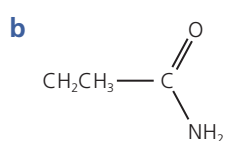
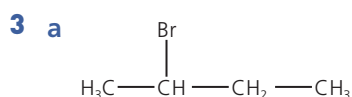


Chapter 12

- 1 The bond energy for nitrogen is almost twice as high as that for oxygen (944 kJ mol^{-1} against 496 kJ mol^{-1}). Breaking the N-N bond is only one part of the reaction and doesn't consider the products.
- 2 CH_4 is $109^\circ 28'$; NH_3 is 107° ; H_2O is 105° . The tetrahedral angle is distorted by the one lone pair on the nitrogen atom in ammonia and the two lone pairs on the oxygen in water. Lone pairs occupy a bigger volume in space than bonded pairs of electrons.
- 3 All nitrates are soluble in water. Whatever nitrate fertiliser is used there is a risk that nitrates will be washed into streams, causing eutrophication and/or getting into drinking water supplies.
- 4 **a** $\text{Al}_2\text{O}_3 + 6\text{H}^+ \rightarrow 2\text{Al}^{3+} + 3\text{H}_2\text{O}$
b $\text{CaCO}_3 + 2\text{H}^+ \rightarrow \text{Ca}^{2+} + \text{CO}_2 + \text{H}_2\text{O}$

Chapter 13

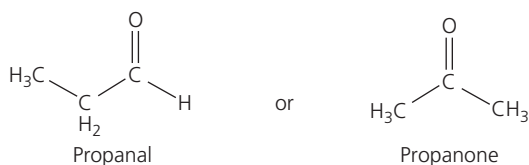
- 1 2-hydroxypropanoic acid
- 2 **a** 1-chlorobutane
b 2-hydroxypropane or propan-2-ol
c hexanoic acid
d 3-methylbutylamine



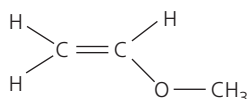
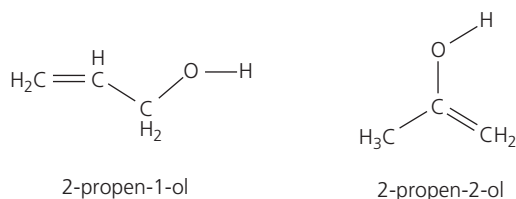
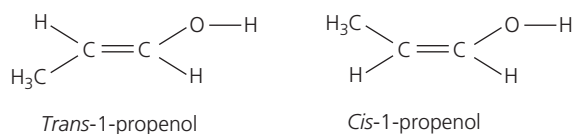
- 4 It contains a lone pair electrons on the oxygen atom.
- 5 In hydrolysis a water molecule is added, forming two new molecules. In condensation a small molecule (like water) is eliminated when two molecules join.

- 6** Ethene has sp^2 -hybridised carbon atoms, and the overlap between these atoms is in a single plane as the hybrid orbitals are planar. In ethane the electrons are sp^3 -hybridised, giving a tetrahedral arrangement.

7 a



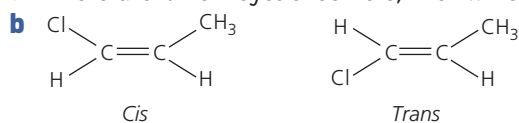
b



Methoxyethene

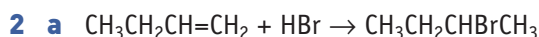
- c** There are 7 isomers, 2 of which are a *cis-trans* pair.

- 8 a** There are 4 non-cyclic isomers, 2 of which are a *cis-trans* pair.



Chapter 14

- 1** free radical substitution



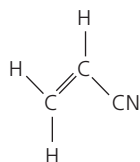
- b** 2-bromobutane

- 3 a** 1,2-dihydroxypropane

- b** ethanoic acid, carbon dioxide and water

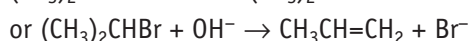
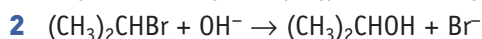
- 4** If aqueous bromine is used, both Br and OH can add to the double bond, forming $\text{CH}_2\text{BrCH}_2\text{OH}$.

5



Chapter 15

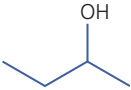
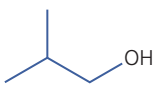
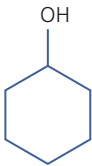
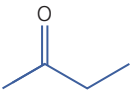
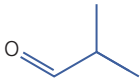
- 1** $\text{CH}_3\text{CH}_2\text{CHBrCH}_3$ and $(\text{CH}_3)_2\text{CHBrCH}_2\text{CH}_3$



- 3** It adds a carbon atom, extending the carbon chain.

- 4** The C-F bond is much stronger than the C-Br bond (467 kJ mol^{-1} against 276 kJ mol^{-1}).

Chapter 16

- 1 **a**  **b** 
- c**  **d** 
- 2 **a** secondary
b primary
c tertiary
d secondary
- 3 **a**  **b**  **c** none
- 4 **a** ethyl propanoate
b propyl methanoate
c propyl ethanoate

Chapter 17

- 1
- | Alcohol | Type of alcohol (1°, 2°, 3°) | Oxidation product |
|-------------------------|------------------------------|-------------------|
| Butan-2-ol | 2° | Ketone |
| 2-methylpropan-1-ol | 1° | Aldehyde |
| 2-methylpropan-2-ol | 3° | None |
| 2,2-dimethylpropan-1-ol | 1° | Aldehyde |
- 2 potassium cyanide plus a small amount of dilute sulfuric acid
- 3 $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}(\text{OH})\text{CN}$
- 4 K is an aldehyde because it reacts both with 2,4-DNPH and with Fehling's solution. It does not react with alkaline aqueous iodine, so it cannot contain the $\text{CH}_3\text{C}=\text{O}$ group. So K must be $\text{CH}_3\text{CH}_2\text{CH}_2\text{CHO}$ and J could be butan-1-ol, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$, or 2-methylpropan-1-ol, $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$.

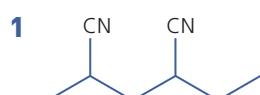
Chapter 18

- 1 ethanal; ethanol; ethanenitrile (CH_3CN)
- 2 Moisture in the atmosphere causes the esters to break down in the reverse of the reaction shown in Figure 18.3
- 3 In an acid, the water and acid push the equilibrium reaction towards the alcohol and ethanoic acid. An alkali is more efficient, forming the sodium salt of ethanoic acid rather than an equilibrium reaction.

Chapter 19

- 1 Both these reaction extend the carbon chain in a molecule.

Chapter 20



Chapter 22

- 1 C–O at $1040\text{--}1300\text{ cm}^{-1}$ strong; C=C at $1500\text{--}1680\text{ cm}^{-1}$ weak; C=O at $1710\text{--}1750\text{ cm}^{-1}$ strong; O–H at $2500\text{--}3000\text{ cm}^{-1}$ strong and broad
- 2 $n = \frac{100 \times A_{M+1}}{1.1 \times A_M} = \frac{43}{8.8} = 4.88$, so 5 carbon atoms are present.

Chapter 23

- 1 The energy change in adding a second electron to an atom that has already had one electron added
- 2 oxygen, sulfur (or any non-metallic element that forms stable $n-$ ions where $n > 1$)
- 3 **a** Entropy increases on melting because the particles are held less rigidly and have more disorder or more ways they can be arranged.
b Entropy decreases as steam condenses because the particles become more ordered or have fewer ways they can be arranged.
- 4 **a** –ve: fewer particles in product
b –ve: fewer particles in product
c +ve: more gaseous particles in products

Chapter 24

- 1 **a** oxygen
b hydrogen
c potassium and sulfate
- 2 **a** $+0.80 + (+0.76) = 1.56\text{ V}$
b $-0.13 + (+2.38) = 2.25\text{ V}$
c $+0.80 + (-0.34) = 0.46\text{ V}$
- 3 **a** $+2.38 + (+1.36) = 3.74\text{ V}$
b $+0.13 + (+1.07) = 1.20\text{ V}$
c $+1.36 + (-0.77) = 0.59\text{ V}$
d $+1.36 + (-1.07) = 0.29\text{ V}$

Chapter 25

- 1 **a** $K_{sp}(\text{MgF}_2) = [\text{Mg}^{2+}][\text{F}^-]^2$ **b** $\text{mol}^3\text{ dm}^{-9}$

Chapter 26

- 1 The step that takes the longest time dictates how long the whole reaction takes.
- 2 Because the only compound present in the rate equation is $(\text{CH}_3)_3\text{Br}$, the second mechanism is correct.
- 3 **a** A heterogeneous catalyst is in a different physical state from the reactants; a homogeneous catalyst is in the same physical state as the reactants.
b A heterogeneous catalyst is usually a solid; a homogeneous catalyst is usually in solution.

Chapter 27

- 1 The small cation at the top of the group has a high charge density; so it can polarise the nitrate anion more.
- 2 BaSO_4 , SrSO_4 , CaSO_4 – as the cations get bigger, the enthalpy of hydration decreases (as the major factor)

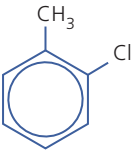
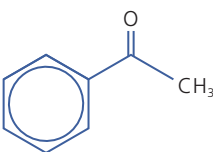
Chapter 28

- 1 **a** Scandium has a low density and only forms the +3 oxidation state (it also has a larger atomic radius).
b Zinc has a relatively low melting point and only forms the +2 oxidation state (it also has a high first ionisation energy).
- 2 The graph shows a large increase after the fifth ionisation energy, which suggests that the sixth electron must come from an inner shell. The removal of the first two electrons requires slightly less energy than the next three, which suggests that these are the two 4s electrons. So, the element is vanadium.
- 3 The two half-equations are:
 $\text{MnO}_4^- + 8\text{H}^+ + 5\text{e}^- \rightarrow \text{Mn}^{2+} + 4\text{H}_2\text{O}$
 $\text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2\text{O}_2$
 Multiply the first equation by 2:
 $2\text{MnO}_4^- + 16\text{H}^+ + 10\text{e}^- \rightarrow 2\text{Mn}^{2+} + 8\text{H}_2\text{O}$
 Multiply the second equation by 5 and reverse it:
 $5\text{H}_2\text{O}_2 \rightarrow 5\text{O}_2 + 10\text{H}^+ + 10\text{e}^-$
 Adding gives:
 $2\text{MnO}_4^- + 5\text{H}_2\text{O}_2 + 6\text{H}^+ \rightarrow 2\text{Mn}^{2+} + 5\text{O}_2 + 8\text{H}_2\text{O}$

- 4 **a**  **b** 
 

- 5 Assume that chromium is in the same oxidation state in each complex. Because the complexes are octahedral, they must be of the type $[\text{CrLig}_6]^{n+}$. Of the three ligands, OH^- gives the smallest d-orbital splitting, then H_2O and finally NH_3 . The complex with hydroxide is green, the complex with water is blue and the complex with ammonia is purple.
- 6 $[\text{CoCl}_4]^{2-}$

Chapter 29

- 1 **a**  **b**  **c** 

- 2 $\text{CH}_3\text{CH}_2\text{CH}_2\text{COCl} + \text{CH}_3\text{NH}_2 \rightarrow \text{CH}_3\text{CH}_2\text{CH}_2\text{CONHCH}_3 + \text{HCl}$

- 3 
 Mirror plane

Chapter 30

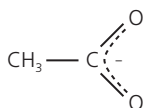
- 1 Adding chlorine would disrupt the stable π system over the ring.
- 2 positions 2 or 4
- 3 **a** ethylbenzene ($\text{CH}_3\text{CH}_2\text{C}_6\text{H}_5$)
b phenylbutanone ($\text{CH}_3\text{CH}_2\text{CH}_2\text{COC}_6\text{H}_5$)

Chapter 32

- 1 One of the lone pairs on the oxygen atom in the $-\text{OH}$ group overlaps with the delocalised ring electron system, which increases the electron density round the ring.
- 2 In phenol the lone pairs of electrons on oxygen overlap with the ring electrons. When phenol loses a proton, the negative charge can be delocalised over the whole π system, stabilising the anion.

Chapter 33

- 1 The by-product is a gas – HCl .
- 2 In the ethanoate anion the electrons are delocalised over both oxygens and the carbon atom between them, as shown.



- 3 $K_a = \frac{[\text{H}^+][\text{A}^-]}{[\text{HA}]}$ and $\text{p}K_a = -\log_{10} K_a$

In equimolar solutions of the two acids, $[\text{HA}]$ are equal and can be ignored, and in each solution $[\text{H}^+] = [\text{A}^-]$ so K_a is proportional to $[\text{H}^+]^2$. The $\text{p}K_a$ values differ by $4.76 - 0.65 \approx 4$ so $[\text{H}^+]^2$ is about 10^4 times higher, hence $[\text{H}^+]$ is about 100 times higher, in trichloroethanoic acid than in ethanoic acid.

Chapter 34

- 1 The reaction proceeds with the elimination of a small molecule, in this case HCl .
- 2 $\text{C}_6\text{H}_6 + \text{HNO}_3 \rightarrow \text{C}_6\text{H}_5\text{NO}_2 + \text{H}_2\text{O}$
 Heat benzene with a mixture of concentrated nitric and sulfuric acids at a temperature $< 50^\circ\text{C}$ to form nitrobenzene.
 Heat the nitrobenzene under reflux with tin and hydrochloric acid on a boiling water bath. When reaction is complete add aqueous sodium hydroxide and extract the phenylamine by steam distillation.
- 3 **a** With phenylamine, the lone pair of electrons on the nitrogen atom become delocalised with the π electrons on the benzene ring, making it less easy to protonate.
b With ethylamine, the ethyl group pushes electrons towards the nitrogen, enhancing its ability to be protonated.
- 4 Asp has an extra $-\text{CO}_2\text{H}$ group and Lys has an extra $-\text{NH}_2$ group.
- 5 $\text{HO}_2\text{CCH}_2\text{CH}(\text{NH}_3^+)\text{CO}_2\text{H}$

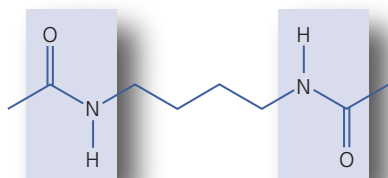
Chapter 35

- 1** In condensation polymerisation:
- A small molecule is eliminated.
 - The monomer(s) need two different functional groups.

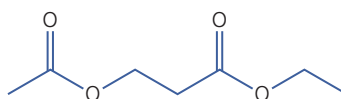
In addition polymerisation:

- The empirical formula of the polymer is the same as that of the monomer.
- An unsaturated carbon–carbon bond must be present.

2 a



b



Chapter 37

- 1** Paper chromatography relies on partition; thin-layer chromatography relies on adsorption to separate mixtures.
- 2** Although the temperature of the column and the flow rate of the carrier gas can be adjusted, it is the volatility of the sample and the interactions between the components of the sample with both the mobile and stationary phases that are critical.
- 3** The peak is shifted to the left in the ^1H NMR spectrum.
- 4 a** 2
- b** Peak at approx. $\delta = 2.0$ is $-\text{OH}$ and that at approx. $\delta = 1.2$ is $-\text{CH}_3$.
- c** J is $\text{CH}_3\text{C}(\text{CH}_3)_2\text{OH}$ (2-methylpropan-2-ol) because the ^1H NMR spectrum shows two peaks in a 9:1 ratio.
- d** Other alcohols are $(\text{CH}_3)_2\text{CHCH}_2\text{OH}$ (4 absorptions), $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{OH}$ (5 absorptions) and $\text{CH}_3\text{CH}_2\text{CH}(\text{OH})\text{CH}_3$ (5 absorptions).

Revision activity answers

Chapter 1

- a 19p, 21n, 18e
- b X has two more neutrons and one fewer electron than potassium – it must be the cation of an isotope of potassium.
- c 1st ionisation energy
- d It would be larger because the second electron is being removed from a complete inner shell.

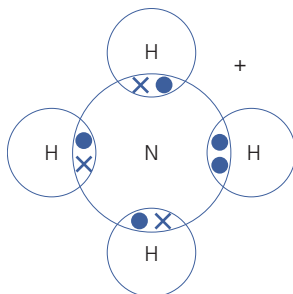
Chapter 2

- a 7.1 g
- b 12.5 cm^3
- c 25.0 cm^3

Chapter 3

- a In a covalent bond the electrons are shared between the two atoms; in an ionic bond one (or more) electrons are transferred from one atom to the other.
- b van der Waals' < permanent dipole–dipole < hydrogen
- c 120°
- d In NH_3 the lone pair of electrons on nitrogen occupy a greater volume of space than the bonded electrons, reducing the H–N–H angle from the tetrahedral angle of 109.5° .

e



- f $\text{B}^{\delta+}-\text{F}^{\delta-}$; $\text{Li}^{\delta+}-\text{O}^{\delta-}$; $\text{N}^{\delta+}-\text{O}^{\delta-}$; $\text{Li}^{\delta+}-\text{O}^{\delta-}$ is the most polar

Chapter 4

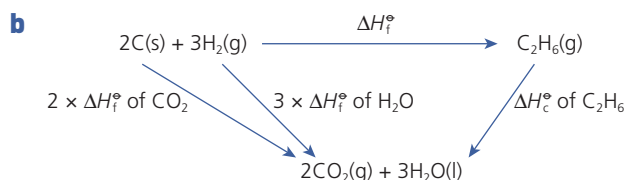
- a i Use $\frac{V_1}{T_1} = \frac{V_2}{T_2}$. So, $\frac{100}{298} = \frac{V_2}{398}$ and $V_2 = 100 \times \frac{398}{298} = 134 \text{ cm}^3$ (to 3 s.f.).
 ii Use $p_1V_1 = p_2V_2$. So, $1 \times 100 = 10 \times V_2$, and $V_2 = 10.0 \text{ cm}^3$ (to 3 s.f.).
 iii Use $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$. So, $1 \times \frac{100}{298} = 10 \times \frac{V_2}{398}$, and $V_2 = \frac{100 \times 398}{10 \times 298} = 13.4 \text{ cm}^3$ (to 3 s.f.).
- b Real gases can be liquefied, indicating that forces must exist between the particles.
- c *Simple molecular*: buckminsterfullerene; *giant covalent*: diamond, graphite, graphene

d

Substance	Melting point	Solubility	Electrical conductivity
Potassium bromide	High	Good	Good when molten or in aqueous solution
Aluminium	High	Insoluble	Very good in solid and molten states

Chapter 5

- a**
- i enthalpy change of formation of MgO
 - ii enthalpy change of combustion of ethene
 - iii enthalpy change of reaction



- c** $-1427.7 \text{ kJ mol}^{-1}$

Chapter 6

- a** +1, -1, +5
- b** $\text{ClO}^- + \text{H}_2\text{O} + 2\text{e}^- \rightarrow \text{Cl}^- + 2\text{OH}^-$ reduction
 $\text{ClO}^- + 4\text{OH}^- \rightarrow \text{ClO}_3^- + 2\text{H}_2\text{O} + 4\text{e}^-$ oxidation

Chapter 7

- a**
- i $K_c = \frac{[\text{X}_2\text{Y}]}{[\text{X}]^2[\text{Y}]}$
 - ii The reaction is endothermic, so increasing the temperature will shift the equilibrium to the right increasing $[\text{X}_2\text{Y}]$, so K_c increases.
 - iii Increasing $[\text{Y}]$ will have no effect on K_c .
 - iv Adding a catalyst will have no effect on K_c .

b

$$K_p = \frac{p(\text{NH}_3)^2}{p(\text{H}_2)^3 p(\text{N}_2)}$$

$$1.45 \times 10^{-5} = \frac{p(\text{NH}_3)^2}{0.928^3 \times 0.432}$$

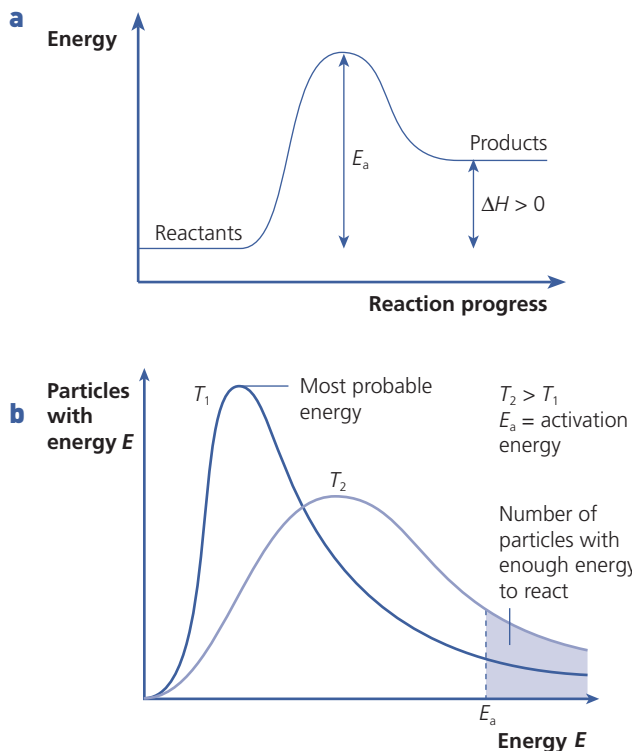
$$p(\text{NH}_3)^2 = 1.45 \times 10^{-5} \times 0.928^3 \times 0.432$$

$$= 5.006 \times 10^{-6}$$

$$p(\text{NH}_3) = 2.24 \times 10^{-3}$$

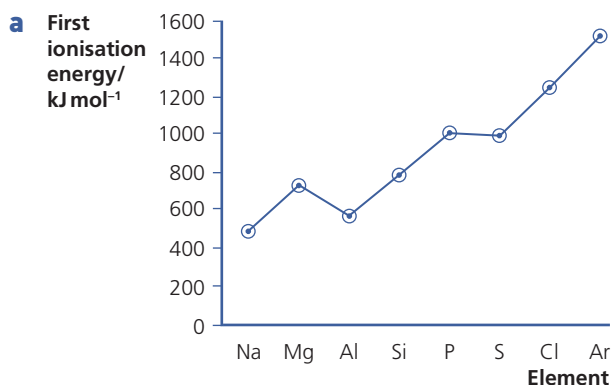
- c**
- i Acids: H_3PO_4 , HCO_2H , H_2S ; Bases: PH_3 , NH_3
 - ii Strong – H_3PO_4 ; all the others are weak

Chapter 8

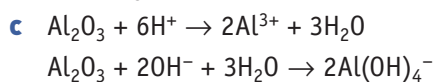


From the two curves you can see that at T_2 a greater number of particles have enough energy to react.

Chapter 9



b i Al_2O_3 , SiO_2 **ii** phosphorus **iii** silicon **iv** magnesium



Chapter 10

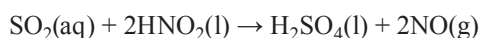
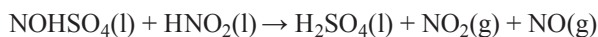
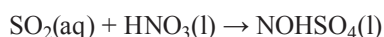
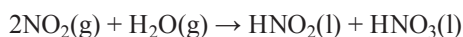
- a** The reactions are similar, but the elements are less reactive.
b To form the Group 2 ion, two electrons have to be removed from the atom; this requires more energy.

Chapter 11

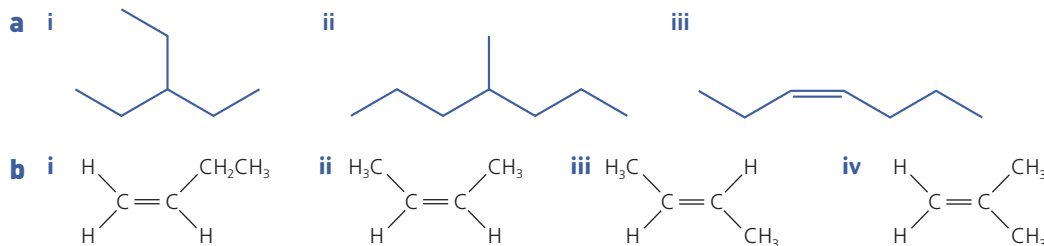
- a** a reaction in which an element is both oxidised and reduced
- b** e.g. $\text{Cl}_2(\text{aq}) + 2\text{OH}^-(\text{aq}) \rightarrow \text{Cl}^-(\text{aq}) + \text{ClO}^-(\text{aq}) + \text{H}_2\text{O}(\text{l})$
- c** **(1)** Add silver nitrate solution. A chloride will give a white precipitate, a bromide a cream precipitate and an iodide a pale-yellow precipitate.
- (2)** Add concentrated sulfuric acid to the solid. A chloride will give steamy fumes, a bromide a mixture of steamy and orange-brown fumes and an iodide a mixture of steamy and purple fumes.
- (3)** Add chlorine water to solutions of the compound and shake with cyclohexane. A chloride will show no reaction, a bromide will produce an orange colour in the cyclohexane, an iodide will produce a purple colour in the cyclohexane.

Chapter 12

- a** The $\text{N}\equiv\text{N}$ bond energy is very high, and the bond requires a lot of energy to be broken.
- b** In NH_4^+ the four bonds are equivalent so the ammonium ion is tetrahedral. In NH_3 the lone pair of electrons on nitrogen occupy a bigger volume than the bonded electrons, reducing the $\text{H}-\text{N}-\text{H}$ angle from the tetrahedral angle of 109.5° .
- c** NO_x is believed to play a part in the reactions that form sulfuric acid in the atmosphere. For example:



Chapter 13



Structures ii and iii are *cis-trans* isomers.

- c** An electrophilic reagent attacks negatively charged centres; a nucleophilic reagent attacks positively charged centres.
- d** In an alkane all the carbon atoms are saturated, with four single bonds around them already.

Chapter 14

- a** Breaking them into smaller fragments produces compounds that are commercially more 'useful'.
- b** alkenes

Chapter 15

- a** Carbon and halogens have different electronegativity values and so have different attraction for the electrons in the bond.
- b** A C–Cl bond is much stronger than a C–I bond.
- c** $(\text{CH}_3)_2\text{CHBr} > \text{CH}_3\text{CH}_2\text{Br} > \text{CH}_3\text{CH}_2\text{Cl}$

Chapter 16

- a**
 - i** primary
 - ii** secondary
 - iii** tertiary
 - iv** two secondary
 - v** primary (left), secondary (right)
 - vi** secondary (left) and tertiary (right)
- b** Both primary and secondary alcohols cause the acidified potassium dichromate(VI) solution to turn green. On warming the mixture the primary alcohol is oxidised to the carboxylic acid. The smell of this is quite different to the ketone produced by the secondary alcohol. The tertiary alcohol shows no reaction.

Chapter 17

- a** Oxidation of the secondary alcohol to an acid would require a C–C bond to be broken.
- b**
 - i** nucleophilic
 - ii** addition (across the C=O bond)
- c** The iodoform reaction also gives a positive result with ethanal and the $\text{CH}_3\text{CH}(\text{OH})-$ group in alcohols.

Chapter 18

- a** (primary) alcohols, aldehydes and nitriles
- b** alcohols, esters and salts
- c** any three from: perfumes, flavours, margarine, soap, solvents

Chapter 19

- a** Alkyl groups are electron-donating and push electrons onto the nitrogen and strengthening its attraction for the proton. The more alkyl groups, the stronger the base.
- b** $\text{CH}_3\text{CH}_2\text{NH}_2 < (\text{CH}_3\text{CH}_2)_2\text{NH} < (\text{CH}_3\text{CH}_2)_3\text{N}$

Chapter 20

- a** A C=C double bond
- b** as a side group

Chapter 21

React the ethene with HBr to form bromoethane, $\text{CH}_3\text{CH}_2\text{Br}$.

Use KCN in dilute acid to substitute the Br with CN to form $\text{CH}_3\text{CH}_2\text{CN}$.

Hydrolyse the nitrile with aqueous sulfuric acid and heat to form propanoic acid, $\text{CH}_3\text{CH}_2\text{COOH}$.

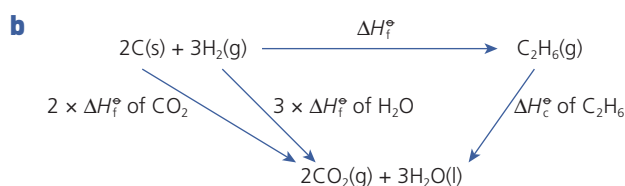
React the propanoic acid with the ethanol using concentrated sulfuric acid and heat to give the ester, $\text{CH}_3\text{CH}_2\text{COOCH}_2\text{CH}_3$.

Chapter 22

- a the bonds in the molecule
- b If they contain the same bonds, they will have similar spectra.
- c i A (2950 cm^{-1}) is due to alkyl; B (1740 cm^{-1}) is due to $\text{C}=\text{O}$; and C (1050 cm^{-1}) is due to $\text{C}-\text{O}$.
 - ii $\text{C}_3\text{H}_6\text{O}_2$
 - iii $\text{CH}_3\text{CO}_2\text{CH}_3$
- d CH_3^+ m/e 15; $^+\text{C}=\text{O}$ m/e 28

Chapter 23

- a i enthalpy change of formation
- ii enthalpy change of atomisation
- iii enthalpy change of hydration



- c $-1427.7\text{ kJ mol}^{-1}$
- d You would expect it to be less exothermic because only two molecules of water are formed, but you also have to consider the enthalpy of formation of ethene – it is not a simple comparison.

Chapter 24

- a Use $E = E^\ominus + \frac{0.059}{z} \log \frac{[\text{oxidised species}]}{[\text{reduced species}]}$

$$\begin{aligned}
 \text{In this case } E_{\text{Cu}} &= E^\ominus_{\text{Cu}} + \frac{0.059}{2} \log \frac{[\text{Cu}^{2+}(\text{aq})]}{[\text{Cu}(\text{s})]} \\
 &= +0.34 + \frac{0.059}{2} \times (\log(0.01) - \log(1)) \\
 &= +0.34 + \frac{0.059}{2} \times (-2 - 0) \\
 &= +0.34 - 0.059 = +0.281
 \end{aligned}$$

$$E_{\text{cell}} = +0.77 + (-0.281) = 0.489\text{ V}$$

- b In a more dilute solution, E_{Cu} would be lower than $+0.281\text{ V}$, hence the cell potential would be closer to $+0.77\text{ V}$.

Chapter 25

a $K_a = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$

$$\frac{[H^+]^2}{0.01} = 4.4 \times 10^{-7}, \text{ so } [H^+]^2 = 4.4 \times 10^{-7} \times 0.01 \text{ and } [H^+] = 6.63 \times 10^{-5}$$

So pH = 4.18

b Use $pH = pK_a + \log \frac{[\text{salt}]}{[\text{acid}]}$

Mixing the two solutions means that the total volume is 75 cm³ so the concentrations are reduced to $\frac{2}{3}$ and $\frac{1}{3}$ of the initial concentration respectively.

$$pH = \log(1.80 \times 10^{-5}) + \log\left(\frac{\frac{2}{3} \times 0.200}{\frac{1}{3} \times 0.200}\right)$$

$$= \log(1.80 \times 10^{-5}) + \log 2$$

$$= 5.05$$

Chapter 26

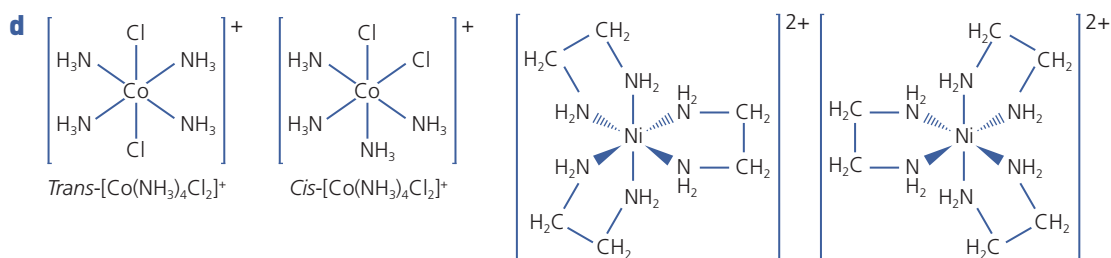
- a** When [A] is doubled (runs 2 and 3) the initial rate is doubled, but when [B] is doubled (runs 1 and 2) there is no change in initial rate. So the rate equation is rate = $k[A]$.
- b i** Platinum, rhodium and palladium are commonly used.
- ii** NO_x is converted into N₂ and O₂; CO is converted into CO₂; hydrocarbons are converted into CO₂ and H₂O.
- c i** The usual answer here is Fe²⁺/Fe³⁺ catalysing the iodide–peroxodisulfate reaction, but equally acceptable would be the reaction of chlorine radicals with ozone.
- ii** For Fe²⁺:
- $$S_2O_8^{2-} + 2Fe^{2+} \rightarrow 2SO_4^{2-} + 2Fe^{3+}$$
- $$2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$$
- For Cl[•]:
- $$Cl^{\bullet} + O_3 \rightarrow ClO^{\bullet} + O_2$$
- $$ClO^{\bullet} + O_3 \rightarrow Cl^{\bullet} + O_2$$

Chapter 27

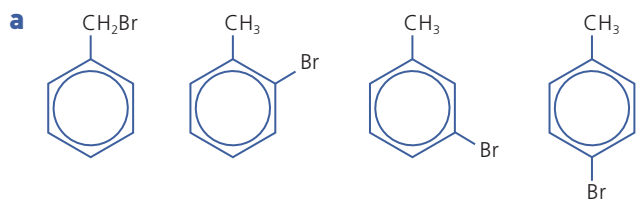
MgCO₃ is less stable than BaCO₃ because the smaller cation has a higher charge density, polarising the anion.

Chapter 28

- a** Calcium has no 3d-electrons and is unable to form more than a +2 oxidation state.
- b** Chromium produces complex ions, can form coloured compounds and has multiple oxidation states.
- c** geometrical and optical isomerism



Chapter 29



- b** Alkenes undergo addition reactions but arenes undergo electrophilic substitution.
c It can only be superimposed on the image your right hand forms in a mirror.

Chapter 30

- a** It reacts with bromine in a substitution reaction rather than an addition reaction.
b Methylbenzene can undergo ring- or side-chain substitution.
c **i** $(\text{CH}_3)_2\text{CHCl}$ **ii** $\text{C}_6\text{H}_5\text{COCl}$

Chapter 31

- a** The lone pair electrons on chlorine delocalise with the ring electrons in chlorobenzene, making the C–Cl bond stronger in chlorobenzene than in 1-chlorohexane.
b With benzene the product is bromobenzene as all ring positions are equivalent. With methylbenzene, two isomers are formed with bromine in the 2- and 4-positions relative to the methyl group.

Chapter 32

Benzene requires vigorous conditions for nitration – a mixture of hot concentrated nitric and sulfuric acids. Phenol on the other hand only requires dilute nitric acid, reacting without the need for heat. The presence of the –OH ‘activates’ the ring, making it much more reactive, and directs the nitro- group to the 2- and 4-positions relative to the –OH group. In phenol, the removal of the proton produces the phenoxide ion and the electrons delocalise with the ring electron, producing negative charge density on carbon atoms 2 and 4 which attract the NO_2^+ .

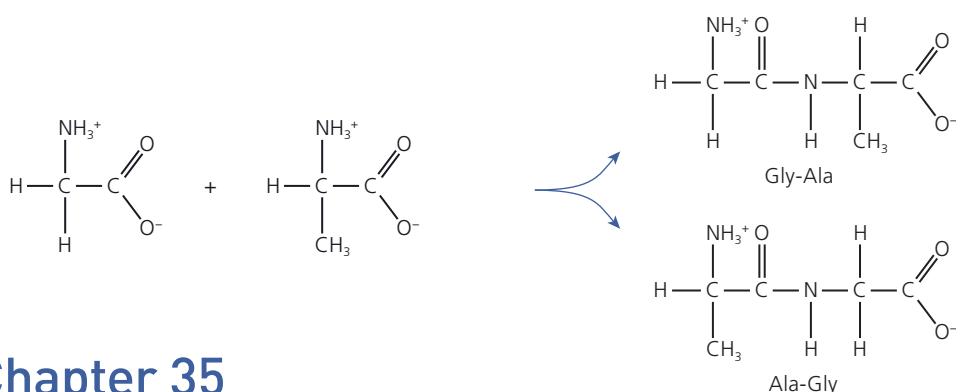
Chapter 33

In comparison with ethanoic acid, the low $\text{p}K_a$ for $\text{CH}_2\text{ClCO}_2\text{H}$ is caused by the electronegative chlorine atom attracting electrons from the $\text{O}=\text{C}$ group, making it easier to lose the H^+ ion. In the case of $\text{CH}_3\text{CH}_2\text{CO}_2\text{H}$, the ethyl group is electron-releasing, making it less easy for the H^+ to be lost.

Chapter 34

- a** diazotisation
b amines
c They undergo internal ionisation, e.g. $\text{H}_3\text{N}^+-\text{CH}_2-\text{CO}_2^-$.

d



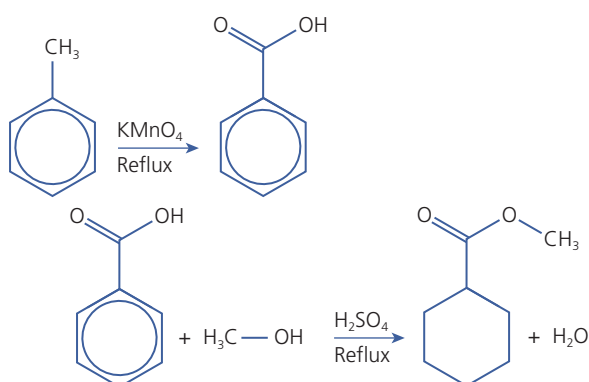
Chapter 35

- a water and hydrogen chloride
- b i Condensation between amino acid molecules
ii Condensation between a dicarboxylic acid and a diamine
- c
- d hydrogen bonding

Chapter 36

- a none
- b aldehyde (cannot be an alcohol because sodium does not react; cannot be a ketone because MnO_4^- is decolorised)

c



Chapter 37

- a Partition relies on the different solubilities of the material in two solvents. Adsorption relies on the attraction of the material to a solid.
- b In a ^{13}C NMR spectrum there will be two lines, corresponding to the two carbon atoms. In a ^1H NMR spectrum there will be three groups of lines, corresponding to protons in three different chemical environments. These will consist of a single peak, a group of peaks with heights 1 : 3 : 3 : 1, and a group of peaks with heights 1 : 2 : 1.
- c protons attached to oxygen or nitrogen atom, which can exchange with deuterium atoms