

## Examination answers

## 1.1 Atoms and reactions

1 (a)

particle	relative mass	relative charge
proton	1	+1
neutron	1	0
electron	1/2000	-1

- (b) (i) Number of neutrons  
 ${}^7\text{Li}$  has one more neutron than  ${}^6\text{Li}$
- (ii) Number of electrons  
 ${}^{32}\text{S}^{2-}$  has two more electrons than  ${}^{32}\text{S}$
- (iii) Number of protons  
 ${}^{40}\text{Ca}^{2+}$  has one more proton than  ${}^{39}\text{K}^+$

2 (a)

isotope	protons	neutrons	electrons
nickel-58	28	30	28
nickel-60	28	32	28
nickel-62	28	34	28

- (b) (i) Mass spectrometry
- (ii) The weighted mean mass of an atom of an element compared with 1/12th the mass of the carbon-12 isotope

$$\text{(iii)} \quad A_r = 63.0 \times \frac{77.2}{100} + 65.0 \times \frac{22.8}{100} = 63.456$$

$$= 63.5$$

(iv) Copper

- (c) (i) mass Ni =  $\frac{25}{100} \times 8.0 = 2.0 \text{ g}$   
amount =  $\frac{2.0}{58.7} = 0.034 \text{ mol}$

$$\text{(ii)} \quad \text{number} = 0.034 \times 6.02 \times 10^{23}$$

$$= 2.05 \times 10^{22} \text{ atoms}$$

- 3 (a) (i) amount =  $\frac{1.80}{24.0} = 0.0750 \text{ mol}$

$$\text{(ii)} \quad M(\text{NaN}_3) = 65.0 \text{ g mol}^{-1}$$

$$0.0500 \text{ mol NaN}_3 \rightarrow 0.0750 \text{ mol N}_2 \text{ (from equation)}$$

$$n = \frac{m}{M} \quad \therefore m = 0.0500 \times 65.0 = 3.25 \text{ g}$$

- (b)  $n(\text{Na}) = \frac{m}{M} = \frac{1.15}{23.0} = 0.0500 \text{ mol}$

 $\therefore 0.0500 \text{ mol NaOH}$  (from equation)

$$n = \frac{c \times V}{1000} \quad \therefore c = \frac{1000 \times n}{V} = \frac{1000 \times 0.0500}{25.0}$$

$$= 2.00 \text{ mol dm}^{-3}$$

- (c) (i) Good conductor of heat
- (ii) Sodium is very reactive

- 4 (a) In NaClO, oxidation number of Cl = +1  
In NaCl, oxidation number of Cl = -1  
 $\therefore$  oxidation number decreases and Cl is reduced

$$\text{(b) (i)} \quad n = \frac{84}{24000} = 3.5 \times 10^{-3} \text{ mol}$$

- (ii) From equation, 1 mol NaClO  $\rightarrow$  1 mol O<sub>2</sub>  
 $\therefore$  amount (NaClO) =  $3.5 \times 10^{-3} \text{ mol}$

$$\text{(iii)} \quad n = \frac{c \times V}{1000} \quad \therefore c = \frac{1000 \times n}{V} = \frac{1000 \times 3.5 \times 10^{-3}}{5.0}$$

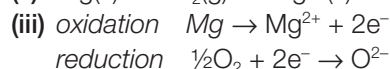
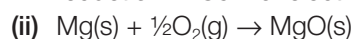
$$= 0.70 \text{ mol dm}^{-3}$$

- (c)  $M(\text{NaClO}) = 74.5 \text{ g mol}^{-1}$

 $\therefore$  bleach has a mass concentration of  $74.5 \times 0.70 = 52.15 \text{ g dm}^{-3}$ This is 5.215 g per 100 cm<sup>3</sup> and label information is therefore correct

- (d)  $\text{NaClO} + 2\text{HCl} \rightarrow \text{Cl}_2 + \text{H}_2\text{O} + \text{NaCl}$

- 5 (a) (i) *oxidation* Loss of electrons  
*reduction* Gain of electrons



- (b) (i) There would be excess solid (MgO) remaining

$$\text{(ii)} \quad n = c \times \frac{V}{1000} = \frac{2.00 \times 25.0}{1000} = 0.0500 \text{ mol}$$

- (iii) From equation,  
1 mol MgO reacts with 2 mol HNO<sub>3</sub>  
 $\therefore$  amount of MgO = 0.0250 mol

$$\text{(iv)} \quad n = \frac{m}{M} \quad \therefore m(\text{MgO}) = n \times M = 0.0250 \times 40.3$$

$$= 1.0075 \text{ g} = 1.01 \text{ g}$$

- (v) Mg: in MgO, ox no = +2; in Mg(NO<sub>3</sub>)<sub>2</sub>, ox no = +2  
H: in HNO<sub>3</sub>, ox no = +1; in H<sub>2</sub>O, ox no = +1  
O: in MgO + HNO<sub>3</sub>, ox no = -2;  
in Mg(NO<sub>3</sub>)<sub>2</sub> + H<sub>2</sub>O, ox no = -2  
No ox no changes,  $\therefore$  reaction is NOT redox

- 6 (a) (i) Loss of electrons

(ii) Gain of electrons

- (b) Ba

0 to +2

- (c) (i)  $n = \frac{m}{M} = \frac{2.74}{137.3} = 0.01996 = 0.0200 \text{ mol}$

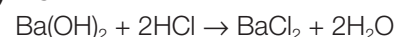
- (ii) From equation, 1 mol Ba  $\rightarrow$  1 mol H<sub>2</sub>  
 $\therefore 0.0200 \text{ mol Ba} \rightarrow 0.0200 \text{ mol H}_2$   
volume H<sub>2</sub> =  $0.0200 \times 24.0 = 0.480 \text{ dm}^3$

- (iii) From equation, 0.0200 mol Ba  $\rightarrow$  0.0200 mol Ba(OH)<sub>2</sub>

$$n = \frac{c \times V}{1000} \quad \therefore c = \frac{n \times 1000}{V} = \frac{0.0200 \times 1000}{250}$$

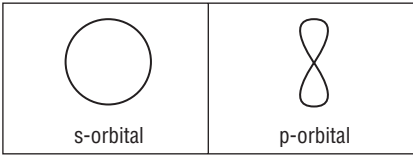
$$= 0.0800 \text{ mol dm}^{-3}$$

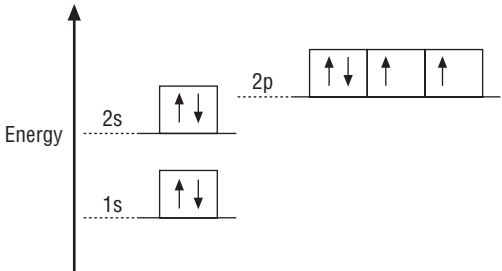
- (iv) HCl



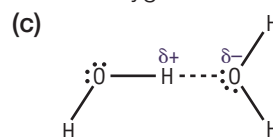
- 7 (a) (i) Ammonia is a base  
 (ii)  $n(\text{NH}_3) = \frac{m}{M} = \frac{100}{17.0} = 5.88 \text{ mol}$   
 $2 \text{ mol NH}_3 \rightarrow 1 \text{ mol (NH}_4)_2\text{SO}_4$   
 $\therefore 2.94 \text{ mol (NH}_4)_2\text{SO}_4 \text{ forms}$   
 $m = n \times M = 2.94 \times 132.1$   
 $\text{mass} = 388 \text{ g}$   
 (iii) fertiliser
- (b) Solid disappears, gas evolves  
 $2\text{HNO}_3 + \text{MgCO}_3 \rightarrow \text{Mg(NO}_3)_2 + \text{H}_2\text{O} + \text{CO}_2$
- 8 (a) (i)  $n = \frac{432}{24.0} = 18.0 \text{ mol}$   
 (ii)  $n = c \times V \text{ in dm}^3$   
 $\therefore c = \frac{n}{V} = \frac{18.0}{1.40} = 12.9 \text{ mol dm}^{-3}$
- (b) (i) Solid disappears  
 $\text{MgO} + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{H}_2\text{O}$   
 (ii) Bubbles and solid disappears  
 $\text{MgCO}_3 + 2\text{HCl} \rightarrow \text{MgCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$

## 1.2 Electrons, bonding and structure

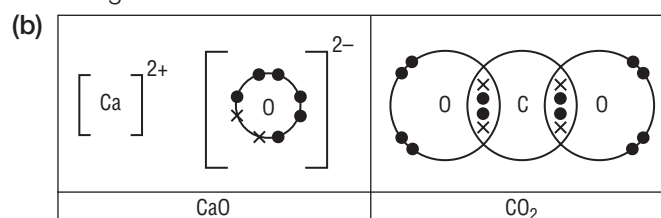
- 1 (a) 
- (b) 

	number of electrons
a d-orbital	2
a p sub-shell	6
the third shell ( $n = 3$ )	18
- (c) 
- (d) (i) The energy required to remove 1 electron from each atom in 1 mole of gaseous atoms.  
 (ii)  $\text{O}^{2+}(\text{g}) \rightarrow \text{O}^{3+}(\text{g}) + \text{e}^-$   
 (iii) There is a large jump in ionisation energies between the 6th and 7th. This indicates that the seventh electron has been removed from a different shell, closer to the nucleus.
- 2 (a) (i) The electrostatic attraction between oppositely charged ions.  
 (ii) A shared pair of electrons.

- (b) (i) The attraction of a bonded atom for the pair of electrons in a covalent bond.  
 (ii)  $\text{O}^{\delta-} \text{---} \text{X} \text{---} \text{H}^{\delta+}$   
 In the example above, the electron pair is attracted closer to the more electronegative oxygen atom.

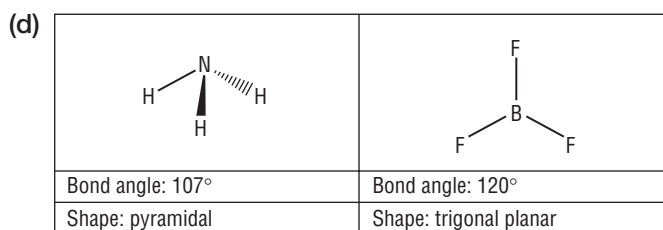
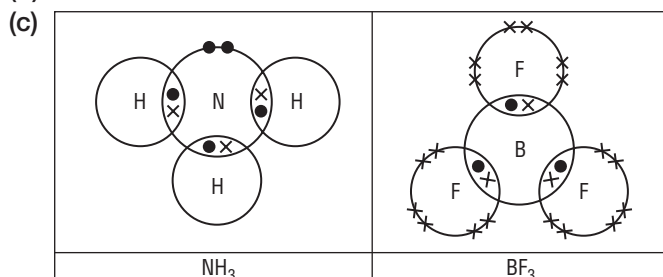
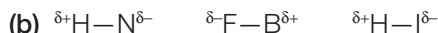


- 3 (a) The electrostatic attraction between oppositely charged ions.

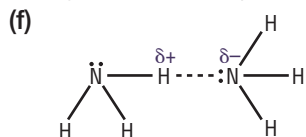


- (c)  $1s^2 2s^2 2p^6 3s^2 3p^6$
- (d) (i)  $n = \frac{m}{M} = \frac{1.50}{56.1} = 0.0267 \text{ mol}$   
 (ii) From equation,  
 $1 \text{ mol CaO reacts with } 2 \text{ mol HNO}_3$   
 $\therefore 0.0267 \text{ mol CaO reacts with } 0.0534 \text{ mol HNO}_3$   
 $n = \frac{c \times V}{1000} \therefore V = \frac{1000 \times n}{c} = \frac{1000 \times 0.0534}{2.50}$   
 $= 21.4 \text{ cm}^3$
- (e) (i) A covalent bond is a shared pair of electrons. In a dative covalent bond, the shared pair comes from one of the bonded atoms only.  
 (ii)  $\text{Ca(NO}_3)_2 \rightarrow \text{CaO} + 2\text{NO}_2 + \frac{1}{2}\text{O}_2$
- 4 (a) Na has metallic bonding with attraction between  $\text{Na}^+$  ions and delocalised electrons.  
 $\text{Cl}_2$  has covalent bonding with a shared pair of electrons between the Cl atoms.  
 $\text{NaCl}$  has ionic bonding with electrostatic attractions between  $\text{Na}^+$  and  $\text{Cl}^-$  ions.
- (b)  $\text{Cl}_2$  does not conduct electricity as there are no mobile charge carriers.  $\text{Cl}_2$  also has low melting and boiling points because the intermolecular forces are weak.  
 $\text{NaCl}$  cannot conduct electricity when solid as the ions are fixed in position in the ionic lattice structure. When molten or aqueous, the ions can move, conducting electricity.  
 $\text{NaCl}$  has high melting and boiling points because the ionic bonds are strong and these are broken during melting and boiling.

5 (a) The attraction of a bonded atom for the pair of electrons in a covalent bond.

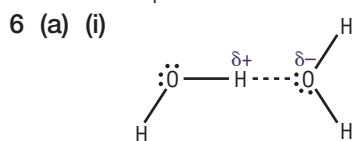


(e) In NH<sub>3</sub> the bonds are polar and the molecule is non-symmetrical. Therefore there is an overall dipole. In BF<sub>3</sub>, the dipoles cancel as the molecule has a symmetrical shape.



(g) In NH<sub>3</sub>, there are 3 bonded pairs and 1 lone pair of electrons surrounding the N.

In NH<sub>4</sub><sup>+</sup>, there are 4 bonded pairs. Lone pairs repel more than bonded pairs.



(ii) Ice is less dense than water because hydrogen bonds hold the water molecules apart in an open lattice structure.

Water has a higher boiling point than expected because hydrogen bonds act between the molecules and extra energy has to be supplied to break the hydrogen bonds.

(b) N is surrounded by 3 bonded pairs and 1 lone pair. This would give a tetrahedral arrangement of electron pairs around the N as the electron pairs repel one another to break as far apart as possible. The lone pair repels more, reducing the tetrahedral bond angle to 107°.

7 Sodium chloride does not conduct electricity because the ions have fixed positions in the ionic lattice and cannot move. In graphite, the delocalised electrons between the layers can move and conduct electricity.

The ionic bonding in sodium chloride is strong and a large amount of energy is required to break the ions from the solid lattice.

In graphite the carbon atom in the layers are bonded covalently. The bonds are strong and require a large amount of energy to break.

Sodium chloride interacts with water, the ions being attracted to the polar water molecules. Hence NaCl is soluble.

Graphite is non-polar and does not interact with polar water molecules.

### 1.3 The Periodic Table

1 (a) (i) Si  
(ii) F  
(iii) C

(b) Across a period, the number of protons increases. Electrons are added to the same shell.

The attraction on the outer electrons from the nucleus increases, drawing the electrons closer in.

(c) Na<sup>+</sup> is smaller.

It has one fewer shell than Na and the remaining electrons will be attracted more to the nucleus.

2 (a)

element	structure	bonding
Mg	giant	metallic
Si	giant	covalent
S	simple	covalent

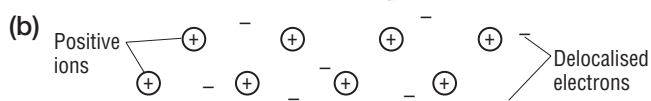
(b) Silicon has strong bonds (covalent bonds) that are broken on boiling.

Phosphorus has weak forces between molecules that are broken on boiling.

(c) From sodium to aluminium, the number of delocalised electrons increases. The ionic charge also increases. The overall effect is that attraction between the ions and electrons increases.

3 (a)

element	Na	Mg	Al	Si	P	S	Cl
boiling point/°C	883	1107	2467	2355	280	445	-35
bonding	M	M	M	C	C	C	C
structure	G	G	G	G	S	S	S



Metallic bonding is the electrostatic attraction between positive ions and delocalised electrons.

- (c) (i) Phosphorus has weak forces between molecules that are broken on boiling. Silicon has strong forces (covalent bonds) that are broken on boiling.

- (ii) Aluminium has more delocalised electrons than magnesium.  $\text{Al}^{3+}$  ions are present rather than  $\text{Mg}^{2+}$ .

The overall effect is that the ion/electron attraction is stronger in aluminium than in magnesium.

- 4 (a)  $\text{RaCl}_2$

- (b)  $\text{Ra}^{2+}$  gains electrons to form Ra

- (c) (i) Bubbles  
Solid radium disappears.

- (ii) 14

- (d) (i) First ionisation energy



- (ii) The atomic radius and electron shielding are greater in radium. There will be less attraction from the nucleus despite the nuclear charge increasing.

- 5 (a) (i)  $24.3 + 35.2 \times 2 + 6 \times (1.0 \times 2 + 16) = 203.3$

- (ii) White precipitate forms.

- (iii)  $\text{Ag}^+(\text{aq}) + \text{Cl}^-(\text{aq}) \rightarrow \text{AgCl(s)}$

- (iv)  $\text{AgCl(s)}$  dissolves in dilute  $\text{NH}_3(\text{aq})$   
 $\text{AgBr(s)}$  dissolves in concentrated  $\text{NH}_3(\text{aq})$   
 $\text{AgI(s)}$  is insoluble in concentrated  $\text{NH}_3(\text{aq})$

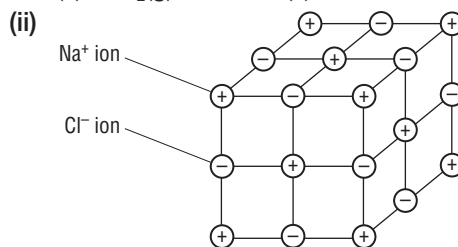
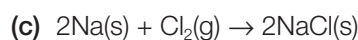
- (b) (i) 0  
+1  
-1

- (ii) Tap water contains dissolved  $\text{Cl}^-$  ions which would react with the aqueous silver nitrate.

- 6 (a) (i)  $n = \frac{c \times V}{1000} = \frac{12.0 \times 50.0}{1000} = 0.600 \text{ mol}$

- (ii) From equation, 4 mol HCl forms 1 mol  $\text{Cl}_2$   
 $\therefore 0.600 \text{ mol HCl}$  forms 0.150 mol  $\text{Cl}_2$   
volume  $\text{Cl}_2 = 0.150 \times 24.0 = 3.60 \text{ dm}^3$

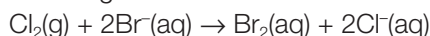
- (b) In  $\text{MnO}_2$ , oxidation number Mn = +4  
In  $\text{MnCl}_2$ , oxidation number Mn = +2  
 $\therefore$  Mn has decreased its oxidation number and has been reduced.



An alternating lattice of  $\text{Na}^+$  and  $\text{Cl}^-$  ions.

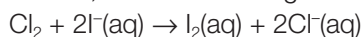
- (d)  $\text{Cl}_2(\text{g})$  and  $\text{Br}^-(\text{aq})$ :

An orange colour of bromine is seen



$\text{Cl}_2(\text{g})$  and  $\text{I}^-(\text{aq})$ :

A brown colour of iodine forms. With an organic solvent, the colour changes to purple.



This shows that chlorine is more reactive than bromine and iodine.

Chlorine has smaller atoms than bromine and iodine and can more readily gain an electron.

It is a stronger oxidising agent.

- 7 (a) (i) Orange

- (ii)  $\text{Cl}_2(\text{g}) + 2\text{KBr(aq)} \rightarrow 2\text{KCl(aq)} + \text{Br}_2(\text{aq})$

- (iii) During oxidation, an electron is lost. Chlorine can take this electron more readily than bromine because the atoms are smaller and the attraction from a chlorine atom's nucleus will be greater than from a bromine atom's nucleus.

- (b) (i) The amount of substance with the same number of particles as are in 12 g of carbon-12.

- (ii)  $n = \frac{c \times V}{1000} = \frac{0.275 \times 120}{1000} = 0.0330 \text{ mol}$

- (iii) From equation, 1 mol  $\text{Cl}_2$  reacts with 2 mol NaOH  
 $\therefore 0.0165 \text{ mol Cl}_2$  reacts with 0.0330 mol NaOH  
volume =  $0.0165 \times 24.0 = 0.396 \text{ dm}^3$

- (iv) Bleach

- (c)  $\text{NaClO}_3$

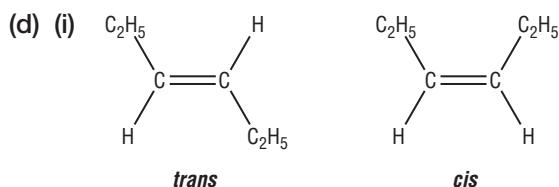
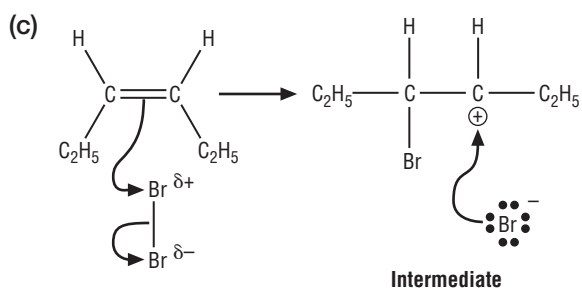
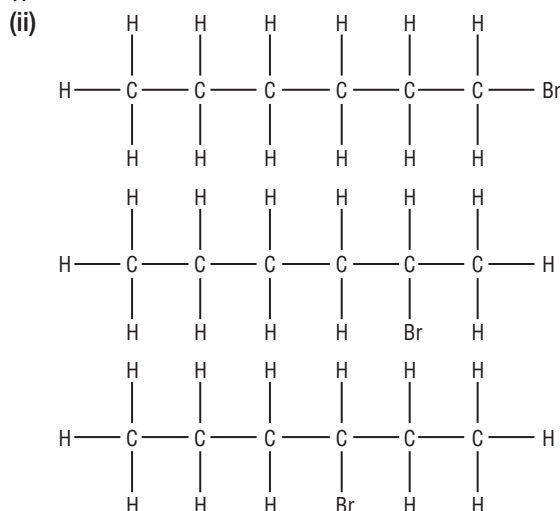
## 2.1 Basic concepts and hydrocarbons

- 1 (a) (i)  $\text{Br} - \text{Br} \rightarrow \text{Br}\cdot + \text{Br}\cdot$

- (ii)  $\text{Br} - \text{Br} \rightarrow \text{Br}^+ + \text{Br}^-$

- (iii)  $\text{Br}\cdot$   
 $\text{Br}^-$

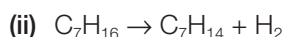
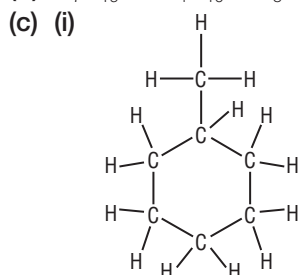
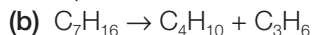
(b) (i) Radical substitution



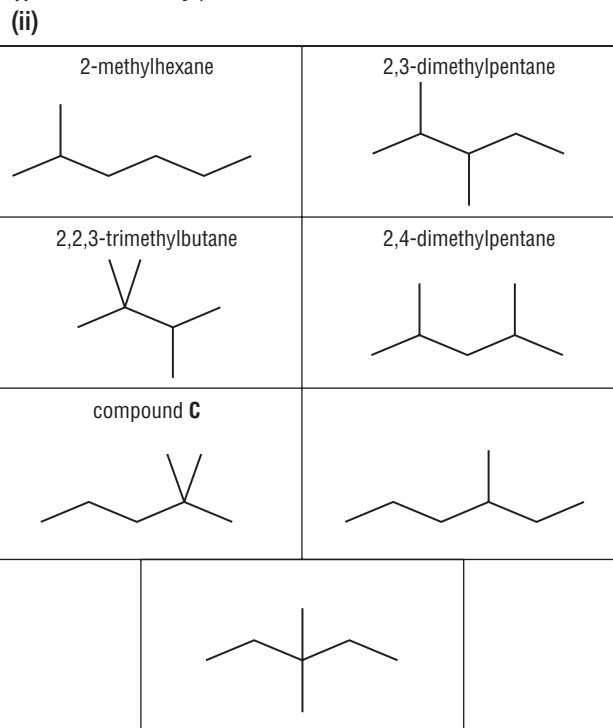
In the *trans* isomer the  $C_2H_5$  groups are arranged diagonally across the double bond.

(ii) The product does not have a double bond and so the groups can freely rotate to give the same structure.

2 (a) The separation of the components in a mixture of liquids on the basis of their boiling points.



(d) (i) 2,2-dimethylpentane



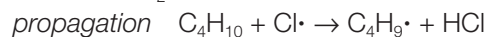
(iii) 2,2,3-trimethylbutane

(iv) Branched chained isomers are more difficult to pack together. The more branching the less van der Waals forces present and the higher the boiling point.

(e) (i) A fuel whose feedstock is obtained from plants or animal waste.

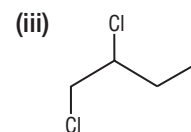
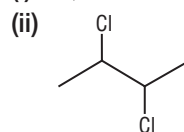
(ii) Fossil fuels are non-renewable because they take millions of years to be formed.  
Ethanol is renewable as sugar can be grown.

3 (a) (i) UV radiation



(iv) Homolytic

(b) (i) 2,3-dichlorobutane



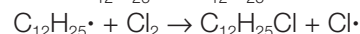
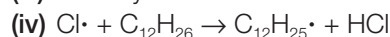
4 (a) (i) A compound containing carbon and hydrogen only



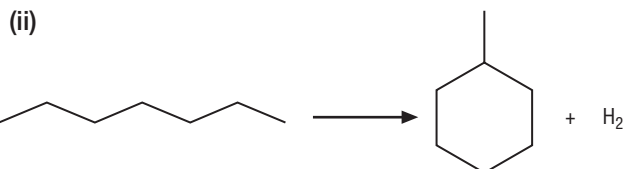
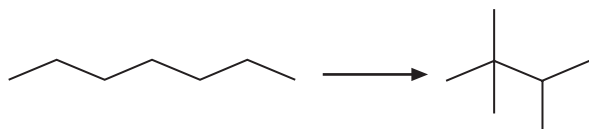
(b) (i) A species with an unpaired electron

(ii) UV radiation

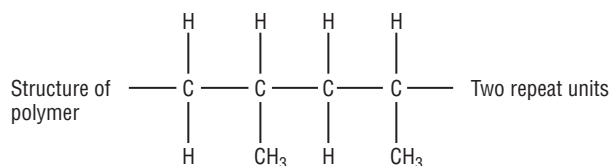
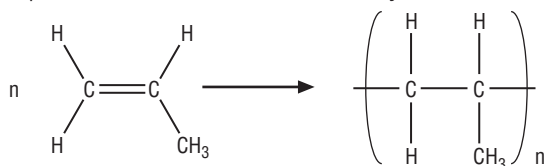
(iii) Homolytic



- (v) Six  
 (c) (i)  $C_{12}H_{26} \rightarrow 2C_2H_4 + C_8H_{18}$   
 (ii) Octane  
 (d) (i)



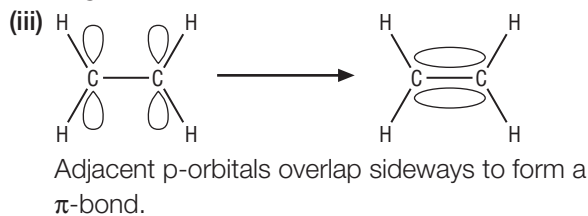
5 Margarine is made from the hydrogenation of unsaturated vegetable fat. It is carried out using hydrogen in the presence of a nickel catalyst. Poly(propene) can be made from propene by polymerisation. This process requires high temperature and pressure and often uses a catalyst.



Addition polymers are non-biodegradable and do not break down naturally in the environment. If burned they produce toxic fumes.

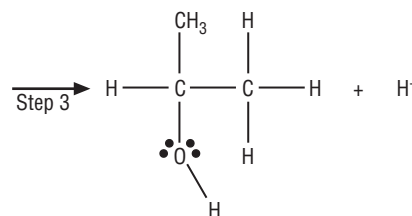
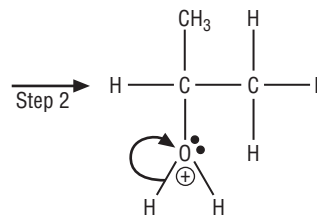
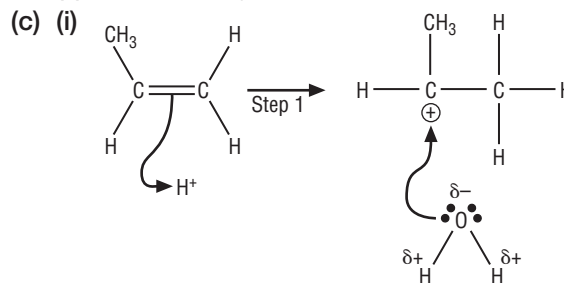
In future these polymers may be recycled or incinerated for energy production. They may be cracked to produce more useful organic materials.

- 6 (a) (i) unsaturated contains double or multiple bonds  
 hydrocarbon contains carbon and hydrogen only  
 (ii) angle a  $109.5^\circ$   
 angle b  $120^\circ$



## 2.2 Alcohols, halogenoalkanes and analysis

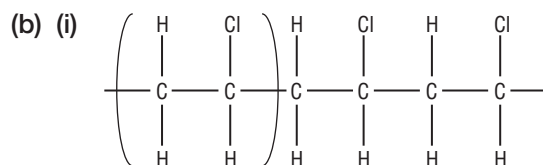
- 1 (a) (i)  $C_6H_{12}O_6(aq) \rightarrow 2C_2H_5OH(aq) + 2CO_2(g)$   
 (ii) The reaction takes place in the absence of air between  $25^\circ\text{C}$  and  $40^\circ\text{C}$  (aqueous and warm)  
 (iii) There would be no more bubbles of  $CO_2$  produced  
 (b) (i) Phosphoric or sulfuric acid  
 (ii) An electron pair donor



- (ii)  $H^+$  acts as a catalyst because it is not consumed in the reaction

- (d)  $CH_3CH(OH)CH_3 + 4\frac{1}{2}O_2 \rightarrow 3CO_2 + 4H_2O$   
 (e)  $CH_3COOH$  Ethanoic acid

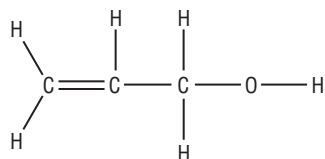
- 2 (a) (i) No of moles =  $\frac{4.44}{74.0} = 0.0600$  mol  
 (ii) No of moles =  $\frac{5.48}{137} = 0.0400$  mol  
 (iii)  $\% = \frac{\text{Actual moles}}{\text{Expected moles}} \times 100 = \frac{0.0400}{0.0600} \times 100 = 66.7\%$



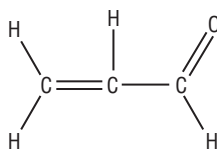
- (ii) Harmful toxic fumes are produced  
 (iii) Recycling of polymers / using as a feedstock  
 Cracking polymers / as a source of fuel  
 Development of biodegradable alternatives

- (c) C–Br because it is the weakest of the three possible C-halogen bonds

3 (a) (i) Prop-2-en-1-ol



Acrolein



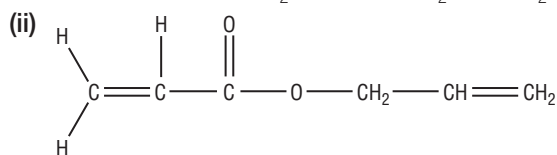
(ii) C=C double bond or alkene

(b) (i)  $K_2Cr_2O_7/H^+$  (acidified dichromate)

(ii)  $CH_2CHCH_2OH + [O] \rightarrow CH_2CHCHO + H_2O$

(c) Acrylic acid because the presence of a strong sharp absorbance at  $1650\text{ cm}^{-1}$  to  $1720\text{ cm}^{-1}$  indicates a C=O. The presence of a strong broad absorbance at  $2500\text{ cm}^{-1}$  to  $3300\text{ cm}^{-1}$  indicates the presence of an O–H in a carboxylic acid.

(d) (i)  $CH_2=CHCOOH + CH_2=CHCH_2OH \rightarrow$   
 $CH_2=CHCOOCH_2CH=CH_2 + H_2O$



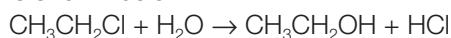
4 (a) A test tube of the halogenoalkane is placed in a water bath at  $60\text{ }^\circ\text{C}$ . A solution of  $AgNO_3$  and ethanol (which acts as a common solvent) is placed in the water bath. The two solutions are then added together and the time taken to form the precipitate is found.

The fastest will be the iodoalkane and the slowest will be the chloroalkane.

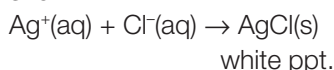
Iodoalkanes undergo hydrolysis faster than bromoalkanes which in turn hydrolyse faster than chloroalkanes.

This is because the carbon–halogen bond gets stronger from an iodoalkane to a bromoalkane with the chloroalkane having the strongest carbon–halogen bond.

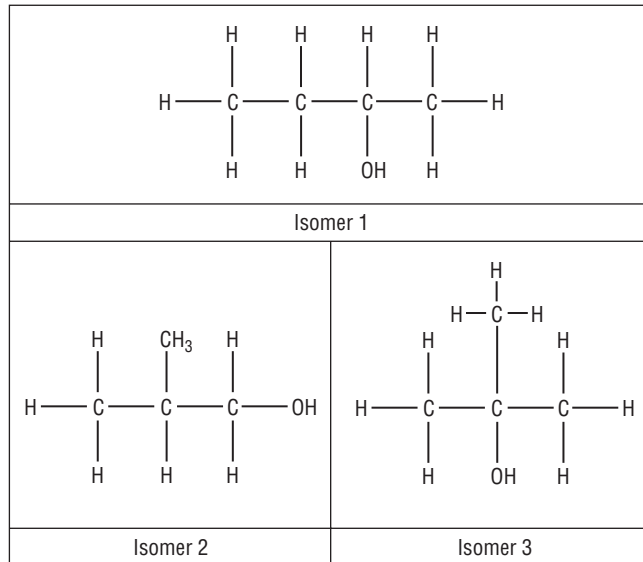
The halogenoalkanes are hydrolysed by water, which acts as the nucleophile. An equation for this reaction is shown below



The chloride ion then reacts with silver nitrate as shown.



5 (a)



(b) (i) Colour changes from orange to green

(ii)  $C_4H_9OH + 2[O] \rightarrow C_3H_7COOH + H_2O$

(iii) isomer 2

(c) (i)  $CH_2 \quad 12 + 2 = 14 \quad \frac{56}{14} = 4$

$\therefore C_4H_8$

(ii)  $C_4H_9OH \rightarrow C_4H_8 + H_2O$

(iii) isomer 1

(d) (i)  $H_2SO_4$

(ii) No of moles =  $\frac{6.96}{116} = 0.0600$

(iii)  $\% = \frac{\text{Actual}}{\text{Expected}} \times 100 = \frac{0.0600}{0.100} \times 100$   
 $= 60.0\%$

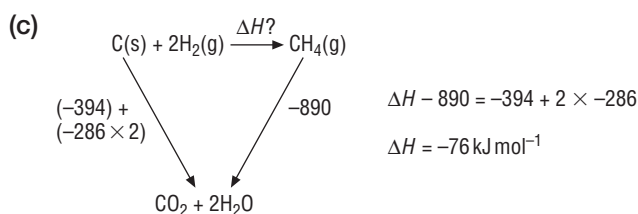
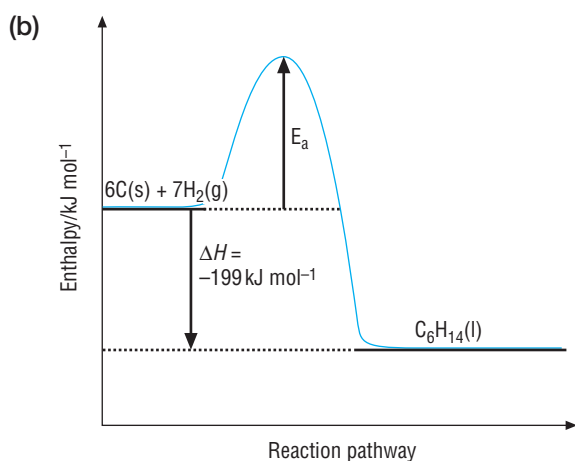
## 2.3 Energy

1 (a) (i) The enthalpy change when one mole of substance in its standard state is formed from its elements in their standard states

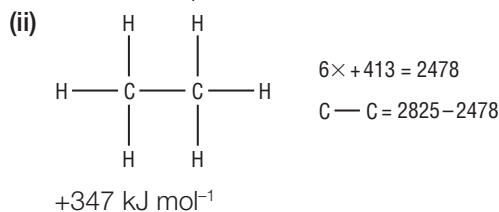
(ii)  $6C(s) + 7H_2(g) \rightarrow C_6H_{14}(l)$

(iii) temperature  $298\text{ K}$

pressure  $1\text{ Atmosphere}$

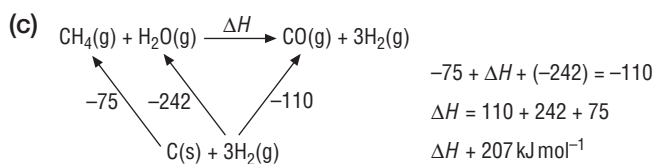


(d) (i)  $\text{C-H} = + \frac{1652}{4} = +413 \text{ kJ mol}^{-1}$



- 2 (a) When a system in equilibrium is subject to a change the system readjusts itself to minimise the change that has been made.
- (b) (i) A decrease of pressure will cause the equilibrium to move to the side with the larger number of gas molecules to oppose the change. Equilibrium moves left so more  $\text{X}_2$  and  $\text{Y}_2$  present.
- (ii) A decrease in pressure means these are the same number of molecules in a greater volume hence the molecules collide less often and the rate of reaction will decrease.
- (c) (i) 17%
- (ii) As the temperature increases the rate of conversion of reactants into products decreases. The position of equilibrium therefore must move to the left. This is consistent with an exothermic reaction.
- (d) (i) A catalyst increases the rate of the reaction because more collisions have energy exceeding the lowered  $E_a$ .
- (ii) No change  
Forward and reverse reactions are changed by the same amount.

- 3 (a)  $\text{C}_3\text{H}_8 + 5\text{O}_2 \rightarrow 3\text{CO}_2 + 4\text{H}_2\text{O}$
- (b) The enthalpy change when one mole of substance is completely burned in excess oxygen under standard conditions.
- (c) (i)  $Q = mc \Delta T$   
 $Q = 200 \times 4.18 \times 50.3$   
 $= 42050 \text{ J}$   
 $= 42.1 \text{ kJ}$
- (ii) amount of  $\text{C}_3\text{H}_8 = \frac{1.00}{44} = 0.0227 \text{ mol}$
- (iii)  $\Delta H = \frac{-42.1}{0.0227} = -1850 \text{ kJ mol}^{-1}$
- 4 (a) (i) Energy is needed to break bonds  
Bond breaking is endothermic
- (ii) The energy required to break one mole of bonds in a gaseous substance to form gaseous atoms. Reaction occurs in gas phase.
- (iii) Bonds broken
- |        |          |                                   |
|--------|----------|-----------------------------------|
| 3 C-H  | 3 × 410  | = 1230                            |
| C-O    | 1 × 336  | = 336                             |
| O-H    | 1 × 465  | = 465                             |
| 1½ O=O | 1½ × 500 | = 750                             |
|        |          | <u>+2781</u> kJ mol <sup>-1</sup> |
- Bonds formed
- |       |           |                                  |
|-------|-----------|----------------------------------|
| 4x OH | = 4 × 465 | = 1860                           |
| 2 C=O | = 2 × 810 | = 1620                           |
|       |           | <u>3470</u> kJ mol <sup>-1</sup> |
- +2781 - 3470 = -689 kJ mol<sup>-1</sup>
- (iv) Actual bond enthalpies may be different from average bond enthalpy values
- (b) (i) Increasing the temperature. The position of equilibrium moves to the left as the forward reaction is exothermic.  
There will be more CO and H<sub>2</sub> produced.  
Increasing the pressure. There will be less CO and H<sub>2</sub>. With an increase in pressure, the position of equilibrium moves to the right to the side with the least number of molecules.
- (ii) Increasing the pressure means there are the same number of molecules in less volume so rate increases as there are more collisions.
- (iii) None - as it speeds up the forward and reverse reaction equally.
- 5 (a) The enthalpy change when one mole of substance is formed from its elements under standard conditions.
- (b)  $\text{C(s)} + 2\text{H}_2\text{(g)} \rightarrow \text{CH}_4\text{(g)}$



(d) Manufacture of ammonia in the Haber process.

## 2.4 Resources

1 (a) (i) A gas that absorbs infrared radiation emitted from the Earth. The gas then re-emits the infrared radiation.

(ii) Water

(iii) An  $\text{N}_2$  molecule has two identical atoms with no polar bond. It doesn't absorb infrared radiation.

(iv) 1 The concentration of the gas.  
2 The residence time of the gas.

2 (a) (i) Ultraviolet radiation

(ii) It absorbs high energy ultraviolet radiation that is damaging to life.

(b) CFCs are unreactive and slowly diffuse into the stratosphere. Once there, the ultraviolet radiation breaks C—Cl bonds in CFCs forming  $\text{Cl}\cdot$  radicals. The  $\text{Cl}\cdot$  radicals react with ozone in a chain reaction, resulting in decreased ozone concentration.

(c) HFCs are chemically broken down as they are more reactive than CFCs. This is achieved by breaking of C—H bonds.

3 (a) (i) Ultraviolet radiation

(ii)  $\text{Cl}\cdot + \text{O}_3 \rightarrow \text{O}_2 + \text{ClO}\cdot$   
 $\text{Cl}\cdot + \text{O} \rightarrow \text{Cl}\cdot + \text{O}_2$

(iii)  $\text{O}_3 + \text{O} \rightarrow 2\text{O}_2$

(iv) Homogeneous catalysis

The catalyst and reactants all have the same physical state (all gases)

(b) (i)  $24.0 + 2.0 + 35.5 + 38.0 = 118.5$

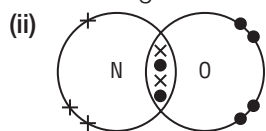
(ii)  $\text{C}_8\text{H}_{18}$

(iii) Hydrocarbons do not lead to breakdown of the ozone layer.

(iv) Hydrocarbons are flammable.

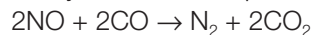
4 (a) Photochemically describes a chemical process that uses light as the energy source.

(b) (i) The first reaction as a bond is being broken. The light energy provides energy for the bond breaking.



There is an unpaired electron on the nitrogen.

(iii) Nitrogen oxides are converted into  $\text{N}_2$  using a catalyst of rhodium, platinum and palladium.



The large surface area of the catalyst adsorbs the reactant molecules, allowing them to react.

(c) Ozone causes irritation to the lungs.

(d) (i) Ozone reacts with C=C bonds, breaking the polymer chain.

(ii) The rubber would crack and crumble.

5 (a) (i)  $\text{C}_8\text{H}_{18} + 12\frac{1}{2}\text{O}_2 \rightarrow 8\text{CO}_2 + 9\text{H}_2\text{O}$

(ii) By reactions of nitrogen and oxygen from the air.

(b) (i) Rhodium, platinum and palladium.

(ii) Gases are adsorbed onto the surface. The bond in the gas molecule weakens allowing reaction to take place by lowering the activation energy and providing an alternative route.

The products desorb from the surface, making it available for more reactant molecules.

(iii)  $2\text{CO} + 2\text{NO} \rightarrow \text{N}_2 + 2\text{CO}$

(c) Ozone

6 (a) Sugar is readily available. It is renewable and can be grown over a short time span.

Ethane is obtained from crude oil which is a finite resource, taking millions of years to form.

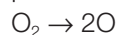
In terms of energy, fermentation requires energy for distillation; hydration requires energy for generation of steam.

In terms of atom economy, fermentation also produces  $\text{CO}_2$ , lowering the atom economy for ethanol production.

Hydration is an addition reaction with 100% atom economy.

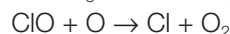
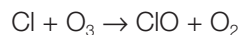
The only identifiable waste product from either method is  $\text{CO}_2$  from fermentation which is non-toxic.

7 (a) (i) The natural balance of ozone is maintained by the process below.



Ultraviolet radiation breaks C—Cl bonds in CFCs forming  $\text{Cl}\cdot$  radicals.

The  $\text{Cl}\cdot$  radicals break down ozone in a chain reaction:



The chain reaction breaks down more ozone than would be the case from the natural balance between  $\text{O}_3$  and  $\text{O}_2$ .

(ii) HFCs are broken down in the lower atmosphere by reactions involving C—H bonds which are absent in CFCs.

- (b) (i) NO is formed by reaction of nitrogen + oxygen from the air in car engines.  
(ii)  $2\text{NO} + \text{O}_2 \rightarrow 2\text{NO}_2$   
(iii) +2
- (c) In the lower atmosphere, photochemical smog. In the stratosphere, ozone may be broken down.
- 8 (a) (i) In the stratosphere temperature is different from 298 K and the pressure is less than 1 atmosphere (101 kPa)  
(ii) 8
- (b) (i) Ultraviolet radiation.  
(ii) Steps 2 and 3 propagate the chain reaction. In step 2, Cl is used up. In step 3, Cl is regenerated.
- (iii)
- 
- (c) (i) Ozone absorbs harmful ultraviolet radiation.  
(ii) Ozone contributes to photochemical smog.  
(iii) CFCs have a long residence time. They also take a long time to diffuse to the ozone layer.  
(iv) The presence of the C–H bond allows HFCs to be broken down naturally before reaching the stratosphere.