## Acknowledgements

**The authors wish to thank Alistair Ross, formerly of Duncanrig Secondary School, East Kilbride for drafting the answers in a student-friendly form.**

**It should also be noted that answers to questions which have come from or have evolved from questions used in Scottish Qualification Authority (SQA) examinations do not emanate from the SQA.**


## Rate of reactions

1. (a) (i) e.g. the reaction between an acid and an alkali, hydrogen gas reacting explosively with oxygen gas to form water.
   (ii) e.g. chalk reacting with acid, magnesium ribbon reacting with dilute acid, calcium granules reacting with water.
   (b) (FASTEST) match igniting > egg frying > milk turning sour > a motor car rusting (SLOWEST)

2. (a) For the same 'amount' of substance, smaller particles have a greater surface area and therefore are more likely to collide with other particles and react.
   (b) Increasing the concentration puts more particles in the same space and therefore the particles are more likely to collide with other particles and react.
   (c) Increasing the temperature of the reactants gives them more energy and so they move around faster. This means they are more likely to collide with other particles and react.

3. (a) Flame temperature increases.
   (b) Increase in concentration of oxygen increases rate of reaction and heat energy is produced faster.

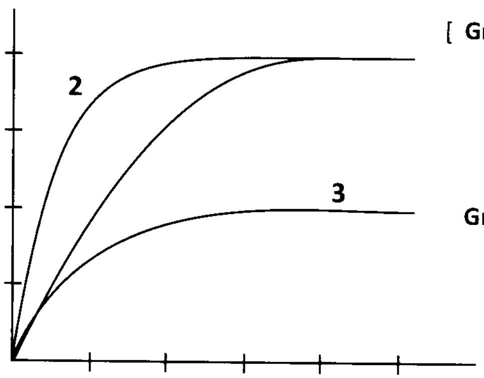
4. The petrol in the spray is spread out as tiny particles. These particles have a greater surface area than the same amount of petrol in a bowl and are more likely to collide with oxygen particles and react.

5. (a) Small sticks have a greater surface area. This increases the rate of the burning reaction.
   (b) Blowing air increases the concentration of oxygen in the fire. This increases the rate of the burning reaction and the fire burns brighter.
   (c) The lower temperature of the fridge decreases the rate at which the food reacts with other substances (usually oxygen) and goes off.
   (d) The higher temperature of the greenhouse increases the rate of plant growth.
   (e) Large potatoes have a smaller surface area than the same mass of smaller potatoes and therefore take longer to cook.
   (f) Air contains about 20% oxygen. The oxy-acetylene flame uses pure (100%) oxygen. The greater concentration of oxygen in the oxy-acetylene flame causes the acetylene to burn faster releasing more energy.

6. (a) (i) **B** reacts faster than **A**. The magnesium powder in **B** has a greater surface area than the ribbon in **A**.
(ii) **A** reacts faster than **C**. The acid in **C** has been diluted with water. The greater concentration of acid in **A** causes it to react faster with the magnesium ribbon.
(b) If experiment **A** was repeated at 50°C the magnesium ribbon would react faster than it did at room temperature (about 20°C). At the higher temperature the acid particles are more likely to collide and react with the magnesium ribbon.

7. (a) (SLOWEST) Experiment **C** > Experiment **A** > Experiment **B** (FASTEST)
(b) The concentration of acid in Experiment **B** is twice that of Experiment **A**. This would produce double the mass of carbon dioxide gas on reaction with magnesium carbonate. As the gas escapes out of the beaker, Experiment **B** loses twice the mass of Experiment **A**.

8.




[ **Graph 2**
Higher temperature hence steeper slope (faster reaction; same mass of powder hence same volume of gas.
**Graph 3**
Same temperature hence same slope; half mass of powder hence half volume of gas. ]

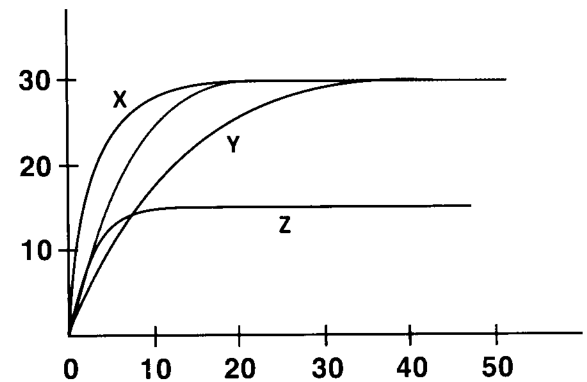
9. (a) (i) Reaction is faster at **A**.
(ii) The graph is steeper at **A**. Reactions slow down as they proceed. The chance of collisions and reaction decreases as the reactants are used up. This is shown by a decrease in the slope of the curve.
(b) (i) The volume of gas collected in the first 20 seconds would increase if the temperature was increased.
(ii) The same mass of calcium carbonate (powder or lumps) would give the same final volume of gas.



10. (a) (i) Curve **X** shows results using zinc powder.
(ii) Powder would react faster than granules and therefore the curve for powder will be steeper.
(b) e.g. mass of zinc, concentration of sulphuric acid, volume of sulphuric acid, temperature of sulphuric acid.

11. (a) 46 $cm^3$ (approx.)
(b) (i) Curve for **Experiment 2** rises less steeply than curve for **Experiment 1**.
(ii) e.g. larger marble chips, lower concentration of acid, lower temperature.
(c) Both experiments produce the same final volume of gas.

12. (a) 25 $cm^3$ (approx.)
(b) 6.5 s (approx.)
(c) 30 $cm^3$ (approx.)
(d)




[ **Graph X**: same mass of magnesium powder hence same volume of gas; double concentration of acid hence steeper slope (faster reaction).

**Graph Y**: same mass of magnesium powder hence same volume of gas; ribbon (rather than powder) hence less steep slope (slower reaction).

**Graph Z**: half mass of magnesium powder hence half volume of gas.]

## Average rate of reaction

1. $7.5\ cm^3\ s^{-1}$

2. $0.36\ g\ min^{-1}$

3. (a) $2\ cm^3\ s^{-1}$
   (b) $0.8\ cm^3\ s^{-1}$
   (c) $0.25\ cm^3\ s^{-1}$

4. (a) $0.0867\ g\ min^{-1}$ [ (246.24 – 245.72) g ÷ (6 – 0) min ]
   (b) $0.035\ g\ min^{-1}$ [ (245.72 – 245.51) g ÷ (12 – 6) min ]

5. (a) $1.33\ cm^3\ s^{-1}$ [ (40 – 0) $cm^3$ ÷ (30 – 0) s ]
   (b) $0.4\ cm^3\ s^{-1}$ [ (52 – 40) $cm^3$ ÷ (60 – 30) s ]

6. (a) $0.07\ g\ min^{-1}$ [ (256.60 – 256.46) g ÷ (4 – 2) min ]
   (b) $0.03\ g\ min^{-1}$ [ (256.46 – 256.40) g ÷ (6 – 4) min ]



## Catalysts

1. (a) Catalysts are special substances that can be used to increase the rate of a chemical reaction but are not used up in the reaction.
   (b) The catalyst is not chemically changed in the reaction.
   (c) The catalyst can be recovered chemically unchanged at the end of the reaction.

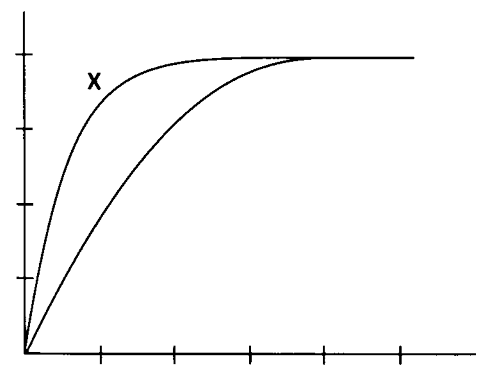
2. (a) An enzyme is a biological catalyst. Enzymes catalyse the reactions taking place in the living cells of plants and animals.
   (b) e.g. the use of an enzyme in yeast in the manufacture of alcohol and bread-making.

3. (a) Catalytic converters in the exhaust systems of cars change harmful gases to harmless gases.
   (b) The large surface area speeds up the conversion reactions of harmful to harmless gases.

4. **D** would be best for use as a catalyst; it has the biggest surface area.

5. (a) Catalysts increase the rate of reaction making production more profitable. Catalysts can also lower the temperature at which the reaction occurs and saving energy costs.
   (b) e.g. An iron catalyst is used in the manufacture of ammonia.

6. (a) 1 g
   (b)




[ Catalyst speeds up reaction hence steeper slope; same volume and concentration of hydrogen peroxide solution hence same volume of oxygen formed. ]

## Elements and compounds

1. (a) There are over 100 elements listed on the Periodic Table.
[ As of Summer 2013, 118 was the exact number. For the latest version of the Periodic Table check out: www.webelements.com ]
(b) (i) About ¾ of the naturally occurring elements are metallic. Iron, copper, aluminium, gold, silver, tin, zinc, mercury, magnesium, calcium and sodium are ten of the best known.
(ii) About ¼ of the naturally occurring elements are non-metallic. Oxygen, nitrogen, hydrogen, carbon, silicon, chlorine, iodine, sulphur, helium and neon are ten of the best known.
(c) (i) The vast majority of the elements are solid at room temperature. All of the metals (except mercury) and some of the non-metals such as silicon, carbon, boron, iodine or sulphur would be good examples.
(ii) Only mercury and bromine are liquid at room temperature.
(iii) Oxygen, nitrogen, hydrogen, helium, fluorine, chlorine, neon, argon and xenon are good examples of gaseous elements at room temperature.
(iv) All the elements from number 93 onwards are made by scientists. Plutonium and americium are two of the best known.

2. (a) sodium * (b) phosphorus (c) carbon (d) hydrogen
(e) tungsten (f) argon (g) chlorine (h) helium
(i) plutonium ** (j) mendelevium (k) californium (l) einsteinium
(m) europium*** (n) strontium (o) nobelium (p) curium

* also potassium or lithium; ** also uranium, neptunium and mercury;
*** also americium

3. (a) A group is a vertical column of the Periodic Table.
(b) A period is a row of the Periodic Table.

4. (a) (i) vanadium (ii) lithium (iii) argon (iv) nickel
(b) (i) 17 (ii) 2 (iii) 92 (iv) 26

5. (a) (i) relative atomic mass scale
(ii) The scale does not have units as it is a relative scale.
(b) (i) 16 (ii) 12 (iii) 32 (iv) 24.5



6. (a) (i) chlorine, bromine, iodine
(ii) sodium, potassium, rubidium
(iii) iron, copper, nickel
(iv) argon, helium, xenon
(b) (i) The alkali metals are all very reactive elements.
(ii) The noble gases are all very unreactive (inert) elements.

7. Germanium and silicon are chemically very similar because they are in the same group of the Periodic Table.

8. (a) solid
(b) very reactive metal

9. (a) using electricity
(b) The further to the left of the Periodic Table a metal is, the more difficult it is to extract.

10. (a) vs [ All other Group 1 metal chlorides are vs. ]
(b) i [ The Group 2 sulphates are becoming more insoluble as you go down the group. ]

11. Effectiveness in reducing "pinking" increases going down a group (I better than Br and Cl, and Te better than Se) and decreases from Group 6 to Group 7 (Te and Se both better than I). Hence lead, at the bottom of Group 4, should be very effective in reducing pinking.

12. (a) Halogens higher in Group 7 will react with compounds of halogens (halides) lower in the group.
(b) no reaction [ Chlorine is lower than fluorine in Group 7. ]

13. (a) Ionisation energy increases across the period from lithium to neon.
(b) Ionisation energy decreases going down a group.
[ Look at the values on the graph for the Group 8 elements with atomic numbers 2, 10 and 18 or the Group 1 elements 3, 11 and 19. ]

14. (a) Elements are made up of atoms of only one kind, but compounds are made up of two or more different kinds of atom chemically joined together.

(b)

| Elements | Compounds |
|---|---|
| carbon | petrol |
| zinc | sodium chloride |
| oxygen | sugar |
| gold | copper sulphate |
| nitrogen | silver oxide |
| aluminium | alcohol |

[ Only elements (no compounds) are listed in the Periodic Table. ]

15. (a) (i) magnesium chloride (ii) lead sulphide
(iii) sodium oxide (iv) hydrogen iodide
(b) potassium sulphate and potassium sulphite

16.

| Formula of substance | Element | Compound | Atoms present |
|---|---|---|---|
| $CaSO_4$ | × | ✓ | calcium, sulphur, oxygen |
| He | ✓ | × | helium |
| NaBr | × | ✓ | sodium, bromine |
| LiCl | × | ✓ | lithium, chlorine |
| $ZnI_2$ | × | ✓ | zinc, iodine |
| Fe | ✓ | × | iron |
| $KNO_3$ | × | ✓ | potassium, nitrogen, oxygen |
| Xe | ✓ | × | xenon |
| $I_2$ | ✓ | × | iodine |

17.

| | |
|---|---|
| **Elements** | oxygen, carbon, hydrogen, iron, zinc, copper, gold |
| **Compounds** | glucose, carbon dioxide, water, starch, methane, petrol |



## Atomic structure

1. (a) (i) nucleus
(ii) positive
(iii) protons and neutrons
(b) (i) electrons
(ii) negative
(c) The total positive charge of the nucleus (protons in the nucleus) is equal to the total negative charge of the electrons.

2.

| Subatomic particle | Mass | Charge | Location in atom |
|---|---|---|---|
| Electron | almost zero | – | outside nucleus |
| Proton | 1 amu | + | nucleus |
| Neutron | 1 amu | 0 | nucleus |

3. (a) (i) sodium (ii) neon (iii) aluminium
(iv) carbon (v) fluorine (vi) silicon
(b) carbon and silicon
[ same group of Periodic Table / same number of outer electrons ]

4. (a) chlorine (b) sodium (c) oxygen

5. (a) (i) The atomic number is equal to the number of protons (and also the number of electrons) in an atom.
(ii) The mass number is equal to the number of protons and the number of neutrons in an atom added together.
(b) **x** is the mass number;
it is equal to the number of protons + number of neutrons.
**y** is the atomic number;
it is equal to the number of protons (and also the number of electrons) in the atom.

6. (a)

| Element | Atomic number | Mass number | Number of protons | Number of neutrons | Number of electrons |
|---|---|---|---|---|---|
| Ne | 10 | 22 | 10 | 12 | 10 |
| N | 7 | 14 | 7 | 7 | 7 |
| Ca | 20 | 40 | 20 | 20 | 20 |
| **A** | 4 | 9 | 4 | 5 | 4 |
| **B** | 6 | 14 | 6 | 8 | 6 |
| **C** | 36 | 80 | 36 | 44 | 36 |
| **D** | 10 | 20 | 10 | 10 | 10 |
| **E** | 15 | 32 | 15 | 17 | 15 |

(b) **A** beryllium; **B** carbon; **C** krypton; **D** neon; **E** phosphorus.

7. (a) p=11; n=12; e=11 (b) p=8; n=8; e=8 (c) p=1; n=2; e=1
(d) p=17; n=18; e=17 (e) p=1; n=0; e=1 (f) p=20; n=20; e=20
(g) p=19; n=20; e=19 (h) p=3; n=4; e=3 (i) p=16; n=16; e=16

8. (a) $^{18}_{8}O$ (b) $^{13}_{6}C$ (c) $^{37}_{17}Cl$ (d) $^{3}_{1}H$

9. 2 protons, 2 neutrons and 0 electrons

10. (a) 93 protons
(b) 135 neutrons
(c) (i) **A** and **B** are not the same element.
(ii) They have different atomic numbers.

11. (a) When two nuclei join together to form one new nucleus, the new nucleus will have more protons than either of the joining nuclei so it must be a different element.
(b) hydrogen [ the only element with nuclei smaller than helium ]

12. (a) (i) 1 proton (ii) 0 neutrons (iii) mass number
(b) (i) 1 proton (ii) 1 neutron
(iii) Deuterium is sometimes referred to as "heavy" hydrogen because its atoms have twice the mass of normal hydrogen atoms.
(c) 1 proton and 2 neutrons



## Relative atomic mass (atomic weight)

1. (a) Isotopes are atoms of the same element with the same atomic number (number of protons) but a different number of neutrons.
(b) There is the same proportion of each isotope.
[ The average of 80 is exactly half way between 79 and 81. ]

2. (a) The atoms have different mass numbers due to a different number of neutrons.
(b) The atoms have the same atomic number (number of protons).
(c) To calculate the relative atomic mass, the relative proportions of each isotope must be known.

3. (a) isotopes
(b) The proportion of $^{35}Cl$ is greater than the proportion of $^{37}Cl$.
[ The average is closer to 35 than 37. ]

4. (a) $^{63}Cu$ has 34 neutrons [ mass number – atomic number (63-29) ]
$^{65}Cu$ has 36 neutrons [ 65-29 ]
(b) $^{63}Cu$ [ The average is closer to 63 than 65. ]

5. (a) Relative atomic mass is the average mass of the isotopes of an element taking into account the relative proportion of each isotope.
(b) 6.9

6. (a) Relative atomic mass is an average and averages are rarely whole numbers.
(b) The relative atomic mass of carbon is listed as 12 because one of the isotopes ($^{12}C$) is much more abundant than the others and so the average mass is very close to a whole number, i.e. 12.

## Covalent bonding

1. (a) A molecule is a group of atoms held together by covalent bonds.
   (b) A covalent bond is the attraction of two positive nuclei for a shared pair of electrons.

2. (a) Atoms of non-metal elements (usually) are involved in covalent bonds.
   (b) (ii) hydrogen chloride, (iii) carbon sulphide, (vi) phosphorus oxide, (viii) $CH_3Cl$, (x) $NO_2$, (xii) $C_2H_5OH$ and (xiv) $C_6H_{12}O$

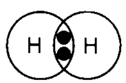
3. (a) $OCl_2$ (b) $H_2$ (c) $C_2H_4$
   (d) $C_6H_6O$ (e) $C_3H_6O$

4. (a) hydrogen chloride (b) nitrogen (c) carbon chloride
   (d) nitrogen hydride (e) hydrogen oxide (f) oxygen
   (g) chlorine

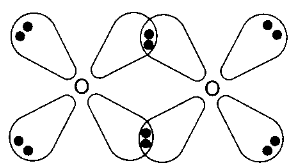
5. (a) $SO_3$ (b) $CO_2$ (c) CO
   (d) $SiF_4$ (e) $PCl_5$ (f) $UF_6$

6. (a) Molecules made up of only two atoms are called diatomic molecules.
   (b) (iii) nitrogen, (v) hydrogen, (vii) chlorine, (x) oxygen and (xi) fluorine
   (c) (ii) HCl and (iv) CO

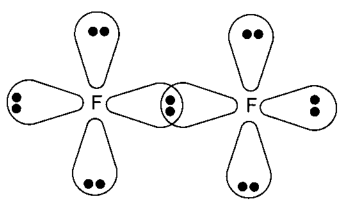
7. (a) hydrogen



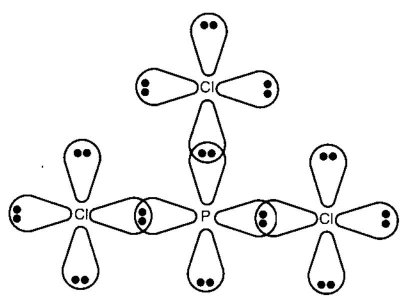

(b) oxygen




(c) fluorine

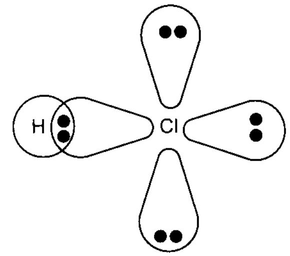



(d) phosphorus chloride

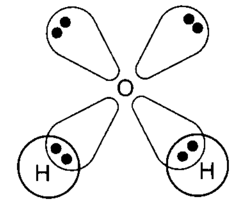




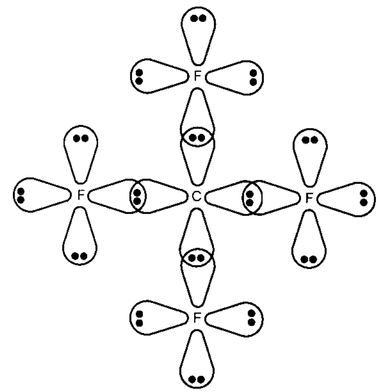

(e) hydrogen chloride



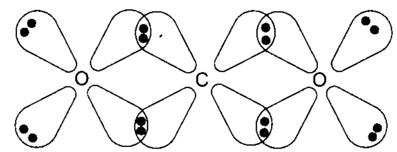

(f) hydrogen oxide



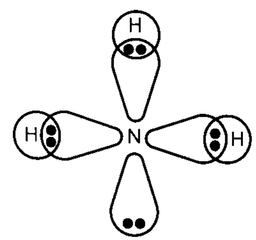

(g) carbon fluoride



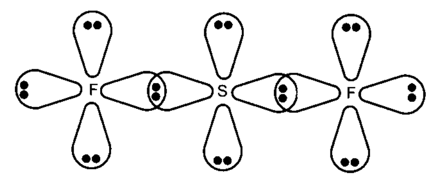

(h) carbon dioxide




(i) nitrogen hydride



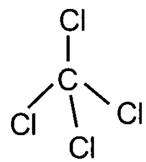

(j) sulphur fluoride

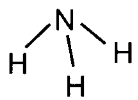


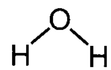

8. (a) $H_2S$ (b) $PF_3$ (c) $NCl_3$
   (d) HI (e) $SCl_2$ (f) $SiO_2$

9. (a) The chemical formula of a covalent substance gives the number of atoms of each element in a molecule of the substance.
(b) The full structural formula shows the three-dimensional arrangement of all the atoms that are joined by the covalent bonds.

10. (a) (i) N≡N

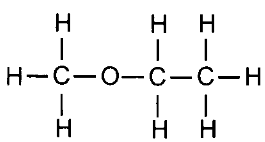
(ii) 

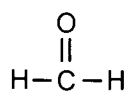

(iii) 


(iv) 


(b) tetrahedral
(c) An $H_2O$ molecule is not linear because the shape of the molecule is based on the two bonds pointing towards the corners of a tetrahedron (and two pairs of non-bonding electrons pointing towards the other two corners of the tetrahedron).

11. Forces of attraction between the positive nuclei of the two hydrogen atoms and the shared pair of electrons between the atoms holds the atoms together.

12. (a) 

(b) 

[ naming error in book; methanol should be methan**al**}

13. H—C≡C—H

14. (a) Relative atomic mass is equal to the density (relative to hydrogen) for the diatomic molecules.
(b) 65.5 [ The density of all the noble gases in the table is half of the relative atomic mass. ]



## Ionic bonding

1. (a) An ion is a charged particle.
(b) An ionic bond is the force of attraction across oppositely charged ions.

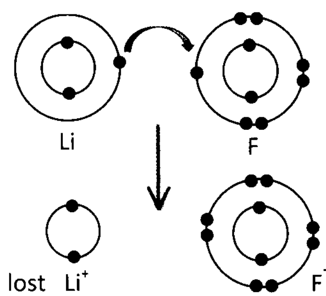
2. (a) 1+ (b) 2– (c) 3– (d) 1–
(e) 3+ (f) 2+ (g) 1– (h) 1+

3. (a) partly agree
(b) Metal atoms prefer to lose electrons to obtain the more stable electron arrangement of a noble gas, but to lose the electrons energy is needed to overcome the force of attraction to the nucleus.

4. The chemical formula of a covalent substance gives the exact number of atoms of each element in a molecule of the substance.
The chemical formula of an ionic substance gives the relative number (ratio) of each ion within the lattice structure of the substance.

5. (a) (i) The chlorine atom gains one extra electron to form the $Cl^-$ ion.
The electron arrangement of the atom (2,8,7) becomes the more stable electron arrangement of 2,8,8 in the ion. This is now the same electron arrangement as the nearest noble gas argon.
(ii) The calcium atom loses two electrons to form the $Ca^{2+}$ ion.
The electron arrangement of the atom (2,8,8,2) becomes the more stable electron arrangement of 2,8,8 in the ion. This is now the same electron arrangement as the nearest noble gas argon.
(b) Each calcium atom provides one electron to two different chlorine atoms. This gives all the ions formed stable noble gas electron arrangements.
The resulting oppositely charged ions ($Ca^{2+}$ and $Cl^-$) attract. This attraction is known as ionic bonding.

6. e.g. lithium atom loses an electron to form a lithium ion.




e.g. fluorine atom gains an electron to form a fluoride ion.

electron lost electron gained

7. (a)

| Ion | Number of protons | Number of electrons |
|---|---|---|
| $Ca^{2+}$ | 20 | 18 |
| $Cl^-$ | 17 | 18 |
| $Al^{3+}$ | 13 | 10 |
| $O^{2-}$ | 8 | 10 |

(b) (i) $Zn^{2+}$ (ii) $S^{2-}$ (iii) $Cu^+$ (iv) $Sn^{2+}$

8. (a) A lattice is the arrangement of ions in a solid with ionic bonding.
(b) A molecule is a small group of atoms joined by **covalent bonding**. Since sodium chloride has **ionic bonding**, with a crystal lattice structure in the solid form, the term molecule cannot be used.

9. (a) $Na^+Br^-$ ; NaBr (b) $(K^+)_2O^{2-}$ ; $K_2O$
(c) $Mg^{2+}(Cl^-)_2$ ; $MgCl_2$ (d) $Ca^{2+}S^{2-}$ ; CaS
(e) $(Al^{3+})_2(O^{2-})_3$ ; $Al_2O_3$ (f) $(Mg^{2+})_3(N^{3-})_2$ ; $Mg_3N_2$
(g) $Ba^{2+}O^{2-}$ ; BaO (h) $Cs^+Br^-$ ; CsBr

10. (a) $Pb^{2+}(Br^-)_2$ ; $PbBr_2$ (b) $Cu^+I^-$ ; CuI
(c) $Fe^{3+}(Cl^-)_3$ ; $FeCl_3$ (d) $Ni^{2+}S^{2-}$ ; NiS
(e) $(Ag^+)_2O^{2-}$ ; $Ag_2O$ (f) $(V^{5+})_2(O^{2-})_5$ ; $V_2O_5$

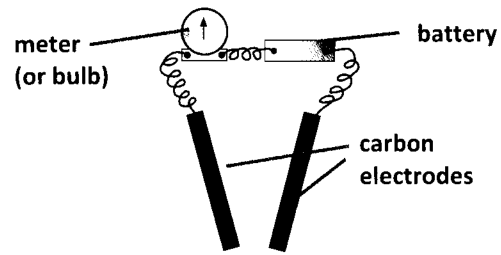
11. (a) $Li^+OH^-$ ; LiOH (b) $(K^+)_2SO_3^{2-}$ ; $K_2SO_3$
(c) $Ca^{2+}(NO_3^-)_2$ ; $Ca(NO_3)_2$ (d) $Fe^{3+}(OH^-)_3$ ; $Fe(OH)_3$
(e) $(NH_4^+)Cl^-$ ; $NH_4Cl$ (f) $Mg^{2+}CO_3^{2-}$ ; $MgCO_3$
(g) $Ra^{2+}CrO_4^{2-}$ ; $RaCrO_4$ (h) $(NH_4^+)_2SO_3^{2-}$ ; $(NH_4)_2SO_3$
(i) $(Na^+)_3PO_4^{3-}$ ; $Na_3PO_4$ (j) $Ba^{2+}(HCO_3^-)_2$ ; $Ba(HCO_3)_2$

12. (a) $Na^+I^-$ ; NaI (b) $Mg^{2+}(OH^-)_2$ ; $Mg(OH)_2$
(c) $Fe^{3+}(Cl^-)_3$ ; $FeCl_3$ (d) $Ca^{2+}(NO_3^-)_2$ ; $Ca(NO_3)_2$
(g) $Mg^{2+}SO_4^{2-}$ ; $MgSO_4$ (h) $(NH_4^+)_2CO_3^{2-}$ ; $(NH_4)_2CO_3$
(e) $NH_4^+Br^-$ ; $NH_4Br$ (f) $Rb^+F^-$ ; RbF
(i) $Cu^{2+}CO_3^{2-}$ ; $CuCO_3$ (j) $(Na^+)_2S^{2-}$ ; $Na_2S$
(k) $Ra^{2+}O^{2-}$ ; RaO (l) $Sn^{4+}(O^{2-})_2$ ; $SnO_2$



## Properties of substances

1. (a)




(b) (i) solid iron, (ii) molten copper, (iv) liquid sodium, (vii) liquid mercury and (viii) solid magnesium

2. (a) Baking powder ($NaHCO_3$) and potash (KCl) will conduct electricity when in aqueous solution.
(b) These substances do not conduct when solid because in that form their ions are unable to move.

3.

| Substance | In solid | In solution | As a liquid (molten) |
|---|---|---|---|
| Metal element | ✓ | insoluble | ✓ |
| Covalent substance (element or compound) | × | × | × |
| Ionic compound | × | ✓ | ✓ |

4. (a) **B** lead
(b) **A** potassium bromide
(c) **C** iodine

5. (a) **P** glucose [ covalent – never conducts electricity ];
**Q** aluminium [ conducts when solid and molten – only metals do this ];
**R** copper bromide [ ionic - conducts when molten but not when solid, blue solution ];
**S** sodium chloride [ ionic - conducts when molten but not when solid; colourless solution ].
(b) **P** has covalent bonding; **R** and **S** have ionic bonding.
(c) **R** and **S** do not conduct when solid because in that form their ions are unable to move. Their ions are able to move when molten.

6. (a) Electrolysis is the passage of electricity through a solution of an ionic compound (or molten ionic compound) which causes the substance to break up.
   (b) (i) chlorine at positive electrode; magnesium at negative electrode
   (ii) iodine at positive electrode; sodium at negative electrode
   (iii) bromine at positive electrode; lead at negative electrode
   (iv) oxygen at positive electrode; calcium at negative electrode

7. (a) With a direct current (d.c.) supply, the direction of the movement of electrons is always the same and the same product is always obtained at each electrode.
   (b) The electrode would become coated with a silver coloured deposit of nickel. [ $Ni^{2+}$ ions are attracted to the negative electrode and gain electrons to form atoms of nickel metal. ]
   (c) A brown solution of bromine would form.
   [ $Br^-$ ions are attracted to the positive electrode, lose electrons and the resulting atoms join to form $Br_2$ molecules. ]
   (d) Carbon tetrabromide is a covalent compound and will not conduct electricity because no ions are present.

8. (a) Solid sodium chloride does not conduct electricity because its ions are unable to move.
   (b) (i) positive electrode
   (ii) The negative chloride ions ($Cl^-$) are attracted to the positive electrode and lose electrons to form chlorine atoms. These atoms join in pairs to form chlorine molecules ($Cl_2$).

9. (a) electrolysis
   (b) (i) glucose
   (ii) covalent
   (c) (i) silver nitrate
   (ii) The $Ag^+$ ions of the silver nitrate solution are attracted to the negative electrode where they combine with electrons from the d.c. supply to form grey silver atoms.

10. (a) blue
   (b) violet
   (c) green



11. The dichromate ion is orange and negatively charged so attracted to the positive electrode.

12. (a) Potassium nitrate solution is a conductor of electricity.
   (b) purple
   (c) (i) A blue colour will be observed around the negative electrode and a purple colour around the positive electrode.
   (ii) Copper ions are blue and positively charged and will be attracted to the negative electrode.
   Permanganate ions are purple and negatively charged and will be attracted to the positive electrode.

13. (a) (i) A green colour will move towards the negative electrode.
   (ii) Nickel ions are green and positively charged and will be attracted to the negative electrode.
   (b) The green colour will now move in the opposite direction.

14. (a) Cadmium iodide is an ionic compound. It will not conduct electricity when solid, i.e. before heating and after cooling, but will conduct when molten (during heating).
   Therefore the bulb only lights during heating.
   (b) negative electrode – cadmium; positive electrode - iodine
   (c) Either both electrodes were touching the nickel metal crucible, or the gap between the electrodes was bridged by cadmium metal formed during the electrolysis.

15. (a) do not agree
   (b) Both ionic bonds and covalent bonds are strong.
   When an ionic compound is melted, the strong ionic bonding between the oppositely charged ions must be broken. Therefore, NaCl has a high melting point as given in the table.
   However, when a covalent compound is melted, the strong covalent bonds between the atoms in the molecule remain unbroken and it is only weak forces between the molecules that must be overcome. This explains the low melting point for $CCl_4$ given in the table.

16. (a) Sodium oxide is an ionic compound. All its ions are held together in a lattice by strong ionic bonds which require much energy to break, so high temperatures (much higher than room temperature) are needed to melt the compound.
(b) Carbon dioxide exists as small molecules with only weak forces between the molecules. The energy required to overcome these attractive forces is very small and therefore the boiling point of carbon dioxide is below room temperature.
(c) Silicon dioxide forms a covalent network structure in which all the atoms are held together by strong covalent bonds. Much energy is required to break these bonds, so high temperatures (much above room temperature) are needed to melt the compound.

17. (a) **Q** and **R** are liquids at room temperature.
[ Substances are gas if the temperature is higher than their boiling point; substances are liquid if the temperature is between their boiling point and melting point; substances are solid if the temperature is lower than their melting point. ]
(b) **Q** and **R** have molecular structures.
[ Covalent molecular substances have low melting and boiling points. ]

18. Titanium (IV) chloride must have covalent bonding (with a molecular structure) due to it having a relatively low melting point (liquid at room temperature).

19. **P** covalent network compound; **P** must be a covalent substance as it never conducts electricity. However, because of the high melting and boiling points, it must have a network structure.
**Q** metal; **Q** must be a metal because only metals conduct when solid or molten.
**R** ionic compound; **R** must be an ionic compound because only ionic compound conduct when molten or in solution.
**S** covalent molecular compound; **S** must be a covalent substance as it never conducts electricity. However, because of the low melting and boiling points, it must have a molecular structure.



## Chemical equations

1. (a) $CCl_4$ (l) (b) $CO_2$ (g) (c) $O_2$ (g) (d) $SiO_2$ (s)
(e) S (s) (f) $I_2$ (s) (g) NaCl (aq) (h) $SO_2$ (aq)

2. (a) magnesium + oxygen → magnesium oxide
(b) iron oxide + carbon monoxide → iron + carbon dioxide
(c) starch → glucose + water
(d) calcium + water → calcium hydroxide + hydrogen
[ Hydrogen is the gas that burns with a "pop". ]
(e) copper carbonate → copper oxide + carbon dioxide
[ Oxygen is not a reactant as copper carbonate is being heated not burned. Carbon dioxide is the gas that turns lime water milky. ]

3. (a) Carbon solid reacts with oxygen gas (burns) to form carbon dioxide gas.
(b) Carbon monoxide gas reacts with oxygen gas (burns) to form carbon dioxide gas.
(c) Carbon solid reacts with chlorine gas to form carbon tetrachloride liquid.
(d) Hydrogen gas reacts with fluorine gas to form hydrogen fluoride gas.
(e) Sulphur dioxide gas reacts with oxygen gas to form sulphur trioxide gas.
(f) Copper oxide * solid reacts with carbon monoxide gas to form copper solid and carbon dioxide gas.
(g) Nitrogen hydride (ammonia) gas reacts to form nitrogen gas and hydrogen gas. **
(h) Hydrogen bromide gas reacts to form hydrogen gas and liquid bromine. **

* copper (II) oxide since the charge on the copper ion is $2^+$.
** where only one reactant is involved, it could be said that the reactant is **decomposing** to form ......

4. (a) $C + O_2 \rightarrow CO_2$
(b) $2 P + 3 Cl_2 \rightarrow 2 PCl_3$
(c) $C + 2 Br_2 \rightarrow CBr_4$
(d) $C_4H_8 + 6 O_2 \rightarrow 4 CO_2 + 4 H_2O$
(e) $2 H_2O_2 \rightarrow 2 H_2O + O_2$
(f) $SiCl_4 + 2 H_2 \rightarrow Si + 4 HCl$

5. (a) $2 Ca + O_2 \rightarrow 2 CaO$
(b) $Mg + 2 AgNO_3 \rightarrow Mg(NO_3)_2 + 2 Ag$
(c) $2 NaOH + H_2SO_4 \rightarrow Na_2SO_4 + 2 H_2O$
(d) $2 AgNO_3 + BaCl_2 \rightarrow Ba(NO_3)_2 + 2 AgCl$
(e) $2 Na + 2 H_2O \rightarrow 2 NaOH + H_2$
(f) $2 Al + 3 Cl_2 \rightarrow 2 AlCl_3$
(g) $4 Ag + O_2 + 2 H_2S \rightarrow 2 Ag_2S + 2 H_2O$
(h) $3 Ag_2S + 2 Al \rightarrow 6 Ag + Al_2S_3$
(i) $2 HCl + Na_2S_2O_3 \rightarrow 2 NaCl + S + SO_2 + H_2O$
(j) $TiCl_4 + 2 H_2O \rightarrow TiO_2 + 4 HCl$
(k) $Ba(OH)_2 + 2 NH_4Cl \rightarrow 2 NH_3 + BaCl_2 + 2 H_2O$

6. (a) $2 CO + O_2 \rightarrow 2 CO_2$
(b) $H_2 + Cl_2 \rightarrow 2 HCl$
(c) $CH_4 + 2 O_2 \rightarrow CO_2 + 2 H_2O$
(d) $2 SO_2 + O_2 \rightarrow 2 SO_3$
(e) $2 P + 3 Cl_2 \rightarrow 2 PCl_3$

7. (a) $4 Na + O_2 \rightarrow 2 Na_2O$
(b) $2 Mg + SO_2 \rightarrow 2 MgO + S$
(c) $Ca + 2 H_2O \rightarrow Ca(OH)_2 + H_2$
(d) $CaO + H_2SO_4 \rightarrow CaSO_4 + H_2O$
(e) $K_2CO_3 + 2 HCl \rightarrow 2 KCl + H_2O + CO_2$
(f) $K_2SO_4 + Ba(NO_3)_2 \rightarrow 2 KNO_3 + BaSO_4$

8. (a) $2 SO_2 + O_2 \rightarrow 2 SO_3$
(b) error in question
(c) $C_3H_8 + 5 O_2 \rightarrow 3 CO_2 + 4 H_2O$
(d) $4 NH_3 + 3 O_2 \rightarrow 2 N_2 + 6 H_2O$
(e) $2 C_2H_2 + 5 O_2 \rightarrow 4 CO_2 + 2 H_2O$
(f) $2 NH_3 \rightarrow N_2 + 3 H_2$



## Calculations

1. (a) 18 (b) 16 (c) 100 (d) 142 (e) 148.5
(f) 17 (g) 44 (h) 138 (i) 102 (j) 53.5
[ Reminder: Formula mass is the sum of the RAMs of all the atoms in the formula. ]

2. (a) 42 g (b) 40.5 g (c) 138 g (d) 180 g (e) 150 g
(f) 60 g (g) 56 g (h) 56 g (i) 120.5 g (j) 85 g
[ Reminder: One mole is the formula mass in grams (GFM). ]

3. (a) 46 g (b) 13.6 g (c) 37.13 g
(d) 320 g (e) 55.7 g (f) 48 g
[ Reminder: mass = no. of moles x GFM ]

4. (a) 3 mol (b) 0.2 mol (c) 0.1 mol
(d) 0.02 mol (e) 0.05 mol (f) 50 mol
[ Reminder: no. of moles = mass / GFM ]

5. 0.015 mol
[ mass of gold in ring = 7.88 x (37.5/100) = 2.955 g;
no. of moles = mass / GFM = 2.955/197 = 0.015 ]

6. 25 mol
[ mass of each H atom is 2 (1 proton and 1 neutron);
GFM of heavy water = (2x2) + 16 = 20 g;
no. of moles = mass / GFM = 500/20 = 25 ]

7. (a) 0.005 mol
[ mass of mercury in 2 g of amalgam = 2.0 x (50/100) = 1.0 g;
no. of moles = mass / GFM = (1.0/200.5) = 0.005 ]
(b) 0.0034
[ mass of tin in 5 g of amalgam = 5.0 x (12.5/100) = 0.625 g;
no. of moles = mass / GFM = (0.625/118.5) = 0.0034 ]

8. (a) 0.5 mol (b) 0.1 mol (c) 0.01 mol
(d) 0.5 mol (e) 0.4 mol
[ Reminder: no. of moles = concentration x Litres ]

9. (a) 10 mol $l^{-1}$ (b) 2.5 mol $l^{-1}$ (c) 0.2 mol $l^{-1}$
(d) 0.8 mol $l^{-1}$ (e) 2 mol $l^{-1}$
[ Reminder: concentration = no. of moles / Litres ]

10. (a) 0.2 litres (200 $cm^3$) (b) 2 litres (c) 0.05 litres (50 $cm^3$)
(d) 5 litres (e) 0.25 litres (250 $cm^3$)
[ Reminder: volume in Litres = no. of moles / concentration ]

11. (a) 4 g (b) 2.8 g (c) 10.6 g
(d) 0.345 g (e) 33 g (f) 8.2 g

[ Step 1:
Work out number of moles ... no. of moles = concentration x Litres;

Step 2:
Change moles to mass ... mass = no. of moles x GFM
(You will need the formula in order to calculate the GFM.)

e.g. (d) no. of moles = concentration x Litres = 0.2 x 0.025 = 0.005;
Formula is $LiNO_3$; GFM = 7+14+(3x16) = 69 g;
mass = no. of moles x GFM = 0.005 x 69 = 0.345 g ]

12. (a) 0.1 mol $l^{-1}$ (b) 0.1 mol $l^{-1}$ (c) 0.8 mol $l^{-1}$
(d) 0.4 mol $l^{-1}$ (e) 0.02 mol $l^{-1}$ (f) 0.005 mol $l^{-1}$

[ Step 1:
Change mass to moles ... no. of moles = mass / GFM
(You will need the formula in order to calculate the GFM.);

Step 2:
Work out concentration ... concentration = no. of moles / Litres ]

e.g. (f) Formula is $FeCl_2$; GFM = 56+(2x35.5) = 127 g;
no. of moles = mass / GFM = 1.27/127 = 0.01;
concentration = no. of moles / Litres = 0.01/2 = 0.005 mol $l^{-1}$ ]



## Acids and bases

1. (a) (i) e.g. hydrochloric acid, sulphuric acid, nitric acid
(ii) e.g. lemon juice, vinegar, cola
(b) (i) e.g. sodium hydroxide, potassium hydroxide and lime water
(ii) e.g. bleach, bicarbonate of soda (baking soda), oven cleaners containing ammonia, drain cleaners containing sodium hydroxide, indigestion tablets and toothpaste are all household products that contain an alkali.

2. (a) pH is a continuous number scale which indicates how much acid or alkali is in a solution.
(b) Universal indicator
(c) (i) Acids change the colour of pH paper to an orange/yellow or red colour.
(ii) Alkalis change the colour of pH paper to a green/blue or blue colour.
(d) (i) Acids have a pH number below 7.
(ii) Alkalis have a pH number above 7.
(e) (i) Neutral solutions turn pH paper a green colour.
(ii) (Pure) water and neutral solutions have a pH of 7.

3. (a) TRUE (b) TRUE (c) TRUE (d) FALSE
(e) TRUE (f) FALSE (g) FALSE

4. Some compounds called 'acids' or 'alkalis', e.g. citric acid, do not behave as acids or alkalis unless water is present. (Dry) crystals of citric acid will therefore have no effect on dry pH paper.

5. (a) (i) Acid rain is rain water (or snow, etc.) with an unusually high concentration of acid.
(ii) Acid rain is formed by non-metal oxides in the atmosphere, e.g. sulphur dioxide or nitrogen dioxide, dissolving in rain water.
(b) (i) e.g. The pH of rivers or lochs can become too low for some animals or plants to survive; trees in forests can become extensively damaged; soils can become too acidic for the healthy growth of plants or crops.
(ii) e.g. Increased corrosion of metal structures such as bridges or pipes; structures made of limestone can react with the acid causing their disintegration (erosion).
(iii) e.g. Breathing and lung problems in children and adults with asthma have been linked to acid rain pollution of the air.

6. (a) carbon dioxide, nitrogen dioxide, phosphorus oxide
[ soluble non-metal oxides ]
(b) sodium oxide, calcium oxide, barium oxide
[ soluble metal oxides – usually Group 1 or 2 metal oxides ]
(c) iron (III) oxide, copper (II) oxide, nickel oxide
[ insoluble metal oxides – often oxides of Transition metals ]

7. (a) The oxides of **A** and **B** are both soluble. **A** gives an acidic solution and **B** gives an alkaline solution.
(b) Element **A** is a non-metal and element **B** is a metal (probably from Group 1 or Group 2 of the Periodic Table).

8. (a) As the temperature of the water increases the solubility of the carbon dioxide decreases.
(b) (i) The pH will increase when the solution is heated.
(ii) When the solution is heated the concentration of carbon dioxide in the solution will decrease. As carbon dioxide is an acidic oxide, the solution will become less acidic and the pH will increase.

9. (a) Apply a lighted splint. Hydrogen will burn with a 'pop' sound.
(b) (i) negative electrode
(ii) The $H^+$ (aq) ions from the acid solution have been attracted to this electrode to form hydrogen gas. As the ions are positively charged the electrode must be negative.

10. (a) Water is added to dilute the acid and make it less corrosive.
(b) The pH of the solution will increase as the acid is now less concentrated.

11. (a) The pH will decrease. The reaction produces $H^+$ (aq) ions making the water become an acidic solution.
(b) Chromium (VI) oxide is an oxide of a metal. Oxides of metals that are soluble in water usually form alkalis.

12. (a) The acidity of the blood is increasing during the first hour.
[ pH decreasing = acidity increasing ]
(b) As the concentration of carbon dioxide increases, the pH decreases.
(c) The equation shows that the reaction between carbon dioxide and water produces $H^+$ (aq) ions. This makes the solution increasingly acidic and so the pH decreases.



13. $H^+$ (aq) ions from the acid would initially produce a red colour in the gel at the positive electrode side of the cell. The colour would move through the gel towards the oppositely charged negative electrode.
$OH^-$ ions from the sodium hydroxide solution would initially produce a blue colour in the gel at the negative electrode side of the cell. The colour would move through the gel towards the oppositely charged positive electrode.
In the area of the gel where these ions meet they would cancel each other out and the gel would remain green.

14. (a) A base is a substance that reacts with an acid forming water.
(b) (ii) nickel hydroxide, (iv) tin(II) hydroxide and (vi) copper(II) carbonate
(c) An alkali is a soluble base. Although both substances are bases because they react with acids to form water, only potassium hydroxide is soluble and therefore also an alkali.

15. (a) This indicates that water does not just consist of molecules, but some ions must also be present in water. These are hydrogen ions, $H^+$ (aq), and hydroxide ions, $OH^-$ (aq),
(b) The conductivity is very poor because the number of ions present is very small.

16. (a) Hydrogen ions, $H^+$ (aq), and hydroxide ions, $OH^-$ (aq), ions are present in pure water.
(b) The solution contains more hydroxide ions.
(c) The concentration of hydroxide ions decreases as water is added.

17. (a) Pure water is not an acid because although it contains a small number of $H^+$ (aq) ions it also contains an equal number of $OH^-$ (aq) ions.
Acids contain more $H^+$ (aq) ions than $OH^-$ (aq) ions.
(b) (i) Adding water decreases the concentration of the acid solution. The solution is therefore less acidic and the pH increases.
(ii) 7
(iii) The acid can only be diluted so that it is almost pure water. The pH therefore moves towards 7, but no further as there can never be an excess of $OH^-$ (aq) ions by adding water.

## Reactions of acids

1. (a) A neutralisation reaction involves the reaction of an acid with a base.
   (b) When an acid is neutralised the pH increases towards 7.
   (c) When an alkali is neutralised the pH decreases towards 7.

2. (a) Lime is a base and neutralises the acidity of the soil.
   (b) Indigestion is caused by excess acidity in the stomach.
   Milk of magnesia is a base, and can neutralise this excess acidity.

3. (a) The scale is a base and reacts with the vinegar which is an acid.
   (b) neutralisation

4. Lithium hydroxide is a base and will react with the carbon dioxide (an acidic oxide) removing it from the cabin's atmosphere.

5. (a) potassium nitrate (b) sodium sulphate (c) lithium chloride

6. (a) hydrochloric acid and sodium hydroxide
   (b) sulphuric acid and potassium hydroxide
   (c) nitric acid and barium hydroxide

7. (a) (i) carbon dioxide
   (ii) Carbon dioxide turns lime water milky.
   (b) (i) calcium sulphate, carbon dioxide and water
   (ii) sodium nitrate, carbon dioxide and water

8. (a) neutralisation
   (b) The pH increases as the crystals are added.
   (c) Excess magnesium oxide can be removed by filtration.
   (d) $MgO\ (s) + H_2SO_4\ (aq) \rightarrow MgSO_4\ (aq) + H_2O\ (l)$

9. (a) carbon dioxide
   (b) **X** is a metal carbonate.

10. (a) hydrochloric acid
    (b) Evaporate until the solution is concentrated. Leave to slowly cool and crystallise. Pour off excess solution and dry the crystals on filter paper.



11. Add dilute hydrochloric acid to both white solids. Only the sodium carbonate will produce a gas. The gas is carbon dioxide and will turn lime water milky.

12. (a) neutralisation
    (b) carbon dioxide
    (c) $Na_2CO_3\ (s) + H_2SO_4\ (aq) \rightarrow Na_2SO_4\ (aq) + CO_2\ (g) + H_2O\ (l)$

13. (a) The hydrogen gas formed in the reaction is lost from the flask to the atmosphere.
    (b) $Mg\ (s) + H_2SO_4\ (aq) \rightarrow MgSO_4\ (aq) + H_2\ (g)$

14. (a) Add a tablet to a small volume of dilute hydrochloric acid to which a few drops of Universal indicator had been added. As the acid is neutralised, the colour of the indicator will gradually change from red to green.
    (b) (i) magnesium chloride and water
    (ii) neutralisation

15. Jill's product can be easily prepared in a neutralisation reaction between an acid and an alkali. This gives a solution of her product (sodium chloride).
    Jack's product cannot be prepared by an acid / alkali neutralisation. It can be prepared by reacting an excess of insoluble copper(II) oxide with the acid. The unreacted copper(II) oxide can then be filtered off to leave a solution of his product (copper(II) sulphate).

16. (a) Any dilute acid solution, e.g. hydrochloric acid, sulphuric acid or nitric acid, and any metal carbonate, e.g. sodium carbonate, magnesium carbonate or calcium carbonate, can be used.
    (b) Potassium hydroxide is an alkali. It will remove any unreacted carbon dioxide which is an acidic gas.

17. (a) copper(II) oxide and sulphuric acid
    (b) neutralisation
    (c) $CuO\ (s) + H_2SO_4\ (aq) \rightarrow CuSO_4\ (aq) + H_2O\ (l)$

18. (a) The student continued to add copper carbonate to ensure that all the acid had been used up.
(b) step 4 – filtration; step 5 – crystallisation
(c) $CuCO_3$ (s) + 2 HCl (aq) → $CuCl_2$ (aq) + $CO_2$ (g) + $H_2O$ (l)

19. (a) $Na^+$ (aq) and $Cl^-$ (aq), i.e. sodium ions and chloride ions
(b) $K^+$ (aq) and $NO_3^-$ (aq), i.e. potassium ions and nitrate ions

20. (a) $K^+$ (aq) and $SO_4^{2-}$ (aq)
2 $OH^-$ (aq) + 2 $H^+$ (aq) → 2 $H_2O$ (l) or
$OH^-$ (aq) + $H^+$ (aq) → $H_2O$ (l)
[ In a balanced equation, it is the ratio of reactant and product species that is important. ]
[ The full equation showing all ions present (including the spectator ions) is:
$2\cancel{K^+}$ (aq) + 2 $OH^-$ (aq) + 2 $H^+$ (aq) + $\cancel{SO_4^{2-}}$ (aq)
→ $2\cancel{K^+}$ (aq) + $\cancel{SO_4^{2-}}$ (aq) + 2 $H_2O$ (l) ]
(b) $Na^+$ (aq) and $NO_3^-$ (aq)
$CO_3^{2-}$ (aq) + 2 $H^+$ (aq) → $CO_2$ + $H_2O$ (l)
[ The full equation showing all ions present (including the spectator ions) is:
$2\cancel{Na^+}$ (aq) + $CO_3^{2-}$ (aq) + $2H^+$ (aq) + $2\cancel{NO_3^-}$ (aq)
→ $2\cancel{Na^+}$ (aq) + $2\cancel{NO_3^-}$ (aq) + $CO_2$ (g) + $H_2O$ (l) ]

## Precipitation

1. (a) precipitation
(b) (i) barium sulphate (ii) calcium carbonate
(iii) iron(III) hydroxide (iv) silver bromide

2. (a) barium nitrate and sodium carbonate
(b) Mix solutions of barium nitrate and sodium carbonate. Filter off barium carbonate precipitate, wash with pure water and allow to dry.

3. (a) A precipitate is an insoluble solid formed in the reaction between two solutions.
(b) lead(II) nitrate and tin(II) chloride



4. (a) barium sulphate
(b) filtration

5. (a) precipitation
(b) $Na^+$ (aq) and $SO_4^{2-}$ (aq), i.e. sodium ions and sulphate ions

6. (a) silver chloride
(b) sodium ions [ $Na^+$ (aq) ] and nitrate ions [ $NO_3^-$ (aq) ]

7. (a) Any soluble barium compound, e.g. barium nitrate, barium hydroxide, and any soluble sulphate compound, e.g. sodium sulphate, potassium sulphate or sulphuric acid, could be used to prepare barium sulphate.
(b) Barium sulphate is insoluble and therefore cannot be absorbed into the bloodstream from the digestive system and cannot act as a poison.

8. (a) $K^+$ (aq) and $Cl^-$ (aq)
$Cu^{2+}$ (aq) + $CO_3^{2-}$ (aq) → $Cu^{2+}CO_3^{2-}$ (s)
[ The full equation showing all ions present (including the spectator ions) would be:
$2\cancel{K^+}$ (aq) + $CO_3^{2-}$ (aq) + $Cu^{2+}$ (aq) + $2\cancel{Cl^-}$ (aq)
→ $Cu^{2+}CO_3^{2-}$ (s) + $2\cancel{K^+}$ (aq) + $2\cancel{Cl^-}$ (aq) ]
(b) $K^+$ (aq) and $NO_3^-$ (aq)
$Ba^{2+}$ (aq) + $SO_4^{2-}$ (aq) → $Ba^{2+}SO_4^{2-}$ (s)
[ The full equation showing all ions present (including the spectator ions) would be:
$Ba^{2+}$ (aq) + $2\cancel{NO_3^-}$ (aq) + $2\cancel{K^+}$ (aq) + $SO_4^{2-}$ (aq)
→ $Ba^{2+}SO_4^{2-}$ (s) + $2\cancel{K^+}$ (aq) + $2\cancel{NO_3^-}$ (aq) ]
(c) $Li^+$ (aq) and $NO_3^-$ (aq)
$Ag^+$ (aq) + $Br^-$ (aq) → $Ag^+Br^-$ (s)
[ The full equation showing all ions present (including the spectator ions) would be:
$Ag^+$ (aq) + $\cancel{NO_3^-}$ (aq) + $\cancel{Li^+}$ (aq) + $Br^-$ (aq)
→ $Ag^+Br^-$ (s) + $\cancel{Li^+}$ (aq) + $\cancel{NO_3^-}$ (aq) ]

## Volumetric titrations

1. (a) 'Rough' indicates that the titration has been carried out to give only an approximate value of the volume of acid required.
   (b) An indicator which would change colour at the exact point of neutralisation would be used.
   (c) 26.9 $cm^3$
   [ Titration 1 is the 'rough' titration. The volume obtained in this titration is ignored and the average volume of the accurate titrations (2 and 3) is used for the calculation. Accurate titrations should normally agree to within 0.2 $cm^3$ of each other. ]

2. (a) 0.0025 mol
   [ no. of moles = concentration x Litres = 0.1 x 0.025 = 0.0025 ]
   (b) 0.067 mol $l^{-1}$
   [ vol x conc x no. of $H^+$ (aq) (ACID) = vol x conc x no. of $OH^-$ (aq) (ALKALI)
   37.4 x conc x 1 = 25 x 0.1 x 1; 37.4 x conc = 2.5
   conc = 2.5 ÷ 37.4 = 0.067 ]

3. (a) 0.002 mol
   [ no. of moles = concentration x Litres = 0.1 x 0.02 = 0.002 ]
   (b) 0.08 mol $l^{-1}$
   [ vol x conc x no. of $H^+$ (aq) (ACID) = vol x conc x no. of $OH^-$ (aq) (ALKALI)
   25 x conc x 1 = 20 x 0.1 x 1; 25 x conc = 2
   conc = 2 ÷ 25 = 0.08 ]

4. (a) 100 $cm^3$
   [ vol x conc x no. of $H^+$ (aq) (ACID) = vol x conc x no. of $OH^-$ (aq) (ALKALI)
   vol x 0.1 x 1 = 50 x 0.2 x 1; 0.1 x vol = 10
   vol = 10 ÷ 0.1 = 100 ]
   (b) 0.25 mol $l^{-1}$
   [ vol x conc x no. of $H^+$ (aq) (ACID) = vol x conc x no. of $OH^-$ (aq) (ALKALI)
   50 x conc x 2 = 25 x 1 x 1; 100 x conc = 25
   conc = 25 ÷ 100 = 0.25 ]



5. (a) 0.16 mol $l^{-1}$
   [ vol x conc x no. of $H^+$ (aq) (ACID) = vol x conc x no. of $OH^-$ (aq) (ALKALI)
   12.6 x conc x 1 = 20 x 0.1 x 1; 12.6 x conc = 2
   conc = 2 ÷ 12.6 = 0.16 ]
   (b) 5 $cm^3$
   [ vol x conc x no. of $H^+$ (aq) (ACID) = vol x conc x no. of $OH^-$ (aq) (ALKALI)
   vol x 2 x 1 = 20 x 0.5 x 1; 2 x vol = 10
   vol = 10 ÷ 2 = 5 ]
   (c) 0.36 mol $l^{-1}$
   [ vol x conc x no. of $H^+$ (aq) (ACID) = vol x conc x no. of $OH^-$ (aq) (ALKALI)
   17.3 x conc x 2 = 25 x 0.5 x 1; 34.6 x conc = 12.5
   conc = 12.5 ÷ 34.6 = 0.36 ]

6. (a) 10 $cm^3$
   [ vol x conc x no. of $H^+$ (aq) (ACID) = vol x conc x no. of $OH^-$ (aq) (ALKALI)
   vol x 0.5 x 2 = 20 x 0.5 x 1; 1 x vol = 10
   vol = 10 ÷ 1 = 10 ]
   (b) Evaporate the ammonium sulphate solution until it is more concentrated. Leave to slowly cool and crystallise. Pour off excess solution and dry the crystals on filter paper.

7. 0.089 mol $l^{-1}$
   [ vol x conc x no. of $H^+$ (aq) (ACID) = vol x conc x no. of $OH^-$ (aq) (ALKALI)
   18.6 x 0.12 x 1 = 25 x conc x 1; 2.232 = 25 x conc
   conc = 2.232 ÷ 25 = 0.089 ]

8. (a) The wire was reacted with excess sulphuric acid to make sure that all the iron in the wire was changed into soluble iron ions (iron(II) sulphate solution).
   (b) (i) 0.00303 mol
   [ no. of moles = concentration x Litres = 0.15 x 0.0202 = 0.00303 ]
   (ii) 0.85 g
   [ 1 mol of potassium permanganate reacts with 5 mol of iron(II) sulphate ($FeSO_4$);
   number of moles of $FeSO_4$ = 5 x 0.00303 = 0.01515;
   1 mol of $FeSO_4$ contains 56 g of iron ( RAM of Fe = 56),
   so mass of iron = 0.01515 x 56 = 0.85 g ]

## Fuels

1*. A **fuel** is any material that has stored energy that can be used for a particular purpose. The energy is released when the fuel is burned. **Combustion** (or burning) is the reaction of a material with oxygen. The reaction releases energy mainly in the form of heat. **Exothermic** describes a reaction in which energy is given out.

2*. (a) A hydrocarbon is a compound made up of **ONLY** hydrogen and carbon atoms.
(b) exothermic
(c) oxygen
(d) carbon dioxide and water
(e) Carbon monoxide can be produced if the gas is burned in a poorly ventilated room. Carbon monoxide is dangerous because it is a poisonous gas.

3*. (a) (i) carbon monoxide (ii) sulphur dioxide (iii) nitrogen dioxide
(b) Air pollution is a result of impurities in the air. Most of these impurities come from burning fossil fuels. This is much more common in industrial areas than non-industrial areas.

4*. (a) If the sulphur dioxide is not removed it will dissolve in rain water to form acid rain.
(b) Limestone is a cheap, relatively available material.

5*. (a) (i) Biomass is plant or animal-based material formed from living or recently-living organisms.
(ii) A renewable source of energy is one that can be constantly replaced.
(b) e.g. wind, tidal and solar energy
(c) e.g. burning wood logs from dead trees
(d) e.g. ethanol and biodiesel: ethanol is produced from crops such as sugar cane and biodiesel is produced from waste vegetable oils and animal fats.

6*. (a) A finite source of energy is a source of energy that having been used up cannot be replaced.
(b) The wood can be used as a fuel and reduce our use of fossil fuels. With organised management of forests, new trees are planted to replace those felled and used makes our forests a sustainable resource.



7*. (a) Greenhouse gases are gases in the atmosphere that trap heat, keeping the Earth warm enough for plants and animals to survive.
(b) The burning of fossil fuels in industrial areas significantly increases the amount of carbon dioxide being released into the atmosphere.

8*. (a) oxygen
(b) carbon monoxide

9*. (a) The volume of oxygen entering the car engine is insufficient for the complete combustion of the petrol (there is incomplete combustion of petrol).
(b) The use of more fuel efficient engines ('lean-burn' engines) increases the air to fuel ratio and can reduce the levels of carbon monoxide being released by cars.

10*. (a) The addition of a catalytic converter helps the exhaust system to convert more pollutant gases (carbon monoxide) to harmless gases.
(b) Increasing the air to fuel ratio through use of 'lean-burn' engines improves the efficiency of combustion and reduces carbon monoxide levels.

11*. As the air to fuel ratio increases, the volume of oxygen entering the car engine becomes sufficient for the complete combustion of the petrol.

12*. (a) Crude oil is formed from dead sea plants and animals that are buried under layers of mud and sediment. The dead organisms are changed over millions of years by the effect of heat, pressure and bacteria into crude oil.
(b) Crude oil is a fossil fuel because it is formed from material that was once living.
(c) e.g. oil spillages at sea and air pollution as a result of burning products obtained from oil

13*. (a) hydrocarbons
(b) (i) Fractional distillation is a process in which crude oil is separated into fractions by heating.
(ii) A fraction is a group of compounds with roughly the same boiling point.
(c) (i) fuel for cars (ii) fuel for cars, buses and lorries (iii) fuel for camping stoves
(iv) aviation fuel (v) tar for roads and roofs

14*. (a) (i) A flammable substance is one that can be easily ignited and burns quickly.

(ii) A viscous substance is a liquid that does not flow easily.

(b) (i) gas

(ii) residue (bitumen)

15*. (a) (i) gas (ii) petrol (naphtha) (iii) kerosene (paraffin)

(iv) diesel (v) residue (bitumen)

(b) (i) diesel

(ii) Diesel has bigger molecules (longer carbon chains) that get more tangled together and need more energy to separate.

## Structure of hydrocarbons

1. (a) A hydrocarbon is a compound made up of **ONLY** hydrogen and carbon atoms.

(b) (i) 4 (ii) 1

(c) (i) $C_7H_{16}$, (iv) $CH_4$, (v) $C_8H_{16}$ and (viii) $C_2H_2$

2. (a) (i) A saturated hydrocarbon is one in which all the carbon to carbon bonds are single covalent bonds.

(ii) An unsaturated hydrocarbon has (at least) one carbon to carbon double bond in each molecule.

(b) (i) butane, cyclopropane, octane, methane

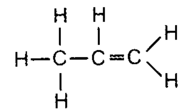
(ii) ethene, pentenecy, clohexene

3. (a) but-1-ene (b) hexane (c) ethane

(d) pent-1-ene (e) cyclobutane (f) Cyclohexene

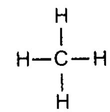


4. (a) (i)



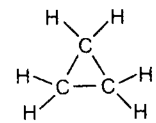
(ii) $CH_3-CH=CH_2$

(b) (i)

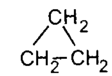


(ii) $CH_4$

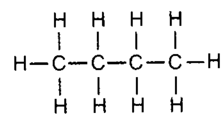
(c) (i)



(ii)

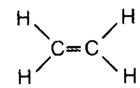


(d) (i)



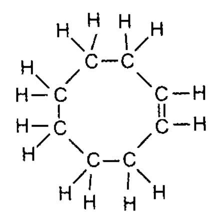
(ii) $CH_3-CH_2-CH_2-CH_3$

(e) (i)

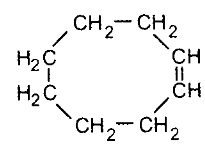


(ii) $CH_2=CH_2$

(f) (i)



(ii)



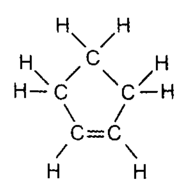
5. (a) $C_{12}H_{26}$ (b) $C_{10}H_{22}$ (c) $C_7H_{14}$

(d) $C_8H_{18}$ (e) $C_6H_{12}$ (f) $C_5H_{10}$

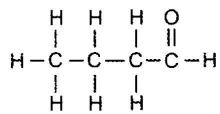
6. (a) A homologous series is a family of chemically similar compounds that can be represented by a general formula.

(b) (i) butene (ii) $C_7H_{14}$ (iii) $CH_4$

7. (a)

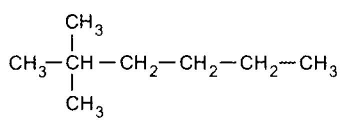


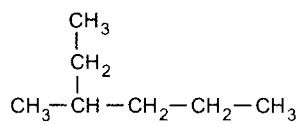
(b) $C_nH_{2n-2}$

8. (a) 

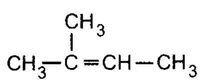
(b) $C_nH_{2n}O$

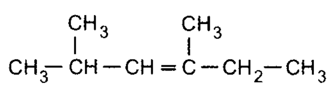
9. (a) 2,4-dimethylpentane
(b) 2,2-dimethylbutane
(c) 3-methylhexane
(d) 1,3-dimethylcyclobutane

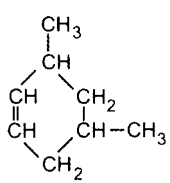
10. (a) 

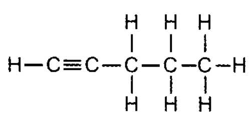
(b) 

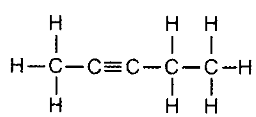
11. (a) hex-2-ene
(b) 2-methylbut-1-ene
(c) 2-methylpent-2-ene

12. (a) 

(b) 

(c) 

13. (a) (i) 

(ii) 

(b) $C_nH_{2n-2}$



## Reactions of hydrocarbons

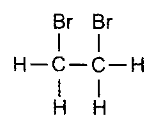
1*. (a) Cracking is an industrial process that breaks up (cracks) larger (longer chain) molecules into smaller (shorter chain) molecules by heating.
(b) (i) The catalyst is used to allow the reaction to take place at a lower temperature but still at an acceptable rate of reaction.
(ii) aluminium oxide

2*. (a) $C_3H_8$ propane
(b) $C_3H_6$ propene
(c) $C_6H_{14}$ hexane
(d) $C_4H_8$ butene
(e) name is not part of course work

3*. (a) The hydrocarbon is saturated. All the carbon to carbon bonds are single covalent bonds (no double bonds).
(b) (i) The gas is unsaturated. There is at least one carbon to carbon double bond.
(ii) cracking
(iii) The delivery tube must be removed from the water before heating is stopped. If this is not done, the resulting decrease in pressure in the heated tube might cause cold water to suck back into the tube which may explode.

4*. (a) The level of heat required would be reduced.
(b) All the carbon to carbon bonds are equally strong. Also, there are not enough hydrogen atoms available to produce only saturated products when any hydrocarbon is cracked.

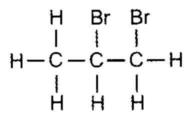
5. Shake a little white spirit with bromine solution in a test tube. If the white spirit contains unsaturated hydrocarbons it should immediately decolourise the bromine solution.

6. (a) 

(b) addition reaction
(c) ethane

7. (a) unsaturated
[ Although $C_3H_6$ could also be cyclopropane, this hydrocarbon would not react with bromine solution so it must be propene. ]

(b)




(c) $C_3H_8$

8. **A** is hexene. **B** is hexane. **C** is cyclohexane.

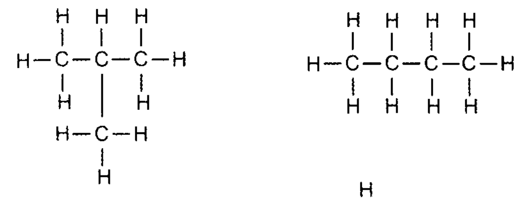
9. (a) $C_4H_6Br_4$
(b) $C_{10}H_{16}Br_4$



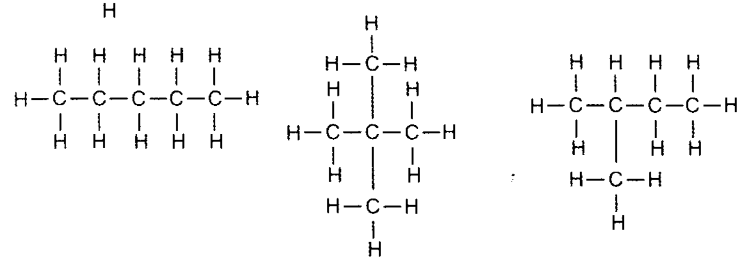
## Isomers

1. (a) Isomers are compounds with the same molecular formula but different structures.

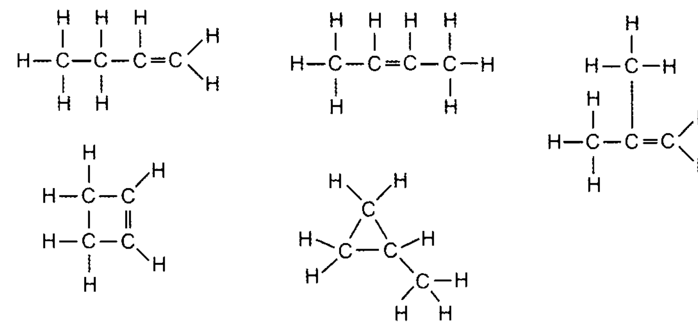
(b)



2. (a)



(b)



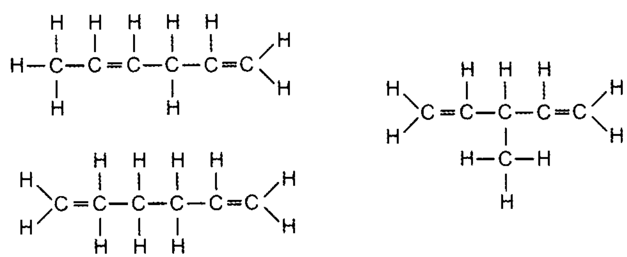
3. (a) Compound **B** can be described as an isomer of compound **A** because they have the same molecular formula ($C_3H_8S$) but different structures.
(b) Compound **C** and compound **A** are not isomers because they have the same molecular formula **AND** the same structure.

4. (a) NOT isomers
[ different formulae ]
(b) NOT isomers
[ different formulae ]
(c) NOT isomers [ same molecule ]
(d) NOT isomers [ same molecule ]
(e) NOT isomers [ same molecule ]
(f) isomers
(g) isomers
(h) NOT isomers [different formulae]
(i) NOT isomers [ same molecule ]
(j) isomers

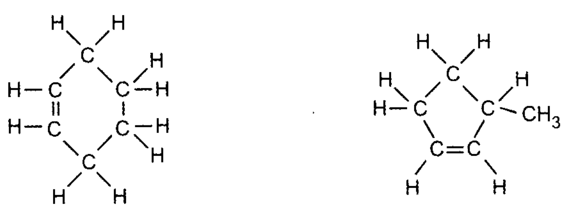
5. (a) NOT isomers
[ different formulae: 2-methylbutane has an extra carbon ]
(b) isomers [ same formula but different structures ]
(c) NOT isomers
[ different formulae: 3-methylhexane has an extra carbon ]
(d) isomers [ same formula but different structures ]
(e) isomers [ same formula but different structures ]

6. (a) NOT isomers
[ same molecule: in each case one chlorine atom on each carbon ]
(b) isomers
[ different structures: chlorine atoms are in different positions ]
(c) NOT isomers
[ same molecule: in each case one bromine atom on each carbon ]
(d) NOT isomers
[ same molecule: in each case one bromine atom on each carbon ]
(e) NOT isomers
[ different formulae : 2$^{nd}$ molecule has an extra carbon ]
(f) isomers [ same formula but different structures ]
(g) NOT isomers
[ different formulae: 2$^{nd}$ molecule has an extra oxygen ]

7. (a) e.g.



(b) e.g.



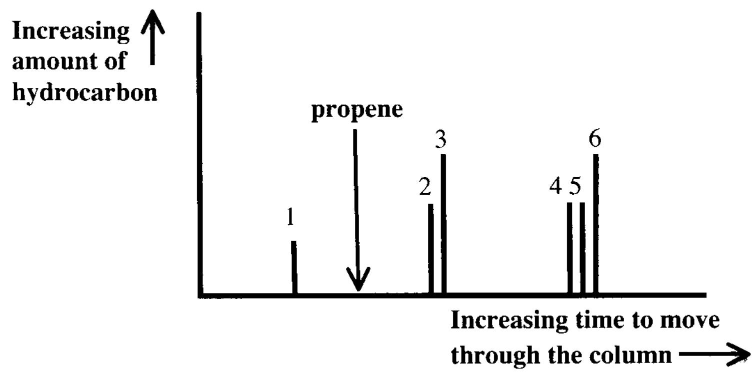


## Patterns in carbon compounds

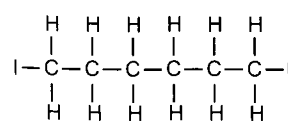
1. (a) All three compounds (**A**, **B** and **C**) are flammable.
(b) (i) Add a small piece of sodium to different test tubes containing compounds **A** and **B**. Only compound **A** will produce a gas.
(ii) Add a small amount of acidified potassium permanganate solution to different test tubes containing compounds **B** and **C**. Only compound **B** will turn the solution colourless.
(c) no reaction
[ It has a similar structure to compound **C** and is likely to react in the same way. ]

2. A shorter main carbon chain and a greater number of branches on the chain give a high octane number.

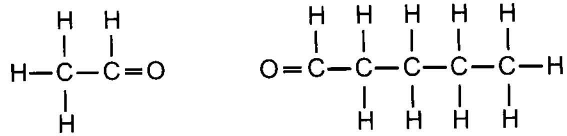
3. (a) The greater the number of carbon atoms the greater the time to move through the column.
For molecules with the same number of carbon atoms, the fewer the number of branches the greater the time to move through the column.
(b)



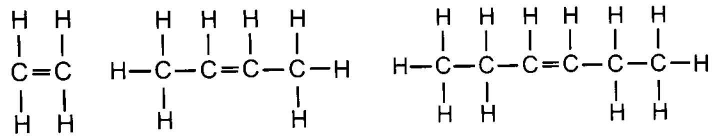

4. (a) butane
(b) iodomethane and iodoethane
(c)



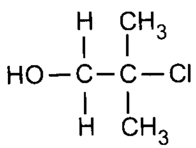
5. (a)



(b) e.g.



6. (a)



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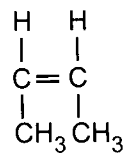
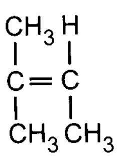
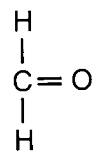


7. (a)

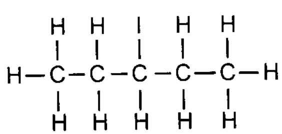


(b)

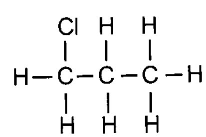


8. (a) The lower the attached halogen atom is in Group 7 of the Periodic Table the higher the boiling point, and haloalkanes with the halogen atom at the end of the chain (carbon 1) have a higher boiling point than those with the halogen atom on carbon 2.

(b) (i)



(ii)





## Carbohydrates

1*. (a) e.g. Any three 'starchy' or 'sugary' foods such as bread, potatoes, pasta, cereals, sweets, cakes, biscuits etc.
(b) carbon, hydrogen and oxygen
[ The hydrogen and oxygen are always present in the ratio of 2:1 – the same as water ]
(c) covalent bonding

2*. (a) carbohydrate (b) NOT carbohydrate (c) NOT carbohydrate
(d) NOT carbohydrate (e) carbohydrate
(f) NOT carbohydrate (g) NOT carbohydrate
[Although (b) and (f) both contain carbon, hydrogen and oxygen, the hydrogen and oxygen are not in the ratio of 2:1. ]

3*. (a) The burning will be faster and brighter in oxygen.
(b) carbon dioxide and water

4*. (a) respiration
(b) glucose
(c) **X** oxygen; **Y** carbon dioxide
(d) movement, heat and growth

5*. (a) **X** carbon dioxide; **Y** oxygen
(b) Glucose is a carbohydrate.
(c) starch

6*. (a) The energy comes from the Sun.
(b) glucose + oxygen → carbon dioxide + water (+ energy)

7*. (a) photosynthesis
(b) The chlorophyll absorbs the light energy from the Sun.
(c) water
(d) polymerisation

8*. (a) **X** photosynthesis; **Y** respiration
(b) More fossil fuels are being burned.
(c) The reduced area occupied by forests means than less carbon dioxide is being taken out of the atmosphere by trees and less oxygen is being returned.

9*. (a) As the temperature increases the solubility of the oxygen decreases.
(b) The lower temperatures of the Arctic waters allow more oxygen to be dissolved in the water supporting more animal life.

10*. (a) 2:1 ratio of hydrogen to oxygen
(b) Glucose has much smaller molecules than starch.
(c) (i) The light beam is not visible in the glucose solution.
(ii) The light beam is visible as it passes through the starch solution. [ Starch molecules are big enough to reflect the beam of light as it passes through making it more visible. ]

11*. (a) (i) iodine solution
(ii) Iodine solution changes from a brown colour to blue/black in the presence of starch.
(b) (i) Benedict's solution
(ii) The Benedict's solution changes from a blue colour to orange/red in the presence of glucose.
(iii) Heat makes the change take place more quickly and the water bath gives an even and gentle heat.

12*. (a) starch
(b) glucose
(c) an enzyme

13*. The starch molecules in the bread are bigger and must be broken down before they can enter the bloodstream and release energy. However, the glucose molecules in the Mars bar are smaller and so they enter the bloodstream more quickly giving the body almost instant energy.

14*. (a) (i) 2.5 (ii) 1 (iii) 2
(iv) 1.5 (v) 3
(b) Alcohol is a sedative and slows down the nervous system, leading to loss of control and affecting balance. Higher intakes of alcohol can result in unconsciousness and even death. Long term abuse of alcohol can cause diseases, e.g. cirrhosis of the liver.



15*. (a) fermentation
(b) e.g. grapes for wine, barley for whisky or beer, apples for cider, potatoes for vodka, etc.
(c) Mix the carbohydrate source with water and yeast and leave at a temperature of 35-40$^{o}$C for some time. Alcohol can be separated from the resulting solution by distillation.

16*. (a) carbon dioxide
(b) an enzyme
(c) distillation

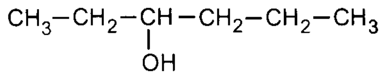
17*. (a) (i) The reaction would not be speeded up by increasing the temperature.
(ii) The temperature of 40 $^{o}$C is the optimum temperature. At a higher (and lower) temperature, the enzyme in the yeast is less efficient so the fermentation process slows down.
(b) At concentrations above about 15%, the alcohol poisons the living organisms in the yeast stopping the fermentation process.

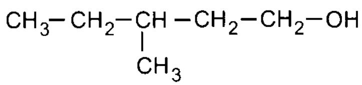
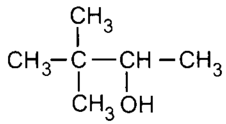
18*. The yeast used to make the bread is not present in the final product due to the high temperatures used in the baking, and so would not be available in the body to make alcohol.

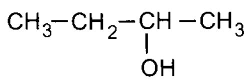
19*. (a) Optimum conditions for the enzyme are the conditions at which it is most efficient, i.e. the rate is fastest.
(b) (i) pH 6 (ii) 30$^{o}$C
(c) 37$^{o}$C is normal body temperature and so body enzymes are at their most efficient at this temperature.

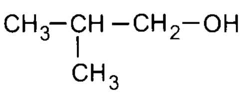
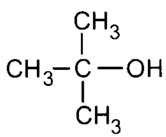
## The alcohols

1. (a) ethanol (b) butan-2-ol
   (c) 2-methylbutan-2-ol (d) 4-methylpentan-2-ol

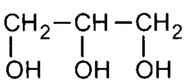
2. (a) $CH_3-CH_2-CH_2-CH_2-OH$ (b) 

   (c)  (d) 

3. (a) $CH_3-CH_2-CH_2-CH_2-OH$ 

   (b)  

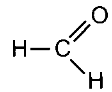
4. (a) A dihydric alcohol is an alcohol that has two –OH (hydroxyl) groups.

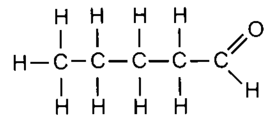
   (b) 

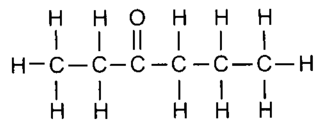
   (c) Alcohols are also used as solvents for substances insoluble in water, cleaning solvents and fuels.



5. (a) When the –OH group is at the end of the carbon chain, an aldehyde is produced; otherwise a ketone is produced.

   (b) (i) 

   (ii) 

   (iii) 

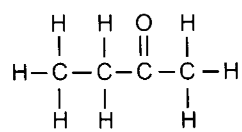
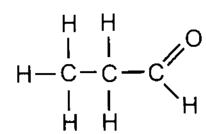
6. (a) methylpropan-1-ol
   [ 2-methylpropan-1-ol is also correct, but strictly speaking the 2 is not necessary as the attached group can only be on the second carbon. ]

   (b) $CH_3-CH=CH-CH_3$

   (c) propan-1-ol

7. (a) When the C=O group is at the end of the carbon chain, an orange precipitate forms; otherwise there is no reaction
   or, when the C=O group is directly attached to an atom of hydrogen, an orange precipitate forms; otherwise there is no reaction.

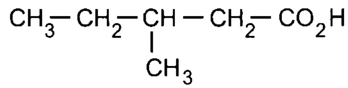
   (b) An orange precipitate will form.
   [ The C=O group is at the end of the carbon chain. ]

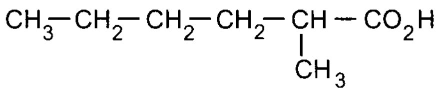
   (c) (i)  (ii) 

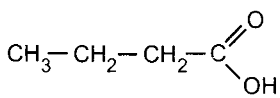
## Carboxylic acids

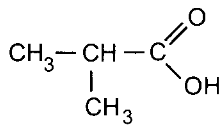
1. (a) ethanoic acid (b) methanoic acid
   (c) 3-methylbutanoic acid (d) 2-methylpentanoic acid

2. (a) $CH_3-CH_2-CO_2H$

   (b) 

   (c) 

3. (a) 

   (b) 

4. (a) ethanoic acid
   (b) (i) e.g. Vinegar is used as a preservative in the food industry.
   (ii) e.g. Vinegar is used to remove insoluble carbonate compounds found on plumbing fixtures.

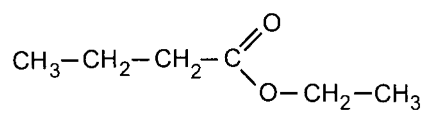


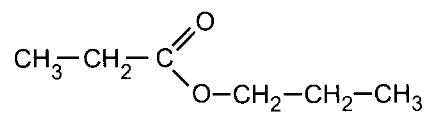
## Esters

1. (a) (i) (concentrated) sulphuric acid
   (ii) A Bunsen burner is not used to heat the reactants because they are flammable.
   (iii) The ester forms as an oily layer on the surface of the reaction mixture. It can be separated from the unreacted alcohol and carboxylic acid using a separating funnel.
   (b) (i) e.g. Esters can be used as perfumes (fragrances) or food flavourings because of their distinctive smells.
   (ii) e.g. Esters can be used as nail polish remover and solvents for glues or paints because of their solvent properties.

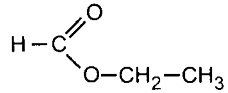
2. (a) Esters have strong, distinctive smells and many esters have a characteristic fruity smell.
   (b) (i) The reaction between a carboxylic acid and an alcohol is used to make an ester.
   (ii) 3. Add a few drops of concentrated sulphuric acid to the mixture of **X** and **Y**.
   4. Place the test tube in a warm water bath for about 10 minutes to allow the ester to form.
   (iii) The paper soaked in cold water acts as a condenser and returns any evaporating reactant to the reaction mixture.

3. (a) methyl ethanoate (b) methyl methanoate
   (c) propyl ethanoate (d) ethyl methanoate

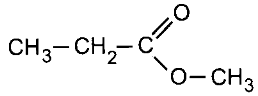
4. (a) 

   (b) 

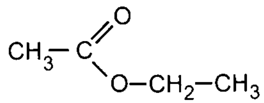
5. (a) ethyl methanoate



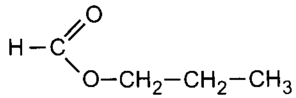
(b) methyl propanoate



(c) ethyl ethanoate



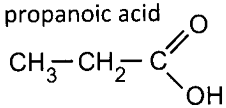
(d) propyl methanoate



6. (a) ethanol

$CH_3-CH_2-OH$

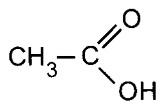
propanoic acid



(b) methanol

$CH_3-OH$

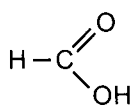
ethanoic acid



(c) ethanol

$CH_3-CH_2-OH$

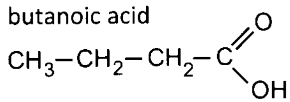
methanoic acid



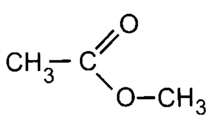
(d) methanol

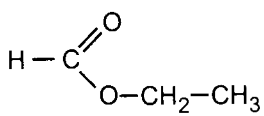
$CH_3-OH$

butanoic acid



7. (a)





(b) methvl ethanoate    ethvl methanoate



## Energy from fuels

1. (a) (i) An exothermic reaction is one in which energy is released to the surroundings which become warmer.
   (ii) An endothermic reaction is one in which energy is taken in during the reaction and the surroundings cool down.
   (b) e.g. Natural gas burning in a Bunsen burner is an example of an exothermic reaction.
   e.g. The reaction between solid ammonium nitrate and hydrated barium hydroxide is an example of an endothermic reaction.

2. During an exothermic reaction, energy is required to **break** bonds in the **reactant** molecules. Energy is then **released** as the bonds are formed in the product molecules. In this type of reaction, more energy is released in the bond **forming** step than is required in the bond **breaking** step.

3. (a) The heat released increases as the number of carbon atoms increases.
   (b) There is a fairly constant difference for any two successive members, as the structure changes by the same difference (an extra $-CH_2$) each time.
   (c) any value between 2660 and 2686 kJ $mol^{-1}$
   [ As the two previous differences were 640 and 653, it is reasonable to assume that a similar small increase would be correct for the gap to butan-1-ol; this would give a value between 2020+640 and 2020+666. ]
   (d) In the lab, the calculated heat energy released is less than the actual value because some energy is lost to the surroundings, e.g. the air and the container for the water.

4. (a) $E_h = c\ m\ \Delta T$
   $E_h = 4.18 \times 0.05 \times 15$ [ 50 $cm^3$ of water = 50 g = 0.05 kg ]
   $E_h$ = **3.14 kJ**
   (b) $E_h = c\ m\ \Delta T$
   $E_h = 4.18 \times 0.1 \times 23.6$ [ 100 $cm^3$ of water = 100 g = 0.1 kg ]
   $E_h$ = **9.86 kJ**
   (c) $E_h = c\ m\ \Delta T$
   $E_h = 4.18 \times 0.15 \times 18.2$ [ 150 $cm^3$ of water = 150 g = 0.15 kg; $\Delta T$ = 39.1-20.9 ]
   $E_h$ = **11.4 kJ**
   (d) $E_h = c\ m\ \Delta T$
   $E_h = 4.18 \times 0.7 \times 6.8$ [ 700 $cm^3$ of water = 700 g = 0.7 kg; $\Delta T$ = 23.1-16.3 ]
   $E_h$ = **19.9 kJ**

   [ Note: All of the above answers are rounded to 3 significant figures. ]

## Calculations based on equations

1. **19.1 g**
[ 1 mol of Mg → 1 mol of $MgCl_2$ (from balanced equation)
Therefore, 24.5 g of Mg → 95.5 g of $MgCl_2$
Therefore, 1 g of Mg → (95.5/24.5) g of $MgCl_2$
Therefore, 4.9 g of Mg → (95.5/24.5) x 4.9 g of $MgCl_2$ = 19.1 g ]

2. **8.8 g**
[ 1 mol of $CH_4$ → 1 mol of $CO_2$ (from balanced equation)
Therefore, 16 g of $CH_4$ → 44 g of $CO_2$
Therefore, 1 g of $CH_4$ → (44/16) g of $CO_2$
Therefore, 3.2 g of $CH_4$ → (44/16) x 3.2 g of $CO_2$ = 8.8 g ]

3. **3.1 g**
[ 4 mol of Na → 2 mol of $Na_2O$ (from balanced equation)
Therefore, (4x23) = 92 g of Na → (2x62) = 124 g of $Na_2O$
Therefore, 1 g of Na → (124/92) g of $Na_2O$
Therefore, 2.3 g of Na → (124/92) x 2.3 g of $Na_2O$ = 3.1 g ]

4. **12 g**
[ 1 mol of $N_2$ reacts with 3 mol of $H_2$ (from balanced equation)
Therefore, 28 g of $N_2$ reacts with (3x2) = 6 g of $H_2$
Therefore, 56 g of $N_2$ reacts with 12 g of $H_2$ ]

5. **2.4 g**
[ 4 mol of Al reacts with 3 mol of $O_2$ (from balanced equation)
Therefore, (4x27) = 108 g of Al reacts with (3x32) = 96 g of $O_2$
Therefore, 1 g of Al reacts with (96/108) g of $O_2$
Therefore, 2.7 g of Al reacts with (96/108) x 2.7 g of $O_2$ = 2.4 g ]

6. **25.4 g**
[ 1 mol of Mg → 1 mol of Cu (from balanced equation)
Therefore, 24.5 g of Mg → 63.5 g of Cu
Therefore, 1 g of Mg → (63.5/24.5) g of Cu
Therefore, 9.8 g of Mg → (63.5/24.5) x 9.8 g of Cu = 25.4 g ]



7. **$1.31 \times 10^6$ kg**
[ 1 mol of $H_2$ → 2 mol of $NH_3$ (from balanced equation)
Therefore, 2 g of $H_2$ → (2x17) g of $NH_3$
Therefore, 1 g of $H_2$ → 17 g of $NH_3$
Therefore, $7.7 \times 10^4$ kg of $H_2$ → $7.7 \times 10^4 \times 17$ kg of $NH_3$
= $1.31 \times 10^6$ kg ]

8. **660 kg**
[ 2 mol of $NH_3$ → 1 mol of $(NH_4)_2SO_4$ (from balanced equation)
GFM of $(NH_4)_2SO_4$ = (2x14)+(8x1)+32+(4x16) = 132 g
Therefore, (2x17) = 34 g of $NH_3$ → 132 g of $(NH_4)_2SO_4$
Therefore, 1 g of $NH_3$ → (132/34) g of $(NH_4)_2SO_4$
Therefore, 170 kg of $NH_3$ → (132/34) x 170 kg of $(NH_4)_2SO_4$ = 660 kg ]

9. **6.8 g**
[ 1 mol of $Mg_3N_2$ → 2 mol of $NH_3$ (from balanced equation)
Therefore, (3x24.5)+(2x14) = 101.5 g of $Mg_3N_2$ → (2x17) = 34 g of $NH_3$
Therefore, 1 g of $Mg_3N_2$ → (34/101.5) g of $NH_3$
Therefore, 20.3 g of $Mg_3N_2$ → (34/101.5) x 20.3 g of $NH_3$ = 6.8 g ]

10. **500 kg**
[ 1 mol of $SO_2$ reacts with 1 mol of $CaCO_3$ (from balanced equation)
Therefore, 32+(2x16) = 64 g of $SO_2$ reacts with 40+12+(3x16) = 100 g of $CaCO_3$
Therefore, 1 g of $SO_2$ reacts with (100/64) g of $CaCO_3$
Therefore, 320 tonnes of $SO_2$ reacts with (100/64) x 320 tonnes of $SO_2$
= 500 kg ]

11. **4200 kg**
[ 1 mol of $C_2H_5OH$ → 1 mol of $C_2H_4$ (from balanced equation)
Therefore, (2x12)+(5x1)+16+1 = 46 g of $C_2H_5OH$ → (2x12)+(4x1) = 28 g of $C_2H_4$
Therefore, 1 g of $C_2H_5OH$ → (28/46) g of $C_2H_4$
Therefore, 6900 kg of $C_2H_5OH$ → (28/46) x 6900 kg of $C_2H_4$
= 4200 kg ]

12. **38.8 g**
[ 2 mol of $NaN_3$ → 3 mol of $N_2$ (from balanced equation)
Therefore, 2 x (23+(3x14)) = 130 g of $NaN_3$ → 3 x (2x14) = 84 g of $N_2$
Therefore, 1 g of $NaN_3$ → (84/130) g of $N_2$
Therefore, 60 g of $NaN_3$ → (84/130) x 60 g of $N_2$ = 38.8 g ]

# Metals

1*. e.g.

| Metal | Property | Makes it useful for |
|---|---|---|
| Aluminium | Strong | Aircraft, cooking pots and pans, window frames. |
| | Good conductor of heat | Cooking pots and pans |
| | Low density | Aircraft |
| | Malleable | Cooking foil |
| Copper | Strong | Hot and cold water pipes and bases of cooking pans |
| | Good conductor of electricity | Electrical wiring |
| | Good conductor of heat | Bases of cooking pans |
| | Unreactive with water | Hot and cold water pipes |

2*. (a) Recycling of metals means collecting and reusing instead of throwing away the waste metal.
(b) Metals are extracted from ores. Ores are finite resources that will eventually run out.

3*. (a) An alloy is a mixture of metals or metals with other non-metallic elements.
(b) e.g. Solder – joining metal pieces in electrical circuits
Mild steel – all types of construction, shipbuilding, car bodies
Stainless steel – sinks, cutlery
Brass – keys, door handles, ornaments
(c) Two aluminium/copper alloys can have different properties depending on the proportion of each metal in the alloy.

4*. (a) The properties of a metal can be changed or improved by mixing with another metal in an alloy.
(b) e.g. Iron is both strong and a good conductor of heat with a high melting point.

5. (a) The structure of metals can be thought of as an array of 'positively charged ions' in a sea of delocalised electrons. Each 'positively charged ion' is attracted to the pool of negative electrons and vice versa. These electrostatic attractions are called metallic bonding.
(b) The electrons in the outermost shells of the metal atoms are not tightly held in position. These delocalised electrons are free to move from one 'ion' to another throughout the metal lattice.



# Reactivity series

1. (a) Potassium, sodium and lithium are all stored under oil.
(b) This indicates that the metals are very reactive in air and water.

2. (a) potassium permanganate
(b) The observed 'fierceness' of the reaction with oxygen varies across the different metals and so can be used to place different metals in an order of reactivity.

3. (a) (i) Hydrogen burns with a 'pop' sound.
(ii) Sodium has a (relatively) low melting point and the heat of the reaction is sufficient to melt the metal.
(b) potassium
(c) Rubidium will react violently with water.

4. (a) (i) e.g. Magnesium, aluminium, zinc, iron, nickel, tin and lead all react with dilute hydrochloric acid.
[ Potassium, sodium and lithium would also react but the reaction would be too violent to be carried out in the lab. ]
(ii) Copper, silver, gold and platinum do not react with hydrochloric acid.
(b) hydrogen
(c) magnesium chloride

5. (a) The pH will increase.
(b) $Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$

6. (a) Gold and silver are very unreactive metals and are found uncombined in the ground.
(b) Sodium and magnesium are very reactive metals. They have to be extracted from ores using electricity which was not discovered until the 18$^{th}$ century.

7. (a) **Uncombined** – not joined up with other elements as part of a compound.
**Extracted** – decomposing a compound of a metal to obtain the metal.
(b) (i) e.g. Silver, gold and platinum are all found uncombined in the ground.
(ii) The metals are very unreactive.
(c) e.g. Zinc, iron, nickel, tin, lead and copper can be obtained from their metal oxides by heating with carbon.

8. (a) Silver oxide would decompose on heating alone.
(b) Sodium oxide would not decompose on heating with carbon.

9. (a) **Y X Z**
(b) **X** could be an oxide of zinc, iron, nickel, tin, lead or copper.
**Y** could be an oxide of potassium, sodium, lithium, calcium, magnesium or aluminium.
**Z** could be an oxide of silver or gold.

10. (a) **L** is a very unreactive metal.
(b) Both metal oxides could be heated with carbon. If only one decomposes to form a metal it is the oxide of the less reactive metal.

11. (a) $Fe_2O_3 + 3\ CO \rightarrow 2\ Fe + 3\ CO_2$
(b) Calcium is too reactive to be extracted in this way. A method involving electricity is required.

12. (a) (i) **W** and **Y** are more reactive than **X** and **Z**.
(ii) **Z** is less reactive than **W**, **X** and **Y**.
(b) **W Y X Z**
(c) **W** could be calcium.
**X** could be copper. **Y** could be magnesium.
**Z** could be silver or gold.

13. (a) (i) **C** and **D** are more reactive than **A**.
(ii) **B** is more reactive than **D**.
(iii) **C** is more reactive than **B**.
(b) **C B D A**
(c) **A** could be silver or gold. **B** could be magnesium.
**C** could be potassium, sodium, lithium or calcium.
**D** could be copper.

14. (a) (i) **A** is more reactive than **M** which is more reactive than **E**, **T** and **L**.
(ii) **E** is less reactive than all of the other metals.
(iii) **M** and **A** are more reactive than **L**, **E** and **T**.
(iv) **M**, **A** and **L** are more reactive than **T** and **E**.
(b) **A M L T E**
(c) The nitrate of metal **E** is most likely to decompose on heating.

15. (a) The chloride ion [ $Cl^-$ (aq) ] is the spectator ion.
(b) The sulphate ion [ $SO_4^{2-}$ (aq) ] is the spectator ion.

16. (a) The sulphate ion [ $SO_4^{2-}$ (aq) ] is the spectator ion.
$Zn\,(s) + 2\,H^+\,(aq) \rightarrow Zn^{2+}\,(aq) + H_2\,(g)$
(b) The chloride ion [ $Cl^-$ (aq) ] is the spectator ion.
$Mg\,(s) + 2\,H^+\,(aq) \rightarrow Mg^{2+}\,(aq) + H_2\,(g)$



## Redox reactions

1. (a) (i) Any reaction involving the loss of electrons is referred to as oxidation.
(ii) Any reaction involving the gain of electrons is referred to as reduction.
(b) (i) $Mg \rightarrow Mg^{2+} + 2e^-$
(ii) $Cu^{2+} + 2e^- \rightarrow Cu$
(iii) $K \rightarrow K^+ + e^-$
(iv) $Al^{3+} + 3e^- \rightarrow Al$
(v) $2Cl^- \rightarrow Cl_2 + 2e^-$
(vi) $F_2 + 2e^- \rightarrow 2F^-$
(vii) $Fe^{2+} \rightarrow Fe^{3+} + e^-$
(viii) $SO_3^{2-} + H_2O \rightarrow SO_4^{2-} + 2H^+ + 2e^-$

2. (a) Redox reactions involve the transfer of electrons from one atom, molecule or ion to another. Therefore, they involve both an oxidation step and a reduction step.
(b) (i) $2Al\,(s) + 6H^+\,(aq) \rightarrow 2Al^{3+}\,(aq) + 3H_2\,(g)$
(ii) $2Ce^{4+}\,(aq) + 2Br^-\,(aq) \rightarrow 2Ce^{3+}\,(aq) + Br_2\,(g)$
(iii) $Cu\,(s) + 2Ag^+\,(aq) \rightarrow Cu^{2+}\,(aq) + 2Ag\,(s)$
(iv) $MnO_4^-\,(aq) + 8H^+\,(aq) + 5Fe^{2+}\,(aq) \rightarrow Mn^{2+}\,(aq) + H_2O\,(l) + 5Fe^{3+}\,(aq)$
(v) $Cr_2O_7^{2-}\,(aq) + 14H^+\,(aq) + 3Sn^{2+}\,(aq) \rightarrow 2Cr^{3+}\,(aq) + 7H_2O\,(l) + 3Sn^{4+}\,(aq)$
(c) (i) Oxidation: $Fe^{2+}\,(aq) \rightarrow Fe^{3+}\,(aq) + e^-$
[ or $2Fe^{2+}\,(aq) \rightarrow 2Fe^{3+}\,(aq) + 2e^-$ ]
Reduction: $Cl_2\,(g) + 2e^- \rightarrow 2Cl^-\,(aq)$
(ii) Oxidation: $Zn\,(s) \rightarrow Zn^{2+}\,(aq) + 2e^-$
Reduction: $Cu^{2+}\,(aq) + 2e^- \rightarrow Cu\,(s)$
(iii) Oxidation: $Mg\,(s) \rightarrow Mg^{2+}\,(aq) + 2e^-$
Reduction: $2H^+\,(aq) + 2e^- \rightarrow H_2\,(g)$
(iv) Oxidation: $2Br^-\,(aq) \rightarrow Br_2\,(g) + 2e^-$
Reduction: $Cl_2\,(g) + 2e^- \rightarrow 2Cl^-\,(aq)$
[ $K^+$ (aq) are spectator ions in this redox reaction. ]
(v) Oxidation: $Na\,(s) \rightarrow Na^+\,(s) + e^-$
[ or $2Na\,(s) \rightarrow 2Na^+\,(s) + 2e^-$ ]
Reduction: $H_2\,(g) + 2e^- \rightarrow 2H^-\,(s)$

3. (a) $2I^-\,(aq) \rightarrow I_2\,(aq) + 2e^-$
(b) redox reaction

4. (a) $Br_2\,(aq) + 2e^- \rightarrow 2Br^-\,(aq)$
(b) $SO_3^{2-}\,(aq) + H_2O\,(l) \rightarrow SO_4^{2-}\,(aq) + 2H^+\,(aq) + 2e^-$

## Displacement

1. Magnesium is higher in the electrochemical series than copper. Therefore, when magnesium is added to the solution containing copper ions, the magnesium atoms lose electrons to form magnesium ions. The copper ions in the solution (blue) gain these electrons to form atoms of copper metal (the brown solid). The magnesium sulphate solution formed is colourless.
There is no reaction between magnesium and sodium sulphate solution, as magnesium is below sodium in the electrochemical series and cannot displace it from solution.

2. As copper is above silver in the electrochemical series, the copper atoms lose electrons to the silver ions in the solution forming atoms of silver on the surface of the coin. This gives the coin a grey colour.
There is no reaction between the copper coin and sodium chloride solution, as copper is below sodium in the electrochemical series and cannot displace it from solution.

3. (a) Uranium is less reactive than magnesium.
[ Magnesium is displacing uranium metal from $UF_4$. ]
(b) displacement reaction

4. (a) Metal **X** would displace copper, forming copper metal and a solution of **X** sulphate.
(b) There would not be a reaction.

5. (a) When magnesium displaces other metals from solutions there is a rise in temperature. This rise in temperature increases as the distance between magnesium and the other metal in the electrochemical series increases.
(b) e.g. Use the same mass of magnesium, same form of magnesium, e.g. ribbon or powder, and same concentration of solution in each experiment.

6. (a) chloride ion [ $Cl^-$ (aq) ]
(b) nitrate ion [ $NO_3^-$ (aq) ]
(c) nitrate ion [ $NO_3^-$ (aq) ]
(d) sulphate ion [ $SO_4^{2-}$ (aq) ]



7. (a) (i) reaction (ii) no reaction (iii) reaction
(iv) no reaction (v) no reaction (vi) no reaction

(b) (i) $Mg \rightarrow Mg^{2+} + 2e^-$ oxidation
$Cu^{2+} + 2e^- \rightarrow Cu$ reduction
(iii) $Zn \rightarrow Zn^{2+} + 2e^-$ oxidation
$Ag^+ + e^- \rightarrow Ag$ reduction

8. (a) **P** could be iron, nickel or tin.
[ All of these metals are below zinc, but above lead in the electrochemical series. ]
**Q** could be potassium, sodium, lithium, calcium, magnesium or aluminium.
[ All of these metals are above zinc in the electrochemical series. ]
(b) (i) blue [ copper(II) nitrate solution ]
(ii) $Cu \rightarrow Cu^{2+} + 2e^-$

9. (a) (i) The zinc metal wears away as its atoms change to zinc ions and become part of the solution.
(ii) The copper(II) ions gain electrons and change into atoms of red-brown copper metal.
(iii) The solution changes from blue to colourless.
(b) $Zn (s) \rightarrow Zn^{2+} (aq) + 2e^-$ oxidation
$Cu^{2+} (aq) + 2e^- \rightarrow Cu (s)$ reduction

## Electrochemical cells

1*. (a) The chemicals that take part in the chemical reactions in the dry cell get used up.
(b) The ammonium chloride paste is the electrolyte in the cell and completes the circuit by allowing ions to move between the electrodes.
(c) If the ammonium chloride was completely dry its ions would be unable to move and it would be unable to act as an electrolyte.
(d) A nickel-cadmium battery is rechargeable.

2*. (a) Cars have a rechargeable lead-acid battery.
(b) electrical to chemical

3*. (a) e.g. An advantage of a radio having batteries is that it is portable.
(b) mains

4. (a) iron to copper
[ from the metal higher in the electrochemical series to the metal lower ]
(b) The electrolyte completes the circuit by allowing ions to move between the copper and iron electrodes.
(c) (i) The voltmeter reading would increase.
[ Zinc is higher than iron in the electrochemical series. ]
(ii) The voltmeter reading would decrease.
[ Tin is closer than copper to iron in the electrochemical series. ]

5. (a) tin to copper
(b) sodium chloride
(c) Sugar is a covalent compound and does not conduct electricity.

6. (a) (i) magnesium to copper
(ii) Magnesium is higher than copper in the electrochemical series and so there is a transfer of electrons from the magnesium atoms.
(b) silver or gold [ metals below copper in the electrochemical series. ]
(c) The voltmeter reading would decrease.
[ Iron is closer than copper to magnesium in the electrochemical series. ]
(d) (i) The meter reading would become zero.
(ii) Sugar is a covalent compound and has no ions to flow between the electrodes to complete the circuit.

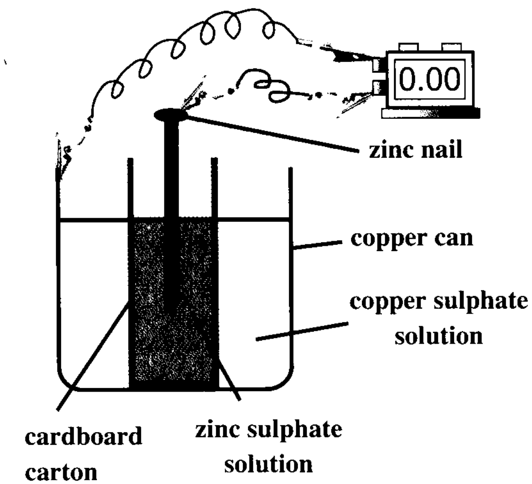


7. (a) Both sodium chloride solution and potassium nitrate solution contain ions which complete the circuit by moving between the electrodes.
Ethanol is a covalent liquid. It has no ions to move between the electrodes.
(b) (i) The voltmeter reading would decrease.
[ Tin is closer than copper to zinc in the electrochemical series. ]
(ii) The voltmeter reading would increase.
[ Silver is lower than copper in the electrochemical series. ]

8. (a) metal **S** [ the only metal that allows an electron flow **towards** zinc ]
(b) **S** zinc **R** **T**
[ **R** is closer to zinc than **T** because it gives a smaller voltage when connected to zinc. ]

9. (a) electrochemical series
(b) (i) 0.1 V (ii) -0.8 V (iii) magnesium
(c) Sugar must have covalent bonding.

10.



11. (a) **A** magnesium sulphate solution; **B** magnesium; **C** copper sulphate solution; **D**
(b) (i) salt bridge
(ii) A salt bridge is used to complete the circuit.
(c) (i) **B** (magnesium)
(ii) **D** (copper)

12. (a) (i) zinc (rod) to copper (can)
(ii) The meter reading would increase. [ Magnesium is further from copper than zinc in the electrochemical series. ]
(iii) The blue copper sulphate solution would become colourless and the zinc rod would be smaller/thinner.
(b) The bulb would not light as the circuit would not be complete as ions would be unable to move between the zinc chloride solution and the copper chloride solution.

13. (a) (i) copper to silver
(ii) Copper is higher in the electrochemical series than silver. Copper atoms lose electrons to form ions more easily than silver.
(b) $Cu \rightarrow Cu^{2+} + 2e^-$
$Ag^+ + e^- \rightarrow Ag$

14. (a) magnesium to metal **X**
(b) $Mg \rightarrow Mg^{2+} + 2e^-$
(c) magnesium
(d) $\mathbf{X}^+ + e^- \rightarrow \mathbf{X}$
[ **X** must be a 1+ ion as **X**$NO_3$ has one **X** ion for every one nitrate ion and this ion has a 1- charge ($NO_3^-$). ]

15. (a) (i) oxidation **A** (ii) reduction **B**
(b) $SO_3^{2-}(aq) + H_2O(l) \rightarrow SO_4^{2-}(aq) + 2H^+(aq) + 2e^-$
(c) Ions move through the salt bridge to complete the circuit.

16. (a) reduction
(b) electrode **A** to electrode **B**
(c) (i) iodine
(ii) $2I^-(aq) \rightarrow I_2(aq) + 2e^-$



17. (a) **X** sodium sulphite solution; **Y** bromine solution
(b) The filter paper soaked in electrolyte acts as a salt bridge completing the circuit between the two beakers.
(c) $Br_2(aq) + 2e^- \rightarrow 2Br^-(aq)$
(d) The bromine solution would be decolourised.

18. (a) oxidation
(b) electrode **B** (half cell containing sodium sulphite solution) to electrode **A** (half cell containing iron (III) chloride solution)
(c) (i) The $Fe^{3+}$ ions accept an electron coming from the other half cell and are reduced to form $Fe^{2+}$ ions.
(ii) $Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$

19. (a) Lithium is a very reactive metal which is easily oxidised to form $Li^+$ ions and release electrons.
(b) The electrolyte allows ions to flow between the two electrodes.
(c) Water would react with the lithium to produce hydrogen gas which would make the battery explode.

20. (a) As the fuel cell is being continually supplied with chemicals (hydrogen and oxygen in this case) the reactions producing the electricity do not stop.
(b) air [ The oxygen could be obtained by distillation of liquid air. ]
(c) (i) $H_2(g) \rightarrow 2H^+(aq) + 2e^-$
(ii) oxidation [ The hydrogen gas is losing electrons. ]

## Using electricity

1. (a) A d.c. supply must be used so that the products of the electrolysis can be identified. It ensures that the positive ions move to the negative electrode only and the negative ions to the positive electrode only.
   (b) (i) $Cu^{2+}$ (aq) + $2e^-$ → Cu (s)
   (ii) $2Cl^-$ (aq) → $Cl_2$ (g) + $2e^-$
   (c) The reaction involving the formation of the chlorine gas is oxidation. The reaction involving the formation of the solid copper is reduction.

2. (a) $Ni^{2+}$ (aq) + $2e^-$ → Ni (s)
   (b) reduction
   (c) negative electrode [ $Ni^{2+}$ ions are attracted to the oppositely charged electrode where they become nickel atoms. ]

3. (a) oxidation
   (b) positive electrode
   (c) The mass of the pure copper electrode increases.
   (d) $Cu^{2+}$ (aq) + $2e^-$ → Cu (s)

4. (a) electrolysis
   (b) reduction
   (c) $2Cl^-$ (aq) → $Cl_2$ (g) + $2e^-$
   (d) This makes the process more efficient by avoiding the need to shut down the cell to replace the sodium chloride solution.

5. (a) reduction
   (b) The pH will increase as the concentration of $OH^-$ (aq) ions is increasing.

6. (a) electrolysis or redox
   (b) (i) reduction (ii) oxidation

7. (a) If the mixture was not molten the ions in the mixture would be unable to move to the electrodes.
   (b) Aluminium ions are positive ($Al^{3+}$) and are attracted to the oppositely charged negative electrode.
   (c) The carbon is used up by reacting with the oxygen gas formed at the electrode producing carbon dioxide gas.

8. (a) electrolysis or redox or oxidation of the aluminium
   (b) The aluminium is the positive electrode.
   (c) e.g. Anodised aluminium is used to make parts of doors, window frames, boats, planes, sports equipment and food preparation equipment.



## Corrosion

1. (a) Corrosion is a chemical reaction at the surface of metal in which atoms of the metal react to form a compound.
   (b) rusting
   (c)

| A substance that corrodes | A substance that does NOT corrode |
|---|---|
| magnesium<br>sodium<br>aluminium<br>calcium<br>zinc | glass<br>sandstone<br>sulphur<br>calcium carbonate<br>plastic |

2. (a) oxygen (air) and water
   (b) When iron rusts the atoms lose two electrons to form $Fe^{2+}$ ions

3. (a) The plastic forms a barrier preventing oxygen and water reaching the steel and causing corrosion.
   (b) The salt dissolved in the sea water provides many ions in solution which allow easier electron transfer from the metal atoms and causing the corrosion to take place at a faster rate.
   (c) The coating of paint forms a barrier preventing oxygen and water reaching the metal in the painted railings and causing corrosion.
   (d) The flow of electrons from the battery helps prevent the iron atoms in the steel from losing electrons.

4. (a) Acid rain increases the rate of corrosion of metals.
   (b) The acid rain provides ions in solution which allow easier electron transfer from the metal atoms and causing the corrosion to take place at a faster rate.

5. (a) $Fe^{2+}$ ions give a blue colour with ferroxyl indicator. The more intense the blue colour formed in the same time the faster the rate of corrosion.
   (b) Glucose must have covalent bonding.

6. (a) ferroxyl indicator
   (b) Galvanised iron is iron which has been coated with a thin surface layer of zinc.

7. (a) electroplating
(b) The coating of silver or gold forms a barrier preventing oxygen and water reaching the iron and causing corrosion.

8. The rusting of iron is a chemical reaction. At low temperatures the air contains very little water which is needed for corrosion.
In addition, if the equipment is trapped in ice, very little oxygen which is needed for corrosion can reach the equipment.

9. e.g. The main structure of the rig could be attached to scrap magnesium at several points. Magnesium is high in the electrochemical series and more reactive than iron (steel). The magnesium has a high ability to lose electrons which will flow towards the less reactive iron and prevent the iron atoms from losing electrons.

10. (a) (i) **B** 'tin' can
(ii) If the coating of tin is complete, no oxygen (air) or water can reach the iron and cause corrosion.
(b) (i) **C** scratched 'tin' can
(ii) When the coating of tin is scratched and the iron is exposed to oxygen (air) and water it will corrode and even faster than normal because it is attached to less reactive tin.

11. (a) nail **B**
(b) Magnesium is more reactive than iron and corrodes in preference to the iron. Electrons are transferred to the iron, slowing down the formation of $Fe^{2+}$ ions.
(c) Experiment 1 illustrates the method of protection involving connecting a metal to the negative terminal of a battery, which is used to protect the bodywork of cars. This method is sometimes known as cathodic protection.
Experiment 2 illustrates sacrificial protection (connecting the metal to be protected to a more reactive metal), which is used to protect underground pipes, the hulls of ships and oil rigs.

12. (a) **Y**
(b) **Y** [ In sacrificial protection, the metal being protected must be attached to a more reactive metal. ]



13. (a) (i) experiment in which iron is attached to copper
(ii) experiment in which iron is attached to magnesium
(b) When iron is attached to copper, it is the more reactive metal and will corrode in preference to the copper.
When iron is attached to magnesium, the magnesium is the more reactive metal. The magnesium will corrode in preference, sacrificially protecting the iron by supplying it with electrons.

14. (a) Chromium is less reactive than iron.
(b) e.g. nickel, tin, lead, copper, silver or gold
[ any metal below iron in the electrochemical series ]

15. (a) galvanising
(b) Zinc is more reactive than iron and would sacrificially protect the iron from corrosion even if the coating was damaged. Tin is less reactive than iron and if the coating was damaged the iron would corrode faster.

16. Gold is less reactive than mercury, silver or tin. Electrons will therefore flow from the amalgam to the gold, allowing the metals in the amalgam to corrode more quickly.

17. (a) Zinc is more reactive than silver. Electrons will therefore flow from the zinc to the sword converting some silver ions back to silver.
(b) Copper is less reactive than iron. Electrons flow from iron to copper causing iron to be oxidised to iron(II) ions more quickly.

18. Ethylene glycol has covalent bonding and does not act as an electrolyte by allowing ions to move within the solution in the radiator.

19. Iron is more reactive than copper and electrons will flow from iron to copper. The iron nails will rust very quickly and fail to secure the copper to the hull. With copper nails and copper sheeting there will be no corrosion of the nails.

20. (a) oxidation
(b) (i) $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$ (ii) $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$
(iii) $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$ (iv) $Al(s) \rightarrow Al^{3+}(aq) + 3e^-$
(c) (i) $Fe^{2+}(aq) \rightarrow Fe^{3+}(aq) + e^-$
(ii) oxidation
(d) $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$

21. (a) (i), (ii) $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$ oxidation
$2H^+(aq) + 2e^- \rightarrow H_2(g)$ reduction
(b) The acid will quickly react with the zinc coating on the surface of the iron, preventing the zinc from protecting the iron either by sacrificial protection or by providing a barrier.

22. (a) (i) $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$
(ii) oxidation
Iron is more reactive than copper and electrons will flow from the iron to the copper making the iron rust more quickly, but making the copper corrode more slowly.

23. (a) (i) iron to carbon
(ii) iron electrode: $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
carbon electrode: $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
(b) (i) iron to tin
(ii) iron electrode: blue colour
[ $Fe^{2+}(aq)$ ions give a blue colour with ferroxyl indicator. ]
tin electrode: pink colour
[ $OH^-(aq)$ ions give a pink colour with ferroxyl indicator. ]
(iii) iron electrode: $Fe(s) \rightarrow Fe^{2+}(aq) + 2e^-$
tin electrode: $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
(c) (i) zinc to iron
(ii) zinc electrode: no colour
iron electrode: pink colour
(iii) zinc electrode: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$
iron electrode: $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$



## Plastics

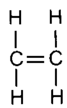
1.* (a) A synthetic material is one that is man-made by the chemical industry.
(b) (i) e.g. Most plastics are relatively light, non-biodegradable, insoluble in water, poor conductors of heat and non-conductors of electricity.
(ii) e.g. plastic spoons replacing metal spoons because they are poor conductors of heat; polystyrene packaging being used for fragile objects because it is light; plastic covering being used on the outside of electric cable because it is a non-conductor of electricity; plastic gutters and drainpipes because they are light and insoluble in water.
(c) (i) e.g. Rulers were mainly made of wood but are now usually plastic.
(ii) e.g. Both internal and external water pipes are now often made from plastic, whereas in the past they were usually metal.
(iii) e.g. The bags we use to bring home shopping are now generally plastic, whereas in the past they were often paper.

2.* (a) (i) Thermosetting plastics are moulded by heating but do not melt or soften on reheating.
(ii) Thermoplastics soften on heating and can be reshaped over and over again.
(b) e.g. Thermosetting plastics – melamine formaldehyde, urea formaldehyde
Thermoplastics – poly(ethene), poly(chloroethene), nylon, polystyrene.

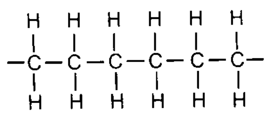
3.* (a) Non-biodegradable means that the material is unable to rot away naturally.
(b) thermoplastic [ It softens on heating. ]
(c) Burning plastics increases the levels of carbon dioxide in the atmosphere and may contribute to global warming. With some plastics the burning also produces poisonous gases.

4. (a) (i) Monomers are small molecules that can link together to form a large chain.
(ii) A polymer is a long chain molecule formed by many small molecules (monomers) linking together.
(b) polymerisation
(c) (i) poly(phenylethene) [ polystyrene ]
(ii) poly(propene)
(iii) poly(chloroethene) [ polyvinylchloride (PVC) ]
(d) All the monomers used in making the polymers in (c) have a carbon to carbon double bond (C=C).

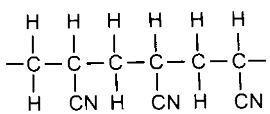
5. (a) (i) ethene
(ii)



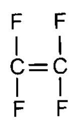
(b)



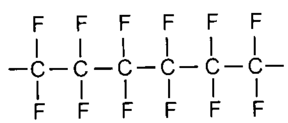
6. (a) polyacrylonitrile
(b)



7. (a) poly(tetrafluoroethene)
(b)

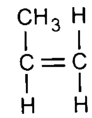


(c)





8. (a) (i) propene
(ii)



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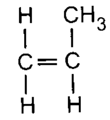
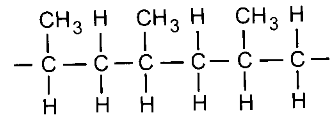
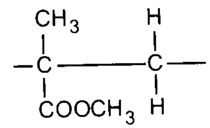


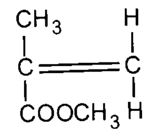
(b)



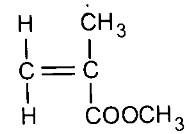
9. (a)



(b)

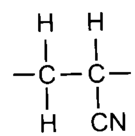


or

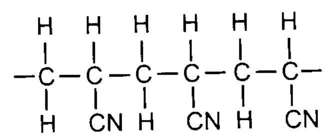


(c) addition polymerisation

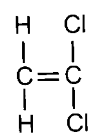
10. (a)



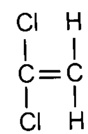
(b)



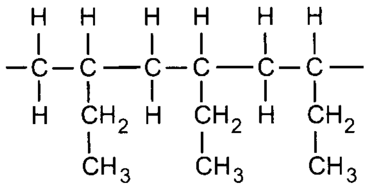
11. (a) An addition polymer is a long chain molecule formed by many small unsaturated molecules joining together.
(b) 1,1-dichloroethene
(c) 3
(d)



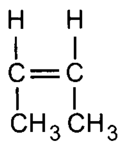
or



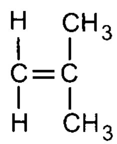
12. (a)



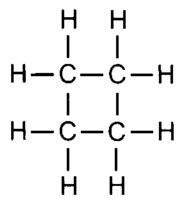
(b) (i)



or

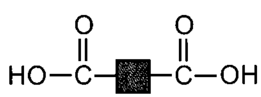


(ii)

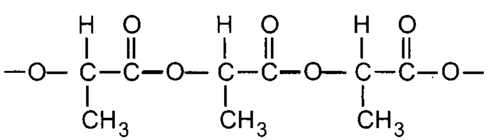


13. (a) Addition polymers are (usually) formed from only one type of small unsaturated monomer and apart from the polymer no other product is formed.
Condensation polymers are formed from two different types of monomer (or monomers with different functional groups at either end), and as well as the polymer a small molecule product is also formed, e.g. water, $H_2O$.
(b) hydroxyl group (-OH) and carboxyl group (-COOH)

14. (a) condensation polymer
(b)



15. (a)



(b) condensation polymerisation



## Fertilisers

1*. (a) (i) A man-made substance added to soil to replace essential nutrients.
(ii) Plant or animal remains and waste products that can decay in soil to release essential nutrients.
(b) Many nitrates, phosphates, compounds of potassium and ammonium compounds are examples of synthetic fertilisers, e.g. potassium nitrate, ammonium phosphate, etc.
e.g. Animal manures, compost and bone meal are all natural fertilisers.
(c) The amount of natural fertiliser available for use on farmland is insufficient to produce the quantity of food required by the rapidly increasing world population.
(d) e.g. Fertilisers can be washed out of the ground by rain-water into rivers and lochs causing problems for fish life and polluting natural water supplies.

2*. (a) nitrogen (N), phosphorus (P) and potassium (K)
(b) Fertilisers must be soluble in water so that they can be taken in by plants through the roots.
(c) The natural processes of growth, death and decay recycle essential nutrients to the soil in natural woodland.
Cropping removes these nutrients on farmland and large quantities of fertilisers are required to replace them.

3*. (a) Nitrate fertilisers are added to the soil at this time when many crops are beginning to grow.
(b) The rapidly growing crops take up large quantities of nitrates at this time.
(c) As nitrates are very soluble they can be easily washed out of the soil during periods of heavy rain. This not only means that they are no longer available to crops but they can also become pollutants in rivers and lochs.

4*. (a) (i) potassium
(ii) e.g. potassium nitrate, potassium phosphate, potassium sulphate
(b) It dissolves slowly and is not washed out of soil as quickly by heavy rainfall.

5. (a) ammonia $NH_3$ ; ammonium nitrate $NH_4NO_3$
(b) nitric acid

6. (a) potassium hydroxide
(b) water
(c) Nitrate compounds provide a relatively inexpensive source of the nutrient element nitrogen and because they are very soluble in water they provide the nitrogen in a form which is easily absorbed by plants.

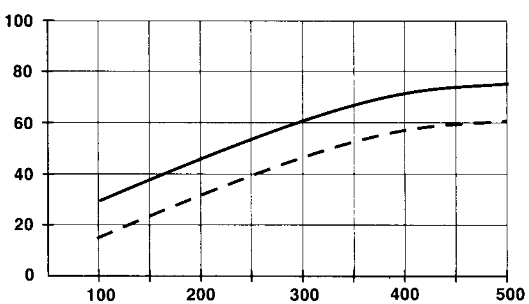
7. (a) ammonium sulphate
(b) sulphuric acid

8. (a) ammonia
(b) iron
(c) high pressure, moderately high temperature

9. (a) The main use of ammonia is in the manufacture of nitrogen fertilisers.
(b) nitrogen, hydrogen
(c) Haber Process
(d) Ammonia is cooled whilst still under pressure. The ammonia condenses as a liquid and is pumped away from the reaction mixture.

10. (a) nitrogen and hydrogen
(b) The yield decreases as the temperature is increased.
(c) The higher the temperature the faster the rate of reaction. However, the higher the temperature the lower the yield of ammonia. Therefore, to give an acceptable yield at a reasonable rate a moderately high temperature is used.
(d) The reaction is reversible. Some of the ammonia formed decomposes back to nitrogen and hydrogen, so a 100% yield is not possible.

11. (a)




(b) The lower the temperature the higher the yield for reactions carried out at the same pressure. However, the temperature is not reduced below 350 °C as the rate of the reaction would become too slow for the process to be profitable.



12. (a) The yield of ammonia is greater at lower temperatures.
(b) The pipes have thick walls to withstand the very high pressures of the reactant gases.

13. (a) To make nitrogen dioxide from nitrogen requires a very large amount of electricity. This is not an efficient process and energy costs for the process would be very high.
(b) ammonia
(c) As with the Haber Process, the higher the temperature the faster the reaction, but the lower the yield of ammonia. Therefore, a moderately high temperature is used.
(d) (i) no
(ii) Since the reaction is exothermic (heat is given out) there is no need to heat once the reaction has started.

14. (a) Air and water are both cheap and readily available raw materials.
(b) hydrogen
(c) (i) Ostwald Process
(ii) platinum
(d) $Ca_3(PO_4)_2$ [ or $(Ca^{2+})_3(PO_4^{3-})_2$ ]
(e) ammonium phosphate

## Percentage mass

1. (a) Formula is $CO_2$
Formula mass = 12 + (2 x 16) = 12 + 32 = 44
% by mass of carbon = (12÷44) x 100 = **27.3%**
% by mass of oxygen = (32÷44) x 100 = **72.7%**

(b) Formula is $CH_4$
Formula mass = 12 + (4 x 1) = 12 + 4 = 16
% by mass of carbon = (12÷16) x 100 = **75%**
% by mass of hydrogen = (4÷16) x 100 = **25%**

(c) Formula is $NH_3$
Formula mass = 14 + (3 x 1) = 14 + 3 = 17
% by mass of nitrogen = (14÷17) x 100 = **82.4%**
% by mass of hydrogen = (3÷17) x 100 = **17.6%**

(d) Formula is $CuSO_4$
Formula mass = 63.5 + 32 + (4 x 16) = 63.5 + 32 + 64 = 159.5
% by mass of copper = (63.5÷159.5) x 100 = **39.8%**
% by mass of sulphur = (32÷159.5) x 100 = **20.1%**
% by mass of oxygen = (64÷159.5) x 100 = **40.1%**

(e) Formula is $CaCO_3$
Formula mass = 40 + 12 + (3 x 16) = 40 + 12 + 48 = 100
% by mass of calcium = (40÷100) x 100 = **40%**
% by mass of carbon = (12÷100) x 100 = **12%**
% by mass of oxygen = (48÷100) x 100 = **48%**

(f) Formula is $K_2SO_4$
Formula mass = (2 x 39) + 32 + (4 x 16) = 78 + 32 + 64 = 174
% by mass of potassium = (78÷174) x 100 = **44.8%**
% by mass of sulphur = (32÷174) x 100 = **18.4%**
% by mass of oxygen = (64÷174) x 100 = **36.8%**

(g) Formula is $Al(OH)_3$
Formula mass = 27 + (3 x 16) + (3 x 1) = 27 + 48 + 3 = 78
% by mass of aluminium = (27÷78) x 100 = **34.6%**
% by mass of oxygen = (48÷78) x 100 = **61.5%**
% by mass of hydrogen = (3÷78) x 100 = **3.8%**

(h) Formula is $Mg(NO_3)_2$
Formula mass = 24.5 + (2 x 14) + (6 x 16) = 24.5 + 28 + 96 = 148.5
% by mass of magnesium = (24.5÷148.5) x 100 = **16.5%**
% by mass of nitrogen = (28÷148.5) x 100 = **18.9%**
% by mass of oxygen = (96÷148.5) x 100 = **64.6%**



2. Urea
Formula is $CO(NH_2)_2$
Formula mass = 12 + 16 + (2 x 14) + (4 x 1) = 12 + 16 + 28 + 4 = 60
% by mass of nitrogen = (28÷60) x 100 = **46.7%**

Ammonium sulphate
Formula is $(NH_4)_2SO_4$
Formula mass = (2 x 14) + (8 x 1) + 32 + (4 x 16) = 28 + 8 + 32 + 64 = 132
% by mass of nitrogen = (28÷132) x 100 = **21.2%**

Ammonium nitrate
Formula is $NH_4NO_3$
Formula mass = (2 x 14) + (4 x 1) + (3 x 16) = 28 + 4 + 48 = 80
% by mass of nitrogen = (28÷80) x 100 = **35.0%**

**Urea** is the most useful fertiliser because it has the highest percentage of nitrogen.

3. Formula is $(NH_4)_3PO_4$
Formula mass = (3 x 14) + (12 x 1) + 31 + (4 x 16) = 42 + 12 + 31 + 64 = 149

(a) % by mass of nitrogen = (42÷149) x 100 = 28.2%
Therefore, 100 g of ammonium phosphate contains **28.2 g** of nitrogen.

(b) % by mass of phosphorus = (31÷149) x 100 = 20.8%
Therefore, 1 kg of ammonium phosphate contains
(20.8÷100) x 1000 g = **208 g** of phosphorus.

## Radioactivity

1. (a) Nuclear fusion is a nuclear reaction in which the nuclei of smaller atoms join together to form a heavier nucleus with the release of energy.
(b) The energy of the stars comes from nuclear fusion reactions, e.g. the energy reaching Earth from the Sun.
Controlled nuclear fusion reactions for the production of electricity, and the design of workable reactors for these reactions, are important areas of current scientific research.

2. (a) e.g. radioactive waste from nuclear power stations, radioactive fallout from the testing of nuclear weapons, use of X-rays in medical investigations and treatments.
   (b) e.g. cosmic rays, naturally occurring radioisotopes in rocks.

3. (a) Radioisotopes are unstable because their neutron to proton ratio lies outside the band of stability.
   (b) In α-emitting radioisotopes, 2 protons and 2 neutrons leave the nucleus.
   In β-emitting radioisotopes, a neutron changes into a proton and a highly energy electron (the β-particle) is expelled from the nucleus.

4. (a) nuclear fusion
   (b) Nuclear fusion reactions occur in the stars, e.g. the Sun, and in hydrogen bombs.

5.

| Radiation | Alpha | Beta | Gamma |
|---|---|---|---|
| **Symbol** | $\alpha$ / ${}^{4}_{2}He$ | $\beta$ / ${}^{0}_{-1}e$ | $\gamma$ |
| **Mass** | 4 | 0 | 0 |
| **Charge** | 2+ | 1- | 0 |

6. (a) gamma radiation (γ)
   (b) alpha radiation (α)
   (c) beta radiation (β) (but also less penetrating alpha (α) radiation)

7. (a) The lead block ensures that radiation can escape in one direction only.
   (b) Beta particles are fast moving negatively charged electrons and are strongly attracted towards the positive plate of the electric field.
   Alpha particles are positively charged helium nuclei and are attracted towards the negative plate of the electric field; since they are heavier than beta particles, they are deflected less than beta particles by the same strength of electric field.
   Gamma rays are high energy electromagnetic radiation and are unaffected by electric fields.



## Nuclear equations

1. **y** has a mass of 0, a charge of 1- and is a beta particle.
   **z** has a mass of 4, a charge of 2+ and is an alpha particle.

2. (a) ${}^{24}_{12}Mg$ [ ${}^{24}_{11}Na \rightarrow {}^{24}_{12}Mg + {}^{0}_{-1}e$ ]
   (b) ${}^{238}_{92}U$ [ ${}^{242}_{94}Pu \rightarrow {}^{238}_{92}U + {}^{4}_{2}He$ ]

3. (a) ${}^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$
   (b) ${}^{3}_{1}H \rightarrow {}^{3}_{2}He + {}^{0}_{-1}e$
   (c) ${}^{226}_{88}Ra \rightarrow {}^{222}_{86}Rn + {}^{4}_{2}He$
   (d) ${}^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + {}^{0}_{-1}e$

4. (a) ${}^{232}_{90}Th \rightarrow {}^{228}_{88}Ra + {}^{4}_{2}He$
   (b) ${}^{232}_{90}Th$ has 142 neutrons and 90 protons, a ratio of 1.578:1.
   ${}^{228}_{88}Ra$ has 140 neutrons and 88 protons, a ratio of 1.591:1.

5. ${}^{27}_{13}Al + {}^{4}_{2}He \rightarrow {}^{30}_{15}P + {}^{1}_{0}n$ ; **Y** ${}^{30}_{15}P$

6. (a) ${}^{6}_{3}Li + {}^{1}_{0}n \rightarrow {}^{3}_{1}H + {}^{4}_{2}He$ ; **R** is an α-particle.
   (b) ${}^{238}_{92}U + {}^{4}_{2}He \rightarrow {}^{239}_{94}Pu + 3\,{}^{1}_{0}n$ ; **S** is a neutron.

7. (a) **x** has a mass of 1 and a charge of 1+; **x** is a proton.
   (b) **y** has a mass of 1 and a charge of 0; **y** is a neutron.

8. (a) **p** = 7 and **q**= 3; **X** lithium, i.e. ${}^{7}_{3}Li$
   (b) **a** = 23 and **b** = 11; **Y** sodium, i.e. ${}^{23}_{11}Na$

9. ${}^{210}_{83}Bi$ [ ${}^{210}_{83}Bi \rightarrow {}^{210}_{84}Po + {}^{0}_{-1}e$ then ${}^{210}_{84}Po \rightarrow {}^{206}_{82}Pb + {}^{4}_{2}He$ ]

10. **S** has an atomic number of 88 and a mass number of 228.
   [ ${}^{228}_{88}\mathbf{P} \rightarrow {}^{0}_{-1}e + {}^{228}_{89}\mathbf{Q} \rightarrow {}^{0}_{-1}e + {}^{228}_{90}\mathbf{R} \rightarrow {}^{4}_{2}He + {}^{224}_{88}\mathbf{S}$ ]

11. **b** = 215 and **a**= 83; **X** bismuth, i.e. ${}^{215}_{83}Bi$
   [ Emission of 3 α-particles and 2 β-particles involves a total decrease in mass number of (3 x 4) for α-particles + (2 x 0) for β-particles, i.e. 12, and a total decrease in atomic number of (3 x 2) for α-particles + (2 x -1) for β-particles, i.e. 4.
   Therefore, ${}^{227}_{87}Fr$ becomes ${}^{215}_{83}Bi$.]

## Half-life

1. (a) same (b) same (c) different (d) different (e) same

2. 1 g samples of radium oxide and radium sulphate contain a different mass of radium and hence different numbers of radium atoms, therefore the number of disintegrations per second will be different.

3. (a) The half-life is the time taken for half the numbers of atoms in the original sample of a radioisotope to disintegrate (or decay).
   (b) 0.781 g
   [ 200 hours = 8 half-life periods (200÷15); fraction of original sample remaining is $1/2^8 = 1/256$;
   mass left after 200 hours = 200 ÷ 256 g = 0.781 g ]
   [ This example is more difficult than you will find in the actual examination. You can expect to be asked about the mass remaining after 60 hours – this would be 12.5 g (after 4 half-life periods). ]

4. 2 minutes
   [ If fraction remaining is ⅛ then 3 half-life periods have passed (1 to ½ to ¼ to ⅛); since total elapsed time is 6 minutes, each half-life period is 2 minutes. ]

5. 18 hours
   [ 3 half-life periods have passed (120 counts/minute to 60 counts/minute to 30 counts/minute to 15 counts/minute);
   since half-life period is 6 hours the total time passed is 18 hours. ]

6. 24 days
   [ 2 half-life periods have passed (1 to ½ to ¼);
   since sample is 48 days old each half-life period must be 24 days. ]

7. (a) 1000 counts $min^{-1}$
   [ 4.5 hours between 9.00 am and 1.30 pm;
   since half-life period is 1.5 hours, 3 half-life periods have passed;
   therefore count rate goes 8000 to 4000 to 2000 to 1000. ]
   (b) The half-life would be the same.

8. ¼ of the sample will remain.
   [ 280 days = 2 half-life periods; remaining mass of sample will go 1 to ½ to ¼ over 2 half-life periods. ]

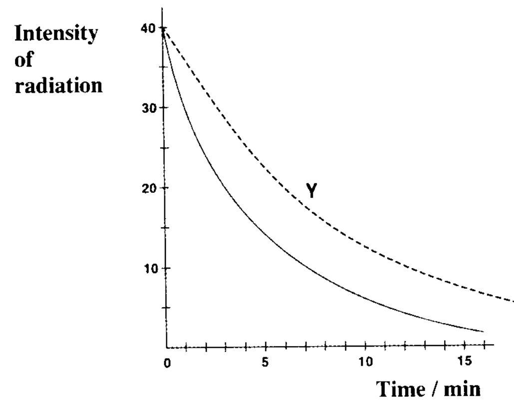


9. 0.8 g
   [ 15 days = 3 half-life periods; if only 0.1 g remains after this time the mass has changed from 0.8 g to 0.4 g to 0.2g to 0.1 g. ]

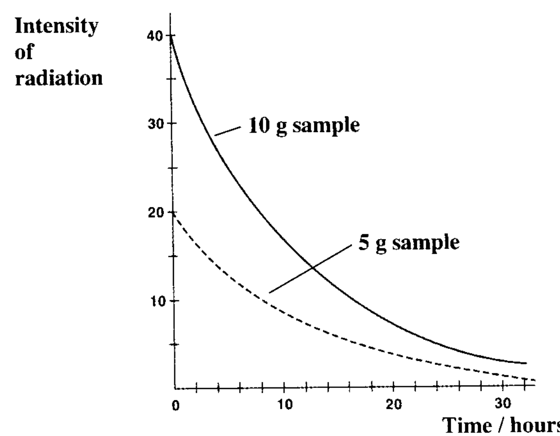
10. 12 days
    [ One mole of $^{131}I$ has a mass of 131g;
    over 2 half-life periods this changes from 131 g to 65.5 g to 32.75 g;
    if sample is now 24 days old each half-life period is 12 days. ]

11. 154.5 g
    [ One mole of $^{210}Po$ has a mass of 210g;
    over 2 half-life periods ¼ remains unchanged and therefore ¾ has changed to $^{206}Pb$; mass of lead formed = ¾ x 206 g = 154.5 g.]

12. (a) 3.5 minutes
    (b)



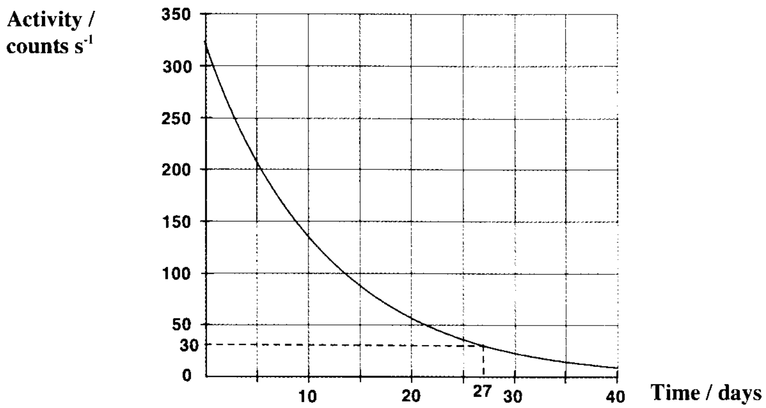

13. (a)
    (b)



14. (a) 15 hours (b) 1 g

15. (a) (i) 12.33 years (ii) 37 years
(b) No change to rate of decay if temperature is increased.

16. (a)




(b) From graph, counts per second reaches 30 at 27 days. Linen bags should therefore be stored for 27 days before disposal.

## Chemical analysis

1. Qualitative analysis gives an indication of the presence or absence of particular atoms, ions or molecules in a substance.
Quantitative analysis involves the measurement of the quantities of particular atoms, ions or molecules present in a substance.

2. (a) (i) blue-green (ii) lilac (iii) yellow
(b) qualitative analysis

3. (a) Litmus identifies the substance being tested as either an acid or an alkali but does not measure the quantity of acid or alkali present.
(b) pH measurement uses a number scale which indicates the quantity of acid or alkali present in terms of concentration.

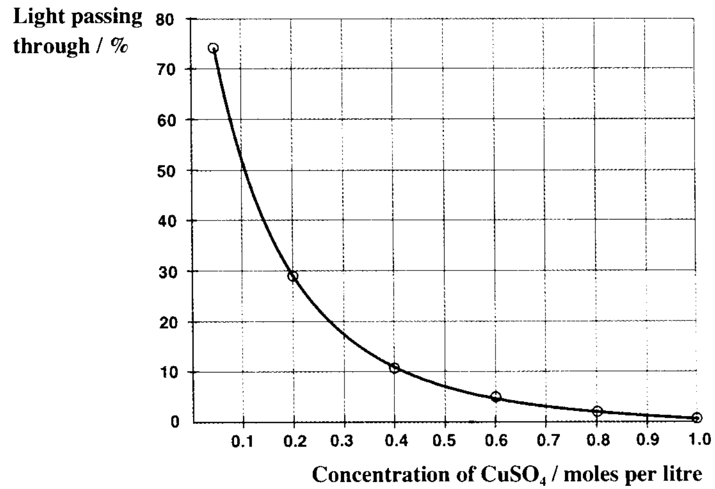
4. 0.0014 mol $l^{-1}$ [ 25 x 0.002 x 1 = 34.5 x conc. of $H^+$ x 1 ]

5. 0.8 mol $l^{-1}$
[ GFM of AgCl = 108 + 35.5 = 143.5 g;
no. of moles = mass / GFM = 2.87 ÷ 143.5 = 0.02;
concentration = no. of moles / Litres = 0.02 ÷ 0.025 = 0.8 ]



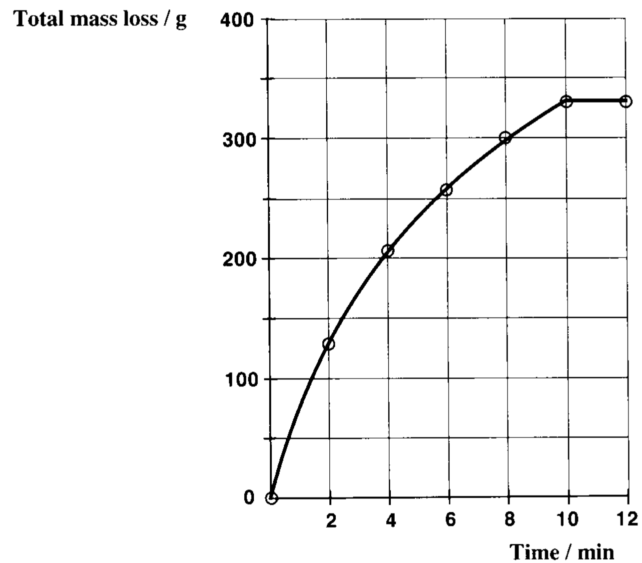
## Graphs

1. (a)



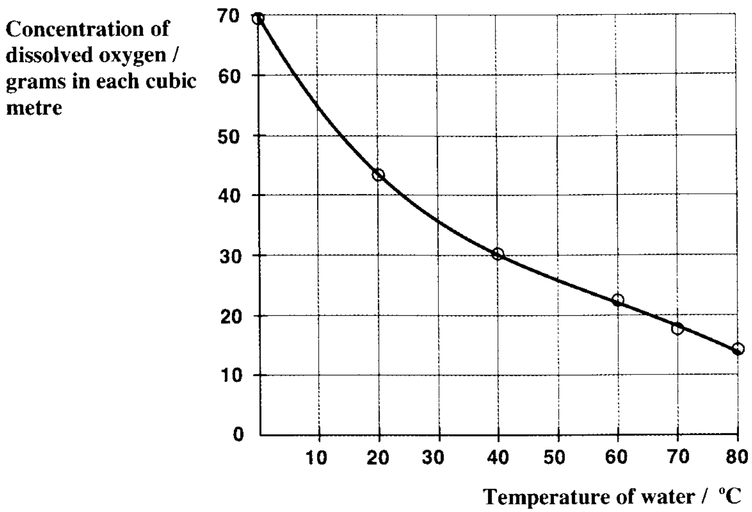

(b) As the concentration increases the amount of light passing through decreases.
(c) approx. 0.12 mol $l^{-1}$

2. (a) The reaction produces hydrogen gas which escapes from the flask.
(b)




(c) approx. 155 mg

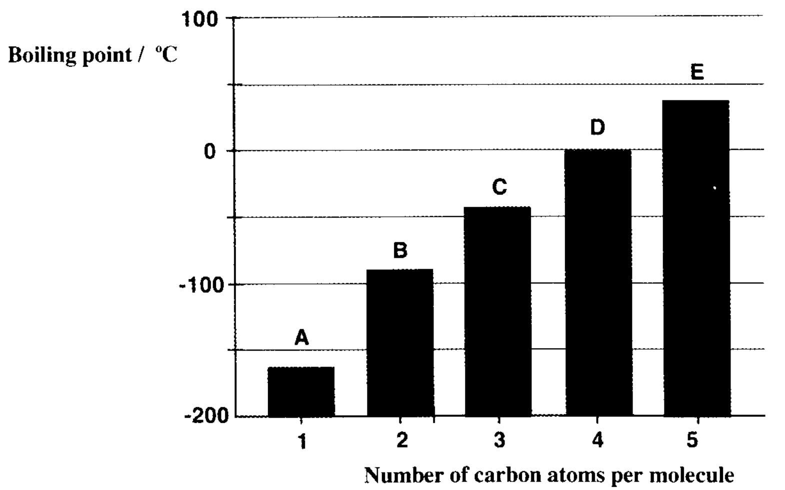
3. (a)




(b) approx. 57 grams in each cubic metre

(c) approx. 54 °C

4. (a)

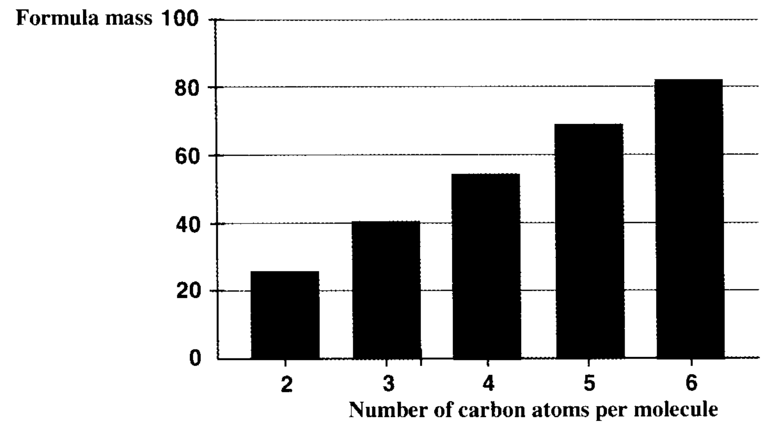



(b) (i) **A** and **B** (ii) **A**, **B**, **C** and **D**

[ Substances are gases if the temperature is above the boiling point of the substance. ]



5. (a)




(b) 110 [ Formula mass increases by 14 for each extra carbon. ]

## Skills

1. Sodium has a much lower melting point than iron.

2. Iron(II) ($Fe^{2+}$)

3. (a) approx. 0.4 kg
   (b) approx. 1.2 kg
   (c) approx. 25 kg [ From graph: approx. 2.5 kg per 10 $m^2$ soil; therefore 25 kg for 100 $m^2$ ]

4. Bleach **A** gave (100 ÷ 6) = 16.7 $cm^3$ of chlorine per $cm^3$ of bleach;
   Bleach **B** gave (150 ÷ 9) = 16.7 $cm^3$ of chlorine per $cm^3$ of bleach;
   Bleach **C** gave (90 ÷ 4) = 22.5 $cm^3$ of chlorine per $cm^3$ of bleach.
   Therefore, Bleach **C** contains the most sodium hypochlorite per litre.

5. (a) **Z** [ As the solubility of calcium oxide is between 1 and 10 g $l^{-1}$ (s), it is impossible to tell if all 5 g will dissolve completely. ]
   (b) **Y** [ As the solubility of lead(II) iodide is less than 1 g $l^{-1}$ (i), most of the 5 g will not dissolve. ]
   (c) **X** [ As the solubility of potassium chloride is greater than 10 g $l^{-1}$ (vs), all of the 5 g will dissolve. ]

6. (a) Aluminium has a much lower density than copper.
   (b) The steel core in the cable gives it greater strength.

7. (a) All acids give hydrogen gas at the negative electrode when electrolysed.
   (b) (i) positive electrode: chlorine; negative electrode: hydrogen
   (ii) positive electrode: oxygen; negative electrode: hydrogen

8. (a) To ensure that all the oxygen in the air sample reacts with the heated copper powder.
   (b) 19.5%
   [ Volume of oxygen in the sample = (80 – 64.4) = 15.6 $cm^3$
   Therefore, percentage oxygen in the sample = (15.6 ÷ 80) x 100
   = 19.5 ]
   (c) There was not enough copper powder to completely react with all the available oxygen
   or the air was not passed backwards and forwards for long enough
   or the temperature was not high enough for all the copper to react.

9. (a) e.g. depth of electrodes in solution, volume of solution, temperature of solution, type and size of electrodes.
   (b) As the concentration of a solution increases its ability to conduct electricity increases.
   (c) hydrochloric acid, sodium hydroxide, sodium chloride

10. (a) There would have been no effect on final water level.
   (b) As some phosphorus remains when a smaller piece was used it is the volume of oxygen in the test tube that controls the level to which the water rises. If a bigger piece of phosphorus had been used, more phosphorus would have been left when all the oxygen had been used up.

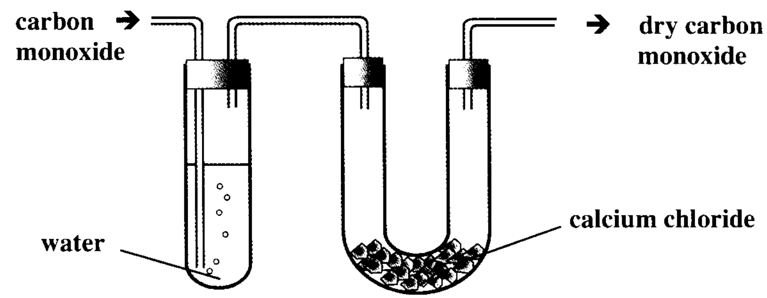
11. (a) GAS
   (b) approx. –6°C



## Design and plan

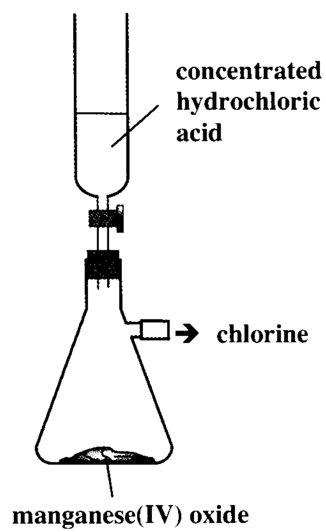
1. **B** [ The gas is less dense than air. ]

2.

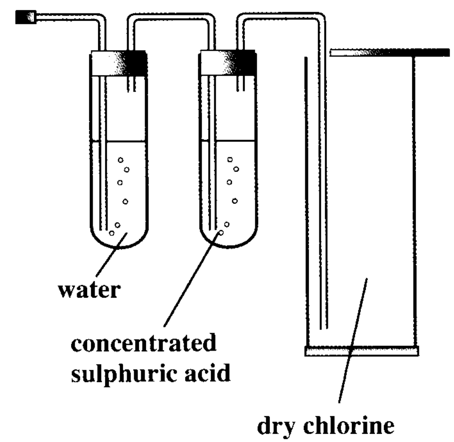



3. Use a measuring cylinder to accurately measure 10 $cm^3$ of vegetable oil.
Carefully pour the vegetable oil into a beaker.
Fill a syringe with iodine solution and note the volume of iodine.
Slowly add the iodine solution to the vegetable oil while stirring continuously.
Note the final volume of iodine remaining in the syringe when the iodine is no longer decolourised and the colour persists.
The "iodine value" is the difference between the starting and final volumes of iodine.

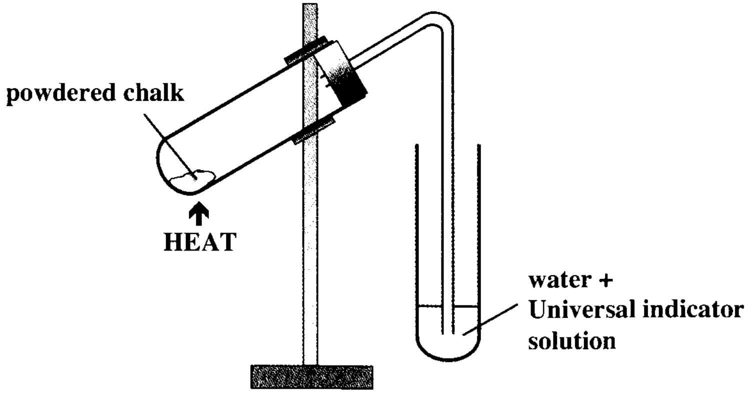
4. (a)




(b)



5. (a)



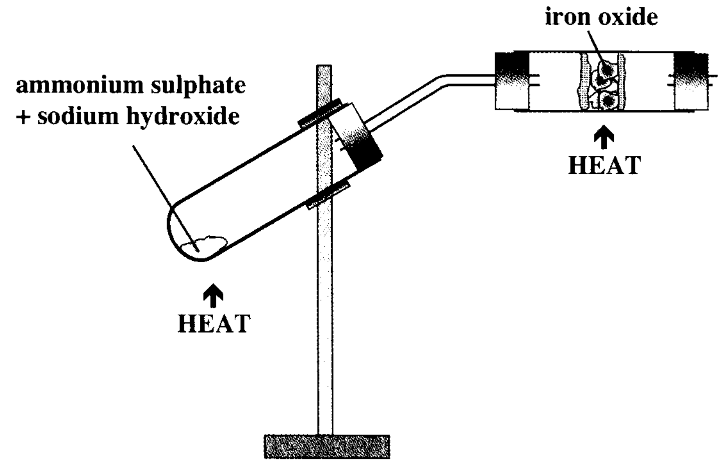

(b) Remove the delivery tube from the indicator solution before stopping heating to avoid the potential "suck-back" of cold liquid into a hot test tube.

6. Place a known number of identical size ice cubes into a filter funnel and place the end of the funnel in a measuring cylinder.
Leave for a known time, e.g. 10 minutes, and at the end of the time record the volume of water collected in the cylinder.
Repeat with the same number of identical size ice cubes, but in this experiment sprinkle powdered salt over the cubes.
If the volume of water collected in the same time is lower, the melting point of the ice has been reduced by the salt.

7. Add a known mass of magnesium powder (or ribbon) to sulphuric acid of known volume and concentration.
Using a delivery tube, collect the hydrogen gas produced in a fixed time by bubbling through water and collecting in a large water-filled container with a volume scale, e.g. a measuring cylinder. The time to collect a fixed volume of gas, e.g. to fill a test tube, could also be noted.
Repeat the experiment exactly as before, but with a small volume of copper sulphate solution added to the acid.



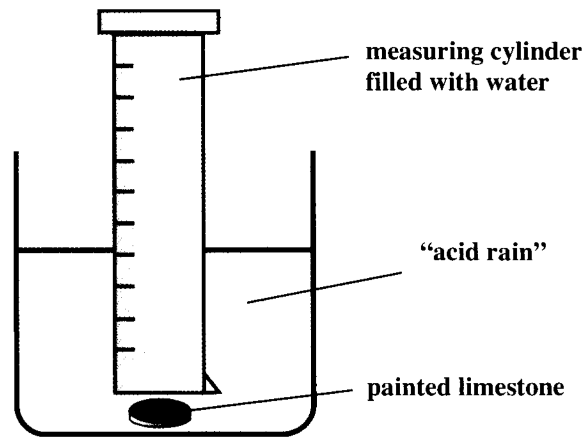
8.




9. (a) There has to be sufficient sodium dichromate solution to ensure that all the sulphur dioxide released by heating can react. Three test tubes allow the colour change to be followed three times rather than just the once making it easier to detect different levels of sulphur dioxide.

(b) It is bubbled through liquid paraffin to allow the flow rate of the oxygen to be measured (by the number of bubbles) and kept the same in each experiment.

10. (a)




(b) e.g. concentration of acid rain, volume of acid rain, mass of limestone, mass of paint used , temperature, time over which the gas is collected.

11. e.g. mass of compound, form of compound (lump or powder), volume of water, temperature of water, amount of stirring.

12. e.g. mass of metal, volume of acid, concentration of acid, temperature of acid.

13. e.g. the depth of electrodes in solution, volume of solution, concentration of solution, temperature of solution, type and size of electrodes.

14. (a) Experiments 2 and 5 are at the same temperature and contain the same volume of water.

(b) Comparing experiments 1, 2 and 3 would show the effect of changing temperature on the rate of dissolving.