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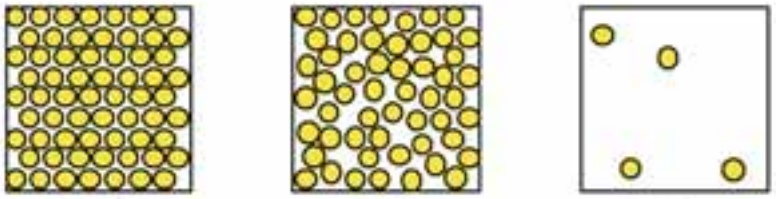
Answers

Chapter 1

1. a) melting
   b) freezing
   c) subliming / sublimation
   d) subliming / sublimation

2. a)



solid liquid gas

Note: Solids should have regularly packed particles touching. Liquids should have most of the particles touching at least some of their neighbours, but with gaps here and there, and no regularity. Gases should have the particles well spaced.

b) Solids: vibration around a fixed point. Liquids: particles can move around into vacant spaces, but with some difficulty because of the relatively close packing.

c) Evaporation: Some faster moving particles break away from the surface of the liquid. Boiling: Attractive forces are broken throughout the liquid to produce bubbles of vapour.

d) In a sealed container, vapour particles in the space above the liquid return and stick to the surface of the liquid at the same rate as liquid particles are evaporating.

3. a) A - gas ; B - liquid; C - solid; D - liquid; E - solid

b) C. It sublimes at a very high temperature and so takes the most heat energy to break the attractions between the particles to form a gas.

c) A. It turns to a gas at the lowest temperature and so takes the least heat energy to break the attractions between the particles to form a gas.

d) A, because it is a gas.

e) It sublimes. That means that it turns straight from a solid to a gas and so there is never any liquid to boil.

f) D. It has the lower boiling point of the two liquids (B and D), and therefore the weaker attractions between its particles. A higher proportion of its particles will have enough energy to escape from the surface.

4. a) The ammonia and hydrogen chloride particles have to diffuse through the air in the tube, colliding with air particles all the way.

   b) (i) Its particles will move faster.

   (ii) It would take slightly longer for the white ring to form, because the gas particles would be moving more slowly at the lower temperature.

c) Ammonia particles are lighter than hydrogen chloride particles and so move faster. The ammonia covers more distance than the hydrogen chloride in the same time.

d) (i) ammonium bromide

(ii) The heavier hydrogen bromide particles would move more slowly than the hydrogen chloride particles, and so the ring would form even closer to the hydrobromic acid end than it was to the hydrochloric acid end. The ring will also take slightly longer to form because of the slower moving particles.

There's no "right" answer to this. The question is designed to show students how carefully they need to think about practical details of experiments they suggest, and to stimulate discussion.

Key points:

The two liquids should be compared in identical apparatus, side by side so that the temperature is always identical for the two throughout the time needed to run the experiment. You would need equal volumes of liquids, and equal volumes of water. All this stresses the importance of a "fair test". Likely suggestions would involve having two tubes (gas jars, measuring cylinders, burettes, for example) of water with the coloured liquids introduced into the bottom of them. A simple observation of the progress of the colours up the tubes would be enough. There could be some problems if the liquids varied markedly in colour intensity. A student suggesting that you might put some white card or paper behind the tubes to make it easier to see would deserve some praise.

The main practical problem lies in getting the bottom coloured layer into place without any prior mixing. You could have the liquids in small weighing bottles (as in the text) which are lowered into water in a (wide) measuring cylinder or gas jar on a bit of cotton, but there will inevitably be some mixing. Alternatively, you could place the weighing bottle in the bottom of an empty gas jar or measuring cylinder, and then add water very carefully to avoid mixing (perhaps via a bit of rubber tubing to the bottom of the gas jar, and added very slowly). Students should be explicit about how they get the weighing bottle and the water into the gas jar with as little mixing as possible.

A better alternative, which would make comparisons easier, might be to use burettes full of water, and introduce the coloured liquids using the bulbs from teat pipettes (or similar). Fill the bulb with liquid, and attach it to the tip of the burette. Open the tap, squeeze very gently to force the coloured liquid into the burette, and then close the tap again. However, it would be a quite exceptional student who thought of that this early on in the course.

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Chapter 2

1. a) 9
   b) sum of protons + neutrons in the nucleus
   c) 9p, 10n, 9e
   d) Dots or crosses diagram showing 2,7

2. a) 26 p, 30 n, 26 e
   b) 41 p, 52 n, 41 e
   c) 92 p, 143 n, 92 e

3. a) Atoms with the same atomic number but different mass numbers. They have the same number of protons, but different numbers of neutrons.
   b) ^{35}Cl: 17 p, 18 n, 17 e; ^{37}Cl: 17 p, 20 n, 17 e
   c) Both: 2,8,7

4. Dots or crosses diagrams showing a) 2,8,1; b) 2,8,4; c) 2,8,6

5. a) 5; b) 7; c) 4; d) 8

6. a) A, F
   b) A
   c) C
   d) B, D
   e) calcium
   f) 82, lead
   g) Dots or crosses diagram showing 2,8,8,1

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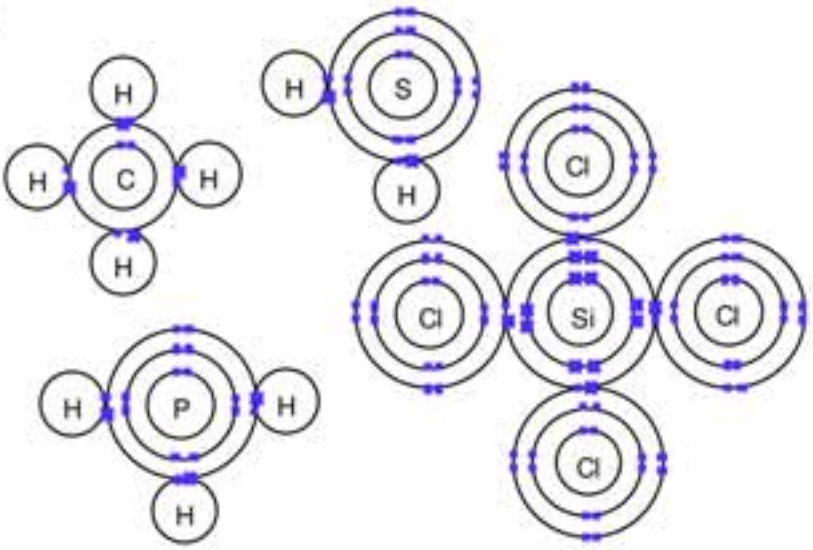
Chapter 3

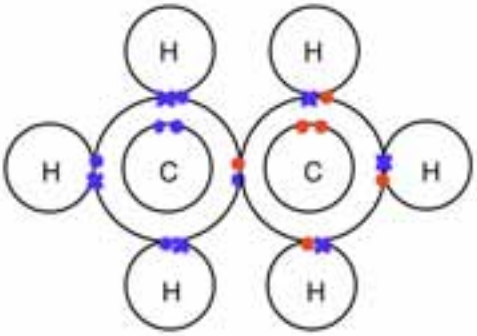
1. a) A pair of electrons which is shared between two atoms. The atoms are held together because the nucleus of each is attracted to the shared pair.

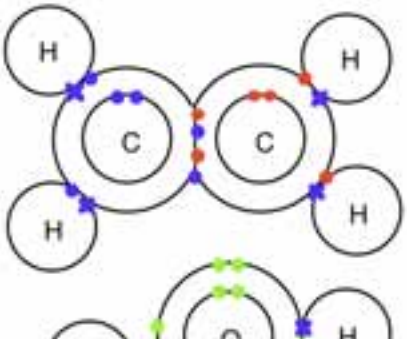
b)

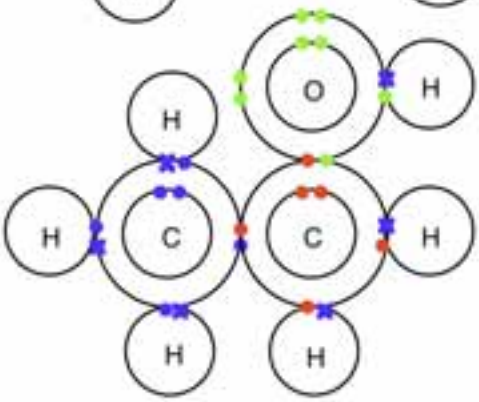


It doesn't matter whether students use dots or crosses or just different colours - or what positions (N,S,E,W) the hydrogens occupy in the H_2S or PH_3.

2.







It doesn't matter what variations of colours or dots and crosses are used.

In the ethanol case, the -OH group could equally well have been drawn swapped with either of the other two hydrogens on the right-hand carbon atom.

3. a) (i) An atom or group of atoms which carries an electrical charge.
(ii) Attractions between positively and negatively charged ions holding them together.

b) Correct electronic structures for
(i) Na 2,8,1 and Cl 2,8,7
(ii) Li 2,1 and O 2,6
(iii) Mg 2,8,2 and F 2,7.

Diagrams (similar to those in the chapter) showing transfer of electrons, and the charges and electronic structures of the ions formed. (or words to the same effect).

In (i), show 1 electron transferred from Na to Cl leaving Na^+ $[2,8]^+$ and Cl^- $[2,8,8]^-$

In (ii), show 2 lithium atoms each giving 1 electron to O leaving 2 x Li^+ $[2]^+$ and O^{2-} $[2,8]^{2-}$

In (iii) , show 1 Mg giving an electron each to 2 fluorines leaving Mg^{2+} $[2,8]^{2+}$ and 2 x F^- $[2,8]^-$

4. a) Mg 2,8,2. Explanation in words or diagrams showing the 2 outer electrons forming a sea of electrons (becoming delocalised) - similar to the sodium diagram in the chapter, but with 2 outer electrons rather than 1, and 2 positive charges on the ions.

   b) Boiling point is a guide to the energy needed to break the metallic bond. The stronger the bond, the more energy is needed to separate the particles and the higher the boiling point. The bonds get stronger from Na to Mg to Al.

   c) The metals have 1, 2 and 3 electrons respectively in their outer energy level. These can be delocalised to leave increasingly positively charged ions and an increasing number of electrons in the "sea" as you go from Na to Mg to Al. This leads to increasing amounts of attraction between ions and "sea", and hence more energy is needed to break them.

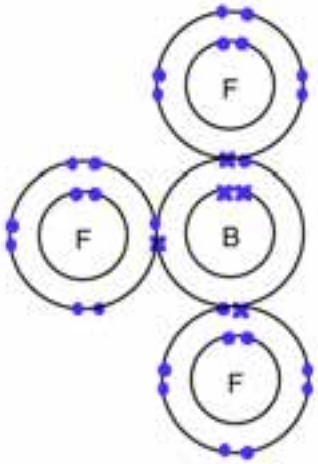
   d) Delocalised electrons are mobile.

5. (weakest) hydrogen, phosphorus trifluoride, ammonia, ethanol, water, ethanamide (strongest). Higher intermolecular attractions produce higher boiling points.

6. a)

   Note: This is included because it is a simple example of a perfectly stable covalent compound where there aren't four pairs of electrons around one of the atoms - in other words, it is nothing like a noble gas structure. Despite the impression often given at GCSE, such compounds are very common - although in the great majority of cases, there are *more* than 8 electrons around one atom rather than fewer.

   Students might ask why it doesn't form ionic bonds. The amount of energy needed to remove 3 electrons so close to the boron nucleus is too great. Point out that this will be explored in some detail in chemistry at a higher level.



b) Correct electronic structures for Al 2,8,3 and F 2,7. Diagrams (similar to those in the chapter) showing transfer of electrons, and the charges and electronic structures of the ions formed. (or words to the same effect).
Show 1 Al giving an electron each to 3 fluorines leaving Al^{3+} $[2,8]^{3+}$ and 3 x F^{-} $[2,8]^{-}$

(c) The outer level of the boron in BF_3 only contains 3 pairs of electrons (6 electrons) whereas there would be room for 4 pairs (8 electrons).

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Chapter 4

1. a) Diagrams as those in chapter. Graphite diagram should show the layer structure or state this in words. The diamond structure must be accurate, with no "spare" bonds between unconnected atoms.

   b) Similar: One of, for example: high melting points (strong covalent bonds all have to be broken); lack of solubility in solvents (same reason).

   Different: 2 of: diamond hard, graphite soft (strong covalent bonds in 3D in diamond difficult to break; weaker forces between layers in graphite allow layers to slide); graphite less dense than diamond (comparatively large distances between the layers in graphite mean that less atoms can be fitted into a given volume); graphite conducts electricity, diamond doesn't (each carbon in graphite forms only 3 ordinary covalent bonds, with the other electron free to move. All diamond's outer electrons are locked in single covalent bonds and aren't free to move).

2. a) The atoms in the metal crystal can roll over each other into new positions. Diagram similar to the one in the chapter would be useful.

   b) Any of:
   Strong *or* high melting point *or* high boiling point, because of the powerful attractions in the metallic bond which take a lot of force *or* heat energy to break.
   Conducts electricity, because the delocalised electrons in the metallic bond are free to move.
   Conducts heat, because heat energy is transferred by the movement of the delocalised electrons.

   c) The presence of differently sized atoms breaks up the regular pattern and stops layers sliding easily. Diagram similar to the one in the chapter would help.

3. a) Strong attractions between positive and negative ions need large amounts of energy to break.

   b) A small displacement of the layers of ions if subjected to a stress brings like charges together. Repulsion shatters the crystal.

   c) Attractions between ions and polar water molecules are strong enough to overcome the attractions between the ions themselves. Crystal is pulled apart.

4. a) Giant covalent
   b) Molecular
   c) Molecular
   d) Giant ionic
   e) Giant metallic
   f) Molecular
   g) Giant metallic
   h) Giant covalent

5. a) Solid. Giant covalent structure with strong covalent bonds in 3-dimensions.

   b) Hard. Explanation as in a).

   c) No. No ions present to give strong attractions with water molecules, and the bonds in silicon dioxide are too strong to be easily broken.

   d) Occurs as quartz - a component of rocks like granite. Quartz is a hard solid which doesn't dissolve in water (otherwise it would wash out of the rocks which contain it). This is all consistent with the predictions in a) to c).

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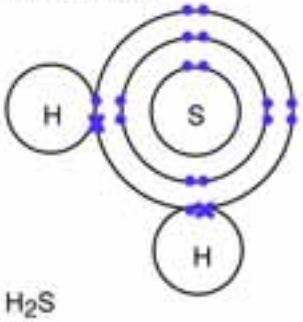
Chapter 5

1.

PbO	NaBr
$MgSO_4$	$ZnCl_2$
K_2CO_3	$(NH_4)_2S$
$Ca(NO_3)_2$	$Fe(OH)_3$
$FeSO_4$	$CuCO_3$
$Al_2(SO_4)_3$	$Ca(OH)_2$
$CoCl_2$	CaO
$AgNO_3$	FeF_3
NH_4NO_3	RbI
Na_2SO_4	Cr_2O_3

2. (a) (i) H: 1; S: 2,8,6

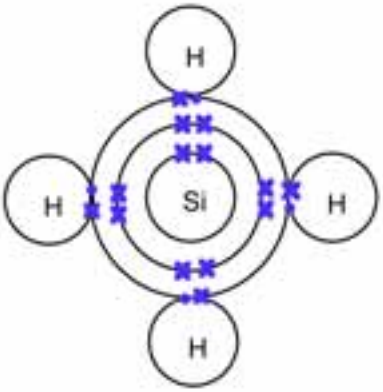
(ii)



(iii) H_2S

(b) There are 4 unpaired electrons in the outer level of silicon, and therefore room for 4 hydrogens to form covalent bonds.

The formula is SiH_4. (Allow H_4Si. Nothing so far has determined which way around it is likely to be written.)



3. a) $Ca + 2H_2O \longrightarrow Ca(OH)_2 + H_2$

b) $2Al + Cr_2O_3 \longrightarrow Al_2O_3 + 2Cr$

c) $Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$

d) $2NaHCO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + 2CO_2 + 2H_2O$

e) $2C_8H_{18} + 25O_2 \longrightarrow 16CO_2 + 18H_2O$

f) $Fe + 2HCl \longrightarrow FeCl_2 + H_2$

g) $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$

h) $Fe_3O_4 + 4H_2 \longrightarrow 3Fe + 4H_2O$

i) $2Mg + O_2 \longrightarrow 2MgO$

j) $Pb + 2AgNO_3 \longrightarrow Pb(NO_3)_2 + 2Ag$

k) $2AgNO_3 + MgCl_2 \longrightarrow Mg(NO_3)_2 + 2AgCl$

l) $C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

m) $Fe_2O_3 + 3C \longrightarrow 2Fe + 3CO$

4. a) $Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$

b) $2NaOH + H_2SO_4 \longrightarrow Na_2SO_4 + 2H_2O$

c) $2Na + 2H_2O \longrightarrow 2NaOH + H_2$

d) $2Na + Cl_2 \longrightarrow 2NaCl$

e) $Fe_2O_3 + 6HNO_3 \longrightarrow 2Fe(NO_3)_3 + 3H_2O$

f) $2Zn + O_2 \longrightarrow 2ZnO$

g) $CuO + 2HCl \longrightarrow CuCl_2 + H_2O$

h) $BaCl_2 + Na_2SO_4 \longrightarrow BaSO_4 + 2NaCl$

i) $Zn + Pb(NO_3)_2 \longrightarrow Pb + Zn(NO_3)_2$

j) $CuSO_4 + 2KOH \longrightarrow Cu(OH)_2 + K_2SO_4$

k) $Mg + CuO \longrightarrow MgO + Cu$

l) $4Na + O_2 \longrightarrow 2Na_2O$

m) $2Fe + 3Cl_2 \longrightarrow 2FeCl_3$

5. a) $CaCO_3(s) + 2HCl(aq) \longrightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

b) $Zn(s) + CuSO_4(aq) \longrightarrow Cu(s) + ZnSO_4(aq)$

c) $Mg(s) + H_2SO_4(aq) \longrightarrow MgSO_4(aq) + H_2(g)$

d) $Fe_2(SO_4)_3(aq) + 6NaOH(aq) \longrightarrow 2Fe(OH)_3(s) + 3Na_2SO_4(aq)$

e) $2Al(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2(g)$

f) $Fe_2O_3(s) + 3H_2SO_4(aq) \longrightarrow Fe_2(SO_4)_3(aq) + 3H_2O(l)$

g) $PbCO_3(s) + 2HNO_3(aq) \longrightarrow Pb(NO_3)_2(aq) + CO_2(g) + H_2O(l)$

h) $Mg(s) + H_2O(g) \longrightarrow MgO(s) + H_2(g)$

i) $C(s) + 2CuO(s) \longrightarrow 2Cu(s) + CO_2(g)$

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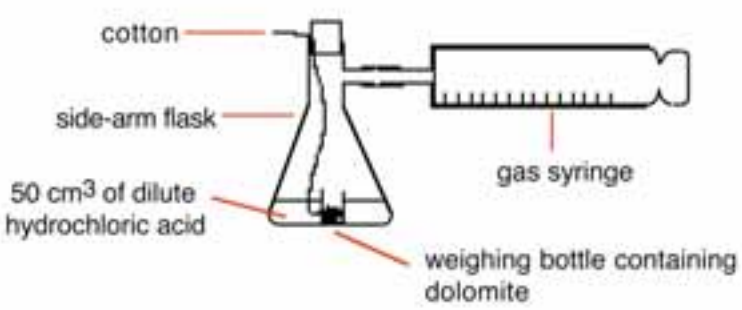
Chapter 6

1. a)



Collection of gas over water into an inverted measuring cylinder is an acceptable alternative. Pieces of dolomite in weighing bottle so that reaction can be started with no loss of gas. Description should include shaking the flask to upset the weighing bottle, followed by constant shaking, and recording the volume of gas in syringe at 30 second intervals.

b) Graph should be completely smooth with the axes properly labelled.

c) At the very beginning of the reaction. Reaction can only happen when acid particles hit the solid dolomite. Numbers of acid particles are greatest at the beginning of the reaction before any get used up - therefore the greatest number of collisions per second and the fastest reaction is at the beginning.

d) 70 secs (read this off the graph, and allow some tolerance depending on the size of graph paper available.)

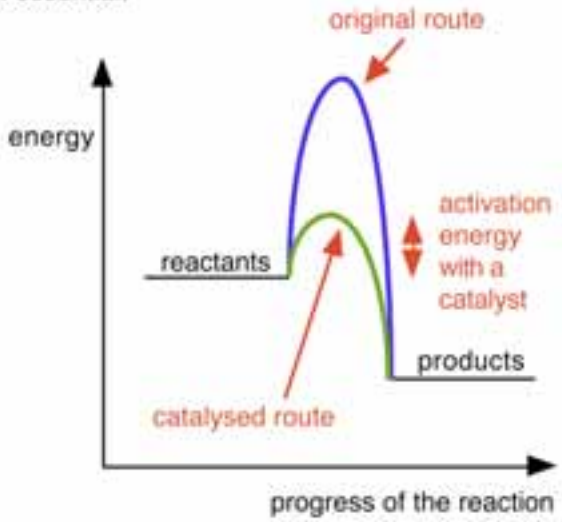
e) (i) lower initial rate; same volume of gas.
(ii) initial rate lower; half the volume of gas (50 cm^3).
(iii) initial rate the same; half the volume of gas (50 cm^3). (The initial rate depends on the original concentration of the acid which is still the same.)
(iv) initial rate faster; same volume of gas.

2. a) Time taken for the reaction would increase. Reaction happens when acid particles collide with the magnesium. The concentration of acid is less and so there will be fewer collisions per second, and therefore a slower reaction.

b) Time taken for the reaction would decrease. The acid particles are moving faster and so collide with the magnesium more often. Reaction only happens if the energy of the collision equals or exceeds activation energy. At higher temperatures the collisions are more energetic and so a greater proportion of them are effective.

(c) Answers could include: Acid will be used up quickly immediately around the magnesium; stirring brings fresh acid into contact with it. Bubbles of hydrogen form around the magnesium, preventing acid from reaching it; stirring helps to dislodge the bubbles. Bubbles of hydrogen lift the magnesium to the surface (sometimes above the surface) of the acid, lowering contact between acid and magnesium; stirring helps to prevent this.

3. a) Reactions only happen if collisions have energies equalling or exceeding activation energy. Catalysts provide an alternative route for the reaction with a lower activation energy. A diagram would be useful, but not essential.



b) To find out whether it speeds the reaction up: You could do this most simply by having two test tubes with equal volumes of the same hydrogen peroxide solution side-by-side. Add some copper(II) oxide to one and look for the faster production of bubbles. Trying to measure the difference is unnecessary.

To show that it is unchanged: Use a known mass of copper(II) oxide. When the reaction stops, filter through previously weighed filter paper, allow to dry, and reweigh. Show that the mass of copper(II) oxide is unchanged. (If it *had* changed, and you hadn't lost any during the separation process, it must have reacted in some way.)

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End of Section A Questions

1. a) B: Equal numbers of protons and electrons.

   b) Li^+. 1 mark for Li, one for correct charge.

   c) 1 mark each for 1, 1, -1 (reading vertically).

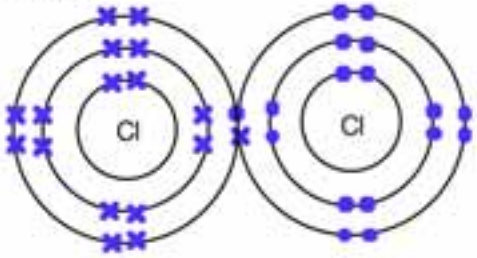
   d) Sr: 2; Br 7

   e) one Sr gives an electron to each of 2 bromines (or equivalent using diagrams).

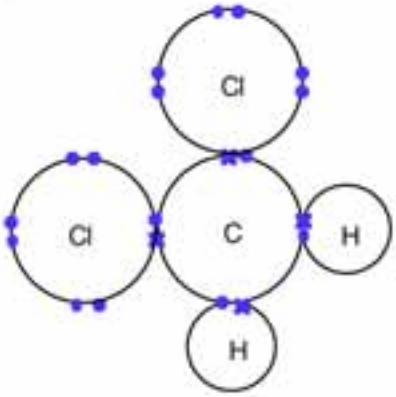
   f) $SrBr_2$

   g) High. Strong forces between positive and negative ions need large amounts of energy to break.

2. a) (i) diagram showing 2,8,7 (1 mark)
   (ii) diagram showing 2,8,8 (1 mark)
   (iii) Diagram as shown: everything correct (2); showing shared pair of electrons with flaw(s) elsewhere (1).



   b) Everything correct (ignore inner electrons if drawn) showing covalent bonding (3). Lose 1 mark for each error.



   The placing of the two chlorines and the two hydrogens around the carbon doesn't matter. For example, the two chlorines could just as well be drawn north and south, or north and east, or any other combination!

   c) Covalent bonds not broken on melting/boiling. Intermolecular forces are weak.

3. a) (i) B, (ii) C, (iii) A. All correct (2). 1 correct (1)

   b) (i) Atoms can slide over each other on stretching. (1)
   (ii) Delocalised electrons (allow "sea of electrons" or equivalent) are free to move.
   (iii) Small displacement brings ions of like charge together causing repulsion.
   (iv) Strong bonds in 3-dimensions.

   c) (i) Any acceptable property showing a difference (e.g. hardness, conduction of electricity, density (1).
   (ii) For example: Graphite has layer structure. Sliding layers make graphite soft. Diamond is hard because strong bonds in 3-D. OR: Graphite has delocalised electrons, which are free to move. In diamond all the electrons are fixed between the atoms. OR: Larger gaps between layers in graphite than between atoms in diamond structure. Wasted space in graphite makes it less dense.

4. a) Any correct formula with ratio 1:2 (or 2:1). (1)

   b) Before the reaction the substances taking part would have atoms of a particular mass. (1)
   Reaction rearranges them but would involve no change in total mass. (1)

   c) (i) isotopes
   (ii) ^{20}Ne: 10p, 10n, 10e; ^{22}Ne: 10p, 12n, 10e (1 mark per isotope)
   (iii) No - chemical properties are governed by electrons; same number in each isotope.

5. a) $2H_2O_{2(aq)} \longrightarrow 2H_2O_{(l)} + O_{2(g)}$ balancing (1); state symbols all correct (1)

   b) Sensible collection (e.g. gas syringe) (1). Gas tight apparatus (1).

   c) Uses most of graph paper (1). Labels axes (1). Correct plot of points (1). Smooth and accurate curve (1).

   d) 130 s (+/- 2) (1)

   e) Reaction has stopped (1), because all the hydrogen peroxide has decomposed (1).

   f) Same volume of gas produced at end of reaction. (1) More shallow curve than original plot. (1)

   g) Half volume of gas (30 cm^3) produced at end of reaction. (1) More shallow curve than original plot. (1)

6. a) (i) Gas particles move faster. More frequent collisions. More energetic collisions. More reach activation energy. More energy to break bonds. (any 3 points)
   (ii) Particles closer together. More frequent collisions.
   (iii) Reaction happens on surface. Gauze has greater surface area.

   b) More product formed in given time. Catalyst not used up. Otherwise need to spend more on heating . . . or on increased pressure. (any 2 points)

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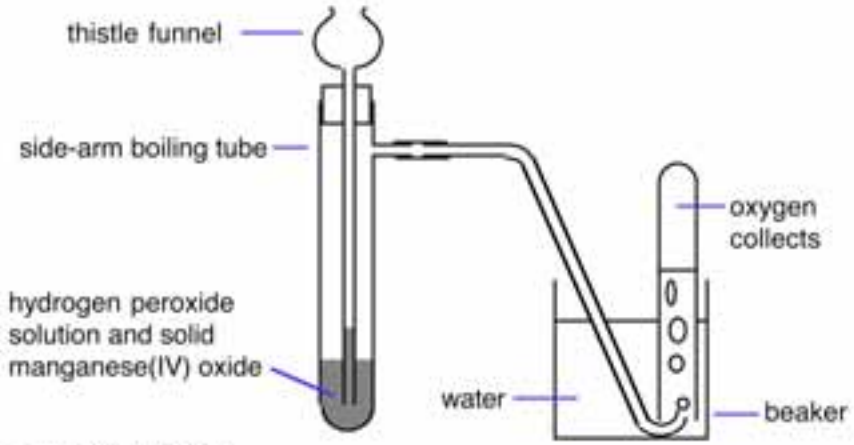
Chapter 7

1. a)



b) $2H_2O_2(aq) \longrightarrow 2H_2O(l) + O_2(g)$

c) Relights a glowing splint.

2. a) non-metal (sulfur)
b) metal (sodium)
c) metal (copper)
d) non-metal (carbon as graphite)

3. a) React with a named heated metal (most obvious would be to pass over heated copper). Valid equation for reaction used, e.g.:
$2Cu(s) + O_2(g) \longrightarrow 2CuO(s)$

b) e.g. pass through a solution of an alkali. Lime water will probably be suggested, but this isn't very effective because of the very dilute solution used. Sodium hydroxide solution is better. (Useful discussion point)

c) $3Mg(s) + N_2(g) \longrightarrow Mg_3N_2(s)$

d) Denser. Mixing it with nitrogen increases the density of the nitrogen.

e) Any two noble gases apart from argon.

4. a) Carbon dioxide is heavier than air and doesn't burn or support combustion (except for burning metals like magnesium). It smothers the flame preventing oxygen getting at the fuel.

b) Gases are more soluble in water if you increase the pressure, and so carbon dioxide is dissolved in water under pressure. When the top is released, the pressure drops to atmospheric. The gas becomes less soluble, and bubbles out of solution.

c) The sulfur (or sulfur compound) burns to make sulfur dioxide. The sulfur dioxide reacts with water and oxygen in the atmosphere to produce very dilute sulfuric acid which falls as acid rain.

d) The spark in the engine which is intended to ignite the petrol/air mixture also causes nitrogen to react with oxygen to give various oxides of nitrogen.

e) The catalyst has to be hot to work properly. During a short journey it may not reach a high enough temperature.

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Chapter 8

1. a) Na, Al, Fe, Cu

   b) (i) magnesium oxide, copper
   (ii) $Mg(s) + CuO(s) \longrightarrow MgO(s) + Cu(s)$ (Include state symbols in all equations for preference.)
   (iii) CuO
   (iv) CuO

   c) (i) zinc
   (ii) A reducing agent is a substance which reduces something else. Zinc removes oxygen from the cobalt(II) oxide. Removal of oxygen is reduction.
   (iii) zinc

   d) Al, Mn, Cr (Statement 1: Al is above Cr. Statement 2: Mn is below Al. Statement 3: Mn is above Cr. Putting this together gives the final list.)

2. a) oxidised; gain of oxygen
   b) reduced; loss of oxygen
   c) oxidised; loss of electrons
   d) reduced; gain of electrons

3. a) magnesium is above lead because it removes the oxygen from the lead(II) oxide.

   b) $Mg(s) + Pb^{2+}(s) \longrightarrow Mg^{2+}(s) + Pb(s)$

4. a) Either: grey iron filings become coated with brown solid. Or: solution fades from blue to colourless (very pale green).

   b) iron

   c) $Fe(s) + CuSO_4(aq) \longrightarrow FeSO_4(aq) + Cu(s)$

5. a) Ni, Cu, Ag

   b) (i) Either: colour of solution changes from blue to green. Or: nickel becomes coated with brown solid.
   (ii) $Ni(s) + CuSO_4(aq) \longrightarrow NiSO_4(aq) + Cu(s)$
   (iii) $Ni(s) + Cu^{2+}(aq) \longrightarrow Ni^{2+}(aq) + Cu(s)$
   Nickel has been oxidised by loss of electrons.

6. a) X is between iron and hydrogen in the reactivity series. It displaces hydrogen from dilute hydrochloric acid, and copper from copper(II) sulphate, and so must be above hydrogen and copper. It won't displace iron from iron(II) sulphate, and so must be below iron.

   b) (i) Yes: X nitrate and silver
   (ii) No
   (iii) No (at least, not in the short term)
   (iv) Yes: X chloride and copper
   (v) Yes: X sulphate and hydrogen

7. a) hydrogen

   b) aluminium chloride

   c) $2Al(s) + 6HCl(aq) \longrightarrow 2AlCl_3(aq) + 3H_2(g)$

d) Aluminium is covered by a very thin, but very strong, layer of aluminium oxide which prevents the acid getting at the aluminium underneath. On heating, the acid reacts with the oxide and removes it. The aluminium then shows its true reactivity, and produces a vigorous reaction.

8. Drop a very small piece into cold water. If it reacts, judge its reactivity relative to K, Na, Ca or Mg.

   If it doesn't react, add a small piece to dilute hydrochloric acid and warm if necessary. Rapid reaction in the cold would place it as "similar to magnesium". A few bubbles of hydrogen in the cold, but more on heating would place it as "similar to iron or zinc".

   If no reaction, then it is "below hydrogen". (A good student might mention that "no reaction" could also be caused by an effect similar to the oxide coating on aluminium. That would be worth some praise.)

   Note: Students might also suggest reacting the metal with steam. Point out that this is much more tedious than dropping a piece of metal into dilute hydrochloric acid, and that they should go for the easiest option available.

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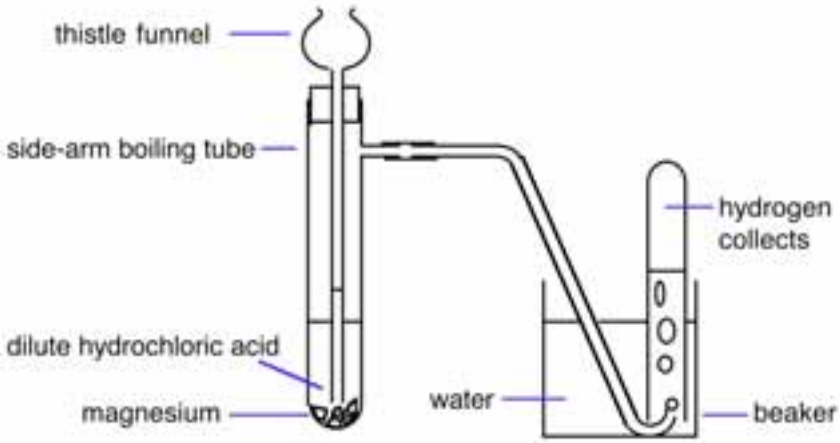
Chapter 9

1. a) copper(II) oxide, copper(II) hydroxide, copper(II) carbonate.

   b) $CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$
   $Cu(OH)_2(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + 2H_2O(l)$
   $CuCO_3(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + CO_2(g) + H_2O(l)$

2. a)



$Mg(s) + 2HCl(aq) \longrightarrow MgCl_2(aq) + H_2(g)$

b) Pops with a lighted splint.

c) Anything underneath hydrogen in the Reactivity Series - e.g. copper, silver, gold, platinum.

d) Anything above calcium in the Reactivity Series - e.g. potassium, sodium, lithium. Calcium is safe as long as the acid is really dilute, but it still gets *very* hot!

e) (i) water: $2H_2(g) + O_2(g) \longrightarrow 2H_2O(l)$

(ii) The hydrogen is much less dense than air and so rises quickly. The flame rises with the hydrogen.

3. a) A = copper; B = copper(II) oxide; C = copper(II) sulfate; D = copper(II) carbonate; E = carbon dioxide; F = copper(II) nitrate

   b) (i) $CuO(s) + H_2SO_4(aq) \longrightarrow CuSO4(aq) + H_2O(l)$
   (ii) $CuCO_3(s) + 2HNO_3(aq) \longrightarrow Cu(NO_3)_2(aq) + CO_2(g) + H_2O(l)$

4. a) Description could include: Silvery metal. Colourless acid. Slow bubbles of gas on warming. Formation of green solution. Possible disappearance of nickel if very small quantities were used.

   Testing for gas: Pops with lighted splint held to mouth of tube.

   b) $Ni(s) + H_2SO_4(aq) \longrightarrow NiSO_4(aq) + H_2(g)$

(c) Description could include: Green solid. Colourless acid. Bubbles of gas produced in the cold. Formation of green solution. Green powder disappears if excess acid is used.

Testing for gas: Bubble through lime water to give a white precipitate (milky, cloudy).

(d) (i) $NiCO_3(s) + 2HCl(aq) \longrightarrow NiCl_2(aq) + CO_2(g) + H_2O(l)$

(ii) $CO_3^{2-}(s) + 2H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$

Some teachers may prefer to write this as

$NiCO_3(s) + 2H^+(aq) \longrightarrow Ni^{2+}(aq) + CO_2(g) + H_2O(l)$

5. a) acid: H_2SO_4 base: MgO

b) acid: H^+ base: CO_3^{2-}

c) not acid-base (actually a redox reaction)

d) acid: HCl base: H_2O

e) not acid-base (another redox reaction)

f) acid: HCl base: NH_3

g) acid: HCl base: NaOH

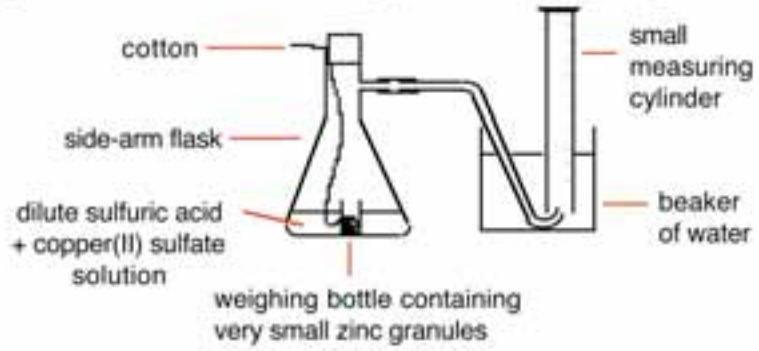
6. a) (i) Water: gives a hydrogen ion to a hydride ion.
(ii) Hydride ion: accepts a hydrogen ion.

b) sodium hydroxide, hydrogen

c) Fizzing. Colourless gas. White solid dissolves in colourless liquid to give colourless solution.

d) Accept any pH from reasonably to very alkaline.

7. The most obvious way of doing this would be to use an initial rate experiment, and measure the time taken for a small fixed volume (say 5 cm^3) of hydrogen to be produced. The apparatus should allow mixing of the zinc and acid without any possible loss of hydrogen. For example:



The reaction would be started by shaking the flask vigorously to upset the weighing bottle and mix all the reactants. Record how long it takes for a small fixed volume of hydrogen to be produced.

The reason for choosing very small zinc granules is because it would otherwise be very difficult to get exactly the same mass and surface area of zinc from one reaction to the next. In each experiment, the mass of zinc should be the same, and the same volume of the same sulfuric acid should be used. It has to be assumed that the lab temperature doesn't change significantly during the practical session.

To vary the amount of copper(II) sulfate present, it would be easiest to start with, say, 10 cm^3 of copper(II) sulfate solution for the first experiment. For the second experiment, use 9 cm^3 topped up with 1 cm^3 of water, and then continue diluting it in this way in subsequent experiments. In each case, the total volume of copper(II) sulfate solution added to the sulfuric acid must be constant, otherwise the acid is being diluted by varying amounts throughout the experiments.

Process the results by plotting rate (in terms of cm^3 of hydrogen per second) against the volume of copper(II) sulfate solution used.

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Chapter 10

1.

soluble	insoluble
sodium chloride	lead(II) sulfate
zinc nitrate	calcium carbonate
iron(III) sulfate	lead(II) chloride
potassium sulfate	copper(II) carbonate
aluminium nitrate	silver chloride
ammonium chloride	barium sulfate
magnesium nitrate	calcium sulfate (almost insoluble)
sodium phosphate	nickel(II) carbonate
potassium dichromate(VI)	chromium(III) hydroxide

2. a) Dilute sulphuric acid in a beaker / flask. Heat gently. Add copper(II) oxide a little at a time until no more reacts. Filter into an evaporating basin. Evaporate gently until a sample will crystallise on cooling. Leave to crystallise. Separate and dry crystals.

(b) (i) $CuO(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + H_2O(l)$

(ii) $CuSO_4(aq) + 5H_2O(l) \longrightarrow CuSO_4.5H_2O(s)$

3. a) using a pipette: Need to be able to measure the volume of sodium carbonate solution accurately so that exactly the same volume can be used later without the indicator.

few drops of methyl orange . . .: An indicator to show when the solution becomes "neutral". (In fact the colour change happens around pH 4. The pH changes very quickly around the end point for the indicator, and the difference in volume of acid added to take the pH from the desired pH 7 to the actual pH 4 for the indicator will be a fraction of a drop.)

. . . becomes orange: Exactly the right volume of acid has been added (the "neutral" colour for methyl orange).

without the methyl orange: Otherwise the crystals would be contaminated by methyl orange.

evaporated until . . .: Shows when the solution is sufficiently concentrated to crystallise on cooling. If a sample will crystallise, so will the bulk of the solution.

. . . left to cool: Crystals form on cooling because the solubility of the sodium sulphate is lower in the cold.

(b) (i) $Na_2CO_3(aq) + H_2SO_4(aq) \longrightarrow Na_2SO_4(aq) + CO_2(g) + H_2O_{(l)}$

(ii) $Na_2SO_4(aq) + 10H_2O(l) \longrightarrow Na_2SO_4.10H_2O(s)$

4. a) A solution of any soluble silver salt (silver nitrate is always used) plus a solution of any soluble chloride including dilute hydrochloric acid.

$Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$

b) A solution of any soluble calcium salt (calcium chloride or nitrate) plus a solution of a soluble carbonate (sodium, potassium or ammonium carbonate).

$Ca^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow CaCO_3(s)$

c) A solution of a soluble lead(II) salt (most commonly, lead(II) nitrate) plus a solution of any soluble sulfate including dilute sulfuric acid.

$Pb^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow PbSO_4(s)$

d) A solution of a soluble lead(II) salt (most commonly, lead(II) nitrate) plus a solution of any soluble chloride including dilute hydrochloric acid.

$Pb^{2+}(aq) + 2Cl^{-}(aq) \longrightarrow PbCl_2(s)$

5. Mix solutions of barium chloride or barium nitrate and sodium carbonate, potassium carbonate or ammonium carbonate. Filter, wash and dry the precipitate.

$Ba^{2+}(aq) + CO_3^{2-}(aq) \longrightarrow BaCO_3(s)$

6. a) A: dilute sulfuric acid + solid zinc (or zinc oxide, hydroxide or carbonate)

$H_2SO_4(aq) + Zn(s) \longrightarrow ZnSO_4(aq) + H_2(g)$

or $H_2SO_4(aq) + ZnO(s) \longrightarrow ZnSO_4(aq) + H_2O(l)$

or $H_2SO_4(aq) + Zn(OH)_2(s) \longrightarrow ZnSO_4(aq) + 2H_2O(l)$

or $H_2SO_4(aq) + ZnCO_3(s) \longrightarrow ZnSO_4(aq) + H_2O(l) + CO_2(g)$

b) C: solutions of a soluble barium salt + soluble sulfate (including H_2SO_4)

$Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

There is no point in writing full equations for precipitation reactions like this. The ionic equation is always easier.

c) B: dilute nitric acid + potassium hydroxide or carbonate solution

$HNO_3(aq) + KOH(aq) \longrightarrow KNO_3(aq) + H_2O(l)$

or $2HNO_3(aq) + K_2CO_3(aq) \longrightarrow 2KNO_3(aq) + H_2O(l) + CO_2(g)$

d) A: dilute nitric acid + solid copper(II) oxide or hydroxide or carbonate.

$2HNO_3(aq) + CuO(s) \longrightarrow Cu(NO_3)_2(aq) + H_2O(l)$

or $2HNO_3(aq) + Cu(OH)_2(s) \longrightarrow Cu(NO_3)_2(aq) + 2H_2O(l)$

or $2HNO_3(aq) + CuCO_3(s) \longrightarrow Cu(NO_3)_2(aq) + H_2O(l) + CO_2(g)$

(Unlike the other simple acids, nitric acid also reacts with copper metal, but it doesn't produce hydrogen, and is not on the Edexcel IGCSE syllabus. Any equation using copper to produce hydrogen should be disallowed.)

e) C: solutions of a soluble lead(II) salt (normally the nitrate) + a soluble chromate(VI). (Since you don't know anything specifically about chromates, choose one of sodium, potassium or ammonium chromate(VI) - these are bound to be soluble because all sodium, potassium and ammonium salts are soluble.)

$Pb^{2+}(aq) + CrO_4^{2-}(aq) \longrightarrow PbCrO_4(s)$

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Chapter 11

1. a) A
   b) D
   c) C
   d) B

2. For example: Stir with a large enough volume of cold water to dissolve all the sugar. Filter to leave the diamonds on the filter paper. Wash on the filter paper with more water to remove any last traces of sugar solution. Allow to dry.

3. a) chlorine
   b) ammonia
   c) carbon dioxide
   d) hydrogen
   e) oxygen

4. a) M
   b) R
   c) G and T
   d) P

5. a) Clean a nichrome or platinum wire by dipping it into concentrated hydrochloric acid and then into a flame until no colour shows. Moisten the wire with concentrated hydrochloric acid, dip it into the solid, and then back into flame. Lithium ions give a red flame colour.

   b) Warm the solid very gently with sodium hydroxide solution. Test any gases given off with a piece of damp red litmus paper. If it turns blue, ammonia is being given off from an ammonium compound.

   c) Make a solution in pure water. Add dilute hydrochloric acid + barium chloride solution. A white precipitate shows the sulfate ions.

   d) Drop the liquid onto blue cobalt chloride paper (which turns pink), or onto white anhydrous copper(II) sulfate (which turns blue).

   e) Add dilute hydrochloric acid or dilute nitric acid. (Not sulfuric acid which forms an insoluble layer of calcium sulfate around the calcium carbonate, which stops the reaction.) Look for a colourless odourless gas turning lime water milky.

   (f) Make a solution in pure water. Add dilute nitric acid + silver nitrate solution. A yellow precipitate shows the iodide ions.

6. a) A = iron(III) chloride; B = iron(III) hydroxide; C = silver chloride

   b) B: $Fe^{3+}(aq) + 3OH^-(aq) \longrightarrow Fe(OH)_3(s)$
   or: $FeCl_3(aq) + 3NaOH(aq) \longrightarrow Fe(OH)_3(s) + 3NaCl(aq)$

   C: $Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$
   or $3AgNO_3(aq) + FeCl_3(aq) \longrightarrow 3AgCl(s) + Fe(NO_3)_3(aq)$

7. a) D = iron(II) sulphate; E = iron(II) hydroxide; F = barium sulphate

   b) E: $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$
   or: $FeSO_4(aq) + 2NaOH(aq) \longrightarrow Fe(OH)_2(s) + Na_2SO_4(aq)$

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F: $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

or $BaCl_2(aq) + MgSO_4(aq) \longrightarrow BaSO_4(s) + MgCl_2(aq)$

8. a) G = potassium carbonate; H = potassium nitrate; I = carbon dioxide (Note: G could also be potassium hydrogencarbonate, but, because hydrogencarbonates haven't been covered in the course, a student is unlikely to come up with it.)

b) $CO_3^{2-}(s) + 2H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$

or $K_2CO_3(s) + 2HNO_3(aq) \longrightarrow 2KNO_3(aq) + CO_2(g) + H_2O(l)$

9. a) Dissolve the mixture in the minimum possible amount of hot water, and then allow it to cool again. The small amount of the more soluble potassium carbonate will stay in solution, but crystals of potassium nitrate will be formed on cooling. Filter these off, and wash them on the filter paper with a small amount of very cold water. Allow them to dry.

b) Take a sample and add any named dilute acid. If the crystals are free of potassium carbonate, there won't be any fizzing.

10. a) A = copper(II) carbonate
B = sulfuric acid
C = copper(II) sulfate
D = carbon dioxide
E = barium sulfate
F = copper(II) oxide
G = carbon dioxide
H = copper(II) chloride
I = copper(II) hydroxide

(b) (i) $CuCO_3(s) + H_2SO_4(aq) \longrightarrow CuSO_4(aq) + CO_2(g) + H_2O(l)$

or: $CO_3^{2-}(s) + 2H^+(aq) \longrightarrow CO_2(g) + H_2O(l)$

(ii) $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$

or $BaCl_2(aq) + CuSO_4(aq) \longrightarrow BaSO_4(s) + CuCl_2(aq)$

(iii) $Cu^{2+}(aq) + 2OH^-(aq) \longrightarrow Cu(OH)_2(s)$

or $CuSO_4(aq) + 2NaOH(aq) \longrightarrow Cu(OH)_2(s) + Na_2SO_4(aq)$

(iv) $CuO(s) + 2HCl(aq) \longrightarrow CuCl_2(aq) + H_2O(l)$

(v) $CuCO_3(s) \longrightarrow CuO(s) + CO_2(g)$

(Hardly anyone would write the ionic equations for the last two.)

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Chapter 12

1. a) (i) strontium
(ii) chlorine
(iii) nitrogen

b) (i) 2; (ii) 7; (iii) 5

c) metals: caesium, molybdenum, nickel, strontium, tin
non-metals: chlorine, neon, nitrogen

d) molybdenum and nickel

e) (i) caesium
(ii) neon

2. a) A = lithium

b) B = potassium; C = hydrogen; D = potassium hydroxide

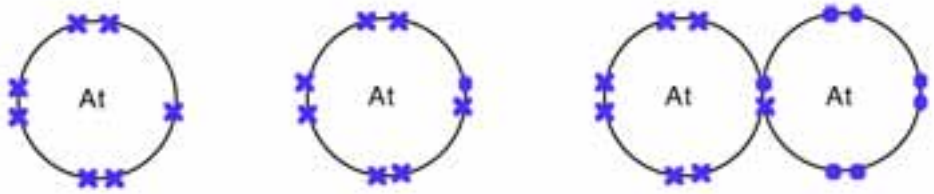
c) E = sodium; F = chlorine; G = sodium chloride

d) (i) $2K(s) + 2H_2O(l) \longrightarrow 2KOH(aq) + H_2(g)$
(ii) $2Na(s) + Cl_2(g) \longrightarrow 2NaCl(s)$
(You could easily justify (l) as the state symbol for both K and Na.)

e) red turns blue; no change to the blue.

b) Lots of heat evolved. Melting point of potassium is low.

3. a)



atom ion molecule

b) solid

c) less

d) steamy gas; solution with a pH about 1

e) A white solid, soluble in water. It will be an ionic solid, because that's typical of compounds formed when Group 1 and Group VII elements combine. The other Group 1 halides are soluble in water. There isn't a transition element present, so it is unlikely to be coloured.

f) $2At^-(aq) + Cl_2(aq) \longrightarrow At_2(s) + 2Cl^-(aq)$
A redox reaction is one in which reduction and oxidation occur. The astatide ions have lost electrons, and so have been oxidised. The chlorine molecules have gained electrons, and so have been reduced.

4. 5 from: high melting point, high boiling point, high density, hard, good conductor of electricity, good conductor of heat, malleable and ductile, useful catalyst, compounds are coloured (+ anything else which seems sensible)

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5. a) Ne atoms have 8 electrons in their outer level. No room to share electrons to form covalent bonds and therefore monatomic. Gases because the only forces possible between the individual atoms are weak intermolecular attractions. Unreactive because of the lack of possibility of forming covalent bonds or stable ions.

   b) Both metals react by their atoms losing their single outer electron to form 1+ ions. In potassium, this electron is further from the attraction of the nucleus and so lost more easily.
   (A full answer should really include a mention of increased nuclear charge being offset by increased screening.)

   c) $Cl_2(aq) + 2Br^-(aq) \longrightarrow 2Cl^-(aq) + Br_2(aq)$

   Chlorine removes an electron from a Br^- ion and uses it to form Cl^-. This happens because chlorine is a smaller atom than bromine and so an extra electron is closer to, and more attracted to, the chlorine nucleus than it was to the bromine nucleus.
   (A full answer should really include a mention of increased nuclear charge being offset by increased screening.)

6. a) Noble gas: Physical data shows a gas. Lack of reactivity suggests a noble gas rather than fluorine or chlorine from Group 7.

   b) Transition element: High melting point metal (conducts electricity) with coloured compounds. Not Group 1 or 2 because of lowish reactivity and coloured compounds.

   c) Group 1 or 2 element: Physical data and reactions suggest a metal. Reactivity suggests Groups 1 or 2. Lack of coloured compounds suggests not a transition metal.

7. There's no "right" answer to this. A sample response might be:

Test	**Observation**
Appearance	*Shiny grey solid*
Hit with a hammer	*Very little effect. Edges bent slightly.*
Put into electrical circuit with battery and bulb	*Bulb lights up. Conducts electricity.*
Warm with dilute hydrocloric acid	*No reaction*

From its apearance, its lack of brittleness and its electrical conductivity, the element is a metal. Its lack of reaction with dilute hydrochloric acid must be because it is either below hydrogen in the Reactivity Series, or has a very strong oxide coating.

Most students would give a positive result with the acid. The negative result is included here to make the point that any inconsistent result should be explained.

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Chapter 13

1.

	cathode	anode
a)	lead	bromine
b)	zinc	chlorine
c)	hydrogen	iodine
d)	sodium	iodine
e)	copper	chlorine
f)	hydrogen	chlorine
g)	hydrogen	oxygen
h)	hydrogen	oxygen

2. a) Ions weren't free to move.
b) anode
c) iodine: $2I^-(l) \longrightarrow I_2(g) + 2e^-$
d) $K^+(l) + e^- \longrightarrow K(l)$
e) Orange flashes around the cathode (sodium burning) and brown fumes (bromine) around the anode.
f) cathode: $Na^+(l) + e^- \longrightarrow Na(l)$
anode: $2Br^-(l) \longrightarrow Br_2(g) + 2e^-$

3. a) (i) $Pb^{2+}(l) + 2e^- \longrightarrow Pb(l)$
(ii) $2Br^-(l) \longrightarrow Br_2(g) + 2e^-$
(iii) Oxidised: bromide ions. Reduced: lead(II) ions.

b) (i) $2H^+(aq) + 2e^- \longrightarrow H_2(g)$
(ii) $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-$
(iii) Oxidised: chloride ions. Reduced: hydrogen ions.

c) (i) $2H^+(aq) + 2e^- \longrightarrow H_2(g)$
(ii) $2Br^-(aq) \longrightarrow Br_2$(aq or l) $+ 2e^-$
(iii) Oxidised: bromide ions. Reduced: hydrogen ions.

d) (i) $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$
(ii) $4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e^-$
(iii) Oxidised: hydroxide ions. Reduced: copper(II) ions.

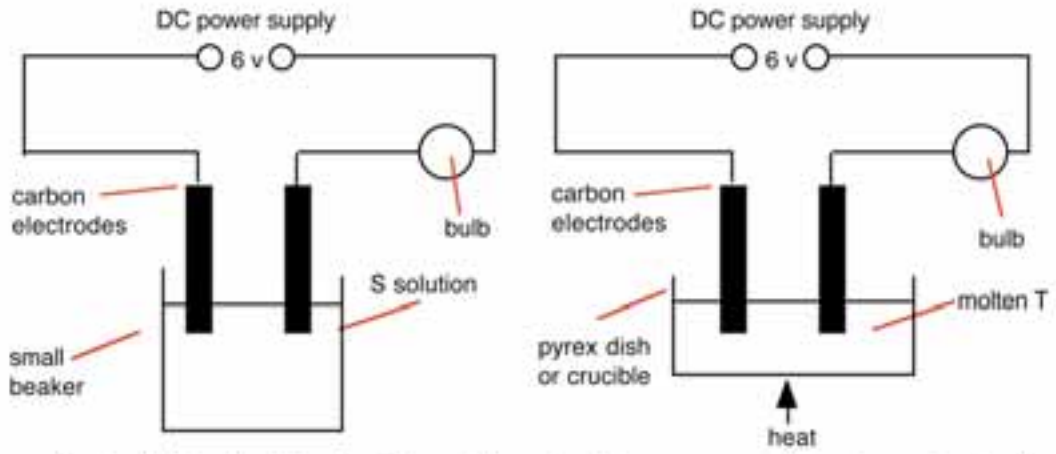
e) (i) $2H^+(aq) + 2e^- \longrightarrow H_2(g)$
(ii) $4OH^-(aq) \longrightarrow 2H_2O(l) + O_2(g) + 4e^-$
(iii) Oxidised: hydroxide ions. Reduced: hydrogen ions.

f) (i) $Mg^{2+}(l) + 2e^- \longrightarrow Mg$(s or l)
(ii) $2I^-(l) \longrightarrow I_2(g) + 2e^-$
(iii) Oxidised: iodide ions. Reduced: magnesium ions.

g) (i) $2H^+(aq) + 2e^- \longrightarrow H_2(g)$
(ii) $2Cl^-(aq) \longrightarrow Cl_{2(g)} + 2e^-$
(iii) Oxidised: chloride ions. Reduced: hydrogen ions.

4. The melting point of S is too high to reach using a bunsen, and so you would have to test a solution in water.

On the other hand, T would melt easily, and won't dissolve. Heat it until it melts.



(You could also do the electrolysis of the solution using the more complicated apparatus in the chapter, but since there is no need to collect anything, there isn't much point.)

If the substances are electrolytes, the bulbs will light up, and there will be signs of activity around the electrodes (gases given off, solids deposited, etc).

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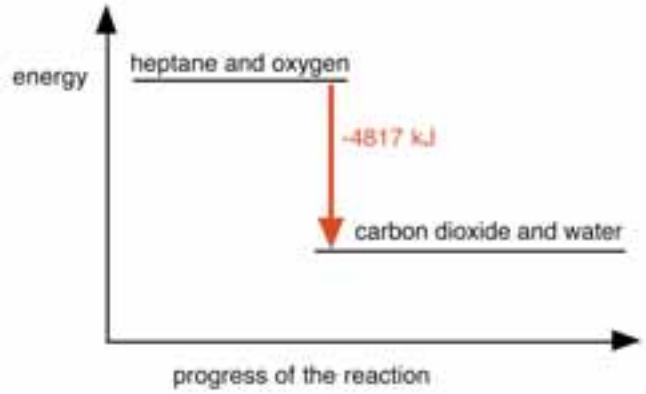
Chapter 14

1. a) A reaction in which heat energy is produced. Correctly balanced equations (including state symbols) for any two exothermic reactions - e.g. the obvious ones are any combustion reactions (metals, hydrogen, hydrocarbons, etc, in oxygen), neutralisation reactions involving oxides or hydroxides and acids, magnesium and acids. See chapter for specific examples.

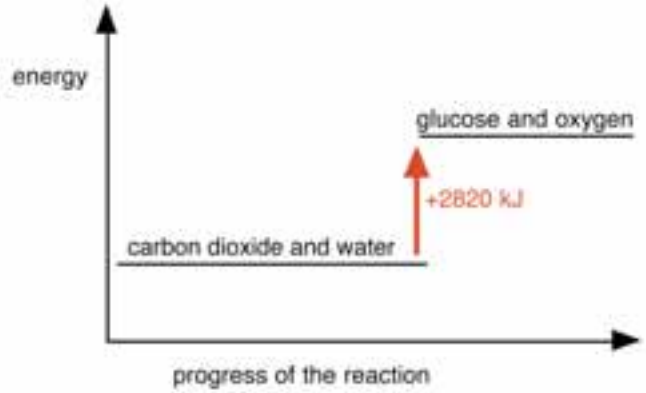
   b)



   c) Energy is needed to break the bonds in heptane and in oxygen. Energy is released when new bonds are made to produce the carbon dioxide and water. More energy is released when the new bonds are made than was used to break the old ones.

2. a) A reaction in which energy is absorbed. The chapter uses the effect of heat on carbonates as examples of endothermic reactions. It is easiest to choose any two of these.

   b)



3. a) exothermic
   b) exothermic
   c) endothermic
   d) exothermic
   e) endothermic
   f) exothermic

4. The cans are double skinned - the gap between the skins containing calcium oxide and (kept separate) water. Pushing a button on the bottom of the can breaks a seal and allows the reactants into contact, and you get the reaction described in the chapter.

   $CaO(s) + H_2O(l) \longrightarrow Ca(OH)_2(s)$

   It is easy to find lots of information on this by an Internet search.

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Chapter 15

1. a) If a dynamic equilibrium is disturbed by changing the conditions, the reaction moves to counteract the change.

   b) (i) *Dynamic* means that the reactions are still continuing. *Equilibrium* means that the total amounts of the various things present are constant. This is because the forward and back reactions are happening at the same rates.

   (ii) An increase in pressure will produce more N_2O_4. According to Le Chatelier, the equilibrium moves to reduce the pressure again by producing fewer molecules.

   (iii) A decrease in temperature will produce more N_2O_4. According to Le Chatelier, the equilibrium moves to increase the temperature again by favouring the exothermic change.

2. a) Less carbon monoxide and hydrogen would be produced. (A high pressure favours the reaction producing fewer molecules.)

   b) Raising the temperature moves the equilibrium in the direction which would tend to reduce it again, and so a high temperature favours the endothermic change (in this case, the forward reaction).

   c) The reaction would be too slow in the absence of the catalyst.

   d) Increasing the proportion of steam will favour the forward reaction (Le Chatelier's Principle). Steam is also much cheaper than methane and an excess will help ensure the maximum conversion of the methane into products.

3. a) Adding extra hydrogen ions favours the back reaction as the equilibrium shifts to reduce their concentration again (Le Chatelier's Principle). This produces more HLit, which is red.

   b) The hydroxide ions react with the hydrogen ions in the equilibrium, reducing their concentration. The equilibrium moves to replace them again, producing extra Lit^- ions which are blue.

4. a) A high pressure favours the reaction producing fewer molecules (Le Chatelier's Principle - fewer molecules produce a lower pressure) - in this case, the production of ammonia.

   b) Very high pressures are expensive to produce for two reasons: all the reaction vessels and pipework have to be built much more strongly, and it takes a lot more energy to drive the compressors producing the very high pressures. The extra ammonia produced isn't worth the extra cost.

   c) The forward reaction producing ammonia is exothermic. This is favoured by a low temperature according to Le Chatelier's Principle (the equilibrium moves in a direction to increase the temperature again).

   d) At low temperatures the reaction is extremely slow even in the presence of a catalyst. 450°C is chosen because it gives a reasonable percentage of ammonia in the equilibrium mixture reasonably quickly.

End of Section B Questions

1. a) (i) barium sulfate (1)
(ii) $Ba^{2+}(aq) + SO_4^{2-}(aq) \longrightarrow BaSO_4(s)$ (1)

b) Add sodium hydroxide solution (1) and look for blue precipitate (1).

c) (i) Brown precipitate (1). Solution fades from blue to colourless (1).
(ii) zinc (1). Loss of electrons (1).

d) (i) cathode (or negative) (1)
(ii) $Cu^{2+}(aq) + 2e^- \longrightarrow Cu(s)$ (1)
(iii) reduction (1). Gain of electrons (1).

2. a) (i) solid copper(II) oxide (or hydroxide or carbonate) (1)
(ii) sodium hydroxide (or carbonate) solution (1)
(iii) silver nitrate solution (1)

b) Add a measured volume of potassium hydroxide solution to a flask using a pipette (or measuring cylinder) (1). Add a named indicator (1). Add acid from a burette (1) until a correctly stated colour change (1). Note the volume of acid added (1). Mix the same volumes of acid and potassium hydroxide solution without the indicator (1).

3. a) (i) A = chlorine (1)
(ii) B = hydrogen (1) (Allow one mark overall if reversed)

b) (i) bleaches (1) damp litmus paper (1)
(ii) pops (1) with lighted splint (1) (Consequential marking from part (a). e.g. If A was mis-named as oxygen, allow a correct test for oxygen.)

c) (i) red / brown (1) solution (1) instead of colourless gas
(ii) no change (1)

d) copper(II) (1) bromide (1)

4. a) (i) $Cl_2(g) + 2I^-(aq) \longrightarrow 2Cl^-(aq) + I_2(s)$ (1)
(ii) Colourless solution + green gas (1) gives dark grey precipitate (1) (allow red/brown solution).
(iii) Oxidising agent (1) because it removes electrons (1) from the iodide ions.

b) (i) iron(II) (1) chloride (1)
(ii) I = iron(II) hydroxide (1). K = iron(III) hydroxide (1)
(iii) iron(III) chloride (1)
(iv) $Fe^{2+}(aq) + 2OH^-(aq) \longrightarrow Fe(OH)_2(s)$ (1)

5. a) Any sensible physical property (1) - e.g. solid rather than gas.

b) Correct reagent (e.g. water or oxygen or chlorine) (1). Name products (1). Correctly balanced equation (2)

c) (i) Dots-and-crosses diagrams showing all the electrons: Na 2,8,1; K 2,8,8,1 (2 x 1 = 2)
(ii) Loss of outer electron (1)
(iii) Potassium's electron is further from nucleus (1) and so experiences less attraction (1). Some mention of increased nuclear charge being offset by extra screening (1).

d) A molecule consisting of a single atom (1). Argon's outer level contains 8 electrons (1). No room

for sharing another electron to make the covalent bond needed to join other atoms to it. (1)

6. a) redox (1)
   b) thermal decomposition (1)
   c) neutralisation (1)
   d) precipitation (1)
   e) redox (1)
   f) redox (1)

7. a) ΔH shows the amount of heat evolved or absorbed during the reaction (1). The positive sign shows heat is absorbed (1).

   b) (i) increases
   (ii) decreases

   c) (i) $N_2(g) + O_2(g) \longrightarrow 2NO(g)$ (1)
   (ii) acid rain (1). Any valid consequence of acid rain (e.g. death of trees, loss of life in lakes, corrosion of iron or limestone) (1)
   (iii) sulfur dioxide (1)

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Answers

Chapter 16

1. Burn sulfur in air to give sulfur dioxide.

   $S(s) + O_2(g) \longrightarrow SO_2(g)$

   Pass this with more air over a vanadium(V) oxide catalyst at a temperature of 450°C and a pressure of 1 to 2 atmospheres to give sulfur trioxide.

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

   Absorb the sulfur trioxide in concentrated sulfuric acid to give fuming sulfuric acid.

   $H_2SO_4(l) + SO_3(g) \longrightarrow H_2S_2O_7(l)$

   Dilute this carefully with water to give concentrated sulfuric acid.

   $H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4(l)$

2. a) (i) % ammonia decreases. Rate increases.
   (ii) % ammonia increases. Rate increases.
   (iii) % ammonia no change. Rate increases.

   b) High pressures increase both the percentage conversion and the rate of the reaction. However, *very* high pressures are very expensive to produce. Typically, about 200 atmospheres is as high a pressure as it is economic to use.

   c) nitrogen: air. hydrogen: natural gas

3. a) That makes sure that the flow of liquid is always from left to right, preventing any of the sodium hydroxide solution formed finding its way back to where chlorine is being produced. That stops the two from reacting.

   b) Titanium anode. Steel cathode.

   c) (i) $H_2O(l) \rightleftharpoons H^+(aq) + OH^-(aq)$

   (ii) sodium and hydrogen

   (iii) hydrogen

   (iv) The sodium ions in the sodium hydroxide solution are there because they are attracted to the cathode. As the hydrogen ions are discharged to give hydrogen gas, the equilibrium in part (i) moves to the right to replace them (Le Chatelier's Principle), producing hydroxide ions. There is therefore a build-up of sodium ions and hydroxide ions in the cathode compartment.

   d) (i) Any valid use for sodium hydroxide solution (see chapter)
   (ii) Any valid use for chlorine (see chapter)
   (Care over phrasing! For example, sodium hydroxide isn't used *as* a bleach - it is used to *make* bleach.)

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4. a) Add a measured volume of ammonia solution to a flask using a pipette (or measuring cylinder) . Add a named indicator. Add sulfuric acid from a burette until a correctly stated colour change. Note the volume of acid added. Mix the same volumes of acid and ammonia solution without the indicator.

   b) Any sensible design involving a control. For example, germinate at least two lots of grass seed in identical trays of weaky fertilised compost (John Innes seed compost, or similar). When the grass is growing properly, water one with plain water, and the other with the same volume of a very dilute solution of ammonium sulfate. Keep side-by-side under the same conditions. Compare the growth and appearance of the two trays.

   (The dilution of the solution would be fairly hit-and-miss. It would be better to have more trays so that you could compare the effects of varying concentrations in order to find the best one.)

5. a) The reaction is strongly exothermic (large negative number for ΔH). Once the reaction starts, there is enough heat produced to keep the catalyst hot.

   b) The catalyst isn't used up, and without it the reaction would be too slow. (In fact, the catayst is in the form of a number of very large platinum-rhodium gauzes, which do get damaged over time. They can, however, be sent back to the manufactures and remade.)

   c) $2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$

   d) $2H_2O(l) + 4NO_2(g) + O_2(g) \longrightarrow 4HNO_3(aq)$

   e) Any valid use. Easy to find ones include the manufacture of explosives, drugs, dyes. (The question isn't looking for any detail. A simple answer, for example "Manufacture of explosives", is enough.)

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Chapter 17

1. a) Sodium is high in the Reactivity Series, and so will need to be produced by electrolysis. Manufacture it by electrolysing molten sodium chloride using suitable electrodes (industrially, carbon anode, steel cathode), keeping the sodium and chlorine apart to prevent them from reacting back to give sodium chloride again.

   Sodium would be released at the cathode: $Na^+(l) + e^- \longrightarrow Na(l)$

   b) Needed discovery of electricity.

   c) Any other metals high in the RS - e.g. potassium, lithium, calcium, magnesium.

   d) An alloy of copper and tin. Both metals are lowish in the RS and easily produced by heating their ores with carbon.

2. a) bauxite

   b) a solution of aluminium oxide in molten cryolite

   c) cathode (or negative)

   d) $Al^{3+}(l) + 3e^- \longrightarrow Al(l)$ reduction

   e) Reacts with the carbon anodes and burns them away.

   f) (i) low density
   (ii) alloys are stronger

3. a) A

   b) (i) coke
   (ii) air
   (iii) iron ore
   (iv) limestone

   c) $CaO(s) + SiO_2(s) \longrightarrow CaSiO_3(l)$

   d) $Fe_2O_3(s) + 3C(s) \longrightarrow 2Fe(l) + 3CO(g)$

4. a) (i) carbon, about 4%
   (ii) Makes it brittle.

   b) Mixture of iron, nickel and chromium. Nickel and chromium form thin layers of strongly adherent oxides which protect the iron from air and water attack. Any valid use (see chapter for examples).

   c) (i) Iron coated with zinc.
   (ii) It would take much longer before the car went rusty. Zinc is more reactive than iron and so corrodes more easily. The corrosion of zinc forms zinc ions and releases electrons. These electrons flow to the iron and prevent its ionisation (which would lead to rusting). Painting has no similar effect, so galvanising lengthens the life of the car.

End of Section C questions

1. a) Removal of oxygen (allow addition of electrons) (1)

   b) iron(III) oxide (1) (must include oxidation state)

   c) exothermic (1)

   d) $C(s) + CO_2(g) \longrightarrow 2CO(g)$ (1)

   e) $Fe_2O_3(s) + 3CO(g) \longrightarrow 2Fe(l) + 3CO_2(g)$ (1)

   f) Limestone is calcium carbonate (1). Decomposes to give calcium oxide (1), which combines with silicon dioxide to give calcium silicate (1). Or 3 marks for both correct equations.

   g) (i) One valid use for each (see chapter) (4 x 1)
   (ii) Makes it harder (1) and more brittle (1).

2. a) (i) bauxite (1)
   (ii) cathode (or negative) (1)
   (iii) carbon (1) electrode burns (1) and needs replacing (1). Max 2.
   (iv) needs large quantities of expensive electricity (1)

   b) (i) less dense (1)
   (ii) strengthened (1)
   (iii) e.g. stronger (1), cheaper (1)
   (iv) iron coated with zinc (1)
   (v) Zinc more reactive than iron (1). Sacrificial protection (*or* zinc corrodes in preference to iron) (1). Corrosion of zinc forms ions and releases electrons (1). These flow to iron and prevent its ionisation (1). (Maximum 2)

3. a) manufacture of sulfuric acid (1)

   b) $ZnO(s) + C(s) \longrightarrow Zn(g) + CO(g)$ (1)

   c) dilute sulfuric acid (1). $ZnO(s) + H_2SO_4(aq) \longrightarrow ZnSO_4(aq) + H_2O(l)$ (1)

   d) cathode (or negative) (1). $Zn^{2+}(aq) + 2e^- \longrightarrow Zn(s)$ (1)

4. a) hydrogen (1), chlorine (1), sodium hydroxide (1) + a valid use for each (see chapter) (3 x 1)

   b) chlorine (1) $2Cl^-(aq) \longrightarrow Cl_2(g) + 2e^-$ (1)

5. a) (i) the air (1)
   (ii) natural gas (methane) (1)

   b) A reversible reaction (strictly, a reversible reaction in a state of dynamic equilibrium) (1)

   c) an exothermic reaction (1)

   d) iron (1)

   e) (i) 450°C (1)
   (ii) 200 atmospheres (allow anything in the region of ~150 to 1000 atm) (1)

   f) It is cooled and condenses to a liquid. (1)

g) Any two valid uses - e.g. making fertilisers (allow "as a fertiliser" - some ammonia is injected directly into the soil), making nitric acid, making nylon (2 x 1)

6. a) burnt in air (1)

b) (i) vanadium(V) oxide (1)

(ii) Greater at a low temperature (1). Equilibrium moves to counter a lower temperature by doing the exothermic change - in this case the formation of more sulfur trioxide (1).

(iii) At a lower temperature, the rate of the reaction is too slow (1). 450°C is a compromise giving a good yield reasonably quickly (1).

(iv) Good yield even at low pressures (1). Not economically worthwhile to use higher pressures (1).

c) $H_2SO_4(l) + SO_3(g) \longrightarrow H_2S_2O_7(l)$ (1)
$H_2S_2O_7(l) + H_2O(l) \longrightarrow 2H_2SO_4(l)$ (1)

d) Any two valid uses - e.g. manufacture of fertilisers, manufacture of detergents, and manufacture of paints. (2 x 1)

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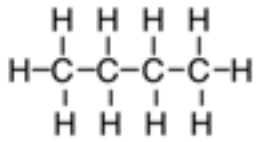
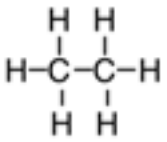
Chapter 18

1. a) (i) methane
(ii) propane
(iii) pentane
(iv) propene
(v) ethene
(vi) but-1-ene

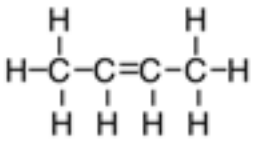
b)



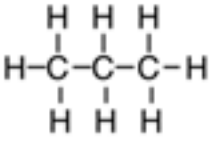
(i) butane



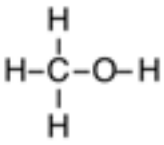
(ii) ethane



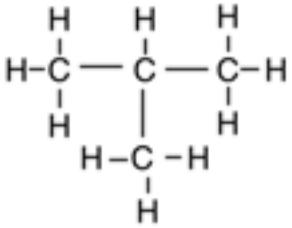
(iii) but-2-ene



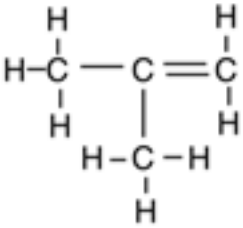
(iv) propane



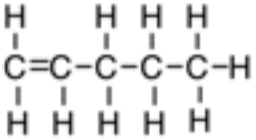
(v) methanol



(vi) 2-methylpropane



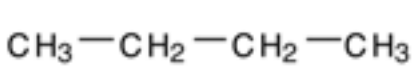
(vii) 2-methylpropene



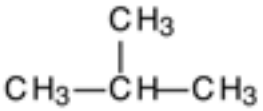
(viii) pent-1-ene

2. a) The existence of molecules with the same molecular formula but different structural formulae.

b)



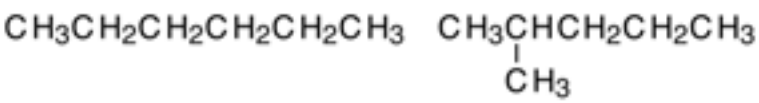
butane



2-methylpropane

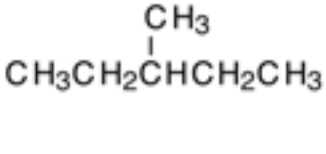
(In these and subsequent formulae, if you aren't asked specifically for displayed formulae, these quicker forms are acceptable.)

c)

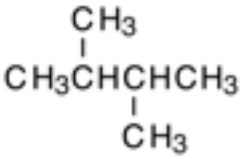


hexane

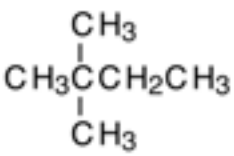
2-methylpentane



3-methylpentane



2,3-dimethylbutane



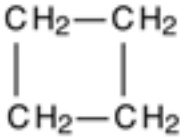
2,2-dimethylbutane

(If you are a home-schooling parent, this is going to be a bit of a nightmare to sort out. Anything else is just a twisted form of one of these. The trick is to make sure that you always draw the longest chain horizontally. Duplicates usually arise from breaking that rule.)

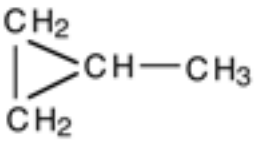
d) $CH_3CH_2CH=CH_2$ $CH_3CH=CHCH_3$ $CH_3C(CH_3)=CH_2$

but-1-ene but-2-ene 2-methylpropene

Also:



cyclobutane



methylcyclopropane

(Few students would find these last two, particularly methylcyclopropane. Give praise if they do find them.)

3. a) (i) (done in question as an example)

(ii) $CH_3CH_2CH(OH)CH_3$

(iii) $CH_3CH(CH_3)CH_2OH$

(iv) $CH_3C(CH_3)_2OH$

(For home schooling parents: It doesn't matter exactly how you have written the molecule as long as everything is joined up in the right way. For example, in part (iv), as long as the central carbon has 3 methyl groups and an -OH group attached, it doesn't matter about their relative orientation - N, S, E or W.)

b) There are 8 of these.

$CH_3CH_2CH_2CH_2CH_2CH_2OH$ pentan-1-ol

$CH_3CH_2CH_2CH(OH)CH_3$ pentan-2-ol

$CH_3CH_2CH(OH)CH_2CH_3$ pentan-3-ol

$CH_3CH_2CH(CH_3)CH_2OH$ 2-methylbutan-1-ol

$CH_3CH(CH_3)CH_2CH_2OH$ 3-methylbutan-1-ol

$CH_3CH_2C(CH_3)(OH)CH_3$ 2-methylbutan-2-ol

$CH_3CH(CH_3)CH(OH)CH_3$ 3-methylbutan-2-ol

$CH_3C(CH_3)_2CH_2OH$ 2,2-dimethylpropan-1-ol

(If you are a home-schooling parent, it is important that you understand how to find all these systematically. In the top row, there are 5-carbon chains, and the -OH group is just moved along them. If you move it one more place to the left, so that it is on the next-to-the-end carbon, that is the same as the second structure, flipped over. In the second row, there are 4-carbon chains, with an -OH on the end, and the methyl group moved along the chain. It can't be on the same carbon as the -OH group, because the longest chain would then have 5 carbons, and it would be the same as

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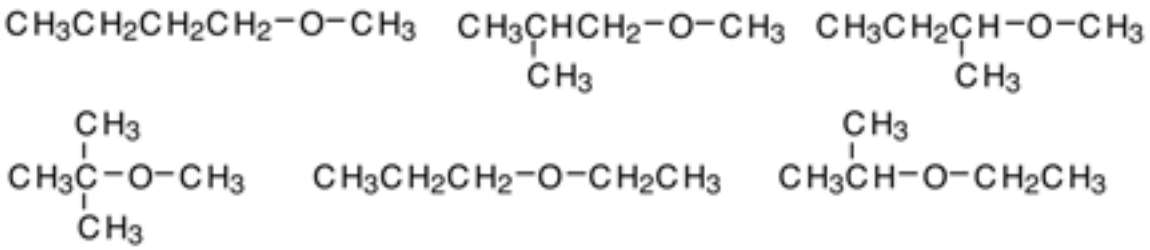
the middle structure in the top row, just bent a bit. In the bottom row, the first two are 4-carbon chains with an -OH on the second carbon, and the methyl group moved around. The last structure is the only one with a 3-carbon chain as the longest chain. As far as naming is concerned, there are some cases where the chain could perhaps be numbered from either end. The rule is to keep the numbers as small as possible - particularly, in these compounds, the numbering of the -OH group. This is way beyond GCSE!)

c) (For home-schooling parents: This next sequence involves oxygen atoms joined to two different carbon atoms, rather than a carbon atom and a hydrogen atom as in the previous structures. These compounds are known as ethers.)



This isn't easy stuff! Anyone who gets more than a couple of them deserves a lot of credit.

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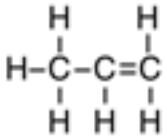
Chapter 19

1. a) Contains as many hydrogen atoms as possible for the given number of carbons. Only carbon-carbon single bonds.

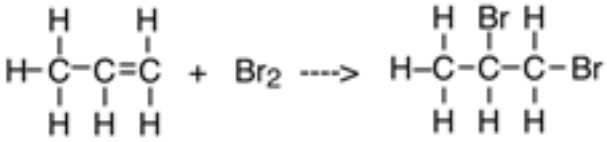
   b) (i) $C_{11}H_{24}$
   (ii) liquid
   (iii) $C_{11}H_{24}(l) + 17O_2(g) \longrightarrow 11CO_2(g) + 12H_2O(l)$

2. a) a carbon-carbon double bond

   b)



   c)



   (Home schooling parents: It doesn't matter what position you draw the bromine in on the right-hand carbon - N, S or E (with hydrogens in the other two positions). All that matters is that one bromine becomes attached to each of the carbons either side of the original double bond.)

   d) (i) $CH_4(g) + Br_2(g) \longrightarrow CH_3Br(g) + HBr(g)$

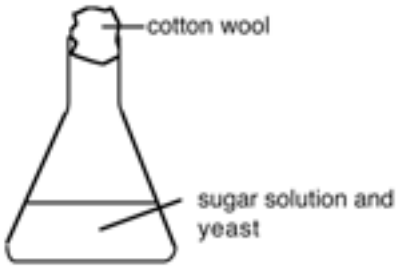
   (ii) In this (substitution) reaction, one of the hydrogens has been replaced by a bromine during the reaction. In the previous (addition) reaction, nothing was lost when the two molecules combined together.

3. a) Ethene is passed with steam at 300°C and 60 - 70 atmospheres over a phosphoric acid catalyst.

   b) e.g. two of: continuous flow process, therefore faster; rapid reaction; purer product.

   c) uses renewal resources; gentle conditions.

4. Dissolve the sugar in water in a conical flask (or similar) and add yeast. You now need some means of keeping the air out while allowing carbon dioxide to escape. You could use a commercial home-winemaking airlock of some sort, but a plug of cotton wool works just as well. Leave the mixture in the warm for a few days until bubbling stops.



   Allow the yeast to settle, and pour off the solution so that it can be fractionally distilled, collecting the fraction which boils at 78°C. (See the diagram for the fractional distillation of an alcohol/water mixture in Chapter 11 of the book.)

continued . . .

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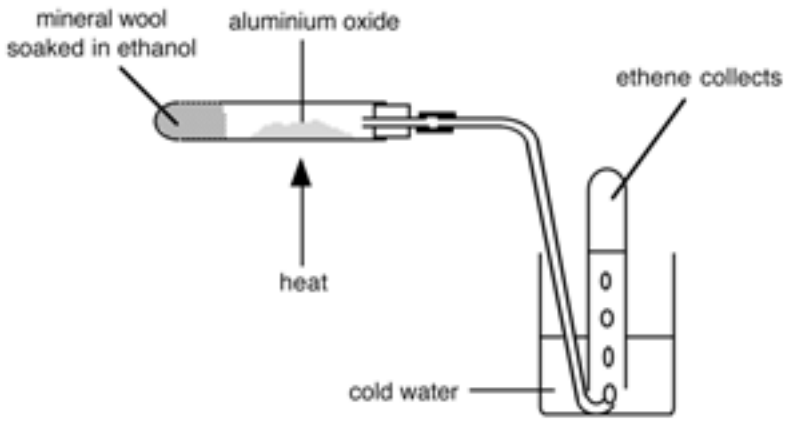
Finally, pass ethanol vapour over hot aluminium oxide using the apparatus on the right, and collect several tubes of ethene.



5. A Google search on *biofuels disadvantages* will produce lots of useful information. Some of the points you will find include:

Increases in food prices:

Crops such as maize (US: corn) used to produce ethanol can't at the same time be used for human consumption. If the supply of these crops going for food falls, but demand stays the same (or, more likely, increases due to increasing population), prices are bound to rise.

Subsidies going to biofuel crops (whether they are food crops or not) cause farmers to divert land away from food production. Again food supply falls, and so prices rise.

Carbon dioxide balance:

Some biofuel crops are being grown on previously undisturbed land, including rain forests. Cutting down and burning rain forests to make space for biofuel crops adds lots of carbon dioxide to the atmosphere. Forests are also much more efficient at removing carbon dioxide from the atmosphere than crops are.

(There are several other disadvantages of current biofuels, but they don't directly address the question.)

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Chapter 20

1. petroleum gases, gasoline, kerosine, diesel oil (gas oil), fuel oil, bitumen. Use for each (see text)

2. a) Compound of carbon and hydrogen only.

   b) $C_7H_{16}(l) + 11O_2(g) \longrightarrow 7CO_2(g) + 8H_2O(l)$

   c) (i) turns to vapour easily / at a low temperature
   (ii) C_8H_{18}. Smaller molecules aren't as strongly attracted to their neighbours as bigger ones (weaker intermolecular attractions). It takes less energy to separate them and so they vaporise at lower temperatures.

   d) Incomplete combustion leads to formation of carbon monoxide which is very poisonous. It combines with haemoglobin preventing transport of oxygen around the blood.

3. a) Crude oil produces too many larger hydrocarbons / not enough of the desirable smaller ones. Cracking introduces C=C double bonds which are more reactive and therefore more useful.

   b) Heat the vaporised fraction in the presence of a silicon dioxide + aluminium oxide catalyst at 500°C.

   c) $C_{11}H_{24} \longrightarrow 2C_2H_4 + C_7H_{16}$

   d) Any other valid cracking equation starting with $C_{11}H_{24}$. For example:

   $C_{11}H_{24} \longrightarrow C_2H_4 + C_9H_{20}$
   or $C_{11}H_{24} \longrightarrow C_2H_4 + C_3H_6 + C_6H_{14}$
   or lots of other variants. In each case, at least one hydrocarbon should be an alkane (C_nH_{2n+2}), and at least one an alkene (C_nH_{2n}).

4. This is entirely open to the student's imagination and ability to think both logically and laterally. It is impossible to suggest "right" answers.

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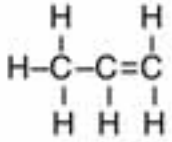
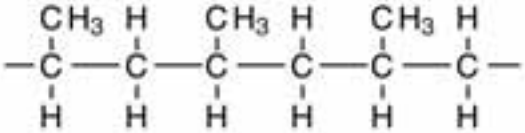
Chapter 21

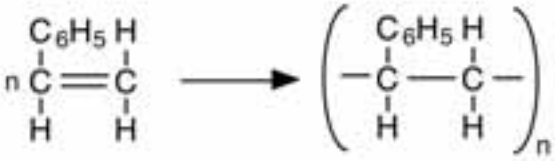
1. a) Joining up of lots of little molecules (the monomers) to make one big one (a polymer).

b) 

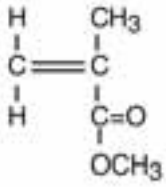
c) 

(The "continuation" bonds at each end are an important part of this structure. Marks will be lost in an exam if they are omitted.)

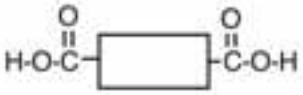
d) Joining two or more molecules together without anything being lost in the process.

e) 

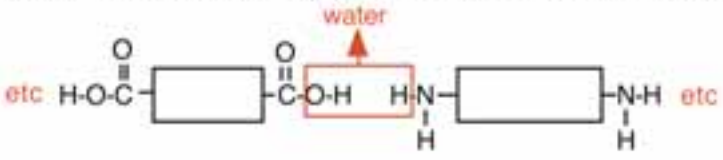
f) Drawing the molecule to show its relationship with the structure of the polymer as drawn in the question:

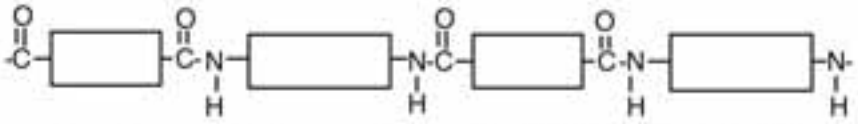


2. a) Drawing 1,6-diaminohexane as 

and hexandioic acid as 

(i) In a condensation reaction, when two molecules join together a small molecule is lost in the process. When the two molecules above join together, a molecule of water is lost every time they come together. In a condensation polymerisation reaction, this happens repeatedly.



(ii) 

b) (i) There will be four more CH_2 groups in the "box" in the part of the diagram which comes from the dioic acid. This time, the box from the dioic acid will be longer than the one from the diamine.

(ii) The bonding between the two monomers will be identical, as will the size of the diamine.

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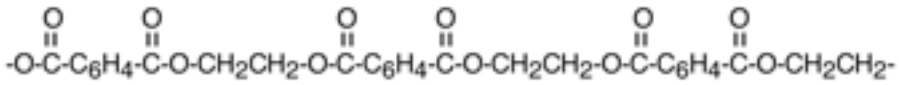
3. 

(For home-schooling parents: Work this out by drawing the structures of the two monomers, as shown in the question, alternately in a row. Then remove water from -OH groups which find themselves next door to each other, and join up what is left.)

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End of Section D Questions

1. a) Compound (1) of carbon and hydrogen only (1).

   b) The higher the number of carbons, the higher the boiling point (1).

   c) fractional distillation (1)

   d) any valid use (see text; "as a fuel" isn't sufficient) (1)

   e) $C_{10}H_{22}$ (1)

   f) $C_{15}H_{32}(l) + 23O_2(g) \longrightarrow 15CO_2(g) + 16H_2O(l)$ (2 marks - deduct 1 for incorrect state symbol for the alkane)

   g) Pass through lime water (1). Turns milky (or alternative) (1).

   h) Incomplete combustion (1) produces carbon monoxide (1). Poisonous (1). Combines with haemoglobin preventing oxygen transport in blood (1).

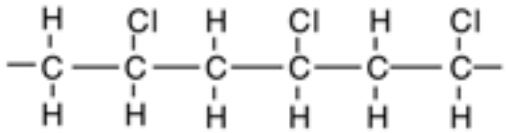
2. a) Saturated: all carbon-carbon bonds are single (1). Unsaturated: contains at least one C=C bond (1).

   b) cracking (1)

   c) (i) $C_{17}H_{36} \longrightarrow 2C_2H_4 + C_3H_6 + C_{10}H_{22}$ (2 marks - allow one for $C_{10}H_{22}$ even if equation is unbalanced. Ignore state symbols, even if they are wrong.)
   (ii) alkane (1)

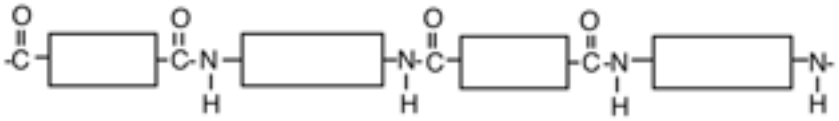
   d) Pass through (or shake with) bromine water (1). Decolourisation (1) shows the presence of C=C.

3. a) Joining up lots of small molecules (1) to make a large molecule (1).

   b) 

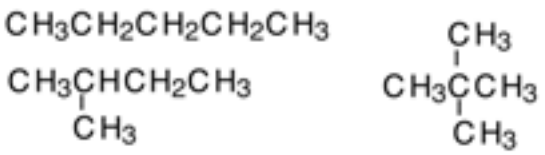
   (2 marks - must include "continuation" bonds for full marks)

   c) A reaction in which a small molecule is lost when two others join together. (1)

   d) 

   (3 marks: alternating different sized or shaped blocks (1). CO and NH groups attached to the correct blocks - i.e. 2 x CO groups on one block, and 2 x NH groups on the other - and bonded correctly (1). "Continuation bonds" at either end of the chain (1).)

4. a) Molecules with the same molecular formula (1) but different structural formulae (1).

   b) 

   (1 mark per structure)

   c) pentane (1)

5. a) Sugar (1) solution (1) plus yeast (1). Leave in warm place for several days (1). Some means of allowing CO_2 to escape without allowing air in (1).

   b) Water: 100°C (1); ethanol: 78°C (1)

   c) $CH_2{=}CH_2(g) + H_2O(g) \longrightarrow CH_3CH_2OH(g)$ (1) (Don't penalise incorrect state symbols.)

   d) 2 of: 300°C. 60 - 70 atm. Phosphoric acid catalyst. (2 x 1 = 2)

   e) (i) fermentation (1). Renewable (1)
   (ii) fermentation (1). Gentle conditions (1)
   (iii) hydration (1). Fermentation is a batch process (1)

Answers

(To save endless repetition, wherever they are included, comments are intended for home-schooling parents who may well lack confidence in this area.)

Chapter 22

1. If you had 100 typical atoms, the total mass would be (60.2 x 69) + (39.8 x 71) = 6980 (3 sig figs)
   RAM is therefore 6980/100 = 69.8

2. If you had 100 atoms of Si-28 and the others in the correct proportion, the total number of atoms would be 100+5.10+3.36 = 108.46
   The total mass would be (100 x 28) + (5.10 x 29) + (3.36 x 30) = 3048.7
   RAM = 3048.7/108.46 = 28.1

3. a) The relative atomic mass of an element is the weighted average mass of the isotopes of the element. It is measured on a scale on which a carbon-12 atom has a mass of exactly 12 units.

   b) Repeat the sum in Q1 twice to give Cu = 63.6 and S = 32.1. Add these together to give CuS = 95.7

4. a) 44
   b) 132
   c) 286
   d) 392
   e) 392
   (The common mistakes in c) and e) would be not to multiply the whole water molecule by 10 or 6. So for example in c) the mass of the $10H_2O$ is 180. Students will commonly and wrongly come up with 36 for this by multiplying the H_2 by 10 but not the O as well. Work out the mass of the whole H_2O first and then multiply it by the number in front. That way you won't make this mistake.)

5. a) 81.8%
   b) 51.2%
   (In each case, work out the M_r and the mass of the element you are interested in and find the percentage.)

6. a) 46.7%
   b) 13.9%
   c) 35%
   d) 21.2%
   (Be careful of the cases where there are two nitrogen atoms in the fertiliser (all except KNO_3). The masses of the nitrogen in those cases will be 28 and not 14.)

7. In each case, work out the M_r by adding up the RAMs, and then attach the unit "g" to give the mass of 1 mole. Then scale it by multiplying by the number of moles you want.
   a) 331 g
   b) 68.8 g
   c) 68.64 g
   (In c), the M_r should be 286. Care with the water! See above. Strictly, this number shouldn't be quoted to more than 2 significant figures, because the number of moles is only quoted to that accuracy.)

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8. In each case, work out the mass of 1 mole as above, and then work out how many moles you've got in the stated mass.
   a) 0.2
   b) 17900 (or 17857 although this is accurate to more significant figures than the RAM). You have to divide 1,000,000 grams by 56 g (the mass of 1 mole of Fe)
   c) 5×10^{-4} (0.0005)

9. These are a random mixture of the sort of conversions that have been explored in earlier examples. The only working is shown for a slight variant.
   a) 234 g
   b) 0.5 mol
   c) 25 mol
   d) 10 g
   e) 40 g
   f) 250 (If 0.004 mol weighs 1 g, then 1 mol weighs 1/0.004 g = 250 g. The relative formula mass is the mass of 1 mole, but without the unit "g".)

10.a)

	K	N	O
combining mass	5.85 g	2.10 g	4.80 g
No of moles of atoms	5.85/39 = 0.15	2.10/14 = 0.15	4.80/16 = 0.3
Ratio of moles	1	1	2

Empirical formula = KNO_2

b)

	Na	S	O
combining mass	3.22 g	4.48 g	3.36 g
No of moles of atoms	3.22/23 = 0.14	4.48/32 = 0.14	3.36/16 = 0.21
Ratio of moles (divide by smallest number)	1 simplifies to 2	1 2	1.5 3

Empirical formula = $Na_2S_2O_3$

c)

	carbon	hydrogen	bromine
given %	22.0	4.6	73.4
combining mass in 100g	22.0 g	4.6 g	73.4 g
No of moles of atoms	22.0/12 = 1.833	4.6/1 = 4.6	73.4/80 = 0.9175
Ratio of moles (divide by smallest number)	2	5	1

Empirical formula = C_2H_5Br

11.a) Calculate the mass of oxygen in the compound (2.84 - 1.24 g), and then a straightforward empirical formula sum as before will lead to P_2O_5

(b) P_2O_5 has a M_r of 142. To get a M_r of 284 needs twice as many atoms - so P_4O_{10}

12.a)

	carbon	hydrogen	oxygen
given %	66.7	11.1	22.2
combining mass in 100g	66.7 g	11.1 g	22.2 g
No of moles of atoms	66.7/12 = 5.558	11.1/1 = 11.1	22.2/16 = 1.3875
Ratio of moles (divide by smallest number)	4	8	1

Empirical formula = C_4H_8O

b) If you add up C_4H_8O, you get 72. The molecular formula is the same as the empirical formula.

13.You know the mass of anhydrous sodium sulphate (1.42 g)
You can work out the mass of water of crystallisation (3.22 - 1.42 g = 1.8 g)

You can work out the mass of 1 mole of sodium sulphate, Na_2SO_4 = 142 g
and the mass of 1 mole of water = 18 g

Number of moles of sodium sulphate = 1.42/142 = 0.01 mol
Number of moles of water = 1.8/18 = 0.1 mol

So for every 1 mole of sodium sulphate, there are 10 moles of water.

14.Work out the mass of $CaSO_4$ = 44.14 - 37.34 = 6.8 g
Work out the mass of water = 45.94 - 44.14 = 1.8 g
Work out how many moles you've got of each and then compare them.
You should find that n = 2.

15.1 mol of water (18 g) contains 6×10^{23} molecules.

Therefore, 18 cm^3 of water contains 6×10^{23} molecules. (Density is 1 g cm^{-3})
1 cm^3 of water contains $6 \times 10^{23} / 18 = 3.333 \times 10^{22}$ molecules.
0.05 cm^3 of water contains $0.05 \times 3.333 \times 10^{22} = 1.67 \times 10^{21}$ molecules.

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Chapter 23

1. From the equation, 4 mol Na gives 1 mol Ti.
Substituting masses: 4 x 23 g Na give 48 g Ti
i.e. 92 g Na give 48 g Ti
Because the ratio is bound to be the same 92 tonnes Na give 48 tonnes Ti.
Therefore, 92/48 tonnes Na give 1 tonne Ti.

   Mass of Na needed = 1.92 tonnes

2. The equation shows that 1 mol $AlCl_3$ gives 3 mol AgCl
Substituting masses: (27 + (3x35.5)) g $AlCl_3$ gives 3 x (108 + 35.5) g AgCl
i.e. 133.5 g $AlCl_3$ gives 3 x 143.5 g AgCl = 430.5 g AgCl
So, 2.67 g $AlCl_3$ gives 2.67/133.5 x 430.5 g AgCl = 8.61 g

   (For students whose maths isn't very good, insert another step by working out what 1 g of $AlCl_3$ would give (divide by 133.5) and then multiplying that by 2.67. The same sort of technique can be used in all examples of this type.)

3. a) From the first equation: 1 mol $CaCO_3$ gives 1 mol CaO
Substituting masses: 100 g $CaCO_3$ gives 56 g CaO
This ratio will be the same for tonnes as for grams:
100 tonnes $CaCO_3$ gives 56 tonnes CaO
So, 1 tonne $CaCO_3$ gives 0.56 tonnes CaO

   b) In the second equation 1 mol CaO needs 1 mol H_2O
56 g CaO needs 18 g H_2O
Or, 56 tonnes CaO needs 18 tonnes H_2O
So, 0.56 tonnes CaO needs 0.18 tonnes H_2O

   c) Again from the second equation, 1 mol CaO produces 1 mol $Ca(OH)_2$
56 g CaO gives (40 + 2 x (16 + 1)) g $Ca(OH)_2$ = 74 g $Ca(OH)_2$
56 tonnes CaO gives 74 tonnes $Ca(OH)_2$
0.56 tonnes CaO gives 0.74 tonnes $Ca(OH)_2$

4. a) Tracing the equations through, 1 mol CuO will eventually produce 1 mol $CuSO_4.5H_2O$
80 g CuO will give 64 + 32 + (4x16) + (5 x 18) g $CuSO_4.5H_2O$ = 250 g
4 g CuO will give 4/80 x 250 g $CuSO_4.5H_2O$ = 12.5 g

   b) Percentage yield = 11.25 / 12.5 x 100% = 90%

5. a) From the equation: 1 mol Cr_2O_3 reacts with 2 mol Al
(2 x 52) + (3 x 16) g Cr_2O_3 reacts with 2 x 27 g Al
152 g Cr_2O_3 reacts with 54 g Al
Or, 152 tonnes Cr_2O_3 reacts with 54 tonnes Al
So, 1 tonne Cr_2O_3 reacts with 54/152 tonnes Al = 0.355 tonnes Al

   (b) 1 mol Cr_2O_3 produces 2 mol Cr
152 g Cr_2O_3 produces 104 g Cr
152 tonnes Cr_2O_3 produces 104 tonnes Cr

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1 tonne Cr_2O_3 produces 104/152 tonnes Cr = 0.684 tonnes Cr

6. 4 mol FeS_2 produces 2 mol Fe_2O_3 and 8 mol SO_2
(4 x 120) g FeS_2 produces (2 x 160) g Fe_2O_3 and (8 x 64) g SO_2
480 g FeS_2 produces 320 g Fe_2O_3 and 512 g SO_2
Or, 480 tonnes FeS_2 produces 320 tonnes Fe_2O_3 and 512 tonnes SO_2
1 tonne of ore contains 0.5 tonnes FeS_2
So, 0.5 tonnes FeS_2 produces 0.5/480 x 320 tonnes Fe_2O_3 and 0.5/480 x 512 tonnes SO_2
Therefore (a) mass of Fe_2O_3 = 0.333 tonnes, and (b) mass of SO_2 = 0.533 tonnes

7. a) 1 mol Cl_2 weighs 71 g
If 24000 cm^3 (at rtp) weighs 71 g
200 cm^3 weighs 200/24000 x 71 g = 0.592 g

b) 1 mol O_2 weighs 32 g
So 32 g O_2 occupies 24000 cm^3 at rtp
and 0.16 g O_2 occupies 0.16/32 x 24000 cm^3 at rtp = 120 cm^3
(or you could have worked in dm^3 - giving 0.12 dm^3)

c) The mass of 1 mole is what would occupy 24 dm^3 at rtp
If 1 dm^3 weighs 1.42 g, 24 dm^3 weighs 24 x 1.42 g = 34.1 g

8. The equation says that 1 mol Mg gives 1 mol H_2
So, 24 g Mg gives 24000 cm^3 H_2 at rtp
Therefore, 0.240 g Mg gives 0.240/24 x 24000 cm^3 H_2 = 240 cm^3 H_2

9. The equation says that 2 mol KNO_3 gives 1 mol O_2
So, (2 x 101) g KNO_3 gives 24 dm^3 O_2
Or, 202 g KNO_3 gives 24 dm^3 O_2
Therefore, to get 1 dm^3, you would need 202/24 g KNO_3 = 8.42 g

10. The equation says that 1 mol MnO_2 gives 1 mol Cl_2
So, 87 g MnO_2 gives 24000 cm^3 Cl_2
Therefore, 2.00 g MnO_2 gives 2.00/87 x 24000 cm^3 Cl_2 = 552 cm^3

11.a) 1 mol $BaSO_4$ weighs 233 g
So, 0.328 g $BaSO_4$ is 0.328 / 233 mol = 1.41 x 10^{-3} mol (0.00141 mol)

b) The second equation shows that 1 mol $BaSO_4$ comes from 1 mol Na_2SO_4
Therefore the mixture contained 1.41 x 10^{-3} mol Na_2SO_4

c) 1 mol Na_2SO_4 weighs 142 g
Therefore 1.41 x 10^{-3} mol weighs 1.41 x 10^{-3} x 142 g = 0.200 g

d) The total mixture of sodium sulfate and sodium sulfite weighed 1.000 g.
Remaining sodium sulfite weighs 1.000 - 0.200 g = 0.800 g
Percentage remaining = 0.800/1.000 x 100 = 80.0%

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Chapter 24

1. A current of 0.50 amps for 1 hour = 0.50 x 60 x 60 coulombs
= 1800 coulombs

1 mol of copper deposited needs 2 mol of electrons = 2 x 96000 coulombs
= 192000 coulombs

If 192000 coulombs causes 1 mol Cu to be deposited
then 1800 coulombs causes 1800/192000 mol Cu to be deposited

1 mol Cu weighs 64 g

1800/192000 mol Cu weighs 1800/192000 x 64 g = 0.60 g

2. a) No of coulombs = 0.350 x 1000
= 350

1 mol Pb (207 g) is deposited by 2 mol electrons = 2 x 96000 coulombs
= 192000 coulombs

350 coulombs deposit 350/192000 x 207 g Pb = 0.377 g

b) 1 mol O_2 (24000 cm^3 at rtp) is given off by 4 mol electrons = 4 x 96000 coulombs
= 384000 coulombs

350 coulombs will release 350/384000 x 24000 cm^3 at rtp = 21.9 cm^3

3. a) No of coulombs = 0.40 x 75 x 60
= 1800

1 mol Cu (64 g) is deposited by 2 mol electrons = 2 x 96000 coulombs
= 192000 coulombs

1800 coulombs will deposit 1800/192000 x 64 g Cu = 0.60 g

(b) The equations show that, for a given number of electrons flowing, the mass of copper gained by the cathode is exactly the same as the mass of copper lost from the anode.

Therefore, of the 0.80 g actually lost, 0.60 g is pure copper.

Percentage purity = 0.60/0.80 x 100 % = 75%

4. The equation shows that 1 mol Al (27 g) is produced from 3 mol e^- = 3 x 96000 coulombs
= 288000 coulombs

1 tonne (1000000 g) would be produced by 1000000 / 27 x 288000 coulombs
= 1.067×10^{10} coulombs

The current has flowed for 24 hours = 24 x 60 x 60 secs = 86400 secs

Coulombs = amps x secs,
and so amps = coulombs/secs
Current needed = 1.067×10^{10} / 86400 amps
= 123000 amps

(Yes, that's pretty big - but it's the sort of currents they actually use!)

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5. a) Working from the cobalt figure to start with:

1 mol Co (59 g) is deposited by 2 mol electrons = 2 x 96000 coulombs
= 192000 coulombs

0.295 g Co is deposited by 0.295/59 x 192000 coulombs = 960 coulombs

b) For chromium, 1 mol Cr (52 g) is deposited by 3 mol electrons = 3 x 96000 coulombs
= 288000 coulombs

The same quantity of electricity (960 coulombs) flows through both beakers.

960 coulombs will deposit 960/288000 x 52 g Cr = 0.173 g

6. There are two ways of doing this calculation. You could do it exactly as in Q6, but notice that the question doesn't give a value for the faraday. The solution below shows a short cut method, but there is no reason why you can't do it by the longer method in Q6 if you want to. You should get the same answer either way.

Notice that 2 mol of electrons are needed to deposit 1 mol of either lead or copper.
That means that you will always get the same number of moles of both.

Moles of copper = 0.64/64 = 0.01

Therefore, moles of lead also = 0.01

mass of lead = 0.01 x 207 g = 2.07 g

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Chapter 25

1. a) Bonds broken: 4 x C-H = 4 x (+413) = +1652
1 x Br-Br = + 193
total = +1845

Bonds made: 3 x C-H = 3 x (-413) = -1239
1 x C-Br = - 290
1 x H-Br = - 366
total = -1895

Overall change = +1845 - 1895 = -50 kJ (exothermic)

b) Bonds broken: 1 x H-H = +436
1 x Cl-Cl = +243
total = +679

Bonds made: 2 x H-Cl = 2 x (-432) = -864

Overall change = +679 - 864 = -185 kJ (exothermic)

c) Bonds broken: 2 x H-H = 2 x (+436) = +872
1 x O=O = +498
total = +1370

Bonds made: 4 x O-H = 4 x (-464) = -1856

Overall change = +1370 - 1856 = -486 kJ (exothermic)

2. a) Her first two results weren't reliable - there was too much difference between them.

b) Two of: Danger of fire from burning hexane if spilt. Danger of scalding from hot water. Danger of cuts if fragile thermometer or flask are broken. (Plus anything else relevant to your school's risk assessment policies.)

c) Heat evolved = mass x specific heat x temperature rise.

Mass is taken as the mass of water = 100 g
Specific heat = 4.18 J g^{-1} $°C^{-1}$
Temperature rise = 55.0 - 19.0 = 36.0°C

Heat evolved = 100 x 4.18 x 36.0 J = 15048 J (or 15.048 kJ or 15.0 kJ to 3 sf)

d) Mass of hexane burnt = 35.62 - 35.23 g = 0.39 g

Heat evolved per gram = 15.0 / 0.39 kJ = 38.5 kJ

e) 1 mol hexane weighs 86 g

Heat evolved per mole = 38.5 x 86 kJ = 3310 kJ

(It is important to notice that we have introduced rounding errors here. Every time you feed a rounded answer into the next part of the calculation, you introduce a small extra error. If you simply used the number on your calculator for the next step rather than the rounded one, you would get a final answer of 3320 kJ (to 3 sf). On the other hand, there is no simple way of showing that you have done that in an exam, and so you could end up with an answer inconsistent with your working.)

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f) There must be some precision here, and the reason given must have produced a higher value for the heat evolved. For example:

- Misreading one of the weighings of the spirit burner so that it looked as if less hexane had been burnt that was really the case.
- Misreading the thermometer to give a final temperature higher than it should have been.
- Adding less than 100 cm^3 of water to the flask, so that the temperature went up more than it should because the heat was going into a smaller volume of water.

g) Massive heat losses. Not all of the heat from the burner goes into the water in the flask; much will go straight into the air. No account is taken of the heat being used to warm up the flask or the thermometer. Heat is lost from the water to the surrounding air as the water warms up, and the higher its temperature, the faster it loses heat.

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Chapter 26

1. 1 mol H_2SO_4 weighs 98 g
   4.90 g is 4.9/98 mol = 0.0500 mol
   Concentration = 0.0500 mol dm^{-3} (0.0500 to show that the answer is accurate to 3 sig figs)

2. KOH is 0.200 mol dm^{-3}
   1 mol KOH weighs 56 g
   0.200 mol weighs 0.200 x 56 g = 11.2 g
   Concentration = 11.2 g dm^{-3}

3. Relative formula mass Na_2CO_3 = 106
   So 1 mol Na_2CO_3 weighs 106 g
   0.100 mol weighs 10.6 g
   To get a 0.100 mol dm^{-3} solution you would have to dissolve 10.6 g in 1 dm^3 (1000 cm^3)
   If you only wanted 100 cm^3 of solution you would only need 1.06 g Na_2CO_3

4. No of moles of copper(II) sulphate = 20/1000 x 0.100
   = 0.00200 mol

   Equation shows that 1 mol $CuSO_4$ produces 1 mol $BaSO_4$
   No of moles $BaSO_4$ formed = 0.00200 mol

   1 mol $BaSO_4$ weighs 233 g
   0.00200 mol $BaSO_4$ weighs 0.00200 x 233 g = 0.466 g

5. 25.0 cm^3 of 2.00 mol dm^{-3} HCl contains 25.0/1000 x 2.00 mol = 0.0500 mol

   The equation shows that you only need half the number of moles of calcium carbonate as of hydrochloric acid.

   No of moles of $CaCO_3$ = 1/2 x 0.0500 mol
   = 0.0250 mol

   I mole of $CaCO_3$ weighs 100 g.
   0.0250 mol $CaCO_3$ weighs 0.0250 x 100 g = 2.50 g

6. No of moles of H_2SO_4 = 25/1000 x 1.0 = 0.025 mol
   The equations show that 1 mol CuO will produce 1 mol of $CuSO_4.5H_2O$
   1 mol of $CuSO_4.5H_2O$ weighs 250 g.
   Mass produced = 0.025 x 250 g = 6.25 g

7. a) No of moles of NaOH solution = 25.0/1000 x 0.400 mol = 0.0100 mol
   The equation shows that you need half as many moles of sulfuric acid = 0.00500 mol
   The acid has a concentration of 0.200 mol dm^{-3} . . .
   . . . which means that 0.200 mol is contained in 1000 cm^3
   Therefore 0.00500 mol is contained in 0.00500/0.200 x 1000 cm^3 = 25.0 cm^3

   b) 1 mol of $CaCO_3$ weighs 100 g.
   Therefore 10.0 g is 0.100 mol
   From the equation, you need twice as many moles of HCl = 0.200 mol
   The acid has a concentration of 2.00 mol dm^{-3} . . .

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. . . which means that 1000 cm^3 contains 2.00 mol
Therefore 0.200 mol is contained in 100 cm^3.

8. (For home-schooling parents: In each of these examples, start from what you know most about and work from there. If a student needs to put extra steps in, encourage them to do so. For example, if there are 0.2 mol in 1000 cm^3, there are 0.2/1000 mol in 1 cm^3 and 25 x 0.2/1000 mol in 25 cm^3.

   Or, if there are 0.05 mol in 24 cm^3, there are 0.05/24 mol in 1 cm^3 and 1000 x 0.05/24 mol in 1000 cm^3.

   There is no embarrassment in doing this. All that matters is getting the answer right!)

   a) No of moles of NaOH = 25/1000 x 0.100 = 0.00250 mol

   The equation shows a 1:1 reaction.

   No of moles of HNO_3 = 0.00250 mol
   That's in 20.0 cm^3.

   Concentration of HNO_3 = 1000/20.0 x 0.00250 mol dm^{-3} = 0.125 mol dm^{-3}

   b) No of moles of HNO_3 = 30.0/1000 x 0.100 = 0.00300 mol

   The equation shows that you need half as many moles of sodium carbonate as of nitric acid.

   No of moles of Na_2CO_3 = 1/2 x 0.00300 mol
   = 0.00150 mol
   That's in 25.0 cm^3.

   Concentration of Na_2CO_3 = 1000/25.0 x 0.00150 mol dm^{-3} = 0.0600 mol dm^{-3}

   c) No of moles of K_2CO_3 = 25.0/1000 x 0.250 = 0.00625 mol

   The equation shows that you need twice as many moles of ethanoic acid as of potassium carbonate.

   No of moles of CH_3COOH = 2 x 0.00625 mol
   = 0.0125 mol

   That's in 12.5 cm^3.

   Concentration of CH_3COOH = 1000/12.5 x 0.0125 = 1.00 mol dm^{-3}

9. a) No of moles of HCl = 18.8/1000 x 0.04 mol = 7.52×10^{-4} mol (0.000752 mol)
   The equation shows that this reacts with half that number of moles of calcium hydroxide.
   No of moles of $Ca(OH)_2$ = 3.76×10^{-4} mol (0.000376 mol)
   That's in 25 cm^3.
   Concentration of $Ca(OH)_2$ = 1000/25 x 3.76×10^{-4} mol dm^{-3} = 0.0150 mol dm^{-3}

   b) 1 mol $Ca(OH)_2$ weighs 74 g.
   Concentration = 0.0150 x 74 g dm^{-3} = 1.11 g dm^{-3}

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End of Section E Questions

1. a) The relative atomic mass of an element is the weighted average mass of the isotopes of the element.(1) It is measured on a scale on which a carbon-12 atom has a mass of exactly 12 units.(1).

   b) The total mass of 100 atoms = (75 x 35) + (25 x 37) = 3550 (1)
   The average mass of 1 atom = 3550/100 = 35.5 (1)

   c) 1 mole of KI weighs 39 + 127 g = 166 g (1)
   4.15 g of KI = 4.15/166 mol = 0.025 mol (1)
   From the equation, 2 mol KI gives 1 mol I_2
   Number of moles of I_2 = 0.025/2 mol = 0.0125 mol (1)
   Mass of I_2 = 0.0125 x 254 g = 3.175 g (1)

   d) 1 mole of chlorine, Cl_2, weighs 71 g
   24.0 dm^3 weighs 71 g (1)
   1 dm^3 weighs 71/24 g = 2.96 g
   Density = 2.96 g dm^{-3} (1)

2. a) Mass of lead = 24.16 - 17.95 = 6.21 g (1)

   b) Mass of oxygen = 24.80 - 24.16 g = 0.64 g (1)

c)	Pb		O	
Combining masses	6.21 g		0.64 g	
No of moles of atoms	6.21/207 = 0.03		0.64/16 = 0.04	(1)
Ratio of moles	3	:	4	(1)
Empirical formula:		Pb_3O_4 (1)		

   d) RFM of PbO_2 = 239 (1)
   % Pb = 207/239 x 100 = 86.6 % (1)

3. a) RFM CO_2 = 44 (or mass of 1 mole = 44g) (1)
   No of moles = 0.55/44 = 0.0125 (1)

   b) 0.0125 mol (1) (Equation shows 1:1 relationship between calcium carbonate and CO_2)

   c) RFM $CaCO_3$ = 100 (or mass of 1 mole = 100g) (1)
   No of moles = 0.0125 x 100 = 1.25 g (1)

   d) % of $CaCO_3$ in sand = 1.25/1.86 x 100 =67.2 % (1)

4. a) (i) RFM $CuFeS_2$ = 184 (1)
   % of copper = 64/184 x 100 = 34.8 % (1)

   (ii) % of copper in total ore would be 0.5 x 34.8 % = 17.4% (1)
   Therefore 1 tonne contains 0.174 tonnes of Cu (1) (or any other valid method)

   b) (i) 1 mol Cu gives 1 mol $Cu(NO_3)_2$ (1)
   64 g Cu gives 188 g $Cu(NO_3)_2$ (1)
   8.00 g Cu gives 8.00/64 x 188 g $Cu(NO_3)_2$ = 23.5 g (1)

(ii) 1 mol Cu gives 2 mol NO_2

64 g Cu gives 2 x 24.0 dm^3 NO_2 = 48.0 dm^3 (1)

8.00 g Cu gives 8.00/64 x 48.0 dm^3 = 6.00 dm^3 (1)

5. a) 4 mol FeS_2 gives 2 mol Fe_2O_3
4 x 120 g = 480 g FeS_2 gives 2 x 160 g = 320 g Fe_2O_3 (1)
480 kg FeS_2 gives 320 kg Fe_2O_3 (1)

b) 480 g FeS_2 would give 4 mol Fe = 4 x 56 g = 224 g Fe (1)
480 kg FeS_2 gives 224 kg Fe (1)

c) 480 g pyrite gives 8 x 24.0 dm^3 SO_2 (1) = 192 dm^3 (1)
480 kg gives 1000 x 192 dm^3 = 192000 dm^3 (1)

d) 96000 dm^3 (1) (half the answer to part (c) - using Avogadro's Law)

6. a) Moles of HCl = 32.8/1000 x 0.100 = 3.28 x 10^{-3} mol (1)

b) 3.28 x 10^{-3}/2 mol = 1.64 x 10^{-3} mol (1)

c) 1000/25.0 x 1.64 x 10^{-3} (1) = 0.0656 mol dm^{-3} (1)

d) RFM $Sr(OH)_2$ = 122 (1) (or mass of 1 mol = 122 g)
Concentration = 0.0656 x 122 g dm^{-3} = 8.00 g dm^{-3}

7. a) 1000 cm^{-3} needs 40 x 0.100 g = 4.00 g (1)
250 cm^3 needs 1.00 g (1)

b) Moles of NaOH = 25.0/1000 x 0.100 = 2.5 x 10^{-3} mol (1)
Need half the number of moles of H_2SO_4 (1)
Moles of H_2SO_4 = 0.5 x 2.5 x 10^{-3} = 1.25 x 10^{-3} mol (1)
Concentration of acid = 1000/20.0 x 1.25 x 10^{-3} = 0.0625 mol dm^{-3} (1)

c) (i) 0.0625 mol H_2SO_4 reacts with 0.0625 mol Mg
Mass Mg = 0.0625 x 24 g (1) = 1.50 g (1)

(ii) 0.0625 mol H_2SO_4 gives 0.0625 mol H_2
Vol of H_2 = 0.0625 x 24.0 dm^3 (1) = 1.50 dm^3 (1)

8. a) 0.64 g Cu is 0.64/64 mol = 0.01 mol (1)
Same number of moles of Cl_2 formed.
Vol Cl_2 = 0.01 x 24.0 dm^3 = 0.24 dm^3 (1)

b) (i) 1 mol Mg (24 g) produced by 2 mol e^- (1)
1.20 tonne Mg produced by 1,200,000/24 x 2 mol e^- =100,000 mol e- (1)
(ii) No of coulombs = 100,000 x 96000 = 9.6 x 10^9 (1)

(iii) coulombs = amps x time in secs
Time in secs = 9.6 x 10^9 / 250,000 = 38400 secs (1)
Time in hours = 38400 /3600 = 10.7 hours (1)