Relatively low cost of petroleum in Australia, and discovery of reserves here.

3. (a) mixture of hydrocarbons, mainly $C_5$ to $C_{12}$
   (b)

| Ethanol | Petrol |
|---|---|
| Renewable. | Non-renewable. |
| Spills more easily biodegraded or diluted. | Spills do not biodegrade and cause much damage to living organisms. |
| But harder to contain and recover. | Spills may be easier to be contained and recovered |
| Combustion is more complete. | More pollutants produced. |
| At present ethanol cannot be produced at a competitive cost or in the volume required to replace petrol. | More readily available at present but supplies will eventually run out and will need to be replaced by some other source of energy. |

4. (a) Heat energy released by the combustion of 1 mole of a fuel.
   (b) (i)

| Fuel | Heat of combustion (kJ/g) |
|---|---|
| Hydrogen | 142.5 |
| Coke (carbon) | 32.8 |
| Methane | 55.6 |
| Ethane | 52 |
| Propane | 50.5 |
| Ethyne (acetylene) | 50 |
| Methanol | 22.7 |
| Ethanol | 29.7 |

   (ii) hydrogen
   (iii) rocket fuel
   (c) safety, ignition temperature, weight of fuel

5. (a) 16.042 g
   (b) (i) 16 680 kJ
   (ii) 222 500 kJ
   (c) Loss of heat to environment, e.g. air and container.
   (d) It is still possible to compare the heats of combustion of a number of fuels, as long as they are all measured in the same way.

6. (a) Various. For example:
   List the steps in your method, starting each step with a verb.
   Describe how you set up the equipment you used (or state the apparatus was set up as shown in the diagram). You probably used equipment such as that shown in Figure 16.1. Remember to label the diagram fully.
   Include instructions detailing how you measured the volume of fuel used — did you weigh it before and after combustion for a set time, or did you measure a volume of fuel and burn it all?
   (b) Various. For example:
   This experiment provides notoriously inaccurate results — which provides you with the opportunity to discuss the disadvantages of using it to calculate the actual heat of combustion, compared to its usefulness in comparing heats of combustion of different fuels (same errors for all).
   (c) Various, e.g. the inaccuracy in this experiment provides lots of scope for suggesting ways to improve your experimental design so as to avoid loss of heat to the environment.
   (d) Various, e.g. you are dealing with flammable substances, so safety is very important — check the school safety package for instructions regarding each of the alkanols you used and describe general safety procedures as well as any specific for each fuel.

7. (a) 312.07 kJ $mol^{-1}$
   (b) Very inaccurate. Calculated heat of combustion is 1 367 kJ $mol^{-1}$ compared to the experimental heat of combustion of 312.07 kJ $mol^{-1}$. The experiment needs to be modified to reduce the loss of heat to the surroundings.

8. (a) Value placed on using personal transport for work and recreation (using fossil fuels) has increased the demand for fuels.
   (b) Increased demand and useage has led to a shortage of fossil fuels as they are non-renewable. Attempts to find replacements for fossil fuels has led to technological developments such as the development of solar cells, electric cars and the production of ethanol from renewable sources.

9. (a) molar heat of combustion
   (b) Ethanol is renewable, petrol is non-renewable.
   (c) sugar cane, corn
   (d) distillation
   (e) ethanol

## 17 Assumed Knowledge

1. voltmeter
2. electrodes
3. ions
4. decomposition of a compound by passing electric current through it (do not use the term electricity as this includes static electricity)
5. electrical energy to chemical energy
6. electrolyte/ionic compound
7. any salt solution, hydroxide or acidic solution
8. hydrogen, oxygen



9. oxygen
10. (a) hydrogen
    (b) oxygen
    (c) chlorine
    (d) carbon dioxide
11. voltameter
12. aluminium
13. chemical change
14. new substance produced as shown by: colour change; gas produced (bubbles); heat absorbed or released; precipitate formed
15. breaking down of a compound
16. loses
17. gains
18. (a) An atom loses or gains one or more electrons.
    (b) Energy needed to remove the outermost electron from an atom or ion in the gaseous state.
19. copper
20. (a) $Mg \rightarrow Mg^{2+} + 2e^-$
    (b) $Cl + e^- \rightarrow Cl^-$
21. sodium, magnesium, aluminium, iron, copper, lead
22.

| Column A | Column B |
|---|---|
| Loses electron(s) to form an ion | Metal |
| Gains electron(s) to form an ion | Non-metal |
| Negatively-charged ion | Anion |
| Positively-charged ion | Cation |
| Can be decomposed by electric current | Compound |

23.

| Atomic symbol | Loses or gains electron(s) | No. of electrons lost or gained | Symbol for ion |
|---|---|---|---|
| Ca | Loses | 2 | $Ca^{2+}$ |
| S | Gains | 2 | $S^{2-}$ |
| Al | Loses | 3 | $Al^{3+}$ |
| Na | Loses | 1 | $Na^+$ |
| Cl | Gains | 1 | $Cl^-$ |
| O | Gains | 2 | $O^{2-}$ |

24. magnesium, X, copper
25. ion that contains more than one atom, e.g. sulfate ion $SO_4^{2-}$
26. (a) (i) $Mg(s) + 2HCl(aq) \rightarrow H_2(g) + MgCl_2(aq)$
    (ii) $Ca(s) + H_2SO_4(aq) \rightarrow H_2(g) + CaSO_4(aq)$
    (b) Full ionic equations:
    (i) $Mg(s) + 2H^+(aq) + 2Cl^-(aq) \rightarrow H_2(g) + Mg^{2+}(aq) + 2Cl^-(aq)$
    (ii) $Ca(s) + 2H^+(aq) + SO_4^{2-}(aq) \rightarrow H_2(g) + Ca^{2+}(aq) + SO_4^{2-}(aq)$
    Net ionic equations:
    (i) $Mg(s) + 2H^+(aq) \rightarrow H_2(g) + Mg^{2+}(aq)$
    (ii) $Ca(s) + 2H^+(aq) \rightarrow H_2(g) + Ca^{2+}(aq)$
    (c) (i) $Mg(s) \rightarrow Mg^{2+}(aq) + 2e^-$
    $2H^+(aq) + 2e^- \rightarrow H_2(g)$
    (ii) $Ca(s) \rightarrow Ca^{2+}(aq) + 2e^-$
    $2H^+(aq) + 2e^- \rightarrow H_2(g)$

## 18 Oxidation/Reduction

1. A
2. D
3. A
4. B
5. (a) (i) Zn is more active than Ag, so Zn forms ions in solution, replacing $Ag^+$, which precipitates out.
   (ii) Zn loses 2 electrons to form Zn ions; silver ion gains an electron to form Ag atoms.
   (b) $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$
   $2Ag^+(aq) + 2e^- \rightarrow 2Ag(s)$
   (c) $2Ag^+(aq) + Zn(s) \rightarrow Zn^{2+}(aq) + 2Ag(s)$
6. (a) A reaction in which a more active metal is placed in solution containing the ion of a less active metal. The more active metal displaces the less active metal from solution.
   (b) (i), (iv) and (vi)
7. (a) A reaction that involves the loss of electrons.
   (b) A reaction that involves the gain of electrons.
   (c) An electron transfer reaction involving oxidation and reduction.
   (d) An oxidising agent, a substance that causes oxidation.
8. (a) reduction
   (b) reduction
   (c) redox
   (d) oxidation
   (e) redox
9. No electron transfer. Ions are exchanged, not electrons.
10. There are many possible answers here. Check your answers with your teacher.
    (a) $Ca(s) + 2H^+(aq) \rightarrow Ca^{2+}(aq) + H_2(g)$
    (b) $2Na(s) + 2H^+(aq) \rightarrow 2Na^+(aq) + H_2(g)$
    (c) $2Al(s) + 3Fe^{2+}(aq) \rightarrow 2Al^{3+}(aq) + 3Fe(s)$
    (d) $Cl_2(g) + 2Br^-(aq) \rightarrow 2Cl^-(aq) + Br_2(g)$
    (e) $Mg(s) + 2Cl^-(aq) \rightarrow Mg^{2+}(aq) + Cl_2(g)$
11. (a) loses; reductant
    (b) non-metals
    (c) electrons; oxidant
    (d) metals
12. (a) Oxidant causes oxidation and gets reduced (it gains electrons) whereas a reductant causes reduction and gets oxidised (it loses electrons).

(b) (i) oxidiser/oxidising agent
(ii) reducer/reducing agent

(c)

| Oxidant/oxidising agent (i.e. the substance reduced) — it gains electrons | Reductant/reducing agent (i.e. the substance being oxidised) |
|---|---|
| (i) Hydrogen ions | Calcium atoms |
| (ii) Hydrogen ions | Sodium atoms |
| (iii) Iron ions | Aluminium atoms |
| (iv) Chlorine atoms | Bromide ions |

(d) (i) from calcium atoms to hydrogen ions
(ii) from sodium atoms to hydrogen ions
(iii) from aluminium atoms to iron ions
(iv) from bromide ions to chlorine atoms

(e) $Zn(s) + Ag^+(aq) \rightarrow Zn^{2+}(aq) + Ag(s)$

13. (a) redox
(b) zinc
(c) zinc

14. oxidation

15. $Mg(s) \rightarrow Mg^{2+} + 2e^-$
$2H^+ + 2e^- \rightarrow H_2$

16. (a)

| Substance | Gains or loses electrons | Gets oxidised or reduced | Is an oxidant or reductant |
|---|---|---|---|
| Mg | Loses | Oxidised | Reductant |
| $Fe^{2+}$ | Gains | Reduced | Oxidant |

(b)

| Substance | Gains or loses electrons | Gets oxidised or reduced | Is an oxidant or reductant |
|---|---|---|---|
| $Fe^{2+}$ | Loses | Oxidised | Reductant |
| $Cl_2$ | Gains | Reduced | Oxidant |

17. (a) (i) zero
(ii) their ion
(iii) oxides; peroxides
(iv) non-metals; metals
(v) all its atoms

(b) (i) 0
(ii) −2
(iii) +1
(iv) +2
(v) +4
(vi) +7

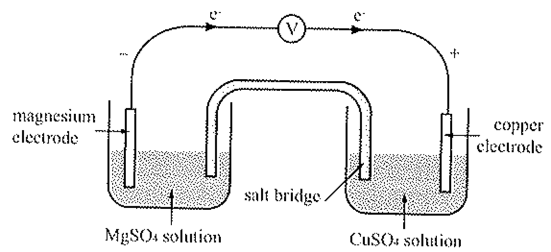
18. (a) chlorine atoms
(b) silver ions
(c) hydrogen ions
(d) hydrogen ions
(e) fluorine atoms
(f) zinc ions
(g) chlorine atoms

19. Oxidants.

20. (a) oxidised
(b) an oxidant
(c) a reductant
(d) electrons
(e) displaced/reduced
(f) activity series
(g) 0
(h) (i) 0 (ii) −2 (iii) 0 (iv) 3

## 19 Galvanic Cells

1. C
2. D
3. D
4. Standard hydrogen electrode consists of a platinum electrode immersed in a solution containing 1 mole of hydrogen ions with hydrogen gas bubbled in under pressure. The reduction potential of this electrode is said to be zero and all other reduction potentials are measured relative to this.
The redox table has been developed by comparing the strengths of oxidants and reductants to that of the standard hydrogen electrode.
5. (a) Various, e.g. magnesium and copper or copper and iron.
(b) Various, e.g. for Mg and Cu you might have used magnesium sulfate for the Mg electrode and $CuSO_4$ for the Cu electrode.
(c) Various, e.g.




(d) Various, e.g. salt bridge could dry out — keep it moist.
(e) Various, e.g. spilling or splashing of chemicals — detail toxicity where necessary. Wear safety goggles to protect the eyes and also protective clothing. Wash hands thoroughly after using toxic chemicals.
(f) Various, e.g. filter paper folded and soaked in solution such as potassium chloride, with one end dipping into each electrolyte. With the magnesium and copper cell, electrons would flow from magnesium to copper.

6. (a) $Al(s) \rightarrow Al^{3+}(aq) + 3e^-$
(b) $Ag^+(aq) + e^- \rightarrow Ag(s)$
(c) $Al(s) + 3Ag^+(aq) \rightarrow Al^{3+}(aq) + 3Ag(s)$

7. (a) copper
(b) $Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$



(c) $Ag^+(aq) + e^- \rightarrow Ag(s)$
(d) silver ions

8. It allows the movement of charge and maintenance of the balance of ions.

9. (a) galvanic cell
(b) electrochemical/galvanic cell
(c) Daniell cell.
(d) anode
(e) anode
(f) hydrogen electrode
(g) salt bridge

## 20 The Redox Table

1. C
2. (a) (i) −2.87 V
(ii) −0.23 V
(iii) −2.36 V
(iv) −0.76 V
(b) (ii) (iv) (iii) (i)
(c) (i) $Ca(s) \rightarrow Ca^{2+} + 2e^-$ + 2.87 V
(ii) $Ni(s) \rightarrow Ni^{2+} + 2e^-$ + 0.23 V
(iii) $Mg(s) \rightarrow Mg^{2+} + 2e^-$ + 2.36 V
(iv) $Zn(s) \rightarrow Zn^{2+} + 2e^-$ + 0.76 V
(d) (i) calcium ions, nickel ions, magnesium ions, zinc ions
(ii) calcium atoms, nickel atoms, magnesium atoms, zinc atoms

3. (a) reduction potential
(b) oxidising agent
(c) left
(d) increasing
(e) oxidised
(f) reductions
(g) lower
(h) lower
(i) decreases

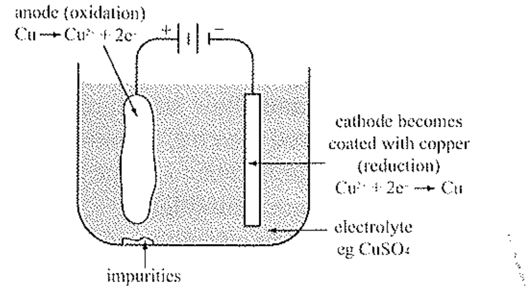
## 21 Using Galvanic/Voltaic Cells

1. See tables.
2. Various — you should not find this difficult to research. All of the standard texts have diagrams of batteries and they are also available on the internet — some even animated.
Label your diagrams to show the electrodes (cathode and anode) and electrolytes.
3. Advantages:
Solar energy is renewable, and supply is unlimited, especially in countries such as Australia which have a high number of hours of sunlight each day. Use of solar energy involves little or no pollution.
Disadvantages:
More research is needed to develop more efficient solar cells.

## 22 Electrolysis

1. (a) Plating tableware and jewellery with silver; coating steel cans with tin; coating lead or steel with chromium.
(b) Silver and gold coatings on stronger metals improves durability and appearance. Galvanising protects underlying iron from corrosion.

2. (a)

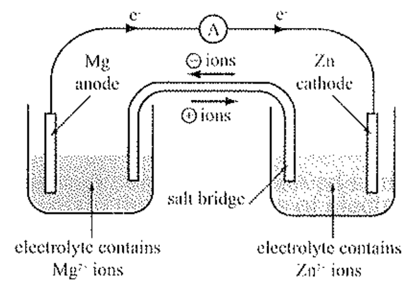



(b) Anode:
$Cu(s) \rightarrow Cu^{2+}(aq) + 2e^-$ −0.35 V
Cathode:
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$ + 0.35 V
(c) $Cu(s) + Cu^{2+}(aq) \rightarrow Cu^{2+}(aq) + Cu(s)$ 0 V

3.

| Galvanic/voltaic cells | Electrolytic cells |
|---|---|
| Chemical energy to electrical energy | **Electrical energy to chemical energy** |
| Two half cells with separate electrolytes and a salt bridge or porous barrier | Electrodes usually in the same **electrolyte** |
| Chemical reaction is **spontaneous.** $E°_{total}$ is **positive.** | Chemical reaction forced by applying voltage — not spontaneous. $E°_{total}$ is negative. |
| Anode — negative terminal. Cathode — positive terminal. Oxidation always occurs at the **anode.** | Anode is positive. Cathode is negative. Oxidation occurs at the **anode.** |
| Uses: **Batteries for torches, radios, toys, phones, computers, hearing aids, microphones, cars etc.** | Uses: **To protect against corrosion or improve the appearance of an object** |

4. (a) Electrolytic cell. Electricity is being supplied to drive the reaction, indicating the reaction is not spontaneous.
(b)



(c) Anode is magnesium.
Cathode is zinc.

(d) $Mg \rightarrow Mg^{2+} + 2e^-$
$Zn^{2+} + 2e^- \rightarrow Zn$

(e) +2.36 + (–0.76) = 1.60 volts

(f) Chemicals used up, electrolyte concentration decreases.

(g) Allows for movement of ions and maintenance of charge balance.

5. (a) Knowledge about electroplating led to the galvanising of iron and steel to prevent corrosion and allow structures to last longer. This reduced the cost of building and meant that structures such as homes and factories could be more durable.
Electroplating also allowed jewellery to be made more cheaply, using only a thin layer of silver or gold over a stronger, cheaper metal. This meant more people could afford jewellery.
Electrolysis made possible the commercial production of such chemicals as chlorine and sodium hydroxide, both of which have many uses in industry, e.g. chlorine is used to purify drinking water and sodium hydroxide is used to manufacture soap.

(b) Knowledge of redox reactions led to a search for uses — chemists developed techniques to use this information to extract useful metals and to coat substances so as to improve their durability and/or appearance.

(c) Led to the development of batteries that allow for greater mobility, e.g people can keep in contact by mobile phone even where there is no phone line. Also, the development of small batteries with constant voltage has led to the development of medical devices such as pacemakers that prolong the lives of people affected by heart disease.

6. (a) electrolytic cell
(b) anode
(c) anode
(d) electroplating
(e) galvanising
(f) protect from corrosion or improve appearance

## 23 Radioisotopes

1. (a) Isotopes are forms of an element with different numbers of neutrons in the atom and thus different atomic masses. They are the same element so they have the same number of protons (same atomic number), but their mass numbers differ (different numbers of neutrons).

(b) Atoms of both have 29 protons. Cu-63 has 34 neutrons (29 + 34 = 63)whereas Cu-65 has 36 neutrons (29 + 36 = 65).

(c) Same chemical properties as they have the same atomic number and are the same element. Some physical properties different due to the greater mass of copper-65.

(d) Isotope — same element but different number of neutrons.
Allotrope — same element, same number of neutrons — atoms are identical but arranged differently in allotropes.

2.

| Isotope | Atomic Number | Mass Number | Number of protons | Number of neutrons | Number of electrons |
|---|---|---|---|---|---|
| Cu-63 | 29 | 63 | 29 | 34 | 29 |
| Cu-65 | 29 | 65 | 29 | 36 | 29 |
| Pb-204 | 82 | 204 | 82 | 122 | 82 |
| Pb-206 | 82 | 206 | 82 | 124 | 82 |
| Pb-208 | 82 | 208 | 82 | 126 | 82 |
| U-235 | 92 | 235 | 92 | 143 | 92 |
| U-238 | 92 | 238 | 92 | 146 | 92 |
| H-1 | 1 | 1 | 1 | 0 | 1 |
| H-2 (Deuterium) | 1 | 2 | 1 | 1 | 1 |

3. (a) Stable — atom does not spontaneously disintegrate or emit particles or energy.
Unstable — atoms spontaneously disintegrate and emit alpha, beta and/or gamma radiation.

(b) The stability of isotopes is determined by the number of particles in the nucleus and also by the ratio of neutrons to protons. For light elements, the stable neutron to proton ratio is approximately 1:1; for heavy elements the stable neutron to proton ratio is approximately 1.5:1.

4. (a) Isotope that is unstable and spontaneously disintegrates and emits radiation.

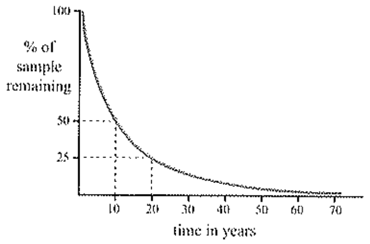
(b) Natural — unstable isotope that occurs naturally — mostly have a nucleus that is too large to be stable; they include elements with atomic numbers from 84 (polonium) to 92 (uranium).
Synthetic — isotope made unstable, usually by hitting it with sub-atomic particles. Produced in nuclear reactors by bombarding nuclei with sub-atomic particles such as neutrons. Examples include isotopes with atomic numbers greater than 92 as well as technetium (Z = 43) and promethium (Z = 61).



5. B
6. C
7. Chemical reaction involves the rearrangement of the outer shell electrons.
Decay of a radioisotope involves changes in the nucleus of atoms, not in the outer shell electrons.

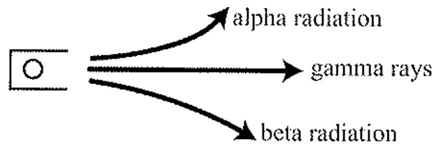
8. (a) The time taken for half of a sample of a radioisotope to decay.
(b) (i) Mass of radium-226 would have halved.
(ii) halved
(c) 1/32

9.




10. See Table 23.1.

11.




12. (a) Nucleus loses 2 protons and 2 neutrons, so atomic number drops by 2 and mass number drops by 4.
(b) Nucleus loses one neutron — this disintegrates and becomes a proton and an electron. Thus one neutron is replaced by one proton. Mass number stays the same, but atomic number increases by 1.

13. (a) radioisotope
(b) helium
(c) electrons
(d) gamma radiation
(e) half-life
(f) alpha, beta and gamma radiation
(g) gamma
(h) decreases by 4
(i) Neutron disintegrates, forming one electron (and one proton).
(j) increases by 1

## 24 Uses of Radioisotopes

1. (a) Cobalt-60.
Benefits — can be used to destroy cancer cells because of its ability to destroy living tissues.
Also used to sterilise equipment without causing the damage that could be caused by heat and steam sterilisation.
Problems — must be careful to ensure safety of personnel handling it and to minimise as far as possible its effect on the non-cancer cells of the patient.

(b) Americium-241.
Benefits — allows the operation of smoke detectors that can warn people when a fire is starting and thus save lives and property.
Problems — care in handling the isotope during manufacture. Gamma radiation is low energy so causes little harm; alpha radiation could cause damage to cells on contact or when very close, but has little ability to penetrate.

2. Strontium is similar to calcium (Sr is under Ca in Group II) so it could replace calcium in bones and teeth. Here it would continue to emit radiation that could harm the organism.

3. It emits gamma radiation — can pass through metal to detect flaws; can destroy living cells and microorganisms.

4. Radiation can affect the structure of enzymes so they cannot act as catalysts; the structure of membranes can be changed, thus preventing transport within and between cells; the structure of a DNA molecule can be altered so it can no longer function correctly, e.g. in cell division, sex cells can be altered and the changes passed on, causing defects in offspring.

5. type of radiation, strength of the source and exposure time; distance from the source; age; type of cells exposed; origin of the source — inside or outside the body; chemical properties; general health

6. limiting the time exposed; ensuring the maximum distance from the source and using remote handling facilities if appropriate; the use of shielding and protective clothing; monitoring staff exposure, containment of radioactive substances and use of warning notices

7. (a) molybdenum-99
(b) short half-life, easily excreted
(c) (i) medical diagnosis
(ii) treating cancer, sterilising surgical equipment
(iii) smoke detectors
(e) Cells multiply too rapidly without maturing and form cancer, mutation of genes in sex cells that can be passed on to offspring.

## 25 Production of Radioisotopes

1. A
2. (a) A device that allows a uranium chain reaction to occur safely, at a slow and controlled rate.
(b) A machine that allows particles (e.g. protons) to be accelerated to high speed and fired at nuclei of atoms with controlled energies in order to study nuclear reactions or make radioisotopes e.g. cyclotrons and synchrotrons.

3. (a) Neptunian, americium.
   (b) A nuclear reactor or an accelerator.
4. To study nuclear reactions or make radioisotopes.
5. In a nuclear reactor, a target is bombarded with neutrons to produce a radioactive species with extra neutrons in the nucleus.
6. Nuclear research and the production of radioactive substances.
7. Accelerator — produces neutron-deficient isotopes. Nuclear reactor — produces neutron-rich isotopes.
8. (a) accelerators
   (b) transuranic elements
   (c) accelerators
   (d) nuclear reactor
   (e) accelerator
   (f) Lucas Heights, Sydney

## 26 Detectors of Radiation

1. The badges worn by workers may contain a small piece of film, which is developed regularly to check for exposure to radiation.
2. (a) See Figure 26.1.
   (b) High energy radiation will ionise the argon gas so ions can move to electrodes and thus a current can flow.
3. The Bohr atom describes electrons as existing in orbits of different energy level. Low energy, non-ionising radiation can provide enough energy to excite electrons and push them to higher energy orbits than they usually occupy.
   Scintillation counters detect light given out as these excited electrons return to their usual orbits.
4. Various, e.g. discuss how knowledge of the structure of the atom led to the development of such things as the nuclear reactor, radioisotopes and Geiger counter.
5. Various, e.g. the development of radioisotopes such as technicium-99m and its production by a transportable generator. This allowed its use as a tracer for diagnosis. Thus people could survive longer and with a better quality of life.
   The use of a nuclear reactor to produce the molybdenum-99 needed to make technetium-99m could have harmful effects on the environment if waste is allowed to escape and cause contamination. The safe disposal of wastes from reactors is an unsolved problem.
   You should mention benefits and problems associated with the application you discuss.
6. (a) Geiger-Müller tube; thermo-luminescent dosimeter; scintillation counter; photographic film
   (b) alpha radiation
   (c) nucleus
   (d) (i) Geiger-Müller tube
       (ii) thermo-luminescent dosimeter
       (iii) scintillation counter