

- 1.1.1** Petroleum consists of crude oil and natural gas. Petroleum contains a mixture of up to 300 hydrocarbons, as well as sulfur and nitrogen compounds.

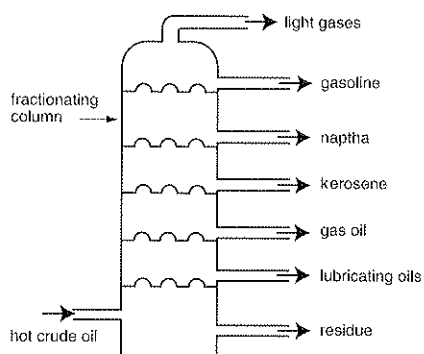
Crude oil (liquid petroleum) contains mainly alkanes and alkenes from C1 to about C25.

Natural gas is a mixture of methane (75-90%), ethane (5-10%), propane and butane (3-6%) and smaller amounts of other alkanes. It may also contain nitrogen, water vapour, carbon dioxide and traces of hydrogen sulfide.

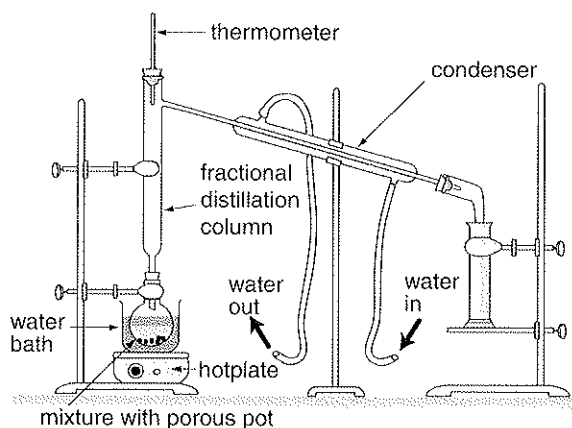
- 1.1.2** Various, e.g. gases; petroleum ether; gasoline (petrol); kerosene; diesel; gas oil; lubrication oil and wax; bitumen

- 1.1.3** (a) Process used to separate a mixture such as petroleum into its components, depending on the components having different boiling points.

(b)

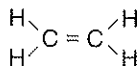


(c)



- 1.1.4** (a) Ethene

(b)



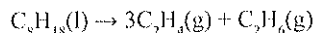
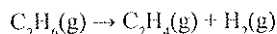
- (c) Petroleum and natural gas. In Europe and Japan, ethylene (ethene) is obtained from petroleum by fractional distillation to produce fractions, followed by the cracking of some of the fractions.

In Australia and the USA, where natural gas is more readily available, we mostly pipe natural gas directly from its source and crack the ethane, propane and butane to obtain ethylene (ethene).

1.1.5 Cracking is a process in which molecules of carbon compounds are broken down into smaller molecules with the help of heat and/or catalysts.

Inorganic catalysts such as alumina-silica gel are used in the cracking process.

Examples of cracking are:



1.2.1 alkenes, --C=C-- , share, carbon, two, electrons

1.2.2 (a)

Homologous series	General formula	Functional group
Alkane	$\text{C}_n\text{H}_{2n+2}$	--C--C--
Alkene	C_nH_{2n}	--C=C--
Alkyne	$\text{C}_n\text{H}_{2n-2}$	$\text{--C}\equiv\text{C--}$

(b) (i) C_2H_6

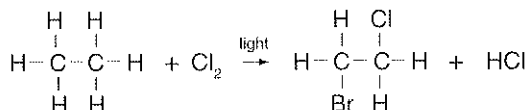
(ii) C_2H_4

(iii) C_2H_2

1.2.3 Ethene is more reactive than ethane, because ethene contains a double carbon-carbon bond whereas ethane only has a single carbon-carbon bond. The double bond (--C=C--) is much more reactive than the single (--C--C--) bond.

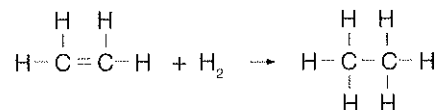
1.2.4 (a) A reaction in which an atom is substituted for another already in the molecule, e.g. a hydrogen atom may be replaced with a halogen atom. Light energy is required.

(b) Various, e.g.

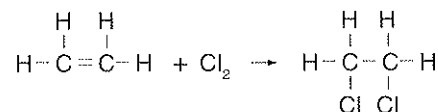


1.2.5 (a) A double bond is broken, and other atoms, or group of atoms, are added into the molecule.

(b)



(c)

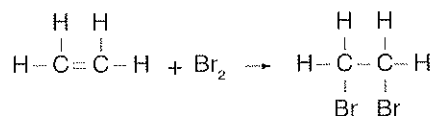


1.3.1 To a sample of the hydrocarbon add bromine water, which is a red-brown colour, and see if it reacts.

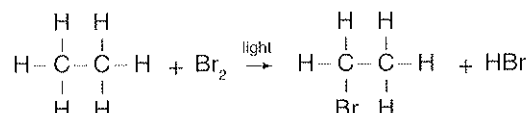
An **alkene**, such as ethene, will undergo an addition reaction, even in the dark, and the bromine water will change from red-brown to colourless very quickly. (*Note:* You must always state colour changes – from... to ...; it is not enough to say the bromine water decolourises.)

An **alkane**, such as ethane, will undergo a substitution reaction with bromine water, but this reaction is very slow and only occurs in the presence of light. This reaction may take several hours, or even days, to complete.

Alkene

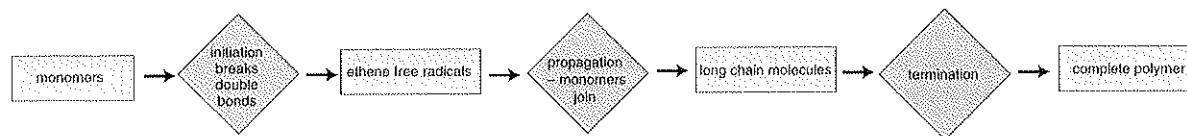


Alkane



- 1.3.2** (a) Various – you probably used cyclohexane and cyclohexene because they are colourless and liquid at room temperature. This allows you to readily see colour changes.
- (b) Various, e.g. You must carry out this experiment in a fume cupboard, using very small quantities of chemicals and wearing protective clothing including gloves and safety glasses.
- These precautions are to avoid bromine water, cyclohexane and cyclohexene from coming into contact with the skin and eyes or being inhaled.
- Such precautions are essential as bromine water is toxic by all routes of exposure. It is a skin irritant, vapour irritant and it is corrosive.
- Cyclohexane and cyclohexene are also toxic by all routes of exposure as well as being highly flammable.
- 1.4.1** (a) A monomer is a small molecule, such as ethylene (ethene). Many monomer molecules can be joined together to form a long chain molecule called a polymer.
- (b) A polymer is a large molecule consisting of a large number of identical small molecules (monomers) joined together, for example plastics, rubber, synthetic textiles, starch, cellulose, protein and DNA in our genes.
- (c) Polymerisation.
- 1.4.2** Ethene is a small molecule. Many ethane molecules can be joined together to form a polymer such as polyethylene.
- 1.4.3** Monomers – b, c Polymers – a, d
- 1.5.1** A long chain molecule that can be formed from an addition reaction involving many molecules of one or more monomers with double bonds.
- 1.5.2** (a) Ethylene (ethene)
- (b)
- | | | |
|-----------------------------|---------------------------------|---------------------------------|
| ethylene | | polyethylene |
| (ethene) | → | (polyethene) |
| $n\text{CH}_2=\text{CH}_2$ | $\xrightarrow{\text{catalyst}}$ | $(-\text{CH}_2-\text{CH}_2-)_n$ |
| (where n is a large number) | | |
- (c)
- $$\begin{array}{ccccccc} | & | & | & | & | & | & | \\ -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & -\text{C} & - \\ | & | & | & | & | & | & | \end{array}$$
- 1.6.1** Various – in your answer you should include the following points:
- Describe some commercial uses of polyethylene and link these uses to its properties, e.g. Polyethylene is used for milk bottles, detergent containers, food containers and garbage bins. It can be used for these purposes as it is insoluble in water, inert, lightweight (low density), tough and strong.
 - Explain, e.g. These products must be strong so they do not break easily; inert so they do not dissolve in or react with their contents; and light for ease of transport.
 - Justify the importance, e.g. Thus polyethylene is important commercially because its properties make it suitable for a wide range of commercial uses.
- 1.6.2** Initiation – A chemical called an initiator starts (initiates) the reaction by opening the double bond of an ethylene (ethene) monomer. This forms an ethylene (ethene) free radical.
- Propagation – The monomers join, to form a chain.
- Termination – When free radical ethylene (ethene) chains combine, a complete polyethylene (polyethene) molecule is formed and the process stops (it is terminated).
- 1.6.3** (a) A species with an unpaired outer shell electron.
- (b) A free radical is very reactive because of the presence of an unpaired outer shell electron. Free radical ethene molecules readily join together.
- 1.6.4** (a) Transition metal catalysts also called Zeigler-Natta catalysts.
- (b) Affects the rate of reaction and allows the process to be carried out at a lower temperature and pressure. These catalysts can also affect the arrangement of units attached to the main chain and thus the polymer's physical properties such as density and stability to heat.

1.6.5



1.6.6 Factors – Various, e.g. molecular weight, density, type and amount of additives and purity of the product.

Quality control is necessary to ensure the product, in this case polyethylene, is of uniform high quality, with the same composition and absence of impurities so that customers will feel confident that the polyethylene will always have the same properties and so they will continue to purchase the product.

1.6.7 The reaction is exothermic, so heat is constantly being released. This heat may make the polymer decompose as it is formed, decreasing the yield.

1.7.1 Various, e.g. you might have made models of ethene molecules, then broken the double bonds and joined them together.

1.8.1

Common name of monomer	Systematic name of monomer	Formula of monomer	Name of polymer
Vinyl chloride	Chloroethene	$\begin{array}{c} \text{H} & & \text{H} \\ & \backslash & / \\ & \text{C} = \text{C} \\ & / & \backslash \\ \text{H} & & \text{Cl} \end{array}$	Polyvinylchloride (PVC)
Styrene (Vinyl benzene)	Ethenylbenzene	$\begin{array}{c} \text{H} & & \text{H} \\ & \backslash & / \\ & \text{C} = \text{C} \\ & / & \backslash \\ \text{H} & & \text{C}_6\text{H}_5 \end{array}$	Polystyrene

1.9.1

Name of polymer	Structure of polymer	Uses – Various, e.g.
Polyvinylchloride (PVC)	$\left[\begin{array}{c} \text{H} & & \text{H} \\ & \backslash & / \\ & \text{C} = \text{C} \\ & / & \backslash \\ \text{H} & & \text{Cl} \end{array} \right]_n$	Containers, wrapping film, blister packaging, vegetable oil bottles, electrical insulation, pipes and hoses, vinyl flooring, records, outdoor furniture, videos and credit cards
Polystyrene	$\left[\begin{array}{c} \text{H} & & \text{H} \\ & \backslash & / \\ & \text{C} = \text{C} \\ & / & \backslash \\ \text{H} & & \text{C}_6\text{H}_5 \end{array} \right]_n$	Fruit boxes, clothes hangers, packing foam, foam egg cartons, meat trays, compact disc and audiocassette cases, plastic cutlery, toys, surfboards and hot drink cups

1.9.2

Name of polymer	Use	Property that determines this use
PVC	Flooring and carpet backing	Soft and pliable Low static electricity Fire and water resistant
PVC	Sheets for roofs and skylights	Rigid and strong Will not dissolve in water or let water through
Polyethylene	Natural gas pipes Coating steel pipes	Strong, insoluble in water High resistance to chemical corrosion
Polyethylene	Plastic bags and food containers	High tensile strength Transparent or translucent Soft and flexible Insoluble in water Low reactivity with food Low density
Polyethylene	Sheathing for wire cables used for phone and TV	Electrical insulator Flexible Insoluble in water
Polystyrene	Disposable foam cups	Relatively cheap Low density and keep their shape Heat insulator Not chemically active
Polystyrene	Surfboards	Cheap Low density Rigid Not chemically active

1.9.3 Various. In your answer you should include the following:

- Identify at least three manufactured polymers by name and state the formula of each, e.g. polyethylene, polystyrene and polyvinyl chloride.
- Outline the manufacture of these polymers – identify the monomers used in each case, and identify the steps in the production process – initiation, polymerisation and termination.
- Describe some uses of the three polymers.
- Describe BOTH advantages and disadvantages of using these polymers. Include effects on the environment and on people, e.g.

Plastic cups are cheaper, less dense and safer than those made of glass. If they break, they are less likely to cause damage especially to children. The use of plastic containers also helps to conserve beach sand as this is used in glass production. If they are made from a polymer which can be recycled, then they are also environmentally friendly. Early plastics could not be recycled which caused problems with their disposal and led to accumulation of wastes.

The development of polymers has also led to the production of cheap, disposable articles suitable for medical uses, e.g. tubing and needles. The use of these can greatly decrease the spread of infection among society, but has increased the problems of waste disposal. Recently, the development of biodegradable polymers has helped to decrease the problem of waste disposal.

- You could also include problems in the manufacture of polymers and the need for precautions to be taken when producing these chemicals, e.g.

Vinyl chloride is the monomer used to manufacture PVC. This chemical irritates the eyes, skin and respiratory tract, causes liver damage and may be carcinogenic. It is highly toxic to marine life. Workers in industries using vinyl chloride and polyvinylchloride should wear protective clothing and eye protection; have masks available in case of leaks; check frequently for leaks so as to avoid contamination of air or water. Some workers were affected adversely before the dangers of using these chemicals were realised.

- Then make an assessment about the impact of the development of these chemicals. Your assessment should be consistent with the evidence you have presented as mostly favourable or unfavourable. You should also qualify the impact, e.g. has it had a slight impact or a huge impact on society and has it had a slight impact or a huge impact on the environment.

2.1.1 Industries that produce or use compounds which use petroleum as a raw material, e.g. production and use of fossil fuels, production of polymers, lubricating oils.

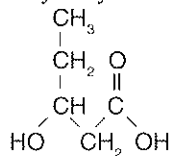
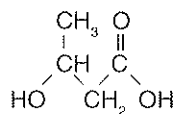
2.1.2 Various, e.g. petrol, aviation fuel, diesel, candle wax, road tar, ethene, polyethylene, polyvinylchloride, kerosene, lubricating oils, synthetic fabrics.

2.1.3 Various, e.g. in your answer you should include the following:

- Define petrochemical industry.
- Identify a variety of chemicals produced by the petrochemical industry and their uses.
- Point out that the petroleum industry is based on the use of fossil fuels which are non-renewable and most are likely to run out within the next 100 years, some much sooner.
- Discuss the effects on our lives if we can no longer produce some of the chemicals we currently make using fossil fuels and petroleum.
- Draw a conclusion, e.g. that it is/is not important we investigate other sources of these chemicals.

2.2.1 A biopolymer is a naturally-occurring long chain chemical made from renewable resources, usually plants or micro-organisms. Examples of biopolymers are cellulose, starch, cotton, proteins and gluten.

- 2.2.2 (a) Various, e.g. Biopol[®]
- (b) Biopol[®] is a polyhydroxyalkanoate (PHA). It is a copolymer, as it consists of two monomers, 3-hydroxybutyrate and 3-hydroxyvalerate.
- (c) 3-hydroxybutyrate and 3-hydroxyvalerate



- (d) They occur naturally in bacteria such as *Azobacter* and *Pseudomonas*.

- 2.2.3 (a) Bacteria, e.g. *Alcaligenes eutrophus*.
- (b) The polymer is presently produced industrially by bacteria (especially *Alcaligenes eutrophus*) growing in tanks with a carbon-based food source. The polymer is then isolated and purified.

Recently, attempts to produce the polymer more economically have used genetic engineering techniques, an example of biotechnology. Genetically-engineered bacteria, such as *E. coli*, can be used to produce PHA. The advantages are faster growth, better yields, easier recovery and the production of less extra waste biomass. Also cheaper substrates can be used to grow the bacteria, e.g. whey, molasses and agricultural wastes.

Genetically engineering plants such as cress and potatoes can also be made to produce biodegradable plastics rather than storing starch.

Although these biopolymers are at present more expensive to produce than conventional plastics, they have the advantage of being biodegradable, thus allowing better waste management, and of being made from renewable crops rather than fossil fuels. The use of transgenic plants is expected to lower costs so this polymer becomes price competitive with traditional petroleum-produced polymers.

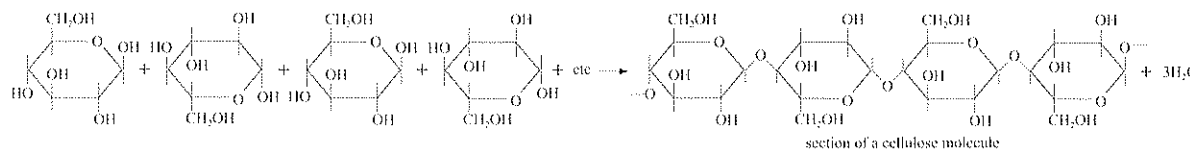
- (c) Various, e.g. a carrier for slow release of insecticides, herbicides or fertilisers; disposable containers for shampoo and cosmetics, and disposable items such as razors, rubbish bags, disposable nappies, fast food utensils and plastic plates.
- (d) Similar to those of polypropylene, e.g. insoluble in water, permeable to oxygen, resistant to UV light, acids and bases, soluble in chlorinated hydrocarbons, high melting point, high tensile strength and more dense than water. It is also non-toxic, biocompatible and biodegradable.
- (e) Various, e.g. medical applications such as the production of surgical pins and sutures.

Properties, e.g. high tensile strength, insoluble in water, non-toxic, biodegradable (its products decompose naturally and no surgery is needed to remove them) and it is biocompatible (the body does not react to this polymer or reject it as a foreign object).

- (f) Uses of Biopol[®] are varied, and more are continually being found. As it is biodegradable and biocompatible, it is increasingly used for medical applications and the production of items which previously presented a disposal problem. For medical applications, where biodegradability and biocompatibility are important properties, there is often no fossil fuel-based alternative.

- 2.3.1 A long chain compound formed when monomer molecules join together, forming a polymer, and releasing a small molecule such as water. Examples are cellulose, nylon, polyester, cotton, cellophane, dacron.

- 2.4.1 Various, e.g.

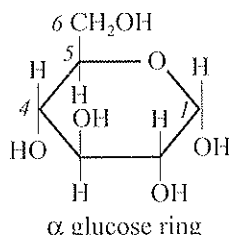


- 2.4.2 Small monomer molecules each release one or more atoms and the molecules join at that point. The released atoms combine to form a new compound. For example, in the formation of cellulose, an H and an OH, released from adjoining monomers, combine to form a molecule of water.

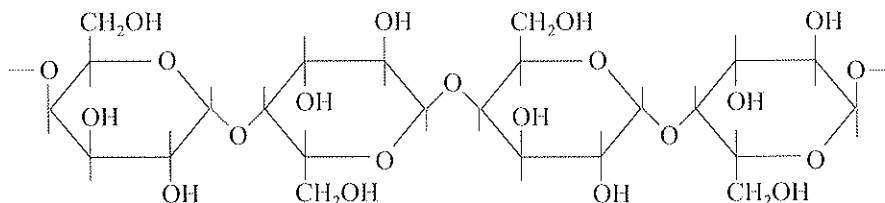
Condensation reactions	Addition reactions
Both involve monomers joining to form a long chain molecule.	
No double bonds necessary.	Monomer has double bond which breaks during polymerisation.
Polymer forms and also another small molecule.	No small molecule produced.

2.5.1

- (a) Glucose (molecular formula $C_6H_{12}O_6$) is a ring structure. Five carbon atoms and one oxygen atom form the ring and OH and H groups protrude above and below the ring. It also has a CH_2 group out of the ring. In solution the ring can open, forming a straight chain structure.



- (b) Cellulose is a very long polymer containing about 2000 to 8000 glucose molecules in long chains. These glucose molecules are strongly linked together by covalent bonds. Hydrogen bonding between the chains makes cellulose chains linear, rigid, strong and resistant to chemical attack.



section of a cellulose molecule

- (c) Monomers join together without the breaking of a double bond forming cellulose and a water molecule. (See equation for Question 2.4.1.)

2.5.2

Cellulose is a polymer of the sugar glucose. It makes up the cell walls of plants and is the most abundant carbohydrate on Earth. Cellulose is the main component of biomass and thus is a potentially important raw material for the production of synthetic polymers.

2.6.1

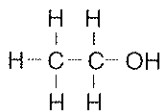
Petrochemicals are carbon-based compounds, so substances used to manufacture petrochemicals must also be carbon based. Also, being a major component of biomass, cellulose is a readily available renewable raw material for the production of petrochemicals.

2.6.2

Your answer should include the following points:

- Cellulose is a carbon-based compound, as are petrochemicals.
- Cellulose is readily available. It is one of the main components of biomass.
- Biomass is organic matter produced from plants.
- The use of food crops to make polymers presents ethical problems as there are people starving in many parts of the world.
- Potentially useful biomass includes the waste plant matter from agricultural products such as sugar cane and corn crops, waste from forestry such as sawdust and woodchip, and sewage. Normally such wastes are difficult to dispose of, so using them to make substances such as polymers is desirable.
- Sum up, e.g. Cellulose has huge potential in the manufacture of petrochemicals as it is readily available in huge amounts and can be converted to petrochemicals thus reducing our reliance on petroleum. This is important as petroleum supplies are running out.

3.1.1 (a)

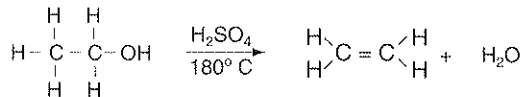


(b) Ethanol is an alkanol because it fits the following description of alkanols:

- Its formula ($\text{C}_2\text{H}_5\text{OH}$) fits the general formula: ROH , where R stands for a saturated carbon chain with formula $\text{C}_n\text{H}_{(2n+1)}$.
- It contains the functional OH (hydroxyl) group.

3.1.2 (a) A reaction in which a molecule of water is released as one product.

(b)



(c) A molecule of water is removed (dehydration). A hydrogen atom and an OH group are removed from adjacent carbon atoms to form a water molecule. To do this the ethanol is heated to between 100 and 200°C with concentrated sulfuric acid used as a catalyst.

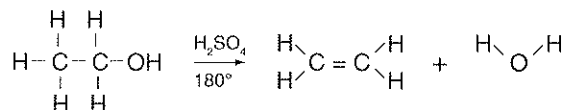
3.1.3 The catalyst, concentrated sulfuric acid, speeds up the reaction.

3.2.1 $\text{C}_2\text{H}_4(\text{g}) + \text{H}_2\text{O}(\text{l}) \rightarrow \text{C}_2\text{H}_5\text{OH}(\text{l})$

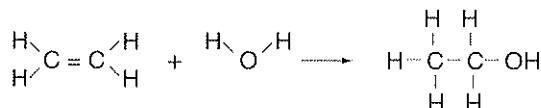
3.2.2 Water is added to ethylene (ethene), using sulfuric acid as a catalyst.

3.3.1 Use structural formulas to model the following reactions:

(a) dehydration of ethanol



(b) addition of water to ethylene (ethene)



3.3.2 Various, e.g. computer simulations or using a molecular model kit. Describe how you did this.

3.4.1 Ethanol can be produced by fermenting sugar in soluble forms such as sucrose and molasses from sugar cane, and fructose from corn plants. If cellulose is present, it needs to be first hydrolysed to glucose.

The sugars are fermented by enzymes produced by fungi such as the yeast *Saccharomyces cerevisiae*.About 30% of the sugar produced from plant matter is in the form of **xylose**, a sugar that cannot be fermented by fungi. To overcome this problem, genetically engineered *E. coli* bacteria are now being used instead of fungi as they can ferment both glucose and xylose.

After fermentation the ethanol must be separated from the reaction mixture by distillation.

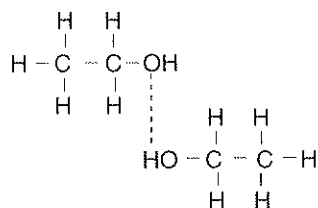
3.4.2 A – Filtering, B – Fermentation, C – Distillation.

3.5.1 (a) Covalent bonds.

(b) Covalent bonds within the molecule are polar and do not balance each other out. Oxygen is more electronegative than carbon or hydrogen atoms, so a dipole forms.

(c) Dispersion (Van der Waals) forces, dipole-dipole forces and hydrogen bonds.

(d)

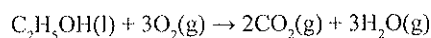


----- = hydrogen bond

3.5.2 Ethanol is a solvent for both polar and non-polar substances. It is used as a solvent in medicines, e.g. cough mixtures and in many industrial processes, e.g. the production of perfumes, varnishes, adhesives and plastics. Ethanol is polar, so it is able to dissolve polar substances by forming dipole-dipole forces or hydrogen bonds with them. Its carbon chain allows it to bond with and dissolve non-polar substances.

Ethanol is very useful in dissolving substances that are not soluble in water and hence allowing these substances to become soluble in water/ethanol mixtures. This allows medicines that are not water soluble to be taken as a liquid.

3.6.1 Ethanol readily undergoes relatively complete combustion, in air or oxygen, releasing 1367 kJ of energy per mole of ethanol burned.



Ethanol is mainly used as a fuel to supplement petrol supplies. It is mixed with petrol, usually with no more than 10% ethanol to avoid engine damage.

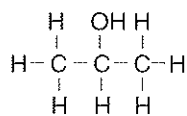
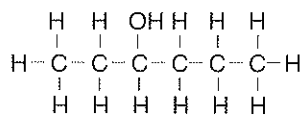
3.6.2 Ethanol is a renewable resource because it is mainly produced by the fermentation of plant matter, such as the residues from the production of corn and sugar cane. More crops can be grown to make more ethanol and replace that which is used.

3.6.3 Renew – able to grow more and replace that which was used.

Reuse and recycle – use a substance again, e.g. melt down aluminium cans and recast them to use again. Note that you cannot reuse or recycle a fuel.

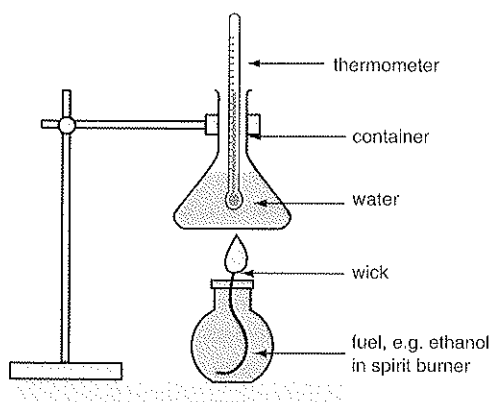
Name	Molecular formula	Structural formula
Methanol	CH_3OH	$\begin{array}{c} \text{H} \\ \\ \text{H}-\text{C}-\text{OH} \\ \\ \text{H} \end{array}$
Ethanol	$\text{C}_2\text{H}_5\text{OH}$	$\begin{array}{c} \text{H} \quad \text{H} \\ \quad \\ \text{H}-\text{C}-\text{C}-\text{OH} \\ \quad \\ \text{H} \quad \text{H} \end{array}$
Propanol	$\text{C}_3\text{H}_7\text{OH}$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \end{array}$
Butanol	$\text{C}_4\text{H}_9\text{OH}$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$
Pentanol	$\text{C}_5\text{H}_{11}\text{OH}$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$
Hexanol	$\text{C}_6\text{H}_{13}\text{OH}$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$
Heptanol	$\text{C}_7\text{H}_{15}\text{OH}$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \quad \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$
Octanol	$\text{C}_8\text{H}_{17}\text{OH}$	$\begin{array}{c} \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \\ \quad \quad \quad \quad \quad \quad \quad \\ \text{H}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{C}-\text{OH} \\ \quad \quad \quad \quad \quad \quad \quad \\ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \end{array}$

(b) (i) 3-hexanol (ii) 2-propanol



3.8.1 (a) Various, e.g. ethanol, methanol, 1-propanol

(b) Various, e.g.



- (c) This experimental design provides extremely inaccurate results due to the large loss of heat to the environment hence it is not suitable for measuring the actual heat of combustion. However, it can be used to compare heats of combustion of different alkanols as they will all have the same order of inaccuracy as long as they are measured in exactly the same way.
- (d) Reduce loss of heat to the environment, e.g. Use a metal can rather than a flask as this will conduct the heat to the water more efficiently, insulate the can, reduce the gap between the flame and water container, ensure oxygen supply is sufficient to allow for complete combustion of the alkanol, enclose equipment to protect from draughts, use a lid on the flask or can.
- (e) Various – Alkanols represent a fire hazard so you should have an extinguisher handy to quickly put out any fires if an accident occurs. 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. Use safety goggles to protect eyes.

3.9.1 Molar heat of combustion is the heat energy, in joules or kilojoules, released by the combustion of 1 mole of a fuel.

3.9.2 (a)

Fuel	Formula	Heat of combustion (kJ/mole)	Heat of combustion (kJ/gram)
Hydrogen	H ₂	285	142.5
Coke (carbon)	C	393	32.8
Methane	CH ₄	890	55.6
Ethane	C ₂ H ₆	1560	51.9
Propane	C ₃ H ₈	2220	50.5
Methanol	CH ₃ OH	727	22.7
Ethanol	C ₂ H ₅ OH	1367	29.7

(b) Hydrogen

(c) Methanol has the lower heat of combustion. Therefore methanol releases less energy per gram burnt than ethanol. Thus methanol would be more expensive to use as a fuel.

3.9.3 193 kJ mol⁻¹

3.10.1 Various, e.g.

Ethanol is mainly used, mixed with petrol, as a fuel to supplement petrol supplies.

Brazil and the United States use ethanol as a supplement to reduce the purchase of foreign oil supplies and to reduce pollution levels.

In the United States, ethanol is manufactured mainly by fermentation of corn and sugar cane residues and sales of ethanol-gasoline blends make up about 8-9 % of the total gasoline fuel sales per year.

Sugar cane and wheat have been fermented in Australia to produce ethanol. However, in Australia there has not been widespread acceptance of ethanol/petrol blends.

The large scale production of ethanol is generally considered an uneconomic proposition, mainly because of the huge cost of distillation and the difficulty of removing all water from the alcohol. However, recent increases in fuel prices have made the use of ethanol as a supplement to petrol more attractive. It would be expected that, in the future, as the price of petrol increases, ethanol/petrol blends will be more widely valued and used in Australia.

3.10.2 Various, e.g. you may have used information from websites set up by the government, a petrol company, an ethanol manufacturer or an organisation such as the NRMA.

To assess the validity of this source of information, you would need to consider how reputable it is, e.g. is it a government source or an established university. If the source is an environmental organisation or a petrol company or a company manufacturing ethanol, then the information needs to be viewed as possibly biased. A range of different sources is essential to compare the information obtained.

3.11.1 To answer this question fully you should include the following:

- State, describe AND explain at least three advantages AND disadvantages of ethanol as a fuel (see below).
- Include equations wherever possible.
- Make an assessment based on the points you have included. Any assessment is correct as long as it is based on facts. If you say ethanol has huge potential as a fuel, you must have described more advantages than disadvantages. Consider: Does ethanol have huge potential or little potential? Can it be used alone or only as an extender?
- Here are some examples of what is meant by state, describe and explain.

Advantages of using ethanol:

Statement	Description	Explanation
Ethanol is produced from a renewable source (unlike fossil fuels).	Ethanol is produced by the fermentation of biomass whereas other fuels are produced from petroleum.	Ethanol is produced by fermenting biomass – this comes from plants which are renewable as they can be grown to replace the ones used. Fermentation is by fungi such as the yeast <i>Saccharomyces cerevisia</i> and genetically engineered <i>E. coli</i> bacteria.
Ethanol burns more completely/cleanly than fossil fuels.	$C_2H_5OH(l) + 3O_2(g) \rightarrow 2CO_2(g) + 3H_2O(g)$ Toxic carbon monoxide is reduced by 25-30%. Little or no carbon is produced so less is deposited in the car and spark plugs last longer.	The oxygen in the ethanol molecule ensures that less oxygen is needed to allow complete combustion of the fuel. Ethanol is an excellent solvent, dissolving deposits built up in the engine.
Carbon dioxide neutral	Net CO_2 stays constant. The amount of CO_2 used to produce crops for ethanol production = CO_2 produced when ethanol burns.	Carbon dioxide is produced when ethanol burns. CO_2 used in photosynthesis to make crops that will later be converted to ethanol. $2CO_2(g) + 3H_2O(g) \rightarrow C_2H_5OH(l) + 3O_2(g)$
10% ethanol can be safely added to petrol.	Ethanol acts as a petrol extender without damage to engines.	No engine modification needed if only 10% added. Makes petrol supplies last longer.

Disadvantages of using ethanol:

Statement	Description	Explanation
Ethanol has a lower heat of combustion (29.7 kJ g^{-1}) than petrol (47.9 kJ g^{-1}).	Combustion of ethanol produces less energy than combustion of same amount of octane.	Car can travel further with the same amount of octane than ethanol thus ethanol is more expensive.
Existing car engines need to be modified if > 10% ethanol used in fuel.	It is difficult to remove all water during distillation of fermented biomass.	Water causes corrosion of engines and fuel lines.
Large areas of land needed.	Land is needed to grow crops to make ethanol.	This is a problem because land is also needed to grow food crops and removal of forests is not acceptable on ecological grounds. (Note: Ethanol can now be produced from waste left over from food crops which removes this objection and means that it could be listed as an advantage – it gets rid of wastes from crops such as sugar cane without having to burn off.)
Lots of energy is used in production of ethanol.	Ethanol has to be distilled from the fermentation mix.	This is a problem because distillation is energy intensive – energy is obtained by burning fossil fuels and also costs are high, making ethanol expensive.

3.12.1 Various. Your answer should include a description of:

- the equipment you used (use a diagram)
- making up of the glucose solution
- sterilisation of the equipment
- how long the mixture was allowed to react and under what conditions
- mass changes and how you measured them
- distillation to separate the alcohol produced from the reaction mixture (include a diagram)
- how you proved that alcohol was produced.

You should also include a labelled diagram of your equipment.

3.12.2 (a) $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \xrightarrow{\text{fermentation by yeast}} 2\text{C}_2\text{H}_5\text{OH}(\text{l}) + 2\text{CO}_2(\text{g})$

(b) Various, e.g.

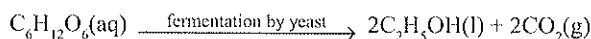
- Ensuring all equipment is sterile to begin with so other organisms do not grow in the sugar solution
--- describe how you sterilise the equipment.
- Difficulty of distilling alcohol produced as some water bonds to the alcohol molecules.
- The problem of the alcohol produced killing yeast cells when concentration of alcohol reaches about 15%
--- so alcohol must be removed as it forms.
- Need to maintain a constant temperature as yeast grows best at 37°C and dies if the medium is too hot or cold.

(c) Mass of reacting vessel and contents decreases as carbon dioxide gas is produced and this escapes from the container.

3.13.1 Maintain at a temperature of 37°C (or as near as possible), remove alcohol as it is produced, ensure all equipment is sterile before starting. Also to produce ethanol, respiration needs to be anaerobic so oxygen needs to be excluded as far as possible, e.g. you may have boiled the water before starting to reduce the dissolved oxygen content.

3.14.1 Yeast cells (a fungus) grow in the sugar solution and produce ethanol and carbon dioxide as products under anaerobic conditions. Enzyme reactions are involved so conditions suitable for the enzymes are required, e.g. temperature of 37°C.

This process involves many steps but can be summarised by the equation:



3.15.1 $\text{C}_6\text{H}_{12}\text{O}_6(\text{aq}) \xrightarrow{\text{fermentation by yeast}} 2\text{C}_2\text{H}_5\text{OH}(\text{l}) + 2\text{CO}_2(\text{g})$

- 4.1.1**
- Two half-cells are needed, each containing an electrode in an electrolyte solution.
 - A wire connects the two electrodes to allow the electrons produced to flow from one to the other.
 - If the two solutions are in separate containers a salt bridge connects them to maintain the balance of charge.
 - The salt bridge is saturated with a substance, such as potassium nitrate, that allows ions to flow from one container to the other but does not react with any ions in the solutions.

4.1.2 (a) Various, e.g.

We took two beakers.

In one we put a solution of zinc sulfate with a strip of zinc (zinc electrode) in it.

In the other we put a copper sulfate solution and a strip of copper (copper electrode).

We connected the two electrodes to a wire and voltmeter.

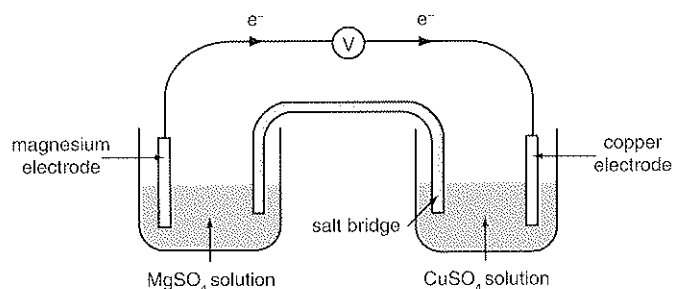
We soaked a strip of filter paper in potassium nitrate and placed this so its ends dipped into the two solutions.

(b) Various, e.g. A voltage was observed on the voltmeter.

If the salt bridge was not used, or if it was not in both solutions, there was no voltage (as the circuit is not complete).

Mention if gas is produced, an electrode wore away or a substance was deposited on an electrode.

- 4.2.1 (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.



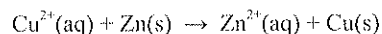
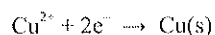
- (d) Various, e.g. salt bridge could dry out – keep it moist.
 Make sure salt bridge is immersed in both solutions.
 (e) Various, e.g. spilling or splashing of chemicals – describe their toxicity if relevant.
 Wear safety goggles and protective clothing to protect the eyes and skin from splashes of chemicals. Wash hands thoroughly after using chemicals.
 (f) Various, e.g. folded filter paper (or a flexible tube filled with absorbent paper) soaked in a solution such as potassium nitrate, with one end dipping into each electrolyte. With the magnesium and copper cell, positive ions (cations) move to the cathode and negative ions (anions) move to the anode.

4.3.1 Active metals will displace less active metal ions from solution; for example, zinc metal will displace copper ions from solution of copper sulfate.

Zinc releases electrons from its outer shell, forming zinc ions and going into solution.

The electrons are accepted by the copper ions (in solution) so they become solid copper atoms.

We can show this by writing two half equations and then adding them to see the full reaction.



4.4.1 Active metals displace less active metals from solution. The greater the difference in activity between the two metals, the more vigorous the displacement reaction.

4.4.2 Most active Least active

Na Ca Mg Al Zn Fe Pb Cu Ag

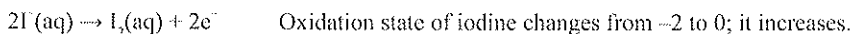
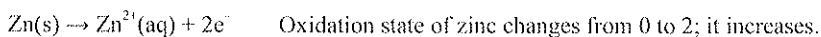
4.4.3 (a)

Solution	Metal added	Any displacement reaction
Calcium chloride	Zinc	No reaction
Zinc chloride	Calcium	Calcium goes into solution, zinc is deposited
Lead chloride	Magnesium	Magnesium goes into solution, lead is deposited
Lead chloride	Silver	No reaction

- (b) Magnesium in silver nitrate. There is a greater difference in activity between magnesium and silver than between magnesium and zinc.
 (c) Zinc must be more active than copper because the zinc has displaced the copper from solution.

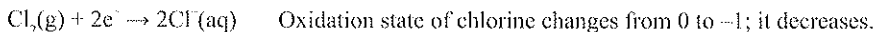
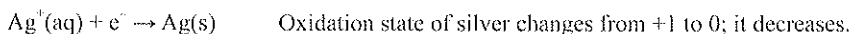
4.5.1 An increase in oxidation state occurs during oxidation.

Oxidation is the loss of electrons. For example:



A decrease in oxidation state occurs during reduction.

Reduction is the gain of electrons. For example:



- 4.5.2**
- Uncombined elements have an oxidation state of 0 (e.g. Na = 0, H₂ = 0).
 - Ions have an oxidation state equal to the charge on their ion (e.g. Na⁺ = +1, S²⁻ = -2).
 - Oxygen in compounds has a charge of -2 in oxides and -1 in peroxides.
 - Hydrogen in compounds has a charge of +1 when combined with non-metals (e.g. in H₂S) and -1 when combined with metals (e.g. in NaH).
 - The oxidation state of a compound or polyatomic ion is the sum of the oxidation states of all its atoms. For a compound the sum is 0.
 - Oxidation involves an increase in oxidation state.
 - Reduction involves a decrease in oxidation state.

4.5.3 (a) +2

(b) +3

(c) 0

(d) -2

(e) -1

(f) +7

4.6.1 A galvanic (voltaic/electrochemical) cell is an arrangement of chemicals and equipment that allows a spontaneous redox reaction to take place in such a way that electricity is produced. It consists of two half-cells, oxidation occurs in one and reduction in the other. Each half-cell contains an electrode in an electrolyte.

- 4.6.2**
- (a) reaction that involves the loss of electrons
 - (b) reaction that involves the gain of electrons
 - (c) electron transfer reaction involving oxidation and reduction
 - (d) a substance that causes oxidation and is itself reduced
 - (e) a substance that causes reduction and is itself oxidised

4.6.3 In a galvanic cell, there are two half-cells. In one half-cell there is a spontaneous oxidation reaction and in the other a reduction reaction occurs. Oxidation occurs at the anode, releasing electrons. Reduction occurs at the cathode which gains electrons. A wire connects the two electrodes so that electrons can transfer from the anode to the cathode.

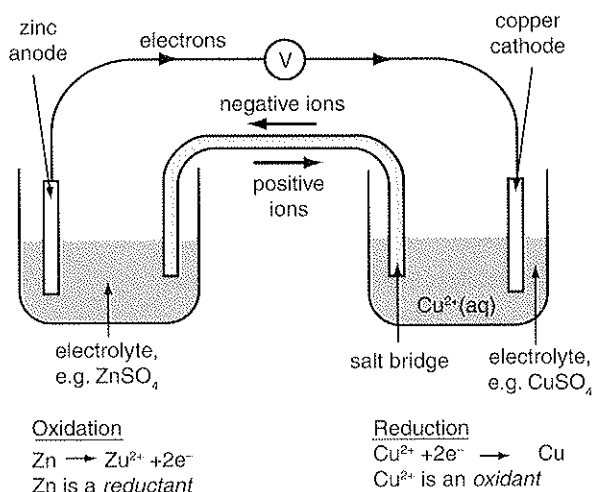
4.7.1 Two half-cells are set up, each containing an electrode in an electrolyte solution.

A wire connects the two electrodes to allow the electrons produced to flow from one to the other.

A salt bridge, saturated with potassium nitrate, is set up so that it dips into both electrolytes.

4.7.2 (a) Electrons flow from the anode (where oxidation occurs) to the cathode (where reduction occurs).

(b)



4.8.1 (a) A device which carries electric current into and out of a cell.

(b) An electrolyte is a chemical that conducts electric current.

(c) The electrode where oxidation occurs.

(d) The electrode where reduction takes place.

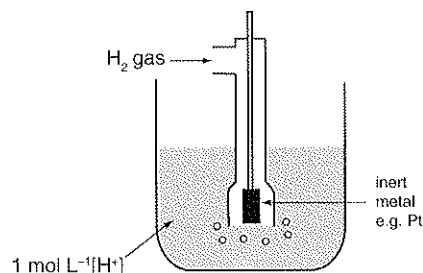
4.8.2 (a) To produce an electric current.

(b) Release of electrons occurs during oxidation at the anode. These have to travel to the cathode. By having the anode and cathode in separate cells, we can use the flow of electrons as a source of electric current/voltage.

4.9.1 (a) Standard reduction potential is a measure of the relative tendency of a substance to gain one or more electrons compared to the standard hydrogen half-cell.

These are measured under standard conditions of 25°C , 1 atmosphere pressure and using a 1 mol/L electrolyte solution. The larger the E^\ominus value, the greater the oxidising power of a substance.

(b) A half-cell containing a standard hydrogen electrode as shown in the diagram below:



(c) Voltmeter

4.9.2 (a) The redox table is a list of standard reduction potentials (E^\ominus). A copy of this table can be found at the back of this book.

(b) Reduction, reduced, reversing, left, down, fluorine, electrons, top, give up, reduced, lower down, hydrogen, oxidising.

4.9.3

- (a) -0.41 volts
- (b) (i) $\text{Al(s)} \rightleftharpoons \text{Al}^{3+} + 3\text{e}^-$ +1.66 V
(ii) $\text{Cu(s)} \rightleftharpoons \text{Cu}^{2+} + 2\text{e}^-$ -0.35 V
- (c) There is no reaction with iron in a solution of aluminium ions.
For the iron in copper sulfate solution, the reaction is as follows:
 $\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu(s)}$ +0.35 V
 $\text{Fe(s)} \rightleftharpoons \text{Fe}^{2+} + 2\text{e}^-$ +0.41 V

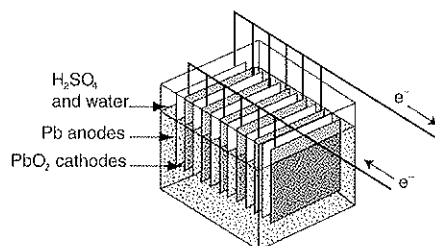
 $\text{Cu}^{2+} + \text{Fe(s)} \rightleftharpoons \text{Fe}^{2+} + \text{Cu(s)}$ +0.76 V $E^\ominus = 0.76$ volts
- (d) $\text{Cu}^{2+} + 2\text{e}^- \rightleftharpoons \text{Cu(s)}$ +0.35 V
 $\text{Zn(s)} \rightleftharpoons \text{Zn}^{2+} + 2\text{e}^-$ +0.76 V

 $\text{Cu}^{2+} + \text{Zn(s)} \rightleftharpoons \text{Zn}^{2+} + \text{Cu(s)}$ +1.11 V $E^\ominus = 1.11$ volts

4.10.1

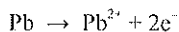
- (a) Various, e.g.

Diagram of lead acid cell:

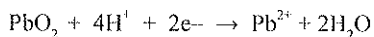


Chemistry of lead acid cell:

Anode: lead plates



Cathode: lead dioxide

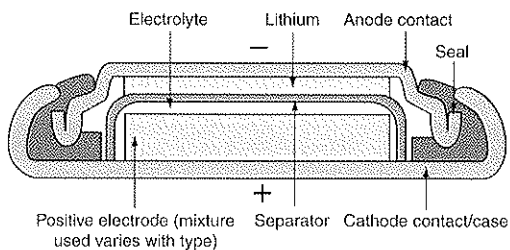


Pb ions combine with sulfate ions and form lead sulfate.

Electrolyte: 6 mol L⁻¹ sulfuric acid

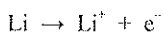
- (b) Various, e.g.

Diagram of lithium cell:



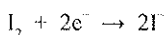
Chemistry of lithium cell:

Anode: lithium



Cathode: carbon

Reaction involves silver chromate or iodine, e.g.



Electrolyte: lithium iodide

4.10.2

	Lead acid cell	Lithium cell
Cost and Practicality	Expensive, but long lasting. Used as car batteries. Practical for this purpose as they do not need to be portable. They can be recharged. The reactions above are reversed by the car generator forcing current back into the battery. They work in a wide range of temperatures.	Expensive compared to other batteries. Used in cardiac pacemakers, cellular phones, watches, computers and cameras. Practical for these uses as they are long-lasting, rechargeable and high voltage. Lithium batteries are very light and deliver more power (about 3 V) than dry cell and alkaline batteries (1.5 V).
Impact on society	Their development meant that cars could be started much more easily and reliably – they did not have to be cranked. They improved the capability of people to move around and travel long distances.	The development of these long-lasting, rechargeable, very light batteries that produce a constant, relatively high voltage has led to the development of medical applications such as cardiac pacemakers which have saved lives. Their small size and portability have allowed the development of smaller electronic devices such as cameras, watches and phones. These have improved our ability to communicate over distance.
Environmental impact	Contains concentrated sulfuric acid (about 6 mol L ⁻¹) which must be disposed of safely as it is highly corrosive. Also lead is a toxic heavy metal so must be disposed of carefully.	Lithium must be transported and disposed of safely to avoid environmental damage.

4.10.3 Various, e.g. a dry cell versus a button cell:

Dry cells are useful and quite adequate for some purposes, e.g. in torches, toys and radios. The dry cell was an improvement over earlier cells as it contained no liquid. However, eventually the zinc casing may be used up and allow the battery to leak. Also, if used continuously, ammonia may be produced and cause the cell to burst.

The **button cell** represents improvements in design as it also contains no liquid, it is smaller, has a longer shelf life and provides a more constant voltage for a longer period of time. These advantages have made possible the development of small watches, hearing aids, microphones and calculators. The reduction in size of these appliances has made them more portable and made them available to a greater percentage of the population. Hearing aids, which were previously bulky and obvious are now smaller and more convenient.

At present the button cell is more expensive than the dry cell however, and it usually contains the heavy metal silver so must be disposed of carefully to prevent environmental damage. Heavy metals such as silver are toxic and they can bioaccumulate.

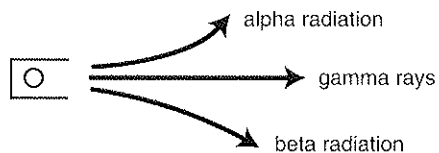
Overall, the button cell is superior, its small size and constant voltage making possible the developments of small electronic devices that would not otherwise be possible. Its cost limits its use slightly, however, with time and mass production, this should decrease.

- 5.1.1
- Isotopes are forms of an element with different numbers of neutrons in the atom and thus different atomic masses. They have the same number of protons, and the same atomic number, as they are the same element. But their mass numbers differ.
 - A stable isotope does not normally disintegrate.
An unstable isotope is said to be radioactive. It continuously emits alpha, beta and/or gamma radiation from its nucleus.
 - 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.

5.1.2

	Alpha radiation	Beta radiation	Gamma radiation
Structure	Particles	Particles	Electromagnetic radiation
Consist of	2 protons and 2 neutrons (same as a helium nucleus)	Electron from the nucleus	High frequency radiation
Charge	+2	-1	Nil
Ionising ability	Good	Fair	Poor
Penetration	Poor (2–10 cm in air)	Fair (5 m in air, 2 mm in aluminium)	Very good (several cm of lead)
Deflection in electric field	Towards negative plate	Towards positive plate	Nil

5.1.3



- 5.1.4 (a) Radioactive atoms decay at random. The nucleus emits particles and/or energy in order to attain a stable structure. The time taken for half of a sample of a radioisotope to decay is called its half-life. The decay of a radioisotope is a nuclear, not a chemical, reaction.
- (b) Half-life is the time taken for half of the atoms in a sample of a radioactive element to decay.

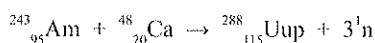
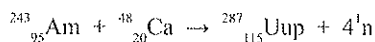
5.2.1 The first element to exist only in the laboratory was technetium (atomic number 43), created in 1937 by bombarding molybdenum with deuterium nuclei. During and after World War II an American team, led by Glenn Seaborg, created 10 new elements in an accelerator, including neptunium, the first element heavier than uranium, and plutonium, the element used in the atomic bomb dropped on Nagasaki.

Since the mid-1970s, synthesis of ever heavier new elements has depended on new generations of particle accelerators.

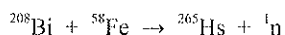
During the last decade, a number of new elements have been produced artificially, e.g. hassium and ununpentium. Many recent discoveries are elements that only exist for a fraction of a second.

5.2.2 Various, e.g.

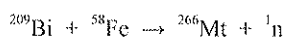
Element 115 – ununpentium – isolated a few atoms of three radioactive isotopes in 2003-4 using a cyclotron and the fusion of nuclei of calcium and americium. (Not yet confirmed by IUPAC.)



Element 108 – hassium – isolated a few atoms by a nuclear reaction involving the fusion of isotopes of lead and iron. Hassium is radioactive and decays very rapidly.



Element 109 – meitnerium – isolated a few atoms by the fusion of isotopes of bismuth and iron. Meitnerium is radioactive and decays very rapidly.



5.3.1 (a) An element heavier than uranium, e.g. neptunium, americium.

(b) Synthesised in a nuclear reactor or an accelerator.

During the past 20 years, transuranic elements have been created in nuclear reactors and by accelerator laboratories in the United States, Germany and Russia. Most of the radioisotopes produced in this way exist for only a short time as they are radioactive and spontaneously decay.

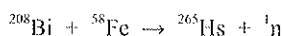
Nuclear reactors bombard targets with neutrons produced by uranium decay. For example neptunium and americium are produced in this way.

Accelerators bombard target atoms with positive particles such as protons or nuclei of atoms such as helium or iron. For example, meitnerium and hassium were produced in this way.

(c) Various, e.g.

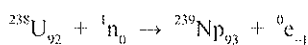
In accelerators, e.g.:

Hassium produced by bombarding bismuth with iron.

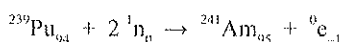


In nuclear reactors:

Neptunium ($z = 93$) – obtained by neutron bombardment of uranium-238.



Americium – obtained by neutron bombardment of plutonium.



5.4.1 (a) Various, e.g. cobalt-60, strontium-90, iodine -123, iodine-131.

(Note: You must be able to state name and mass number.)

(b) Commercial radioisotopes are produced by accelerators and nuclear reactors.

An **accelerator** is a machine that allows particles (e.g. protons, helium nuclei or other nuclei) to be accelerated to high speed and fired at nuclei of atoms with controlled energies in order to study nuclear reactions or make radioisotopes. Cyclotrons are accelerators.

Accelerators produce neutron-deficient isotopes (e.g. iodine-123, fluorine-18).

A **nuclear reactor** is a device that allows a uranium chain reaction to occur safely, releasing neutrons at a slow and controlled rate. A target is bombarded with neutrons to produce a radioactive species with extra neutrons in the nucleus so nuclear reactors produce neutron-rich isotopes (e.g. iodine-131, strontium-90, cobalt-60).

5.5.1 Geiger-Müller tube, badges containing photographic film, thermoluminescent dosimeter, scintillation counter.

5.5.2 Various, e.g.

Geiger-Müller tube

This consists of a sealed glass tube with a thin mica window at one end. The gas inside the tube, often argon, is ionised by radiation entering the tube. This causes a current to flow through the attached circuit, which has a recording device included. This device is most effective in detecting beta particles; it can also detect alpha particles if the source is within 2 cm of the window.

Thermoluminescent dosimeter (TLD)

A TLD measures the amount of gamma radiation received over a period of time. It consists of a badge that contains crystals of an inorganic salt that absorbs the radiation.

When these chemicals are heated, the energy they have gained from radiation is released as light. The intensity of the light emitted on heating gives a measure of the radiation the person wearing the badge has received.

5.6.1 (a) Various, e.g. Americium-241 is used in smoke alarms.

(b) Various, e.g. Technetium-99m is used in the diagnosis of disease.

5.7.1 (a) Americium-241 is used in smoke alarms where it emits alpha particles and low energy gamma rays to form neptunium-237. $^{241}\text{Am}_{95} \rightarrow ^{237}\text{Np}_{93} + ^4\text{He}_2$

When no smoke is present, the alpha particles ionise nitrogen and oxygen in the air in the detector.

When smoke is present, the smoke absorbs the alpha particles emitted, so the rate of ionisation drops and this sets off the alarm.

(b) Technetium-99m is used in the diagnosis of disease. It is injected and the low energy gamma rays it emits can be detected externally. Technetium can show blood flow abnormalities, heart defects, and the size and location of cancerous growths. It can be attached to a range of biological carriers and thus can concentrate in a number of different types of tissues and organs.

5.7.2 Technetium-99m is suitable for use in nuclear medicine because of its properties, such as:

- Its short half-life of 6 hours – this is long enough for medical investigations and short enough to minimise the patient's exposure to radiation.
- It is readily excreted (minimum exposure).
- It emits low energy gamma radiation – thus causing minimal damage to healthy cells.
- It can be attached to a range of biological carriers and thus can concentrate in a number of different types of tissues and organs.
- It can be made when and where needed from molybdenum-99 (99Mo) in a transportable generator. Molybdenum-99 is a product of nuclear fission in a nuclear reactor.

5.8.1 Various, e.g.

Many radioisotopes are used in medicine (e.g. cobalt-60, iron-59 and iodine-131). Their roles include the diagnosis and treatment of disease, monitoring the effectiveness of drugs and sterilising medical and surgical equipment. Cobalt-60 emits gamma rays which can be used to sterilise equipment and also to kill cancer cells in humans.

Radioisotopes perform many useful functions in industry, such as measuring thickness of plastic films and steel sheeting, checking the interior of solid objects for wear and cracks, analysis for forensic science and determining when containers are full.

5.8.2 One problem associated with the use of radioisotopes in industries and medicine is their effects on living cells.

- 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 DNA molecules can be altered so DNA can no longer function correctly.
- Sex cells can be altered and the changes passed on, causing defects in offspring.

Because of these harmful effects, the use of radioactive isotopes must be carefully monitored.

Another problem is with security during transport and storage of radioactive substances and wastes.

Waste disposal is also a problem. At present radioactive wastes are stored pending agreement on safe disposal.

Notes

[illegible]