1. Fossil fuels provide both energy and raw materials such as ethylene, for the production of other substances

1) Construct word and balanced chemical equations of chemical reactions as they are encountered
   - Methane + oxygen → carbon dioxide + water
   - $CH_{4(g)} + 2O_{2(g)} \rightarrow CO_{2(g)} + 2H_2O_{(l)}$

2) Identify the industrial source of ethylene from the cracking of some of the fractions from refining of petroleum

Generally, demand for petrol exceeds supply produced from fractional distillation of crude oil. Thus, oil refineries increase the proportion of the desired hydrocarbon (ie ethylene) by converting lower demand fractions. This process is called catalytic cracking.

Catalytic Cracking: process where high molecular weight fractions from crude oil are broken into lower molecular weight compounds.

3) Identify that ethylene, because of the high reactivity of its double bond, is readily transformed into many suitable products

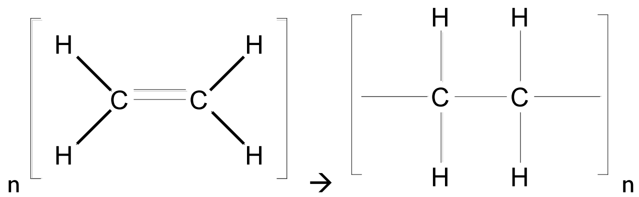
The two bonds of ethylene are not identical. The second bond (pi-bond) is weaker than the first bond (sigma-bond). Thus, only a small amount of energy is needed to enter the system in order to convert a double bond into a single bond. This results in ethylene's high reactivity.

4) Identify that ethylene serves as a monomer from which polymers are made

   - Ethylene is polymerised to polyethylene
   - High pressures produce soft, low density polyethylene, consisting of tangled chains (with molecular masses <100,000)
   - Low pressures produce hard, high density polyethylene, consisting of aligned chains (with molecular masses >100,000)

5) Identify polyethylene as an addition polymer and explain the meaning of the term

Addition polymerisation: a process in which many identical small molecules combine to form one large molecule, with no by-products. The small molecules are called monomers, while the large molecule is called a polymer.



In addition polymerisation, no other products are formed.

6) Outline the steps in the production of polyethylene as an example of a commercially and industrially important polymer

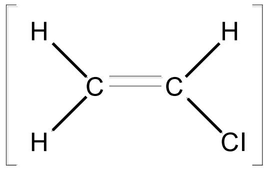
There are two processes used to produce polyethylene:
   - Older gas phase process – high pressure (1000-3000atm), high temperature (300°C), initiator (organic peroxide)
     (1) Initiation

     (2) Propagation

     (3) Termination

7) Identify the following as commercially significant monomers – vinyl chloride, styrene – by both their systematic and common names

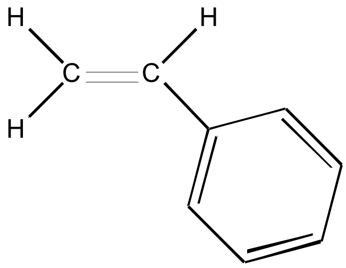
Vinyl Chloride



Systematic name: chloroethene
Common name: vinyl chloride
Polymer: PVC (polyvinyl chloride); polychloroethene

Properties: water-resistant, flame-resistant, flexible
Uses: raincoats, guttering, flexible tubing, floor tiles

Styrene



Systematic name: ethenyl benzene
Common name: styrene
Polymer: polystyrene; poly(ethenylbenzene)

Properties: transparent, rigid, chemically stable
Uses: CD cases, food packaging, expanded form used in foam cups, and food packaging

8) Describe the uses of the polymers made from the above monomers in terms of their properties

9) Gather and present information from first-hand or secondary sources to write equations to represent all chemical reactions encountered in the HSC course

10) Identify data, plan and perform a first-hand investigation to compare the reactivities of appropriate alkenes with the corresponding alkanes in bromine water

See Prac Book (1.1)

11) analyse information from secondary sources such as computer simulations, molecular model kits or multimedia resources to model the polymerisation process

2. Some scientists research the extraction of materials from biomass to reduce our dependence on fossil fuels

1) Discuss the need for alternative sources of the compounds presently obtained from the petrochemical industry

The raw materials used to make petrochemical compounds such as ethylene are chiefly obtained from crude oil. The rate of crude oil consumption far outstrips the planet's ability to convert organic matter into oil. There is a considerable concern that the world will deplete its available oil reserves within the next few decades.

By far, the biggest consumption of crude oil is as a fuel for various methods of transportation. Comparatively, the petrochemical industry currently consumes only about 5% of the total oil used in the world.

There is a general consensus among the world community that oil supplies will eventually be exhausted in the foreseeable future, and there is a great pressure to develop alternative sources of the raw materials used in the petrochemical industry.

Over the past 20 years or so, there have been many attempts to solve this problem. Often, the complexity and expense of the alternatives has made them uneconomical and they have failed to become widely adopted. However, rising world oil prices are slowly changing the economics of the situation, and soon these alternatives may become not only financially viable but mainstream.

2) Explain what is meant by a condensation polymer

A condensation polymer is formed when monomer molecules condense out small molecule such as water when they are polymerised into long chains

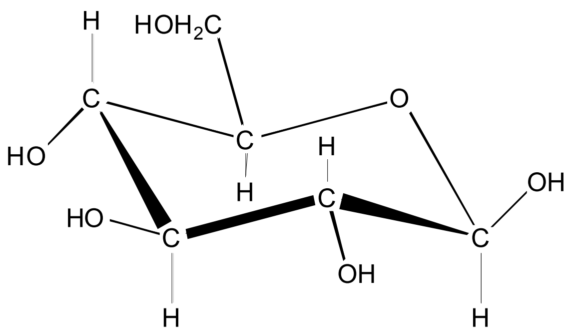
For example, when two glucose monomer molecules react through two hydroxy groups -OH, an H-OH molecule is condensed out, leaving an -O- linking the two monomer molecules. The first two glucose molecules to join condense out an H-OH, and every glucose molecule added to the growing chain then condenses out another H-OH.

3) Describe the reaction involved when a condensation polymer is formed

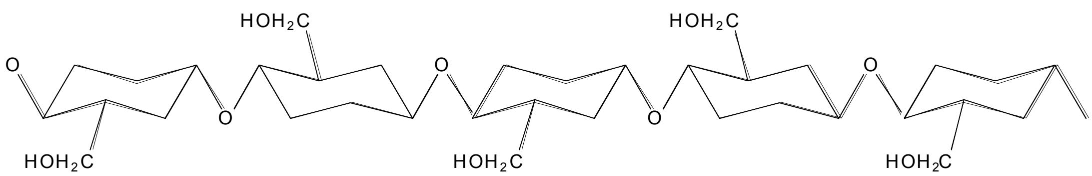
See above

4) Describe the structure of cellulose and identify it as an example of a condensation polymer found as a major component of biomass

Cellulose is a flat, straight and rigid molecule. It is formed by the condensation polymerisation of glucose molecules



When glucose molecules join to form cellulose, the OH on the right carbon atom of one molecule combines with the OH on the left carbon atom of another glucose molecule producing:



The polymerisation causes the ejection of a water molecule for every bond created between glucose monomers

For bonding to occur, alternate glucose units must be inverted.
This type of bonding produces a very linear polymer molecule.

Cellulose is a major component of biomass. It comprises between 1/3 and half of all vegetative matter. Biomass is a material produced by living organisms; mainly it is plant material though the term also includes animal excreta and material made by algae.

5) Identify that cellulose contains the basic carbon chain structures needed to build petrochemicals and discuss its potential as a raw material

Each glucose unit of cellulose has six carbon atoms joined together in a chain, so it could be regarded as a basic structure for making starting molecules for petrochemicals e.g. ethene (2C), propene (3C), butene (4C).

Unfortunately, at the present time there is no easy process to break cellulose down into simple carbon chains, nor is there a micro-organism that can perform this function. This has been a barrier for the widespread use of cellulose as a raw material for petrochemicals.
Although some progress is being made in the production of polymers from biological materials, cellulose has not been the focal point. Nonetheless considerable scientific effort and financial backing is being directed into methods of exploiting cellulose as an alternative source of chemical we currently obtain from crude oil. Whilst, the process is currently expensive, the diminishing world supplies of crude oil may eventually make it financially feasible.

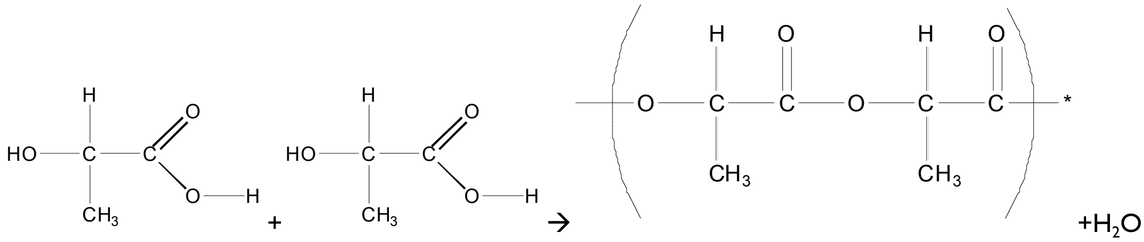
6) Analyse progress in the recent development and use of a named biopolymer

Biopolymers are polymers that are made totally or in a large part by living organisms.

Most synthetic polymers are non-biodegradable. They are dumped in landfills, and exist in the environment unchanged for hundreds of years. As a result biodegradable polymers and plastics are being developed. One such biopolymer is poly-lactic acid (PLA).

PLA is a biodegradable polymer which can be produced from lactic acid, which is found in all living organisms. It has the desired properties of strength and flexibility. Lactic acid can be obtained from the petrochemical industry, but its cost is quite high. A cheaper and more environmentally friendly source is starch waste (e.g. potato waste, sorghum, cheese whey).

The steps involved in its production are:
1. conversion of starch into simple sugars
2. bacterial fermentation of the sugars to form lactic acid
3. removal of water to form a lactide
4. conversion of lactide into a polymer using a solvent free polymerisation process



There is a great potential for the use of poly-lactic acid in the production of plastic items which have a widespread environmental impact. Items such as grocery shopping bags are currently made from non-biodegradable polymers. They comprise a significant amount of the rubbish polluting the natural environment. If we adopted the use of poly-lactic acid in the production of these items, the amount of visible pollution would greatly decrease resulting in a cleaner environment. The biodegradable nature of poly-lactic acid allows items such as plastic bags which are made from it to slowly decay safely into the environment.

Poly-lactic acid is also clear and rigid, having excellent gas barrier properties. It has a potential use as a chemicals container.

Disadvantages: expensive production process.

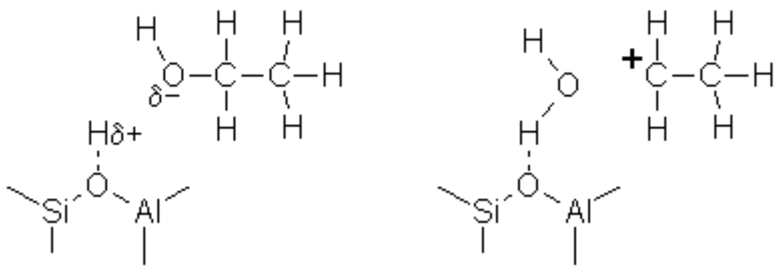
3. Other resources, such as ethanol, are readily available from renewable resources such as plants

1) Describe the dehydration of ethanol to ethylene and identify the need for a catalyst in this process and the catalyst used

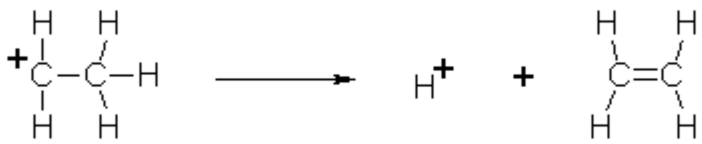
Ethene is produced from ethanol by a process called dehydration. This reaction involves the removal of water.

The best way to do this is to use a zeolite catalyst, in much the same way as is done in the cracking of hydrocarbons. A zeolite can provide highly reactive sites in a controlled environment, safe from the chaos that prevails in a solution.

The exact mechanism of this process is unclear, but the crucial step can be thought of as an acid-base reaction. One way to break up ethanol is to give a base - the hydroxy, OH^- ion - and an acid - the ethyl carbenium ion, $CH3CH2^+$. Strongly acid sites in the pores of the zeolite attack the OH substituent of ethanol, giving a water molecule bound to the surface and an ethyl carbenium ion.



Though this ion is highly reactive and cannot survive long in the presence of water, in the restricted environment of the zeolite pores, ethyl carbenium ion finds it easier to lose a hydrogen ion, giving ethene.



2) Describe the addition of water to ethylene resulting in the production of ethanol and identify the need for a catalyst in this process and the catalyst used

Ethanol can be made in two ways: by fermentation of sugars, or by hydration (adding water) to ethene. Due to the low costs of ethene as a raw material, approximately 95% of the industrial ethanol made in the developed world is produced by the second process.

The double bond of ethene is electron rich and is liable to attack by any chemical species that is poor in electrons. The hydrogen ion, H^+, is perhaps the simplest example of such a species, and for this reason strong acids are used to hydrate ethene.

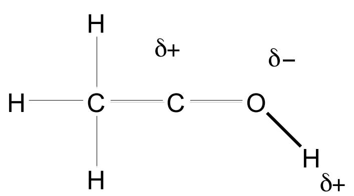
One synthetic route involves the use of concentrated sulfuric acid; H+ adds across the double bond, generating a cation, which receives two electrons from the HSO4- ion to form ethyl sulfate.

$$H_2C{=}CH_2 + H_2SO_4 \underset{1.0-1.4MPa}{\overset{50-90^\circ C}{\rightarrow}} HSO_3\text{-}O\text{-}H_2C\text{-}CH_3$$

When the ethyl sulfate is removed from the concentrated sulfuric acid and added to water, the -O-SO3 group is replaced by the more powerful base -OH to give ethanol in high yield.

$$HSO_3\text{-}O\text{-}H_2C\text{-}CH_3 + H_2O \xrightarrow{70^\circ C} HO\text{-}H_2C\text{-}CH_3 + H_2SO_4$$

3) Describe and account for the many uses of ethanol as a solvent for polar and non-polar substances



Ethanol is a suitable solvent for both polar and non-polar substances due to its unique molecular structure. It has a non-polar CH3 end which has the ability to dissolve other non-polar substances. It also has a hydrophilic (water-loving) hydroxy group which is slight electronegative at the oxygen atom, and slightly electropositive at the carbon and hydrogen atoms. Thus, it is suitable as a solvent for both polar and non-polar substances.

Ethanol can be used as a solvent for medicines and food-additives which do not dissolve easily in water. Once the non-polar material is dissolved in ethanol, water can be added to prepare a suitable solution that is mostly water.

4) Outline the use of ethanol as a fuel and explain why it can be called a renewable resource
The chemical combustion of ethanol is given in the equation below:

$$CH_3\text{-}CH_2\text{-}OH_{(l)} + \frac{7}{2}O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$$

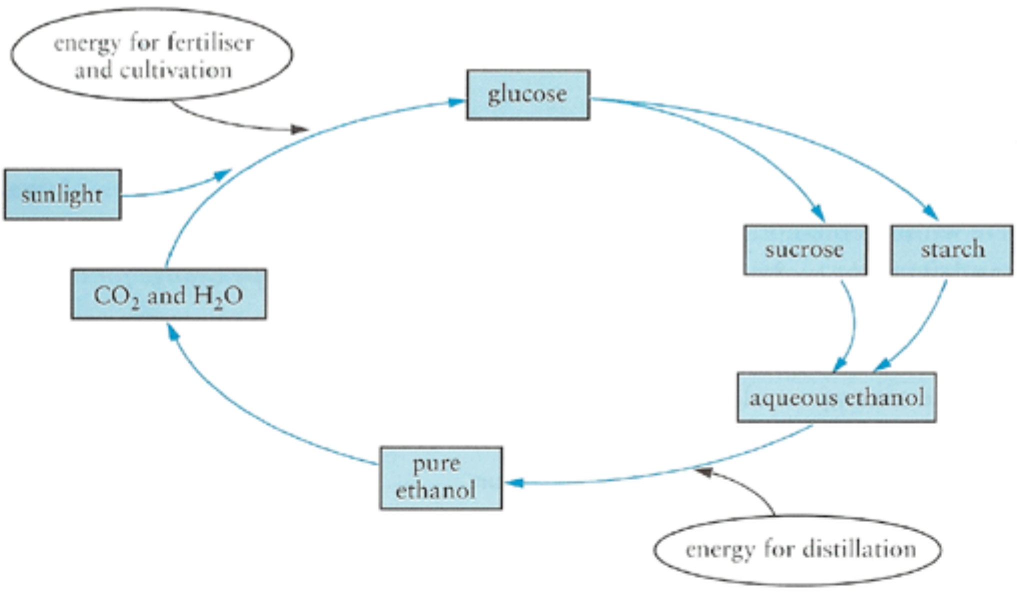
This reaction generates about 1409.4 kJ of energy per mole of ethanol. In other words, 90g of ethanol is required to heat water from 20°C to 80°C. Thus, ethanol has the potential to release a decent amount of energy once combusted. Consequently, ethanol has the potential to be quite a useful fuel.

Ethanol also has an oxygen atom in its structure, thus it requires less oxygen to combust than an equivalent hydrocarbon, resulting in a cleaner burn, with less soot. This is quite a beneficial environmental advantage.

Brazil in the 1970s and 1980s adopted ethanol as its major source of fuel for cars. It grew sugar cane specifically for conversion to ethanol. The purpose was two-fold: to reduce consumption of non-renewable crude oil and to address a trade imbalance problem. The experiment proved expensive and has now been abandoned.

Petrol containing 10 to 20% ethanol can be used in ordinary petrol engines without any engine modification, resulting in its widespread adoption in Australia as a fuel additive.

Ethanol can be called a renewable resource because it can be manufactured from plant material. Once it is combusted it releases carbon dioxide and water as a by-product, as well as energy. Carbon dioxide and water are the raw materials required for plants to photosynthesise.



The ethanol cycle: the blue cycle is 'greenhouse neutral'; the black inputs mean that using ethanol as a fuel still contributes significantly to greenhouse emissions

5) Describe conditions under which fermentation of sugars is promoted
6) Summarise the chemistry of the fermentation process

$$C_6H_{12}O_6 \xrightarrow[37^\circ C]{yeast} 2CH_3C_HOH + 2CO_{2(g)}$$

The conditions that promote fermentation of sugars are:

- A suitable micro-organism, such as yeast
- A suitable temperature (30-40°C)
- A small amount of yeast nutrient such as a phosphate salt

Once ethanol concentration reaches 14-15%, the yeast cannot survive and the fermentation process effectively stops.

The condition under which fermentation of sugars is promoted is an anaerobic environment operating at about 37°C. This is the type of condition where enzymes produced by yeast can work most effectively to convert sugars from biomass into ethanol.

In wine-making, molasses is extracted from sugar cane and mixed with water; the solution is then clarified to remove excess water. Yeast is added and the mixture kept in the aforementioned conditions to be fermented. After the concentration of ethanol reaches about 14-15% the yeast stops producing enzymes because it is being poisoned by the ethanol. The mixture is then distilled using difference in boiling points (87.3°C for ethanol), producing a 95% concentrated solution of ethanol. If a purer solution is required, the remaining water is removed by a molecular sieve which attracts the water molecules away from the ethanol.

7) Define the molar heat of combustion of a compound and calculate the value for ethanol from first-hand data

The molar heat of combustion is the heat change when one mole of the substance is combusted to form products in their standard states (that is, solid, liquid or gas) at 105 Pa (100 kPa) and 25°C (298K)

$$CH_3CH_2OH_{(l)} + \frac{7}{2}O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)} \ \Delta H = -1360 \text{ kJ/mol}$$

8) Identify the IUPAC nomenclature for straight-chained alkanols from C_1 to C_8

- C_1 – methanol
- C_2 – ethanol
- C_3 – propanol
- C_4 – butanol
- C_5 – propanol
- C_6 – hexanol
- C_7 – heptanol
- C_8 – octanol

9) Process information from secondary sources such as molecular model kits, digital technologies or computer simulations to model: the addition of water to ethene; the dehydration of ethanol

See Prac Book (1.2)

10) Summarise the process involved in the industrial production of ethanol from sugar cane

- Sugar cane fermented
- Ethanol and water mixture
- Distillation of water and ethanol
- Ethanol separated from water

11) Summarise the use of ethanol as an alternative car fuel, evaluating the success of current usage

Ethanol is a liquid fuel that readily combusts in air:

$$C_2H_5OH_{(l)} + 3O_{2(g)} \rightarrow 2CO_{2(g)} + 3H_2O_{(l)}$$

It is an easily transportable liquid, and consequently has been proposed as a possible alternative fuel for motor vehicles. It is added to fuel as a petrol extender. Petrol containing 10-20% ethanol can be used in current engines with no necessary modifications. In fact it is preferable to have some ethanol in the petrol, as the oxygen already present in the molecular structure of ethanol contributes to less sooty burn. To use 100% ethanol fuels, car engines must be appropriately modified. Countries such as brazil have, in the 1970s and 80s, implemented the use of ethanol as a main fuel, by growing large areas of sugar cane for the specific conversion to ethanol. The trial had only limited success due to the high costs involved.

Ethanol has been advocated mainly on environmental grounds, that it has a neutral effect on the greenhouse effect. The carbon dioxide that is liberated when ethanol is combusted is equal to the amount that was used in its synthesis
Advantages: renewable; could reduce greenhouse gas emissions

Disadvantages: large areas of agricultural land would need to be devoted to suitable crops, consequently, soil erosion, salinity, deforestation; disposal of large amount of odorous waste fermentation liquors after removal of ethanol would present further environmental problems

12) Perform a first-hand investigation to carry out the fermentation of glucose and monitor mass changes

See Prac Book (1.3)

13) Present information from secondary sources by writing a balanced equation for the fermentation of glucose to ethanol

$$C_6H_{12}O_{6(aq)} \xrightarrow[37°C]{yeast} 2CH_3CH_2OH_{(l)} + 2CO_{2(g)}$$

Mass changes are due to the release of carbon dioxide gas

14) Perform a first-hand investigation to determine and compare heats of combustion of at least three liquid alkanols per gram and per mole

See Prac Book (1.4)

4. Oxidation-reduction reactions are increasingly important as a source of energy

1) Explain the displacement of metals from solution in terms of transfer of electrons

A displacement reaction is one where a metal converts the ion of another metal to the neutral atom.

A more reactive metal will displace less reactive metal ions from solution in an oxidation-reduction reaction.

Oxidation **i**s **l**oss of electrons (OIL)
Reduction **i**s **g**ain of electrons (RIG)

2) Identify that the relationship between displacement of metal ions in solution by other metals to the relative activity of metals

If a metal is higher in the activity series, the metal atoms will react when put in a solution of ions of a metal that is lower in the activity series. The less active metal ions are displaced from solution as they form atoms.

In reacting, the more active metal atom (M) changes to a metal ion (M^{n+}) by losing one or more electrons to form a cation.

3) Account for changes in the oxidation state of species in terms of their loss or gain of electrons

The oxidation state of an element is zero. The oxidation state of a metal cation (M^{n+}) is (+)n.

When a metal atom undergoes oxidation (a loss of electrons), there is an increase in oxidation number from 0 to n. Similarly, when a metal ion undergoes reduction (a gain of electrons), there is a reduction in oxidation number from n to 0.

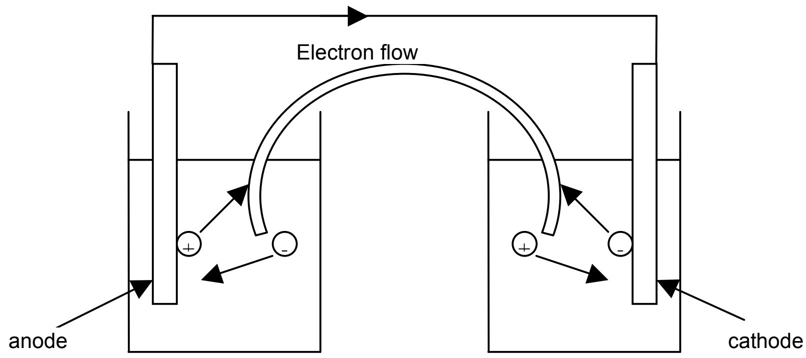
When a substance acts as a reductant, it is oxidised e.g. $Zn \rightarrow Zn^{2+} + 2e^-$
When a substance acts as and oxidant, it is reduced e.g. $I_2 + 2e^- \rightarrow 2I^-$

4) Describe and explain galvanic cells in terms of oxidation/reduction reactions
5) Outline the construction of galvanic cells and trace the direction of electron flow

6) Define the terms anode, cathode, electrode, and electrolyte to describe galvanic cells

Oxidation/reduction reactions usually take place by direct transfer of electrons between the reductant and oxidant.

A galvanic cell is a device constructed so that a reductant and oxidant are physically separated, but connected by an external circuit made of a conductor (to carry electrons) and a salt bridge (to carry charged ions in solution). A galvanic cell is thus composed of two half cells, a reductant half cell, and an oxidant half cell.



the electrons move through the conductor from the reductant half-cell to the oxidant half-cell. The energy of the moving electrons is electrical energy

Galvanic cell: chemical energy → electrical energy
Electrode: part where electrons flow into/out of half-cells
Electrolyte: any solution containing ions

The salt bridge could be filter paper soaked in potassium nitrate. Potassium and nitrate ions do not form insoluble precipitates with other ions. The salt bridge allows movement of ions between the half-cells. This prevents the build up of positive charge at the oxidation half-cell and a build up of negative charge at the reduction half-cell.

Oxidation occurs at the anode
Reduction occurs at the cathode

7) Perform a first-hand investigation to identify the conditions under which a galvanic cell is produced

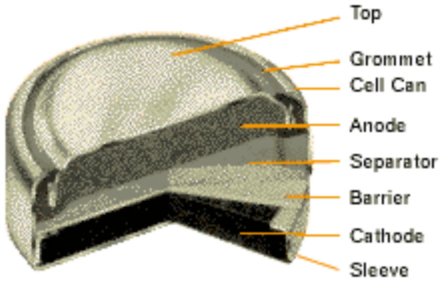
See Prac Book (1.5)

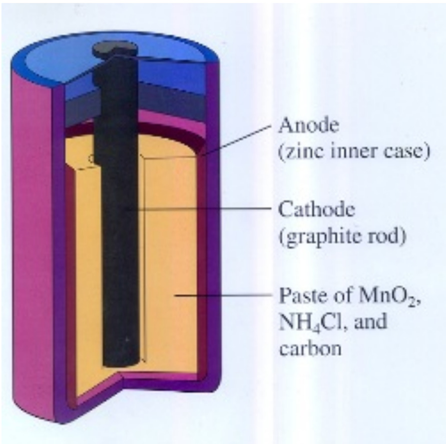
8) Perform a first-hand investigation and gather first-hand information to measure the difference in potential of different combinations of metals in an electrolyte solution

See Prac Book (1.6)

9) Gather and present information on the structure and chemistry of a dry cell or lead-acid cell and evaluate it in comparison to [a button cell] in terms of: chemistry; cost and practicability; impact on society; environmental impact

Cell feature	Dry cell	Button cell (Silver Oxide)
Anode	$Zn_{(s)} \rightarrow Zn^{2+} + 2e^-$	$Zn + 2OH^- \rightarrow ZnO + H_2O + 2e^-$
Cathode	$NH_4^+ + MnO_2 + H_2O + e^- \rightarrow Mn(OH)_3 + NH_3$	$Ag_2O + H_2O + 2e^- \rightarrow 2Ag + 2\ OH^-$
Electrolyte	NH_4Cl	KOH
Voltage	1.5V	1.6V
Energy density (kWh/kg)	0.09	0.125
Cost and practicability	Cheap and portable	More expensive than dry cells, but still relatively cheap; portable
Impact on society	The dry cell was the first commercial battery and therefore had a large impact on society because it made things like torches, radios, and battery-operated devices possible. Even today, when cells which deliver a higher charge are possible, the dry cell is still used for devices which need only small currents such as radios or LCD calculators. The dry cell is robust and easy to store. The button cell, whilst slightly more expensive than the dry cell, delivers a higher voltage for a much smaller volume. Thus it made items such as digital wrist-watches, which are necessarily small physically possible.	
Impact on environment	The dry cell causes minimal environmental problems upon disposal. The manganese (III) is readily oxidised to insoluble manganese (IV) oxide and so immobilised. Small quantities of zinc are not a problem and ammonium salts and carbon are harmless.	





10) Solve problems and analyse information to calculate the potential E° requirement of named electrochemical processes using table of standard potential and half-equations

$$E^\circ = E^\circ_{(reduction)} + E^\circ_{(oxidation)}$$

5. Nuclear chemistry provides a range of materials

1) Distinguish between stable and radioactive isotopes and describe the conditions under which a nucleus is unstable

A radioactive isotope is an isotope which emits radiation, whiles a stable one does not.

If we graph the number of neutrons against the number of protons in the nuclei for isotopes that are stable, we find the points lie within a narrow band. They lie in a 'band of stability'.

For light elements ($Z<20$), the ratio of neutrons to protons is about 1:1. for $Z \approx 50$, the n:p ratio is about 1.3:1 and for $Z \approx 80$, it is about 1.5:1.

A nucleus is unstable if:

- The number of protons is >82
- The n:p ratio lies outside the band of stability.

Radioactive substances can produce three different types of radiation which were originally called alpha (α) beta (β), and gamma (γ) rays because their true identities were unknown.

Eventually it was discovered that alpha particles are helium nuclei, and that beta particles are electrons. Gamma rays are a type of electromagnetic radiation like radio waves, light, and X-rays. Gamma rays have shorter wavelengths than the other forms of radiation and therefore carry large amounts of energy

Name	**Symbols**	**Identity**	**Relative Charge**	**Relative Mass**	**Penetrating Power**
alpha	$\alpha,\ {}^{4}_{2}He$	Helium nucleus	+2	4	Low
beta	$\beta,\ {}^{0}_{-1}e$	Electron	-1	1/2000	Moderate
gamma	γ	Electromagnetic radiation	0	0	high

2) Describe how transuranic elements are formed
3) Describe how commercial radioisotopes are produced

Transuranic elements are elements with an atomic number above that of uranium with atomic number Z= 92. They are synthesised by bombarding uranium with alpha particles or neutrons in nuclear reactors. Likewise, they can be placed in a particle accelerator (cyclotron).

4) Identify instruments and processes that can be used to detect radiation

Photographic film	Nuclear technicians wear sealed badges with photographic film; the amount of radiation can be measured by the darkness of the film
Cloud chamber	An instrument which contains supersaturated vapour of water or alcohol. As radiation passes through, it ionises some of the air; the ions formed act as nuclei upon which droplets of liquid form. In this way the path of the radiation is made visible
Geiger-Müller counter	Radiation causes argon atoms inside the Geiger-Müller tube to become ionised. An electric pulse is created and detected
Scintillation counter	When substances are irradiated with alpha, beta or gamma rays, they emit a flash of light which can then be collected and amplified in a photomultiplier

5) Identify one use of a named radioisotope: in industry; in medicine
6) Describe the way in which the above named industrial and medical radioisotopes are used and explain their use in terms of their chemical properties

Radioactive Isotope	Uses	Benefits	Problems
Sodium-24	Detect leaks in pipes	Short half-life (15 hours) and a beta-emitter. Not hazardous to health	
Technetium-99m	Locates accurate positions of brain tumours, It can be injected into the bloodstream in association with tin compounds and it soon binds with red blood cells	Short half-life (6 hours), Low energy gamma rays easily pass out of the body, so they can be detected by the gamma camera	Can also be produced in instruments called cyclotrons directly, but is far more expensive, Gamma emitting, therefore can kill healthy body cells

7) Process information from secondary sources to describe recent discoveries of elements
8) Use available evidence to analyse benefits and problems associated with the use of radioactive isotopes in identified industries and medicine