9.2 The Identification and Production of Materials

Gavin Edwards

School of Chemistry

UNSW

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

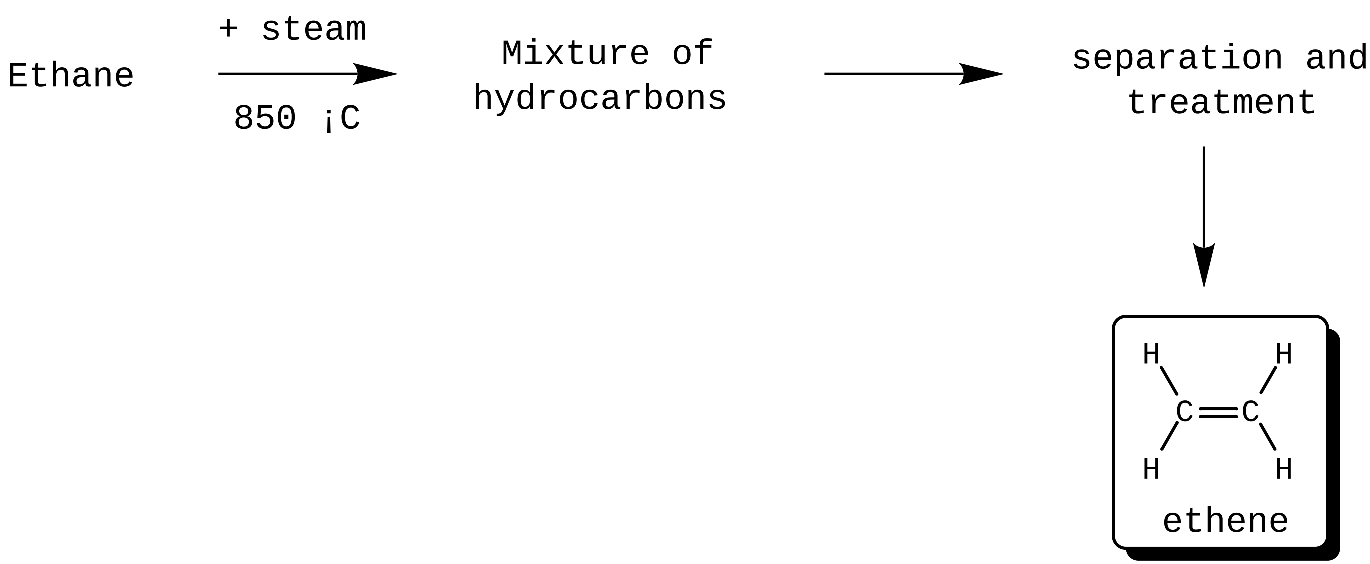
Part coverage in Old Syllabus Core 11

Catalysts - discussed in Energy module of new syllabus

1.1 Identify the industrial source of ethene from the catalytic cracking of some of the fractions from the refining of petroleum

- ¥ Ethene does not occur naturally in large quantities
- ¥ Many possible industrial methods for production
- ¥ Two processes:
- ¥ STEAM CRACKING - pyrolysis in absence of a catalyst (NOT mentioned in syllabus)
- ¥ CATALYTIC CRACKING - pyrolysis in presence of a catalyst (in the new syllabus)
- ¥ Ethane is the major raw material for ethene production at Orica, Botany - by a process called STEAM CRACKING

Steam Cracking of Ethane



Steam(?) cracking different hydrocarbons yields different ratios of products, and gives different yields of ETHENE

Precursor→ Product (%)↓	ethane	propane	butane	Naphtha 40¡-180¡	AGO *	VGO *
Methane	3.82	25.30	21.70	18.00	11.20	12.60
Ethene	53.00	39.04	39.20	34.30	26.50	29.00
Propylene	0.89	11.34	15.34	14.10	13.40	13.10
C6 to C8#	0.39	0.31	1.45	0.80	1.20	1.40
Aromatic HCs ƒ	0.45	4.01	3.43	9.66	12.19	12.70
C9 to C18	0.00	1.33	1.45	5.57	18.41	14.96

- *AGO = atmospheric gas oil; *VGO = vacuum gas oil
- # Non-aromatic hydrocarbons
- ƒ Benzene, Toluene, Xylenes, Ethylbenzene, and Styrene
- Source: Ethylene Senior Chemistry Series, Orica

1.2 Explain that catalytic cracking is an example of an industrial process that involves surface reactions with inorganic catalysts

- ¥ CATALYTIC CRACKING (Cat cracking) of higher alkanes and other petrochemicals provides ethene and other hydrocarbons
- ¥ Higher boiling distillates can be converted to lighter hydrocarbons better suited as fuels
- ¥ *i.e.*, shorter hydrocarbon chains are produced
- ¥ Cat cracking requires energy
- ¥ Catalysts are used to lower operating temps. and to increase yields
- ¥ Early catalysts were natural silica/alumina clays
- ¥ By mid 1970 s - zeolites and molecular sieve-based catalysts
- ¥ Zeolites - more selective for desired ranges of products
- ¥ High catalyst surface areas are required for high reaction rates

A schematic picture of a catalytic cracker

This picture is available at:

http://www.britannica.com/bcom/art/00015/73.gif

1.3 Explain the relationship between the properties of alkanes and alkenes and their non-polar nature and weak dispersion forces

- This point follows the Energy module in the Preliminary course
- Alkanes are less reactive than alkenes
- Alkanes and alkenes have similar boiling points
- Alkenes often have lower melting points than alkanes, because the rigid double bond prevents tight packing in the crystal lattice

Compound	Boiling Point (C)	Melting Point (¡C)
Hexane	69	-95
trans-2-Hexene	68	-133
cis-2-Hexene	69	-141
trans-3-Hexene	67	-113
cis-3-Hexene	66	-138

1.4 Identify that ethene, because of the high reactivity of its double bond, is readily transformed into many useful products

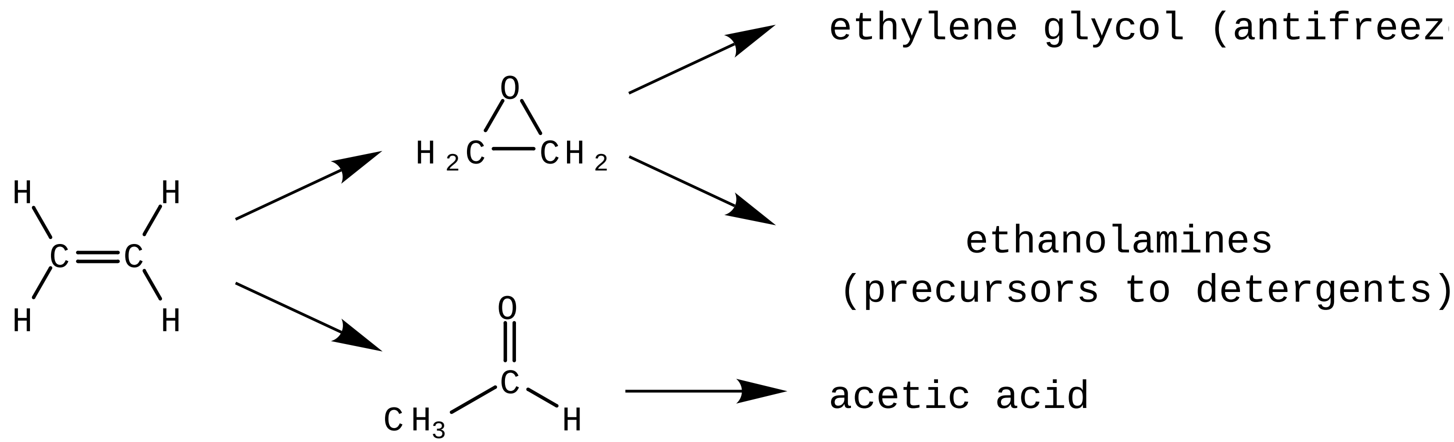
¥ Old Syllabus: Core 11.2 (Carbon Chemistry)

¥ Issues: Application to ***OTHER*** alkenes? (YES!)

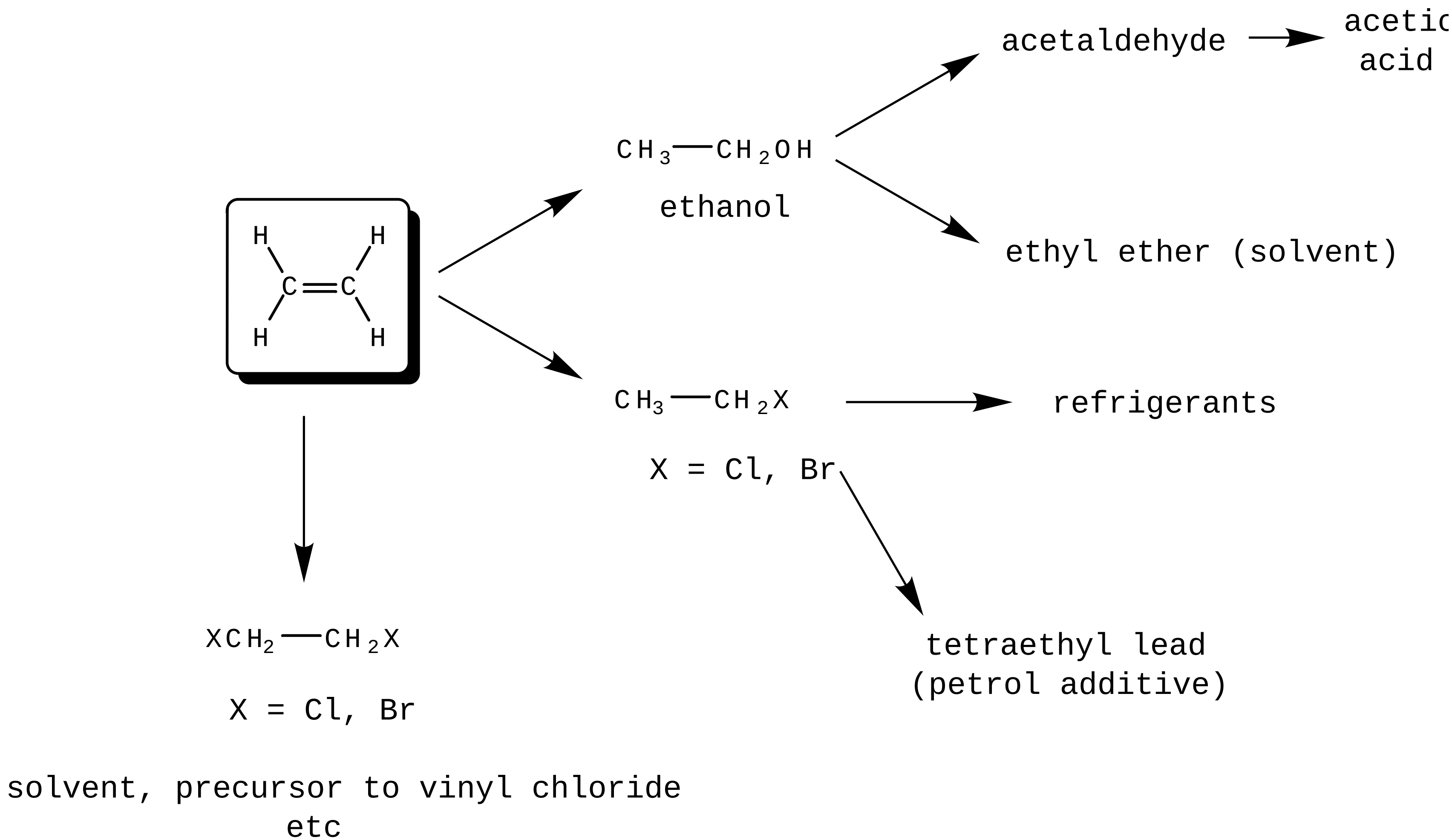
¥ Orientation of addition (Markovnikov s Rule)? (Not in old syllabus)

¥ Mechanisms? (NO!)

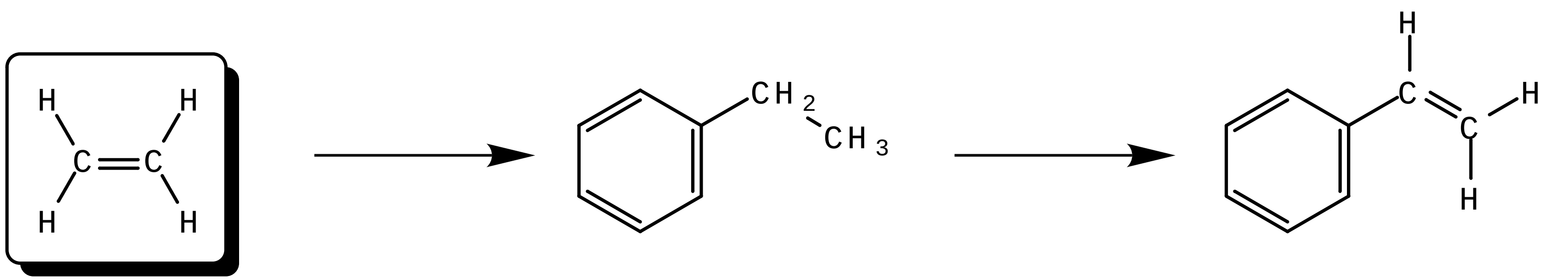
¥ **Oxidation leads to some useful materials**



Hydration, hydrohalogenation and halogenation lead to useful addition products



Alkylation ultimately leads to important monomers such as STYRENE



Styrene

1.5 Identify that ethene serves as a monomer from which polymers are made

¥ Information sheets on ethene and poly(ethene) from http://www.orica.com.au

¥ Poly(ethene) also known more widely as polythene or polyethylene

¥ There are different overall structures - high and low density poly(ethene): HDPE & LDPE

¥ HDPE - low branching

¥ LDPE - significant level of branching

¥ Copolymers with other monomers give new materials (don t include it, but be aware that most source material will mention copolymers)

High Density Poly(ethene) - HDPE

- Produced at low pressure
- *Uses*: blow-moulded milk bottles, pressurised water pipe, supermarket check-out bags

A picture is available at:

http://www.britannica.com/bcom/art/00016/72.gif

Low Density Poly(ethene) - LDPE

¥ Produced at high pressure
¥ *Uses*: flexible films, packages

A picture is available at:

http://www.britannica.com/bcom/art/00016/84.gif

1.6 Identify poly(ethene) as an addition polymer and explain the meaning of this term

¥ Polymer formed from repetitive bonding of many monomer units

¥ Two types: ADDITION & CONDENSATION

¥ Monomers for addition polymers are ALKENES (sometimes ALKYNES)

¥ Monomers ADD to one another: double bonds break and new single carbon-carbon bonds join the units

¥ Polymer chains grow by successive additions of monomer units to the chain

¥ The backbone is usually an unbroken chain of carbon atoms

1.7 Outline the steps in the production of poly(ethene) as an example of a commercially and industrially important polymer

Pictures are available at:

http://www.britannica.com/bcom/art/00016/77.gif

http://www.britannica.com/bcom/art/00016/81.gif

Steps in the production of poly(ethene) - two ways to approach this topic

- **The actual SYNTHESIS requires:**
- Initiation, to start things off;
- Propagation, where the MONOMERS add to a reactive end, extending the chain; and
- Termination, where the polymerisation process stops.
- **Also, you can discuss:**
- SYNTHESIS
- Manipulation of the raw polymer (pelletising)
- Extrusion, moulding *etc.*

1.8 Identify the following as commercially significant monomers:

¥ Vinyl chloride (chlorothene)

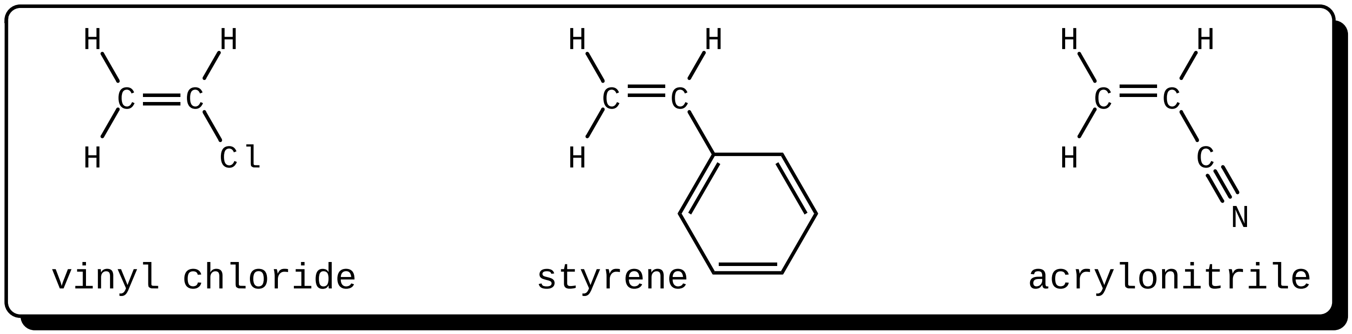
¥ Acrylonitrile (propenenitrile)

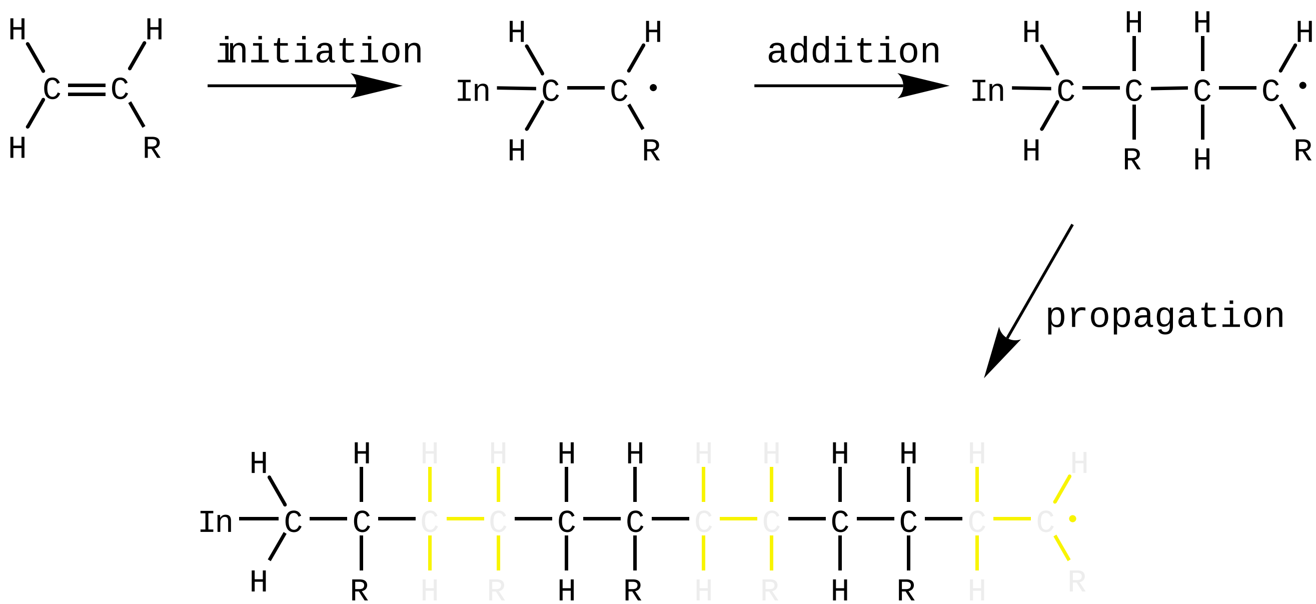
¥ Styrene (phenylethene)

¥ Students should know both systematic and common names!

¥ A cute polymer Website is **http://www.psrc.usm.edu/macrog/index.htm**

Polymerisation - general schematic representation





note the head-to-tail arrangement

1.9 Account for the uses of the polymers made from the above monomers in terms of their properties

- **Poly(vinyl chloride) - PVC** - a good electrical insulator that does not burn easily. It is tough and durable. Some uses include flooring, footwear, films for shrink-wrapping, pipes ..
- A PVC Website: **http://www.ramsay.co.uk/**
- **Polystyrene** - two forms:
- a hard form, used for many objects that require durability (computer and TV casings, household objects, CD cases .); and
- an expanded form that floats well and has excellent thermal insulating properties. Uses: foam packaging, drinking cups, bike helmets ..
- Polystyrene Website: **http://www.polystyrene.org/facts.html**

And polyacrylonitrile .

- ¥ **Polyacrylonitrile** - main uses: synthesis of carbon fibre, yarns
- ¥ Carbon fibre: **http://www.psrc.usm.edu/macrog/carfsyn.htm**
- ¥ Its main importance is when acrylonitrile is present in copolymers

2. Some scientists continue to research the extraction of materials and energy from BIOMASS to reduce our dependence on fossil fuels

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

¥ Energy module in Preliminary course: Living organisms make high energy compounds

¥ Website about biomass

¥ **http://solstice.crest.org/renewables/re-kiosk/biomass/index.shtml**

¥ It mainly concerns the use of biomass for energy

2.2 Explain what is meant by a condensation polymer and describe the reaction involved when a condensation polymer is formed

¥ Monomers for condensation polymerisation MUST have two functional groups (*e.g.,* amine and carboxylic acid chloride)

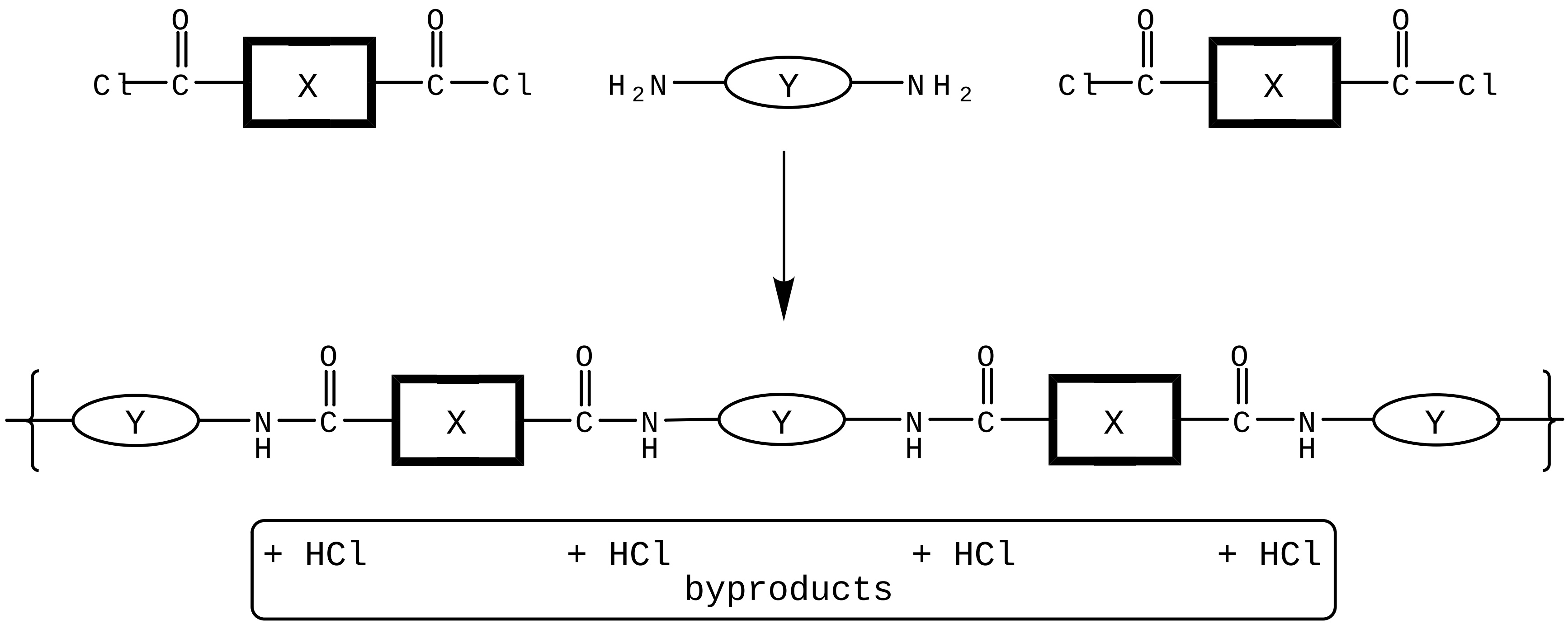
¥ The monomers react together giving a more complex structure with loss of a small molecule (usually water or HCl)

¥ Condensation polymers usually require two different monomers

¥ The most common synthetic condensation polymers have amide linkages (the Nylons, and the Aramids such as Kevlar), and ester linkages (polyesters such as disco wear, and PET)

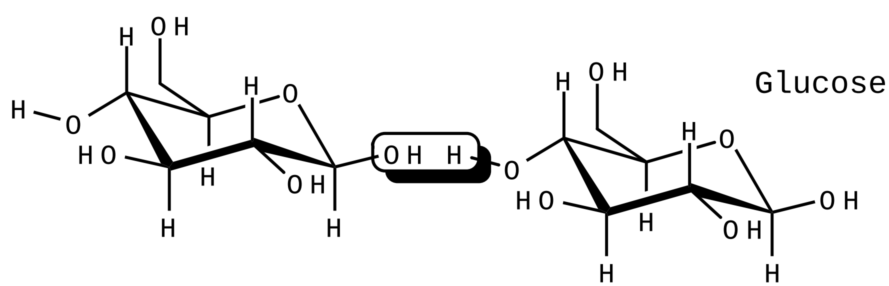
¥ Many naturally occurring polymers are also condensation polymers (proteins, polysaccharides, DNA), although the structures are often very complex.

Schematic representation of polyamide formation

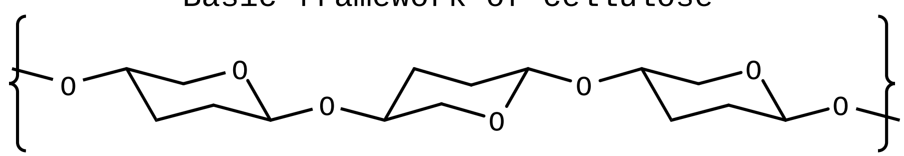


2.3 Describe the structure of cellulose; identify it as an example of a condensation polymer found as a major component of biomass

- Cellulose is a condensation polymer made up of 3,000 or more GLUCOSE units, linked from C1 of one unit to C4 of another
- Cellulose is the basic structural component of plant cell walls
- It comprises ¯ 33% of all vegetable matter (90% of cotton, 50% of wood)



Basic framework of cellulose



Some polymer structures

The picture is available at:

http://www.britannica.com/bcom/art/00075/33.gif

2.4 Identify that cellulose has the basic carbon-chain structures needed to build petrochemicals and discuss its potential as a raw material

- Cellulose has repeating six carbon units
- Digestion of cellulose with acid yields glucose
- Fermentation of cellulose (or glucose) produces simpler molecules such as ethanol.
- Methane can be converted to higher hydrocarbons using gas-to-liquid technology

2.5 Assess current developments in the use of biopolymers and describe a process currently used industrially to produce biopolymers

¥ CELLULOSE - modification results in useful polymers (cellulose acetate is a non-flammable film used for movie film, and it also forms the fabric Rayon; cellulose nitrate is gun cotton)

¥ Some simple organic materials (glycerol, acetone) are produced by fermentation.

¥ Poly(hydroxybutanoate) - PHB - a natural polyester made by some bacteria; ZENECA markets a realted biopolymer as Biopol, it usually biodegrades completely within 9 months.

¥ Cyclodextrins and chemically modified cyclodextrins: their use to aid in making drugs more soluble and stabilising compounds.

¥ http://www.cyclodex.com/

¥ http://www.goldbridge.com/web/cyclodex.html

The Board s definition of Biopolymers

¥ These are naturally occurring polymers such as cellulose, starch, and gluten which are already being used in several food and non-food areas. Biopolymers offer unique possibilities for the development of new products in a large variety of application areas. A large variety of natural polymers is available with special properties and with the advantage of biodegradability and renewability.

Biopol

¥ A family of linear polyesters

¥ Poly(3-hydroxybutanoate-*co*-3-hydroxypentanoate)

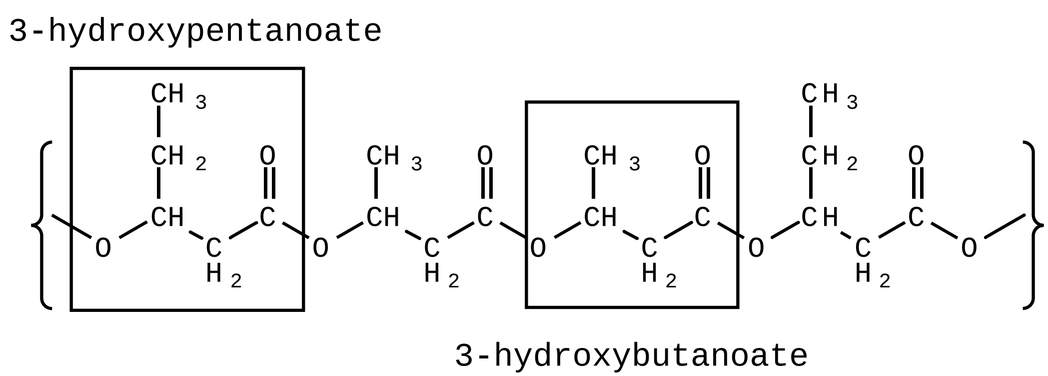
¥ Produced in nature from the fermentation of sugars by the bacterium *Alcaligenes eutrophus*

¥ Stable in air, and humid conditions

¥ Renewable, and biodegradable (soil microorganisms)

¥ Degrades in an robic environments (landfills)

¥ A thermoplastic - can be injection- and blow-moulded



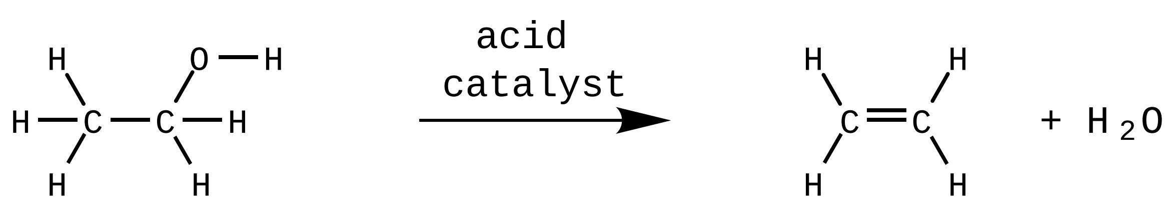
3 . Other resources, such as ethanol, are readily available from plants. Such renewable resources will be of increasing importance as fossil fuel reserves are depleted.

3.1 Describe the dehydration of ethanol to ethene and identify the need for a catalyst in this process and the catalyst used.

¥ Ethanol is stable and does not spontaneously convert to ethene

¥ Ethanol can be dehydrated using acidic catalysts

¥ The dehydration requires mineral acid catalysis, *e.g.*, H_2SO_4 (conc.)



3.2 Describe the addition of water to ethene resulting in the production of ethanol and identify the need for a catalyst in this process and the catalyst used.

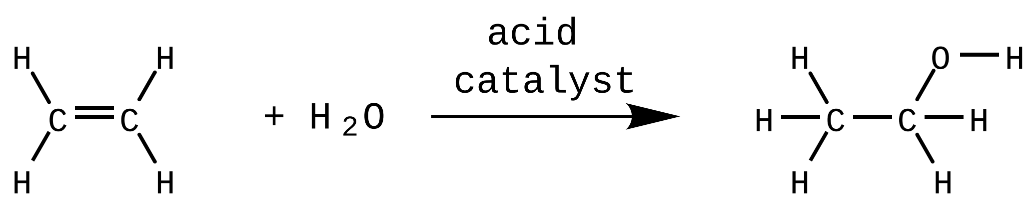
¥ Ethene does not react with neutral water

¥ In the presence of an acidic catalyst, an addition reaction takes place

¥ Again, a mineral acid catalyst is required

¥ Industry: Phosphoric acid / 300 ¡C

¥ In 1995, US produced 280 000 000 kgs



3.3 Describe the uses of ethanol as a solvent and relate this to the polar nature of the ethanol molecule

- ¥ Solvents - discussed in the Water module, Preliminary course
- ¥ Ethanol is a polar molecule
- ¥ The OH group makes ethanol completely miscible with water (formation of hydrogen bonds).
- ¥ The CH_3CH_2 unit provides an organic part which enables organic materials to dissolve in it (a non-polar hydrocarbon chain).
- ¥ Like dissolves like - but BEWARE! Hexane and ethanol are miscible!
- ¥ Definition of soluble ?? (Completely / partly / very slightly / insoluble)

3.4 Outline the use of ethanol as a fuel and explain why it can be called a renewable resource

¥ Combustion of ethanol is exothermic

¥ $C_2H_5OH + 3\ O_2$ Ł $2\ CO_2 + 3\ H_2O$

¥ Ethanol is prepared by hydration of ethene.

¥ Ethanol can also be prepared by biological methods - fermentation

¥ Fermentation uses carbohydrates which renew very quickly

¥ Concept of fractional distillation to purify ethanol

3.5 Describe conditions under which fermentation of sugars are promoted

¥ Old syllabus: Core 11.3
¥ Fermentation breaks complex structures into simpler ones, providing energy for the host organism
¥ Fermentation is catalysed by enzymes.
¥ Enzymes are biological catalysts which are proteins
¥ Proteins are condensation polymers with amide backbones
¥ Fermentation can usually only occur within narrow temperature ranges

3.6 Summarise the chemistry of the fermentation process

- ¥ The chemistry involved is extremely complex
- ¥ A number of biological pathways are known as fermentation
- ¥ The conversion of sugars to ethanol also produces carbon dioxide.
- ¥ $C_6H_{12}O_6$ (glucose) gives 2 moles of ethanol and 2 moles of CO_2
- ¥ The initial step is isomerisation of glucose (or its phosphate) to fructose, then cleavage to two trioses
- ¥ The trioses (such as pyruvate) then lose CO_2, ultimately giving ethanol.
- ¥ A scheme is available at:
- ¥ http://www.fgi.net/~corpalt/science/glycol.gif
- ¥ (more complex than needed!)

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

¥ When one mole of a substance combines with oxygen in a complete combustion reaction, the heat of reaction is the MOLAR HEAT OF COMBUSTION

¥ The molar heat of combustion can be calculated once the heats of formation of all participants are known.

¥ The data presented on the next slide are probably too advanced for HSC students, but it would be interesting to compare results obtained from their first-hand investigations with the real McCoy!

Molar Heats of Combustion - II

- ΔH_f [$C_2H_5OH(l)$] = -277.0 kJ mol^{-1}; ΔH_f (O_2) = 0 kJ mol^{-1}
- ΔH_f [$CO_2(g)$] = -393.51 kJ mol^{-1}
- ΔH_f [$H_2O(l)$] = -285.83 kJ mol^{-1}
- **$C_2H_5OH + 3\ O_2 \rightarrow 2\ CO_2 + 3\ H_2O$**
- **ΔH_{comb} = (-393.51).2 + (-285.83).3 - (-277.0) - (0).3**
- So ΔH_{comb} [$C_2H_5OH(l)$] = -1367.51 kJ mol^{-1}
- (Data: PW Atkins, Physical Chemistry 1978)

3.8 Assess the potential of ethanol as an alternative fuel; discuss the advantages and disadvantages of its use

¥ Ethanol can be blended with petrol to produce gasohol ; usually about 10% of ethanol is added.

¥ Ethanol burns cleanly, and CO_2 that is produced is recycled into biomass.

¥ Ethanol is a renewable resource

¥ BUT

¥ Ethanol is more highly oxidised than hydrocarbon fuels, so it has a lower energy yield per gram

¥ ΔH_{comb} [$C_2H_5OH(l)$] = -29.7 kJ g^{-1}

¥ ΔH_{comb} [$C_2H_6(g)$] = -51.9 kJ g^{-1}

¥ ΔH_{comb} [$CH_4(g)$] = -55.5 kJ g^{-1}

¥ And fuel ethanol currently has higher production costs than conventional fuels (economic arguments - how valid are they?)

4. Electrochemical methods are important in producing materials and making energy available

Follows from:

¥Old Syllabus: Elective 2 - Oxidation & Reduction

¥Relates to Metals in Prelim. course

4.1 Explain the displacement of metals from solution in terms of transfer of electrons

¥ Metals in solution = MX_n

¥ Oxidation state (Oxidation number) of metals as elements = 0

¥ Salts: metal ions carry a +ve charge,

¥ *i.e.* no. of electrons < no. of protons

¥ Displacement of elemental metal from solution of a salt requires:

¥ M^{n+} + n*e*— Ł M

¥ *i.e.,* transfer of electrons TO the metal

¥ *i.e.,* REDUCTION of the metal

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

- ¥ Metals can be ranked by their ability to displace one another from solution
- ¥ $Zn(s) + Cu^{2+}(aq)$ Ł $Zn^{2+}(aq) + Cu(s)$
- ¥ $Cu(s) + 2\ Ag^{+}(aq)$ Ł $Cu^{2+}(aq) + 2\ Ag(s)$
- ¥ Observations can lead to an activity series (Zn should displace Ag^{+})
- ¥ Predictions can be made based on this series
- ¥ Some metals can also displace H_2 from either H_2O or acid solution
- ¥ $2\ Al(s) + 6\ H_2O(l)$ Ł $2\ Al(OH)_3(s) + 3\ H_2(g)$
- ¥ *N.B.* Protective oxide layers on Al, Mg

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

¥ Oxidation and Reduction OCCUR TOGETHER

¥ **OXIDATION**: Loss of electrons

¥ A species that is oxidised increases its oxidation number

¥ A species that is oxidised is also the REDUCTANT in the reaction

¥ **REDUCTION**: Gain of electrons

¥ A species that is reduced decreases its oxidation number

¥ A species that is reduced is also the OXIDANT in the reaction

¥ $3\ MnO_2 + 4\ Al$ Ł $3\ Mn + 2\ Al_2O_3$

¥ Mn(IV) and Al(0) react to give Mn(0) and Al(III)

Determining Oxidation Numbers (ON)

- ¥ In elemental form: ON = 0 (*e.g.*, Na, Cl_2, S_8)
- ¥ Monoatomic ions: ON = ion charge
- ¥ The sum of all ON s for electrically neutral compounds equals zero
- ¥ For an ion, the sum of all ON s must equal the overall charge
- ¥ Group 1A: ON = +1
- ¥ Group 2A: ON = +2
- ¥ Hydrogen: ON = +1 combined with non-metals; ON = -1 with metals
- ¥ Fluorine: ON = -1
- ¥ Oxygen: ON = -2, except in peroxides (ON = -1) {or with F}

4.4 Describe and explain galvanic cells in terms of oxidation/reduction reactions

4.6 Identify the use the terms anode, cathode, electrode and electrolyte to describe galvanic cells

¥ Zn(s) + Cu^{2+}(aq) Ł Zn $^{2+}$(aq) + Cu(s)

¥ Oxidation and reduction - a transfer of electrons (current???)

¥ Separation of two half-reactions - energy can be harnessed

¥ Components of each half-reaction placed in separate containers, or **half-cells**

¥ (Inert conducting electrodes, *e.g.*, Pt, used if neither component of a half-cell is a conducting solid, *e.g.*, Fe^{2+}/Fe^{3+})

¥ OXIDATION - occurs at the anode

¥ REDUCTION - occurs at the cathode

¥ Electrolyte

¥ Salt bridge - addresses charge imbalance

A typical galvanic cell

http://www.funsci.com/fun3_en/electro/electro.htm

Diagram of a cell is at:
http://www.funsci.com/fun3_en/electro/elec_06.gif

4.5 Outline the construction of galvanic cells and trace the direction of electron flow

¥ Separate the half-cells

¥ Connect by an external circuit & salt bridge or porous membrane

¥ Standard reduction potentials and calculation of E^o_{cell}

¥ More positive $E^o \Rightarrow$ stronger oxidant

¥ Cell runs in the direction that produces a +ve cell potential

¥ In calculations: half cells are written in the reduction form. E^o for the cell is calculated by taking the E^o of the more positive half cell (cathode) minus the E^o of the less positive half cell (anode)

¥ Usually: $E_{measured}$ › E^o_{cell} : non-standard conditions *e.g.*, concentrations?

4.7 Describe the industrial use of electrolysis for refining a named metal identifying:

- ¥ Relates closely to Metals module 1.4 in New Syllabus
- ¥ **Oxidant**
- ¥ **Reductant**
- ¥ **Electrolyte used**
- ¥ **Conditions under which the electrolysis must occur and the reason for the conditions**
- ¥ **Electrolysis** - the reverse of a galvanic cell
- ¥ Possibilities: Al? Na?

Refining of Aluminium - I

¥ Aluminium - 3rd most abundant element on Earth

¥ Ore called Bauxite (contains impure Al_2O_3)

¥ Two stages - refining the crude ore to remove impurities, and electrolytic recovery of the metal

¥ **RECOVERY**

¥ Bauxite reacts with NaOH(aq)

¥ $Al_2O_3(s) + 2\ OH^{-}(aq) + 3\ H_2O(l)$ Ł $2\ Al(OH)_4^{-}(aq)$

¥ Acidification with CO_2 produces hydrated alumina

¥ $2\ CO_2 + 2\ Al(OH)_4^{-}(aq) + (n\text{-}3)H_2O(l)$ Ł $2\ HCO_3^{-}(aq) + Al_2O_3.nH_2O(s)$

¥ Dehydration produces pure alumina

Refining of Aluminium - II

¥ A mixture of purified alumina and CRYOLITE (Na_3AlF_6) is melted

¥ (m.p. of Al_2O_3 is 2050 ¡C; mixture melts at 1000¡C)

¥ Overall electrolytic cell reaction is not well understood

¥ Anode: 2 $Al_2OF_6^{2-}$ + $12F^-$ + C Ł 4 AlF_6^{3-} + CO_2 + $4e^-$

¥ Cathode: AlF_6^{3-} + $3e^-$ Ł Al + 6 F^-

¥ Overall cell reaction:

¥ 2 Al_2O_3 (in Na_3AlF_6) + 3 C(s) Ł 4Al(l) + 3CO_2(g)

¥ Reaction must be carried out in the melt: H_2O is more easily reduced than Al^{3+}

¥ Recycling: MANUFACTURE of 1 mol of Al requires 365.8 kJ

¥ RECYCLING of 1 mol of Al requires 26 kJ

4.8 Identify an example of the use of electroplating and explain why the process is used

- Tin cans - a thin coating of Sn over steel cans
- Cr plating of steel bumper bars
- Ag & Au plating of spoons and jewellery
- Electroplating serves protective (from corrosion and wear) and decorative roles
- Electroplating in the classroom (Ni onto Cu pennies): **http://www.finishing.com/faqs/school.html**

5. Nuclear chemistry provides a range of materials to assist in tracing and thus better understanding complex chemical reactions

Relates to: Old syllabus: Core 3 Atomic structure

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

¥ Many nuclei are RADIOACTIVE (only 279 of ¯ 2 000 known nuclides are stable!)

¥ Nuclear stability: when **nuclear strong force** outweighs electrostatic repulsion

¥ Radioactive nuclei DECAY to form another nucleus and one or more particles:

¥ α-particles are helium nuclei

¥ β-particles are electrons

¥ γ-rays are high energy photons

¥ Other modes of decay, *e.g.*, electron capture: don t include them!

¥ Define **half-life**: the time required for the number of nuclides to reach half its initial value.

Which elements/nuclides are radioactive?

- ALL NUCLIDES with 84 or more protons are unstable with respect to radioactive decay
- Apart from that, there are few hard and fast rules
- Very few stable nuclides exist with neutron:proton ratio < 1
- (exceptions: $^{1}H_{1}$, $^{3}He_{2}$) ***(I know it s not the right format ..)***
- Light nuclides: stable when neutron:proton ratio ¯ 1)
- (But note: $^{8}Be_{4}$ has $t_{1/2} = 6.7 \times 10^{-17}$s !!)
- Heavier nuclides (>20 protons) - require a higher neutron:proton ratio

Radioactive decay

- Students should be able to balance nuclear decay reactions
- The total no of protons, and total no of neutrons and protons, in the reactants,
- MUST equal those in the products
- $^{226}Ra_{88}$ Ł ^{222} $Rn_{86} + {}^{4}He_{2}$
- $^{63}Ni_{28}$ Ł ^{63} $Cu_{29} + {}^{0}\beta_{-1}$
- $^{238}U_{92}$ Ł ^{234} $Th_{90} + {}^{4}He_{2} + 2\ {}^{0}\gamma_{0}$
- They should be aware that radioactive decays can occur as part of a series
- Often >1 decays are required to reach a stable nuclide

$$^{238}_{92}\mathrm{U} \xrightarrow{\alpha\ \text{decay}} {}^{234}_{90}\mathrm{Th} \xrightarrow{\beta\ \text{decay}} {}^{234}_{91}\mathrm{Pa} \xrightarrow{\alpha\ \text{decay}} {}^{234}_{92}\mathrm{U} \quad \text{etc}$$

5.2 Describe how transuranic elements are produced in nuclear reactors

¥ Particle accelerators used to impart high velocities to nuclear particles

¥ Particle accelerators use a combination of electric and magnetic fields

¥ The high energy overcomes electrostatic repulsion

¥ Two nuclei collide and fuse

¥ This produces transuranic elements (Z = 93 to 112 .)

¥ All transuranic elements are radioactive, usually with short half-lives

¥ Often, only a few atoms are created

Examples of transuranic elements produced by particle accelerators

¥ $^{239}Pu_{94} + {}^{4}He_{2}$ Ł $^{240}Am_{95} + {}^{1}H_{1} + 2\,{}^{1}n_{0}$ ($t_{1/2}$ = 50.9 h)

¥ $^{252}Cf_{98} + {}^{10}B_{5}$ Ł $^{256}Lr_{103} + 6\,{}^{1}n_{0}$ ($t_{1/2}$ = 28 s)

¥ $^{249}Cf_{98} + {}^{18}O_{8}$ Ł $^{263}Sg_{106} + 4\,{}^{1}n_{0}$ ($t_{1/2}$ = 0.8 s)

5.3 Describe how commercial radioisotopes are produced in nuclear reactors

¥ Nuclear fission - differs from radioactive decay

¥ Nuclides *e.g.*, $^{235}U_{92}$, are bombarded with neutrons

¥ Nuclides split into lighter elements, also producing neutrons

¥ $^{235}U_{92} + {}^{1}n_{0}$ Ł $^{141}Ba_{56} + {}^{92}Kr_{36} + 3\,{}^{1}n_{0}$ + energy

¥ ***OR*** $^{235}U_{92} + {}^{1}n_{0}$ Ł $^{137}\ Te_{52} + {}^{97}Zn_{40} + 2\,{}^{1}n_{0}$ + energy

¥ > 200 isotopes of 35 elements produced from fission of $^{235}U_{92}$

¥ Radioisotope generators: http://lunis.luc.edu/nucmed/tutorial/radpharm/sect-f1b.htm

5.4 Identify instruments and processes that can be used to detect radiation

- ¥ **Photographic emulsions** - interaction of the silver halide with a charged particle produces an image for each such interaction
- ¥ **Geiger counters** (Geiger-Mueller counters)
- ¥ High energy particles from radioactive decay IONISE argon within the Geiger counter
- ¥ Formation of ions and electrons allows a current to flow, and this current is detected electronically
- ¥ **Scintillation counters** - substances such a zinc sulfide give off light when struck with high energy radiation
- ¥ Photocells sense the emitted light

5.5 Identify one use of a named radioisotope in industry

¥ Cobalt-60: a γ-emitter - used for γ-sterilisation - this process is useful for many items that would be damaged by heat sterilisation

¥ http://www.ansto.gov.au/info/brochures/rad2.html

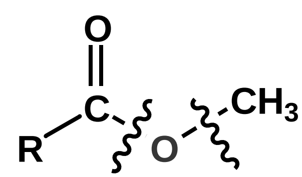
5.6 Identify one use of a named radioisotope in medicine

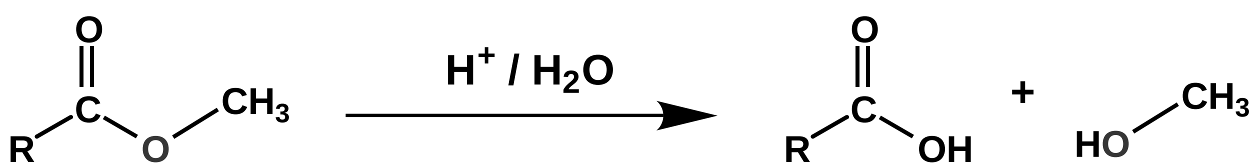
- The ANSTO Website lists many radioisotopes used in Autralia, and their uses.
- **http://www.ansto.gov.au/ansto/nucmed.html**
- There is a brochure that is downloadable(!) as a PDF file:
- http://www.ansto.gov.au/info/brochures/Isotopes.pdf

5.7 Identify one use of a named radioisotope to determine and/or verify reaction mechanisms in chemistry

- ¥ Radioisotopes can be used to trace the fate of an atom
- ¥ Iodide/Periodate reaction:
- ¥ $IO_4^{-} + 2\,^{128}I^{-} + H_2O$ Ł $^{128}I_2 + IO_3^{-} + 2OH^{-}$
- ¥ Hydrolysis of esters - alkyl or acyl C—O fission?

Which bond cleaves in ester hydrolysis?





Biochemical applications

¥ Use labelled sources such as ^{14}C-labelled acetate, or ^{32}P phosphate

¥ Allows metabolic pathways to be traced, such as:

¥ The carbon atoms from cholesterol come from acetate

¥ Glycine is a precursor of purines

5.8 Describe the way in which the above named radioisotopes are used and relate this to the chemical properties of the radioisotopes described

¥ Radioisotopes have similar physical and chemical properties to non-radioactive nuclides of the same element

Some sources

¥ The Ask Jeeves Search engine **http://www.ask.com**

¥ http://britannica.com

¥ http://www.orica.com.au (for ethene and polymers)

¥ M. Silberberg, CHEMISTRY: The Molecular Nature of Matter and Change WCB McGraw Hill, 1996

¥ S.S. Zumdahl, CHEMISTRY 4th Ed, Houghton Mifflin, 1997