PRODUCTION OF MATERIALS

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9.2.1 Synthetic Polymers

Cracking

- Petroleum (crude oil and natural petroleum gas) fractionally distilled
- Cracking: long hydrocarbons broken into smaller ones, **endothermic**
- Catalytic – **zeolite** (aluminosilicates), **500°C,** around **1 atm, no air**
- Thermal – steam (inert diluent), **700 to 1000°C, 70 atm**

Ethylene to useful products

- **Alkene**, more reactive than alkanes (addition reaction; double bond)
- E + **H_2O** – **ethanol** (CH_3CH_2OH), industrial solvent and reactant
- E + **O_2** – **ethylene oxide** (CH_2CH_2O), fumigant, steriliser
- Used to make monomers: **vinyl chloride, styrene, vinyl acetate**

Polymerisation and Polyethylene

- Polymerisation: chemical reaction where **identical small molecules combine** to form a large molecule
  - Monomer: small molecules, polymer: large product molecule
- Double bond breaks, becomes **polyethylene (PE):** $\left(CH_2 - CH_2 \right)_n$
- Is an addition polymer: polymer formed **without loss** of atoms

Production of Polyethylene

- **LDPE** – **80 to 300°C, 1000 to 3000 atm**
  - Free **radical** (**initiator**) from splitting peroxide and its O–O
  - **Chain branching** – cannot pack close/linearly
- **HDPE** – **60°C, 1 atm**
  - **Catalyst trialkylaluminium + titanium chloride** compound
  - More ordered, long **unbranched**/**aligned** molecules
- Process:
  - Initiator/catalyst **attaches** to ethylene, molecules join
  - Process stops when **two chains join**, forms **variable lengths**

Other Monomers and their polymers

Polymer Name	**Common + Syst. Monomer Name**	**Properties**	**Uses**
LDPE	ethylene; ethene	Soft, flexible	Bags, cling wrap
HDPE		Hard,tough	Bins, laundry bottles
PVC	Vinyl chloride; chloroethene	+add'ves: rigid, flame/water resist	Electrical insulation, hoses, water pipes
Polystyrene	Styrene; ethenylbenzene	Transparent, heat insulation, floats	CD cases, cups, foam packing material

9.2.2 Biological Polymers

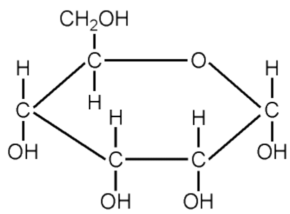
- Alternate sources needed, instead of **petrochemical industry**
  - Crude oil is **limited, non-renewable**, run out in few decades
- Renewable **biomass**: material produced by **living organisms**
  - E.g. plant material, animal excreta, organic waste

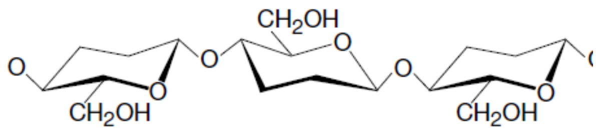
Condensation Polymerisation

- Condensation polymer: polymer forming by **elimination of small molecule** (often water)¸ may be biodegradable (unlike addition)
- E.g. **cellulose** from **glucose** – OH joins with H to form water, nylon, carbohydrates, proteins, silk
- Formation: when a pair of monomers join together, a **molecule splits out** between function groups

Cellulose as a polymer

- Monomer: **glucose**, 5 C's with OH's, one O, one CH_2OH instead of OH
- Polymer: cellulose, C–O–C bonds, H_2O splits out
  - Alternating α (up) and β (down) units





- Major component of **plant material/biomass** – plant cell walls, structural comp. of woody plants/fibres – cotton, flax, hemp

Cellulose for **petrochemicals**

- Cellulose made into **ethanol** by breaking down into glucose – difficult
  - Digestion by **cellulose enzymes** (ground up and NaOH added)
  - Digestion with **strong acid** (conc. H_2SO_4)

Cellulose potential as a **raw material**

- Biopolymers: polymers made by **living organisms** (e.g. cellulose)
  - Rayon (reconstituted cellulose), cellophane
- Also has **three/four**-carbon chains, useful for polymers, if able to separate cellulose

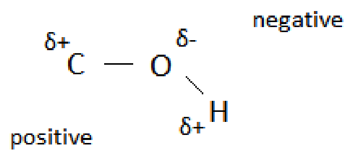
9.2.3 Ethanol

Ethanol

- Dehydration: water **removed** from compound
    - $C_2H_5OH_{(l)} \xrightarrow{\text{conc. } H_2SO_4 \text{ catalyst}} C_2H_{4\,(l)} + H_2O_{(l)}$
- Hydration: water **added** to a compound
    - $C_2H_{4\,(l)} + H_2O_{(l)} \xrightarrow{\text{dil. } H_2SO_4 \text{ catalyst}} C_2H_5OH_{(l)}$
- Heat of combustion: -1360 kJ/mol (calc. in practical booklet)

Ethanol as a solvent

- Dissolves **polar**: **OH end** is polar, O more electronegative/H bonding
    - E.g. Chloroform, ether, $CHCl_2$
- Dissolves **non-polar**: **alkyl** section makes **dispersion forces**
    - E.g. Short chained hydrocarbons
- Forms **homogenous mixture** with water (H bonding)

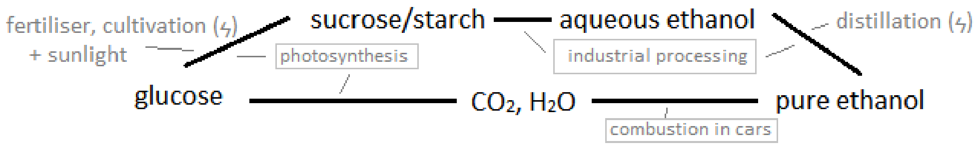


Ethanol as a fuel

- $C_2H_5OH_{(l)} + 3O_{2\,(g)} \rightarrow 2CO_{2\,(g)} + 3H_2O_{(l)}\ \Delta H =$
- **Renewable**: made from CO_2 and H_2O, returns CO_2 and H_2O
    - Some **industrial processes/cultivation** need energy

Advantages	**Disadvantages**
Renewable (lower use of fossil fuels)	Large agricultural land required – soil erosion, deforestation, salinity
Greenhouse neutral	Engines require modifications > 15%
Easy to transport (liquid)	Lower
Low C and CO emissions (extra O)	

Fermentation



- From sucrose/starch to ethanol, it undergoes **fermentation**
- Enzymes (**biological catalysts**):
- $C_6H_{12}O_{6\,(aq)} \xrightarrow{\text{yeast}} 2C_2H_5OH_{(aq)} + 2CO_{2\,(g)}$
    - Around **15%** ethanol – higher level kills yeast, distillation: **95%**
- **Conditions**: suitable micro-organism (**yeast**), suitable **grain/fruit** with high starch/sugars, low **oxygen**, around **37°C**

9.2.4 Electrochemistry

Oxidation-reduction reactions

- Displacement reaction: metal **converts an ion** to a **neutral** atom
- For the reaction $Zn_{(s)} + CuNO_{3\ (aq)} \rightarrow 2Cu_{(s)} + ZnNO_{3\ (aq)}$
  - Net ionic equation: $Zn_{(s)} + Cu^{2+}_{(aq)} \rightarrow 2Cu_{(s)} + Zn^{2+}_{(aq)}$
  - **OIL RIG** – oxidation is losing, reduction is gaining electrons
  - Oxidation ½ equation: $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^{-}$
  - Reduction ½ equation: $Cu^{2+}_{(aq)} + 2e^{-} \rightarrow Cu_{(s)}$
- Metal **higher** in activity series **displaces other metal** (e.g. Zn above)
  - Because: more active metals lose electrons more easily
  - Hydrogen is the reaction of **acid** to form $\mathbf{H_2}$
- Oxidation States: the charge of an ion – **O is -2, H is +1**
  - Increase = losing electrons = oxidising (0 → +2 above)
  - Decreasing = gaining electrons = reducing (+2 → 0 above)

Oxidises (reductant)

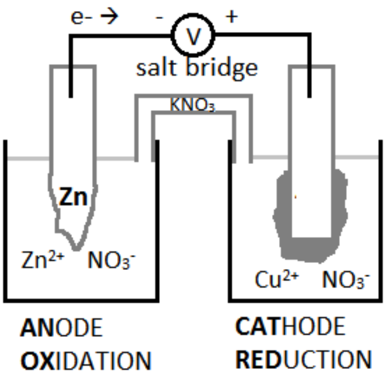
reverse this metal's half-equation

reactivity series (back of periodic table)

Reduces (oxidant)

Galvanic Cells

- **Separate locations**, **spontaneous**
- Anode: Electrode in which **oxidation occurs:** $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^{-}$
- Cathode: Electrode in which **reduction occurs:** $Cu^{2+}_{(aq)} + 2e^{-} \rightarrow Cu_{(s)}$
- Electrode: conductor of a cell, connected to external circuit
- Electrolyte: substance which conducts electricity
- Salt Bridge: used to balance the imbalance of ions
  - NO_3^- towards **anode**, Zn^{2+} towards **cathode**
- Electrons travel **left to right (voltage always positive)**



9.2.5 Nuclear Chemistry

Stable and Radioactive Isotopes

- Isotopes: elements with **different number of neutrons**

$${}^{A}_{Z}X$$

A = MASS NUMBER = p + n
Z = ATOMIC NO. = p

- Neutron: ${}^{1}_{0}n$, can decompose to p and n: $\mathbf{{}^{1}_{0}n \rightarrow {}^{1}_{1}p + {}^{0}_{-1}e}$
- Stable neutron ratio (1n:p) is 1, 50=1:1.3, 80=1:1.5, >83=all unstable
- Radioactive isotopes release **radiation (spontaneous emission)**

Type	Formula	Rel. Mass	Penetration
alpha (α)	${}^{4}_{2}He$	4	Low – paper
beta (β)	${}^{0}_{-1}e$	1/2000	Medium – 0.5 mm Al, 0.6 mm Pb
gamma (γ)		0	High – 5 cm Pb, 15 cm concrete

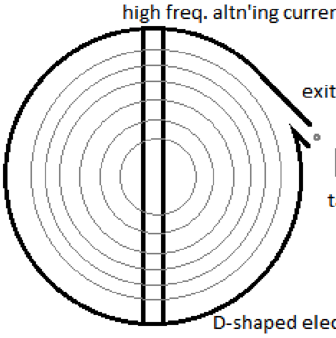
Transuranic Elements

- Transuranic Element: Atomic number > 92 (uranium), not in nature
- Made when isotope is **not fissile** (able to be split), e.g.:
- $^{238}_{92}U + ^{1}_{0}n \rightarrow ^{239}_{92}U\ (unstable) \rightarrow ^{239}_{93}Np + ^{0}_{-1}e$

Detecting Radiation

1. **Photographic film**: darkens, used in radiation badges
2. **Cloud Chamber**: supersaturated water/alcohol vapour
   - Radiation ionises (loses e^-) air, becomes liquid
     α: straight dense tracks, β: zigzag, γ: faint
3. **Geiger Muller counter**: (argon), radiation ionises gas
   - Gas moves to middle to create **electric pulse**
4. **Scintillation counter**: light flash collected + amplified

Production of commercial radioisotopes



- Nuclear Reactor: structure where controlled **nuclear fission** occurs
  - Neutrons bombard atoms, **splits into 2 fragments**, e.g.
    $^{235}_{92}U + ^{1}_{0}n \rightarrow ^{141}_{56}Ba + ^{92}_{36}Kr + 3(^{1}_{0}n) + energy$
  - **Extra n absorbed by rods** to prevent hitting more U atoms
  - Electricity for Japan/USA, Australia for medical/industrial use
- Particle Accelerator: bombard heavy nuclei with high speed particles
  - Linear: **straight line** > 1 km, alternating + and – tubes
  - Cyclotron: **compact spiral**, high frequency alt. current

Radioisotopes in Industry and Medicine

- Cobalt 60 in **industrial radiography to inspect metal parts and welds for defects**
  - Radiation directed towards object, film on other side
  - More gamma radiation passes through metal parts
  - ½ life 4 to 6 years, chemically inert = long life equipment
- Technetium 99m (m = unstable) in **detecting circulation disorders**
  - Attached to appropriate substance, picks up to detect clotting
  - Measured using scintillation counter
  - ½ life 6 hours, low energy γ radiation – low damage to tissues, quickly removed from body