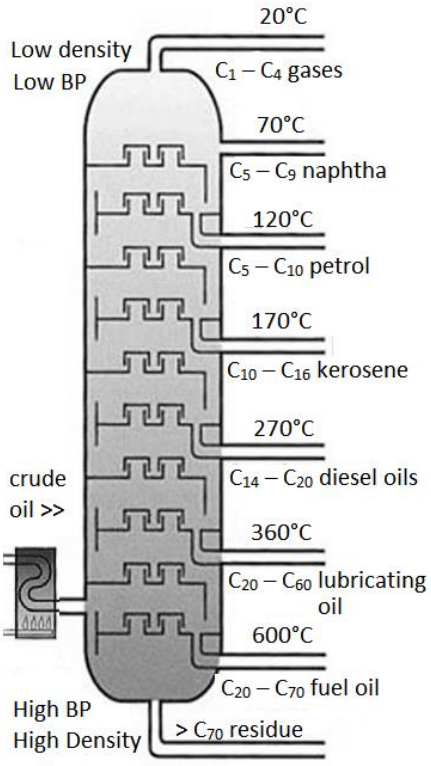
CHEM 9.2.1 SYNTHETIC POLYMERS

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

1.1 Construct word and balanced formulae **equations of chemical reactions** as they are encountered

- Reactants → Products
- Balance and states
- Add equations for 'explain' or 'higher' verbs

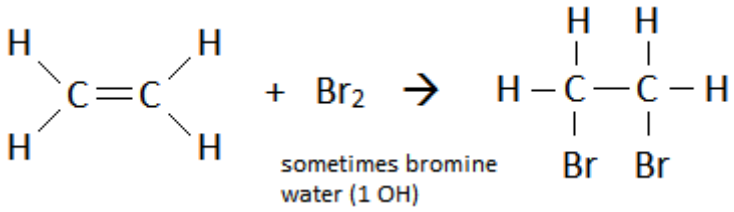


1.2 Identify the **industrial source of ethylene** from the **cracking** of some of the fractions from the refining of petroleum

- Petroleum (crude oil and natural petroleum gas) → fractional distillation
- **Cracking** – break less useful large hydrocarbons to smaller ones, endo
- **Catalytic** – use of catalysts: SiO_2, Al_2O_3, zeolites
  - **Zeolites – crystalline aluminosilicate** (Al, Si, O and metal ions)
  - Cat cracker @ **500°C w/o air**, pressure above atmospheric
  - Products are alkanes and alkenes of shorter chains
- **Thermal/Steam** – steam passed through tubes 700 to 1000°C
  - Steam – inert diluent to keep concentrations low + abv atm. pres
  - Decompose alkanes completely into small alkenes + H_2

1.3 Identify that ethylene, because of the **high reactivity of** its **double bond**, is readily **transformed into many useful products**

- Ethylene (ethene) is an **alkene**.
- Non-polar molecules, weak intermolecular dispersion forces between molecules
- Very reactive (unlike alkanes)
  - Alkanes **burn in air** and have **substitution reactions** (Cl_2 or Br_2 + light)
  - Alk*enes*: **Addition reaction**: double bond breaks open to form 2 single bonds – e.g. bromine



- Ethylene can be **transformed into**:

Useful Products	**Reaction**	**Uses**
Ethanol ($CH_3 - CH_2 - OH$)	ethylene + H_2O/H^+	Industrial solvent and reactant
Ethylene oxide ($CH_2 - CH_2 - O$) [△]	ethylene + O_2	Fumigant
*Ethylene glycol ($HO - CH_2 - CH_2 - OH$)	ethylene oxide + H_2O/H^+	Anti-freeze, polymer
*Vinyl chloride ($CH_2 = CH - Cl$)	ethylene + Cl_2 + O_2 + cat	Polymer
*Styrene ($C_6H_5 - CH = CH_2$)		Polymer
*Vinyl acetate ($CH_2 = CH - O - CO - CH_3$)		Polymer

* Used for polymers – poly(vinyl chloride) PVC, polystyrene, poly(vinyl acetate) PVA, polyester PET

1.4 Identify that ethylene serves as a **monomer** from which **polymers are made**

- **Polymerisation** – chemical reaction where identical **small molecules combine** to form a large molecule
  - **Monomer** – small molecules, **polymer** – large product molecule
  - **Catalyst** used to speed process up
- Ethylene is a monomer that polymerises to form **polyethylene**
  - Double bond is broken and links made
  - 300 to a 3000 monomers

$$-(CH_2 - CH_2)-_n$$

1.5 Identify **polyethylene** as an **addition polymer** and explain the **meaning** of this term

- Polyethylene is an **addition polymer** – formed by molecules **w/o loss** of atoms
- Polyethylene is capable of **adding more ethylene molecules** at the end of chain

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

LOW DENSITY POLYETHYLENE (LDPE) – GAS PHASE PROCESS

- High temp (**80 to 300°C**) and high pressure (**1000 to 3000x atmospheric**)
- Uses **initiator** (organic peroxide, compound w/ $-O-O-$, oxygen gas) to produce **free radicals**
  - **Not a catalyst** – incorporated into actual polymer
  - Free radical is formed when covalent bond is broken and bonding electron is left
    - E.g. in $-O-O-$, the oxygen atoms are split from covalent bond and form two free radicals
- **Propagation** – growth of polymer as monomers are added to chain
- **Chain branching** – at some C atoms, a H is replaced with an alkyl group
  - Cannot **pack close** or **linearly/orderly**
  - **Dispersion forces are weakened** (btwn chains) = low MP
- Soft, tough, flexible, translucent

HIGH DENSITY POLYETHYLENE (HDPE) – ZIEGLER-NATTA PROCESS

- Low temp (**60°C**) and **normal (1x)** atmospheric pressure
- Uses a **catalyst** – titanium (II) chloride and a trialkyl aluminium compound - **triethylaluminium**
- Greater mechanical strength (6x), more crystalline, > density – straighter

THE PROCESS

- Initiator/catalyst **activates ethylene** by attaching to it, ordinary ethylene molecules join

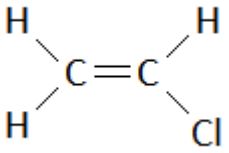
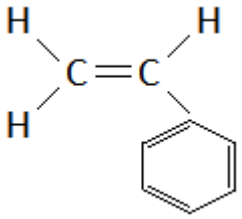
$$R\bullet - CH_2 + CH_2 = CH_2 \rightarrow R - CH_2 - CH_2 - CH_2\bullet$$

- Process stops when (a) two activated chains join or (b) H ion exchanged

$$R\bullet - (CH_2 - CH_2)_x + R\bullet - (CH_2 - CH_2)_y \begin{cases} \text{a. } R\bullet - (CH_2 - CH_2)_{x+y} - R\bullet \\ \text{b. } R\bullet - (CH_2 - CH_2)_{x-1} - CH = CH_2 + R\bullet - (CH_2 - CH_2)_{y-1} - CH_2 - CH_3 \end{cases} \Big] \text{ stable molecules}$$

- Variable lengths = Distribution of molecular weights – average molecular weight measured

1.7 Identify the following as **commercially significant monomers**: **vinyl chloride and styrene**, by both their **systematic** and **common** names

Common Name	Systematic Name	Structural Formula
Vinyl Chloride	Chloroethene	
Styrene	Ethenylbenzene	

1.8 Describe the **uses** of the polymers made from the above monomers **in terms of their properties**

Polymer*	Properties	Uses
LDPE	Low density, soft, flexible	Milk bottles, soft toys, wrapping film
HDPE	High density, hard	Kitchen utensils + containers, rigid toys, rubbish bins, tough carry bags
PVC	+Additives: rigid and flame resistant, water resistant	Electrical insulation, garden hoses, water pipes, guttering
Polystyrene	Transparent (few crystals), heat insulation, floats	Car battery cases, tool handles, furniture, CD cases, drink cups, foam packing material

*Polymer has brackets if it is two words or begins with number