Topic 5a – Introduction to Organic Chemistry
Revision Notes

1) Formulae

Be able to recognise and use the different ways of showing organic compounds:

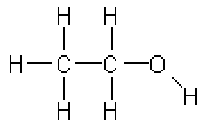
- **Molecular formula** is the actual number of atoms of each element in a molecule e.g. C_2H_6O for ethanol

- **Empirical formula** is the simplest whole number ratio of the atoms of each element in a molecule e.g. CH_2 for ethene (from molecular formula $C_2H_4 \div 2$)

- **General formula** is the simplest algebraic formula for a member of a homologous series e.g. C_nH_{2n+2} for alkanes

- **Structural formula** is the minimum detail that shows the arrangement of the atoms in a molecule e.g. CH_3CH_2OH for ethanol

- **Displayed formula** shows the relative positioning of atoms and the bonds between them e.g. for ethanol:



All bonds should be shown. **Do not** put –OH for the alcohol group

2) Functional groups and naming organic compounds

Be able to recognise and use the following terms:

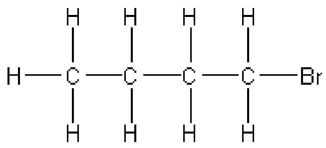
- **A homologous series** is a series of organic compounds having the same functional group with successive members differing by CH_2
- Alkanes, alkenes, alcohols and halogenoalkanes are all homologous series
- **A functional group** is a group of atoms responsible for the characteristic reactions of a compound e.g. C=C for alkenes and –OH for alcohols

The rules for naming organic compounds were devised by IUPAC (International Union of Pure and Applied Chemistry). They are as follows.

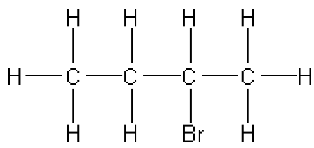
1) The functional group gives the ending of the name e.g. –ol for an alcohol
2) The number of carbons gives the first part of the name e.g. prop- or propan- for 3 carbons
3) Number the carbon chain to give the functional group carbon the lowest number
4) Any side chains (branches) or halogens go at the front of the name with commas between numbers and dashes between numbers and words e.g. 2,2-dimethylhexane
5) With more than 1 side chain or halogen, use alphabetical order e.g. 1-bromo-2-methylbutane

3) Structural isomers

- Structural isomers have the same molecular formula but different structural formulae
- There are 3 types of structural isomers: chain, position and functional group
- **Position isomers** differ in the location of the functional group e.g.

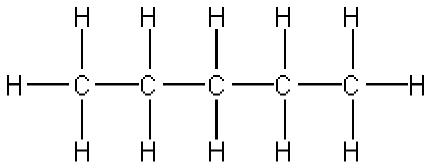


1-bromobutane

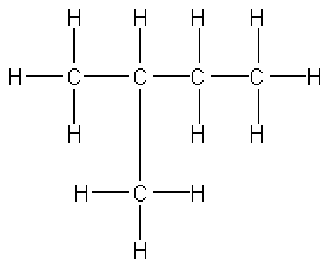


2-bromobutane

- **Chain isomers** have different arrangements of the carbon chain e.g.



Pentane



2-methylbutane

- A molecular formula can be common to compounds from different families. These are **functional group isomers** e.g.
    - o C_3H_6O can be either propanal, CH_3CH_2CHO, or propanone, CH_3COCH_3
    - o C_3H_6 can be either propene or cyclopropane
    - o $C_3H_6O_2$ can be propanoic acid, methyl ethanoate or ethyl methanoate
    - o C_2H_6O can be either ethanol or methoxymethane, CH_3OCH_3 (an ether)

- **For CHEM1, the only pair of functional group isomers needed is alkenes and cyclic alkanes (both of which have general formula C_nH_{2n})**

Topic 6b – Alkanes
Revision Notes

1) General

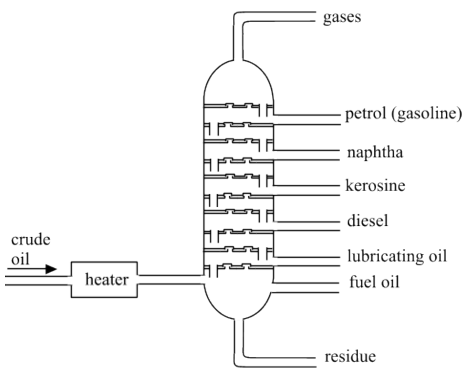
- Alkanes are saturated hydrocarbons with general formula C_nH_{2n+2}
- Saturated = only single C-C bonds
- Hydrocarbon = contains C and H only
- Alkane molecules are non-polar so the only intermolecular forces are Van der Waal's forces

2) Boiling points

- Boiling point increases with chain length – more electrons, more Van der Waal's forces between molecules
- Boiling point decreases as branching increases – branched alkanes have less surface area in contact so intermolecular forces are weaker (or straighter chains can pack closer, more Van der Waal's forces between molecules)
- The first four alkanes are gases and are used as fuels (methane for domestic heating and cooking, propane as LPG and in canisters for camping/caravanning, butane for cigarette lighters and in canisters)
- Petrol consists of liquid alkanes with between 5 and 8 carbons

3) Fractional Distillation

- Crude oil (petroleum) is a mixture of many compounds, most of which are alkanes
- Crude oil is separated into fractions, many of which can be used directly as fuels
- The separation process is called fractional distillation. This involves:
    - Separation is based on the different boiling points of alkanes
    - The boiling points of alkanes depend on the size of the molecule (and strength of Van der Waals forces)
    - Vaporised crude oil is fed into a column that is hot at the bottom and cool at the top
    - Smaller molecules with lower boiling points come out at the top of the column. Larger molecules with higher boiling points come out at the bottom



4) Cracking

- Crude oil contains more long chain alkanes than are needed. Cracking breaks these alkanes down into products for which there is **higher demand**
- Cracking involves the breaking of C-C bonds in alkanes and this requires a high temperature

Example: $C_{10}H_{22} \rightarrow C_8H_{18} + C_2H_4$
Decane octane ethene

- Thermal cracking gives a high proportion of alkenes. It needs a high temperature (400-900°C) and a high pressure (7000 kPa)
- The alkenes from thermal cracking are used to make polymers and alcohols
- Catalytic cracking produces motor fuels and aromatic hydrocarbons. It needs a zeolite catalyst, a high temperature (450°C) and a slight pressure

5) Combustion

a) Introduction

- Complete combustion requires a plentiful supply of oxygen e.g.

$$C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$$

- Combustion of fossil fuels, including alkanes, results in the release of carbon dioxide into the atmosphere
- In a limited supply of air, incomplete combustion occurs forming CO or C (soot)

$$C_5H_{12} + 5.5O_2 \rightarrow 5CO + 6H_2O$$
$$C_5H_{12} + 3O_2 \rightarrow 5C + 6H_2O$$

- Incomplete combustion wastes petrol meaning more fuel is needed

b) Catalytic converters

- The pollutants produced by car engines include carbon, C, carbon monoxide, CO, sulphur dioxide, SO_2, oxides of nitrogen, NO_x and unburnt hydrocarbons
- Carbon monoxide and carbon come from the incomplete combustion of the hydrocarbons in petrol and are toxic. Carbon is also a respiratory irritant
- Sulphur dioxide is produced when traces of sulphur in the fuel react with oxygen. SO_2 causes acid rain
- Oxides of nitrogen are produced when oxygen and nitrogen from the air react together due to the very high temperatures reached inside car engines. NO_2 is toxic, triggers asthma attacks and forms HNO_3 (i.e. acid rain) when it reacts with water and oxygen
- Small amounts of hydrocarbons pass straight through a car engine without being burnt
- Catalytic converters consist of a honeycomb of ceramic material coated with platinum, palladium or rhodium (Pt/Pd/Rh)
- The honeycomb produces a large surface area on which reactions can occur
- Catalytic converters reduce the emission of CO and NO by allowing them to react together to make harmless products

$$2CO(g) + 2NO(g) \rightarrow 2CO_2(g) + N_2(g)$$

c) Global Warming

- In the troposphere (lowest level of the atmosphere), various gases absorb infrared radiation and keep the atmosphere warm

- Infrared radiation is absorbed by C=O bonds in CO_2, O-H bonds in H_2O and C-H bonds in methane. The absorbed energy makes the bonds vibrate
- Increased concentrations of greenhouse gases, like CO_2, may contribute to global warming because of the increased absorption of IR radiation

d) Acid Rain

- Combustion of fuels containing sulphur produces sulphur dioxide
- Acid rain is formed when SO_2 dissolves in water
- SO_2, which is acidic, can be removed from flue gases using CaO, which is a base. This is a neutralisation reaction.

$$\mathbf{SO_2 + CaO \rightarrow CaSO_3}$$