TOPIC 21 Alkanes and Alkenes

Objectives

Candidates should be able to:

(a) describe an homologous series as a group of compounds with a general formula, similar chemical properties and showing a gradation in physical properties as a result of increase in the size and mass of the molecules, e.g. melting and boiling points; viscosity; flammability
(b) describe the alkanes as an homologous series of saturated hydrocarbons with the general formula C_nH_{2n+2}
(c) draw the structures of branched and unbranched alkanes, C_1 to C_4, and name the unbranched alkanes methane to butane
(d) define *isomerism* and identify isomers
(e) describe the properties of alkanes (exemplified by methane) as being generally unreactive except in terms of combustion and substitution by chlorine
(f) describe the alkenes as an homologous series of unsaturated hydrocarbons with the general formula C_nH_{2n}
(g) draw the structures of branched and unbranched alkenes, C_2 to C_4, and name the unbranched alkenes ethene to butene
(h) describe the manufacture of alkenes and hydrogen by cracking hydrocarbons and recognise that cracking is essential to match the demand for fractions containing smaller molecules from the refinery process
(i) describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine
(j) describe the properties of alkenes (exemplified by ethene) in terms of combustion, polymerisation and the addition reactions with bromine, steam and hydrogen
(k) state the meaning of *polyunsaturated* when applied to food products
(l) describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetable oils to form a solid product

1. Alkanes

Alkanes are saturated hydrocarbons with the general formula C_nH_{2n+2}, where $n \geqslant 1$. Names of alkanes usually end with '-ane'. The first four members of the alkane homologous series are listed in the following table.

Name	Methane	Ethane	Propane	Butane
n	1	2	3	4
Molecular formula	CH_4	C_2H_6	C_3H_8	C_4H_{10}

Moving down the series, the molecular size of the alkanes increases. This means that the intermolecular forces of attraction become stronger. This leads to an increase in melting and boiling points and an increase in viscosity down the series. The flammability however decreases with an increase in molecular size of the alkanes.

2. Chemical Properties of Alkanes

Alkanes are generally unreactive as C – C and C – H bonds are not easily broken. They can only undergo combustion and substitution reactions.

Combustion occurs when an alkane combines with oxygen. The reaction is exothermic and hence, alkanes are used as fuels and are burned for energy.

If the alkane burns in excess oxygen, complete combustion occurs to produce carbon dioxide and water only. If the alkane burns under oxygen-deficient conditions, soot (carbon) and carbon monoxide are produced as well.

Alkanes can only react with halogens through substitution reactions. This occurs in the presence of ultraviolet light. Hydrogen atoms are substituted by halogen atoms in the reaction. The reaction produces a mixture of halogen-containing compounds.

3. Alkenes

Alkenes are unsaturated compounds with the general formula C_nH_{2n}, where $n \geqslant 2$.Note that a 1-carbon alkene cannot exist.

Names of alkenes usually end with '-ene'. The first three members of the alkene homologous series are listed in the following table.

Name	Ethene	Propene	Butene
n	2	3	4
Molecular formula	C_2H_4	C_3H_6	C_4H_8

4. Chemical Properties of Alkenes

Like alkanes, alkenes undergo complete combustion when there is sufficient oxygen to form carbon dioxide and water only. They undergo incomplete combustion to produce soot and carbon monoxide.

Due to the higher carbon-to-hydrogen ratio, alkenes burn with a smokier flame than their corresponding alkanes.

Alkenes are called unsaturated compounds due to the presence of C = C bonds. These bonds allow for alkenes to undergo addition reactions, which is a characteristic of alkenes.

Hydrogen gas can be added to an alkene to obtain an alkane. This reaction occurs at 200 °C in the presence of nickel as a catalyst.

ethene + hydrogen → ethane
$C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$

Margarine is produced by adding hydrogen to vegetable oils. Vegetable oil contains many C = C bonds, hence it is described to be polyunsaturated. One hydrogen molecule is added across each C = C bond in this process.

Halogens can be added across the C = C bond at room temperature and pressure to produce halogenoalkanes. An example is the addition of bromine to an alkene.

ethene + bromine → dibromoethane
$C_2H_4(g) + Br_2(aq) \rightarrow C_2H_4Br_2(aq)$

The addition of bromine is used in testing for the presence of unsaturated compounds. Aqueous bromine is reddish-brown and becomes colourless when an unsaturated compound is added.

Alcohols can be produced from the addition of steam to alkenes. This takes place at a temperature of 300 °C and pressure of 60 atm, in the presence of phosphoric(V) acid, which acts as a catalyst.

ethene + steam → ethanol
$C_2H_4(g) + H_2O(g) \rightarrow C_2H_5OH(l)$

Alkene molecules can also react with one another to form a large saturated molecule through addition polymerisation. This process takes place at high temperature and pressure in the presence of a catalyst.

ethene → poly(ethene)

$n\ C_2H_4(g) \rightarrow (C_2H_4)_n(s)$

5. **Cracking**

Large hydrocarbons can be broken down into smaller molecules through cracking. This process requires aluminium oxide or silicon dioxide as catalyst.

The mixture of large hydrocarbons is passed over the catalyst at a high temperature of about 600 °C. These molecules are then broken down into a mixture of small alkanes and alkenes, and hydrogen is sometimes produced as well.

Small hydrocarbon molecules such as ethene are required as starting materials for petrochemical industries. Cracking is important as it converts larger fractions of petroleum, which are of lower demand, into small hydrocarbons which are in high demand.

In addition, cracking provides the source of hydrogen for the production of ammonia in the Haber process.