Name: ______________________ (   ) Class: __________ Date: ___________

Organic Chemistry –
Alkanes and Alkenes

Syllabus

At the end of this topic, students should be able to:

11.2b Describe the alkanes as a homologous series of saturated hydrocarbons with the general formula C_nH_{2n+2}.

11.2c Draw the structures of branched and unbranched alkanes, C_1 to C_4, and name the unbranched alkanes methane to butane.

11.2d Define *isomerism* and identify isomers.

11.2e Describe the properties of alkanes (exemplified by methane) as being generally unreactive except in terms of combustion and substitution by chlorine.

11.3a Describe the alkenes as a homologous series of unsaturated hydrocarbons with the general formula C_nH_{2n}.

11.3b Draw the structures of branched and unbranched alkenes, C_2 to C_4, and name the unbranched alkenes ethene to butene.

11.3c 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.

11.3d Describe the difference between saturated and unsaturated hydrocarbons from their molecular structures and by using aqueous bromine.

11.3e Describe the properties of alkenes (exemplified by ethene) in terms of combustion, polymerisation and the addition reactions with bromine, steam and hydrogen.

11.3f State the meaning of *polyunsaturated* when applied to food products.

11.3g Describe the manufacture of margarine by the addition of hydrogen to unsaturated vegetable oils to form a solid product.

Alkanes

Alkanes are **saturated hydrocarbons** with the general formula of **C_nH_{2n+2}**. This means that each alkane molecule contains only carbon and hydrogen atoms, and **each carbon aom is covalently bonded to four other atoms**.

As with all homologous series, the physical properties of individual members changes with increasing mass/length of carbon chain.

Name	Formula	Melting Point (°C)	Boiling Point (°C)	State at r.t.p.	Density (g/cm^3)	Flammable
Methane	CH_4	– 182	– 162	Gas	0.424	Most
Ethane	C_2H_6	– 183	– 89	Gas	0.546	↓
Propane	C_3H_8	– 188	– 42	Gas	0.584	
Butane	C_4H_{10}	– 138	0	Gas	0.601	
Pentane	C_5H_{12}	– 130	36	Liquid	0.626	
Hexane	C_6H_{14}	– 95	69	Liquid	0.659	
Heptane	C_7H_{16}	– 91	98	Liquid	0.684	
Octane	C_8H_{18}	– 57	126	Liquid	0.703	
Nonane	C_9H_{20}	– 54	151	Liquid	0.718	
Decane	$C_{10}H_{22}$	– 30	174	Liquid	0.730	Least

As the no. of C atoms ↑, viscosity of the molecule ↓
↑
how difficult it is for the substance to flow

- Gases are more flammable than liquid
- Smaller molecules are easier to burn

Isomerism

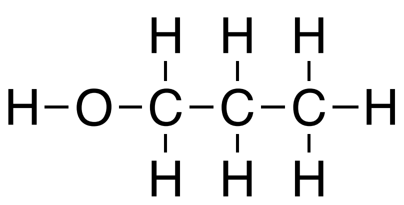
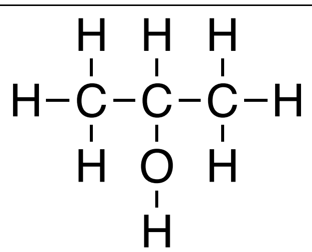
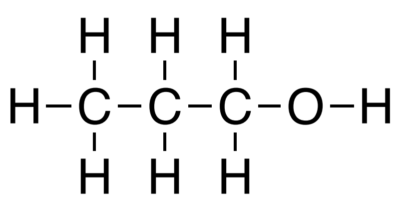
In organic chemistry, molecules with the **same molecular formula** but **different structural formula** are known as structural **isomers**.

Types of structural isomers

- Organic molecules with the same molecular formula but differ in their structure with respect to the position of the functional group. (Positional isomers)
- Organic molecules with the same molecular formula but differ in their structure with respect to the length of the longest carbon chain. (Chain Isomers)

where the functional grp is placed

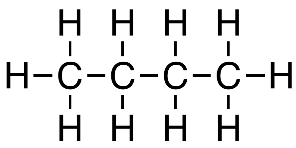
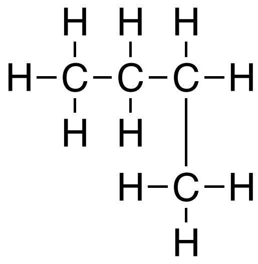
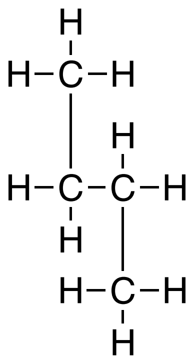
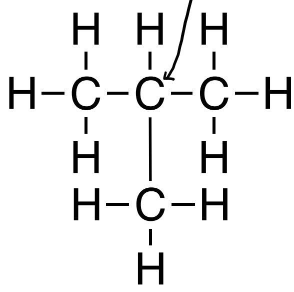
Positional Isomers

Propanol (C_3H_7OH)		
		
Propan-1-ol	Propan-2-ol	Propan-1-ol

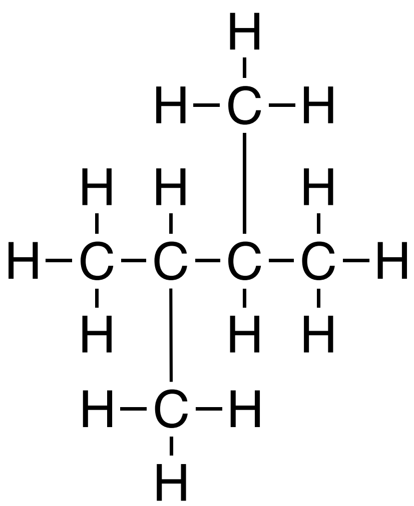
Number of positional isomers for propanol: ......2......

Chain Isomers

carbon atom is covalenty bonded to three other carbon atoms

<table>
<tr><td colspan="4">C_4H_{10}</td></tr>
<tr><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="3">Butane</td><td>2 - Methylpropane</td></tr>
<tr><td colspan="3">Unbranched C_4H_{10} with all carbon atoms joined up in a row</td><td>Branched alkane since it has a branch of a side chain $-CH_3$</td></tr>
<tr><td colspan="3">Boiling point = – 0.5 °C</td><td>Boiling point = – 11.7 °C</td></tr>
</table>

Naming isomers



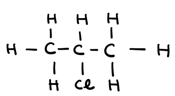
2,3 –	di	methyl	butane
Position of substituent / side chain	Number of (same) substituent / side chain	Name of substituent / side chain	Name of longest straight chain

If 1, no need to write anything

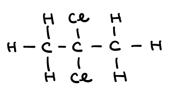
If 3, tri

Name of organic molecule:

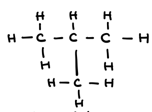
<u>2,3–dimethylbutane</u>



2 – chloropropane



2,2 – dichloropropane



2-methylpropane

Side Chain (alkyl group) / Substituent

No. of carbon atoms		
1	methyl	$-CH_3$
2	ethyl	$-CH_2CH_3$
3	propyl	$-CH_2CH_2CH_3$
4	butyl	$-CH_2CH_2CH_2CH_3$

chloro	$-Cl$
bromo	$-Br$
iodo	$-I$

Reactions of Alkane

Because alkanes are saturated, where the carbon–carbon single (C–C) bonds and the carbon–hydrogen (C–H) bonds are strong, alkanes are generally unreactive. However, alkanes can undergo three types of reactions – **combustion**, **substitution** and **cracking**.

Combustion

Combustion is a chemical reaction whereby a reactant is burnt in the presence of air. Oxygen in the air reacts with the reactant to produce carbon dioxide and water in the form of steam. Combustion of alkanes are highly exothermic. For alkanes, the combustion reaction is represented by the general equations below:

word equation: alkane + oxygen gas $\rightarrow$ carbon dioxide + steam

chemical equation: $C_xH_y + (x + \frac{y}{4})\, O_2 \rightarrow x\, CO_2 + \frac{y}{2} H_2O$

E.g. combustion of methane : $CH_4 + (1 + \frac{4}{4})\, O_2 \longrightarrow CO_2 + \frac{4}{2} H_2O$

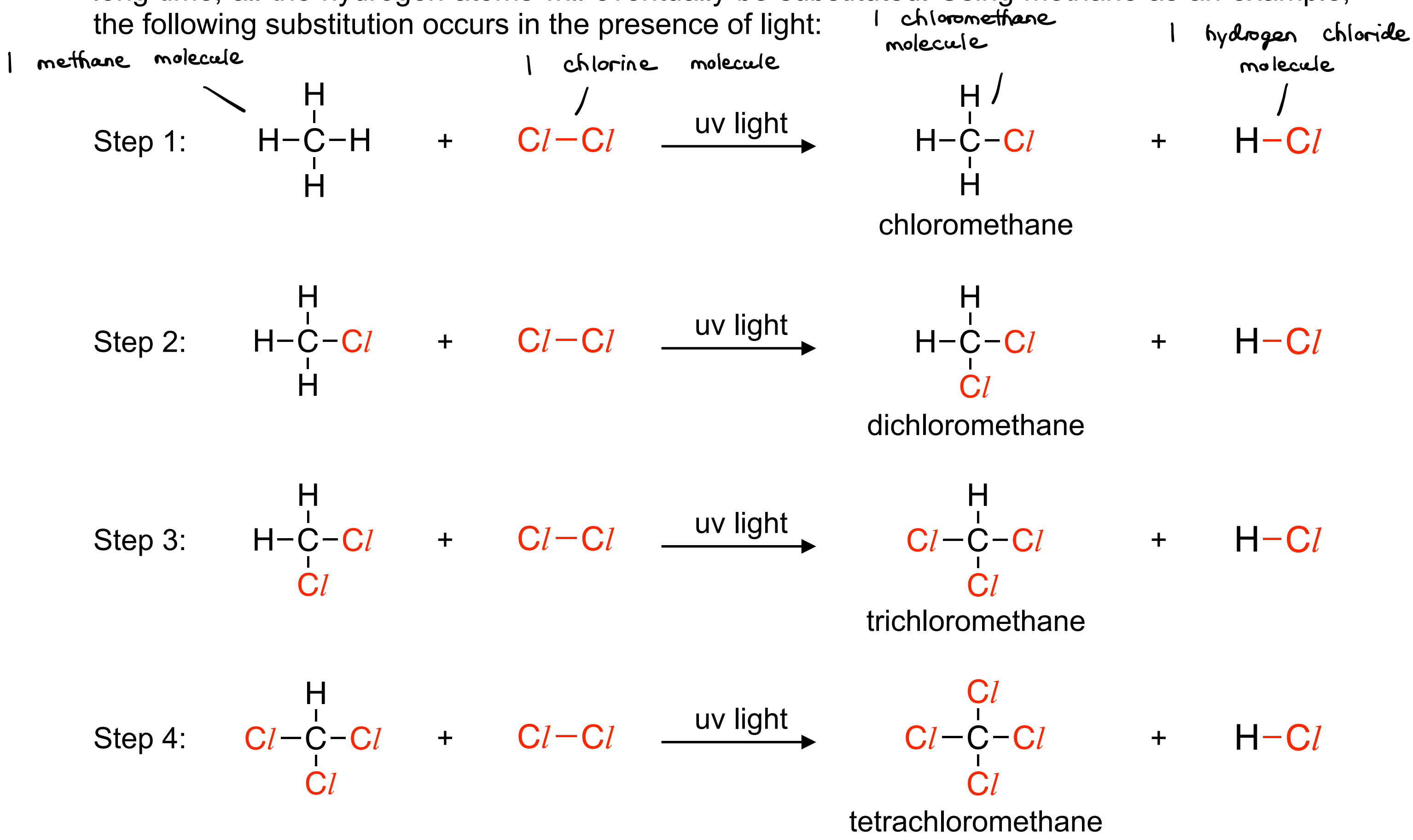
$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$

In the case of incomplete combustion, when the reactant is burnt in insufficient oxygen, soot and carbon monoxide may also be produced.

Substitution

Alkanes can react with halogens

In the presence of light as the catalyst, alkanes can react with chlorine gas. Each hydrogen atom in the alkane molecule will be substituted one at a time by one chlorine atom. If left for a long time, all the hydrogen atoms will eventually be substituted. Using methane as an example, the following substitution occurs in the presence of light:



Cracking

Smaller alkanes are useful because they can burn easily. When the size and mass of the molecules increases, they become more difficult to burn, and are therefore not as efficient as fuels.

Cracking allows for the breaking down of large alkane molecules to produce smaller useful molecules like **alkenes** and **smaller alkanes or hydrogen gas**. It is carried out by heating the molecule to a high temperature (**600 °C**) and passing it over a hot catalyst (**Al_2O_3 or SiO_2**).

There are two different reaction pathways resulting from cracking. This lead to the formation of different products.

Pathway I (form alkane)	Pathway II (form hydrogen gas)
Large Alkane → Alkenes + Smaller Alkanes $C_{10}H_{22} \rightarrow C_5H_{10} + C_5H_{12}$	Large Alkane → Alkenes + Hydrogen Gas $C_{10}H_{22} \rightarrow 2\ C_5H_{10} + H_2$

Cracking is important because it can **cater to the demand for smaller molecule fractions** (for petrol) from the refinery process. It is also important because it **produces hydrogen and alkenes**. Hydrogen is required in the Haber Process while alkenes are starting materials to make ethanol and plastics.

Alkenes

Alkenes are **UNsaturated hydrocarbons** with the general formula of **C_nH_{2n}**. This means that each alkene molecule contains **at least one carbon-carbon double covalent bond**.

If the alkene molecule contains more than one carbon-carbon double bond, we say that the molecule is **polyunsaturated**.

As with all homologous series, the physical properties of individual members changes with increasing mass/length of carbon chain.

Reactions of Alkene

Because alkenes are unsaturated, where each carbon atom is covalently bonded to only three other atoms, this allows for other atoms to be added to it and results in **alkenes being more chemically reactive than alkanes**. Alkenes undergoes **combustion** and **addition** reactions.

Combustion

Similar to alkanes, alkenes react with excess oxygen gas in air to produce carbon dioxide and steam as follows:

word equation: alkene + oxygen gas → carbon dioxide + steam

chemical equation: $C_xH_y + (x + \frac{y}{4})\,O_2 \rightarrow x\,CO_2 + \frac{y}{2}\,H_2O$

However, alkenes burn with a sootier flame than alkanes with a similar number of carbon atoms as alkenes have a relatively higher percentage of carbon than corresponding alkenes. Less steam is produced in alkenes than alkanes of a similar number of carbon atoms.

Try writing down both balanced equation for combustion of ethane and ethene respectively

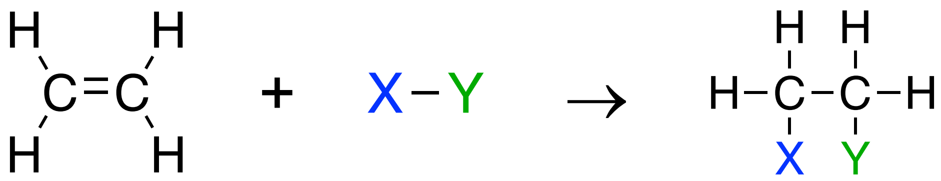
$C_2H_6 + (2 + \frac{6}{4})\,O_2 \longrightarrow 2CO_2 + \frac{6}{2}\,H_2O$

Ethane : $2C_2H_6 + 7O_2 \longrightarrow 4O_2 + 6H_2O$

Ethene : $C_2H_4 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$

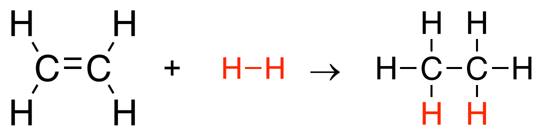
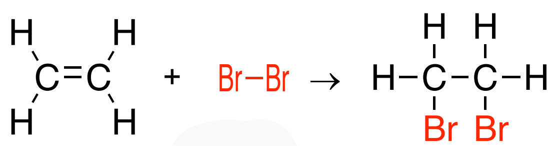
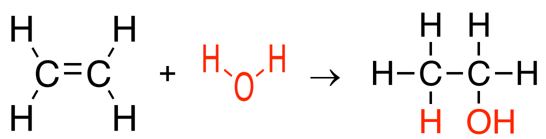
Addition

The carbon-carbon double bond in alkenes are reactive and thus will readily undergo addition reactions. Consider the reaction between ethene and a covalent compound XY in the equation below.



There are three addition reactions of alkenes that are important.

1. Reaction of alkenes with hydrogen (hydrogenation)
2. Reaction of alkenes with aqueous bromine (bromination)
3. Reaction of alkenes with steam (hydration)

Addition Reaction	Conditions	Equations	Application
Hydrogenation (form alkane)	200 °C Presence of metal catalyst such as nickel.	Alkene + Hydrogen ⟶ Alkane $C_2H_4 + H_2 \rightarrow C_2H_6$ 	Converts unsaturated fats to saturated fats. (e.g. forming solid margarine, an alkane, by adding hydrogen to liquid vegetable oils, which contains unsaturated molecules.
Bromination (form bromoalkane)	Immediate reaction when aqueous bromine is added.	Alkene + Bromine(aq) ⟶ Bromoalkane $C_2H_4 + Br_2 \rightarrow CH_2BrCH_2Br$ 	Allows saturated and unsaturated molecules to be distinguished (Test for alkenes). Presence of alkene will decolourise bromine solution rapidly while alkanes do not decolourise bromine solution under normal conditions.
Hydration (form alcohol)	300 °C 60 atm Phosphoric (V) acid (H_3PO_4) as catalyst	Alkene Steam(g) ⟶ Alcohol $C_2H_4 + H_2O \rightarrow C_2H_5OH$ 	Formation of alcohols