5.1 Systematic Organic in Context

This first lesson topic takes an overview of the Organic reactions met in this and previous courses and some of the contexts in which these reactions are met.

**Previous Chemistry**

This activity examines the systematic approach to the reactions met in previous courses.

Substitution - an atom or group will be removed from a normally saturated molecule to allow a different atom or group to take its place.

Equation using systematic names:

\[
\text{methane} + \rightarrow \text{chloromethane} +
\]

Equation using full structural formulae:

\[
\text{H} \quad \text{H—C—H} \quad \text{+} \quad \text{+}
\]

Equation using shortened structural formulae:

\[
\text{CH}_4(\text{g}) + \rightarrow +
\]
**Cracking** - a larger saturated molecule is broken apart to produce smaller molecules, at least one of which will be unsaturated.

Normally, a catalyst will be used. Sometimes only a couple of neighbouring hydrogen atoms will be ‘cracked’ off to produce a single unsaturated product. This reaction can also be called **elimination**.

*Equation using systematic names:*
\[ \text{propane} \rightarrow \text{propene} + \]

*Equation using full structural formulae:*
\[
\begin{array}{cccc}
\text{H} & \text{H} & \text{H} \\
\mid & \mid & \mid \\
\text{H} & \text{C} & \text{C} & \text{C} & \text{H} \\
\mid & \mid & \mid & \mid \\
\text{H} & \text{H} & \text{H} \\
\end{array}
\rightarrow 
\begin{array}{cccc}
\text{H} & \text{C} & \text{C} & \text{H} \\
\mid & \mid & \mid \\
\text{H} & \text{H} & \text{H} \\
\end{array}
+ \]

*Equation using shortened structural formulae:*
\[ \text{C}_3\text{H}_8\text{(g)} \rightarrow \text{C}_3\text{H}_6\text{(g)} + \]

**Dehydration** - a specific **elimination** reaction in which neighbouring hydrogen and hydroxyl group (—OH) will be ‘cracked’ off to produce an unsaturated product. The eliminated atoms form a stable water molecule.

*Equation using systematic names:*
\[ \text{propan-1-ol} \rightarrow \text{propene} + \]

*Equation using full structural formulae:*
\[
\begin{array}{cccc}
\text{H} & \text{H} & \text{H} \\
\mid & \mid & \mid \\
\text{H} & \text{C} & \text{C} & \text{C} & \text{OH} \\
\mid & \mid & \mid & \mid \\
\text{H} & \text{H} & \text{H} \\
\end{array}
\rightarrow 
\begin{array}{cccc}
\text{H} & \text{C} & \text{C} & \text{H} \\
\mid & \mid & \mid \\
\text{H} & \text{H} & \text{H} \\
\end{array}
+ \]

*Equation using shortened structural formulae:*
\[ \text{C}_3\text{H}_7\text{OH} (\text{l}) \rightarrow \text{C}_3\text{H}_6\text{(g)} + \text{H}_2\text{O} (\text{l}) \]

**Elim** is the reverse reaction to **add**.
**Addition** - a small molecule reacts with an **unsaturated** molecule and adds **across** the double bond to make a **saturated** product.

Many different molecules can be added and many of these reactions have their own names.

**Hydrogenation** - add **hydrogen**

*Equation using systematic names:*

\[
\text{Ni catalyst} \quad \text{propene} + \text{hydrogen} \rightarrow \text{propane}
\]

*Equation using full structural formulae:*

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} \\
\quad & \quad & \quad \\
\text{H} & \quad \text{C} & \quad \text{C} = \text{C} & \quad \text{H} + & \quad \rightarrow \quad \\
\quad & \quad & \quad \\
\quad & \quad & \quad \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H}
\end{align*}
\]

*Equation using shortened structural formulae:*

\[
\text{C}_3\text{H}_6(g) + \rightarrow
\]

**Hydrogenation** is mainly used to convert **highly unsaturated** oils into **more saturated** fats.

E.g. vegetable oil can be thickened and solidified to make margarine by **hydrogenation**.

**Halogenogenation** - add **halogen**

*Equation using systematic names:*

\[
\text{propene} + \text{bromine} \rightarrow 1,2\text{-dibromo propane}
\]

*Equation using full structural formulae:*

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} \\
\quad & \quad & \quad \\
\text{H} & \quad \text{C} & \quad \text{C} = \text{C} & \quad \text{H} + & \quad \rightarrow \quad \\
\quad & \quad & \quad \\
\quad & \quad & \quad \\
\quad & \quad & \quad \\
\quad & \quad & \quad \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H}
\end{align*}
\]

*Equation using shortened structural formulae:*

\[
\text{C}_3\text{H}_6(g) + \rightarrow
\]

The **addition** reaction with a **halogen**, usually **bromine**, remains the accepted test for **unsaturation** - the presence of a C = C **double** or C ≡ C **triple** bond.

The **halogenation** is decolourised **bromine**, **chlorine**, or **iodine** --- **colourless**.

\[
\begin{align*}
\text{bromine} & \rightarrow \text{colourless} \\
\text{chlorine} & \rightarrow \text{colourless} \\
\text{iodine} & \rightarrow \text{colourless}
\end{align*}
\]
Hydrohalogenation - add of hyd hal

Equation using systematic names:
\[
\text{propene} + \text{hydrogen iodide} \rightarrow 1\text{-iodo}
\]

Equation using full structural formulae:
\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad + \\
\text{H} & \quad & \quad & \quad & \quad & \quad & \quad & \quad & \quad \\
\end{align*}
\]

Equation using shortened structural formulae:
\[
\text{C}_3\text{H}_6(g) + \rightarrow
\]

Hydr is an alternative when only one halo atom is wanted on the product molecule. Depending on the position of the double bond, however, more than one isomer is possible. In the above example, 2-iodopropane is another possible product.

Hydration - add of wa

Equation using systematic names:
\[
\text{propene} + \text{water} \rightarrow \text{propan-1-ol}
\]

Equation using full structural formulae:
\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad + \\
\text{H} & \quad & \quad & \quad & \quad & \quad & \quad & \quad & \quad \\
\end{align*}
\]

Equation using shortened structural formulae:
\[
\text{C}_3\text{H}_6(g) + \rightarrow
\]

Hydr of an alk is an important method for making alcohols but, like the previous example, more than one product can be formed.

In this case, the second isomer would be propan-2-ol.

Propan-1-ol is a primary alcohol while propan-2-ol is a secondary alcohol. The significance of these labels will become clearer in later lessons.
Condensation - two smaller molecule react to join together and form a larger molecule, eliminating a small stable molecule, usually water through one molecule losing an \(-H\) atom whilst the other molecule loses an \(-OH\) (hydroxyl) group.

Equation using systematic names:

\[
\text{propanoic acid} + \text{ethanol} \rightarrow
\]

Equation using full structural formulae:

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{O} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{O} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{O} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{O} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{O} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{N} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H}
\end{align*}
\]

\[+ \quad \text{H} \quad \text{O} \quad \text{H}
\]

Equation using shortened structural formulae:

\[
\text{C}_2\text{H}_5\text{COOH}_\text{(l)} + \text{ } \rightarrow
\]

The other main condensation reaction that you will meet will involve an acid reacting with an amine to form an amide. This is very similar to the ester forming reaction above.

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{O} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{O} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{O} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{N} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} \\
\text{H} & \quad \text{H} & \quad \text{O} & \quad \text{H} & \quad \text{H} & \quad \text{H}
\end{align*}
\]

\[+ \quad \text{H} \quad \text{O} \quad \text{H}
\]

This is the reaction used to join many amino acids together to form proteins.
New Chemistry

This activity looks at some of the new reactions / families that you will meet in this Unit.

Much of the new Chemistry revolves round learning \textit{Oxi} in more detail.

As can be seen, there are 3 types of \textit{Alc} to be learnt and they have different products - \textit{Ald} or \textit{Ket}, or none - when oxidised.

\textit{Ald} are the intermediates formed when a \textit{Prim Alc} is oxidised to eventually form an \textit{Ac}.

\textit{Cond} becomes even more important - along with the reverse reaction, \textit{Hyd}.

Not just \textit{Est} are formed by a \textit{Cond} reaction - \textit{Prot} and \textit{Fa} \& \textit{Oi} are also formed by \textit{Cond} and broken down by the \textit{Hyd} reaction.

\textit{So} are the \textit{Sa} of \textit{Fatty Acids} formed when \textit{Alk Hyd} is done to a \textit{Fat} or \textit{Oil}.

\textit{Ter} are natural \textit{hydrocarbons}, found mainly in plants, formed by joining together smaller molecules called \textit{isoprene}, 
\hspace{1cm} 2-methylbutha-1,3-diene.

\textit{Terp} belong to a group of chemicals usually referred to as \textit{essential oils} which should not be mixed up with \textit{edible oils} (\textit{Fats} \& \textit{Oils}) and \textit{mineral oils} derived from \textit{Crude Oil} and made by the \textit{Petrochemical} industry.
**Functional Groups & Properties**

This activity explains the functional groups found in these molecules and their possible effect on the chemical and physical properties of the molecule.

<table>
<thead>
<tr>
<th>Family Name</th>
<th>Functional Group</th>
<th>Name of Group</th>
<th>Chemical Reactions</th>
<th>Intermolecular Forces</th>
<th>Solubility in Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>alkane</td>
<td>( \text{C-C} )</td>
<td>carbon to carbon single</td>
<td></td>
<td>london dispersion forces</td>
<td>insoluble</td>
</tr>
<tr>
<td>alkene</td>
<td>( \text{C=C} )</td>
<td>carbon to carbon double</td>
<td></td>
<td></td>
<td>insoluble</td>
</tr>
<tr>
<td>alcohol</td>
<td>( \text{C-O-H} )</td>
<td></td>
<td>oxidation condensation</td>
<td></td>
<td>very soluble</td>
</tr>
<tr>
<td>aldehyde</td>
<td>( \text{C-H=C=O} )</td>
<td></td>
<td></td>
<td></td>
<td>limited solubility</td>
</tr>
<tr>
<td>ketone</td>
<td>( \text{C=O} )</td>
<td></td>
<td>none</td>
<td>polar-polar</td>
<td></td>
</tr>
<tr>
<td>acid</td>
<td>( \text{C-C=O} )</td>
<td>carboxyl group</td>
<td>condensation</td>
<td>hydrogen bonding</td>
<td>very soluble</td>
</tr>
<tr>
<td>ester</td>
<td>( \text{C-C=O} )</td>
<td>carboxylate group</td>
<td>carboxylation</td>
<td>polar-polar</td>
<td>insoluble</td>
</tr>
<tr>
<td>amine</td>
<td>( \text{C-N-H} )</td>
<td>amide link</td>
<td>hydrogen bonding</td>
<td></td>
<td>only small amides soluble</td>
</tr>
<tr>
<td>amide</td>
<td>( \text{C-N-C} )</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As well as determining their **Chemical Reactions, Functional Groups** can also effect the **Physical Properties**. Properties such as **Volutility**, **Solubility**, **Mps & BPs** are determined by the strength of the **intermolecular forces** (existing between molecules).

**Polar Molecules**

- **hydrogen bonding**
- **polar-polar attractions**
- **london dispersion**

**Non-Polar Molecules**

**Acids** | **Alcohols** | **Amines** | **Aldehydes** | **Ketones** | **Esters** | **Aromatics** | **Alkenes** | **Alkanes**
---|---|---|---|---|---|---|---|---

For example, the *vanilla bean* produces a compound called *vanillin*, which is used as a flavouring additive in sweet foods such as ice cream.

![Vanillin Molecule](image)

This molecule has effectively, 4 **func groups**:-

- The **ben ring** and the **ether** group (—O—CH₃) are dealt with in **Advanced Higher**.
- The **hydr** group (—OH) and the **carb** group (—CH=O) will be expected to be learnt well this year.

Within the same molecule there can be **non-po groups** such as the **aro ben ring**, whilst the **ether** and **ald carb** (carb) are **sli polar**.

Probably the most influential group will be the **very po hydr group** which is capable of **hydr bonding** and may make this molecule **water sol**.
Context - Kitchen Chemistry

This activity demonstrates how much of the Organic Chemistry met in this Unit will be taught within the context of Kitchen Chemistry