# National 5 Chemistry

## Unit 2:

### Nature's Chemistry

### Topic 5

#### Hydrocarbon Families

<table>
<thead>
<tr>
<th>Topics</th>
<th>Sections</th>
<th>Done</th>
<th>Checked</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>5.1 The Alkanes</strong></td>
<td>1. Alkane Molecules</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Alkane Structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Branched Alkanes</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5.2 Alkanes Properties &amp; Uses</strong></td>
<td>1. Attraction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Uses</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5.3 The Alkenes</strong></td>
<td>1. Alkene Molecules</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Alkene Names</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Alkene Structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Branched Alkenes</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5. Attraction, Properties &amp; Uses</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5.4 The Cycloalkanes</strong></td>
<td>1. Cycloalkane Molecules</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Cycloalkane Names</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Properties</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5.5 Hydrocarbon Reactions</strong></td>
<td>1. Combustion</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. The Bromine Test</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Addition Reactions</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>4. Cracking</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Consolidation Work</strong></td>
<td>1. Self Check Questions 1 - 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Self Check Questions 4 - 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. Self Check Questions 1 - 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>End-of-Topic Assessment</strong></td>
<td>Score:</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

---

KHS Dec 2013/Jan 2014  National 5
**Fuels and Combustion 1**

- An *exothermic* reaction is one in which heat energy is released
- A *fuel* is a substance that releases a large amount of energy when it burns
- When a substance burns it reacts with *oxygen*
- *Combustion* is another word for burning

**Coal, oil and natural gas**

- Coal, oil and natural gas are *fossil fuels*, formed millions of years ago
- A *fossil fuel* is one that has been formed from the remains of living things
- *Coal* was formed from plant material, including trees
- *Oil* and *natural gas* were formed from tiny *sea* creatures and plants

**Fractional distillation**

- Oil requires a complex process of *refining* before it can be used
- Crude oil is a mixture of carbon compounds, mainly *hydrocarbons*
- *Hydrocarbons* are compounds containing carbon and hydrogen *only*
- *Fractional distillation* is used to separate crude oil into *fractions*
- A *fraction* is a group of compounds with similar boiling points

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Boiling Range °C</th>
<th>Carbon atoms</th>
<th>End-uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>gas</td>
<td>-160 to 20</td>
<td>1 to 4</td>
<td>fuel gases</td>
</tr>
<tr>
<td>gasoline</td>
<td>20 to 65</td>
<td>5 to 6</td>
<td>petrol</td>
</tr>
<tr>
<td>naphtha</td>
<td>65 to 180</td>
<td>6 to 11</td>
<td>petrochemicals</td>
</tr>
<tr>
<td>kerosene</td>
<td>180 to 250</td>
<td>9 to 15</td>
<td>heating / jet fuel</td>
</tr>
<tr>
<td>gas oils</td>
<td>250 to 350</td>
<td>15 to 25</td>
<td>diesel fuel</td>
</tr>
<tr>
<td>residue</td>
<td>&gt; 350</td>
<td>&gt; 25</td>
<td>bitumen, wax etc</td>
</tr>
</tbody>
</table>

- The fractions vary in *viscosity* (how ‘thick”) and *flammability*

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Molecular Size</th>
<th>Boiling Point</th>
<th>Ease of Evaporation</th>
<th>Flammability</th>
<th>Viscosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>gas</td>
<td>decreasing</td>
<td>increasing</td>
<td>increasing</td>
<td>increasing</td>
<td>increasing</td>
</tr>
<tr>
<td>gasoline</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>naphtha</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>kerosene</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gas oils</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>residue</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Explanation of Variations

- **Boiling range** and **viscosity** increase as the molecular size increases because the forces of attraction between molecules are also increasing.
- **Evaporation** and **flammability** are also linked to molecular size. The smaller the molecules, the weaker the forces of attraction and easier to change liquid → gas.

Fuels and Combustion 2

- Many fuels contain **carbon** and **hydrogen**. When burned completely they produce **carbon dioxide** and **water**.
- The test for **carbon dioxide** is that it turns **lime water milky**.
- The test for water is that it freezes at 0 °C and boils at 100 °C.
- Water also turns **cobalt chloride paper** from **blue** to **pink**.
- **Incomplete** combustion of a carbon fuel can produce carbon (**soot**) and **carbon monoxide**.
- **Carbon monoxide** is a poisonous gas.

Pollution problems

- Burning fossil fuels produces carbon dioxide a ‘greenhouse gas’ that causes **global warming**
- Sulphur in fuels (mainly coal) produce **sulphur dioxide** which causes **acid rain** (sulphur is removed from oil and gas during refining).
- In petrol engines nitrogen and oxygen react to form poisonous oxides of nitrogen, including **nitrogen dioxide**.
- Special exhaust systems can convert pollutant gases into harmless gases.
- Using less fuel compared to air in car engines also reduces pollution.
- All new cars are fitted with **catalytic convertors**.
  - These convert the oxides of nitrogen back into nitrogen.
  - They change unburnt hydrocarbons and carbon monoxide into water and carbon dioxide.

Cracking

- Fractional distillation of crude oil gives more long-chained hydrocarbons (mainly alkanes) than are needed by industry.
- **Cracking** is a method of producing smaller, more useful molecules by heating large hydrocarbon molecules in the presence of a catalyst.
- Cracking alkane molecules produces a **mixture** of alkanes and alkenes.
There are not enough hydrogen atoms in an alkane molecule for it to produce only smaller alkanes on cracking

The presence of a catalyst, such as steel wool or aluminium oxide, allows cracking to take place at a lower temperature, making the process cheaper

**Plastics**

- **Plastics** and other **synthetic fibres** are examples of **polymers** - very large molecules formed by joining many small molecules called **monomers**
- **Monomers** are the small molecules that join together to form a large **polymer**
- **Polymerisation** is the process of making a polymer from many monomers
- Most plastics and synthetic fibres are made from molecules found in **crude oil**
- A **synthetic** fibre is one that is man-made e.g. nylon and terylene
- A **natural** fibre is one that is found in nature e.g. wool, silk and cotton
- Plastics are often used instead of traditional materials like wood, paper etc
- The particular use is related to the **properties** of the plastic.
- Most plastics have **low density**, are good heat and electrical **insulators**, and are **water resistant**

**Plastics and Pollution**

- Very few plastics are **biodegradable** - they do not rot away
- Natural materials such as wood, paper and cardboard are biodegradable
- Plastics can release poisonous **carbon monoxide** if combustion is incomplete
- Some plastics can also give off other **toxic** fumes when they burn or smoulder
- The gases given off during burning or smouldering can be related to the elements in the plastic
  - carbon monoxide, $CO$ when $C$ present e.g polystyrene
  - hydrogen chloride, $HCl$ when $Cl$ present e.g PVC
  - hydrogen cyanide, $HCN$ when $N$ present e.g. polyurethane

**Thermoplastics and Thermosetting plastics**

- A **thermoplastic** is one that softens on heating e.g. polythene, perspex etc
- A **thermosetting** plastic does not soften on heating e.g. bakelite, formica etc
- Only **thermoplastics** can be **recycled**
5.1 The ALKANES

Alkane Molecules

The alkanes are a family of hydrocarbons; molecules made from carbon and hydrogen atoms only.

The first (smallest) member of the family is methane, CH₄.

Carbon atoms always have 4 unpaired electrons in their outer shell and so can form 4 bonds.

actual shape

‘tetrahedral’

The bonds keep as far apart as possible; the hydrogen atoms lie at the corners of a pyramid.

structural formula

It is much easier to draw flat pictures to show how each of the atoms are joined to each other.

Having as many as 4 bonds gives carbon atoms the ability to form chains and rings of carbon atoms. They can also join together with single, C — C, double, C = C, or even triple bonds, C ≡ C.

The Alkene family is made up of chains where all the carbon atoms join together with a single bond.

Alkane Names

The surname is -ane to tell you it is a member of the alkane family, the first name tells you the number of carbon atoms in each molecule.

<table>
<thead>
<tr>
<th>First Name</th>
<th>Number of Carbon Atoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meth-</td>
<td>1 Carbon atom</td>
</tr>
<tr>
<td>Eth-</td>
<td>2 Carbon atoms</td>
</tr>
<tr>
<td>Prop-</td>
<td>3 Carbon atoms</td>
</tr>
<tr>
<td>But-</td>
<td>4 Carbon atoms</td>
</tr>
<tr>
<td>Pent-</td>
<td>5 Carbon atoms</td>
</tr>
<tr>
<td>Hex-</td>
<td>6 Carbon atoms</td>
</tr>
<tr>
<td>Hept-</td>
<td>7 Carbon atoms</td>
</tr>
<tr>
<td>Oct-</td>
<td>8 Carbon atoms</td>
</tr>
</tbody>
</table>
### Hydrocarbon Families

#### Alkane Structures

<table>
<thead>
<tr>
<th>Number of carbon atoms</th>
<th>Name of alkane</th>
<th>Structural formula</th>
<th>Molecular formula</th>
</tr>
</thead>
</table>
| 1                      | methane        | \[
\begin{array}{c}
\text{H} \\
\text{H -- C -- H} \\
\text{H} \\
\end{array}
\] | CH$_4$ |
| 2                      | ethane         | \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H -- C -- C -- H} \\
\text{H} \\
\end{array}
\] | C$_2$H$_6$ |
| 3                      | propane        | \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{H -- C -- C -- C -- H} \\
\text{H} \\
\end{array}
\] | C$_3$H$_8$ |
| 4                      | butane         | \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{H -- C -- C -- C -- C -- H} \\
\text{H} \\
\end{array}
\] | C$_4$H$_{10}$ |
| 5                      | pentane        | \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H -- C -- C -- C -- C -- H} \\
\text{H} \\
\end{array}
\] | C$_5$H$_{12}$ |
| 6                      | hexane         | \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{H -- C -- C -- C -- C -- C -- H} \\
\text{H} \\
\end{array}
\] | C$_6$H$_{14}$ |
| 7                      | heptane        | \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H -- C -- C -- C -- C -- C -- C -- H} \\
\text{H} \\
\end{array}
\] | C$_7$H$_{16}$ |
| 8                      | octane         | \[
\begin{array}{c}
\text{H} \\
\text{H} \\
\text{H} \\
\text{H} \\
\text{H -- C -- C -- C -- C -- C -- C -- C -- H} \\
\text{H} \\
\end{array}
\] | C$_8$H$_{18}$ |

The alkanes are called a homologous series of molecules. This is because each molecule differs from the previous molecule by the same amount, —CH$_2$—, (homo- = same, logous = difference).

This makes it possible to write a General Formula for the alkane family. There are always twice plus two hydrogens for any number of carbon atoms.
There are a number of different ways of representing molecules, but great care must be taken in exams where different definitions might prevail.

**Full Structural Formula:** should show every individual atom and every bond.

In an exam, **this is what you should draw** whenever you are asked for a structural formula.

**Semi-Structural Formula;**

**Shortened Structural Formula;**

**Extended Molecular Formula;**

In an exam, you can sometimes include one bond to show a branch in a shortened structural formula.

For perfection, try and put branches in brackets as shown here.

**Molecular Formula:** should show each type of atom and number only.

<table>
<thead>
<tr>
<th>Name</th>
<th>Structural Formula</th>
<th>Shortened Structural</th>
<th>3-D Model</th>
<th>Molecular Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>methane</td>
<td>( \text{H} - \text{C} - \text{H} )</td>
<td>( \text{CH}_4 )</td>
<td>CH(_4)</td>
<td>( \text{CH}_4 )</td>
</tr>
<tr>
<td>ethane</td>
<td>( \text{H} - \text{C} - \text{C} - \text{H} )</td>
<td>( \text{CH}_3\text{CH}_3 )</td>
<td>CH(_2\text{H}_6)</td>
<td>( \text{C}_2\text{H}_6 )</td>
</tr>
<tr>
<td>propane</td>
<td>( \text{H} - \text{C} - \text{C} - \text{C} - \text{H} )</td>
<td>( \text{CH}_3\text{CH}_2\text{CH}_3 )</td>
<td>CH(_3\text{H}_8)</td>
<td>( \text{C}_3\text{H}_8 )</td>
</tr>
<tr>
<td>butane</td>
<td>( \text{H} - \text{C} - \text{C} - \text{C} - \text{C} - \text{H} )</td>
<td>( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3 )</td>
<td>CH(<em>4\text{H}</em>{10})</td>
<td>( \text{C}<em>4\text{H}</em>{10} )</td>
</tr>
</tbody>
</table>
Branched Alkanes

In a \textit{straight-chain} hydrocarbon, all the \textit{carbon} atoms in the molecule are linked one after the other in a \textit{single} continuous chain.

In a \textit{branched-chain} hydrocarbon, the molecule has one or more \textit{side chains} of carbon atoms coming from the main chain.

Because of branching, it is possible to have \textit{different structural arrangements} for the \textit{same molecular formula}. \textit{Butane}, \(\text{C}_4\text{H}_{10}\), has two \textit{different structures} called \textit{isomers}. Clearly both of them cannot have \textit{exactly} the same name.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|}
\hline
\textbf{Shortened Structural Formula} & \textbf{Systematic Name} \\
\hline
\text{CH}_3\text{CH}_2\text{CHCH}_2\text{CH}_3 & \text{3-methylpentane} \\
\text{CH}_3 & \\
\text{CH}_3\text{CH}_2\text{CH}_2\text{CHCH}_3 & \text{2-methylpentane} \\
\text{CH}_3 & \\
\text{CH}_3\text{CHCHCH}_3 & \text{2,3-dimethylbutane} \\
\text{CH}_3 & \\
\hline
\end{tabular}
\caption{Isomers are molecules with the same molecular formula but have different structures.}
\end{table}
<table>
<thead>
<tr>
<th>Systematic name</th>
<th>Full Structural formula</th>
<th>Shortened Structural formula</th>
</tr>
</thead>
</table>
| 3-methylpentane                  | H H CH₃ H H
 | H — C — C — C — C — C — H
 | H H H H H H                      | CH₃ CH₂ CH(CH₃) CH₂ CH₃ |
| 3,3-dimethylhexane               | H H CH₃ H H H H          | CH₃ CH₂ CH₂ CH(CH₃)₂ CH₂ CH₃ |
| 3-ethyl-2-methylpentane          | H H C₂H₅ H H              | CH₃ CH(CH₃) CH(C₂H₅) CH₂ CH₃ |
| Incorrect name                  |                         | Correct Systematic name    |
| 3-methylbutane                   |                         | 2-methylbutane              |
| 2-ethylbutane                    |                         | 3-methylpentane             |
| 3-methyl-5-ethyloctane           |                         | 5-ethyl-3-methyloctane      |
Q1.
Name the next five molecules.

a) 2-methylpropane

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH} & \quad \text{CH}_3 \\
\text{H}_3\text{C} & \quad \text{CH} & \quad \text{CH}_3 \\
\end{align*}
\]

b) 2,2-dimethylpentane

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_2 & \quad \text{C} & \quad \text{CH}_3 \\
\text{H}_3\text{C} & \quad \text{CH}_2 & \quad \text{C} & \quad \text{CH}_3 \\
\end{align*}
\]

c) 5-ethyl-3,4-dimethylnonane

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH} & \quad \text{C} & \quad \text{CH}_2 & \quad \text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} \\
\text{H}_2\text{C} & \quad \text{CH}_2 & \quad \text{C} & \quad \text{CH}_3 \\
\end{align*}
\]

d) 3,3,5-trimethylheptane

\[
\begin{align*}
\text{CH}_3 & \quad \text{C} & \quad \text{CH}_2 & \quad \text{CH}_2 & \quad \text{CH}_3 \\
\text{H}_3\text{C} & \quad \text{HC} & \quad \text{CH}_2 & \quad \text{C} & \quad \text{CH}_3 \\
\end{align*}
\]

e) 2,2,5-trimethylhexane

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH}_3 & \quad \text{CH}_3 & \quad \text{CH} & \quad \text{C} & \quad \text{CH}_3 \\
\text{H}_3\text{C} & \quad \text{HC} & \quad \text{CH}_2 & \quad \text{C} & \quad \text{CH}_3 \\
\end{align*}
\]

Q2.
For the next four questions, draw the full structural formula for each structure. Then, write the shortened structural formula. (Use your jotter - more space needed!)

a) 2-methylbutane

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3 \\
\end{align*}
\]

b) 3-ethyl-3-methylhexane

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3 & \quad \text{CH}_3\text{H} \\
\end{align*}
\]

c) 2,2-dimethylpropane

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3 \\
\end{align*}
\]

d) 3-ethyl-3,4-dimethylhexane

\[
\begin{align*}
\text{CH}_3 & \quad \text{CH} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3 & \quad \text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CH}_3 \\
\end{align*}
\]

Q3.
In the next three questions, the name of each structure is incorrect. Draw the structure that each name describes. Rename each structure correctly. (Use your jotter!)

a) 4-methylbutane

\[
\begin{align*}
\text{CH}_3 & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{pentane} \\
\end{align*}
\]

b) 3-propylheptane

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{3-ethyloctane} \\
\end{align*}
\]

c) 2,3,3-triethylpentane

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{CH}_3 & \quad \text{CH}_3 & \quad \text{H} \\
\text{H} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{C} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{3,3-diethyl-4-methylhexane} \\
\end{align*}
\]
5.2 ALKANES - Properties & Uses

**Attractions**

The *alkanes* are a family of *hydrocarbons*; molecules made from *carbon* and *hydrogen* atoms *only*.

Neither *carbon* or *hydrogen* atoms have significantly *stronger attractions* for the *shared electrons* so the *molecules* are *non-polar*.

<table>
<thead>
<tr>
<th>methane</th>
<th>name</th>
<th>water</th>
</tr>
</thead>
<tbody>
<tr>
<td>$CH_4$</td>
<td>formula</td>
<td>$H_2O$</td>
</tr>
<tr>
<td>16 amu</td>
<td>mass</td>
<td>18 amu</td>
</tr>
<tr>
<td>non-polar</td>
<td>type</td>
<td>polar</td>
</tr>
<tr>
<td>-164</td>
<td>$BPt$ (°C)</td>
<td>100</td>
</tr>
</tbody>
</table>

The *attractions* between *alkane* molecules are significantly *weaker* than *polar molecules* such as *water*. They do, however, get *stronger as the molecules get bigger*.

![Graph showing melting and boiling points of alkanes](image)
Properties

Most properties of the Alkanes are a result of the weak attractions between the molecules.

Melting & Boiling Pts

as seen, the melting and boiling points increase as the size of the molecules increase.

One way of measuring the flammability of a substance is to determine its Flash Point - the lowest temperature at which it can vaporise to form an ignitable mixture in air.

<table>
<thead>
<tr>
<th>Hydrocarbon</th>
<th>Formula</th>
<th>Flash Pt (°C)</th>
<th>Boiling Pt (°C)</th>
<th>Flammability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Propane</td>
<td>CH₃CH₂CH₃</td>
<td>-104</td>
<td>-42</td>
<td>Flammable</td>
</tr>
<tr>
<td>Isobutane</td>
<td>(CH₃)₂CH</td>
<td>-84</td>
<td>-12</td>
<td>Flammable</td>
</tr>
<tr>
<td>Butane</td>
<td>CH₃(CH₂)₂CH₃</td>
<td>-60</td>
<td>-1</td>
<td>Flammable</td>
</tr>
<tr>
<td>Pentane</td>
<td>CH₃(CH₂)₂CH₃</td>
<td>-40</td>
<td>36-38</td>
<td>Flammable</td>
</tr>
<tr>
<td>Hexane</td>
<td>CH₃(CH₂)₄CH₃</td>
<td>-22 to -26</td>
<td>65-69</td>
<td>Flammable</td>
</tr>
<tr>
<td>Heptane</td>
<td>CH₃(CH₂)₃CH₃</td>
<td>-8</td>
<td>92-100</td>
<td>Flammable</td>
</tr>
<tr>
<td>Octane</td>
<td>CH₃(CH₂)₆CH₃</td>
<td>16</td>
<td>125-127</td>
<td>Flammable</td>
</tr>
<tr>
<td>Nonane</td>
<td>CH₃(CH₂)₇CH₃</td>
<td>31</td>
<td>151</td>
<td>Flammable</td>
</tr>
<tr>
<td>Decane</td>
<td>CH₃(CH₂)₈CH₃</td>
<td>46</td>
<td>174</td>
<td>Combustible</td>
</tr>
<tr>
<td>Kerosene</td>
<td>HC mixture</td>
<td>43-82</td>
<td>151-301</td>
<td>Combustible</td>
</tr>
<tr>
<td>Isopar® H</td>
<td>C₁₁₋C₁₂ Isoparaffin</td>
<td>57</td>
<td>182</td>
<td>Combustible</td>
</tr>
<tr>
<td>Undecane</td>
<td>CH₃(CH₂)₉CH₃</td>
<td>60</td>
<td>196</td>
<td>Combustible</td>
</tr>
<tr>
<td>Dodecane</td>
<td>CH₃(CH₂)₁₀CH₃</td>
<td>71</td>
<td>215-217</td>
<td>Combustible</td>
</tr>
<tr>
<td>Tridecane</td>
<td>CH₃(CH₂)₁₁CH₃</td>
<td>79</td>
<td>234</td>
<td>Combustible</td>
</tr>
<tr>
<td>Tetradecane</td>
<td>CH₃(CH₂)₁₂CH₃</td>
<td>100</td>
<td>252</td>
<td>Combustible</td>
</tr>
<tr>
<td>Pentadecane</td>
<td>CH₃(CH₂)₁₃CH₃</td>
<td>132</td>
<td>270</td>
<td>Combustible</td>
</tr>
<tr>
<td>Hexadecane</td>
<td>CH₃(CH₂)₁₄CH₃</td>
<td>135</td>
<td>287</td>
<td>Combustible</td>
</tr>
<tr>
<td>Mineral oil</td>
<td>Paraffin Oil</td>
<td>199</td>
<td>260-360</td>
<td>Combustible</td>
</tr>
</tbody>
</table>

Notice that these hydrocarbons can be ignited at temperatures well below their boiling points - it is only necessary to convert a small proportion into gas to be able to produce a flame.

However, those hydrocarbons which are already gases at room temperature (C₁ to C₄) will be the most flammable.

Flammability

as can be seen, the flammability increases as the size of the molecules decrease.
Non-polar alkane molecules cannot compete with the strength of attractions that exist between water molecules so alkanes are insoluble in water.

Most alkanes are liquids so separate layers will form with the (usually) less dense alkane floating on top of the water. Liquids that do not mix due to insolubility are often described as immiscible.

**Solubility**

alkane molecules of all sizes, are insoluble (immiscible) in water but will dissolve (are miscible) in similar non-polar liquids.

Hydrocarbons, including alkanes, were used in many of the early dry-cleaners as they could dissolve many stains. Modern dry-cleaners use less flammable molecules derived from simple hydrocarbons.

**Uses**

Not surprisingly, most of the uses of alkanes are linked to their ability to release large amounts of energy when burnt.

One method of measuring the 'energy content' of a fuel involves determining the energy released (exothermic) when one mole of the fuel burns in a good supply of oxygen (complete combustion).

This is called the Heat (or Enthalpy) of Combustion and is measured in kiloJoules per mole (kJ mol\(^{-1}\)).
Q1.

The table below gives information about some members of the alkane family.

<table>
<thead>
<tr>
<th>Number of carbons</th>
<th>Molecular formula</th>
<th>Name</th>
<th>Condensed structure</th>
<th>Density (g/mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>CH₄</td>
<td>methane</td>
<td>CH₄</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>C₂H₆</td>
<td>ethane</td>
<td>CH3(CH3)</td>
<td>0.7692</td>
</tr>
<tr>
<td>3</td>
<td>C₃H₈</td>
<td>propane</td>
<td>CH₃CH₂CH₃</td>
<td>0.6650</td>
</tr>
<tr>
<td>4</td>
<td>C₄H₁₀</td>
<td>butane</td>
<td>CH₃CH₂CH₂CH₃</td>
<td>0.6837</td>
</tr>
<tr>
<td>5</td>
<td>C₅H₁₂</td>
<td>pentane</td>
<td>CH₃(CH₂)₃CH₃</td>
<td>0.5572</td>
</tr>
<tr>
<td>6</td>
<td>C₆H₁₄</td>
<td>hexane</td>
<td>CH₃(CH₂)₄CH₃</td>
<td>0.4863</td>
</tr>
<tr>
<td>7</td>
<td>C₇H₁₆</td>
<td>heptane</td>
<td>CH₃(CH₂)₅CH₃</td>
<td>0.4526</td>
</tr>
<tr>
<td>8</td>
<td>C₈H₁₈</td>
<td>octane</td>
<td>CH₃(CH₂)₆CH₃</td>
<td>0.4182</td>
</tr>
<tr>
<td>9</td>
<td>C₉H₂₀</td>
<td>nonane</td>
<td>CH₃(CH₂)₇CH₃</td>
<td>0.3951</td>
</tr>
<tr>
<td>10</td>
<td>C₁₀H₂₂</td>
<td>decane</td>
<td>CH₃(CH₂)₈CH₃</td>
<td>0.3799</td>
</tr>
<tr>
<td>11</td>
<td>C₁₁H₂₄</td>
<td>dodecane</td>
<td>CH₃(CH₂)₉CH₃</td>
<td>0.3640</td>
</tr>
<tr>
<td>12</td>
<td>C₁₂H₂₆</td>
<td>tetradecane</td>
<td>CH₃(CH₂)₁₀CH₃</td>
<td>0.3507</td>
</tr>
<tr>
<td>13</td>
<td>C₁₃H₂₈</td>
<td>tridecane</td>
<td>CH₃(CH₂)₁₁CH₃</td>
<td>0.3376</td>
</tr>
</tbody>
</table>

(a) State the density of pentane. \(0.5572 \text{ g/ml}\)

(b) Suggest the name and the condensed structure of the alkane with 14 carbons.

name: tetradecane
condensed structure: \(CH₃(CH₂)₁₂CH₃\)

The density of pentadecane (C₁₅H₃₂) is 0.7692. Comparing this with the density of pentane provides us with the effect of increasing the number of carbon atoms by 10.

c) What is the increase in density between pentane and pentadecane? \(0.7692 - 0.5572 = 0.2120 \text{ g/ml}\)

d) Predict the density of the alkane with 25 carbon atoms. \(0.7692 + 0.2120 = 0.9812 \text{ g/ml}\)

e) What is the density of water? \(1.0000 \text{ g/ml}\)

(f) Predict the size of the first alkane that would sink if mixed with water. > 27 carbon atoms

g) Use the graph below to explain why your prediction is unlikely to be correct.

*the large increase from \(C₅\) to \(C₆\) distorts the trend / the real increase in density is much more gradual*

Q2.

The graph below shows the relationship between temperature and the composition of a reaction mixture of 2-methylbutane and pentane in the presence of a catalyst.

(a) The reaction mixture contain the most of which isomer? 2-methylbutane

(b) Could you obtain better yields of the isomer 2-methylbutane by running the reaction at higher or lower temperatures? **lower temperatures**

(c) At what temperature could you run the reaction to obtain a mixture that contains about 25% pentane? **225 °C**

The graph below shows the boiling points of straight chained alkanes (\(n\)-alkanes) and the 2-methyl isomers (isoalkanes).

(d) Describe the relationship between the boiling point of an alkane and the number of carbons in the molecule.

*the boiling point of an alkane increases as the number of carbons in the molecule increases*

(e) Describe the relationship between the boiling point of an alkane and the boiling point of an isoalkane.

*in general the boiling point of an isoalkane is lower than that of the equivalent alkane*

(f) Explain why there are no isoalkanes for methane, ethane and propane.

*chains are too short to have branched isomers*
5.3 The ALKENES

Alkene Molecules

The *alkanes* are a family of *hydrocarbons*; molecules made from *carbon* and *hydrogen* atoms only.

The first (smallest) member of the family is *ethane*, \( \text{C}_2\text{H}_4 \).

**actual shape**

*Carbon* atoms always have 4 unpaired *electrons* in their *outer* shell and so can form 4 bonds in total.

**double bond**

In the *alkene* family, two of the *carbon* atoms will share two pairs of *electrons*. This forms a *double* bond.

**structural formula**

It is much easier to draw flat pictures to show how each of the atoms are joined to each other.

The *Alkane* family is made up of *chains* where most of the *carbon* atoms join together with a *single* bond, but two of the *carbon* atoms will have joined with a *double* bond.

Alkene Names

The same system is used to name the *alkenes* as was used to name the *alkanes*.

The *surname* is -ene to tell you it is a *member* of the *alkene* family, the *first name* tells you the *number* of *carbon* atoms in each molecule.

- **Pent-** = 5 *Carbon* atoms
- **Eth-** = 2 *Carbon* atoms
- **Hex-** = 6 *Carbon* atoms
- **Prop-** = 3 *Carbon* atoms
- **Hept-** = 7 *Carbon* atoms
- **But-** = 4 *Carbon* atoms
- **Oct-** = 8 *Carbon* atoms

<table>
<thead>
<tr>
<th>Monkeys</th>
<th>Eat</th>
<th>Peanut</th>
<th>Butter</th>
<th>Perched</th>
<th>High</th>
<th>High</th>
<th>Overhead</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
</tr>
</tbody>
</table>
## Alkene Structures

<table>
<thead>
<tr>
<th>Number of carbon atoms</th>
<th>Name of alkene</th>
<th>Structural formula of alkene</th>
<th>Molecular formula of alkene</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>ethene</td>
<td><img src="image" alt="Ethene structure" /></td>
<td>$C_2H_4$</td>
</tr>
<tr>
<td>3</td>
<td>propene</td>
<td><img src="image" alt="Propene structure" /></td>
<td>$C_3H_6$</td>
</tr>
<tr>
<td>4</td>
<td>butene</td>
<td><img src="image" alt="Butene structure" /></td>
<td>$C_4H_8$</td>
</tr>
<tr>
<td>5</td>
<td>pentene</td>
<td><img src="image" alt="Pentene structure" /></td>
<td>$C_5H_{10}$</td>
</tr>
<tr>
<td>6</td>
<td>hexene</td>
<td><img src="image" alt="Hexene structure" /></td>
<td>$C_6H_{12}$</td>
</tr>
<tr>
<td>7</td>
<td>heptene</td>
<td><img src="image" alt="Heptene structure" /></td>
<td>$C_7H_{14}$</td>
</tr>
<tr>
<td>8</td>
<td>octene</td>
<td><img src="image" alt="Octene structure" /></td>
<td>$C_8H_{16}$</td>
</tr>
</tbody>
</table>

The **alkenes** are called a **homologous series** of **molecules**. This is because each mole**cule** differs from the previous molecule by the **same amount**, $\text{CH}_2$ $\text{—}$, ($\text{homo}$-$=$ same, $\text{logous}$ = difference).

The alkene family can be characterized by the **general formula** $\text{C}_n\text{H}_{2n}$. This makes it possible to write a **general formula** for the alkene family. There are always **twice** as many **hydrogens** atoms for any number of **carbon** atoms.

The **alkane** family is different from the **alkene** family. Since they have no **double bond**, there is room for **two** extra **hydrogen** atoms on an alkane with the same number of carbon atoms.
There are even more isomers possible in the alkene family. Again there are straight-chain alkenes and branched-chain alkenes.

In addition, it is possible to change the position of the double bond to introduce even more different structural formulae.

In alkenes, the C = C is given priority and the chain is numbered from end nearest double bond. (i.e. the number should be as low as possible.)

<table>
<thead>
<tr>
<th>Name:</th>
<th>5-methylhept-2-ene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td><img src="image1" alt="Structural Formula" /></td>
</tr>
<tr>
<td>Molecular Formula:</td>
<td>$C_8H_{16}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name:</th>
<th>3-methylhex-3-ene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td><img src="image2" alt="Structural Formula" /></td>
</tr>
<tr>
<td>Molecular Formula:</td>
<td>$C_7H_{14}$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name:</th>
<th>2,3-dimethylpent-2-ene</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full Structural Formula:</td>
<td><img src="image3" alt="Structural Formula" /></td>
</tr>
<tr>
<td>Molecular Formula:</td>
<td>$C_7H_{14}$</td>
</tr>
</tbody>
</table>
The \textit{alkenes} are a family of \textit{hydrocarbons}; molecules made from \textit{carbon} and \textit{hydrogen} atoms only.

Neither \textit{carbon} or \textit{hydrogen} atoms have significantly \textit{stronger attractions} for the \textit{shared electrons} so the \textit{molecules} are \textit{non-polar}.

\begin{center}
\begin{tabular}{|c|c|c|}
\hline
\textbf{name} & \textbf{formula} & \textbf{mass} & \textbf{type} & \textbf{BPt (°C)} \\
\hline
ethene & \(C_2H_4\) & 28 amu & non-polar & -104 \\
methanol & \(CH_3OH\) & 32 amu & polar & 65 \\
\hline
\end{tabular}
\end{center}

The \textit{attractions between alkene} molecules are significantly \textit{weaker} than \textit{polar molecules} such as \textit{methanol}.

They do, however, get \textit{stronger} as \textit{the molecules get bigger} and are not much different from the equivalent \textit{alkane}.

Most \textit{properties} of the \textit{Alkenes} are a result of the \textit{weak attractions between the molecules}. In general, there are very \textit{small differences} between the \textit{properties} of the \textit{alkenes} and the \textit{alkanes}.

\begin{itemize}
\item \textbf{Melting & Boiling Pts}: again, the \textit{melting and boiling points increase} as the \textit{size of the molecules increase}.
\item \textbf{Flammability}: again, the \textit{flammability increases} as the \textit{size of the molecules decrease}.
\item \textbf{Solubility}: alkene molecules of all sizes, are insoluble (\textit{immiscible}) in water but will dissolve (are \textit{miscible}) in similar non-polar liquids.
\end{itemize}
Though alkenes **release large amounts of energy when burnt**, they have much more important uses so are rarely used as fuels.

**Alkenes**, particularly *ethene* are important in the **manufacture of other chemicals** such as **plastics**, **ethanol**, **ethanoic acid**, **esters**, **halogen derivatives** etc.

<table>
<thead>
<tr>
<th>Monomer Name</th>
<th>Monomer Structure</th>
<th>Polymer Name</th>
<th>Uses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethylene</td>
<td>$\text{H}_2\text{C}==\text{CH}_2$</td>
<td>Polyethylene</td>
<td>Bottles, ropes, pulleys, medical tubing, insulation, plastic pipe</td>
</tr>
<tr>
<td>Propylene</td>
<td>$\text{H}_2\text{C}==\text{CH}==\text{CH}_3$</td>
<td>Polypropylene</td>
<td></td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>$\text{H}_2\text{C}==\text{CH}==\text{Cl}$</td>
<td>Poly(vinyl chloride)</td>
<td></td>
</tr>
<tr>
<td>Styrene</td>
<td>$\text{H}_2\text{C}==\text{CH}$</td>
<td>Polystyrene</td>
<td>Foams and molded plastics</td>
</tr>
<tr>
<td>Styrene and butadiene</td>
<td>$\text{H}_2\text{C}==\text{CH}$ and $\text{H}_2\text{C}==\text{CH}==\text{CH}_2$</td>
<td>Styrene-butadiene rubber (SBR)</td>
<td>Synthetic rubber for tires</td>
</tr>
<tr>
<td>Acrylonitrile</td>
<td>$\text{H}_2\text{C}==\text{CH}==\text{CN}$</td>
<td>Orlon, Acrylon</td>
<td>Fibers, outdoor carpeting</td>
</tr>
<tr>
<td>Methyl methacrylate</td>
<td>$\text{H}_2\text{C}==\text{COCH}_3$</td>
<td>Plexiglas, Lucite</td>
<td>Windows, contact lenses, fiber optics</td>
</tr>
<tr>
<td>Tetrafluoroethylene</td>
<td>$\text{F}_2\text{C}==\text{CF}_2$</td>
<td>Teflon</td>
<td>Non-stick coatings, bearings, replacement heart valves and blood vessels</td>
</tr>
</tbody>
</table>

Other families, such as **alcohols**, **acids** and **esters** will be met later in this Unit.
Q1.
Name the next five molecules.

a) \( \text{H}_3\text{C} \equiv \text{CH} \equiv \text{CH} \equiv \text{CH}_2 \equiv \text{CH}_3 \)

\text{pent-2-ene}

b) \( \text{H}_2\text{C} \equiv \text{CH} \equiv \text{CH} \equiv \text{CH}_2 \equiv \text{CH}_3 \)

\text{3-methylbut-1-ene}

c) \( \text{H}_3\text{C} \equiv \text{CH} \equiv \text{C} \equiv \text{CH}_2 \equiv \text{CH}_3 \)

\text{4,4-dimethylhex-2-ene}

d) \( \text{H}_2\text{C} \equiv \text{C} \equiv \text{CH}_2 \equiv \text{CH}_2 \equiv \text{CH}_3 \)

\text{2-ethylpent-1-ene}

e) \( \text{H}_3\text{C} \equiv \text{C} \equiv \text{CH} \equiv \text{CH}_2 \equiv \text{CH}_3 \)

\text{3,4-diethylhex-2-ene}

Q2.
For the next four questions, draw the full structural formula for each structure. Then, write the shortened structural formula. (Use your jotter - more space needed!)

a) \( \text{pent-2-ene} \)

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{CH}_3 \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad & & & & & & \text{CH}_3\text{CH}_2\text{CH}_3\text{CH}_3
\end{align*}
\]

b) \( \text{2-methylbut-1-ene} \)

\[
\begin{align*}
\text{H} & \quad \text{CH}_3 & \quad \text{H} \\
\text{H} & \quad \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad & & & & & & \text{CH}_3\text{CH}_2\text{CH}_3
\end{align*}
\]

c) \( \text{3-methylhept-2-ene} \)

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{CH}_3 & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{CH}_3 \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad & & & & & & \text{CH}_3\text{(CH}_2\text{CH}_3\text{CH}_3
\end{align*}
\]

d) \( \text{2,5-dimethylhex-2-ene} \)

\[
\begin{align*}
\text{CH}_3\text{CH}_2\text{CH}_3\text{CH}_3 & \quad \text{CH}_3 \quad \text{H} \quad \text{CH}_3 \\
\text{H} & \quad \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad & & & & & & \text{CH}_3\text{CH}_2\text{CH}_3\text{CH}_3\text{CH}_3
\end{align*}
\]

Q3.
In the next three questions, the name of each structure is incorrect. Draw the structure that each name describes. Rename each structure correctly. (Use your jotter!)

a) \( \text{hex-4-ene} \)

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

\text{hex-2-ene}

b) \( \text{3-propylhept-5-ene} \)

\[
\begin{align*}
\text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H} \\
\text{H} & \quad \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{H} \\
\text{H} & \quad \text{H} & \quad \text{C}_3\text{H}_7 & \quad & & & & & & \text{H} & \quad \text{H} & \quad \text{H} & \quad \text{H}
\end{align*}
\]

\text{5-ethyloct-2-ene}

c) \( \text{3,3-dimethylprop-2-ene} \)

\[
\begin{align*}
\text{H} & \quad \text{CH}_3 \\
\text{H} & \quad \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{C} & \equiv & \text{H} \\
\text{H} & \quad \text{H} & \quad \text{H} & \quad & & & & & & \text{CH}_3
\end{align*}
\]

\text{2-methylbut-2-ene}
5.4 The CYCLOALKANES

Cycloalkane Molecules

The cycloalkanes are a family of hydrocarbons; made from carbon and hydrogen atoms only.

The first (smallest) member of the family is cyclopropane, C₃H₆.

The cycloalkane family is made up of rings where all of the carbon atoms join together with a single bond. Molecules with single bonds only are described as saturated since they have the maximum number of hydrogens attached.

Cycloalkane Names

The same system is used to name the cycloalkanes as was used to name the alkanes.

The surname is -ane to tell you it is like a member of the alkane family (only single bonds), the first name tells you the number of carbon atoms in each molecule. Cyclo tells you the carbons are in a ring.

- cyclopropane - = 3 C's
- cyclobutane - = 4 C's
- cyclopentane - = 5 C's
- cyclohexane - = 6 C's
- cycloheptane - = 7 C’s
- cyclooctane - = 8 C’s

1 2 3 4 5 6 7 8
Monkeys Eat Peanut Butter Perched High High Overhead
Hydrocarbon Families

Topic 5

Just like \textit{alkanes} and \textit{alkenes} the \textit{cycloalkanes} can also have \textit{branches} and the same system for naming these \textit{branches} is used.

The molecule opposite would be named as: \textit{methylcyclohexane}

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{cycloalkanes.png}
\caption{Cycloalkanes}
\end{figure}

\textbf{Properties}

Most \textit{properties} of the \textit{cycloalkanes} are a result of the \textit{weak attractions} between the \textit{molecules}. In general, there are very \textit{small differences} between the \textit{properties} of the \textit{cycloalkanes} and the \textit{alkanes}.

\textbf{Melting & Boiling Pts}

again, the \textit{melting and boiling points increase} as the \textit{size of the molecules} increase.

\textbf{Flammability}

again, the \textit{flammability increases} as the \textit{size of the molecules decrease}.

\textbf{Solubility}

cycloalkane molecules of all sizes, are insoluble (\textit{immiscible}) in water but will dissolve (are \textit{miscible}) in similar non-polar liquids.

However, though similar, the more rigid structure of the \textit{cycloalkanes} does allow stronger attractions than \textit{alkanes}.

As a result they have slightly higher \textit{Boiling Points} than expected.

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|}
\hline
\textbf{No of C atoms} & \textbf{Cycloalkane Boiling Point (°C)} & \textbf{Alkane Boiling Point (°C)} \\
\hline
3 & 33 & 42 \\
4 & 12 & 1 \\
5 & 49 & 36 \\
6 & 81 & 69 \\
7 & 119 & 98 \\
8 & 149 & 126 \\
\hline
\end{tabular}
\caption{Boiling Points of Cycloalkanes and Alkanes}
\end{table}
Q1. Int2

Which of the following compounds belongs to the same homologous series as the compound with the molecular formula C₃H₈?

A \[ \begin{array}{c}
H \\
H-C-C-H \\
H \\
\end{array} \]

B \[ \begin{array}{c}
H \\
H-C=C-H \\
H \\
\end{array} \]

C \[ \begin{array}{c}
H \\
H-C-C-C-H \\
H \\
\end{array} \]

D \[ \begin{array}{c}
H \\
H-C-C-C-H \\
H \\
\end{array} \]

Q2. Int2

The properties of hydrocarbons depend on the sizes of their molecules. Compared with a hydrocarbon made up of small molecules, a hydrocarbon with large molecules will

A be more viscous
B be more flammable
C evaporate more readily
D have a lower boiling point range.

Q3. Int2

Which of the following compounds fits the general formula, CₙH₂ₙ, and will rapidly decolourise bromine solution?

A cyclopentane
B pentane
C pentene
D cyclopentene

Q4. SGC

The structures of some hydrocarbons are shown in the grid.

A \[ \begin{array}{c}
H \\
H-C-C-H \\
H \\
\end{array} \]

B \[ \begin{array}{c}
H \\
H-C=C-H \\
H \\
\end{array} \]

C \[ \begin{array}{c}
H \\
H-C-C-C-H \\
H \\
\end{array} \]

D \[ \begin{array}{c}
H \\
H-C-C-C-H \\
H \\
\end{array} \]

E \[ \begin{array}{c}
H \\
H-C-C-C-H \\
H \\
\end{array} \]

F \[ \begin{array}{c}
H \\
H-C-C-C-H \\
H \\
\end{array} \]

\[ \begin{array}{c}
\text{a) Identify the two hydrocarbons with the general} \\
\text{formula CₙH₂ₙ, which do not react} \\
\text{quickly with bromine solution.} \quad B \text{ and } F \end{array} \]

\[ \begin{array}{c}
\text{b) Identify the hydrocarbon which is the} \\
\text{first member of a homologous series.} \quad B \end{array} \]

\[ \begin{array}{c}
\text{c) Identify the two isomers of} \\
\text{H-C-C-C-H} \quad E \text{ and } F \end{array} \]

Q5. Int2

Which of the following hydrocarbons does not belong to the same homologous series as the others?

A CH₄
B C₃H₈
C C₄H₁₀
D C₆H₁₂

Q6. SGC

The table gives information about some members of the cycloalkane family

<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular Formula</th>
<th>Boiling Point (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>cyclopropane</td>
<td>C₃H₆</td>
<td>-33</td>
</tr>
<tr>
<td>cyclobutane</td>
<td>C₄H₈</td>
<td>up by 21 -12</td>
</tr>
<tr>
<td>cyclopentane</td>
<td>C₅H₁₀</td>
<td>up by 61 49</td>
</tr>
<tr>
<td>cyclohexane</td>
<td>C₆H₁₂</td>
<td>up by 32 81</td>
</tr>
<tr>
<td>cycloheptane</td>
<td>C₇H₁₄</td>
<td>average = + 38</td>
</tr>
</tbody>
</table>

\[ \begin{array}{c}
\text{a) Predict the boiling point of cycloheptane.} \quad 81 + 38 = 119 \\
\text{actual} = 118 °C \quad 115 - 125 °C \end{array} \]

\[ \begin{array}{c}
\text{b) What term is used to describe any family of} \\
\text{compounds, like the cycloalkanes, which have} \\
\text{the same general formula and similar chemical properties?} \\
\text{homologous series} \end{array} \]

\[ \begin{array}{c}
\text{c) Draw and name a saturated} \\
\text{isomer of cyclobutane.} \quad \text{methylcyclopropane} \end{array} \]

\[ \begin{array}{c}
\text{d) Draw and name an unsaturated} \\
\text{isomer of cyclobutane.} \quad \text{but-2-ene or but-1-ene or} \\
\text{2-methylpropene} \end{array} \]
5.5 Hydrocarbon Reactions

Combustion

This reaction is effectively the same for all 3 Hydrocarbon families - Alkanes, Alkenes & Cycloalkanes.

\[
\text{carbon } \rightarrow \text{ carbon dioxide}: \quad \text{as shown by the lime water turning milky / cloudy}
\]

\[
\text{hydrogen } \rightarrow \text{ water}: \quad \text{as shown by the blue Cobalt Chloride paper turning pink}
\]

\[
\text{methane } + \text{ oxygen } \rightarrow \text{ carbon dioxide } + \text{ water} \\
\text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O}
\]

\[
\text{butene } + \text{ oxygen } \rightarrow \text{ carbon dioxide } + \text{ water} \\
\text{C}_4\text{H}_8 + 6\text{O}_2 \rightarrow 4\text{CO}_2 + 4\text{H}_2\text{O}
\]

\[
\text{cyclopentane } + \text{ oxygen } \rightarrow \text{ carbon dioxide } + \text{ water} \\
2\text{C}_5\text{H}_{10} + 15\text{O}_2 \rightarrow 10\text{CO}_2 + 10\text{H}_2\text{O}
\]

\[
\text{hydrocarbon } + \text{ oxygen } \rightarrow \text{ carbon dioxide } + \text{ water}
\]
This reaction is often used to help tell the *difference* between our 3 families - *Alkanes*, *Alkenes* & *Cycloalkanes*.

The orange colour of bromine disappears when it reacts with an alkene.

<table>
<thead>
<tr>
<th>Family</th>
<th>General Formula</th>
<th>Example</th>
<th>Type of C to C bond</th>
<th>Result with Bromine</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Alkane</em></td>
<td>$C_nH_{2n+2}$</td>
<td><img src="image_url1" alt="Image" /></td>
<td><em>single bonds only</em> (saturated)</td>
<td><em>bromine stays brown</em> (decolourises slowly)</td>
</tr>
<tr>
<td><em>Cycloalkane</em></td>
<td>$C_nH_{2n}$</td>
<td><img src="image_url2" alt="Image" /></td>
<td><em>single bonds only</em> (saturated)</td>
<td><em>bromine stays brown</em> (decolourises slowly)</td>
</tr>
<tr>
<td><em>Alkene</em></td>
<td>$C_nH_{2n}$</td>
<td><img src="image_url3" alt="Image" /></td>
<td><em>one double bond</em> (unsaturated)</td>
<td><em>bromine decolourise immediately</em></td>
</tr>
</tbody>
</table>

*Alkenes* react with *bromine* because they take part in an *addition* reaction.

Two molecules react together to form just one product.

\[
\text{unsaturated} \quad \xrightarrow{\text{Br-Br}} \quad \text{saturated}
\]
Addition Reactions

These are important reactions that only molecules with C = C bonds (unsaturated) can do. They can be used to make many useful products.

This reaction can be done with halogen molecules:

\( F_2, Cl_2, Br_2 \) and \( I_2 \)

or with hydrogen halide molecules:

\( H—F, H—Cl, H—Br, H—I \)

In each case the molecule will break into two parts and they will add on to the C atoms making up the C = C double bond.

\[
\text{Br — Br} \quad \text{or} \quad \text{H — Br}
\]

**Halogenation**

Halogenation

- **Propellants (aerosols)**
- **Refrigerants**

**Addition Reactions**

**Halogenation**

- Ethene + bromine → 1,2-dibromoethane

\[
\text{C}_2\text{H}_4 + \text{Br}_2 \rightarrow \text{C}_2\text{H}_4\text{Br}_2
\]

- Ethene + hydrogen bromide → bromoethane

\[
\text{C}_2\text{H}_4 + \text{HBr} \rightarrow \text{C}_2\text{H}_3\text{Br}
\]
Example 1
Equation using full structural formulae:

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

Equation using shortened structural formulae:

\[
\begin{align*}
\text{CH}_3\text{CH} = \text{CH}_2 + \text{Cl}_2 & \quad \longrightarrow & \quad \text{CH}_3\text{CHClCH}_2\text{Cl}
\end{align*}
\]

Equation using systematic names:

\[
\text{prop-1-ene} + \text{chlorine} \quad \longrightarrow \quad 1,2\text{-dichloropropane}
\]

Example 2
Equation using full structural formulae:

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

Equation using shortened structural formulae:

\[
\begin{align*}
\text{CH}_3\text{CH} = \text{CH}_2 \text{CH}_3 + \text{Br}_2 & \quad \longrightarrow & \quad \text{CH}_3\text{CHBrCHBrCH}_2\text{CH}_3
\end{align*}
\]

Equation using systematic names:

\[
\text{pent-2-ene} + \text{bromine} \quad \longrightarrow \quad 2,3\text{-dibromopentane}
\]

The alkenes are described as unsaturated because they contains a C = C double bond, whereas the products are saturated because they contains only C — C single bonds, and their names end in -ane to show this.

The Bromine Test is really a test for unsaturation - the presence of a C = C double bond.
Example 3

Equation using full structural formulae:

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

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

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

Equation using shortened structural formulae:

\[
\text{CH}_3\text{CH} = \text{CHCH}_3 \quad + \quad \text{HCl} \quad \longrightarrow \quad \text{CH}_3\text{CHClCH}_2\text{CH}_3
\]

Equation using systematic names:

\[\text{but-2-ene} \quad + \quad \text{hydrogen chloride} \quad \longrightarrow \quad \text{2-chlorobutane}\]

Example 4 - two possible isomeric products

Equation using full structural formulae:

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

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

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

or

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

Equation using shortened structural formulae:

\[
\text{CH}_2 = \text{CHCH}_2\text{CH}_2\text{CH}_3 \quad + \quad \text{HI} \quad \longrightarrow \quad \text{CH}_3\text{CHI CH}_2\text{CH}_2\text{CH}_3 \quad \text{or} \quad \text{CH}_2\text{I CH}_2\text{CH}_2\text{CH}_2\text{CH}_3
\]

Equation using systematic names:

\[\text{pent-1-ene} \quad + \quad \text{hydrogen iodide} \quad \longrightarrow \quad \text{2-iodopentane} \quad \text{or} \quad \text{1-iodopentane}\]
This reaction uses the **water molecules**: \( H_2O \)

Again, the **molecule** will break into **two parts** and they will **add on to the C atoms making up the C = C double bond**.

\[ H \text{—OH} \rightarrow H \text{ and OH (hydroxyl group)} \]

\[
\begin{align*}
\text{ethene} + \text{water} & \rightarrow \text{ethanol} \\
C_2H_4 + H_2O & \rightarrow C_2H_5OH
\end{align*}
\]

**Example 5**

*Equation using full structural formulae:*

\[
\text{H—C=CH—CH—H} + \text{H—OH} \rightarrow \text{H—C—C—OH}
\]

*Equation using shortened structural formulae:*

\[
\text{CH}_3\text{CH} = \text{CHCH}_3 + H_2O \rightarrow \text{CH}_3\text{CHOHCH}_2\text{CH}_3
\]

*Equation using systematic names:*

**but-2-ene** + **water** \( \rightarrow \) **butan-2-ol**
Hydrocarbon Families

**Hydrogenation**

This reaction uses the **hydrogen molecules**: \( H_2 \)

Again, the **molecule** will break into **two parts** and they will **add on to the C atoms making up the C = C double bond**.

\[
\text{H} - \text{H} \quad \rightarrow \quad \text{H} \quad \text{and} \quad \text{H}
\]

\[
\text{C} = \text{C} \quad + \quad \text{H} - \text{H} \quad \rightarrow \quad \text{H} \quad \text{C} = \text{C} \quad \text{H}
\]

**ethene**   +  **hydrogen**   \( \rightarrow \)  **ethane**

\[
\text{C}_2\text{H}_4 \quad + \quad \text{H}_2 \quad \rightarrow \quad \text{C}_2\text{H}_6
\]

There is no obvious advantage in turning a **reactive, very useful alkene** into a **less reactive, less useful alkane**.

However, **animal fats**, like **butter**, contain mainly **saturated fats** (C—C **single** bonds) while **vegetable oils** have more **unsaturated fats** (C = C **double** bonds) and are **healthier for us**.

Food scientists use **hydrogenation** to convert some of the **unsaturated fats** in a **liquid oil** into **saturated fats** to produce a more **solid** form - **margarine** - which is still **healthier** than butter and has the advantage that it can 'spread straight from the fridge'
**Ethene** is an unsaturated hydrocarbon, and the double bond, C = C, makes it very reactive. The double bond can break open allowing new atoms or molecules to add on to the carbon atoms. When many many small molecules join together in this way it is called addition polymerisation.

![Diagram showing polymerisation process]

Even with a **reactive double bond**, you need high pressures to force the ethene molecules close together and a high temperature to help break the bonds open. A **catalyst** is also needed to help the reaction go faster.

<table>
<thead>
<tr>
<th>Name of Monomer</th>
<th>Structure of Monomer</th>
<th>Structure of Polymer</th>
<th>Repeating Unit</th>
<th>Name of Polymer</th>
</tr>
</thead>
<tbody>
<tr>
<td>chloroethene</td>
<td>ClH</td>
<td>ClH ClH ClH ClH ClH</td>
<td>ClH ClH</td>
<td>polychlorethene (PVC)</td>
</tr>
<tr>
<td>(vinylchloride)</td>
<td>C = C</td>
<td>H H H H H</td>
<td>C C C C C C</td>
<td></td>
</tr>
<tr>
<td>propene</td>
<td>CH₃H</td>
<td>CH₃H CH₃H CH₃H CH₃H</td>
<td>CH₃H</td>
<td>polypropene</td>
</tr>
<tr>
<td></td>
<td>C = C</td>
<td>H H H H H</td>
<td>C C C C C C</td>
<td></td>
</tr>
<tr>
<td>butene</td>
<td>CH₃H</td>
<td>CH₃H CH₃H CH₃H CH₃H</td>
<td>CH₃H</td>
<td>polybutene</td>
</tr>
<tr>
<td></td>
<td>C = C</td>
<td>H CH₃ H H CH₃ H CH₃</td>
<td>C C C C C C</td>
<td></td>
</tr>
<tr>
<td>styrene</td>
<td>C₆H₅H</td>
<td>C₆H₅H C₆H₅H C₆H₅H C₆H₅H</td>
<td>C₆H₅H</td>
<td>polystyrene</td>
</tr>
<tr>
<td></td>
<td>C = C</td>
<td>H H H H H</td>
<td>C C C C C C</td>
<td></td>
</tr>
<tr>
<td>tetrafluoroethene</td>
<td>F F</td>
<td>F F F F F F F F F F F</td>
<td>F F F F</td>
<td>polytetrafluoroethene</td>
</tr>
<tr>
<td></td>
<td>C = C</td>
<td>F C F C C C C C C C</td>
<td>C C C C</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F F</td>
<td>F F F F F F F F F F</td>
<td>F F F F</td>
<td></td>
</tr>
</tbody>
</table>
**Cracking** allows the *oil* industry to change *less useful, long chained alkanes* into a *more useful* mixture of *short chained alkanes* and *alkenes*.

It is *not* possible for *all* the *smaller* molecules produced to be *alkanes*. There are not enough *hydrogen* atoms available. At least one of the *molecules* will need to form a *double* bond, *C = C*, instead. It is also possible to produce a *cycloalkane* during cracking.

Modern *catalysts* allow for more precise *cracking* of smaller *alkanes* to produce the equivalent *alkene* - particularly useful in producing the *monomers* needed for the formation of *addition polymers*. A molecule of *hydrogen* is also produced.
Q1. Process X
\[ C_8H_{18} \rightarrow \text{Ethene} + \text{Compound Y} \]
Which line in the table correctly identifies Process X and Compound Y?

<table>
<thead>
<tr>
<th>Process X</th>
<th>Compound Y</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>cracking</td>
</tr>
<tr>
<td>B</td>
<td>cracking</td>
</tr>
<tr>
<td>C</td>
<td>distillation</td>
</tr>
<tr>
<td>D</td>
<td>distillation</td>
</tr>
</tbody>
</table>

Q2. 1 mole of a hydrocarbon burns completely in oxygen to produce 2 moles of carbon dioxide and 2 moles of water. The formula for the hydrocarbon is

A. \( C_2H_4 \)
B. \( C_2H_6 \)
C. \( C_4H_8 \)
D. \( C_4H_{10} \)

Q3. A student performed the Bromine Test on 4 unknown hydrocarbons.

<table>
<thead>
<tr>
<th>Hydrocarbon</th>
<th>Molecular Formula</th>
<th>Observation with bromine solution</th>
<th>Saturated or unsaturated</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>( C_6H_{14} )</td>
<td>no change</td>
<td>saturated</td>
</tr>
<tr>
<td>B</td>
<td>( C_6H_{12} )</td>
<td>bromine decolourises</td>
<td>unsaturated</td>
</tr>
<tr>
<td>C</td>
<td>( C_6H_{12} )</td>
<td>no change</td>
<td>saturated</td>
</tr>
<tr>
<td>D</td>
<td>( C_6H_{10} )</td>
<td>bromine decolourises</td>
<td>unsaturated</td>
</tr>
</tbody>
</table>

- a) Complete the table.
- b) Suggest a possible name for hydrocarbon C. **cyclohexane**
- c) Suggest a possible structure for hydrocarbon D 
  a cycloalkene or a diene or an alkyne

Q4. When propene undergoes an addition reaction with hydrogen bromide, two products are formed.

Which of the following alkenes will also produce two products when it undergoes an addition reaction with hydrogen bromide?

A. Ethene
B. But-1-ene
C. But-2-ene
D. Hex-3-ene

Q5. The structure below shows a section of an addition polymer.

Which molecule is used to make this polymer?

A. [Molecule A]
B. [Molecule B]
C. [Molecule C]
D. [Molecule D]
Homologous Series

- A homologous series is a group of compounds with:
  - similar chemical properties
  - the same general formula
  - a gradual change in physical properties such as melting and boiling point.

- Examples of homologous series include families of compounds called the *alkanes*, *cycloalkanes* and *alkenes*.

Alkanes

- The *alkanes* are the main family of *hydrocarbons* found in natural gas / oil.

<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular Formula</th>
<th>Shortened Structural Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>methane</td>
<td>CH$_4$ (g)</td>
<td>CH$_4$</td>
</tr>
<tr>
<td>ethane</td>
<td>C$_2$H$_6$ (g)</td>
<td>CH$_3$CH$_3$</td>
</tr>
<tr>
<td>propane</td>
<td>C$_3$H$_8$ (g)</td>
<td>CH$_3$CH$_2$CH$_3$</td>
</tr>
<tr>
<td>butane</td>
<td>C$<em>4$H$</em>{10}$ (g)</td>
<td>CH$_3$CH$_2$CH$_2$CH$_3$</td>
</tr>
<tr>
<td>pentane</td>
<td>C$<em>5$H$</em>{12}$ (l)</td>
<td>CH$_3$CH$_2$CH$_2$CH$_2$CH$_3$</td>
</tr>
<tr>
<td>hexane</td>
<td>C$<em>6$H$</em>{14}$ (l)</td>
<td>CH$_3$CH$_2$CH$_2$CH$_2$CH$_2$CH$_3$</td>
</tr>
<tr>
<td>heptane</td>
<td>C$<em>7$H$</em>{16}$ (l)</td>
<td>CH$_3$CH$_2$CH$_2$CH$_2$CH$_2$CH$_2$CH$_3$</td>
</tr>
<tr>
<td>octane</td>
<td>C$<em>8$H$</em>{18}$(l)</td>
<td>CH$_3$CH$_2$CH$_2$CH$_2$CH$_2$CH$_2$CH$_2$CH$_3$</td>
</tr>
</tbody>
</table>

- The *general formula* for the alkanes is $\text{C}_n\text{H}_{2n+2}$
- The simpler alkanes are mainly used as fuels
- The alkanes burn to give carbon dioxide and water on *complete combustion*
- The alkanes are said to be *saturated* because they contain only *single* C—C bonds
- The alkanes cannot *decolourise* bromine water immediately on mixing
- The alkanes have very *weak attractions* between their molecules and the early (smaller) members of the family
  - have *very low melting & boiling points*
  - are *volatile, flammable* and *non-viscous* (runny)
  - are *insoluble* (immiscible) in water
Hydrocarbon Families

- Alkanes can be *straight chained or branched.*

\[
\begin{array}{c}
H \quad H \quad H \\
| \quad | \quad |
\end{array}
\quad
\begin{array}{c}
H \quad C \quad C \quad C \quad C \quad H \\
| \quad | \quad | \quad | \quad |
\end{array}
\quad
\begin{array}{c}
H \quad C \quad H \\
| \quad |
\end{array}
\]

- Branched alkanes can be *named* systematically according to rules set down by the International Union of Pure and Applied Chemistry (IUPAC).

\textit{butane} \quad \textit{2-methylpropane}

### Alkenes

- The \textit{alkanes} are another family of \textit{hydrocarbons} but contain \textit{double} \( \text{C} = \text{C} \) bonds

<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular Formula</th>
<th>Shortened Structural Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>ethene</td>
<td>( \text{C}_2\text{H}_4 ) (g)</td>
<td>( \text{CH}_2 = \text{CH}_2 )</td>
</tr>
<tr>
<td>propene</td>
<td>( \text{C}_3\text{H}_6 ) (g)</td>
<td>( \text{CH}_3\text{CH} = \text{CH}_2 )</td>
</tr>
<tr>
<td>hexene</td>
<td>( \text{C}<em>6\text{H}</em>{12} ) (l)</td>
<td>( \text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{CH} = \text{CH}_2 )</td>
</tr>
</tbody>
</table>

- The \textit{general formula} for the \textit{alkenes} is \( \text{C}_n\text{H}_{2n} \)
- The alkenes burn to give carbon dioxide and water on \textit{complete combustion}
- The alkenes are said to be \textit{unsaturated} because they contain a \textit{double} \( \text{C} = \text{C} \) bond
- The presence of the \( \text{C} = \text{C} \) bond makes alkenes more reactive than alkanes
- The alkenes can undergo many \textit{addition} reactions eg.

\begin{align*}
\text{hydrogenation} & \quad \text{CH}_2 = \text{CH}_2 + \text{H}_2 \rightarrow \text{CH}_3\text{CH}_3 \\
\text{hydration} & \quad \text{CH}_2 = \text{CH}_2 + \text{H}_2\text{O} \rightarrow \text{CH}_3\text{CH}_2\text{OH} \\
\text{bromination} & \quad \text{CH}_2 = \text{CH}_2 + \text{Br}_2 \rightarrow \text{CH}_2\text{Br CH}_2\text{Br}
\end{align*}

- The alkenes \textit{can decolourise} bromine water immediately on mixing
- \textit{Decolourising bromine water is a test for unsaturation}
- The alkenes have very \textit{weak attractions} between their molecules and the early (smaller) members of the family
  - have \textit{very low melting & boiling points}
  - are \textit{volatile, flammable} and \textit{non-viscous} (runny)
  - are \textit{insoluble} (immiscible) in water
Alkenes can be straight chained or branched. The double bond can be found anywhere in the molecule.

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

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

Alkenes can be named systematically according to rules set down by the International Union of Pure and Applied Chemistry (IUPAC).

- but-1-ene
- but-2-ene
- 2-methylpropene

Cycloalkanes

- The cycloalkanes are another family of hydrocarbons that contain single C—C bonds joined in rings

<table>
<thead>
<tr>
<th>Name</th>
<th>Molecular Formula</th>
<th>Shortened Structural Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>cyclopropane</td>
<td>C₃H₆ (g)</td>
<td></td>
</tr>
<tr>
<td>cyclopentane</td>
<td>C₅H₁₀ (l)</td>
<td></td>
</tr>
</tbody>
</table>

- The general formula for the cycloalkanes is CₙH₂ₙ
- The cycloalkanes burn to give CO₂ and H₂O on complete combustion
- The cycloalkanes are saturated because they contain single C—C bonds
- The cycloalkanes cannot decolourise bromine water immediately on mixing
- The cycloalkanes have very weak attractions between their molecules and the early (smaller) members of the family
  - have very low melting & boiling points
  - are volatile, flammable and non-viscous (runny)
  - are insoluble (immiscible) in water
- Cycloalkanes are rings which can also have branches.

- Cycloalkanes can be named systematically according to rules set down by the International Union of Pure and Applied Chemistry (IUPAC).
  - cyclopentane
  - methylcyclopentane
  - 1,3-dimethylcyclopentane
**Isomers**

- **Isomers** are compounds that have the **same molecular formula** but have **different structural formulae**

\[
\begin{align*}
\text{Isobutane} & \quad (2\text{-methylpropane}) \\
\text{m.p.} & \quad -145^\circ C \\
\text{b.p.} & \quad -10^\circ C
\end{align*}
\]

- **Isomers** will have slightly different properties

**Making Addition Polymers**

- Many polymers are made from the small unsaturated \( C = C \) molecules made by **cracking**
- Many monomers made from **ethene** e.g chloroethene (vinyl chloride → PVC)
- During the polymerisation of ethene, many ethene monomers join to make one large **poly(ethene)** molecule
Hydrocarbon Families

CONSORTIATION QUESTIONS

Q1. Int2
Which of the following could be the molecular formula of a cycloalkane?

A \( C_7H_{10} \)
B \( C_7H_{12} \)
C \( C_7H_{14} \)
D \( C_7H_{16} \)

Q2. Int2
Compared with pentane, propane
A is less flammable and contains larger molecules
B is less flammable and contains smaller molecules
C is more flammable and contains larger molecules
D is more flammable and contains smaller molecules.

Q3. Int2
When methane burns in a plentiful supply of air, the products are
A carbon monoxide and water vapour
B carbon and water vapour
C carbon dioxide and hydrogen
D carbon dioxide and water vapour

Q4. SGC
The monomer in superglue has the structure shown opposite.

\[ \text{a)} \quad \text{Draw a section of the polymer, showing three monomer units joined together.} \]

\[ \text{b)} \quad \text{What name is given to this type of polymerisation?} \quad \text{addition} \]

\[ \text{c)} \quad \text{Bromine reacts with the monomer to produce a saturated compound. Draw the structural formula for this compound.} \]

\[ \text{H} \quad \text{COOCH}_3 \quad \text{H} \quad \text{COOCH}_3 \quad \text{H} \quad \text{COOCH}_3 \]
\[ \text{C} = \text{C} \quad \text{H} \quad \text{CN} \]

\[ \text{H} \quad \text{Br} \quad \text{Br} \]

Q5. Int2
The name of the above compound is
A 1, 1-dimethylpropane
B 2-ethylpropane
C 2-methylbutane
D 3-methylbutane

Q6. Int2
Which of the following molecules is an isomer of heptane?
A
B
C
D

Q7. Int2

\[ \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \]
\[ \text{H} \quad \text{C} = \text{C} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \quad \text{H} \]

KHS Dec 2013/Jan 2014
Hydrocarbon Families

Q1. Int 2

Part of the structure of an addition polymer is shown below. It is made using two different monomers.

\[
\begin{array}{cccccccc}
\text{H} & \text{H} & \text{CH}_3\text{H} & \text{H} & \text{H} \\
\ldots & \ldots & \ldots & \ldots & \ldots \\
\text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} & \text{H} \\
\end{array}
\]

Which pair of alkenes could be used as monomers for this polymer?

A ethene and propene  
B ethene and butene  
C propene and butene  
D ethene and pentene

Q2. Int 2

The flow diagram shows the manufacture of polythene from hydrocarbons in crude oil.

Crude oil \[\rightarrow\] Process X \[\rightarrow\] Alkanes \[\rightarrow\] Process Y \[\rightarrow\] Ethene \[\rightarrow\] Process Z \[\rightarrow\] Polythene

Which line in the table identifies processes X, Y and Z?

<table>
<thead>
<tr>
<th>Process X</th>
<th>Process Y</th>
<th>Process Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>A distillation</td>
<td>cracking</td>
<td>hydration</td>
</tr>
<tr>
<td>B cracking</td>
<td>combustion</td>
<td>polymerisation</td>
</tr>
<tr>
<td>C polymerisation</td>
<td>distillation</td>
<td>hydration</td>
</tr>
<tr>
<td>D distillation</td>
<td>cracking</td>
<td>polymerisation</td>
</tr>
</tbody>
</table>

Q3. Int 2

The octane number of petrol is a measure of how efficiently it burns as a fuel. The higher the octane number, the more efficient the fuel.

a) **What is a fuel?**

substances that releases a large amount of energy when burnt

The octane numbers for some hydrocarbons are shown.

<table>
<thead>
<tr>
<th>Hydrocarbon</th>
<th>Number of carbon atoms</th>
<th>Octane number</th>
</tr>
</thead>
<tbody>
<tr>
<td>hexane</td>
<td>6</td>
<td>20 - 25</td>
</tr>
<tr>
<td>heptane</td>
<td>7</td>
<td>0</td>
</tr>
<tr>
<td>octane</td>
<td>8</td>
<td>-19</td>
</tr>
<tr>
<td>2-methylpentane</td>
<td>6</td>
<td>71</td>
</tr>
<tr>
<td>2-methylhexane</td>
<td>7</td>
<td>44</td>
</tr>
<tr>
<td>2-methylheptane</td>
<td>8</td>
<td>23</td>
</tr>
</tbody>
</table>

b) Predict the octane number for hexane.

20 - 25

c) State a relationship between the structure of the hydrocarbon and their efficiency as fuels.

efficiency decreases as number of carbons increases  
or  
branched molecules are more efficient than chains

Q4. SGC

The grid shows the structural formulae of some hydrocarbons.

a) Identify the hydrocarbon which undergoes an addition reaction to form butane.

F

b) Identify the two isomers.

C and D

c) Identify the structural formula which represents propene.

D
c) Name the hydrocarbon shown in box E.

cyclopentane
CONSOLIDATION QUESTIONS

Q1. The shortened structural formula for an organic compound is

\[
\text{CH}_4\text{CH}(\text{CH}_3)\text{CH(OH)}\text{C}(\text{CH}_3)_3
\]

Which of the following is another way of representing this structure?

A

\[
\text{H} \quad \text{H} \quad \text{OH} \quad \text{CH}_3
\]

\[
\text{H} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{CH}_3
\]

B

\[
\text{H} \quad \text{H} \quad \text{H} \quad \text{OH} \quad \text{CH}_3
\]

\[
\text{H} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{CH}_3
\]

C

\[
\text{H} \quad \text{H} \quad \text{H} \quad \text{CH}_3 \quad \text{CH}_3
\]

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

D

\[
\text{H} \quad \text{H} \quad \text{H} \quad \text{OH} \quad \text{H} \quad \text{H}
\]

\[
\text{H} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{C} \quad \text{CH}_3
\]

Q2. The apparatus shown can be used to identify what is produced when a gas is burned.

When gas X was burned, a colourless liquid collected in the cooled test tube but there was no change in the limewater. Gas X could be

A methane
B carbon monoxide
C hydrogen
D ethene

Q3. The above compound could be formed by adding water to

A

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

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

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

B

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

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

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

C

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

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

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

D

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

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

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

Q4. Three members of the cycloalkene homologous series are:

The general formula for this homologous series is

A \( \text{C}_n \text{H}_{2n+2} \)
B \( \text{C}_n \text{H}_{2n} \)
C \( \text{C}_n \text{H}_{2n-2} \)
D \( \text{C}_n \text{H}_{2n-4} \)
Q1. Int2

Some household cleaners contain the chemical limonene which gives them a lemon smell. The structure of limonene is shown.

Using bromine solution, a student carried out titrations to determine the concentration of limonene in a household cleaner.

\[
0.50 \text{ mol L}^{-1} \text{ bromine solution (orange/red)}
\]

\[
20.0 \text{ cm}^3 \text{ household cleaner (colourless)}
\]

<table>
<thead>
<tr>
<th>Titration</th>
<th>Initial burette reading (cm³)</th>
<th>Final burette reading (cm³)</th>
<th>Titre (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5</td>
<td>16.6</td>
<td>16.1</td>
</tr>
<tr>
<td>2</td>
<td>0.2</td>
<td>16.3</td>
<td>16.1</td>
</tr>
<tr>
<td>3</td>
<td>0.1</td>
<td>16.0</td>
<td>15.9</td>
</tr>
</tbody>
</table>

a) What colour change would be seen in the flask that indicates the end point of the titrations?  

\[ \text{colourless} \text{ to } \text{brown} \]

b) What average volume should be used in calculating the concentration of limonene?  

\[ 16.0 \text{ cm}^3 \]

c) Calculate the number of moles of bromine used.  

\[ n = C \times V \text{ (data book)} \]

\[ n = 0.008 \text{ moles of } \text{Br}_2 \]

d) From the structure of limonene, how many moles of bromine would react with 1 mole of limonene?  

\[ 2 \text{ moles} \]

e) How many moles of limonene were present in the flask?  

\[ \frac{0.008}{2} = 0.004 \text{ moles} \]

f) The mass of 1 mole of limonene (C₁₀H₁₆) is 136g. Calculate the mass of limonene present in 1 litre of the household cleaner.  

\[ n = \frac{m}{gfm} \text{ (data book)} \]

\[ m = 0.004 \times 136 \]

\[ m = n \times gfm = 0.544 \text{ g} \]

Q2. Int2

Chlorofluorocarbons (CFCs) are a family of compounds which are highly effective as refrigerants and aerosol propellants.

However, they are now known to damage the ozone layer. One example of a CFC molecule is shown.

a) What term is used to describe the shape of this molecule?  

\[ \text{tetrahedral} \]

Scientists have developed compounds to replace CFCs. The table shows information about the ratio of atoms in CCl₂F₂ and compounds used to replace it.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Number of atoms</th>
<th>Atmospheric life (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CCl₂F₂</td>
<td>1 C 2 Cl 2 F 0 H</td>
<td>102</td>
</tr>
<tr>
<td>Replacement 1</td>
<td>1 C 2 Cl 2 F 0 H</td>
<td>13-3</td>
</tr>
<tr>
<td>Replacement 2</td>
<td>1 C 0 Cl 3 F 2 H</td>
<td>14-6</td>
</tr>
<tr>
<td>Replacement 3</td>
<td>1 C 2 Cl 1 F 2 H</td>
<td>5-6</td>
</tr>
</tbody>
</table>

b) Draw a possible structure for Replacement 2.

\[ F \text{ F} \]

\[ \text{H C C H} \]

\[ \text{H F F} \]

c) Compared with CCl₂F₂, the replacement compounds contain less of which element?  

\[ \text{chlorine} \]

d) From the table, what is the advantage of using the replacement molecules as refrigerants and aerosol propellants?

\[ \text{they have a much shorter 'lifespan' meaning that they will do less damage to the ozone} \]

This halogen derivative can be made by reacting H—Cl with an alkene.

H—Cl with an alkene.

\[ H - C - C - C - H \]

\[ H - H - H \]

e) State the name of the alkene that would be used.  

\[ \text{propene} \]

f) State the name of this type of reaction.  

\[ \text{addition} \]

g) A second, isomeric, halogen derivative could also have been made.

Draw the structure of this other product.

\[ \text{Cl H H} \]

\[ \text{H C C H} \]

\[ \text{H H H} \]