AQA Chemistry A-level

3.3.2: Alkanes

Detailed Notes
3.3.2.1 - Fractional Distillation

Crude oil is a mixture of different hydrocarbons. It can be separated into the separate molecules by fractional distillation as the different chain lengths of molecules result in them having different boiling points.

Crude oil is separated in the following way:

1. The mixture is vapourised and fed into the fractionating column.
2. Vapours rise, cool and condense.
3. Products are siphoned off for different uses.

Products with short carbon chains have lower boiling points, meaning they rise higher up the column before reaching their boiling point. Therefore they are collected at the top of the column.

Products with long carbon chains have higher boiling points, meaning they don’t rise very far up the column before reaching their boiling point. They condense and are collected at the bottom of the fractionating column.

The compounds collected from the fractionating column are then broken down further via the method of cracking.
3.3.2.2 - Cracking

Longer carbon chains are not very useful, therefore they are broken down to form smaller, more useful molecules. The carbon-carbon bonds are broken in order to do this, which require quite harsh reaction conditions. There are two main types of cracking which result in slightly different organic compounds.

**Thermal Cracking**
This method produces a high proportion of alkanes and alkenes. High temperatures around 1200 K and pressures around 7000 kPa are used to crack the carbon chains.

**Catalytic Cracking**
This method produces aromatic compounds with carbon rings. Lower temperatures around 720 K are used along with normal pressure, but a zeolite catalyst is needed to compensate for these less harsh conditions.

3.3.2.3 - Combustion of Alkanes

Alkanes make good fuels as they release a lot of energy when burned. With sufficient oxygen present, they undergo complete combustion to produce carbon dioxide and water.

*Example:*

\[ \text{CH}_4 + 2\text{O}_2 \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} \]

If the oxygen present is insufficient, combustion is incomplete and carbon monoxide is produced alongside water.

*Example:*

\[ 2\text{CH}_4 + 3\text{O}_2 \rightarrow 2\text{CO} + 4\text{H}_2\text{O} \]

**Catalytic Converters**
Carbon monoxide is a toxic gaseous product which is especially dangerous to humans as it has no odor or colour. Oxides of nitrogen are also produced as a byproduct of alkane combustion.
Both of these gaseous products can be removed from systems using a **catalytic converter**. This uses a **rhodium catalyst** to convert harmful products into more stable products such as $\text{CO}_2$ or $\text{H}_2\text{O}$.

**Example:**

![Three-way catalyst](image-url)

**Carbon Particulates**
Incomplete combustion can also produce **carbon particulates**, small fragments of unburned hydrocarbon. Unless removed from the waste products in industry, these can cause serious **respiratory problems** as they pollute the air.

**Flue Gas Desulfurisation**
Sulfur impurities can lead to the **acidification of water** in the Earth’s atmosphere as they react to form a weak form of $\text{H}_2\text{SO}_4$. The impurities can be removed from waste products via **flue gas desulfurisation**. **Calcium oxide and gypsum** are used in this process.

**Example:**
Unless treated or removed, all of these pollutants can contribute to global warming, acid rain and health issues in humans.

3.3.2.4 - Chlorination of Alkanes

Alkanes react with halogens in the presence of UV light to produce halogenoalkanes. The UV light breaks down the halogen bonds producing reactive intermediates called free radicals. These attack the alkanes resulting in a series of reactions: initiation, propagation and termination.

*Example:*  
1. **Initiation** - the halogen is broken down.
   
   \[
   \text{Cl}_2 \xrightarrow{\text{UV}} 2\text{Cl}^* 
   \]
   
   *Free radicals are shown using a dot.*

2. **Propagation** - a hydrogen is replaced and the Cl\(^{•}\) radical reformed as a catalyst
   
   \[
   \text{Cl}^{•} + \text{CH}_4 \longrightarrow \text{•CH}_3 + \text{HCl} \\
   \text{•CH}_3 + \text{Cl}_2 \longrightarrow \text{CH}_3\text{Cl} + \text{Cl}^{•}
   \]

3. **Termination** - two radicals join to end the chain reaction and form a stable product.

   \[
   \text{•CH}_3 + \text{•CH}_3 \longrightarrow \text{C}_2\text{H}_6
   \]

The propagation step can continue many times to result in multiple substitutions, this is a chain reaction. Condition of the reaction can be altered to favour the termination step and limit the number of substitutions.