Alkanes: Reactions

Combustion —

Complete combustion:

alkane + oxygen $\rightarrow$ carbon dioxide + water + HEAT

$\text{CH}_4 + 2 \text{O}_2 \rightarrow \text{CO}_2 + 2 \text{H}_2\text{O} + \text{HEAT}$

$\text{C}_2\text{H}_6 + 7/2 \text{O}_2 \rightarrow 2 \text{CO}_2 + 3 \text{H}_2\text{O} + \text{HEAT}$

$\text{C}_3\text{H}_8 + 5 \text{O}_2 \rightarrow 3 \text{CO}_2 + 4 \text{H}_2\text{O} + \text{HEAT}$

Incomplete combustion:

In addition to carbon dioxide, water and heat a variety of products are possible.

One such product is the odorless, poisonous gas, carbon monoxide, CO.

Another is carbon black, a sooty material produced by burning hydrocarbons in a limited amount of air. It has a high carbon to hydrogen ratio and is used in the manufacture of automobile tires, increasing the durability of the rubber in the tires.
Halogenation — A substitution reaction, where hydrogen is replaced by Cl or Br.

As an example, consider the reaction of methane with chlorine gas.

No reaction takes place between the two gases at room temperature, but if the mixture is heated or ultraviolet light shines on the mixture a reaction takes place.

The first product formed, chloromethane, CH₃Cl, results from replacement of one H on CH₄ by a Cl.
The second product formed, dichloromethane, CH₂Cl₂, results from replacement of one H on CH₃Cl by a Cl.
The third product formed, trichloromethane, CHCl₃, results from replacement of one H on CH₂Cl₂ by a Cl.
The fourth product formed, tetrachloromethane, CCl₄, results from replacement of the H on CHCl₃ by a Cl.

Overall:

\[
\text{heat or UV} \\
\text{CH}_4 + \text{Cl}_2 \quad \text{-------------------} \quad \text{CH}_3\text{Cl} + \text{CH}_2\text{Cl}_2 + \text{CHCl}_3 \\
\quad + \text{CCl}_4 + \text{HCl}
\]

This reaction takes place by the following mechanism.
This mechanism involves a *chain reaction*. A chain reaction involves a series of steps *in which a product formed in a later step is a reactant in an earlier step.*

<table>
<thead>
<tr>
<th>Initiation-</th>
<th>Propagation-</th>
<th>Termination-</th>
</tr>
</thead>
<tbody>
<tr>
<td>:\text{Cl} \cdot : \text{Cl} :</td>
<td>\begin{array}{c} \text{heat} \ \text{or UV} \end{array} \rightarrow :\text{Cl} \cdot + :\text{Cl} :</td>
<td>:\text{Cl} \cdot + \text{H} : \text{CH}_3 \rightarrow :\text{Cl} : \text{H} + \cdot \text{CH}_3</td>
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<tr>
<td>:\text{Cl} \cdot : \text{Cl} : + \cdot \text{CH}_3 \rightarrow :\text{Cl} \cdot + :\text{Cl} : \text{CH}_3</td>
<td>:\text{Cl} \cdot + :\text{Cl} : \rightarrow :\text{Cl} : :\text{Cl} :</td>
<td>:\text{Cl} \cdot + \cdot \text{CH}_3 \rightarrow :\text{Cl} : \text{CH}_3</td>
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<tr>
<td>2 \cdot \text{CH}_3 \rightarrow \text{H}_3 \text{C} : \text{CH}_3</td>
<td></td>
<td>2 \cdot \text{CH}_3 \rightarrow \text{H}_3 \text{C} : \text{CH}_3</td>
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Note that a small amount of \text{Cl} \cdot formed in the initiation step can lead to the formation of a large amount of \text{Cl} : \text{CH}_3 in the second propagation step.
Ultraviolet Radiation from the Sun and Depletion of the Stratospheric Ozone Layer

How oxygen, O₂, and ozone, O₃, intercept UV radiation from the sun —

Short wavelength UV is absorbed by oxygen in the stratosphere; in the process the oxygen molecule is broken into oxygen atoms. The oxygen atoms may recombine to form O₂ or they may react with O₂ to form O₃.

\[
\text{O}_2 + \text{UV} \rightarrow \text{O} + \text{O}_2
\]

\[
\text{O}_2 + \text{O} \rightarrow \text{O}_3
\]

Longer wavelength UV is absorbed by ozone when it is broken into an oxygen atom + O₂.

\[
\text{O}_3 + \text{UV} \rightarrow \text{O}_2 + \text{O}
\]

This is important because not much else is available in the atmosphere to absorb this longer wavelength UV. Since there is not much ozone in the stratosphere, depletion of what is present will allow more longer wavelength UV to reach the earth's surface.
Chlorofluorocarbons, CFC's, (Freon-12, CF₂Cl₂, for example) are used as refrigerants, cleaning agents and aerosol can propellants. These man-made compounds are not biodegradable; microorganisms are not able to decompose them. Consequently, these materials stay in the atmosphere a long time and are carried into the stratosphere.

In the stratosphere CFC's destroy ozone in the following way —

\[
\text{CF}_2\text{Cl}_2 \xrightarrow{\text{UV}} \text{CF}_2\text{Cl} + \cdot \text{Cl}:
\]

\[
\cdot \text{Cl} + \cdot \text{O} - \text{O} - \text{O} \rightarrow \cdot \text{Cl} - \text{O} - \cdot + \cdot \text{O} - \cdot - \cdot \cdot
\]

\[
\cdot \text{Cl} - \cdot \text{O} - + \cdot \text{O} \rightarrow \cdot \text{Cl} + \cdot \text{O} - \cdot - \cdot - \cdot
\]

\[
\text{from } \text{O}_3 \rightarrow \text{O}_2 + \text{O}
\]
Formation of Amino Acids from Methane –
The Miller-Urey Experiment

Methane reacts with water vapor, ammonia, and hydrogen, in the presence of an electric discharge (spark, lightning) to produce amino acids, the building blocks for proteins.