Reactions of Alkanes

Combustion

Alkanes, and other hydrocarbons can be oxidized (by burning) in the presence of excess molecular oxygen. In this reaction, called combustion, they burn at high temperatures, producing carbon dioxide and water and releasing large amounts of energy as heat.

\[
\text{C}_n\text{H}_{2n+2} + \text{O}_2 \rightarrow \text{CO}_2 + \text{H}_2\text{O} + \text{heat energy}
\]

The following examples show a combustion reaction for a simple alkane

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

Methane

The energy released, along with their availability and relatively low cost, makes hydrocarbons very useful as fuels. In fact, combustion is essential to our very existence. It is the process by which we heat our homes, run our cars, and generate electricity. Although combustion of fossil fuels is vital to industry and society, it also represents a threat to the environment. The buildup of CO\textsubscript{2} may contribute to global warming and change the face of the earth in future generations. Other pollutants are formed as a result of incomplete combustion. If not enough oxygen is present, partial combustion produces compounds such as carbon monoxide, formaldehyde, and acetic acid. The following equations show some incomplete combustion reactions that contribute to air pollution

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

Methane Carbon monoxide

\[
\text{CH}_4 + \text{O}_2 \rightarrow \text{H} = \text{C} = \text{H} + \text{H}_2\text{O}
\]

Methane Methanal (formaldehyde)

\[
2\text{C}_2\text{H}_6 + 3\text{O}_2 \rightarrow 2\text{CH}_3\text{COOH} + 2\text{H}_2\text{O}
\]

Ethane Ethanoic acid (acetic acid)

Halogenation

Alkanes can also react with a halogen (usually chlorine or bromine) in a reaction called halogenation. Halogenation is a substitution reaction, that is, a reaction that results in the replacement of one group for another. In this reaction a halogen atom is substituted for one of the hydrogen atoms in the alkane. The products of this reaction are an alkyl halide or haloalkane and a hydrogen halide. Alkanes are not very reactive molecules. However, alkyl halides are very useful reactants for the synthesis of other organic compounds. Thus, the halogenation reaction is of great value because it converts uncreative alkanes into versatile starting materials for the
synthesis of desired compounds. This is important in the pharmaceutical industry for the synthesis of some drugs. In addition, alkyl halides having two or more halogen atoms are useful solvents, refrigerants, insecticides, and herbicides. Halogenation can occur only in the presence of heat and/or light, as indicated by the reaction conditions noted over the reaction arrows. The general equation for the halogenation of an alkane follows. The R in the general structure for the alkane may be either a hydrogen atom or an alkyl group.

\[
\begin{align*}
R-\text{C}-\text{H} + \text{X}_2 & \xrightarrow{\text{Light or heat}} H-\text{C}-\text{X} + \text{H}-\text{X} \\
\text{Alkane} & \quad \text{Halogen} & \quad \text{Alkyl halide} & \quad \text{Hydrogen halide}
\end{align*}
\]

\[
\begin{align*}
H-\text{C}-\text{H} + \text{Br}_2 & \xrightarrow{\text{Light or heat}} H-\text{C}-\text{Br} + \text{H}-\text{Br} \\
\text{Methane} & \quad \text{Bromine} & \quad \text{Bromomethane} & \quad \text{Hydrogen bromide}
\end{align*}
\]

\[
\begin{align*}
\text{CH}_3\text{CH}_3 + \text{Cl}_2 & \xrightarrow{\text{Light}} \text{CH}_3\text{CH}_2\text{Cl} + \text{HCl} \\
\text{Ethane} & \quad \text{Chlorine} & \quad \text{Chloroethane} & \quad \text{Hydrogen chloride}
\end{align*}
\]

If the halogenation reaction is allowed to continue, the alkyl halide formed may react with other halogen atoms. When this happens, a mixture of products may be formed. For instance, bromination of methane will produce bromomethane (CH$_3$Br), dibromomethane (CH$_2$Br$_2$), tribromomethane (CHBr$_3$), and tetrabromomethane (CBr$_4$). In more complex alkanes, halogenation can occur to some extent at all positions to give a mixture of monosubstituted products. For example, bromination of propane produces a mixture of 1-bromopropane and 2-bromopropane.

**Question**

1- Write a balanced equation for each of the following reactions. Show all possible products.
   a. the monobromination of propane
   b. the complete combustion of ethane
   c. the monochlorination of butane

2- Write a balanced equation for each of the following reactions. Show all possible products.
   a. the monobromination of pentane
   Provide the I.U.P.A.C. names for the products of the reactions in Question 1
   Provide the I.U.P.A.C. names for the products of the reactions in Question 2