Reactions of Hydrocarbons

Hydrocarbons are compounds that only contain carbon and hydrogen. Hydrocarbons can be classified further by the type of bonds they contain. If a hydrocarbon contains only single bonds, it is an **alkane**. If it contains one or more carbon-carbon double bonds, it is classified as an **alkene**. If it contains one or more triple bonds between two carbon atoms, it is an **alkyne**. If it contains a benzene ring, it is considered **aromatic**. (If it does not contain a benzene ring, it is **aliphatic**. Therefore, alkanes, alkenes, and alkynes are all aliphatic hydrocarbons.) These types of compounds react in different ways, so it is possible to distinguish between them using experimental tests.

Physical Properties

Since hydrocarbons contain only carbon and hydrogen, all hydrocarbons are nonpolar. (Carbon and hydrogen have very similar electronegativities.) This means that all hydrocarbons will be insoluble in water. When water is mixed with a nonpolar substance, there are no significant attractive forces between them. However, water molecules are very attracted to each other (since they can hydrogen bond to each other). Therefore, when a nonpolar substance is mixed with water, the water molecules tend to cluster together and exclude the nonpolar substance. If the substances were both liquids, the result would be two layers of liquid, with the more dense liquid on the bottom. Hydrocarbons are less dense than water, so they will float on top of water.

Hydrocarbons, in general, are **volatile**. This means that they have a significant vapor pressure at room temperature so they tend to evaporate easily. The rate of evaporation (for nonpolar substances) is related to the molar mass of the substance. Heavier molecules will evaporate more slowly, since they have stronger intermolecular attractive forces and therefore are more difficult to separate.

Combustion

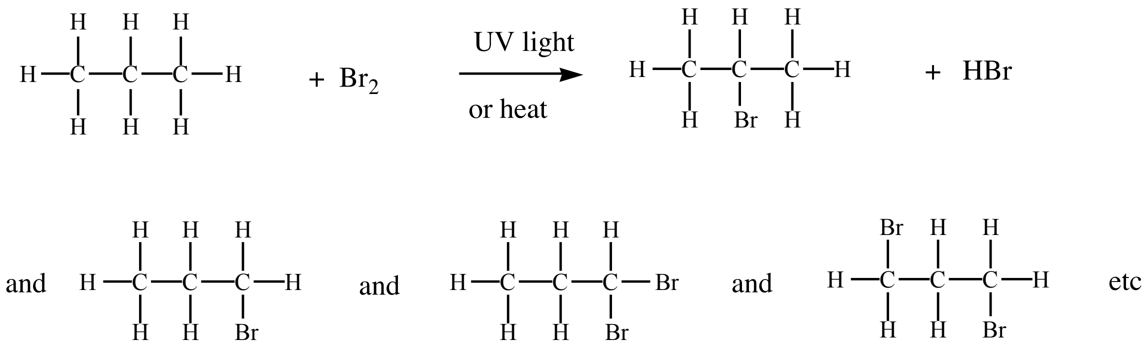
All hydrocarbons will burn in the presence of oxygen (in the air). This reaction is called **combustion**, and the products of this reaction are water and carbon dioxide gas. Here is an example of a combustion reaction:

$$C_3H_{8\,(g)} + 5\,O_{2\,(g)} \rightarrow 3\,CO_{2\,(g)} + 4\,H_2O_{(g)} + \text{heat}$$

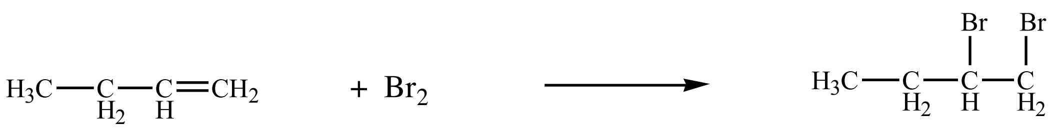
Combustion reactions also give off a great deal of heat. Because of this, many hydrocarbons are used as fuels. Some examples are methane (natural gas), propane, butane, and octane. If there is not an excess of oxygen present during the combustion, then undesirable products are also formed. Carbon monoxide (CO) is an example of an undesirable product of **incomplete combustion**. This compound is toxic.

Halogenation

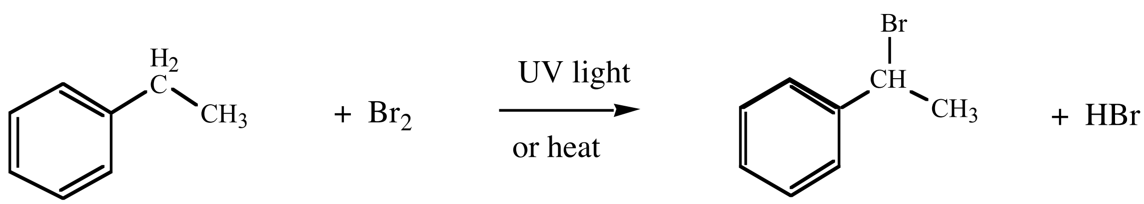
All hydrocarbons can be **halogenated** under certain conditions. Alkanes are very unreactive, but they can be brominated or chlorinated in the presence of ultraviolet (UV) light. This is a **substitution** reaction in which a hydrogen is removed from the alkane and a halogen (Br or Cl) takes its place. The halogen atom can substitute at any site on the molecule. Furthermore, the halogenated products can react further to give disubstituted or trisubstituted products (and so on). This reaction is therefore not at all selective, and mixtures of many products will result.



Alkenes and alkynes are much more reactive than alkanes. They will react readily with Br_2 or Cl_2, and ultraviolet light is not needed for the reaction. This reaction is an **addition** reaction – the halogen atoms will add at the site of the double bond only. Therefore, this reaction is selective– only one product will result.



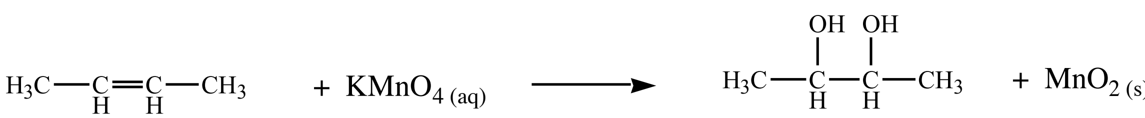
Aromatic compounds are not very reactive. They will not react with Br_2 or Cl_2 under normal conditions. If the aromatic compound has an alkyl substituent, however, the alkyl group can be halogenated in the presence of UV light. The benzene ring will not react under these conditions. (See the reaction on the next page.)



In this experiment, the bromination of several compounds will be attempted. A solution containing bromine will be added to the compounds being tested. The bromine has an orange or brown color. If this color disappears, it means that the bromine is getting used up and therefore the compound is reacting with the bromine. Thus, disappearance of the orange color corresponds to a positive reaction.

Oxidation

Another reaction that alkenes undergo is oxidation. When a purple solution of the oxidizing agent $KMnO_4$ is added to an alkene, the alkene is oxidized to a diol and the $KMnO_4$ is converted to brown MnO_2. Thus, if the purple color changes to brown in this reaction, it is a positive reaction. The diol produced has two adjacent alcohol groups.



Alkanes and aromatic compounds do not react with potassium permanganate.

Disposal