The economies of the world are driven by oil and natural gas. Over the past 100 years, agriculture, transportation and manufacturing have evolved to utilize these non-renewable resources. The demand for products in these sectors of the economy has resulted in a whole new industry called the petrochemical industry. It is difficult to find an aspect of your daily routine that is not in some way tied to the availability of products derived from oil and natural gas.

The petrochemical industry has many branches, including:

- oil and gas exploration
- oil and gas production
- oil and gas refining
- processing of hydrocarbons, and
- plastics production.

Many aspects of this industry rely on an understanding of the physical and chemical properties of hydrocarbons and hydrocarbon derivatives.

Oil Refining and the Properties of Hydrocarbons

Think back to when you studied intermolecular forces. What was the relationship between the boiling points of the halogens and the number of electrons per molecule?

What can you conclude about the boiling point of a substance and the size and shape of its molecules?

Crude oil is homogeneous mixture of many different organic compounds. The individual compounds or groups of compounds are called **fractions**. When crude oil is refined, these miscible fractions are separated from each other. Separation is achieved by heating crude oil so that the various fractions boil off and condense at different heights in a distillation tower (like the ones you see in Come By Chance, NF). This process is repeated over and over in various towers until the crude oil is separated into as many different fractions as possible.

The separation of crude oil on the basis of the different boiling points of its fractions is called **fractional distillation** (or **fractionation**). Can you relate this process to differences in the strengths of intermolecular forces among the fractions in a crude oil sample? This process is well illustrated and explained in your *MHR Chemistry* text on pages 366 - 367.

Combustion Reactions

Hydrocarbons in the range of 7-12 carbons per molecule are the most sought after fractions in crude oil because they eventually become gasoline. Other hydrocarbons such as kerosene or jet fuel ($C_{14}H_{30}$) and diesel ($C_{16}H_{34}$) are also valuable products of refining because like gasoline they are fuels used in transportation. The most common reaction that these hydrocarbons undergo is combustion.

When sufficient amounts of oxygen are available, the combustion of hydrocarbons is **complete** resulting in the production of carbon dioxide and water vapour. The general form of the equation is:

a hydrocarbon + oxygen gas → carbon dioxide + water vapour

or

$$C_xH_{y\,(g)} + (x + \tfrac{y}{4})\,O_{2\,(g)} \rightarrow x\,CO_{2\,(g)} + \tfrac{y}{2}\,H_2O_{(g)}$$

A typical example is the combustion of propane:

propane + oxygen → carbon dioxide + water vapour

or

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

When the amount of oxygen available is insufficient, the combustion is **incomplete** and poisonous carbon monoxide gas is produced.

$$C_3H_{8\,(g)} + \frac{7}{2}\,O_{2\,(g)} \rightarrow 3\,CO_{(g)} + 4\,H_2O_{(g)}$$

In this course, you can assume that hydrocarbon combustion is complete.

What do you notice about the number of moles of oxygen required for complete versus incomplete combustion of propane in the equations above?

Balancing Equations for Combustion Reactions

Balancing chemical equations is an important skill. The following animation illustrates the steps involved. Use the control buttons in the lower right hand corner of the animation to advance the frames.

Cracking and Reforming

About 90% of the crude oil that enters a refinery exits as gasoline, furnace oil, and jet fuel. The other 10% or so is converted to hydrocarbons like ethene and styrene - starting materials used in the plastics industry.

However, the composition of crude oil is not proportional to the substances that are derived from it. Crude oil is not 90% C_8H_{18}, $C_{14}H_{30}$, and $C_{16}H_{34}$ and 10% C_2H_4 and C_8H_8. Crude oil contains hydrocarbons that vary from one to 30 or so carbon atoms per molecule.

Since certain hydrocarbons are in greater demand than others, oil refineries use special processes to convert less valuable hydrocarbons into more valuable ones. Two of the most important processes used for this purpose are cracking and reforming.

Cracking involves converting large alkanes to smaller alkanes, alkenes, and hydrogen. Two important types of cracking are thermal cracking and catalytic cracking. Thermal cracking involves heating large hydrocarbons in the absence of air until the carbon to carbon bonds break. Catalytic involves the use of heat and a special chemical substance called a catalyst to break the bonds. These smaller molecules can then be used in polymerization reactions to produce plastics.

Questions:

1. Describe the process of fractional distillation.
2. Why do we need the processes of cracking and reforming in the oil industry?