Refinery Maze Student Guide

Petroleum Refining Student Text

Distillation

In its crude form, petroleum is of little use to us. To make it into products we know and use, petroleum must be **refined** or separated into its many parts. Those parts are what we use to fuel our world. Petroleum is made of **hydrocarbons**. Hydrocarbons are chemical compounds containing only hydrogen and carbon. These two elements combine in different ways to make hundreds of different compounds that we use to make thousands of products.

The first and most important step in the refining process is **fractional distillation**. Distillation has been around since ancient times. Stills were set up by many cultures to produce alcohol. The first distillation of oil was done at the world's first oil refinery in Romania in 1856.

Fractional distillation is the separation of substances based on their boiling range. Petroleum is not the only thing that is distilled. The chemical industry and the beverage industry also distill their products. Basic distillation follows the same steps regardless of what is being separated.

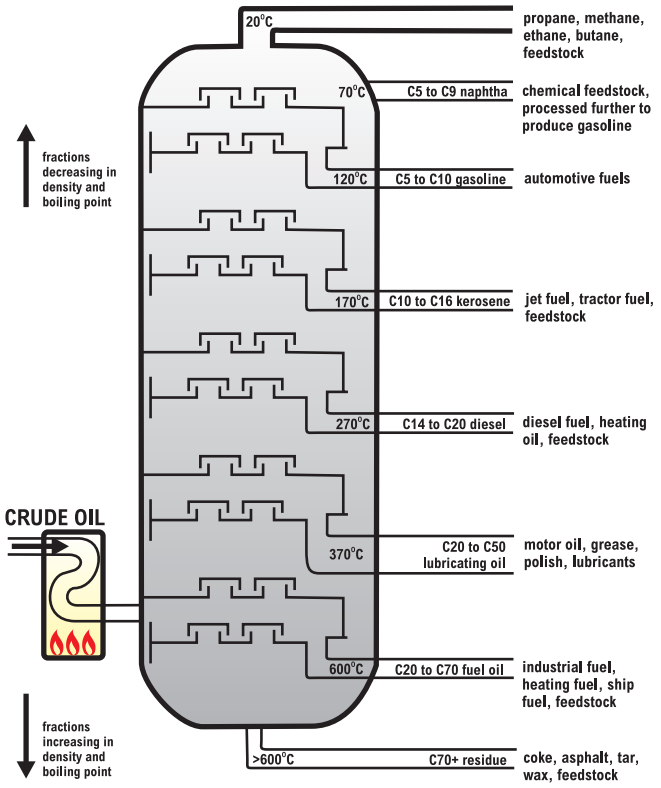
A mixture is heated. As parts of the mixture begin to boil, they rise as gases. These gases are captured in a **fractioning tower**. While the bottom of the tower is very hot, the temperature at the top of the tower is cooler. Smaller molecules with lower densities and boiling points will move to the top of the column, while larger molecules with higher densities and boiling points will collect at the bottom. Trays or plates are placed at different levels inside the tower. These trays or plates have holes in them so that gases can pass through. But as the gas meets a plate that is cooler than the temperature of that gas, it **condenses**, or turns back into a liquid. The condensed liquid that forms on each plate is sent to a pipe. Each plate has its own pipe that carries only the liquids collected on it. The separated liquids move to other machines for further processing.

There are a number of products that come from the refining process. Hydrocarbons with simple molecular structures have lower boiling temperatures. As the molecular structures become more complex, the boiling temperature increases—more energy is required to break the intra-molecular forces between the molecules, which allows for the phase changes.

Once distillation is complete, the light, higher value products like propane, butane, and methane are cleaned and put to use. Heavy, lower value products, like fuel oil and lubricants, are subjected to additional processes to either extract higher value products or alter their chemical make-up to produce higher value products.

After transportation by petroleum tanker or pipeline to a refinery, much of the crude oil is placed in storage facilities or tank farms. These large cylinders hold the crude oil until the refinery is ready to process it.

Fractioning Tower



Processing

These different parts are sent through chemical processing to be turned into useful products. There are three main types of processes. **Cracking** breaks long hydrocarbon chains into smaller ones. **Unification** combines small chains into longer ones. **Alteration** rearranges pieces of hydrocarbon chains to make different hydrocarbons.Cracking can be done in a number of different ways. One method is **thermal cracking**. Thermal cracking uses very high temperatures to break apart long chains of hydrocarbons. This can be done using high temperature steam.

Cracking can also be done by heating the residue from distillation towers to very high temperatures until it separates into useful parts. This process is also known as **coking**, because the material that is left after all of the useful hydrocarbons are removed is **coke**, a hard, porous carbon material. Coke is used by heavy industry, such as iron and aluminum manufacturing.

Another way that long hydrocarbon chains are broken is through **catalytic cracking**. A catalyst is a material that increases the rate of reaction. Catalytic cracking is used to change heavy diesel oils into diesel oil and gasoline.

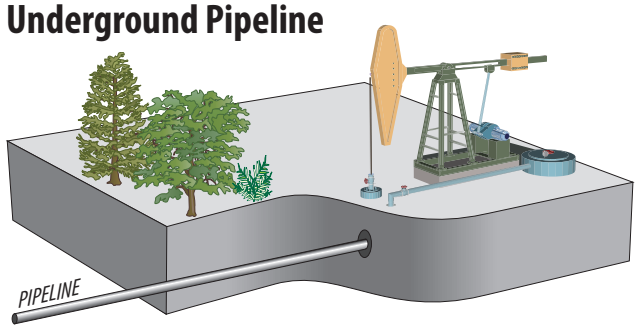
When smaller hydrocarbons are combined to make larger ones through unification, they usually undergo a process of **catalytic reforming**, a process that converts **naphtha** into **aromatics**. Aromatics are cyclic hydrocarbons—meaning the carbons form a ring rather than the simpler straight chain of hydrocarbons. They are named for their distinct "sweet" smell. Aromatics are a very important class of petrochemicals and are typically used to make chemicals and blend gasoline. The main by-product of catalytic reforming is hydrogen gas.

Alteration is the rearrangement of molecules in a hydrocarbon to create a more useful hydrocarbon. Usually this is done with **alkylation**, a process in which hydrocarbons are mixed with a catalyst and an **acid** to create hydrocarbons that are more branched rather than in straight chains. These are called high octane hydrocarbons that burn more smoothly and are often blended with gasoline.

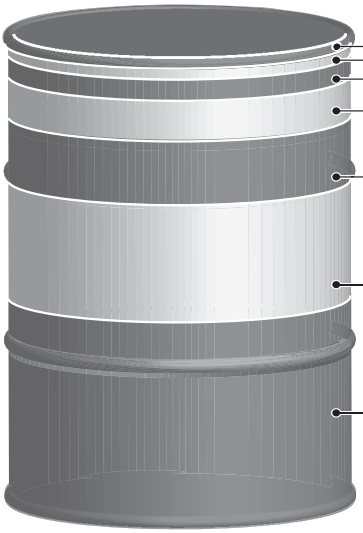
Preparation to Market

Once all the products have been separated from the crude oil that went into the refinery, the products must be prepared to go to market. This last step is known as **treatment**. Gasoline, for example, is treated with additives that help engines operate more smoothly and burn cleaner.

Underground Pipeline



Products Produced From a Barrel of Oil, 2016



2.22% Heating Oil
2.22% Heavy Fuel Oil
4.44% Liquefied Petroleum Gases
8.89% Jet Fuel
13.33% Other Products
24.44% Diesel
44.44% Gasoline

* Total does not equal 100% due to independent rounding.
Data: Energy Information Administration

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Background

After crude oil is brought to the surface, it is transported in order to be separated into its many products. The first step to separating the crude oil into its components is distillation. This takes place in a refinery where a fractional distillation tower, or fractioning tower, is used to separate the products by boiling them. The crude oil is pumped into the tower and heated. Parts of the crude oil mixture turn into gases as the crude boils. The bottom of the tower is very hot, while the top of the tower is allowed to be much cooler. The gas molecules of the crude oil move up the tower based on their boiling points. Larger molecules with higher boiling points and higher densities will collect at the bottom, while smaller molecules with lower boiling points and lower densities will try to push their way to the top. As gas molecules meet an area of the tower that is cooler than their boiling temperature, these gases will condense. There are plates staged throughout the tower that the gases condense onto and then are pumped out of the tower with the materials of similar molecular makeup. Each material can then be further processed into other products. This game enables students to visualize how larger molecules are trapped in certain areas while smaller, lighter molecules can move higher in the tower for separation.

Question

How are different products made from crude oil?

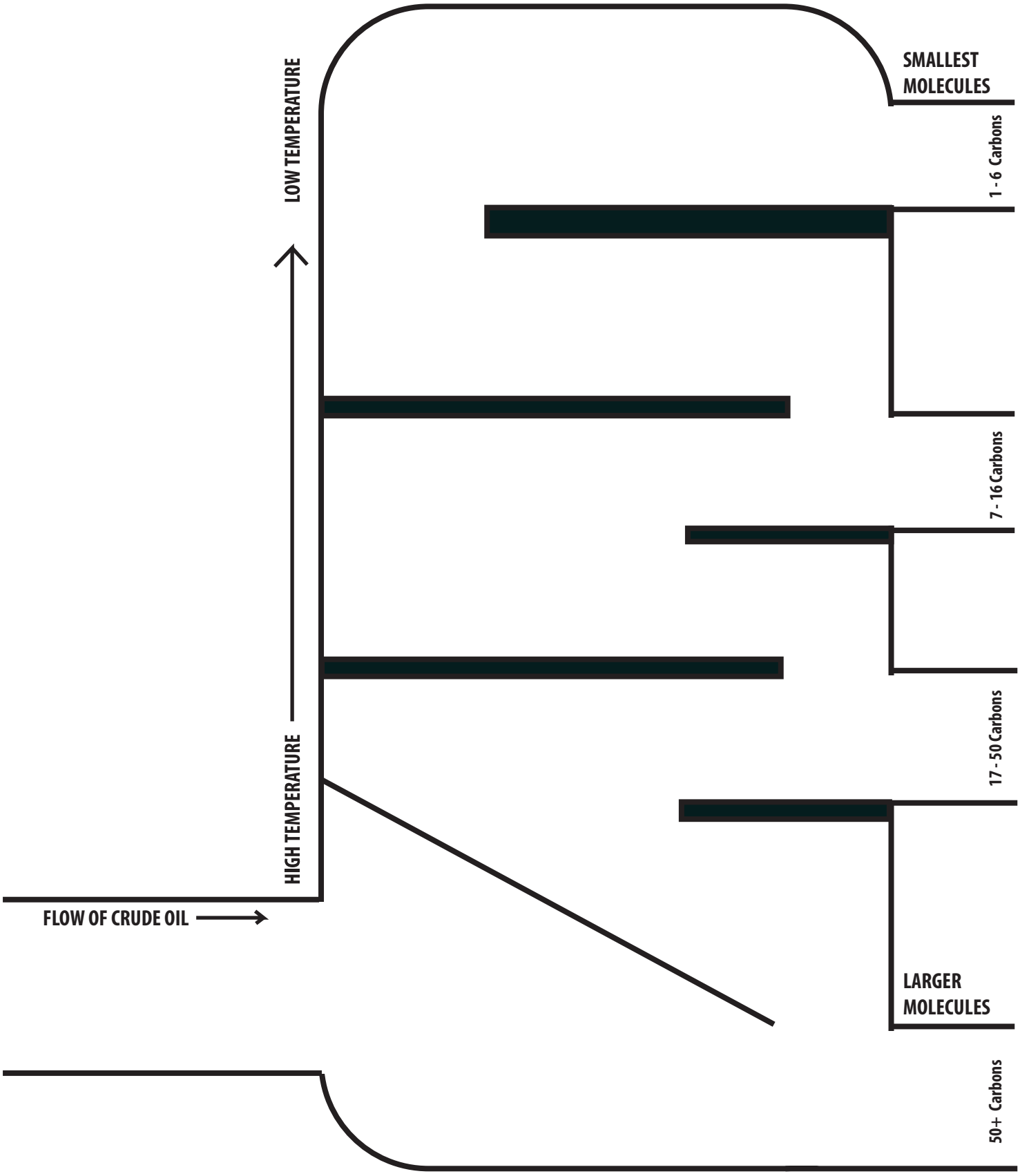
Materials

- One quarter, nickel, dime, and penny
- Straws or pipe cleaners
- Scissors and glue

✔ Procedure

1. Observe the coins and explain or identify the physical characteristics that are different about each coin.
2. Review the process of distillation using the student informational text.
3. Pretend each coin is a hydrocarbon molecule found in a mixture of crude oil. The coins will all enter the fractioning tower for processing together. They will then move through the tower, attempting to get as high as they may travel in the tower before being pumped out.
4. Cut straws or pipe cleaners and glue them onto the borders of the game board to create more rigid borders on which the "molecules" can condense. This ensures coins are not squeezed higher than intended. Be sure to match the edges of all borders and black lines as exactly as possible.
5. Look at the *Fractional Distillation* diagram. Identify which coins might represent certain petroleum products. How does this game board differ from an actual tower? How might you redesign the board to be a better model of the technology and process?

Refinery Maze Game Board



Fractional Distillation