Title: Oil Distillation

By Jim Lokken

Theme: Crude oil is composed of many fractions that can be used for different purposes.

Objectives:

- Students will understand the various components of crude oil.
- Students will perform an experiment to fractionally distill crude oil.
- Students will identify the characteristics of different components of crude oil.

Duration: 45-70 minutes

Age Range: 8th-12th Grade

Materials:

- Distillation apparatus
- Worksheets
  - Crude Oil Distillation - Data Tabulation
  - Identification of Petroleum Fractions
  - Fractional Distillation of Crude Petroleum
- Crude oil sample
- Scale

Background:

Crude petroleum is an exceedingly complex mixture consisting primarily of saturated hydrocarbons of the paraffin or methane series. The separation of components from such a mixture by the process of fractional distillation depends upon the fact that the compounds present in crude petroleum boil at different temperatures (have different boiling points, BP). Such a distillation is not efficient enough to permit the separation of individual pure compounds but yields "fractions" or mixtures of compounds having similar boiling temperatures. This experiment demonstrates what occurs in an oil refinery – the crude oil is heated to different temperatures and the vapors are piped into a tall refinery tower where they cool and condense at different levels. Once they have been distilled into fractions, they are distilled further if necessary.

Preparation:

This activity requires access to a distillation apparatus and needs to be performed in an area with great ventilation. A chemistry lab would be most appropriate. Someone with knowledge of how to operate a distillation apparatus should lead this activity or advise you before you attempt this experiment. Crude oil includes many toxic and flammable chemicals. Use proper safety precautions at all times.

Introductions:

Present students with a container of crude oil. Explain that their task is to distill and identify fractions produced from the crude oil. Remind students of safety protocols and pass out the worksheets.

Activities & Procedures:

Set up the distillation apparatus from which fractions can be taken according to observed temperature changes. Begin by having students calculate the density of the crude oil by dividing weight by volume. The result should be recorded on their Fractional Distillation of Crude Petroleum worksheet.

Have students record the variety of physical data they can measure and observe using the tabulation chart:

1.) Range of temperature in which fraction is taken;
2.) Volume and weight of fraction, from which density can be calculated;
3.) Time required for fixed volume of fraction to flow from pipet of specified volume: measure of viscosity;
4.) Color of fractions and odor;
5.) Qualitative observations of changing refractive index.

Continue through the distillation process as temperature increases until the boiling point of the last fraction is reached. Have students assign names to the respective fractions, according to their probable uses and in terms of their physical properties. Students should complete their worksheets, using the Identification of Petroleum Fractions sheet as a reference.

Wrap-Up:

Review the fractions that were distilled from crude oil. Discuss the different uses of these fractions, and the characteristics of each petroleum fraction that make it useful. Which fraction was most abundant? Which fraction do we utilize most? Consider possible ways to conserve petroleum products.

Evaluation:

The successful distillation of oil fractions will serve as a formative assessment of students' ability to follow lab protocols. Assess student worksheets for completeness, neatness, and accurate work. See suggested answers for worksheet,

but each distillation will be slightly different, so use common sense, your own observations, general guidelines on "Fractional Distillation of Crude Petroleum Worksheet," and comparisons to other student answers to evaluate answers on the data sheet. Observe student cooperation, participation, and adherence to lab safety guidelines during lab work.

Crude Oil Distillation – Tabulate Data

Volume of sample distilled _____ ml
Weight of sample distilled _____ g
Density of crude oil _____ g/ml

Fraction Number	Fraction Boiling Range (C)	Color	Commercial Name	Weight (grams)	Volume (cc)	Density (g/cc)	% of sample by weight	Viscosity (sec)
1								
2								
3								
4								
5								

Identification of Petroleum Fractions Separated from Crude Oil

Name	Average C Composition	Boiling Range ^{0}C	Approx. % of Total Crude
Light gases *			
Petroleum "ether"	~C_2	~0^0	Small
Naptha ("white gas")	~C_5	~25^0	Small
Gasoline	~C_8	50-100^0	~20%
Kerosene and Jet Fuel	~C_{12}	150-200^0	~20%
Heating oil and Diesel Fuel	~C_{15}	200-250^0	~25%
Lubricating oil and Mineral Oil	~C_{30}	250-350^0	~10%
Resibuum	~C_{50} and up	350^0	~25%

Although the boiling point of pure ether is -90^0, quantities of C1 -C4 gases may be held in solution in petroleum at higher temperatures.

Fractional Distillation of Crude Petroleum Worksheet

CALCULATIONS:

1. Calculate density for the crude oil and each of its fractions.

2. Calculate by weight the percent represented by each fraction relative to the crude oil sample distilled.

QUESTIONS:

1. What requirement must be met if two compounds are to be separated by the process of fractional distillation?

2. Judging from the results of the laboratory demonstration, what general relationship exists between molecular weight and volatility?

3. From everyday experience, cite evidence tending to show that the viscosity of a liquid changes with change in temperature.

4. Among the products of the distillation of crude petroleum, is there any apparent relationship between boiling range and viscosity? Explain.

5. By what means may high-boiling fractions such as fuel-oil or paraffin be converted into gasoline? Explain briefly.

6. What evidence is there for the presence of sulfur compounds in this petroleum?

Fractional Distillation of Crude Petroleum Worksheet - *Suggested Answers*

CALCULATIONS:

1. Calculate density for the crude oil and each of its fractions.

2. Calculate by weight the percent represented by each fraction relative to the crude oil sample distilled.

QUESTIONS:

1. What requirement must be met if two compounds are to be separated by the process of fractional distillation?
   The two compounds must have different boiling points.

2. Judging from the results of the laboratory demonstration, what general relationship exists between molecular weight and volatility?
   Lower molecular weights are associated with higher volatility.

3. From everyday experience, cite evidence tending to show that the viscosity of a liquid changes with change in temperature.
   Many possible examples: honey, molasses, oil.

4. Among the products of the distillation of crude petroleum, is there any apparent relationship between boiling range and viscosity? Explain.
   Yes. Items that have a higher boiling point tend to be more viscous.

5. By what means may high-boiling fractions such as fuel-oil or paraffin be converted into gasoline? Explain briefly.
   High-boiling fractions tend to have more carbon atoms in their molecules and a lower ratio of hydrogen atoms. Splitting these larger molecules into smaller ones and/or replacing some carbon with hydrogen could convert fuel-oil or paraffin into gasoline.

6. What evidence is there for the presence of sulfur compounds in this petroleum?
   Scent of rotten eggs. Darker in color and heavier in consistency. Have to be heated to become viscous.

Oil Distillation

Science As Inquiry and Process: Students develop an understanding of the processes and applications of scientific inquiry.

SA1
Students develop an understanding of the processes of science used to investigate problems, design and conduct repeatable scientific investigations, and defend scientific arguments

The student demonstrates an understanding of the processes of science by:

[6, 7, 8, 9] SA1.1 asking questions, predicting, observing, describing, measuring, classifying, making generalizations, inferring, and communicating

Concepts of Physical Science: Students develop an understanding of the concepts, models, theories, universal principles, and facts that explain the physical world.

SB1
Students develop an understanding of the characteristic properties of matter and the relationship of these properties to their structure and behavior.

The student demonstrates understanding of the structure and properties of matter by:

[7] SB1.1 using physical properties (i.e., density, boiling point, freezing point, conductivity) to differentiate among and/or separate materials (i.e., elements, compounds, and mixtures)

SB3 Students develop an understanding of the interactions between matter and energy, including physical, chemical, and nuclear changes, and the effects of these interactions on physical systems.

The student demonstrates an understanding of the interactions between matter and energy and the effects of these interactions on systems by:

[6] SB3.1 recognizing that most substances can exist as a solid, liquid, or gas depending on temperature

[7] SB3.1 recognizing that most substances can exist as a solid, liquid, or gas depending on the motion of their particles

[8] SB3.1 exploring changes of state with increase or decrease of particle speed associated with heat transfer