Return to Lesson Plans
Return to Coal-Education Homepage

Title: **Determining The Chemical Analysis Of Coal**
Level: **Secondary**
Day/Time:

Acdemic Expectations
Core Content for Assessment:

Before You Begin:

There are a large number of coal properties, such as ash and sulfur content, that are frequently measured to help determine if a particular coal is suitable for use in a particular process. The most frequently used analysis is a simple type of chemical analysis called a proximate analysis. This consists of a determination of the moisture and ash content of the coal as well as an estimate of the amount of gas that can be driven from the coal by heating. The final component of a proximate analysis is an estimate of the nonvolatile carbon called fixed carbon.

The moisture content is determined by heating a small sample of powdered coal to a temperature slightly above the boiling point of water (about 105 degree Celsius). This heating will evaporate the moisture from the coal. When the weight of the sample stops changing, the weight loss is equivalent to the weight of the moisture.

The same sample is then burned in air until the weight stops changing. The weight remaining is equivalent to the ash content of the coal. Another sample of the same coal is then heated to 750 degrees in C in the absence of air for seven minutes. The weight loss is equivalent to the volatile matter content. To calculate the fixed carbon, the moisture, ash and volatile matter contents (express the weights in percent) are added together and this sum is subtracted from 100 percent.

The moisture and ash have no heat value and are undesirable. For example, if one hundred railroad cars loaded with coal that has 10 percent ash and 5 percent moisture are shipped to a power plant, the equivalent of ten of those cars carrying rock and five cars are simply carrying water. At the power plant, where the coal is burned, only the volatile matter and the carbon in the coal are burned. Therefore, the most valuable coal has the lowest content of ash and moisture.

Coal is unique among fossil fuels in that it is a metamorphic rock that can undergo a large range of chemical and physical changes. Coal starts out as accumulated plant debris, as it is buried it is subjected to increased heat and pressure which change it both chemically and physically. For example, as the coal is changed, the carbon content and heating value (the amount of heat that a given portion of coal can produce) increase, and the amount of gas (volatile matter) decreases.

The degree of change in these properties forms a natural series called the coalification series. Every sample of coal has been buried and has, therefore, been affected by the coalification process. The process is similar to cooking an egg. Once an egg is heated, it is somewhere between soft boiled

(lignite) and burnt (anthracite). Coal is ranked from lowest to highest: lignite, bituminous and anthracite. The lower the moisture and ash content, the higher the rank.

Activity Duration:

2 to 3 class periods

Objective:

When students complete this activity, they will be able to

- demonstrate how a proximate analysis of coal is determined using actual measurements and calculations and
- identify the difference in the physical and chemical properties of coal samples of different rank.

Materials: (Student groups of 2 or 3)

- samples of coal
  lignite
  bituminous
  anthracite
- data sheet of chemical analysis of coal samples
- pencil and paper

Career Connections:

Chemical Engineering
Environmental Compliance
Quality Control - Quality Assurance

Activity:

Digging In
Calculating a Proximate Analysis from Test Data

Use the data below to calculate the proximate analysis of the sample.

Test One - Moisture

In this test the moisture is evaporated during the heating so that the difference between the starting weight and the final weight represents the moisture. One gram of coal is heated to 105 degrees C. When the weight stops changing, the sample weight remaining is 0.95 grams.

1.0 grams - 0.95 grams = 0.05 grams or

5.0 percent moisture weight

Test Two - Ash

In this test everything except the ash is burned so that the final weight is the ash. The same sample from test one is burned in air to a final weight of 0.12 grams

0.12 grams of ash = 12.0 wt. percent ash

Test Three - Volatile Matter

In this test the volatile matter is evaporated during the heating so that the difference between the starting weight and the final weight represents the volatile matter. An additional one-gram sample of the same coal is heated for seven minutes in the absence of air. The weight at the end of the test is 0.65 grams.

1.00 gram - 0.65 grams = 0.35 grams or 35 percent volatile matter weight Calculate the proximate analysis of this sample. Fixed Carbon = 100% - 5% (moisture) -12% (ash) - 35% (volatile matter) = 48% fixed carbon

Moisture	5.0%	
Ash	12.0%	
Volatile Matter	35.0%	
Fixed Carbon	48.0%	
Total	100.0%	

What About This?

In addition to the proximate analysis, the ultimate analysis is also frequently used. This analysis directly measures the carbon, hydrogen, nitrogen and sulfur in a coal sample. The moisture and ash from the proximate analysis are also included. Oxygen content is calculated by finding the difference in the same way as the fixed carbon is in the proximate analysis.

Another analysis that is becoming increasingly important is the analysis for trace elements. These are elements that occur in coal in very small quantities, usually in the parts per million range.

The Clean Air Act Amendments of 1990 call for stricter limits on SO_3 and NOx emissions and for studies on trace element emissions.

Exploration Points

- One part per million can be seen as one blue marble mixed with 999,999 white ones.
- Ten thousand parts per million equals 1 percent.

Make it Work

Comparing the Physical Properties of Different Ranks of Coal

Examine the three samples of coal and note their differences.

a. color
b. fracture (the appearance of a broken surface)
c. luster (brightness - rate 1 to 4)
d. hardness (rate 1 to 4)

Students should create a table to record their observations.

Comparing the Chemical Properties of Difference Ranks of Coal

Using the table of chemical data given, students will plot the changes in fixed carbon content, heating value and volatile matter with increasing rank- lignite, bituminous and anthracite. Ask students to plot the data on a graph.

Students will discuss how the volatile matter, fixed carbon and heating value vary with rank.

Encourage students to look at the difference in heating value between the bituminous and the anthracite. How many pounds of each coal would it take to get 100,000 Btus?

Return to Lesson Plans
Return to Coal-Education Homepage

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