

ENERGY TRANSFORMATIONS

The main source of the world's energy for the last century has been fossil fuels. Coal and peat, oil (petroleum), and natural gas - formed from the fossils of once living things - are the primary fuels used to power today's society.

To use fossil fuels we must be able to locate and recover them at affordable costs, convert them to usable forms (such as electricity or heat), and use them without wasting them or harming the environment.

Each type of fossil fuel releases a different amount of energy. This energy can be measured in a variety of units. In this activity you will investigate the amount of energy each type of fossil fuel can provide, and the various units used to measure this energy. You will also observe the transformation of a fossil fuel into a usable form of energy, and measure that energy using various units.

Objectives

At the completion of this activity, you should be able to

- show an understanding of the amount of energy found in each kind of fossil fuel,
- list the various units used to measure the energy content of fossil fuels,
- convert these energy units from one unit to another, and
- measure the heat energy obtained from a fossil fuel.

Skills and Knowledge You Need

Safety skills needed to light a propane torch or Bunsen burner and to heat water

Ability to read data tables

Ability to do math calculations needed to solve word problems and conversion problems

Ability to read a thermometer

Words You'll Learn

anthracite coal
barrel
bituminous coal
Btu
calorie

convert
crude oil
gasoline
kilocalorie
kilowatt

kilowatt-hour
peat
therm
transformation
watt

Materials

- Worksheets A, B, C
- calculator (optional)
- clock or watch
- thermometer
- propane torch or Bunsen burner
- water
- ice
- ringstand
- large pyrex beaker to hold 1 quart of water
- safety glasses
- stirring rod

Procedure

1. Look up the definitions for the "Words You'll Learn." Some of the definitions are provided for you on Worksheet A (Units Used for Measuring Energy Content).
2. Worksheet B contains two tables. Table 1 shows the amount of energy contained in five kinds of fossil fuels. Table 2 shows the relationship between different units of energy measurement. Using the information from these tables, answer the questions from the worksheet.
3. Do the experiment on Worksheet C. Follow the directions given, recording your temperatures and predictions on the data table.
4. Answer the questions on Worksheet C. (You will need to refer back to the conversion chart on Worksheet B.)

Questions

1. The Bunsen burner burns natural gas. What usable form of energy was obtained from the natural gas?
2. Based on this activity, which fossil fuels do you think are most desirable to use?
3. Why is it useful to know the relationship between the various energy units?
4. When a water-ice mixture is heated, what action takes place first that makes use of heat energy?

Looking Back

Fossil fuels come in a variety of forms and contain different amounts of energy. This activity has shown you the energy content of different fossil fuels, as well as some of the units used to measure this energy.

Energy content is only one factor to consider in selecting the best fuel for a particular use. The ease of transforming the fuel to usable forms of energy is another factor. (In this experiment you have observed the transformation of natural gas, a fossil fuel, to heat energy.)

There are other factors to consider in selecting a fossil fuel. These include the cost, the ease of extracting, processing, and transporting the fuel, and the environmental effects of both extracting and using it.

Going Further

Use information from the library to compare the advantages and disadvantages of using coal, oil, and natural gas (cost, availability, environmental problems, etc.)

Using sources from your library, find out what substances are found in natural gas and LP gas. Write a paragraph about these substances based on your library research.

Contact a local LP gas dealer and ask for information on uses, safety procedures, and production methods for LP gas.

Invite a guest speaker to discuss current topics relating to fossil fuels: mine safety, environmental problems, toxic waste, etc.

Examine ways of transforming fossil fuels to obtain their energy. Do an experiment to obtain methane from coal.

Using the information on conversion efficiencies from Fossil Fuels Activity 2, determine the amount of energy obtained from each fossil fuel using various energy conversion devices.

Watch a demonstration of the heating of a water-ice mixture that continues past the time when the water boils. As you observe the demonstration, record heating intervals and temperature readings. Display the data on a graph. Read about latent heat and relate that phrase to the graphic display of data.

Worksheet A

Units Used for Measuring Energy Content

barrel: a liquid volume equal to 42 gallons or 159 liters. One barrel of crude oil has about the same heat energy as 448 pounds of bituminous coal, 5,600,000 Btu, or 1,410,579 kilocalories.

Btu: British thermal unit, a unit for measuring heat energy; Btu is the quantity of heat necessary to raise the temperature of one pound of water one degree Fahrenheit, about one-fourth of a kilocalorie (252 calories).

calorie (also: gram calorie): a unit of heat energy; the amount of heat needed to raise the temperature of one gram of water one Celsius degree. It equals 0.00397 Btu.

kilocalorie (kcal): a unit of heat energy equal to 1,000 calories, sometimes called a Calorie or food Calorie.

kilowatt: a measure of power, usually electrical power or heat flow; equal to 1,000 watts or 3,413 Btu per hour.

kilowatt-hour (kWh): the amount of energy equivalent to one kilowatt of power being used for one hour; equal 3,413 Btu, or 860 kcal.

therm: a unit of measure of the heat energy in 100 cubic feet of natural gas. Equal to 100,000 Btu.

watt: a small measure of power, usually electrical power or heat flow; equal to 3.143 Btu per hour. One horsepower = 746 watts.

Worksheet B

Energy Content and Energy Conversion of Fossil Fuels

Directions: Use the following tables to answer the questions below.

Table 1	
Energy Content of Fossil Fuels	
FUEL	ENERGY CONTENT (Btu/Ton)
Coal (Anthracite and Bituminous)	25,000,000
Peat	3,500,000
Gasoline	38,000,000
Natural Gas	47,000,000
Crude Oil	37,000,000

Table 2	
Conversion Chart for Energy Units	
one Btu	= .252 kilocalorie = .000293 kilowatt-hour
one kilocalorie	= 3.97 Btu = .0012 kilowatt-hour
one kilowatt-hour	= 3,413 Btu = 860 kilocalories
one barrel of oil(42 U.S. gallons)	= 5,600,000 Btu = 1,410,579 kilocalories = 1,640.8 kilowatt-hours

Questions

1. Which fuel has the greatest energy content per ton?
2. Which fuel has the least energy per ton?
3. How many kilowatt-hours of electricity could you get from a ton of peat?
4. How many kilowatt-hours of electricity could you get from a ton of coal?
5. How many barrels of oil would give you the same energy as a ton of coal?
6. How many kilocalories are there in one gallon of oil?
7. How many more Btu per ton does gasoline have than crude oil?
8. How many tons of coal would be needed to produce 10,000 kilowatt-hours of electricity?

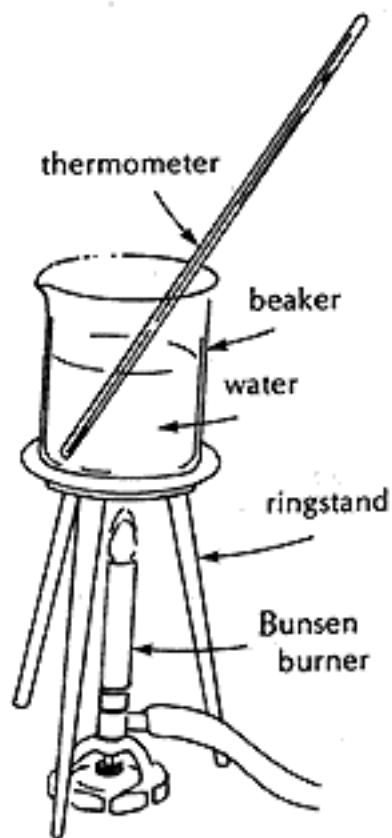
How many tons of natural gas would be needed to produce 20,000 kilocalories of heat energy?

Worksheet C

Converting and Measuring the Energy in a Fossil Fuel

Directions: Follow the steps below to obtain heat energy from natural gas. Use a Fahrenheit thermometer because the Btu's and therms used later are English system units.

1. Pay careful attention to the safety instructions provided by your teacher on the safe use of the Bunsen burner or other kind of gas burner provided. Wear your safety glasses.
2. Fill a large pyrex beaker with enough tap water to weigh one pound (approximately 450 mL). Note: the total weight should equal one pound of water plus the weight of the beaker.
3. Stir the water with a stirring rod. Then lift the thermometer off the bottom of the beaker and read the temperature of the water. Record that temperature under "Heating Trial One" in the data table. The initial time is "Time 0."
4. Set up the apparatus as shown in the diagram. The beaker should be about 3 inches above the top of the burner. Light and adjust the burner to medium-low flame.
5. Use the stirring rod to mix the water as you apply heat as directed by your teacher. At the end of 5 minutes, measure the temperature of the water. Record that temperature under "Heating Trial One" in the data table beside "Time 5."
6. Let the system cool at least three minutes. Repeat Directions for steps "3" and "5". This time your "Time 0" temperature will be higher since the original tap water has been heated somewhat. After heating, record the new temperature measurements under "Heating Trial Two" on the data table.
7. Calculate the temperature change for each trial of the two heatings and record these calculations under the appropriate heating trials. Compare the changes with each other. Check with your teacher to see if more trials are necessary before you proceed to step eight.



8. Refill the beaker with tap water and plenty of ice which together weigh one pound.
Note: the total weight should equal one pound of water and ice plus the weight of the beaker. Remember to stir the water-ice mixture. Read the thermometer until the temperature remains steady. Record that temperature under "Heating Trial Final" in the data table.
9. Based upon the data you collected previously, how many degrees do you predict the temperature of the ice-water mixture will rise when you heat it for five minutes?
Record your prediction under "Heating Trial Final" in the data table.
10. Based on the Time 0 water-ice mixture and your predicted temperature change calculate the predicted temperature at Time 5. Record that calculated prediction under "Heating Trial Final" in the data table.
11. Heat the water-ice mixture for five minutes and record your results under "Heating Trial Final" in the data table.
12. Calculate the actual temperature change and record that calculation under "Heating Trial Final" in the data table.
13. Check with your teacher before cleaning up and answering the "Questions."

Data Table

Heating Trial One

Time 0,
Tap water temperature _____ ° F

Time 5,
Water temperature _____ ° F

Temperature change _____ ° F

Heating Trial Two

Time 0,
Water temperature _____ ° F

Time 5,
Water temperature _____ ° F

Temperature change _____ ° F

Heating Trial Final

Time 0,
Water-ice temperature _____ ° F

Predicted,
Temperature change _____ ° F

Predicted,
Temp. at Time 5 _____ ° F

Time 5,
Temp. water-ice _____ ° F

Actual,
Temperature change _____ ° F

Questions

1. Using Worksheets A and B calculate:
 - a. How many Btu's of heat energy were needed to change the tap water's temperature to the new temperature reached in "Heating Trial One"? _____ Btu
 - b. How many kilocalories of heat energy were needed? _____ kcal
 - c. How many therms of heat energy were needed? _____ therm
 - d. How many kilowatt-hours of heat energy were needed? _____ kWh
2. How many degrees in temperature did you predict the water-ice mixture would rise in five minutes? _____ ° F
3. How many degrees did the temperature actually rise? _____ ° F
4. You have probably experienced a discrepancy. One of the times a discrepancy occurs is when there is a difference between what you expected to observe and what you actually did observe. What questions do you have as a result of the discrepancy you observed?

Teacher Information

Energy Transformations

Suggested Grade Level and Discipline

Grades 7-9

Science

Technology

Mathematics

Skill Objectives

Conducting an experiment

Recording data and observations during an experiment

Reading and interpreting a chart containing numbers

Solving word problems in math

Major Understandings

Each fossil fuel contains a different amount of energy per unit of weight.

Various units are used to measure energy content.

These units of measurement can be converted from one to the other.

Background

Fossil fuels provide most of the energy used in the world today. Despite the many problems associated with their use, they will continue to be our mainstay for years to come.

In light of this, it is important that students become familiar with some of the characteristics of fossil fuels, so that they can deal intelligently with energy issues as they arise.

Fossil fuel energy content is well documented. The chart given in this activity is representative of most that are published. In no way should these figures be thought of as the amount of energy which is available as usable energy after the conversion process. Losses are large in most conversion processes and efficiencies never approach 100%. This point should be discussed with students as part of this activity. (See Fossil Fuels Activity 2- pages 2-4 and 2-6.)

Advance Planning

The instructor should do the computations and complete the answers on Worksheets B and C.

Have a supply of crushed ice in an insulated container on hand for the experiment.

Check with math teachers to see if students have sufficient background to do the word problems.

For "Going Further," check with your librarian to find out whether information is available on LP and natural gas. If it is not, your librarian can obtain it from other libraries or from local LP gas dealers.

Suggested Time Allotment

One period to present background material, look up definitions for "Words You'll Learn," and read Worksheet A

One period to complete Worksheet B

One period to conduct the experiment on Worksheet C, record data, and answer questions

One period to discuss the answers to the questions on Worksheets B and C

Suggested Approach

Using the vocabulary from "Words You'll Learn," discuss the energy content of fossil fuels and the methods of transforming that energy into usable forms. Introduce the units used for measuring energy content.

Allow students to use a calculator to do the computations on Worksheets B and C.

Have students complete Worksheet B. Allow students to work as partners to complete the worksheet.

Have students perform the experiment on Worksheet C. Allow students to work in small groups when completing the experiment. Go over the results of the experiment and the answers to the word problems.

If desired, the experiment can be done as a teacher demonstration.

Rather than weighing out one pound of water and one pound of water-ice mixture, you may wish to use volume by the students measuring 454 mL (454 g). Celsius temperature readings may be converted to Fahrenheit, if necessary, using $9/5 (C) + 32 = F$

If students show interest, have them do follow-up such as one of those listed in the "Going Further" section.

The Energy Transparency/Ditto Masters from the Energy Education Project's Energy Options package may be useful. See Masters A-2, A-16, A-17.

Precautions

Review safety precautions relating to using fire, heating liquids, and burning natural gas.

Caution the students about proper handling of the thermometers to insure accurate temperature reading.

Points for Discussion

How does the energy content of each fossil fuel compare to that of the others?

When the energy stored in fossil fuels is converted for use, what form of energy usually results?

What method of transformation is most commonly used to obtain energy from fossil fuels?

What are the advantages and disadvantages of fossil fuel use? Consider heat content, ease of conversion, environmental problems, etc.

Typical Results

Some students will need to have word problems broken down in steps.

Students will be able to convert from one energy unit to another.

If students perform the wrong arithmetic operations, their results will be unlikely. They should be encouraged to refer to Table 2 on Worksheet B to see if their answers are reasonable.

Students should infer that some heat energy was used to melt the ice, since the mixture was heated but there was no temperature change until the ice melted. (Latent heat is the change in heat content of a substance when its physical state is changed without a change in temperature.)

Key

Worksheet B

1. Natural gas
2. Peat
3. $3,500,000 / 3413 = 1,025.49$ kWh
4. $25,000,000 / 3413 = 7324.93$ kWh
5. $25,000,000 / 5,600,000 = 4.464$ barrels
6. $1,410,579 / 42 = 33585.21$ kcal
7. $38,000,000 - 37,000,000 = 1,000,000$ Btu
8. $3413 \times 10,000 = 34,130,000$ Btu / $25,000,000 = 1.365$
9. $3.97 \times 20,000 = 79,400 / 47,000,000 = .00169$ tons

Worksheet C

1. (Responses depend on ΔT . Here a 25°F change for 5 minutes is assumed.)

$$\begin{aligned} \text{number of Btu} &= 1 \text{ lb} \times \Delta T \\ &= 1 \times 25 = 25 \text{ Btu} \end{aligned}$$

$$\text{number kcal} = .252 \times \text{number of Btu} = .252 \times 25 = 6.3 \text{ kcal}$$

$$\text{number of therms} = \text{number of Btu} / 100,000 = 25 / 100,000 = .00025 \text{ therms}$$

$$\text{number of kilowatt-hours} = \text{number of Btu} / 3,413 = 25 / 3,413 = .00073 \text{ kWh}$$

2. Students should predict a ΔT that is the average of "Heating Trial One" and "Heating Trial Two".

3. The heat energy is being used to melt ice so there should be no change in temperature as long as the ice remains in the mixture.
4. Student questions should have to do with their actual result (no change) not matching their predicted result (same amount of change as before.) This provides an opportunity for you to discuss latent heat.

Evaluation

Give a quiz on the terms from "Words You'll Learn."

Evaluate student responses on Worksheets B and C.

Student responses in discussion may be used as an indicator of understanding of the concepts.

Modifications

A propane torch may be substituted for the Bunsen burner.

Develop a computer program based on the information and word problems on Worksheet B.

Have students use the information regarding energy consumption from utility bills and practice converting the energy units.

References

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