v 1.0

ACTIVITY 8

Collecting Experimental Data for Predictions

LABORATORY

The way in which a wildfire
spreads is affected by the type
and amount of vegetation.

8: COLLECTING EXPERIMENTAL DATA FOR PREDICTIONS

GUIDING QUESTION

How can you use experimental results to make predictions about the real world?

INTRODUCTION

Wildfires can blanket an area with smoke, causing air quality problems for people nearby. Since smoke can travel hundreds or even thousands of miles, it can also affect air quality far from the fire. Using probabilistic reasoning to predict air quality changes from wildfires is challenging because of varying factors such as wind, weather, and the landscape.

Fire scientists investigate the type of plants that burn in a wildfire to help predict how the fire will behave. In this activity, you will take on the role of a fire scientist and explore how different plants, or fuel sources, affect wildfires. Grasses, trees, and shrubs are all examples of fuel sources for wildfires.

Fire is a natural part of many ecosystems. Fire scientists study the causes and benefits of fires and help prevent destructive wildfires.

If you need to review the concepts of combustion, thermal energy, calories, and the law of conservation of energy, you will find a Science Review at the end of this activity.

CONCEPTUAL TOOLS

PROBABILISTIC REASONING

SIGNAL & NOISE

MATERIALS LIST

FOR EACH GROUP OF FOUR STUDENTS

- METAL SODA CAN
- 50 mL GRADUATED CYLINDER
- RULER WITH CENTIMETERS (cm)
- WATER 50 mL PER SAMPLE
- THERMOMETER
- ALUMINUM FOIL
- WIRE GAUZE
- METAL TONGS
- 2–3 PAPER CLIPS
- RING STAND, WITH CLAMP AND RING SUPPORT
- LONG-REACH LIGHTER OR MATCHES
- TIMER
- BALANCE THAT MEASURES TO 0.1 GRAMS
- SAMPLES OF OUTDOOR VEGETATION

FOR EACH STUDENT

- STUDENT SHEET 8.1 "Testing Fuel Sources"
- SAFETY GOGGLES

SAFETY NOTE

Make sure to carefully follow all safety instructions from your teacher.

- Wear safety eyewear during this investigation.
- Keep long hair tied back and loose sleeves rolled up.
- Clear all items near your test area and be especially careful not to get your hair or clothing near the flame. If anything besides the fuel sample begins to burn, inform your teacher immediately.
- Keep a cup of water nearby as a fire safety precaution.
- Note that the wire gauze and burning samples may become quite hot to the touch during the investigation. Use metal tongs to pick up the wire gauze and the burned sample.

PROCEDURE

PART A: SETTING UP YOUR EXPERIMENT

1 With your group of four, read the following fictional scenario.

REGIONAL PARK AT RISK OF EXTREME FIRE

Fire scientists in Meso City are worried that a small fire in Koheegee Park could quickly grow into a large, uncontrollable blaze. A hotter climate and drier conditions make this more likely. If the fire reaches the Koheegee Reservoir, it could affect the water quality for local residents since the reservoir provides about half of the city's water. To understand how fires might spread and how to prevent a large fire, the scientists are testing how different types of fuel sources in the area catch fire (ignite) and burn (combust).

2 Your group will play the role of the Meso City fire scientists. Your goal is to make predictions about how a wildfire might affect different parts of Koheegee Park. You will investigate two characteristics of fuel sources:

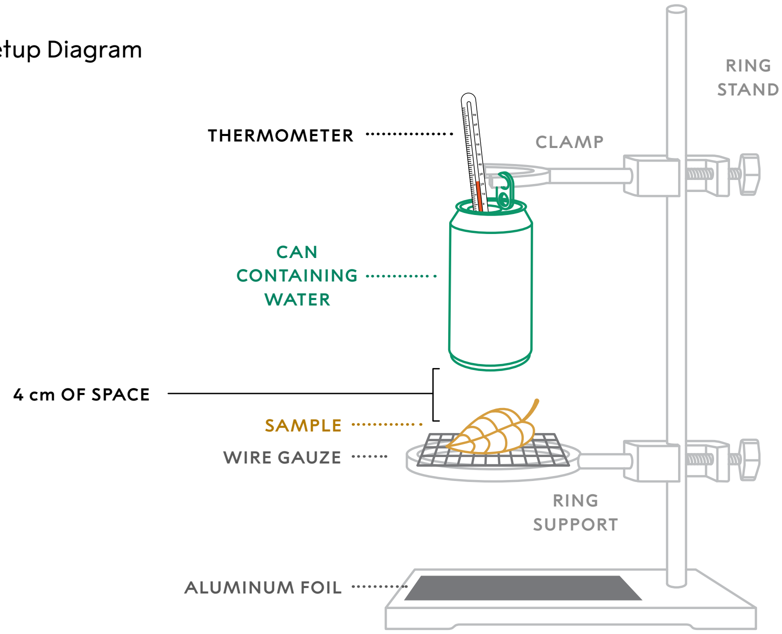
ignition time: how easily or quickly a material will catch on fire

heat of combustion: amount of energy released as heat when a substance is burned

3 As a group, choose two different fuel sources provided by your teacher to test. Record your fuel sources in your science notebook, along with observations about how dry or fresh they are, and a hypothesis as to which fuel source you think will ignite faster, burn hotter, or produce more smoke.

4 Follow your teacher's instructions for setting up the calorimeter. A *calorimeter* is a device used to measure the heat released or absorbed during a chemical reaction or physical change. Figure 8.1 shows a calorimeter constructed using a ring stand. Make sure there is space both above and underneath the wire gauze so air can flow through for your sample to burn.

FIGURE 8.1
Calorimeter Setup Diagram



5 Add 50 milliliters (mL) of water to the can. In Table 1 on Student Sheet 8.1, "Testing Fuel Sources," record the mass of the water in grams (g).

`HINT: For water, 1 mL equals 1 g.`

6 Hang the can from the clamp, using a paper clip if needed. Position the bottom of the can about 4 cm (1.6 inches) above the top of the wire gauze, as shown in Figure 8.1. The bottom of the can should be above the flame of the burning sample but not so low that it will extinguish the flame.

PART B: TESTING YOUR FUEL SOURCES

7 Record a brief description of each sample and its initial mass in Table 1 on Student Sheet 8.1. (You may want to mass your sample on the wire gauze so that you can easily calculate the change in mass after burning.)

8 Place the thermometer in the can. Measure the initial temperature of the water and record it in degrees Celsius (°C) in Table 1 on the student sheet.

9 Position your sample on top of the wire gauze. Light the fuel sample according to your teacher's instructions. Use your timer to measure the time it takes to ignite. Record the ignition time in Table 1.

`HINT: Use the following tips to light the fuel sample:`

- Hold the flame a couple of centimeters below the edge of the sample.
- Make sure there are no drafts blowing on the lighter or match flame.
- If necessary, use the metal tongs to adjust the sample position.
- If your sample fails to ignite after 15 seconds of applying the flame from the lighter, stop using this sample. Choose another sample to test and start over.

10 After the sample ignites, use tongs to promptly slide the sample under the can and start the timer to measure the length of time it burns. As the sample burns, observe:

- the speed at which the flame spreads through the sample.
- the size of the flame.
- how much smoke is produced.
- how long it takes for the sample to finish burning.

Record your observations in Table 1 on your student sheet.

11 Your sample may not burn completely. As soon as the sample stops burning, record the final temperature of the water in Table 1.

12 When the sample has cooled completely, mass the sample again. Record the final mass in Table 1.

13 Repeat Steps 8–12 for your other sample. You may need to replace the water in the can to reset the temperature. Make sure the can has cooled down before replacing the water.

14 Clean up and safely dispose of your samples before moving on to Procedure Part C.

PART C: ANALYZING YOUR DATA

15 Calculate the energy released as heat by the sample as it burned.

a Record the mass of water for each sample in Table 2 on your student sheet.

b Calculate the temperature change of the water by subtracting the initial water temperature from the final water temperature. Record this value for each sample in Table 2 on your student sheet.

c A *calorie* is the amount of energy it takes to raise the temperature of 1 gram of water by 1 degree Celsius. Use the following formula to calculate the energy released by the sample in calories and then record this value for each sample in Table 2.

energy released by sample (calories) = **mass of water** (g) X **temperature change of water** (°C)

16 Use the following steps to calculate the heat of combustion. Since you began with different masses of samples, this calculation will help you compare them to one another.

a Calculate the change in the mass of the sample by subtracting the final mass (after burning) from the initial mass (before burning). Record this value for each sample in Table 2.

b Use the following formula to calculate the heat of combustion. Record this value for each sample in Table 2.

$$\text{heat of combustion (calories/gram)} = \frac{\text{energy released by the sample (cal)}}{\text{change in mass of sample (g)}}$$

17 Share your results with other groups that tested a similar type of sample and with other groups that tested a different type of sample. Use your data and observations to discuss the following:

- Which fuel sample(s) burned most quickly? Which sample(s) burned most slowly? How might this be a factor in a real wildfire with natural fuel sources such as grasses, dry vegetation, and trees?
- Which fuel samples had the greatest heat of combustion? How might this be a factor in a real wildfire?

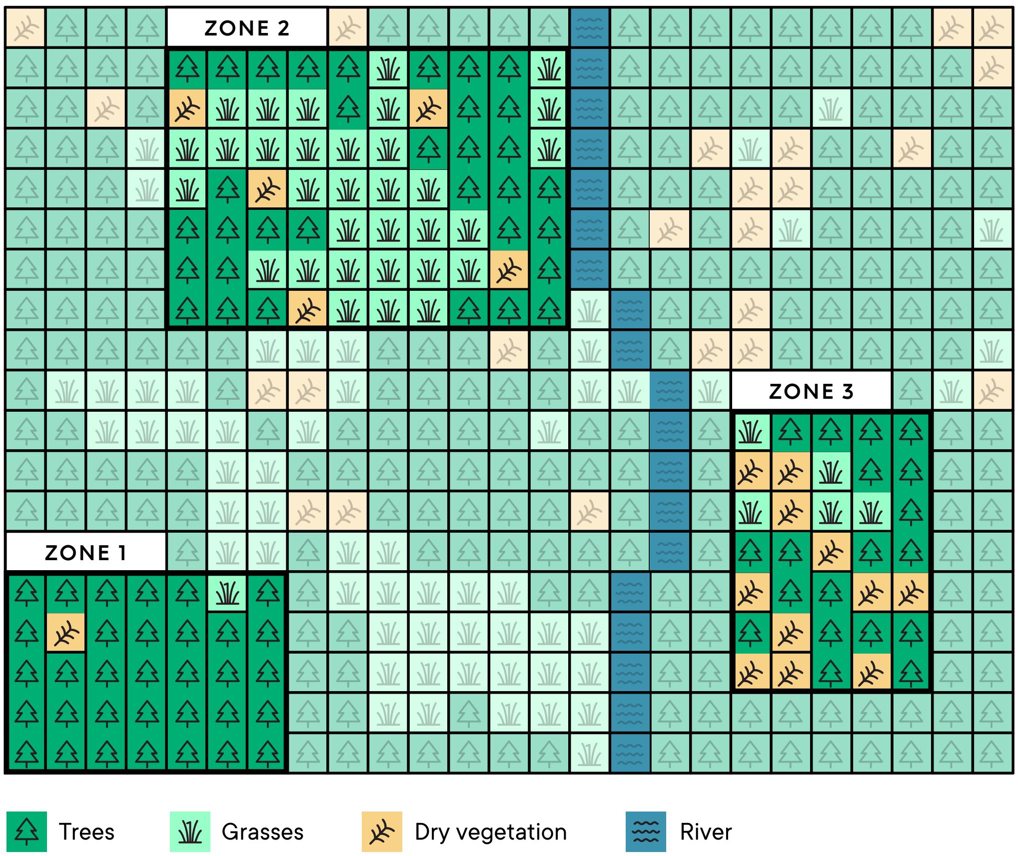
  HINT: Fires that release more energy can burn for longer and may be more difficult to contain.
- Which fuel samples produced the most smoke? How might this be a factor in air quality conditions from a real wildfire?

BUILD UNDERSTANDING

1. You conducted an experiment to compare two different fuel sources. Which of the fuel sources do you think is more likely to be ignited in a wildfire? Use the results from your experiment as well as probabilistic reasoning to explain your prediction.

2. Examine Figure 8.2, which shows a map of a fictional place called Koheegee Park.

FIGURE 8.2
Map of Koheegee Park with 3 Zones



   a. Which of the fuel samples tested by your class would best represent each type of fuel source (trees, grasses, dry vegetation) found in Koheegee Park?

   b. Which section of the park (Zone 1, 2, or 3) is most at risk from a rapidly spreading wildfire? Explain.

3. *Fuel load* is the amount of combustible material in a given area, measured as weight per unit of area. Examine Table 8.1, which shows the annual fuel load in four different regions by latitude.

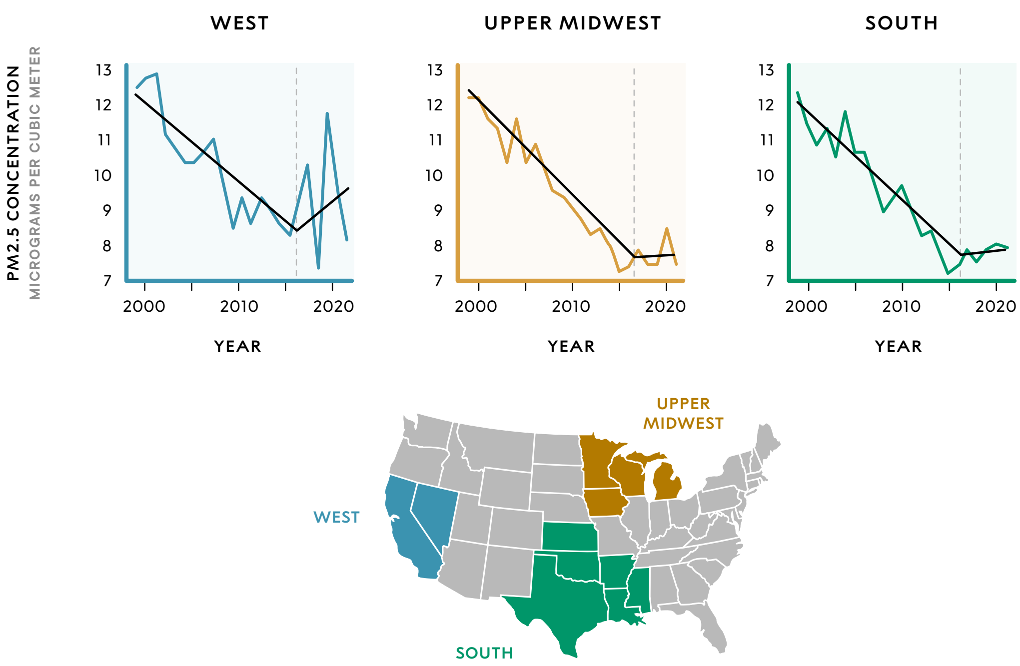
TABLE 8.1
Annual Fuel Load for Four Regions, 2010–2019 (measured in petagrams)

REGION	LIVE FOLIAGE	LIVE WOOD	DEAD FOLIAGE	DEAD WOOD
A (50°N–90°N)	3	76	27	21
B (23.5°N–50°N)	4	61	19	10
C (23.5°S–23.5°N)	9	347	25	34
D (50°S–23.5°S)	1	18	4	5

- **a** Based on this data and the results from your experiment, which region do you think is most at risk for wildfires? Explain your reasoning.
- **b** What other factors could influence the wildfire risk in each region?

4. Researchers examined the contribution of wildfire smoke to average annual PM2.5 concentrations in different regions of the United States by using a combination of ground-based and satellite-based air pollution data from 2000 to 2022. Examine their results, which are shown in Figure 8.3.

FIGURE 8.3
Regional Trends in the United States of PM2.5 Concentrations, 2000–2022



- **a** For each graph, describe the patterns you see in the data both before and after 2016, the year indicated by the dashed vertical line.
- **b** Based on this data, which part of the United States is most likely to have PM2.5 levels that are influenced by wildfire? Explain your reasoning.
- **c** Explain how the trend line on the graph helps you differentiate the signal from the noise.

CONNECTIONS TO EVERYDAY LIFE

5. Imagine you have been saving to go on a trip to an outdoor amusement park during a school break. A ticket costs $100. If you buy your ticket one month in advance, you will get a 20% discount. So far, the weather has been mild and warm with little rain and no snow. Table 8.2 shows average local weather data from the last 5 years for the month you plan to go.

TABLE 8.2
Five-Year Average of Local Weather Data during Annual School Break

YEAR	MINIMUM TEMPERATURE	MAXIMUM TEMPERATURE	TOTAL PRECIPITATION
2020	-1.1°C (30°F)	5.6°C (42°F)	0.1 cm (0.04 in)
2021	3.9°C (39°F)	10.0°C (50°F)	0.2 cm (0.08 in)
2022	0.6°C (33°F)	9.4°C (49°F)	1.0 cm (0.4 in)
2023	11.6°C (53°F)	19.4°C (67°F)	0.0 cm (0.0 in)
2024	5.0°C (41°F)	14.4°C (58°F)	3.0 cm (1.2 in)

- **a** Use probabilistic reasoning to explain whether or not you would buy a ticket in advance.
- **b** What information would reduce the uncertainty in your decision?

EXTENSION

Learn more about predicting and preventing wildfires by watching a video about fire scientists at the Missoula Fire Sciences Lab.

SCIENCE REVIEW

Combustion and Thermal Energy

Combustion is the burning of a substance (the fuel). Combustion converts the fuel into heat, light, sound, water vapor (gas), carbon dioxide, and tiny solids called particulate matter that form smoke. Ash is anything that is not burned completely and is leftover. Combustion requires oxygen to transform the chemical bonds of the fuel into other types of energy. *Thermal energy* is the energy of an object due to the motion of the particles (atoms or molecules) within the object. The amount of thermal energy an object has affects its temperature. The process of combustion is shown in Figure 8.4.

The *heat of combustion* can be measured by calculating the amount of energy released as heat from a fuel while it burns, using a calorimeter. One type of calorimeter is shown in Figure 8.5. It works by absorbing the energy from a combustion reaction contained within a water bath. The amount of energy that enters the water must be equal to the amount that was released by the reaction. This is due to the *law of conservation of energy* that says that energy cannot be created or destroyed, so the total amount of energy in a system is constant. This means that changes in temperature of the water can be used to measure the energy that came from a combustion reaction.

FIGURE 8.4
Combustion

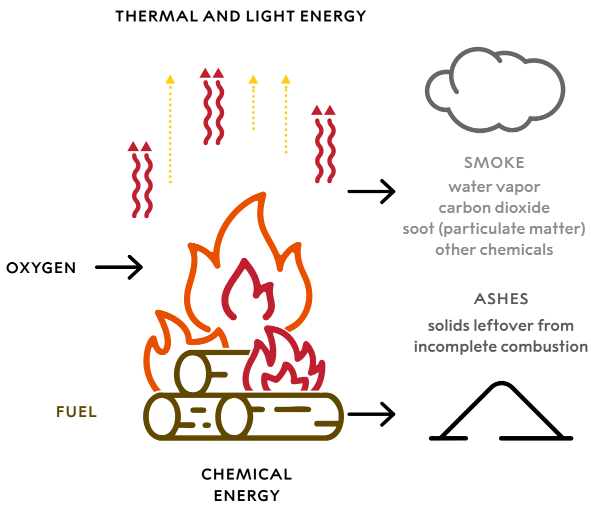


FIGURE 8.5
Calorimeter