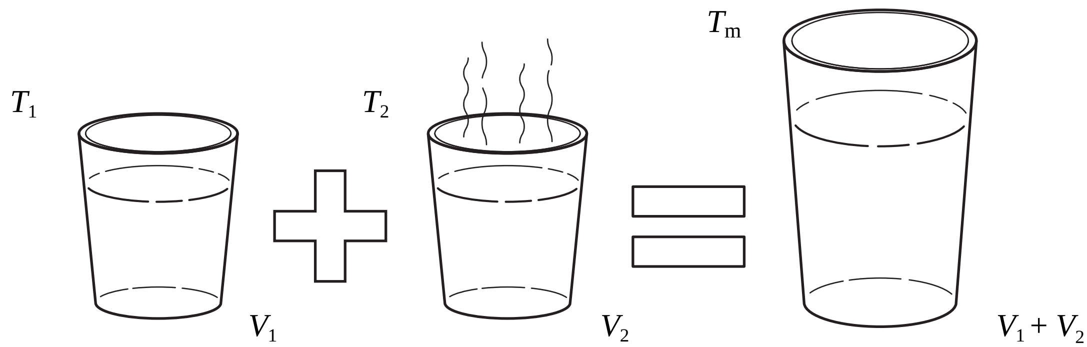
Activity
7

Mix it Up:
Combining Liquids of Different Temperature

Suppose that a hot drink and a cold drink are mixed together and you would like to predict the temperature of the mixture. To do this, you need to know the temperatures of the drinks before they are mixed, T_1 and T_2, and the volumes of each used in the mixture, V_1 and V_2. A visual representation of the problem is shown below, where T_m represents the temperature of the mixture:



Translated into mathematical symbols, we have

$$T_1V_1 + T_2V_2 = T_m(V_1 + V_2)$$

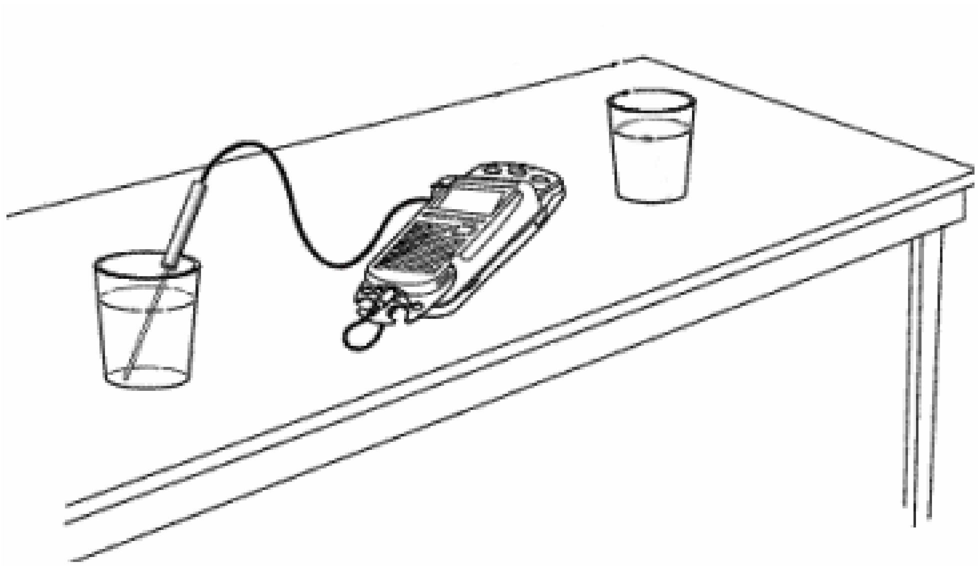
In this activity you will use the concepts described above to predict the resulting temperature when two solutions of different temperatures are mixed. The data needed to perform these calculations will be collected using a pair of Temperature Probes.

OBJECTIVES

- Record temperatures of water samples before and after mixing.
- Compare the mixing temperatures to a linear prediction.

MATERIALS

TI-84 Plus or TI-84 Plus graphing calculator
EasyData application
EasyTemp **or**
Temperature Probe and data-collection interface
graduated measuring cup (in mL)
styrofoam cups or coffee mugs
hot and cold water



PROCEDURE

1. Turn on the calculator. Connect the Temperature Probe to the calculator. (This may require the use of a data-collection interface.)

2. Set up EasyData to record temperature data in single points. This data-collection mode will return an average temperature reading for 10 seconds when commanded.

   a. Start the EasyData application, if it is not already running.
   b. Select **File** from the Main screen, and then select **New** to reset the application.
   c. Select **Setup** from the Main screen, and then select **Single Point**.

3. To test the expression $T_1V_1 + T_2V_2 = T_m(V_1 + V_2)$, you will record the temperature of water in two cups and then find the temperature when the contents of the cups are mixed together. Label one cup or mug as "Cup 1" and the other as "Cup 2."

4. Fill Cup 1 with 100 mL of cold water (about 10 ºC) and Cup 2 with 150 mL of hot water (about 50 ºC). Do not put any ice in the cold water cup.

5. Put the Temperature Probe in Cup 1. Observe the temperature reading on the Main screen. When the readings are stable (0.1-level fluctuations are acceptable) select **Start** from the Main screen. After ten seconds the averaged temperature reading will be displayed. Record the averaged temperature reading in the Data Table on the *Data Collection and Analysis* sheet.

6. Select **OK** to return to the Main screen.

7. Put the Temperature Probe in Cup 2. Observe the temperature readings on the Main screen. When the readings are stable (0.1-level fluctuations are acceptable) select **Start** from the Main screen. After ten seconds the averaged temperature reading will be displayed. Record the averaged temperature reading in the Data Table on the *Data Collection and Analysis* sheet.

8. Select OK to return to the Main screen.

9. Mix the water. Work quickly through the next steps.

   a. Quickly pour the contents of Cup 1 into Cup 2, keeping the Temperature Probe in Cup 2.
   b. Watch the temperature reading on the Main screen. When it stops changing rapidly, select Start to make a ten-second measurement. Record the averaged value in the Data Table on the *Data Collection and Analysis* sheet.
   c. Remove the probe from the water, and discard the water.

10. Select OK to return to the Main screen. Exit EasyData by selecting Quit from the Main screen and then selecting OK.

ANALYSIS

⇒ Answer Questions 1–7 on the *Data Collection and Analysis* sheet.

EXTENSION

Repeat the activity, this time starting with equal amounts of water in Cup 1 and Cup 2. Summarize the volumes used and temperatures measured in a data table. Based on your explanation in Question 7, how might you predict the mixture temperature, given that Cup 1 and Cup 2 contained equal volumes and knowing the temperatures T_1 and T_2? Is your prediction consistent with the measured mixture value?

DATA COLLECTION AND ANALYSIS

Name ______________________________

Date ______________________________

DATA TABLE

Volumes Used (in mL)		Temperatures Measured (in °C)	
Cup 1 (V_1)		**Cup 1 (T_1)**	
Cup 2 (V_2)		**Cup 2 (T_2)**	
		Mixture (T_m)	

QUESTIONS

1. Consider the equation $T_1V_1 + T_2V_2 = T_m(V_1 + V_2)$ related volumes and temperatures for mixed solutions. Solve this equation for the mixture temperature T_m.

2. Use this result, along with the values for the initial temperatures and volumes for the water samples, to predict the temperature of the mixture.

3. How does this value compare to the measured value of T_m listed in the Data Table? What might have caused the difference between the calculated and measured mixture temperature values?

4. What is the average of the cold and warm water temperatures, T_1, and T_2, used in this activity? Calculate this value and record it below:

5. Suppose that you wish to repeat this activity under identical conditions, this time adding exactly the right amount of warm water to Cup 1 so that the mixture temperature, T_m, equals the average temperature value recorded above. Should more or less warm water be added to Cup 1 for this trial compared to the amount you used in the original trial? Why?

6. Exactly what volume of warm water, V_2, should be added to Cup 1 so that the mixture temperature equals the average of T_1 and T_2?
   Hint: To do this, you will need to solve the mixture equation for V_2.

7. How does the value of V_2 found in Question 6 compare to the Cup 1 water volume, V_1?

   Why does using equal volumes of water ensure that the mixture temperature will be the average of the cold and warm water temperatures? Justify your answer algebraically.
   Hint: Let $V_1 = V_2$.

APPLICATIONS

1. The directions on a box of instant cocoa tell you to prepare the drink by adding 150 mL of hot water to the package contents. What amounts of cold water (8 ºC) and boiling water (100 ºC) should be combined to add 150 mL of 68 ºC water to the cocoa mix?

2. Suppose the thermostat of your school's swimming pool malfunctions, causing the water temperature to climb to 34 ºC. The recommended temperature for competition is 25 ºC. If the pool holds 750,000 liters of water, how many liters must be drained from the pool and replaced with tap water (6 ºC) to make it ready for competition?

3. Some types of mixture problems involve combining solutions made up of different percentages of a substance in order to get a mixture with the desired percentage of that substance. The method is the same as that used in the activity you just completed. Solve the following mixture problem.

   Solution A is 5% acid. Solution B is 17% acid. A chemist wants to mix the two to get 500 mL of a solution that is 12% acid. How much of each should be used?