Heat and Temperature, Part II

In this part of the module, we want to find out what happens to the temperature when we combine two containers of water that start at different temperatures.

If we take two containers of water that are at different temperatures, what will happen when we mix the water in them?

Find a Styrofoam cup, a lid, a thermometer, and a graduated cylinder for your group.

Put about 30 ml of cool water in one container. Measure its temperature and record the data. Get 30 ml of warm water (be careful to get as close as possible to the same mass of water as the cool sample), measure its temperature and record the data.

Pour the warm water into the cool water, put on the lid and record the resulting temperature. (It is important to pour rapidly, but carefully!)

- Use a sentence or two and/or a diagram to describe how the cool water changed in temperature and how the warm water changed temperature.

- Describe how your results differed from your predictions.

- If we combine 100 g of warm water (at 60 deg C) and 25 g of cool water (at 20 deg C), what will be the final temperature? Make a prediction (be as specific about the final temperature as possible, explain your ideas and conduct an experiment to test your thoughts.)
➢ Is there a trend in the results from your first and second experiment? If so, explain.

Try at least one more experiment with different masses and temperatures to test your ideas.

➢ Briefly describe your experiment and the results below.

Consult with your instructor before you go on to the next part of the module.
Heat & Temperature-Part III

- Provide a summary of how the starting mass of the water influence the final temperature of the mixed waters in the previous sections:

Next, we’ll look at how scientists describe the events we’ve been looking at:

First, you’ll need a definition of some of the terms we’ll be using:

Scientists describe heat and temperature as two different things.

As we discussed in part 1, scientists measure “temperature” using “degrees Celcius” or “ºC”.

“Heat” is different than temperature (we’ll discuss how in class). “Heat” is measured in units called “calories,” which are abbreviated as “Cal.” A calorie is defined to make the unit easy to work with mathematically as:

A “calorie” = the amount of heat necessary to raise 1 gram of water 1ºC

(Cool Fact: The term “calorie” is familiar to most people because we use it to talk about food. In science-speak the “calories” listed on a food label are really 1,000 calories; scientists call these units “kilocalories,” which are abbreviated “Kcal”. It makes that candy bar seem even more sinful.)

Another way to write the relationship between is:

Heat transfer(H) = mass(m) times change(Δ) in temperature(T)

Or

\[ H = m \times \Delta T \]

- What are the units of this equation? Re-write the equation above showing the units.
Another fundamental (and very useful) concept:

**Heat lost must equal heat gained**

The heat lost by the warm water must equal the heat gained by the cool water. (In reality, even though we try to use good experimental technique, we lose some heat from the warm water to the room, the cup, etc. so our values for the final temperature of the water are usually off *slightly*. Still, the total heat lost by warm water will equal the total heat gained by the cool water, the cup, the room, etc.)

Still another big idea:

*By convention we say that the thermal energy is transferred from the warm object to the cold object, so heat transfer is always from hot to cold.*

Let’s try this out using the equations given above:

- What was the number of calories lost in your first experiment when the masses of the warm and cold water were equal; how many calories did the cool water gain? Show your work below.

- How many calories did the hot water loose?
Answer the following questions individually, then discuss as a group.

This type of calculation works because the masses of water are the same. Our next step is to see if we can predict the final temperature of two different masses of water that started at different temperatures and were then combined.

Water 1: mass = 25 g initial temperature = 20 deg C
Water 2: mass = 100 g initial temperature = 60 deg C

➢ If we combine the two masses of water, what will be the final temperature? Make a prediction of what you think the final temperature will be and explain your logic:

One way to approach this question is to start with the hot water and imagine that we cool it in phases.

➢ If we cool 100 g of water by 1 deg C, how much heat will be removed?

In our experiment, there is only one destination for the heat lost by the hot water; it can only increase the temperature of the cold water.

➢ If we take the number of calories lost by the hot water (as determined in the previous question) and add them to the cool water, how much of a temperature change will there be in the cool water? Explain your logic.

➢ After removing this heat from the hot water (Water 2), what is the temperature of Water 2?

➢ After accepting the heat energy from Water 2, what will be the temperature of Water 1?
Continue this process in the table below, but first, how do you determine when you should stop?

<table>
<thead>
<tr>
<th>Temp of Water 2 (deg C)</th>
<th>heat transferred (cal)</th>
<th>Temperature of Water 2 after transfer (deg C)</th>
<th>Temperature of Water 1 after transfer (deg C)</th>
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</thead>
<tbody>
<tr>
<td>60</td>
<td>100</td>
<td>59</td>
<td>24</td>
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<td>59</td>
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(You can proceed in one degree increments, but you could also take larger jumps so that you do not spend your entire day doing this! Try 5 or 10 degrees!)
Answer the following questions individually, then discuss as a group

Try this again. What is the final temperature of the cool and hot water given the situation below?

<table>
<thead>
<tr>
<th>cool water</th>
<th>hot water</th>
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<tbody>
<tr>
<td>200 g at 25 deg C</td>
<td>50 g at 90 deg C</td>
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</table>

<table>
<thead>
<tr>
<th>Temp of hot water (deg C)</th>
<th>heat transferred (cal)</th>
<th>Temperature of hot water after transfer (deg C)</th>
<th>Temperature of cool water after transfer (deg C)</th>
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</thead>
<tbody>
<tr>
<td>90</td>
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New question: If we combine have 100 g of 25 deg C water and 300 g of water at an unknown temperature and we find that the final temperature is 55 deg C, what was the initial temperature of the 300 g of water?
What is your current definition of **temperature**?

What is your current definition of **heat**?

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**End of Module Questions:**

1) Another common temperature scale for scientific use is the Kelvin scale (named after Lord Kelvin). Water freezes at about 273° K ("two hundred and seventy-three degrees Kelvin"). Water boils at about 373° K.

   a) The coldest thing that most of us have experienced is so called "dry ice," which remains at a temperature of about 195° K (as it "sublimes").

      i) What is a temperature of 195° K in degrees Celsius? (Show your work or explain your reasoning)

      ii) What is a temperature of 195° K in degrees Fahrenheit? (Show your work or explain your reasoning)
Surprisingly, it gets colder than dry ice in places like Antarctica and Siberia. In Vostok, Siberia, the temperature recently dropped to 182° K (the all time lowest recorded temperature on Earth).

iii) What is a temperature of 182° K in degrees Celsius? (Show your work or explain your reasoning)

iv) What is a temperature of 182° K in degrees Fahrenheit? (Show your work or explain your reasoning)

2) A temperature scale that hasn't quite caught on yet is the "degree Bob" (named after Lord Bob). When basaltic lava erupts from a volcano (such as Kilauea in Hawaii), it flows at a temperature of about 100° B ("one hundred degrees Bob"), which is the same as 1100° C. Water boils at a temperature of 0° B (which is the same as 100° C).

3) 
   a) What is the freezing temperature of water in degrees Bob? (Show your work or explain your reasoning)

   b) Lead melts at a temperature of about 200° C. What is the melting temperature of lead in degrees Bob? (Show your work or explain your reasoning)

   c) The hottest temperatures on record in the Sahara Desert are about 60° C. What is a temperature of 60° C in degrees Bob? (Show your work or explain your reasoning).
d) As long as we're on the subject, what is a temperature of 60°C in degrees Fahrenheit? (Show your work or explain your reasoning).

3) You are stranded on a desert island with tools and containers to boil water, a pen, a ruler, and an uncalibrated thermometer. You have begun to calibrate your thermometer by marking off the spots on the thermometer corresponding to body temperature and boiling water. Finish the job by marking the location of 0°C and 50°C. Show your work and explain your reasoning.

4) In a lab experiment, a 30 g sample of water at 60 °C is mixed with 10 g of water at 40 °C.
   a. What is your estimation of what the final temperature of the mixture will be? (Do not do any calculations yet). Explain your reasoning.
   
   b. Complete the following table by filling in the number of calories needed to change the temperature of the hot water by 1 °C, and the resulting temperature change of the cold water. Continue until you have determined the final temperature of the mixture.

<table>
<thead>
<tr>
<th>Total Calories Transferred</th>
<th>Temperature of 30 g of hot water</th>
<th>Temperature of 10 g of cold water</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>60 °C</td>
<td>40 °C</td>
</tr>
<tr>
<td></td>
<td>59 °C</td>
<td></td>
</tr>
</tbody>
</table>

c. What is the final temperature of the mixture?

d. How many total calories are transferred?

e. Compare the heat lost by the hot water to the heat gained by the cold water. Explain your reasoning.
5) Imagine a transfer of heat from the sample of water on the left to the sample of water on the right. The mass and initial temperature of the water samples are shown below.

\[
\text{Mass} = 4 \text{ g} \quad \text{Mass} = 6 \text{ g} \\
\text{Temperature} = 60 \, ^\circ\text{C} \quad \text{Temperature} = 30 \, ^\circ\text{C}.
\]

a. When 20 calories is transferred from the hot water to the cold water, how much heat is lost from each gram?

b. What is the temperature change of each gram?

c. What is the final temperature of the hot water?

d. How much heat is gained by each gram of cold water?

e. What is the temperature change of each gram of cold water?

f. What is the final temperature of the cold water?