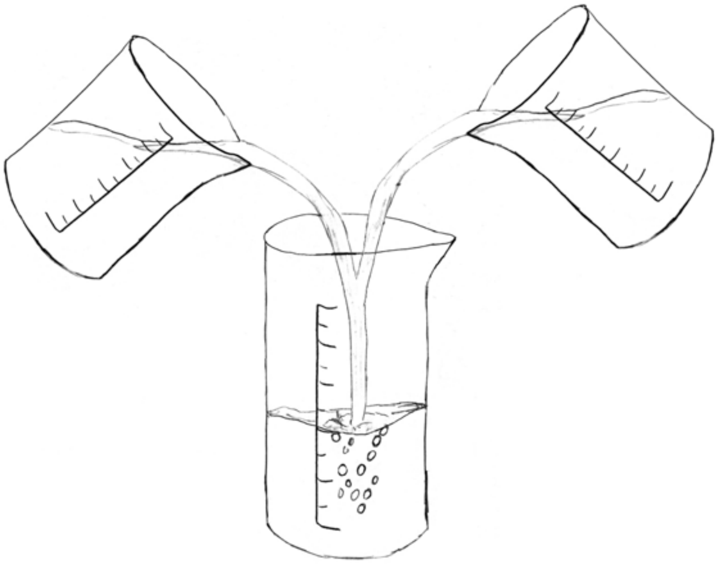
The Seven Percent Solution: Mixing

In this exercise, we will try to predict the final temperature of quantities of water at different temperatures when they are mixed and explore the concepts of thermal equilibrium and Specific Heat (C_v). Materials are simple: two cups or beakers, two thermometers, a bigger cup or container for mixing, hot and cold water. Optional: non-toxic antifreeze.

Commentary

If you mix a bucket of hot water with a bucket of cold water, the final temperature will lie somewhere in between, right? We do something similar when filling the tub for a nice, cozy bath, but using faucets. What information do you need to predict the final temperature? What if we mixed water with some other liquid? Would we get the same results?



One characteristic, or property, of all solids and liquids is something called the **Specific Heat**, abbreviated as C_v. This quantity represents the amount of heat required to raise or lower a given quantity (a gram or a Kilogram) by one degree. Water has an extremely high Specific Heat (1 calorie per gram per degree C). That’s what makes it such a wonderful (and plentiful!) substance for heating and cooling. Blacksmiths have always used it to quench hot steel, your car uses it to cool the engine, and most houses use hot water to transfer heat from the furnace to the rooms.

A rule of thermodynamics (the study of heat and heat transfer) is that when two objects are placed in contact, they will eventually reach **thermal equilibrium**. Energy (heat is a measure of energy in a substance) flows from the warmer object or liquid to the cooler one until they both reach the same temperature (equilibrium). When we mix liquids, this rule must be obeyed.

Inquiry

Use a hotplate or microwave to produce a quantity of hot water everyone can use. Cool water can be obtained from the tap.

- Fill one cup or beaker to about the halfway point (at least a few hundred mL) with hot water. Put the same amount of cold water in another container. Record the temperatures of each:

  T_1 = _________ C

  T_2 = _________ C

- Predict what the final temperature will be when they are mixed:

  T_f = ________ C

- Pour the two into a third container and measure the final temperature:

  T_{actual} = ______ C

- Is there a difference between your prediction and what you observed? What might have caused this?

- After dumping your water into a container or sink for disposal (not back into the hot or cold water), obtain some more hot and cold water. This time put **twice** as much of the hot or cold into one cup as you do for the other. Record the initial temperatures as you did before.

  T_1 = ________ C and T_2 = _________C

- Again predict and measure the final temperature and account for any discrepancy.

- Which of the samples underwent a larger temperature change during the second mixing? Why?

- Now obtain **three** samples, one hot, one cold, and one somewhere in between. The volumes (masses) can be different, but you may wish to make them the same to make the math simpler. Record the three initial temperatures, predict a final temperature, and measure it. How does the measured value compare to the predicted one?

Liquids having different Specific Heats

- As before, obtain a sample of hot water (a few hundred mL) and record its initial temperature.

  T_1 = ________ C

- This time, obtain an equal quantity of non-toxic antifreeze (this is water soluble) in your other cup and measure its temperature.

  T_2 = ________ C

- Again, predict the final temperature one should measure for a mixture which has reached thermal equilibrium.

  T_f = _______ C

- Measure the final temperature and compare this to your predicted value. You were way off this time, weren't you?

- The antifreeze has a much lower Specific heat than water does. That's why adding antifreeze to heating systems to avoid freezing lowers their efficiency greatly! See if you can determine the Specific heat of antifreeze by using the equation for thermal equilibrium (total heat energy before mixing equals total heat energy after, if none is lost to surroundings or heat lost by water equals heat gained by antifreeze) and solving for the unknown C_v:

$$M_w \text{ x } 1 \text{ cal/gm-°C x } (T_1 - T_f) = M_{AF} \text{ x } \underline{\textbf{unknown } \mathbf{C_v}} \text{ x } (T_2 - T_f)$$

- Record your answer to the above and show all of your work. Did you get a value that is significantly smaller than that for water?