25 Thermodynamics
Antifreeze in the Summer?

Purpose

To investigate what effect ethylene glycol (antifreeze) has on the cooling of a car radiator during the summer.

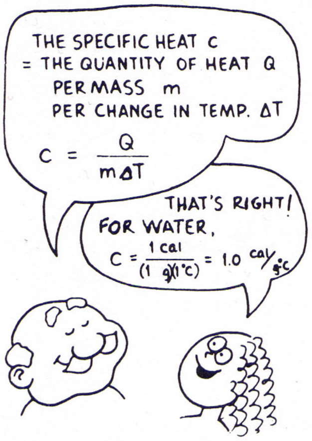
Required Equipment and Supplies

400 mL (400 g) water
390 mL (400 g) 25% mixture of ethylene glycol and water
380 mL (400 g) 50% mixture of ethylene glycol and water
370 mL (400 g) 75% mixture of ethylene glycol and water
500-mL graduated cylinder
four 600-mL beakers
single-element electric immersion heater
thermometer (Celsius with a range of 125°) and timer *or*
    Apple II Series computer
    LabTools software
    interface box
    temperature probe

Part A: Determining Specific Heats

Discussion

Put an iron frying pan on a hot stove and very quickly it will be too hot to touch. But put a pan of water on the same hot stove, and the time for a comparable rise in temperature is considerably longer. Water has a very high capacity for storing internal energy. We say that water has a high *specific heat*. The specific heat of a substance is the quantity of heat required to change the temperature of one gram of the substance one degree Celsius. More precisely, the specific heat, c, is the quantity of heat, Q, absorbed per unit of mass, m, and per change in temperature, ΔT.



$$\text{specific heat} = \frac{\text{quantity of heat absorbed}}{(\text{mass}) \cdot (\text{change in temperature})} = \frac{Q}{m\Delta T}$$

The quantity of heat absorbed by a substance when it changes its temperature by an amount ΔT is then

$$Q = mc\Delta T$$

Each substance has its own specific heat, which is a characteristic of that substance. The specific heat of pure water is 1.00 cal/g·°C. So if 1 calorie (cal) of energy is absorbed by 1 g of water, its temperature will rise by 1°C; similarly, if 1 cal of energy is extracted from 1 g of water, its temperature will decrease by 1°C.

Water has a high specific heat compared to other materials, which makes it an excellent coolant. Hence its use in automobile radiators. But water has a striking disadvantage in winter. It freezes at 0°C, and in doing so, expands. This expansion can crack the automobile engine block. To prevent this from occurring, antifreeze (ethylene glycol) is mixed with the water. The mixture has a much lower freezing point than water. The mixture has its lowest freezing point when the proportions are about 50% water and 50% antifreeze. But what effect does adding the antifreeze have on water's specific heat? In Part A of this experiment you will determine the specific heat of a 50% mixture of antifreeze and water.

To find the specific heat, you will simply measure the quantity of heat that is absorbed and the corresponding temperature change. To supply heat you will use an electric immersion heater.

An immersion heater is a small coil of Nichrome wire commonly used to heat small amounts of liquids. It heats up much like the wire in a toaster. This is a very efficient device, for unlike a hot plate or flame, all the energy dissipated by the heater is transferred to the water. The heater may be rated at 300 watts, but you can't be sure that this value is accurate. Thus, you need to calibrate the heater by applying heat to some water and measuring the corresponding rise in temperature.

If you use a computer with a temperature probe instead of a thermometer, hook up the temperature probe to an interface box. Select the "Thermometer" program from *LabTools* and follow the instructions on the disk to calibrate the temperature probe.

In Part B you will consider the merits of antifreeze in the summer.

Procedure

CAUTION: Plug and unplug the immersion heater only when the heater element is submerged in liquid. Operating it in air destroys it immediately because air cannot remove the thermal energy as rapidly as it is generated by the electric current.

Step 1. Heat 400 mL (400 g) of water with the heater for 200 seconds (a little over 3 minutes). Record the initial and final temperatures, and compute the change in temperature.

initial temperature = ________°C

final temperature = ________ °C

change in temperature (ΔT) = ______°C

Step 2. Find the quantity of heat transferred to the water by using the equation

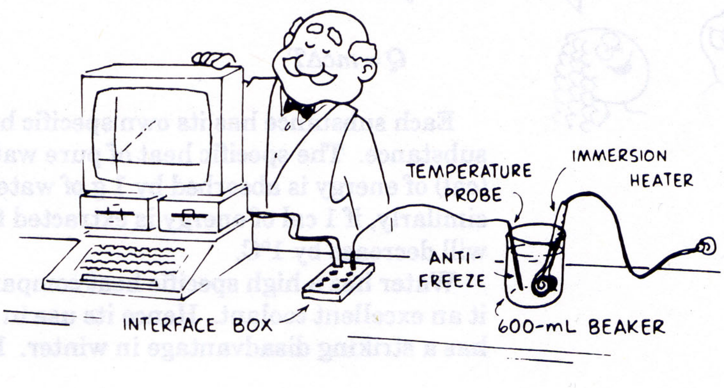
$$Q = mc\Delta T$$

where m = mass of water

c = specific heat of water = 1 cal/g·°C

ΔT = change in temperature

Q = ________ calories



Data Table 25.1

PERCENT ANTIFREEZE	T_i	T_f	ΔT	c	T_{boil}

Step 3. Pour 380 mL of a mixture of 50% antifreeze and 50% water into a beaker. Since antifreeze is slightly denser than water, 380 mL of 50% antifreeze mixture has a mass of 400 g. Heat the 400 g of antifreeze mixture for 200 seconds. Record the initial and final temperatures and the change in temperature in Data Table 25.1.

Step 4. Pour 390 mL of a mixture of 25% antifreeze and 75% water into a beaker. Heat the 400 g of antifreeze mixture for 200 seconds. Record your results in Data Table 25.1.

Step 5. Pour 370 mL of a mixture of 75% antifreeze and 25% water into a beaker. Heat the 400 g of antifreeze mixture for 200 seconds. Record your results in Data Table 25.1.

Step 6. With this data, compute the specific heat of the antifreeze mixtures from the equation

$$c = \frac{Q}{m\Delta T}$$

Record your calculations for the specific heat of each concentration in Data Table 25.1.

Analysis

1. Which liquid has the lower specific heat—pure water or a 50% mixture of antifreeze?

2. Which would warm from 25°C to 40°C faster—pure water or a 50% mixture of antifreeze?

Discussion

By now you have found that the specific heat of antifreeze, whether pure or mixed with water, is lower than that of pure water. This suggests it is a poorer coolant than pure water. Yet it is advisable to continue using antifreeze in summer months. Is there an advantage, other than convenience, in leaving antifreeze in the radiator during summer, or should it be replaced with pure water?

To answer this question, you need to understand the role of the coolant in an automobile. Coolant draws heat from the engine block and then circulates it to the radiator, where it is dissipated to the atmosphere. The coolant is then recycled back to the engine.

The temperature of the coolant increases as it absorbs heat from the engine. But if it reaches its boiling point, the system boils over. So a coolant is effective only at temperatures below boiling. If the coolant is pure water at atmospheric pressure, this temperature is 100°C. (With a pressure cap on the radiator, both the pressure and the boiling point are higher.) Could an antifreeze mixture have a higher boiling point than pure water? If so, this would lessen the likelihood of boilovers when the engine is overworked. You will now experiment to find out.

Step 7. Heat a sample of each concentration of antifreeze mixture with the immersion heater, and measure its boiling point. Record this temperature in Data Table 25.1.

Analysis

3. What effect does the boiling point of the antifreeze mixture have on the mixture's ability to act as a coolant?

4. Would it be appropriate to call ethylene glycol "antiboil" instead of "antifreeze" in climates where the temperature never goes below freezing?

5. How does adding antifreeze to water in the radiator affect its ability to act as a coolant for an engine that is overworked? Which is able to absorb more heat from the engine block before boiling over—pure water or an equal volume of 50% antifreeze mixture? To answer these questions, you need to compare the combined effects of increased boiling point, specific heat, and *density* of the coolant (since the *volume* of the radiator is fixed, the *mass* of coolant depends on the *density*). You need to compute the maximum quantity of heat that each milliliter of coolant can absorb from the engine block without boiling. Assume that the coolant returns from the radiator at 82°C. Since you are computing the heat absorbed per unit volume (cal/mL), you

Data Table 25.2

	50-50 MIXTURE	PURE WATER
d		
c		
ΔT		
$dc\Delta T$		

will need to know that the density of 50% antifreeze mixture is 1.07 g/cm³ (or 1.07 g/mL). The heat absorbed by the coolant is

$$Q = mc\Delta T$$

so the heat absorbed per unit volume is

$$\frac{Q}{V} = \frac{mc\Delta T}{V} = dc\Delta T$$

where d is the density of the coolant. The temperature change in the coolant is from 82°C to the boiling point for each mixture.

Calculate the heat absorbed per unit volume for pure water and the 50-50 mixture of antifreeze by filling in Data Table 25.2.

Using this analysis, which concentration is the better coolant?