Planning Lab: Measuring Specific Heat Capacity

Introduction

As a solid is heated, its atoms vibrate more vigorously. In a liquid, the particles not only vibrate but also rotate when heat is absorbed. In gases, as a result of absorbing heat, the molecules move about more rapidly. In this manner, each substance at each state absorbs a certain amount of heat for a specific increase in temperature for a specific mass of the substance.

The heat absorption capability of a substance is expressed in joules per gram per degree Celsius. It is called the specific heat capacity, c, of that substance under those temperature and pressure conditions.

Metallic substances generally have numerically small specific heats. Metals are good conductors of heat energy and require very little input of heat energy to cause an increase in their temperature. Insulating substances, on the other hand, are very poor conductors of heat energy and have much larger specific heats. The specific heat capacity of water is relatively large, which is why lakes take so long to heat up to a "swimmable" temperature in the spring. However, lakes and swimming pools cool relatively slowly during the summer nights or in the fall, extending the water-sports season considerable. The large specific heat capacity of water makes it the economical choice in hot-water heating systems used in most large buildings, such as hospitals, office towers, and schools.

When any sample of substance undergoes a temperature change, the amount of heat energy, Q, involved in causing the temperature change is given by ...

$$Q = m \bullet c \bullet \Delta T$$

where m is the mass of the sample of substance, c is the specific heat of the substance, and ΔT is the temperature change undergone by the sample.

A working knowledge of the specific heat capacities of substances is useful in a wide range of technologies. In cars and trucks, a liquid antifreeze coolant is circulated around the engine and pumped through the radiator to be cooled by air. The specific heat capacities of the antifreeze, the engine and the radiator metals are critical for sufficient cooling. In nuclear reactors, the heat from the nuclear core is absorbed by water, heavy water, D_2O, or even liquid sodium metal. The specific heat capacities of the coolant and their circulation around the core are critical in maintaining core temperatures at safe levels. The design of every thermal device, from a refrigerator to a toaster, must take into account the specific heat capacities of its component material.

In this experiment, you will use the equipment and materials listed to develop a procedure and then conduct the experiment to measure the specific heat capacity of a substance assigned to you.

Safety

Wear safety glasses.
The water you use is hot, use tongs to handle hot the glassware containing hot water.

Equipment and Materials

Nested styrofoam cups, thermometer, 100 cm^3 graduated cylinder, beakers, balance, sample of substance, 100 cm^3 hot water.

Prelab Assignment

1. From the Introduction, formulate a problem statement.
2. From the Introduction, and Equipment and Materials lists, write a procedure.
3. From your Procedure: (a) state the manipulated and responding variables; and (b) list some controlled variables
4. Relate the hypothesis to the research question.
5. Construct suitable data table(s), that allows for the collection of all relevant data.
6. Check your procedure with me before performing the experiment.

Data Processing and Presentation

Calculate the specific heat capacity of the substance assigned.
Based upon the accepted value of the specific heat capacity of the substance supplied by me, calculate the percent error of your experimental result. Can you determine why your specific heat capacity value differ from the theoretical value.

Conclusion and Evaluation

Give a valid conclusion, based on the correct interpretation of the results, with an explanation.
Evaluate your procedure and results including limitations, and weaknesses or errors.
State realistic suggestions to improve the investigation.

Extension

1. From your Data Book, look up the specific heat of ice. Why is the value for ice not the same as for liquid water.

2. Suppose 61.0 g of hot metal, which is initially at 120.0 ^{O}C, is plunged into 100.0 g of water that is initially at 20.00 ^{O}C. The metal heats up and the water heats up until they reach a common temperature of 26.39 ^{O}C. Calculate the specific heat capacity of metal, using 4.18 J K^{-1} g^{-1} as the specific heat capacity of the water.

3. A mass of 41.0 g of glass at 95 ^{O}C is placed in 175 g of water at 21^{O}C in an insulated container and both are allowed to come to the same temperature. What is the final temperature of the glass-water mixture? The specific heat capacity of glass is 0.5 J g^{-1} $^{O}C^{-1}$

4. Very early in the study of the nature of heat it was observed that if two bodies of equal mass but different temperatures are placed in thermal contact, their specific heat capacities depend inversely on the change in temperature each undergoes on reaching its final temperature. Write a mathematical equation in modern notation to express this fact.

5. In their *Memoir on Heat*, published in 1783, Lavoisier and Leplace reported, "The heat necessary to melt ice is equal to three quarters of the heat that can raise the same mass of water from the temperature of the melting ice to that of boiling water" (English translation). Use this 18th-century observation to compute the amount of heat (in joules) needed to melt 1.00 g of ice. Assume that heating 1.00 g of water requires 4.18 J of heat for each 1.00 ^{O}C throughout the range from 0 ^{O}C to 100 ^{O}C.