Identifying Substances Using Specific Heat

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Class: Chem 101 Fall 205

Aim:

The Aim of this Lab Exercise is to show that the composition of a metal cylinder can be established using a laboratory derived specific heat.

Introduction:

Specific Heat is a property that varies from substance to substance. Specific Heat is a measure of the number of calories needed to raise 1 gram of that substance 1 degree Celsius. Cylinders of unknown composition were placed in a boiling water bath for a sufficient period of time for them to assume the temperature of the bath. Through laboratory activities the cylinder’s specific heat was determined by removing the cylinder from the boiling bath and placing the cylinder in a calorimeter containing a sample of room temperature water, then observing the temperature change of the water. Calorimeters are used to observed thermodynamic exchanges; they insulate and isolate the system from the environment to prevent heat from escaping or entering the system. The system for this exercise was the room temperature water and the metal cylinder. Submerging the cylinder was necessary due to the fact that the temperature of the metal could not be measured directly. It was assumed that all the heat energy the metal lost was absorbed by the water. Therefore the calories calculated by using the data for the water could be used in the calculations for the metal. The temperature change of the water, the initial temperature of the boiling water-bath and the Heat Equation (Heat = (mass) (spec heat) (∆T)) were used in these calculations. The calculated value of Specific Heat was then compared to a chart of known Specific Heats. Using that information and other observable traits of the metal cylinder a guesstimate was formed for the composition of the cylinder.
Method / Procedure:

The following items were used:
- The exchange between the metal cylinder and the water occurred inside the calorimeter to minimize the heat loss to the environment.
- A thermometer was inserted into the Calorimeter to observe the water’s temperature
- A boiling water bath to raise the temperature of the metal cylinder to 100ºC by submersion.
- The subject of our investigation, a metal cylinder of unknown composition was used.
- A laboratory balance that measures to 1/1000 of a gram was used to measure the mass of the cylinder and the mass of the water

Procedure:

Step 1: In order to determine the specific heat of the metal cylinder an observable temperature change was needed, so the cylinder was started in a boiling water bath, a thermometer measured the temp of the bath to a tenth of a degree Celsius.

Step 2: Room temperature purified water was added to the calorimeter and the Mass of the Water was found by taking the difference between the mass of the calorimeter with the water and the mass of the empty calorimeter.

Step 3: The temperature of the calorimeter and water was allowed to come to equilibrium the temperature was read and recorded; this was the Initial Temp of the Water.

Step 4: The temperature of the boiling water bath was recorded before removing the cylinder; this was the Initial Temp of the Cylinder.

Step 5: The hot metal cylinder was placed quickly into the calorimeter and the temperature of the water was monitored with the digital thermometer every 10 seconds for 3 minutes gently swirling the contents every 20 seconds to avoid areas of differently heated water.

Step 6: The highest temperature that the water reached was recorded; this temperature was used as the Final temp of the Water. (to avoid using spikes in temp readings, we graphed the results to obtain our reading from there)

Step 7: The Metal Cylinder was removed from the Calorimeter, dried, and its mass was measured.
**Results:**

Since the metal was fully submerged in the water when it lost its heat it can be assumed that the heat flowed from the cylinder to only the water. So it can also be stated:

Assumption – “The heat lost by the metal is equal to the heat gained by the water.”

The heat gained by the water was calculated first, this was needed to determine the heat lost by the metal.

With the data that was collected the Heat the Water Gained was found using the equation

\[ H = (m)(\text{Spec. Ht.})(\Delta T). \]

Where:

\[ H = \text{Heat Gained by the Water} \]
\[ m = \text{Mass of the Water} = 149.6 \text{grams} \]
\[ \text{Specific Heat of Water} = 1 \text{ cal/g x C}^{\circ} \]

The graph was used to determine the Final Temperature of the water. (see Fig 1)

\[ \Delta T = \text{Change in Temp of the Water} = \]
\[ (\text{Final Temp of the Water} – \text{Initial Temp of the Water}) = \]
\[ 25.2^{\circ}C – 23.2^{\circ}C = 2.0^{\circ}C \]

**Heat Water Gained** = (Mass of Water) (Specific Heat of Water) (Change in Temp of water)

**Heat Water Gained** = (149.6g) (1 cal/g x C\(^{\circ}\)) (2.0C\(^{\circ}\))

**Heat Water Gained** = 299.2cal

Since the metal cylinder was submerged in the water as they reached that final temp we assumed they were at the same temperature and thus used the Final temp of the Water as the Final Temp of the Cylinder.
With the value of the *Heat Lost by the Metal* the *Specific Heat of the Metal* can be found using the same equation. As was stated the *Heat the Water Gained* will be the same as the *Heat the Metal Lost.*

\[ H = (m)(Sp. Ht.)(\Delta T) \]

\[ H = \text{Heat Lost by the Metal} = 299.2\text{cal} \]

\[ m = \text{Mass of the Metal} = 42.57\text{grams} \]

\[ \text{Specific Heat of Metal} = X \frac{\text{cal}}{g \times ^{\circ}C} \]

\[ \Delta T = \text{Change in Temp of the Metal} = (\text{Final Temp of the Metal} - \text{Initial Temp of the Metal}) = 100.2^{\circ}C - 25.2^{\circ}C = 75.0^{\circ}C \]

\[ \text{Heat Metal Lost} = (\text{Mass of Metal})(\text{Specific Heat of Metal})(\text{Change in Temp of Metal}) \]

\[ 299.2\text{cal} = (42.57g) \left( X \frac{\text{cal}}{g \times ^{\circ}C} \right) (75.0^{\circ}C) \]

\[ \text{Specific Heat of Metal} = 0.094 \frac{\text{cal}}{g \times ^{\circ}C} \]

**Discussion:**

The value of Final Temp of the Water/Metal was determined from the graph. The spike at time = 30 seconds was ignored due to the likelihood that it was caused by the thermometer having too close a proximity to the hot cylinder. The temperature reading determined by the cooling line was used.

The measured value for Spec. Heat was then compared to the list of known Specific Heats(1). Laboratory Value = 0.094 \( \frac{\text{cal}}{g \times ^{\circ}C} \) Some possible substances (metals) with Known Values from List had specific heat values equal to 0.095 \( \frac{\text{cal}}{g \times ^{\circ}C} \), a difference of only 0.001 \( \frac{\text{cal}}{g \times ^{\circ}C} \) seemed within an acceptable range to consider.

From the list of known Specific Heats the 3 possibilities were: Brass, Bronze and Copper. Based on this information and by looking at the cylinder’s other properties such as color and factors like the expense and likelihood of Bronze it was determined that the cylinder’s composition was Copper.

The value determined in lab was very close to the value in the Table of Specific Heat.

% ERROR:
\[
\% \text{Error} = \left( \frac{\text{Lab Value} - \text{Known Value}}{\text{Known Value}} \right) \times 100
\]

\[
\left( 0.094 \text{ cal/g x C}^\circ \right) - \left( 0.095 \text{ cal/g x C}^\circ \right) \times 100 = \frac{0.1 \text{ cal/g x C}^\circ}{0.095 \text{ cal/g x C}^\circ} = 1.05\% \text{ Error}
\]

A % Error of 1.05% is acceptable given the equipment used. Some possible sources of error could have been the thermometer not being accurate or not read properly. Another source could have come from heat lost to the cup and air not factored into the equations.

To improve upon this exercise a better calorimeter could be used to better isolate the water and cylinder. Furthermore if the calorimeter’s material and thusly specific heat is known then the heat absorbed by the calorimeter could be calculated adding to the completeness of the data.

Overall this exercise should be considered successful.

Conclusion:

It was shown that finding the Specific Heat of an unknown substance can be used to help identify the object’s composition.

Bibliography

(1) - CRC Handbook of Chemistry and Physics, 81st Edition (c)1999 CRC publishing .....etc.

(2) - Chemistry An Introduction to General, Organic and Biological Chemistry, Timberlake 8th Edition ... etc
Figure 1 shows the temperature curve of the water in the calorimeter when the metal cylinder was placed in the water at time zero.