Heat Capacity of Water

Taylor Larrechea, Colorado Mesa University

April 3, 2018

Abstract

The purpose of this lab is to determine the specific heat of water. The experimentally found value for the specific heat of water was found to be $4,000 \pm 500\ \mathrm{J\,g^{-1}\,K^{-1}}$. The accepted specific heat of water is $4,184\ \mathrm{J\,g^{-1}\,K^{-1}}$ [1].

1 Background

The purpose of this experiment is to find the specific heat of water. The specific heat is defined to be the energy that is required to raise a certain substance of one gram by one degree Kelvin [1]. To determine the specific heat of water we will raise the temperature of water by heating it with a resistor. This change in temperature will then be observed and used to calculate the specific heat of water with knowing the energy that is being supplied to the water.

2 Theory

Objects can all absorb or lose energy via heat transfer from the environment around them. The heat absorbed by a system is [1]

$$Q = mc\triangle T, \tag{1}$$

where the m is mass of the object, the c is the specific heat of the object, and the $\triangle T$ is the change in temperature that the object undergoes. Equation (1) has the heat transfer for a one object system. Some systems that are observed have more than one object in them causing equation (1) to look a little different. In regards to this experiment there were other objects in the system that contributed to the heat of the system.

3 Procedure

The set up for this experiment contained a resistor submerged in a calorimeter along with a stirring stick. The stirring stick was used to assure the water was properly stirred to not construe the data. Because of this, this system is considered to be a multiple object system. For this multiple object system the equation that represents heat transfer is

$$Q = m_w c_w \triangle T + C\triangle T, \tag{2}$$

where C is the heat capacity of the stirrer and calorimeter, m_w and c_w are the mass and specific heats of water respectively. Thus

$$Q = (m_w c_w + C)\triangle T, \tag{3}$$

and with $C_{Tot} = m_w c_w + C$, equation (3) gives

$$Q = C_{Tot}\triangle T. \tag{4}$$

Since the heating of the water is performed with a resistor, a heat equation relating the components of the resistor (Voltage, current, and time) is necessary for calculations. Heat is then [1]

$$Q = \triangle VIt \tag{5}$$

where $\triangle V$ is voltage, I is current, and t is time for which the resistor heated up the calorimeter. Equation (5) and (4) gives

$$\triangle VIt = C_{Tot}\triangle T. \tag{6}$$

The strategy for solving for the specific heat of water will come from knowing the total specific heat C_{Tot}. Equation (6) then implies

$$T = \frac{\triangle VI}{C_{Tot}}t + T_0. \tag{7}$$

A graph of T vs. t should give a slope of

$$m = \frac{\triangle VI}{C_{Tot}}. \tag{8}$$

Thus

$$C_{Tot} = \frac{\triangle VI}{m}, \tag{9}$$

giving the equation for the total specific heat of the system. By knowing that $C_{Tot} = m_w c_w + C$, the specific heat of water can be determined by graphing C_{Tot} versus m_w since these two values are known or calculated. Graphing the following equation

$$C_{Tot} = m_w c_w + C, \tag{10}$$

with the aide of excel the slope of equation (10) is m_w and the y intercept of this line is C. Once the data is collected for this lab, the specific heat of water will be able to be calculated from observations of this graph.

An ammeter was used to read the current through the resistor, observing the power supply let us know the voltage across the resistor, and using a scale with a known mass of the calorimeter let us know the mass of the water. Once this data was recorded and the thermometer with the stirrer was put into the enclosed cup, the water was stirred for three minutes for 10 separate masses of water. Each experiment then had the temperature graphed against time with the aide of the Pasco interface and the temperature sensor. The Pasco interface was then able to find a value for the slope of the graph where then the values for C_{Tot} were used to calculate c_w.

4 Data

Table 1 provides the data collected from the 10 separate experiments.

Mass of Water ±0.001kg	Slope m V A g K J^{-1}	$\triangle V \pm 0.01$V	I ±0.001A	C_{Tot} J g^{-1} K^{-1}
0.141	0.00461	7.71	0.448	0.749
0.146	0.00380	7.37	0.452	0.877
0.167	0.00366	7.39	0.462	0.885
0.178	0.00365	7.53	0.458	0.945
0.232	0.00286	7.45	0.443	1.154
0.239	0.00269	7.49	0.450	1.253
0.246	0.00299	7.43	0.453	1.126
0.246	0.00244	7.39	0.448	1.357
0.248	0.00277	7.36	0.461	1.225
0.257	0.00279	7.36	0.444	1.171

Table 1: Collected Data

Knowing the voltage, current, and slope values, the C_{Tot} value could be calculated using equation (9). The C_{Tot} values entire purpose is to be used to find the specific heat of water using equation (10). In order to be able to determine c_w, C_{Tot} must be graphed against m_w. The slope from this plot is the value for the specific heat of water. Table 2 provides the data used to create a graph of C_{Tot} against m_w. Data from Table 1 was then used to graph C_{Tot} vs. m_w (See Figure 1) to determine c_w for this experiment.

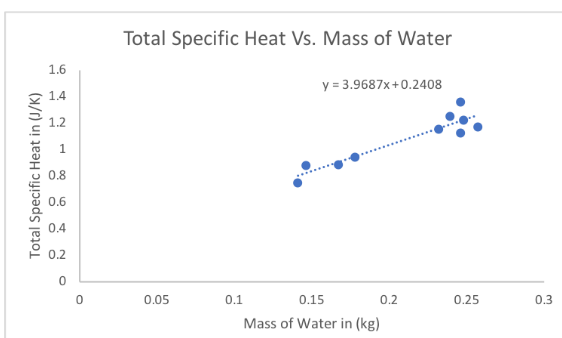

Figure 1: C_{Tot} vs. m_w

Figure 1 has an equation of $y = 3.9687x + 0.2408$ that gives the value for the specific heat of water. From Figure 1 using equation (10) it can be said that the specific heat of water is $c_w = 3.9687$ J kg^{-1} K^{-1}. Regression analysis is done on this equation giving

$$c_w = 4.0 \pm 0.5 \text{J kg}^{-1}\,\text{K}^{-1}. \tag{11}$$

This is the specific heat of water from this experiment for masses in units of kilograms. To be consistent with the stated acceptable value for the specific heat of water, we can write equation (11) as

$$c_w = 4,000 \pm 500 \text{J g}^{-1}\,\text{K}^{-1}. \tag{12}$$

Result (12) gives the final value for the experimental value of the specific heat of water.

5 Conclusion

The accepted specific heat of water [1] is known to be $4,184\ \mathrm{J\,g^{-1}\,K^{-1}}$. The value that was found during this experiment with the same units is $4,000 \pm 500\ \mathrm{J\,g^{-1}\,K^{-1}}$. From the value that was found experimentally, we can say that it is acceptable in reference to the known and accepted value for the specific heat of water. There were errors in this experiment that pertained to the stirring of the water. This error was from the stirrer gradually hitting the resistor that sat inside the calorimeter as well as not having the water start off at the exact same temperature as other runs. It was observed that the more the mass of water that was in the calorimeter the more accurate the run was, which in turn led to better data as a whole. This data was a consequence of less errors coming from less interference between the equipment in the calorimeter. To get more accurate results (Even though the measured value is within the tolerance for the specific heat of water) a better set up is first required where the resistor has no possibility of being touched by the stirrer. This improved set up would allow for more accurate experiments of data with smaller amounts of water in them. Regardless of these ideas for how to make the experiment more accurate, the experiment conducted allowed for an accurate enough measurement for the specific heat of water.

References

[1] Knight, Randall. Physics for Scientists and Engineers. Pearson, 2012.