Measuring The Specific Heat Capacity

Suni Yao

Contents

1 Aim

In this experiment, we aim to measure the specific heat capacity of an unknown metal and therefore determine what the metal is made of, also calculate the percentage uncertainty of the experimental value compared to the measured value.

2 Apparatus

- an unknown metal
- water bath container
- electrical balance
- calorimeter
- thermometer
- cotton string

3 Procedure

1. Weigh the calorimeter, record as m_0
2. Put some water in the calorimeter, record the initial temperature T_0, weigh its mass and record as m_1
3. Place the metal cylinder in boiling water for a few minutes
4. Quickly transfer the metal cylinder to the calorimeter
5. Observe the increase in the water temperature measured by the thermometer in the calorimeter, record the final temperature T_1

Figure 1: Measuring the mass of the unknown metal cylinder, $m = (62.8 \pm 0.1)$g.

4 Safety Precautions

- Tie the cotton wire around the metal cylinder very tightly so that the metal cylinder doesn't drop.
- Place the hot metal cylinder into the calorimeter gently. Make sure that the metal cylinder doesn't touch the thermometer.
- Keep the bulb of the thermometer some distance from the bottom of the calorimeter.

5 Data Collection

By measuring using the electrical balance, the mass of the unknown metal cylinder can be collected $m = (62.8 \pm 0.1)g$ Other measurements are listed below:

$$m_0 = 126.6 \pm 0.1\text{g} \qquad m_1 = 261.2 \pm 0.1\text{g}$$
$$T_0 = 27.5 \pm 0.5°C \qquad T_1 = 29.5 \pm 0.5°C$$

6 Data Processing

As assumed that there is no heat loss, we have the energy absorbed by water is the same as the energy released by the unknown metal cylinder,

$$
\begin{aligned}
Q_{\text{absorbed}} &= Q_{\text{released}} \\
c_{\text{water}} m_{\text{warer}} \Delta T_{\text{water}} &= c_{\text{metal}} m_{\text{metal}} \Delta T_{\text{metal}} \\
\implies c_{\text{metal}} &= \frac{c_{\text{water}} m_{\text{water}} \Delta T_{\text{water}}}{m_{\text{metal}} \Delta T_{\text{metal}}}
\end{aligned}
$$

Because the metal cylinder was originally put in boiled water, the change in temperature $\Delta T_{\text{metal}} = 100 - 29.5 = 70.5 \pm 1°C$. And for water, the change in temperature $\Delta T_{\text{water}} = 29.5 - 27.5 = 2 \pm 1°C$.

The mass of water can be calculated as the difference between m_0 and m_1, $m_{\text{water}} = m_1 - m_0 = 261.2 - 126.6 = 134.6 \pm 0.2\text{g}$.

Therefore,

$$
\begin{aligned}
c_{\text{metal}} &= \frac{134.6 \times 4.2 \times 2}{62.9 \times 71} \\
&= 0.253 \approx 0.3\text{J} \cdot \text{g}^{-1} \cdot^{\circ} C^{-1} = 0.3\text{J} \cdot \text{g}^{-1} \cdot \text{K}^{-1}.
\end{aligned}
$$

And to calculate the absolute uncertainty of c_{metal}, we first calculate the percentage uncertainty,

$$
\begin{aligned}
\frac{\Delta c_{\text{metal}}}{c_{\text{metal}}} &= \frac{\Delta m_{\text{water}}}{m_{\text{water}}} + \frac{\Delta m_{\text{metal}}}{m_{\text{metal}}} + \frac{\Delta(\Delta T_{\text{water}})}{\Delta T_{\text{water}}} + \frac{\Delta(\Delta T_{\text{metal}})}{\Delta T_{\text{metal}}} \\
&= \frac{0.1}{62.8} + \frac{0.2}{134.6} + \frac{1}{71} + \frac{1}{2} \\
&= 0.5172 \approx 0.52 = 52\%
\end{aligned}
$$

so the absolute uncertainty of specific heat capacity is

$$
\Delta c_{\text{metal}} = 0.52 \times 0.253 \approx 0.1\text{J} \cdot \text{g}^{-1} \cdot^{\circ} C^{-1} = 0.1\text{J} \cdot \text{g}^{-1} \cdot \text{K}^{-1}.
$$

Therefore, the specific heat capacity of the unknown metal is $0.3 \pm 0.1\text{J} \cdot \text{g}^{-1} \cdot \text{K}^{-1}$.

7 Conclusion and Evaluation

The metal is actually copper, with the standard specific heat capacity $c_{\text{copper}} = 0.39\text{J/g}$, which shows that the experimental value is lower than the theoretical value. This may be a result of the heat loss to the calorimeter, thermometer, and the surroundings during the transfer from boiling water to the calorimeter.

The uncertainty of the specific heat capacity of the copper cylinder is large, taking up 52% of the experimental value. This large uncertainty can be narrowed by using a thermometer with higher accuracy and smaller minimum scale.