

Estimation of Atomic Mass from Specific Heat

Introduction:

Before the development of mass spectrometry, it was difficult to determine the atomic mass of an element. In 1819, Dulong and Petit discovered that the product (about 26.4) of the atomic mass and the specific heat was nearly the same for many solid elements. This approximation has been found to be valid for metals and solid elements with atomic masses over 40.

Specific heat can be thought of as the amount of heat required to raise the temperature of one gram of a substance one degree Celsius. Specific heat constants have the units of J/g °C. The values of these constants vary greatly. The constant for water is 4.184 J/g °C, while the value for copper is 0.385 J/g °C. This means that over ten times as much heat would be required to raise the temperature of a water sample as compared to an equal mass of copper.

In this experiment you will carry out a standard procedure to determine the specific heat for a metal. Then using the Law of Dulong and Petit, the atomic mass of the metal will be determined. $\text{Atomic Mass} = 26.4 / \text{specific heat}$.

Equipment/Materials:

samples of metals	large test tube
400 mL beaker	hot plate
balance	foam coffee cups
thermometer	

Safety:

- An apron and goggles must be worn in the laboratory.
- Avoid contact with the hot plate.

Procedure:

1. Place about 200 mL of tap water in a 400 mL beaker and place it on the hot plate. Heat the water until it boils.
2. Select a metal cylinder to use for this experiment and mass it. Record the mass in the data table.
3. Carefully transfer the metal to a large test tube. Place the test tube in the hot water bath, and let it sit for 10 minutes.
4. While the metal is heating in the hot water bath, obtain a styrofoam cup. Tare it on the balance. Place about 100 mL of distilled water in the cup, and place it on the balance again to determine the mass of the water.

5. While the metal is heating in the boiling water, measure and record the temperature of the boiling water.
6. When the metal has been heated long enough in the hot water bath, measure and record the temperature of the water in the Styrofoam cup. (It is important that this temperature be taken immediately before adding the metal.) Carefully and quickly transfer the metal to the foam cup, trying not to splash the water. Stir the water, and record the maximum temperature reached by the water in the cup.
7. Repeat the procedure using fresh water in the foam cup each time.

Data:

	Trial 1	Trial 2	Trial 3
Metal Used			
Mass of Metal			
Mass of Water in Foam Cup			
Initial Temperature – Cup			
Final Temperature – Cup			
Temperature Change – Cup			
Temperature Hot Water Bath			
Initial Temperature of Metal			
Final Temperature of Metal			
Temperature Change of Metal			
Heat gained by Water			
Heat lost by Metal			
Specific Heat of Metal			
Atomic Mass			

Calculations:

1. The basic calculation for heat is: $\text{Heat} = \Delta T \times \text{mass} \times \text{specific heat}$. In this experiment, it is assumed that the heat gained by the water in the foam cup is equal to the heat lost by the metal. This relationship could be written as follows:

$$\text{Heat} = \Delta T_{\text{water}} \times \text{mass}_{\text{water}} \times 4.184 \text{ J/g}^\circ\text{C} = \Delta T_{\text{metal}} \times \text{mass}_{\text{metal}} \times \text{Specific heat}_{\text{metal}}.$$

It may be easier to solve for the specific heat value of the metal in a series of steps.

2. Calculate the heat gained by the water in the foam cup. Use the equation

$$\text{Heat} = \Delta T_{\text{water}} \times \text{mass}_{\text{water}} \times 4.184 \text{ J/g}^\circ\text{C}.$$

3. Assume that the heat lost by the metal is the same value as the heat gained by the water. Using the value from the calculation above, and the equation

$$\text{Heat} = \Delta T_{\text{metal}} \times \text{mass}_{\text{metal}} \times \text{Specific heat}_{\text{metal}},$$
 calculate the specific heat of the metal.

4. Calculate the estimated atomic mass for the metal using the specific heat from the step above.
5. Calculate the percent error for this determination.

Questions:

1. How would a calculation for the atomic mass be affected if the hot metal sample cooled off while being transferred to the calorimeter?
2. What are possible sources of error in this experiment?