Electrical Determination of the Heat Capacity of a Calorimeter in Approximately One Minute

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In most general chemistry laboratories, the heat capacity of a calorimeter is determined by measuring the temperature changes that occur when a known mass of water at a higher temperature is added to a known mass of water (or solution) in the calorimeter (1) at room temperature. Another approach is to add a known quantity of electrical energy and measure the temperature change (2). Using a temperature probe with a sensitivity of ±0.1 °C, a heating rate of ~10 W, and 50–100 g of water, 3–5 min of heating is required. With the advent of dataloggers and highly sensitive temperature sensors (±0.01 °C), the heat capacity of a calorimeter can be determined from the electrical energy input rate and the slope in the temperature–time plot. The setup consists of a datalogger, temperature sensor, electric calorimeter, and a dc power source (Figure 1). With data collection lasting 20–30 s, two stations suffice for a lab section of 24 students.

When heat is added to the calorimeter containing a well-stirred solution, the temperature–time plot is linear. The heat capacity of the calorimeter, $C_p$(calorimeter), can be calculated from the heat energy input rate and the slope of the temperature–time plot:

$$C_p(\text{calorimeter}) = \frac{\text{voltage} \times \text{current}}{\text{slope}}$$

Using a small stir bar, heat from stirring is negligible as evidenced by a slope of zero in the temperature–time plot. As an example, consider 60.64 g of H$_2$O in a Styrofoam cup heated at 11.3 W and temperature–time data collected over 20–30 s. The datalogger has a linear regression function that provides the slope, the y-intercept, and $R^2$:

slope = 0.0407 °C/s  y-intercept = 22.50 °C and $R^2$ = 0.9999

Using these values, the heat capacity of the calorimeter is calculated to be 278 J/°C.

We use the electrical determination of the heat capacity in the determination of the specific heat of a metal and the determination of enthalpy of fusion of ice.

Figure 1. Electrical determination of the heat capacity of a calorimeter.

Hazard

When the system is in operation, physical contact with it must be avoided. This operation has been used by over 3000 students without any incident.

Notes

1. Pasco Xplorer GLX (PS2002) Scientific datalogger, Pasco Scientific temperature sensor, Extech DC regulated power supply (model #382213), and Science Lab Supplies electric calorimeter.
2. The voltage (3.80 V) and current (2.98 A) are displayed on the dc power source.

Literature Cited