EXAMPLE 14–6 **Measuring the energy content of a cookie.** Determine the energy content of 100 g of Fahlgren's fudge cookies from the following measurements. A 10-g sample of a cookie is allowed to dry before putting it in a bomb calorimeter. The aluminum bomb has a mass of 0.615 kg and is placed in 2.00 kg of water contained in an aluminum calorimeter cup of mass 0.524 kg. The initial temperature of the system is 15.0°C, and its temperature after ignition is 36.0°C.

APPROACH We apply energy conservation to our system, which we assume is isolated and consists of the cookie sample, the bomb, the calorimeter cup, and the water.

SOLUTION In this case, the heat Q released in the burning of the cookie is absorbed by the system of bomb, calorimeter, and water:

$$\begin{aligned} Q &= \left(m_{\mathrm{w}} c_{\mathrm{w}} + m_{\mathrm{cal}} c_{\mathrm{cal}} + m_{\mathrm{bomb}} c_{\mathrm{bomb}}\right) \Delta T \\ &= \left[(2.00\,\mathrm{kg})(1.0\,\mathrm{kcal/kg \cdot C^\circ}) + (0.524\,\mathrm{kg})(0.22\,\mathrm{kcal/kg \cdot C^\circ}) \right. \\ &\quad \left. + (0.615\,\mathrm{kg})(0.22\,\mathrm{kcal/kg \cdot C^\circ})\right][36.0^\circ\mathrm{C} - 15.0^\circ\mathrm{C}] = 47\,\mathrm{kcal}. \end{aligned}$$

In joules, $Q = (47\,\mathrm{kcal})(4186\,\mathrm{J/kcal}) = 197\,\mathrm{kJ}$. Since 47 kcal is released in the burning of 10 g of cookie, a 100-g portion would contain 470 food Calories, or 1970 kJ.

14–5 Latent Heat

When a material changes phase from solid to liquid, or from liquid to gas (see also Section 13–12), a certain amount of energy is involved in this **change of phase**. For example, let us trace what happens when a 1.0-kg block of ice at −40°C is heated at a slow steady rate until all the ice has changed to water, then the (liquid) water is heated to 100°C and changed to steam above 100°C, all at 1 atm pressure. As shown in the graph of Fig. 14–5, as the ice is heated, its temperature rises at a rate of about 2 C°/kcal of heat added (since for ice, $c \approx 0.50\,\mathrm{kcal/kg \cdot C^\circ}$). However, when 0°C is reached, the temperature stops increasing even though heat is still being added. The ice gradually changes to water in the liquid state, with no change in temperature. After about 40 kcal has been added at 0°C, half the ice remains and half has changed to water. After about 80 kcal, or 330 kJ, has been added, all the ice has changed to water, still at 0°C. Continued addition of heat causes the water's temperature to again increase, now at a rate of 1 C°/kcal. When 100°C is reached, the temperature again remains constant as the heat added changes the liquid water to vapor (steam). About 540 kcal (2260 kJ) is required to change the 1.0 kg of water completely to steam, after which the graph rises again, indicating that the temperature of the steam rises as heat is added.

FIGURE 14–5 Temperature as a function of the heat added to bring 1.0 kg of ice at −40°C to steam above 100°C.