PROBLEM SOLVING Calorimetry

1. Be sure you have sufficient information to apply energy conservation. Ask yourself: **is the system isolated** (or very nearly so, enough to get a good estimate)? Do we know or can we calculate all significant sources of energy transfer?
2. Apply **conservation of energy**:

   heat gained = heat lost.

   For each substance in the system, a heat (energy) term will appear on either the left or right side of this equation. [Alternatively, use $\Sigma Q = 0$.]
3. If **no phase changes** occur, each term in the energy conservation equation (above) will have the form

   $$Q(\text{gain}) = mc(T_\text{f} - T_\text{i})$$

   or

   $$Q(\text{lost}) = mc(T_\text{i} - T_\text{f})$$

   where T_i and T_f are the initial and final temperatures of the substance, and m and c are its mass and specific heat, respectively.
4. If **phase changes** do or might occur, there may be terms in the energy conservation equation of the form $Q = mL$, where L is the latent heat. But *before* applying energy conservation, determine (or estimate) in which phase the final state will be, as we did in Example 14–8 by calculating the different contributing values for heat Q.
5. Be sure each term appears on the correct side of the **energy equation** (heat gained or heat lost) and that each ΔT is positive.
6. Note that when the system reaches thermal **equilibrium**, the final **temperature** of each substance will have the *same* value. There is only one T_f.
7. **Solve** your energy equation for the unknown.

EXAMPLE 14–9 Determining a latent heat. The specific heat of liquid mercury is 140 J/kg·C°. When 1.0 kg of solid mercury at its melting point of −39°C is placed in a 0.50-kg aluminum calorimeter filled with 1.2 kg of water at 20.0°C, the final temperature of the combination is found to be 16.5°C. What is the heat of fusion of mercury in J/kg?

APPROACH We follow the Problem Solving Box explicitly.

SOLUTION

1. **Is the system isolated?** The mercury is placed in a calorimeter, which, by definition, is well insulated. Our isolated system is the calorimeter, the water, and the mercury.
2. **Conservation of energy.** The heat gained by the mercury = the heat lost by the water and calorimeter.

3 and **4. Phase changes.** There is a phase change, plus we use specific heat equations. The heat gained by the mercury (Hg) includes a term representing the melting of the Hg:

$$Q(\text{melt solid Hg}) = m_\text{Hg} L_\text{Hg},$$

plus a term representing the heating of the liquid Hg from −39°C to +16.5°C:

$$Q(\text{heat liquid Hg}) = m_\text{Hg} c_\text{Hg}[16.5°\text{C} - (-39°\text{C})]$$
$$= (1.0\,\text{kg})(140\,\text{J/kg}\cdot\text{C°})(55.5\,\text{C°}) = 7770\,\text{J}.$$

All of this heat gained by the mercury is obtained from the water and calorimeter, which cool down:

$$Q_\text{cal} + Q_{\text{H}_2\text{O}} = m_\text{cal} c_\text{cal}(20.0°\text{C} - 16.5°\text{C}) + m_{\text{H}_2\text{O}} c_{\text{H}_2\text{O}}(20.0°\text{C} - 16.5°\text{C})$$
$$= (0.50\,\text{kg})(900\,\text{J/kg}\cdot\text{C°})(3.5\,\text{C°}) + (1.2\,\text{kg})(4186\,\text{J/kg}\cdot\text{C°})(3.5\,\text{C°})$$
$$= 19{,}200\,\text{J}.$$

5. **Energy equation.** The conservation of energy tells us the heat lost by the water and calorimeter cup must equal the heat gained by the mercury:

$$Q_\text{cal} + Q_{\text{H}_2\text{O}} = Q(\text{melt solid Hg}) + Q(\text{heat liquid Hg})$$

or

$$19{,}200\,\text{J} = m_\text{Hg} L_\text{Hg} + 7770\,\text{J}.$$

6. **Equilibrium temperature.** It is given as 16.5°C, and we already used it.