Specific Heat

The amount of heat gained or lost by a substance is both proportional to the mass of the substance and its temperature change. The proportionality constant is the specific heat, represented by **s**. So

(1) heat = $\mathbf{q = m \times s \times \Delta T}$, where **m** is the mass, and $\mathbf{\Delta T = T_2 - T_1}$, the change in temperature.

The specific heat for water is well known. The unit of heat, the calorie, is defined as the amount of heat necessary to heat 1 gram of water 1 Celsius degree. Thus the specific heat of water is 1.00 cal/(g·C°). It is more common now to calculate all energies in units of joules (1 cal = 4.184 J) so that the specific heat of water is 4.184 J/(g·C°).

By carefully measuring temperature changes accompanying heat transferred to and from water, specific heats of other substances can be determined. In this experiment you will determine the specific heat of an elemental metal by measuring the heat transferred from the hot metal to cool water in coming to an equilibrium temperature. This transfer can be accomplished in a coffee cup calorimeter (styrofoam cup) so that the metal will be the **system** and the water in the cup will be the **surroundings.** Thus the heat change (heat lost) for the metal, $\mathbf{q_M}$, will be exactly equal and opposite in sign to the heat change (heat gained) for the water, $\mathbf{q_W}$ i.e.,

(2) $\mathbf{q_M = -q_W}$

Since $\mathbf{q_W = m_W \times s_W \times \Delta T_W}$, where $\mathbf{m_W}$, $\mathbf{s_W}$, and $\mathbf{\Delta T_W}$ are the mass, specific heat, and temperature change, respectively, of the water, and since $\mathbf{q_M = m_M \times s_M \times \Delta T_M}$, where $\mathbf{m_M}$, $\mathbf{s_M}$, and $\mathbf{\Delta T_M}$ are the mass, specific heat, and temperature change, respectively, of the metal, then

(3) $\mathbf{q_M = m_M \times s_M \times \Delta T_M = -m_W \times s_W \times \Delta T_W = -q_W}$

This equation can easily be solved for $\mathbf{s_M}$, the specific heat of the metal.

	Trial 1	Trial 2
Mass of the metal		
Mass of water in calorimeter		
Temperature of hot metal		
Temperature of cool water		
Temperature--final		
Temperature change of metal		
Temperature change of water		

Calculate the specific heat of the metal for trial 1 data.

PROBLEMS

1. 700.0 grams of water at 18.0°C is placed in a 200.0 g copper kettle and heated to 100.0°C. Calculate the amount of heat required to heat the kettle and the water together from 18.0°C to 100.0°C. Water has specific heat 4.18 J/(g·C°). Copper has specific heat 0.385 J/(g·C°).

2. 80.00 g of a certain metal initially at 95.0 °C is dropped into 120.0 g of water at 16.0 °C. 5.096 kJ of heat is transferred from the metal to the water until they reach the same temperature.

a. Calculate the final temperature of the water (and the metal).

b. Calculate the specific heat of the metal.

	Trial 1	Trial 2
Mass of the metal	*26.34 g*	
Mass of water in calorimeter	*75. g*	
Temperature of hot metal	*98.1 °C*	
Temperature of cool water	*23.3 °C*	
Temperature--final	*28.2 °C*	
Temperature change of metal	*–69.9 C°*	
Temperature change of water	*4.9 C°*	

Calculate the specific heat of the metal for trial 1 data.

$$s_M = -\frac{m_W \times s_W \times \Delta T_W}{m_M \times \Delta T_M} = -\frac{75.g \times 4.184\,\frac{J}{g\cdot C^\circ} \times 4.9C^\circ}{26.34g \times (-69.9C^\circ)} = 0.835\,\frac{J}{g\cdot C^\circ}$$

PROBLEMS

1. 700.0 grams of water at 18.0°C is placed in a 200.0 g copper kettle and heated to 100.0°C. Calculate the amount of heat required to heat the kettle and the water together from 18.0°C to 100.0°C. Water has specific heat 4.184 J/(g·C°). Copper has specific heat 0.385 J/(g·C°).

to heat the water $q = m \times s \times \Delta T = 700.0\ g \times 4.184\ \frac{J}{g\cdot C^\circ} \times 82.0\ C^\circ \times \frac{1\ kJ}{1000\ J} = 240.2\ kJ$

heat the kettle $q = m \times s \times \Delta T = 200.0\ g \times 0.385\ \frac{J}{g\cdot C^\circ} \times 82.0\ C^\circ \times \frac{1\ kJ}{1000\ J} = 6.31\ kJ$

Note: $\Delta T = T_2 - T_1 = 100.0\ °C - 19.0\ °C = 82.0\ C°$ total heat is 240.2 kJ + 6.31 kJ = 246.5 kJ

2. 80.00 g of a certain metal initially at 95.0 °C is dropped into 120.0 g of water at 16.0 °C. 5.096 kJ of heat is transferred from the metal to the water until they reach the same temperature.

a. Calculate the final temperature of the water (and the metal).

for water $q = m \times s \times \Delta T$ so $\Delta T = \dfrac{q}{m \times s} = \dfrac{5096\ \text{J}}{120.\text{g} \times 4.184\ \frac{\text{J}}{\text{g}\cdot\text{C}^\circ}} = 10.15\ \text{C}^\circ = T_2 - T_1$

$T_2 = T_1 + \Delta T = 16.0\ ^\circ\text{C} + 10.15\ \text{C}^\circ = 26.15\ ^\circ\text{C}$

b. Calculate the specific heat of the metal.

for metal $\Delta T = T_2 - T_1 = 26.15\ ^\circ\text{C} - 95.0\ ^\circ\text{C} = -68.85\ \text{C}^\circ$

$$s = \frac{q}{m \times \Delta T} = \frac{-5096\ \text{J}}{80.00\ \text{g} \times (-68.85\text{C}^\circ)} = 0.925\ \frac{\text{J}}{\text{g}\cdot\text{C}^\circ}$$

Note: Heat, q, is negative for the metal because it loses heat to the water. Specific heat can never be negative. q and temperature change must both be positive or both be negative.