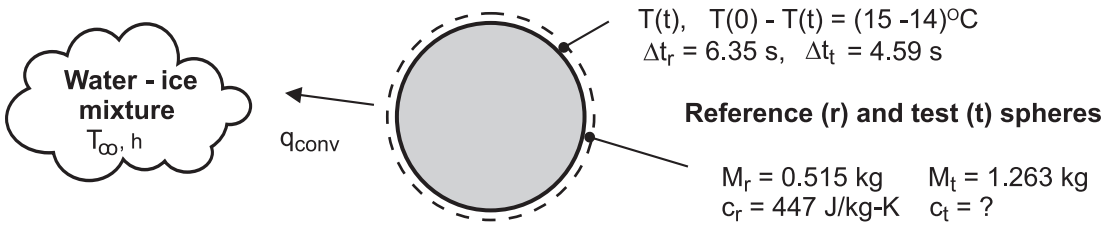
PROBLEM 1.62

KNOWN: Elapsed times corresponding to a temperature change from 15 to 14°C for a reference sphere and test sphere of unknown composition suddenly immersed in a stirred water-ice mixture. Mass and specific heat of reference sphere.

FIND: Specific heat of the test sphere of known mass.

SCHEMATIC:



ASSUMPTIONS: (1) Spheres are of equal diameter, (2) Spheres experience temperature change from 15 to 14°C, (3) Spheres experience same convection heat transfer rate when the time rates of surface temperature are observed, (4) At any time, the temperatures of the spheres are uniform, (5) Negligible heat loss through the thermocouple wires.

PROPERTIES: Reference-grade sphere material: c_r = 447 J/kg K.

ANALYSIS: Apply the conservation of energy requirement at an instant of time, Equation 1.12c, after a sphere has been immersed in the ice-water mixture at T_∞.

$$\dot{E}_{in} - \dot{E}_{out} = \dot{E}_{st}$$

$$-q_{conv} = Mc\frac{dT}{dt}$$

where $q_{conv} = h\,A_s\left(T - T_\infty\right)$. Since the temperatures of the spheres are uniform, the change in energy storage term can be represented with the time rate of temperature change, dT/dt. The convection heat rates are equal at this instant of time, and hence the change in energy storage terms for the reference (r) and test (t) spheres must be equal.

$$M_r\ c_r\ \frac{dT}{dt}\Big)_r = M_t\ c_t\ \frac{dT}{dt}\Big)_t$$

Approximating the instantaneous differential change, dT/dt, by the difference change over a short period of time, $\Delta T/\Delta t$, the specific heat of the test sphere can be calculated.

$$0.515\ \text{kg} \times 447\,\text{J/kg}\cdot\text{K}\ \frac{(15-14)\,\text{K}}{6.35\,\text{s}} = 1.263\,\text{kg} \times c_t \times \frac{(15-14)\,\text{K}}{4.59\,\text{s}}$$

$$c_t = 132\ \text{J/kg}\cdot\text{K} \qquad <$$

COMMENTS: Why was it important to perform the experiments with the reference and test spheres over the same temperature range (from 15 to 14°C)? Why does the analysis require that the spheres have uniform temperatures at all times?