17.62 A copper calorimeter can with mass 0.1 kg contains 0.16 kg of water and 0.018 kg of ice in thermal equilibrium at atmospheric pressure. If 0.75 kg of lead at temperature 255°C is dropped into the calorimeter can, what is the final temperature? Assume no heat is lost to the surroundings.

Copper mass = 0.1 kg
Water mass = 0.16 kg
Ice mass = 0.018 kg

Initially at 0°C (because both ice and water together)

Add 0.75 kg of lead at 255°C

Find final equilibrium temp.

First, find out how much energy it takes to melt the ice:

\[ Q = mL_f = (0.18\text{kg})(334\text{J/kg°C}) = 60.12\text{J} \]

The temperature change of the lead is given by \( Q = mc\Delta T \)

\[ 60.12 = (0.75\text{kg})(130\frac{°\text{C}}{\text{kg}})\Delta T \Rightarrow \Delta T = -61.66°\text{C} \]

Now the lead is at 193.34°C and there will be no more phase changes.

Now we use \( Q = mc\Delta T \) again for all 3 parts - copper, water and lead.

\[ Q_{\text{total}} = Q_{\text{copper}} + Q_{\text{water}} + Q_{\text{lead}} \]

\[ 0 = (0.1\text{kg})(390\frac{°\text{C}}{\text{kg}})(T_f - 0°) + (0.17\text{kg})(4170\frac{°\text{C}}{\text{kg}})(T_f - 0°) + (0.75\text{kg})(130\frac{°\text{C}}{\text{kg}})(T_f - 193.34°) \]

\[ T_f = 21.4° \]
17.66 One end of an insulated metal rod is maintained at 100°C, and the other end is maintained at 0°C by an ice-water mixture. The rod is 60cm long and has a cross-sectional area of 1.25cm². The heat conducted by the rod melts 8.5g of ice in 10 minutes. Find the thermal conductivity $k$ of the metal.

\[ Q_{\text{ice}} = m L = \left( 8.5 \times 10^{-3} \right) \left( 334 \times 10^{-3} \frac{\text{J}}{\text{g} \cdot \text{K}} \right) = 28.39 \text{J} \]

Average Power
\[ P_{\text{ave}} = \frac{Q_{\text{ice}}}{\text{time}} = \frac{28.39 \text{J}}{600 \text{ s}} = 4.73 \text{ watts} \]

\[ H = \frac{k \cdot A \left( T_h - T_c \right)}{L} \Rightarrow k = \frac{H \cdot L}{A \left( T_h - T_c \right)} = \frac{(4.73 \text{ W}) \times (0.6 \text{ m})}{(1.25 \times 10^{-4} \text{ m}^2) \times (100 \text{ K})} \]

\[ k = 227 \text{ W m}^{-1} \text{K}^{-1} \]
A styrofoam bucket of negligible mass contains 1.75kg of water and 0.45kg of ice. More ice, from a refrigerator at -15°C, is added to the mixture in the bucket, and when thermal equilibrium has been reached, the total mass of ice in the bucket is 0.778kg. Assuming no heat is exchanged with the surroundings, what mass of ice was added?

Initially: 

\[ M_{\text{water}} = 1.75\text{kg} \]

\[ M_{\text{ice}} = 0.45\text{kg} \]

At 0°C.

Add some unknown mass of ice at -15°C.

The temperature of the ice that is added must rise to 0°C, and the heat to do this must come from freezing some of the water.

\[ Q_{\text{total}} = 0 \quad \text{so} \quad Q_{\text{raise temp.}} = Q_{\text{freeze water}} \]

\[ M_{\text{new ice}} \left( \frac{334 \text{kJ}}{\text{kg}} \right) \left( 0°C - (-15°C) \right) = M_{\text{freeze water}} \left( \frac{334 \text{kJ}}{\text{kg}} \right) \]

We are given the total mass of ice at the end: 0.778kg.

So:

\[ 0.778\text{kg} = 0.45\text{kg} + M_{\text{new ice}} + M_{\text{freeze water}} \]

We have 2 equations with 2 unknowns:

\[ M_{\text{new ice}} (0.18) = M_{\text{freeze water}} \]

\[ 0.778\text{kg} = 0.45\text{kg} + M_{\text{new ice}} + 0.18 \cdot M_{\text{new ice}} \]

\[ M_{\text{new ice}} = 0.276\text{kg} \]