Answer on Question #80269, Physics / Other

What mass of steam initially at 130°C is needed to warm 200 g of water in a 100 g glass container from 20.0°C to 50.0°C. Take specific heat capacity of steam to be 2.01 x l0^3 J/ kg.°C and that of water to be 4.19 x 10^3 J/ kg.°C.

Hint: The steam loses energy in three stages. In the first stage, the steam is cooled to 100°C where ms is the mass of the steam. In the second stage, the steam is converted to water without the change in temperature. In the third stage, the water created from steam is reduced to water at 50°C.

Solution:

This is a heat transfer problem where we know the final temperature of the glass and water combination. Since there might be a phase transition at the water/steam boundary, we have to do this problem in 3 parts: part 1 is cooling the steam, part 2 is condensing, and part 3 is further cooling of the water:

1) Steam cooling from 130°C to 100°C:

$$Q_1 = m_{steam}c_{steam} \cdot (T_f - T_i) = 30 \cdot m_{steam}c_{steam}$$

2) Steam condensing:

$$Q_2 = m_{steam}L_v$$

3) Water (was steam) cooling from 100°C to 50°C:

$$Q_3 = m_{steam}c_w \cdot (T_f - T_i) = 50 \cdot m_{steam}c_w$$

The total heat liberated by the steam is then the sum of the above:

$$Q_{out} = Q_1 + Q_2 + Q_3$$

The heat gained by the water/glass combination going from 20°C to 50°C is:

$$Q_{in} = m_w c_w \cdot (T_f - T_i) + m_{glass}c_{glass} \cdot (T_f - T_i)$$
$$= (m_w c_w + m_{glass}c_{glass}) \cdot 30°C$$

These two heats must be equal:

$$Q_{out} = Q_{in}$$
$$m_{steam}(30 \cdot c_{steam} + L_v + 50 \cdot c_w) = (m_w c_w + m_{glass}c_{glass}) \cdot 30$$

$$m_{steam} = \frac{(m_w c_w + m_{glass} c_{glass}) \cdot 30}{30 \cdot c_{steam} + L_v + 50 \cdot c_w}$$

The specific heats of glass is 837 J/kg.

So,

$$m_{steam} = \frac{(0.2 \times 4190 + 0.1 \times 837) \cdot 30}{30 \cdot 2010 + 2.26 \times 10^6 + 50 \cdot 4190} = 0.0109\ kg \approx 10.9\ g$$

Answer: $10.9\ g$