Answer on Question #43846 – Physics – Other

Question.

A 93 g piece of copper is heated in a furnace to a temperature T. The copper is then inserted into a 150 g copper calorimeter containing 193 g of water. The initial temperature of the water and calorimeter is 16 °C, and the final temperature after equilibrium is established is 38 °C. When the calorimeter and its contents are weighed, 35.0 g of water are found to have evaporated. What was the temperature T?

$m_{cop} = 93\ g = 0.093\ kg$

$m_{cal} = 150\ g = 0.15\ kg$

$m_{wat} = 193\ g = 0.193\ kg$

$m_{vap} = 35\ g = 0.035\ kg$

$T_{vap} = 100℃ = 373\ K$

$T_{in} = 16℃ = 289\ K$

$T_{fin} = 38℃ = 311\ K$

$c_{cop} = 385\ \frac{J}{kg \cdot K}$ is the heat capacity of copper

$c_{wat} = 4200\ \frac{J}{kg \cdot K}$ is the heat capacity of water

$r = 2.26 \cdot 10^6\ \frac{J}{kg}$ is the heat of vaporization of water

$T = ?$

Solution.

In this task, the following process takes place:

A piece of copper heats m_{vap} of water to T_{vap} degrees and vaporizes it, and the rest of water and calorimeter are heated to T_{fin}. From other hand, itself a piece of copper cools to a temperature T_{fin}.

Write this process in the form of heat balance:

$$Q_{cool} = Q_{heat}$$

$$Q_{cool} = m_{cop} c_{cop} (T - T_{fin})$$

$$Q_{heat} = Q_{heating} + Q_{vaporization}$$

$$Q_{heating} = m_{cal}c_{cop}(T_{fin} - T_{in}) + (m_{wat} - m_{vap})c_{wat}(T_{fin} - T_{in}) + m_{vap}c_{wat}(T_{vap} - T_{in})$$

$$Q_{vaporization} = m_{vap}r$$

So, we received:

$$m_{cop}c_{cop}(T - T_{fin}) = \\ = m_{cal}c_{cop}(T_{fin} - T_{in}) + (m_{wat} - m_{vap})c_{wat}(T_{fin} - T_{in}) \\ + m_{vap}c_{wat}(T_{vap} - T_{in}) + m_{vap}r$$

Therefore,

$$T = T_{fin} + \\ + \frac{m_{cal}c_{cop}(T_{fin} - T_{in}) + (m_{wat} - m_{vap})c_{wat}(T_{fin} - T_{in}) + m_{vap}c_{wat}(T_{vap} - T_{in}) + m_{vap}r}{m_{cop}c_{cop}}$$

Calculate:

$$T = 311 + \frac{1270.5 + 14599.2 + 12348 + 79100}{35.805} = 311 + \frac{107317.7}{35.805} = 311 + 2997 = \\ = 3308\ K = 3035℃$$

I want to notice, that real melting point of copper is $1356\ K$ or $1083℃$. So, this problem is not correct. But from thermodynamics we received the current answer.

Answer.

$$T = T_{fin} + \\ + \frac{m_{cal}c_{cop}(T_{fin} - T_{in}) + (m_{wat} - m_{vap})c_{wat}(T_{fin} - T_{in}) + m_{vap}c_{wat}(T_{vap} - T_{in}) + m_{vap}r}{m_{cop}c_{cop}}$$

$$T = 3308\ K = 3035℃$$