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JEE Advanced 2019 - Paper 1 - Physics 17

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Problem ***[Numerical Value]***

A liquid at 30°C is poured very slowly into a Calorimeter that is at temperature of 110°C. The boiling temperature of the liquid is 80°C. It is found that the first 5 gm of the liquid completely evaporates. After pouring another 80 gm of the liquid the equilibrium temperature is found to be 50°C. The ratio of the latent heat of the liquid to its specific heat will be _____ °C.
[Neglect the heat exchange with surrounding]

What to Observe:

- Initial temperature of the liquid is 30°C.
- Initial temperature of the Calorimeter is 110°C.
- Boiling temperature of the liquid is 80°C.
- First 5 gm of the liquid completely evaporates.
- After pouring another 80 gm of the liquid, equilibrium temperature becomes 50°C.
- Heat exchange with surroundings is neglected.

My Approach:

Heat Discussion

Thought

There are two heat-related quantities required in the question: the specific heat capacity s and the latent heat L.
In both situations, the heat transfer is given by:

$$\Delta Q = ms\Delta T \quad \text{(for temperature change)}$$

and

$$\Delta Q = mL_{\text{vapor}} \quad \text{(for phase change to vapor).}$$

What we need to do is equate the change in heat from the calorimeter to the heat gained by the liquid:

$$\Delta Q_{\text{calorimeter}} = \Delta Q_{\text{liquid}}.$$

Calorimeter:

- Mass $= m_c$
- Specific heat $= s_c$

Liquid:

- Specific heat $= s_l$
- Latent heat of vaporization $= L$

Case 1: 5g Liquid Completely Evaporates

Thought

Since 5 g of liquid at 30°C evaporated and no liquid remained after that, it implies that the calorimeter has reached a final temperature of 80°C. If the temperature had exceeded 80°C, more liquid would have evaporated, which contradicts the given limiting case.

Calorimeter:

- Initial temperature $= 110°C$
- Final temperature $= 80°C$

Liquid:

- Initial temperature $= 30°C$
- Final temperature $= 80°C$
- Mass $= m_l = 5\,\text{g}$

The heat lost by the calorimeter is equal to the heat gained by the liquid. The liquid first heats from 30°C to 80°C, then evaporates.

$$m_c s_c(110 - 80) = m_l s_l(80 - 30) + m_l L$$

Substituting values:

$$m_c s_c \cdot 30 = 5 \cdot s_l \cdot 50 + 5L \tag{1}$$

Case 2: Pouring Another 80g

Calorimeter:

- Initial temperature = 80°C
- Final temperature = 50°C

Liquid:

- Initial temperature = 30°C
- Final temperature = 50°C
- Mass = $m_l = 80\,\text{g}$

The heat lost by the calorimeter equals the heat gained by the liquid:

$$m_c s_c(80 - 50) = m_l s_l(50 - 30)$$

Substituting values:

$$m_c s_c \cdot 30 = 80 \cdot s_l \cdot 20 \tag{2}$$

Calculations

Equating equations (1) and (2):

$$5 \cdot s_l \cdot 50 + 5L = 80 \cdot s_l \cdot 20$$

$$250 s_l + 5L = 1600 s_l$$

$$5L = (1600 - 250) s_l = 1350 s_l$$

$$\frac{L}{s_l} = \frac{1350}{5} = 270\,^\circ\text{C}$$

Conclusion

Based on the detailed analysis and the computed expression for the ratio of latent heat to specific heat of the liquid:

$$\boxed{\text{The value of } \frac{L}{s_l} \text{ is } 270^\circ\text{C}}$$

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