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Problem 25.13 (RHK)

An aluminium electric kettle of mass 0.560 kg *contains a* 2.40-kW *heating element. It is filled with* 0.640 L *of water at* 12.0^0C. *We have to calculate* (a) *the time taken for the water to boil;* (b) *the time for the kettle to boil dry.* (*We may assume that the temperature of the kettle does not exceed* 100^0C *at any time.*)

Solution:

(a)

Mass of 0.640 L of water $= 0.640$ kg.

Amount of heat required for heating the water from 12.0^0C to 100^0C will be

$Q_w = 0.640 \times 4190 \times (100 - 12)$ J $= 2.36 \times 10^5$ J.

In calculating the amount of heat required we have used for the thermal capacity of water $c_w = 4190$ J kg^{-1} K^{-1}.

Mass of the aluminium kettle is 0.560 kg and the specific heat of aluminium is $c_{al} = 900$ J kg^{-1}K^{-1}. Heat required

for the kettle to get warmed from 12.0^0C to 100^0C will be

$Q_{al} = 0.560 \times 900 \times (100 - 12)$ J $= 4.44 \times 10^4$ J.

Total heat required for the water to boil in the kettle will be $Q_w + Q_{al} = 28.04 \times 10^4$ J.

Rate at which heat energy is supplied by the heating element is 2.5×10^3 J s^{-1}.

Therefore, the time required for the kettle to boil will be

$t_{boil} = \frac{28.04 \times 10^4}{2.4 \times 10^3}$ s $= 117$ s.

(b)

Heat of vaporization of water $L_{vap} = 2256 \times 10^3$ J.

Therefore, amount of heat required for 0.640 kg of water to vaporize at 100^0C will be

$Q_{vap} = 0.640 \times 2256 \times 10^3$ J$=1.44 \times 10^6$ J.

Therefore, the additional time taken for vaporization of water at 100^0C will be

$t_{vap} = \frac{1.44 \times 10^6}{2.4 \times 10^3}$ s $= 600$ s.

And the total amount of time taken for vaporization of 0.640 L of water at 12.0^0C using a 2.40-kW heating element will be

$t = t_{boil} + t_{vap} = (117 + 600)\ \text{s} = 717\ \text{s}.$