Numerical problem on

First law of Thermodynamics

QUESTION:

1 kg of water at 373 K is converted into steam at the same temperature. The volume of 1 cm^3 of water becomes 1,671 cm^3 on boiling. Calculate change in the internal energy of the system, if heat of vaporization is 540 cal g^{-1}. Given that standard atmospheric pressure = 1.013 $\times$ 10^5 Nm^{-2}.

SOLUTION:

Given:

Standard atmospheric pressure,

$$P = 1.013 \times 10^5 \ Nm^{-2}$$

Volume of water = 1 cm^3

And volume of steam = 1,671 cm^3

Therefore, increase in volume,

$$dV = 1{,}671\text{-}1 = 1{,}670 \ cm^3$$

$$= 1.67 \times 10^{-3} \ m^3$$

If we assume that the expansion occurs at the constant atmospheric pressure,

then external work done,

$$dW = P\,dV$$

$$= 1.013 \times 10^{5} \times 1.67 \times 10^{-3} \text{ J}$$

$$= 169.17 \text{ J}$$

Now, mass of water, m = 1g;

Latent heat of vaporisation for water,

$$L = 540 \text{ cal } g^{-1}$$

Therefore, heat absorbed by water,

$$dQ = mL$$

$$= 1 \times 540 \text{ cal}$$

$$= 540 \times 4.2 \text{ J}$$

$$= 2268 \text{ J}$$

According to the first law of thermodynamics,

$$dQ = dU + dW$$

$$\therefore \quad dU = dQ - dW$$

$$= 2268 - 169.17$$

$$= 2{,}098.83 \text{ J}$$

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