Answer on Question #45566 – Physics – Molecular Physics | Thermodynamics

Question:

A 0.5 kg piece of metal (c = 600 J/(kg·K)) at 300 degrees celsius is dumped into a large pool of water at 20 degrees celsius. Assuming the change in temperature of water to be negligible, calculate the overall change in entropy for the system.

Answer:

According to the Second Law of thermodynamics for the reversible processes: $dS = \frac{\delta Q}{T}$

We assume that piece of metal undergoes an internally reversible heat transfer such that:

$$dS = \frac{dQ}{T} = \frac{m \cdot c \cdot dT}{T};$$

The assumption that piece of metal has a constant heat capacity allows us to integrate this equation: $\int_{S_1}^{S_2} dS = \int_{T_1}^{T_2} \frac{m \cdot c \cdot dT}{T};$ $\Delta S_{Me} = m \cdot c \cdot \ln T|_{T_1}^{T_2} = m \cdot c \cdot \ln \frac{T_2}{T_1};$

This formula uses absolute temperature T in kelvins. We can apply this equation to piece of metal: $\Delta S_{Me} = 0.5\ \mathrm{kg} \cdot 600 \frac{\mathrm{J}}{\mathrm{kg \cdot K}} \cdot \ln \frac{293\ \mathrm{K}}{573\ \mathrm{K}} = -201.2\ \frac{\mathrm{J}}{\mathrm{K}};$

Assuming the change in temperature of water in the pool to be negligible, we can calculate the change in entropy for it: $\Delta S_w = \frac{\Delta Q}{T_2} = \frac{m \cdot c \cdot \Delta T}{T_2}$

$$\Delta S_w = 0.5\ \mathrm{kg} \cdot 600 \frac{\mathrm{J}}{\mathrm{kg \cdot K}} \cdot \frac{(573-293)\ \mathrm{K}}{293\ \mathrm{K}} = 286.7\ \frac{\mathrm{J}}{\mathrm{K}};$$

The total change in entropy for the system is equal to the sum of these two entropy changes:

$$\Delta S = \Delta S_{Me} + \Delta S_w = -201.2 + 286.7 = 85.5\ \frac{\mathrm{J}}{\mathrm{K}};$$

Answer: $\boldsymbol{\Delta S = 85.5\ \frac{J}{K}}$