8-45 A hot iron block is dropped into water in an insulated tank that is stirred by a paddle-wheel. The mass of the iron block and the exergy destroyed during this process are to be determined. √

Assumptions **1** Both the water and the iron block are incompressible substances with constant specific heats at room temperature. **2** The system is stationary and thus the kinetic and potential energies are negligible. **3** The tank is well-insulated and thus there is no heat transfer.

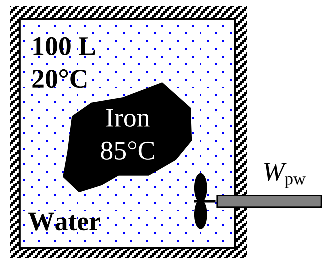
Properties The density and specific heat of water at 25°C are ρ = 997 kg/m³ and c_p = 4.18 kJ/kg.°F. The specific heat of iron at room temperature (the only value available in the tables) is c_p = 0.45 kJ/kg.°C (Table A-3).

Analysis We take the entire contents of the tank, water + iron block, as the system, which is a closed system. The energy balance for this system can be expressed as

$$\underbrace{E_{in} - E_{out}}_{\substack{\text{Net energy transfer}\\ \text{by heat, work, and mass}}} = \underbrace{\Delta E_{system}}_{\substack{\text{Change in internal, kinetic,}\\ \text{potential, etc. energies}}}$$

$$W_{pw,in} = \Delta U = \Delta U_{iron} + \Delta U_{water}$$

$$W_{pw,in} = [mc(T_2 - T_1)]_{iron} + [mc(T_2 - T_1)]_{water}$$



where

$$m_{water} = \rho \boldsymbol{V} = (997\ \text{kg/m}^3)(0.1\ \text{m}^3) = 99.7\ \text{kg}$$

$$W_{pw} = \dot{W}_{pw,in}\Delta t = (0.2\ \text{kJ/s})(20 \times 60\ \text{s}) = 240\ \text{kJ}$$

Substituting,

$$240\ \text{kJ} = m_{iron}(0.45\ \text{kJ/kg}\cdot°\text{C})(24-85)°\text{C} + (99.7\ \text{kg})(4.18\ \text{kJ/kg}\cdot°\text{C})(24-20)°\text{C}$$

$$m_{iron} = \mathbf{52.0\ kg}$$

(*b*) The exergy destruction (or irreversibility) can be determined from its definition $X_{destroyed} = T_0 S_{gen}$ where the entropy generation is determined from an entropy balance on the system, which is an insulated closed system,

$$\underbrace{S_{in} - S_{out}}_{\substack{\text{Net entropy transfer}\\ \text{by heat and mass}}} + \underbrace{S_{gen}}_{\substack{\text{Entropy}\\ \text{generation}}} = \underbrace{\Delta S_{system}}_{\substack{\text{Change}\\ \text{in entropy}}}$$

$$S_{gen} = \Delta S_{system} = \Delta S_{iron} + \Delta S_{water}$$

where

$$\Delta S_{iron} = mc_{avg} \ln\left(\frac{T_2}{T_1}\right) = (52.0\ \text{kg})(0.45\ \text{kJ/kg}\cdot\text{K})\ln\left(\frac{297\ \text{K}}{358\ \text{K}}\right) = -4.371\ \text{kJ/K}$$

$$\Delta S_{water} = mc_{avg} \ln\left(\frac{T_2}{T_1}\right) = (99.7\ \text{kg})(4.18\ \text{kJ/kg}\cdot\text{K})\ln\left(\frac{297\ \text{K}}{293\ \text{K}}\right) = 5.651\ \text{kJ/K}$$

Substituting,

$$X_{destroyed} = T_0 S_{gen} = (293\ \text{K})(-4.371 + 5.651)\ \text{kJ/K} = \mathbf{375.0\ kJ}$$