Definitions

Exergy (Availability) – The maximum USEFUL work that can be obtained from a system at a given state P_1 and T_1 in a specified environment at P_0 and T_0.

Reversible Work – The maximum USEFUL work that can be obtained (or the minimum work that needs to be supplied for processes that require work) as a system undergoes a process between two specified states.

Irreversibility (Exergy Destroyed) – The wasted work potential during a process as a result of irreversibilities.

Surroundings Work – The work done by or against the surroundings during a process. It has significance only for systems whose volume changes during the process (i.e., systems that involve moving boundary work).

$$W_{sur} = P_o\left(V_2 - V_1\right)$$

Useful Work – The difference between the actual work W_{actual} and the surroundings work.

$$W_u = W_{actual} - W_{sur}$$

Any difference between the reversible work and the useful work is due to the irreversibilities present during the process,

$$I = W_{rev,out} - W_{u,out} \quad \text{for work-producing devices}$$
$$I = W_{u,in} - W_{rev,in} \quad \text{for work-consuming devices}$$

Summary

Exergy Change (change in availability) of a closed system:

$$\Delta X = X_2 - X_1 = U_2 - U_1 + P_0\left(V_2 - V_1\right) - T_0\left(S_2 - S_1\right) + m\frac{\left(V_2^2 - V_1^2\right)}{2} + mg\left(z_2 - z_1\right)$$

Reversible Work :

$$W_{rev} = \Delta X$$

Exergy Balance for a closed system:

$$\underbrace{X_{in} - X_{out}}_{\text{Exergy Transfer by Heat and Work}} - X_{destroyed} = X_2 - X_1$$

Exergy Transfer:

$$X_{work} = W_{actual} - W_{sur} \quad \text{for boundary work}$$
$$W_{actual} \quad \text{for other forms of work}$$

$$X_{heat} = \left(1 - \frac{T_o}{T}\right) Q$$

Where T is the heat source temperature
T_o is the environment temperature

Exergy Destroyed:

$$X_{destroyed} = T_o S_{gen}$$

Question

An insulated piston-cylinder device contains 2L of saturated liquid water at a pressure of 150 kPa - which is constant throughout the process. An electric resistance heater inside the cylinder is turned on, and electrical work is done on the water in the amount of 2200 kJ. Assuming the surroundings to be at 25°C and 100 kPa, determine:

a) The minimum work with which this process could be accomplished
b) The exergy destroyed during this process