Q- One mole of an ideal gas is contained in a thermally insulated container that is connected to another container of equal volume that is initially evacuated. The valve connecting the two containers is now opened and the gas allowed to expand isothermally to fill both sides. The new total volume is twice original volume.
a) What is the entropy change for this process?
b) Is this process reversible or irreversible? Why?

Solution:

First of all, against what the work is done? As there is vacuum in the second container the expansion of the ideal gas is free expansion and hence no work will be done. When the gas expands against atmosphere (like piston cylinder case, the other side of piston is pushing the atmosphere) the work is done against atmosphere. Hence the work done by the gas is zero, the internal energy and hence the temperature remains unchanged.

(A)
As there is no interaction with the surrounding, there will not be any change in the entropy of surrounding.

As in this expansion the temperature is constant the process is isothermal hence the change in entropy can be calculated by the formula of the work done as follow.

$$\Delta S = \frac{W}{T} = \frac{nRT\ ln\left(\frac{V_2}{V_1}\right)}{T} = RT\ ln\left(\frac{V_2}{V_1}\right) = RT * ln\ 2 \qquad \text{(n = 1)}$$

Hence the total entropy change will be

$$\Delta S = RT * ln\ 2$$

(B)

As ΔS is greater than zero the process will be irreversible. That can be thought in this way that as the gas cannot be compressed back without doing work hence the process is not reversible.