

Entropy Flow and Entropy Production

When an irreversible process takes place, the entropy of a system can change because entropy may be transferred between the system and its surroundings and because entropy may be produced within the system.

The total change in entropy is therefore written as

$$dS = d_e S + d_i S$$

where $d_e S$ represents the entropy exchanged with the surroundings and $d_i S$ represents the entropy produced within the system.

Entropy Flow

Entropy flow refers to the transfer of entropy between a system and its surroundings or between different parts of a system. Entropy can be carried with heat or matter crossing the boundary of an open system.

For a quantity of heat dq transferred reversibly at temperature T , the entropy transferred with the heat is

$$d_e S = \frac{dq}{T}$$

Thus, entropy can enter or leave a system without necessarily being produced within it.

Entropy Production

Entropy production is the increase in entropy resulting from an irreversible process occurring within the system. It is denoted by $d_i S$.

The second law requires that

$$d_i S \geq 0$$

For a reversible process,

$$d_i S = 0$$

For an irreversible process,

$$d_i S > 0$$

Entropy production is therefore associated with the irreversible character of a process. Processes such as heat transfer through a finite temperature difference, diffusion, viscous flow and chemical reaction are accompanied by entropy production.

Entropy Balance

For a system undergoing a process, the entropy balance is

$$dS = d_e S + d_i S$$

or, in terms of rates,

$$\frac{dS}{dt} = \frac{d_e S}{dt} + \frac{d_i S}{dt}$$

The first term describes the rate of entropy flow into or out of the system, while the second term describes the rate at which entropy is produced internally.

For a reversible process, there is no internal entropy production and the entropy change is entirely due to entropy exchange:

$$d_i S = 0$$

$$dS = d_e S$$

For an irreversible process, part of the entropy change arises from entropy production:

$$d_i S > 0$$

The entropy balance is the starting point for considering the entropy production associated with individual irreversible processes. The expressions for entropy production due to **heat flow** and **chemical reaction** are treated separately.