of temperature and pressure between parts of a system or between a system and its surroundings. We now show that it is a necessary consequence of the second law that the entropy of an isolated system increase in every natural (i.e., irreversible) process.

In mechanics, one of the reasons that justifies the introduction of the concepts of energy, momentum, and angular momentum is that they obey a conservation principle. Entropy is *not* conserved, however, except in reversible processes, and this unfamiliar property, or lack of property, of the entropy function is one reason why such an aura of mystery usually surrounds the concept of entropy. When a beaker of hot water is mixed with a beaker of cold water, the heat lost by the hot water equals the heat gained by the cold water. "Heat" is conserved in this process or, more generally, energy is conserved. On the other hand, while the entropy of the hot water decreases in the mixing process and the entropy of the cold water increases, the decrease in entropy is not equal to the increase, and the total entropy of the system is greater at the end of the process than it was at the beginning. Where did this additional entropy come from? The answer is that the additional entropy was created in the process of mixing the hot and the cold water. Furthermore, once entropy has been created, it can never be destroyed. The universe must forever bear this additional burden of entropy. "Energy can neither be created nor destroyed," says the first law of thermodynamics. "Entropy cannot be destroyed," says the second law, "but it can be created."

In Fig. 8-5, the crosshatching represents a natural (and hence irreversible) process taking place in an isolated system. As a result of this process, the system moves from an equilibrium state represented by point 1 to another equilibrium state represented by point 2. The continuous line represents a reversible process, involving interchanges of energy with heat and work reservoirs, by which the system is returned from state 2 to state 1. Taken together, processes I and II constitute a cycle. The cycle as a whole is irreversible, since part I is irreversible. Hence, from the Clausius inequality,

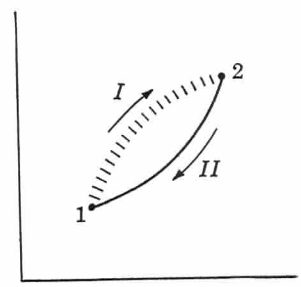


Fig. 8-5. A system undergoes an irreversible process from state (1) to state (2), and is returned by a reversible process from state (2) to state (1).

$$\oint \frac{d'Q}{T} < 0,$$

or, writing the integral as the sum of two integrals,

$$(\text{I})\int_1^2 \frac{d'Q}{T} + (\text{II})\int_2^1 \frac{d'Q}{T} < 0.$$

But the first integral is zero, since the system was isolated in the irreversible process and could not receive or give out heat. This integral, however, is *not* equal to $S_2 - S_1$, since only for *reversible* processes is $dS = d'Q/T$. The second integral, since path II is reversible, is $S_1 - S_2$. It follows that

$$S_1 - S_2 < 0,$$

or

$$S_2 > S_1.$$

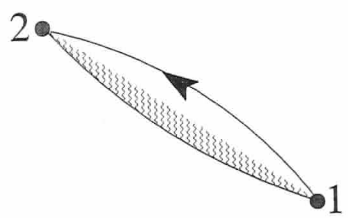
That is, the entropy of the system in state 2 is greater than in state 1. Since the original process was arbitrary, we conclude that *the entropy of an isolated system increases in every natural (i.e., irreversible) process.*

Note that the statement above is restricted to isolated systems and that the entropy refers to the *total* entropy of the system. When natural processes take place in an isolated system, the entropy of parts of the system may decrease and that of other parts may increase. The increases, however, are always greater than the decreases. The entropy of a non-isolated system may either increase or decrease, depending on whether heat is added to or removed from it or whether irreversible processes take place within it. Hence, in discussing increases and decreases in entropy, it is very important that the system under consideration shall be clearly defined.

Según este texto, se pueden hacer dos tipos de camino para pasar desde el estado inicial 1 al estado final 2. Utilizando la desigualdad de Clausius

$$\int \frac{dQ}{T} \leq 0$$

se demuestra (para el camino irreversible) que $S_2 > S_1$. Por otro lado, si el camino es reversible, la desigualdad se convierte en igualdad, y por lo tanto $S_2 = S_1$. ¿Cómo se puede explicar esta discrepancia?



تعاریف انتروپی

- برای یک فرآیند بسیار کوچک هم‌دمای برگشت‌پذیر داریم:

$$dS = \frac{\delta q_{rev}}{T}$$

- انتروپی بردار زمان است یعنی یک شاخص اساسی زمان است.
- از دیدگاه انرژی آزاد انتروپی با گرمایی که برای انجام کار در دسترس نیست، ارتباط دارد.
- انتروپی اندازهٔ بی‌نظمی سامانه (سیستم) یا ماده‌ای است که در حال بررسی است.
- انتروپی معیاری از اشتباهات تصادفی است که در هنگام انتقال یک سیگنال