## 0.1 Entropy

An important inequality that has major consequences in thermodynamics is the *Clausius inequality.*

$$\oint \frac{SQ}{T} \geq 0$$

The cyclic integral of $\frac{SQ}{T}$ is always less than or equal to zero. This inequality is valid for all cycles reversible or irreversible. $\frac{SQ}{T}$ is the sum of all differential amounts of heat transfer to or from a system, divided by the temperature of the boundary.

### 0.1.1 Proof of the Clausius inequality

INSERT PROOF

### 0.1.2 The increase of entropy principle

Consider a cycle. It has two processes:

- Process 1-2: could be reversible or irreversible.
- Process 2-1L Internally reversible.

The Clausius inequality states:

$$\oint \frac{SQ}{T} \geq 0$$

Or,

$$\int_1^2 \frac{SQ}{T} + \int_1^2 \left(\frac{SQ}{T}\right)_{\text{int rev}} \geq 0$$

$$\int_1^2 \frac{SQ}{T} + (S_1 - S_2) \geq 0$$

$$S_2 - S_1 \leq \int_1^2 \frac{SQ}{T}$$

When written in the differential form:

$$ds \leq \frac{SQ}{T}$$

Where T is the thermodynamic temperature at the boundary. SQ is the heat transferred between the system and surroundings. ds is the differential change in energy. When reversible $ds = \frac{SQ}{T}$. When irreversible $ds \leq \frac{SQ}{T}$. This equation shows that:

> Change in entropy of a closed system during an irreversible process is *always greater* than the integral of $\frac{SQ}{T}$ evaluated for that process.