3.11 Combining the first and second law

Combining the first law in the version of Eq. (2.10) and second law in version of Eq. (3.1) for reversible processes we get

$$dU = T\,dS - p\,dV \quad \text{i.e.} \quad dU + p\,dV - T\,dS = 0 \tag{3.22}$$

and consequently for irreversible processes

$$dU + p\,dV - T\,dS \leq 0 \quad \text{i.e.} \quad (dU)_{S,V} \leq 0 \quad \text{and} \quad (dS)_{U,V} \geq 0 \tag{3.23}$$

So Eq. (3.22) for the first time is a representation using the inner energy U as a total differential which allows to take the full benefit of knowledge about thermodynamic potentials. It will need some math to completely understand the consequences and we will start by discussing the difference between dS and δq. Since for irreversible processes the entropy S increases we always find (according to Eq. (3.23)) additional losses in inner energy U (and in all other thermodynamic potentials). So in thermodynamic equilibrium the entropy will stay/be at a maximum and the inner energy will stay/be at a minimum.