Thermodynamic state variables

State variables are the measurable properties of a system. To describe the state of a system at least two independent state variables must be given.

State variables are e.g.:
- pressure \( p \)
- temperature \( T \)
- volume \( V \)
- amount of substance \( n \)

The state functions can be derived from the state variables:
- internal energy \( U \): the thermal energy of a static, closed system. When external energy is added, processes result in a change of the internal energy.
  \[ \Delta U = Q - W \]
  - \( Q \): thermal energy added to the system
  - \( W \): mechanical work done on the system that results in an addition of heat
- enthalpy \( H \): defined as the sum of internal energy plus work: \( p \times V \)
  \[ H = U + p \times V \]
- entropy \( S \): provides information on the order in a system and the associated arrangement options of particles in that system
  The change in entropy \( dS \) is known as reduced heat.
  \[ dS = \frac{\delta Q_{\text{rev}}}{T} \]
  - \( \delta Q_{\text{rev}} \): reversible heat change
  - \( T \): absolute temperature

When the steam engine was developed more than 200 years ago, physicists wondered why only a few percent of the thermal energy was converted into mechanical energy. Rudolf Clausius introduced the term entropy to explain why the efficiency of thermal engines is limited to a few percent. Thermal engines convert a temperature difference into mechanical work. Thermal engines include steam engines, steam turbines or internal combustion engines.

\[ p \times V = m \times R \times T \]
- \( m \): mass
- \( R \): specific gas constant of the corresponding gas

The changes of state listed above are special cases of polytropic change of state, in which part of the heat is exchanged with the environment.

<table>
<thead>
<tr>
<th>n</th>
<th>isochoric</th>
<th>isobaric</th>
<th>isothermal</th>
<th>isentropic</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>heat dissipation</td>
<td>heat absorption</td>
<td>heat exchange</td>
<td>heat absorption</td>
</tr>
</tbody>
</table>

Changes of state can be clearly illustrated in diagrams.