Universität Stuttgart
Institut für Technische Thermodynamik
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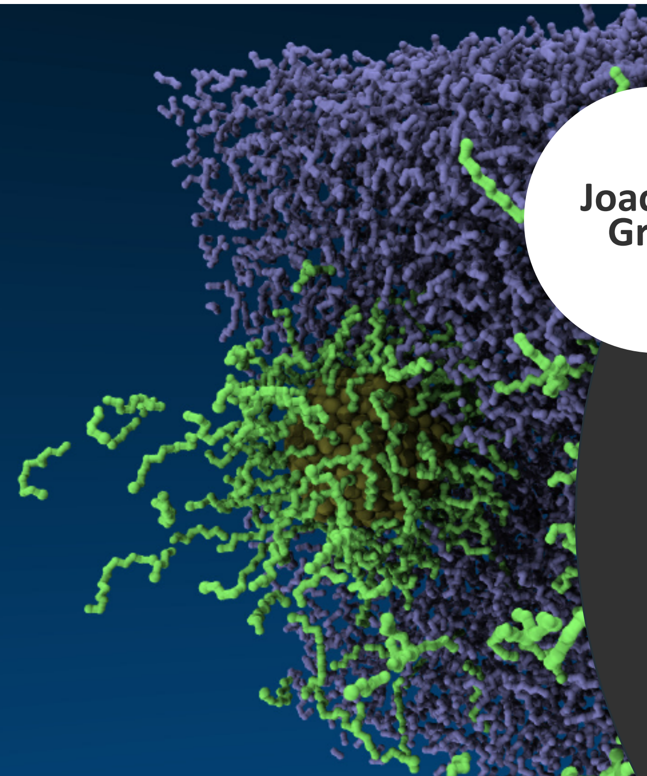


Joachim Gross

Mini lecture
Second law and entropy

SYMPOSIUM
Teaching and Learning Thermodynamics in a Time of Change

How we lecture the 2nd law in BSc-courses – usually along a historical path

First statement of 2nd law — heat does not by itself transfer from a body of low temperature to a body of high temperature

- This development is deductive
- However only, if temperature is introduced and a notion of reversible and irreversible processes is already established

We then develop 2nd law

$$dS = \frac{đQ}{T} + đ\sigma$$

dS: entropy — $đ\sigma$: entropy production

$đ\sigma = 0$ reversible process

$đ\sigma > 0$ irreversible process

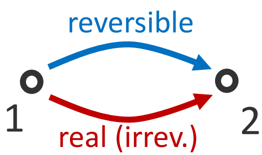
The 2. law – entropy production $\bar{d}\sigma$

$$dS = \frac{\bar{d}Q}{T} + \bar{d}\sigma$$

$\bar{d}\sigma = 0$ reversible process

$\bar{d}\sigma > 0$ irreversible process

- Permits real (irreversible) processes spontaneous in one direction, but not the other



$$dU_{12} = \bar{d}Q_{12}^{rev} + \bar{d}W_{12}^{rev} \qquad dS_{12} = \frac{\bar{d}Q_{12}^{rev}}{T}$$

$$\parallel \qquad\qquad\qquad \parallel$$

$$dU_{12} = \bar{d}Q_{12} + \bar{d}W_{12} \qquad dS_{12} = \frac{\bar{d}Q_{12}}{T} + \bar{d}\sigma_{12}$$

$$= \bar{d}Q_{12} + \bar{d}W_{12}^{rev} + \bar{d}W_{12}^{diss}$$

$$\Longrightarrow \quad dQ_{12}^{rev} = \bar{d}Q_{12} + \bar{d}W_{12}^{diss}$$

$$\Longrightarrow \quad T \cdot \bar{d}\sigma_{12} = \bar{d}W_{12}^{diss} > 0$$

- We see that entropy production is equivalent to lost (dissipated) work
- Dissipated work is what makes technical processes non-sustainable
- Minimize $T \cdot \bar{d}\sigma_{12}$ to systematically minimize non-sustainability of a process

The 2. law – entropy S

$$S = k \ln \Omega$$

number of microscopic (molecular) states

1st law of thermodynamics

$$E$$

Principle of nature:

For equilibrium, minimize E
(if S permits)

2nd law of thermodynamics

$$S = k \ln \Omega$$

Principle of nature:

For equilibrium, maximize S
(if E permits)

combining both principles

Actually combining both balance equations and applying a Legendre transform

$$F = E - TS$$

For equilibrium, minimize F

$\Longrightarrow$ what really happens for defined (T, V, n):
A balance between 2 principles of nature