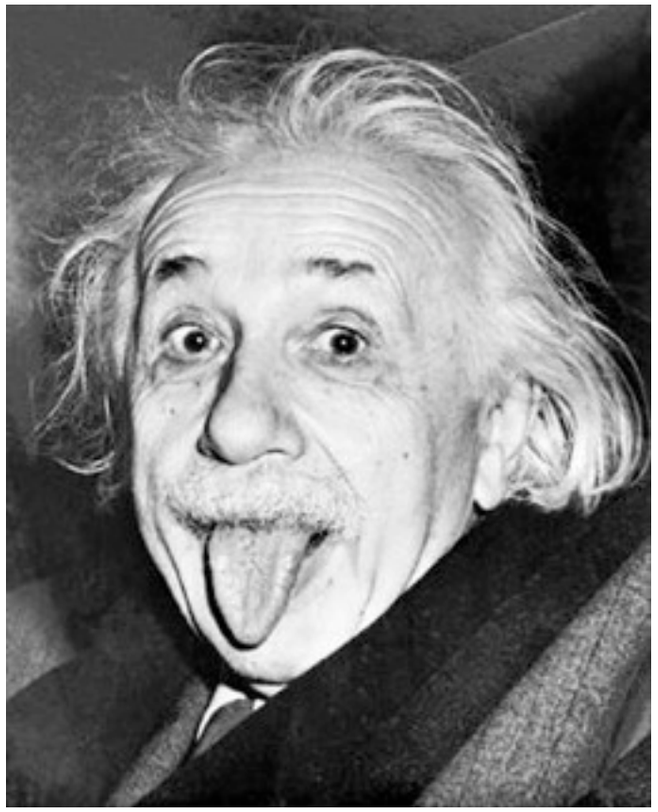
Thermodynamics

PHY 215
Thermodynamics and
Modern Physics

Fall 2025
MSU

Einstein on Thermodynamics

“A theory is the more impressive the greater the simplicity of its premises, the more different kinds of things it relates, and the more extended its area of applicability. Therefore the deep impression that classical thermodynamics made upon me. It is the only physical theory of universal content which I am convinced will never be overthrown, within the framework of applicability of its basic concepts.”



Albert Einstein
1879-1955
Nobel Prize 1921

Outline

- 3rd Law of Thermodynamics (Nernst)
  - Unattainability of 0°K
  - Connection to Quantum Mechanics
- Perspectives on Thermodynamics
  - C. P. Snow's summary

3rd Law of Thermodynamics

- Part I - The entropy change ΔS in any reversible isothermal process approaches zero as the temperature approaches zero. (Nernst)
- Part II - The entropy S(V,T) remains finite as V is held fixed an $T \rightarrow 0^{\circ}K$. (Finite entropy hypothesis)
- $\therefore$ S(V,0) is a finite quantity independent of V.

Walther Nernst

1864-1941

Nobel Prize: 1924

Image: http://en.wikipedia.org

Consequences

- No reversible adiabatic process starting at non-zero temperature can take a system to zero temperature. (Unattainability)
- C_p-$C_V \rightarrow 0$ as $T \rightarrow 0$.

Absolute Entropy

- "The gist of the theorem is contained in the statement that, as the temperature decreases indefinitely, the entropy of a chemically homogeneous body of finite density approaches indefinitely near a definite value, which is independent of pressure, the state of aggregation and the special chemical modification." - Max Planck

Max Planck

1858-1947
Nobel Prize 1918

- $\therefore C_{p,V} \rightarrow 0$ independently, as $T \rightarrow 0$.

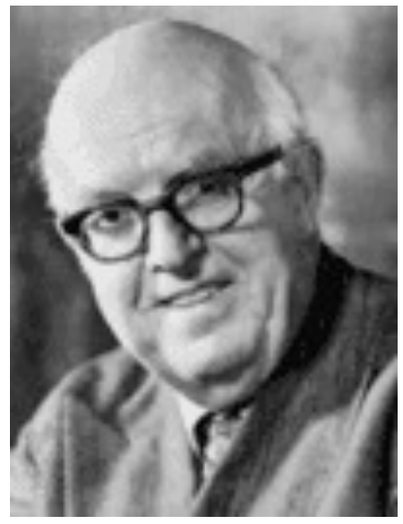
Image: http://en.wikipedia.org

Quantum Connection

- Boltzmann: $\Delta S = k \log(W_f/W_i) \rightarrow 0$ as $T \rightarrow 0$.
- $S(V, T \rightarrow 0)$ independent of V!
- Therefore:
  - The number of microstates is driven to a minimum, and is independent of volume!
- In Quantum Mechanics, this will be shown that there s often only 1 (!) such microstate.

Thermo Summarized

- C.P. Snow summarized the laws of thermodynamics as follows:
  - 1st Law: "You cannot win" (i.e., get something for nothing!).
  - 2nd Law: "You cannot even break even" (i.e. $\eta < 1$).
  - 3rd Law: "You cannot get out of the game" (0°K is unattainable).



C.P. Snow

1905-1980

Image: http://www.britannica.com

Review

- Thermodynamics is the study of heat, and its transformation into work and internal energy.
- These transformations are subject to the constraints of the laws of themodynamics.
- These laws pertain independent of the *microscopic* properties of the system!
- Entropy is a measure of disorder of, and lack of information about, a system.
- The Entropy of the universe never decreses.