Statistical Physics B

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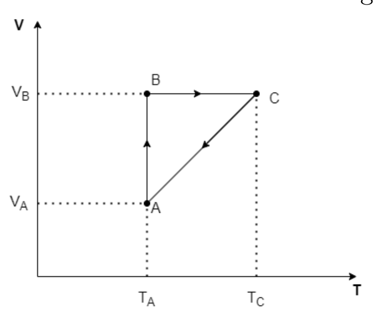
Mateusz Homenda, room 5.26 **mateusz.homenda@fuw.edu.pl**

1. Gentle reminder of thermodynamics
   (a) 0th law of thermodynamics
   Empirical temperature; equation of state
   $$f(T, p, V, n, \dots) = 0$$
   (b) 1st law of thermodynamics
   Conservation of energy in a system with adiathermal walls; internal energy as function of state
   Important remark: ΔU doesn't depend on the specific process but only on the initial and final states at equilibrium
   $$\Delta U = W$$
   In a system with any kind of walls we introduce heat as a work defect.
   $$\Delta U = W + Q$$
   For infinitesimal changes we will write:
   $$dU = đW + đQ$$
   (c) 2nd law of thermodynamics
   Kelvin's formulation: *It is impossible to devise an engine which, working in a cycle, would produce no effect other than the extraction of heat from a reservoir and performance of an equivalent amount of mechanical work.*
   There exists new function of state: entropy

2. **Exercise 1:** Consider a classical gas with equation of state: $pV = nRT$ and internal energy: $U = \frac{3}{2}nRT$



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   (a) Calculate heat transfer Q in every process and in the whole cycle.
   (b) Integrate the quantity $đQ/T$ in every process and in the whole cycle.

Quantity $đQ/T$ represents an infinitesimal change of a new function of state, called entropy.

$$dS = \frac{1}{T}dU + \frac{p}{T}dV - \frac{\mu}{T}dn$$

3. **Exercise 2:** Knowing that $U(T, V, n) = 3/2nRT$ Calculate:
   (a) specific heat at constant volume C_V.
   (b) Can we calculate specific heat at constant pressure C_p? What additional information do we need to do this?
   (c) Knowing equation of state $pV = nRT$ calculate C_p.
   (d) entropy as a function of temperature and volume $S(T, V)$
   (e) Derive entropy as a function of internal energy and volume $S(U, V, n)$

   Conclusion: internal energy as a function of state doesn't allow us to extract all thermodynamic properties of a system. We need the equation of state.

4. **Exercise 3:** In a specific range of temperatures and pressure the entropy of real gasses can be described as follows:
$$S(U, V, n) = ns_0 + nc_v \log \frac{U + \frac{an^2}{V}}{n} + nR \log \frac{V - nb}{n} \qquad ,$$
   where s_0, c_v, R, a, b are some constants.

   Using II law of thermodynamics derive
   (a) equation of state $f(T, v, p) = 0$ for this gas
   (b) internal energy as a function of temperature and volume $u(T, v)$.

   Hint: We start with equation:
$$TdS = dU + pdV - \mu dn$$
   We know that entropy is a function of state $S(U, V, n)$. From this we get the relations:
$$\left(\frac{\partial S}{\partial U}\right)_{V,n} = \frac{1}{T} \qquad \text{and} \qquad \left(\frac{\partial S}{\partial V}\right)_{U,n} = \frac{p}{T}$$
   Conclusion: We show that knowing entropy as a function of a specific set of variables $S(U, V, n)$ we can derive more information than if know $S(T, V, n)$.