Sheet 04: Potentials and Work

Discussion: Thursday 15.06.20

Exercise 1 Thermodynamic potentials and equilibriumt

In chapter 8 we have shown that the free energy F is the appropriate thermodynamic potential, which becomes minimal at equilibrium if we keep T constant through a reservoir. Perform a corresponding argument for the Gibbs energy $G(T, P, \mu)$, as well as the enthalpy $H(S, P, \mu)$. Derive the condition for the extremum and show that these are minima.

Exercise 2 Helmholtz equation

One can derive the Helmholtz equation for $\frac{\partial E}{\partial V}\Big|_T$ in a different way without using Maxwell relations. To do this, consider $\mathrm{d}S$ and express $\mathrm{d}E$ in other variables. *Note:* You will need other second derivatives.

Exercise 3 Reversible work

Our system $\mathcal{S}$ does reversible work $-\xi\,\mathrm{d}X$. How much heat do you have to add to $\mathcal{S}$ to keep the temperature T constant?

Exercise 4 Electrostriction

When we charge a capacitor, the volume V of the enclosed dielectric changes. The work to charge a capacitor is given by

$$\delta W = \Phi\,\mathrm{d}Q\,, \tag{1}$$

where Φ is the potential and Q is the electric charge. The capacitance C is given by,

$$Q = C\Phi\,, \qquad C = C_0\epsilon(T, P)\,, \tag{2}$$

where we assume that the dielectric function $\epsilon(T, P)$ is known.

- How does V change with Q when P and T are held constant?
- Determine $V(T, P, Q)$ starting from $V(T, P, 0)$.

Exercise 5 Gibbs-Helmholtz equations

Write down the Gibbs-Helmholtz equations relating $E \leftrightarrow H$, $F \leftrightarrow G$, and $G \leftrightarrow H$.