## 1.13 The free energy as an example for a thermodynamic potential

The **free energy** is the corresponding thermodynamic potential for the thermal contact of section 1.9.
The corresponding coordinates are therefor $V, N$, and $T$.
It is well known that

$$F(V, N, T) = U(V, N, T) - S(V, N, T)T \tag{1.17}$$

and

$$dF = \mu dN - pdV - SdT \tag{1.18}$$

*Mathematical interpretation*: total differential, partial derivative

| | | |
|---|---|---|
| $\frac{\partial F}{\partial N}\big\vert_{V,T} = \mu$ | $\frac{\partial F}{\partial V}\big\vert_{N,T} = -p$ | $\frac{\partial F}{\partial T}\big\vert_{V,N} = -S$ |

*Physical interpretation*: gradient, forces

| | | |
|---|---|---|
| $\mu$: "force" changing the particle number | $-p$: "force" changing the volume | $-S$: "force" changing the temperature |

here: $V, N, T$: generalized coordinates
$-p, \mu, -S$: generalized forces
For "normal" physical quantities:
Coordinates: extensive parameters
Forces: intensive parameters
Forces and coordinates can be exchanged. There exists no principle difference between these parameters since they are equivalent and just depend on the choice of the thermodynamic contact.