# Mechanocaloric and Thermomechanical Effects [tln34]

Helium II is a mixture of normal fluid and superfluid $^4$He. The superfluid has no viscosity and no entropy.

Consider two vessels $A$ and $B$ with rigid insulating walls, separated by a porous material that allows unimpeded superfluid flow but prevents any normal-fluid flow.

The thermal equilibrium of such a system is characterized by the following relations between intensive variables:

$$T_A \neq T_B, \quad p_A \neq p_B, \quad \mu_A(T_A, p_A) = \mu_B(T_B, p_B).$$

Consider situations in which system $B$ is large compared to system $A$.

Any process in which a change of $p_A$ or $T_A$ is forced in the smaller system must then satisfy $\mu_A(T_A, p_A) = \mu_B(T_B, p_B) = \text{const}$ i.e. $d\mu_A = 0$.

Gibbs-Duhem equation: $S_A dT_A - V_A dp_A + N_A d\mu_A = 0$.

$$d\mu_A = 0 \quad \Rightarrow \quad -\frac{S_A}{N_A}\, dT_A + \frac{V_A}{N_A}\, dp_A = 0 \quad \Rightarrow \; dp_A = \frac{S_A}{V_A}\, dT_A.$$

**Mechanocaloric effect**:

Pouring helium II into system $A$ increases the pressure $p_A$ and causes a superfluid flow through the porous material into system $B$ to maintain chemical equilibrium $d\mu_A = 0$. The fraction of normal fluid in $B$ increases. The temperature $T_A$ rises.

**Thermomechanical effect**:

Heating up helium II in system $A$ increases the temperature $T_A$ and causes a superfluid flow of superfluid flow into system $A$ to maintain chemical equilibrium $d\mu_A = 0$. The pressure $p_a$ rises and may start a fountain.