Exotic Properties of helium II [tln34]

Helium II behaves like a mixture of normal fluid and superfluid. The superfluid portion increases with decreasing temperature at the expense of the normal fluid portion. The superfluid has no viscosity and no entropy.

Consider two vessels A and B with rigid insulating walls, connected by a capillary that allows unimpeded superfluid flow but prevents any normal fluid flow.

In general, the thermal equilibrium of that 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 very 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. $d\mu_A = 0$.

$$\Rightarrow \left(\frac{\partial \mu_A}{\partial T_A}\right)_{p_A} dT_A + \left(\frac{\partial \mu_A}{\partial p_A}\right)_{T_A} dp_A = -\frac{S_A}{N_A}\, dT_A + \frac{V_A}{N_A}\, dp_A = 0.$$

$$\Rightarrow \; dp_A = \frac{S_A}{V_A}\, dT_A.$$

Mechanocaloric effect:
Pressure increase
causes temperature increase.

Thermomechanical effect:
Temperature increase
causes pressure increase.