# Chapter 5.10: Independent spins in a field: adiabatic demagnetization

We had for noninteracting Ising spins $H = -BS$ $Z = 2\cosh\beta B$ $M = -\frac{\partial F}{\partial B} = \tanh\beta B$

General paramagnetic coupling of field to magnetic moments:

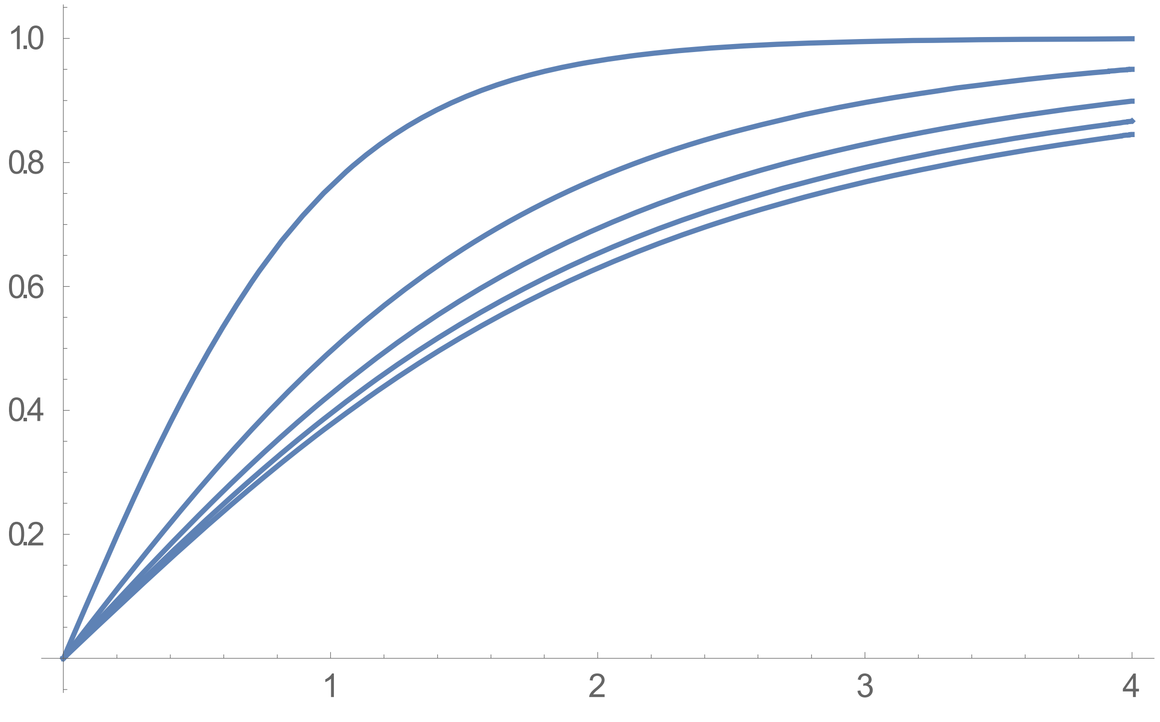
$$H_{\text{field}} = -g\mu_B \vec{J}\cdot\vec{B} \quad \rightarrow \quad -Bj_z$$

$$Z = \sum_{j_z=-j}^{j} e^{\beta B j_z} = \frac{\sinh \beta B(j+\frac{1}{2})}{\sinh\frac{\beta B}{2}}$$

Magnetization $M = -\frac{\partial F}{\partial B} = j\, B_j(j\beta B)$

Brillioouin Function

$$B_j(x) = \frac{2j+1}{2j}\coth\left(\frac{2j+1}{2j}x\right) - \frac{1}{2j}\coth\left(\frac{x}{2j}\right)$$



## Susceptibility: Curie law

General: $$\chi = \frac{\partial M}{\partial B} = -\frac{\partial^2 F}{\partial B^2}$$

Small fields: $$B_j(x) \rightarrow \frac{j+1}{3j} x$$

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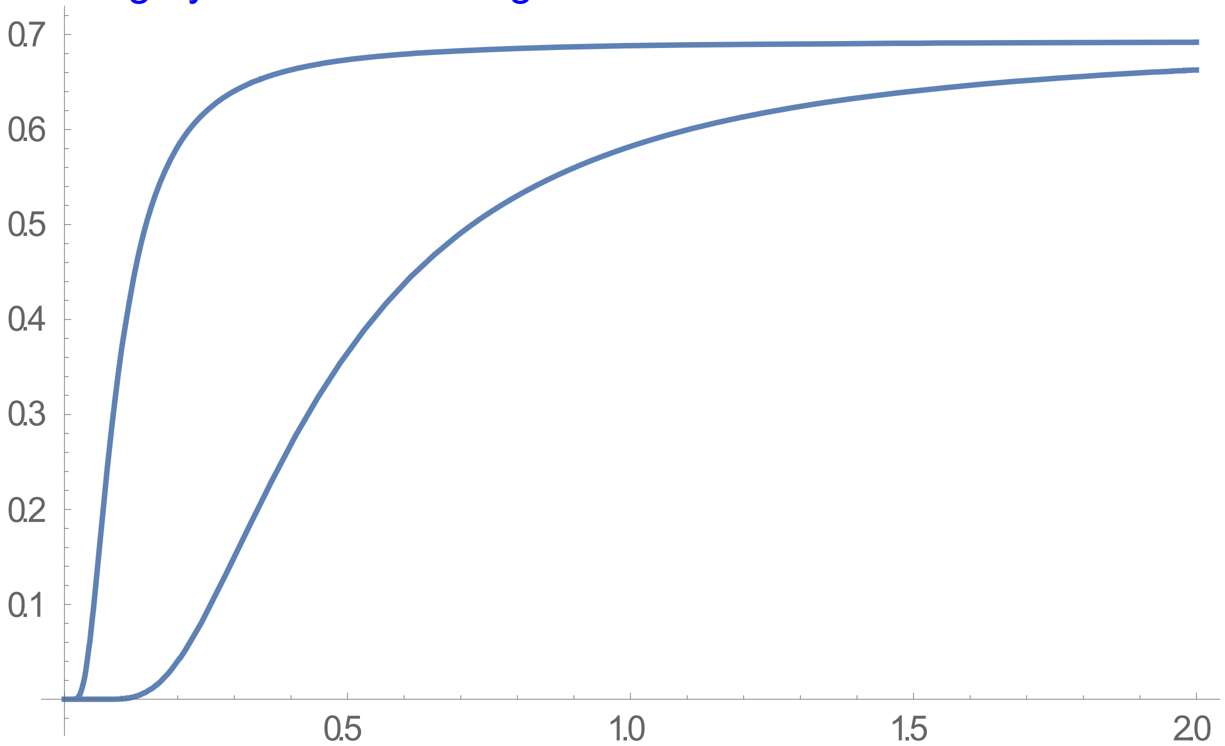
## Entropy

$$S = -\frac{\partial F}{\partial T} = k_B \ln Z + \frac{k_B T}{Z}\frac{\partial Z}{\partial T}$$

## Cooling by adiabatic demagnetization



## Third law of thermodynamics

Nernst 1912: "It is impossible for any procedure to lead to the isotherm $T = 0$ in a finite number of steps."