

## TWO-STATE PARAMAGNET: THE PURCELL & POUND EXPERIMENT WITH LITHIUM

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Reference: Daniel V. Schroeder, *An Introduction to Thermal Physics*, (Addison-Wesley, 2000) - Problem 3.21.

As another example of the formulas we obtained for the two-state paramagnet we can look at the 1951 experiment by Purcell and Pound described in Schroeder on page 102. The dipoles here are provided by lithium nuclei, which is a real-life paramagnet with four spin states, although for the purposes of this problem, we'll pretend it has only two states. The magnetization is given by

$$M = N\mu \tanh \frac{\mu B}{kT} \quad (1)$$

The values in the experiment are

$$\mu = 5 \times 10^{-8} \text{ eV T}^{-1} = 8.01 \times 10^{-27} \text{ J T}^{-1} \quad (2)$$

$$B = 0.63 \text{ T} \quad (3)$$

$$T = 300 \text{ K} \quad (4)$$

The magnetization per particle is

$$\frac{M}{N} = (8.01 \times 10^{-27}) \tanh \frac{(8.01 \times 10^{-27})(0.63)}{(1.38 \times 10^{-23})(300)} \quad (5)$$

$$= 9.76 \times 10^{-33} \text{ J T}^{-1} \quad (6)$$

The energy difference between the parallel and antiparallel dipole alignments is  $\Delta U = 2\mu B$ , so in this experiment, the energy of a photon required to perform a flip is

$$E = 2\mu B \quad (7)$$

$$= 10^{-26} \text{ J} \quad (8)$$

This corresponds to a wavelength which can be calculated from Planck's formula

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$$E = h\nu = \frac{hc}{\lambda} \quad (9)$$

$$\lambda = \frac{hc}{E} \quad (10)$$

$$= \frac{(6.626 \times 10^{-34}) (3 \times 10^8)}{(10^{-26})} \quad (11)$$

$$= 19.9 \text{ m} \quad (12)$$

With a wavelength of around 20 metres, the photon is in the radio wave region of the spectrum.