

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

$$(0.1) \quad M = N\mu \tanh \frac{\mu B}{kT}$$

The values in the experiment are

$$(0.2) \quad \mu = 5 \times 10^{-8} \text{ eV T}^{-1} = 8.01 \times 10^{-27} \text{ J T}^{-1}$$

$$(0.3) \quad B = 0.63 \text{ T}$$

$$(0.4) \quad T = 300 \text{ K}$$

The magnetization per particle is

$$(0.5) \quad \frac{M}{N} = (8.01 \times 10^{-27}) \tanh \frac{(8.01 \times 10^{-27})(0.63)}{(1.38 \times 10^{-23})(300)}$$

$$(0.6) \quad = 9.76 \times 10^{-33} \text{ J T}^{-1}$$

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

$$(0.7) \quad E = 2\mu B$$

$$(0.8) \quad = 10^{-26} \text{ J}$$

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

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$$(0.9) \quad E = h\nu = \frac{hc}{\lambda}$$

$$(0.10) \quad \lambda = \frac{hc}{E}$$

$$(0.11) \quad = \frac{(6.626 \times 10^{-34}) (3 \times 10^8)}{(10^{-26})}$$

$$(0.12) \quad = 19.9 \text{ m}$$

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