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

$$M=N\mu\tanh\frac{\mu B}{kT} \tag{1}$$

The values in the experiment are

$$\begin{aligned}
\mu &= 5\times10^{-8}\text{ eV T}^{-1}=8.01\times10^{-27}\text{ J T}^{-1} && (2)\\
B &= 0.63\text{ T} && (3)\\
T &= 300\text{ K} && (4)
\end{aligned}$$

The magnetization per particle is

$$\begin{aligned}
\frac{M}{N} &= \left(8.01\times10^{-27}\right)\tanh\frac{\left(8.01\times10^{-27}\right)(0.63)}{\left(1.38\times10^{-23}\right)(300)} && (5)\\
&= 9.76\times10^{-33}\text{ J T}^{-1} && (6)
\end{aligned}$$

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

$$\begin{aligned}
E &= 2\mu B && (7)\\
&= 10^{-26}\text{ J} && (8)
\end{aligned}$$

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

$$E = h\nu = \frac{hc}{\lambda} \tag{9}$$

$$\lambda = \frac{hc}{E} \tag{10}$$

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

$$= 19.9 \text{ m} \tag{12}$$

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