

8. A molecule possessing a magnetic dipole moment has squared spin angular momentum $\frac{3}{4}\hbar^2$. Give an expression for the energy of the molecule when it is stationary in a magnetic field of flux density B .

Write down the molecule's partition function Z and show that

$$\left(\frac{\partial Z}{\partial B}\right)_T = -\frac{T}{B} \left(\frac{\partial Z}{\partial T}\right)_B.$$

A crystal is formed out of such molecules. With M the magnetic moment of the crystal, the work done during an infinitesimal change in B is $-MdB$. Assuming that magnetic interactions between molecules are negligible, give a general expression for the change in the crystal's Helmholtz free energy in terms of changes in other thermodynamic variables. Show that the entropy S and magnetic moment of the crystal are related by

$$\left(\frac{\partial S}{\partial B}\right)_T = -\frac{B}{T} \left(\frac{\partial M}{\partial B}\right)_T.$$

Explain physically why there is a minus sign in this equation. If the crystal is thermally isolated, how will its temperature change when B is increased?