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An electron in the outer shell of an ion has magnetic moment of one Bohr magneton μ_B. In a magnetic field H, this outer shell state splits into two energy levels: one level for the spin-up electron with energy $E = E_0 - \mu_B H$ and occupation number $n_\uparrow$ and one level for the spin-down electron with energy $E = E_0 + \mu_B H$ and occupation number $n_\downarrow$. The magnetic moment of the outer shell is given by $M = \mu_B(n_\uparrow - n_\downarrow)$. The ion is part of a solid, which acts as a heat bath with temperature T. Assume that the electron spin can flip as a result of the interaction with the heat bath. Ignore any interactions between electrons.

(a) Give an expression for the average magnetic moment of the outer shell if the ion can exchange electrons with a reservoir which has a fixed chemical potential μ. Other electrons in the solid can serve as such a reservoir.

(b) Give an expression for the average number of electrons in the outer shell and the average magnetic moment of the outer shell for the situation described in part (a), when $\mu = E_0$.

(c) Give an expression for the average magnetic moment of the outer shell which contains one electron, when this shell cannot exchange electrons with any reservoir.