which does not agree with the observed value of

$$\mu_{\text{obs}} = 0.8\mu_N. \tag{3.28}$$

$^{41}Ca^{20}$ has 20 paired neutrons, 20 paired protons, and one unpaired neutron. The shell structure has the form

$$n: (1S_{1/2})^2(1P_{3/2})^4(1P_{1/2})^2(1D_{5/2})^6(2S_{1/2})^2(1D_{3/2})^4(1F_{7/2})^1,$$
$$p: (1S_{1/2})^2(1P_{3/2})^4(1P_{1/2})^2(1D_{5/2})^6(2S_{1/2})^2(1D_{3/2})^4.$$

The last neutron in the state $^1F_{7/2}$ determines

$$J^P = \frac{7}{2}^-, \tag{3.29}$$

consistent with experiment. The predicted value of the magnetic moment is that of the unpaired neutron

$$\mu = -1.91\mu_N, \tag{3.30}$$

which differs somewhat from the observed value of

$$\mu_{\text{obs}} = -1.6\mu_N. \tag{3.31}$$

Problem 3.6 *Consider a somewhat more sophisticated model for the anomalous contribution to the magnetic moment of a nucleon. Assume that the proton can be regarded as a fixed neutral center with a π^+ meson circling about in an $\ell = 1$ orbit. Similarly, take a neutron as an effective proton center with a π^- meson in an $\ell = 1$ orbit around it. Using $m_\pi = 140\,\text{MeV}/c^2$, calculate $\mu = (\frac{e\hbar}{2m_\pi c})\ell$, and compare results with those of Problem 2.5.*

If we assume such an "atomic" model for the nucleons, then the magnetic moment of the π meson will be given by

$$\mu_\pi = \left(\frac{e\hbar}{2m_\pi c}\right)\ell, \tag{3.32}$$

where e represents the charge of the pion, the mass of the pion is given by

$$m_{\pi^+} = m_{\pi^-} = 140\,\text{MeV}/c^2, \tag{3.33}$$

and ℓ represents the orbital angular momentum of the pion. Since the $\pi^\pm$ mesons move in orbits with $\ell = 1$, we obtain

$$\begin{aligned}\mu_{\pi^\pm} &= \left(\frac{e\hbar}{2m_{\pi^\pm}c}\right) \times 1 = \pm\frac{m_p}{m_{\pi^\pm}}\mu_N \\ &= \pm\frac{938.27\,\text{MeV}/c^2}{140\,\text{MeV}/c^2} \times \mu_N \approx \pm 6.7\mu_N. \end{aligned} \tag{3.34}$$

In the model for the proton, where we assume that a π^+ is going around a neutron, we can predict

$$\begin{aligned}\mu_p &= \mu_n + \mu_{\pi^+} \approx (-1.91 + 6.7)\mu_N = 4.79\mu_N \\ &\approx 4.79 \times 3.15 \times 10^{-14}\,\text{MeV/T} \approx 1.51 \times 10^{-13}\,\text{MeV/T}, \end{aligned} \tag{3.35}$$

where we have used the value of μ_N in MeV/T from Eq. (2.30). This is quite comparable to the result in Problem 2.5.

For the neutron, the model assumes that a π^- moves around a stationary proton so that we have

$$\begin{aligned}\mu_n &= \mu_p + \mu_{\pi^-} \approx (2.79 - 6.7)\mu_N = -3.91\mu_N \\ &\approx -3.91 \times 3.15 \times 10^{-14}\,\text{MeV/T} \approx -1.23 \times 10^{-13}\,\text{MeV/T}. \end{aligned} \tag{3.36}$$

Problem 3.7 *The ground state of $^{137}Ba^{56}$ has spin-parity $\frac{3}{2}^+$. That is, its spin is $\frac{3}{2}$ and parity +. The first two excited states have spin parity $\frac{1}{2}^+$ and $\frac{11}{2}^-$. According to the shell model, what assignments would be expected for these excited states? (Hint: The surprise has to do with "pairing energy".)*

$^{137}Ba^{56}$ has 56 protons and 81 neutrons. The protons are all paired and therefore do not contribute to the spin parity. According to the single-particle shell model, the neutrons should fill the energy levels