# hw08

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## 0.1 This Jupyter notebook answers HW08 questions for PHY 981 Nuclear Structure.

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### 0.1.1 HW08 question 3

Calculate the magnetic moments for 17O and 17F. Compare to experiment.

Eq. 18.24

$$\frac{\mu}{\mu_N} = j\left[g_q^\ell \pm \frac{g_q^s - g_q^\ell}{2\ell+1}\right]$$

In O-17 we look at the neutron, since the protons are in a closed shell. Looking at the $0d_{5/2}$ neutron orbit, we calculate $\mu/\mu_N$ as

$$\frac{\mu}{\mu_N} = \frac{5}{2}\left[0 + \frac{-3.826 - 0}{2(2)+1}\right] = -1.913$$

The experimental O-17 $\mu$=$-1.89379$.

In F-17 we look at the proton, since the neutrons are in a closed shell. Again, looking at the $0d5/2$ proton orbit, the magnetic moment is

$$\frac{\mu}{\mu_N} = \frac{5}{2}\left[1 + \frac{5.586 - 1}{2(2)+1}\right] = 4.793$$

The experimental F-17 $\mu$=4.7223

### 0.1.2 HW08 question 4

Calculate the quadrupole moments for 17O and 17F. Use harmonic oscilaltor- radial wave functions with $\hbar\omega = 14$ MeV. Compare to experiment.

Eq. 18.31 (single-particle quadrupole moment)

$$\frac{Q(i)}{e} = -\left(\frac{2\ell}{2\ell+3}\right)\langle n\ell j|r^2|n\ell j\rangle e_q$$

The quadrupole moment for 17O is zero, because the protons are in a closed shell and the neutron charge $e_n$ is zero.

The quadrupole moment for 17F (neutrons are in a closed shell; single proton particle state above the closed shell) is

$$\frac{Q(i)}{e} = -\left(\frac{2(2)}{2(2)+3}\right)\langle 0d5/2|r^2|0d5/2\rangle e_p$$

The matrix element $\langle 0d5/2|r^2|0d5/2\rangle$ we compute using the nushell app `rme`, multiplied by $b^2 = 41.1/14$ fm$^2$ with $\hbar\omega$=14 MeV.

$$\frac{Q(i)}{e} = -\left(\frac{4}{7}\right)3.5 * \frac{41.1}{14}(1) = -5.91 \text{ fm}^2$$

### 0.1.3 HW08 question 5

Calculate the quadrupole moments for 17O and 17F. Use Woods-Saxon radial matrix elements given in the output of `wspot`.

The quadrupole moment for 17O is zero because the protons are in a closed shell and the neutron charge $e_n$ is zero.

For 17F, we have the same equation as the previous question, except the $r^2$ matrix element will be computed in a Woods-Saxon potential. From `wspot`, the RMS radius is 3.719, so the $r^2$ matrix element is 13.83.

$$\frac{Q(i)}{e} = -\left(\frac{4}{7}\right)13.83(1) = -7.90 \text{ fm}^2$$

### 0.1.4 HW08 question 6

Calculate the quadrupole moments for 17O and 17F. Use radial matrix ele- ments given in the output of dens with the Skyrme skx EDF potential.

Again, the 17O quadrupole moment is zero.

For 17F, we get the $r^2$ matrix element from the output of `dens`. For `ia,iz`=17,9, `dens` gives the RMS radius of 2.853 which means the $r^2$ matrix element computed in a Skyrme EDF potential is 8.140

$$\frac{Q(i)}{e} = -\left(\frac{4}{7}\right)8.140(1) = -4.65 \text{ fm}^2$$

### 0.1.5 HW08 question 7

Obtain the values of c in Eq. 19.46 from the Fermi gas model, for symmetric nuclear matter, for neutron matter and for the symmetry energy.

The value of $c$ in Eq 19.46 depends on asymmetry factor $F_{5/3}(I) = \frac{1}{2}\left[(1+I)^{5/3} + (1-I)^{5/3}\right]$ where $I = (N-Z)/A$.

For symmetric nuclear matter, N=Z and I=0. Therefore,

$$F_{5/3}(I=0) = \frac{1}{2}\left[(1)^{5/3} + (1)^{5/3}\right] = 0.5$$

And

$$c = \frac{3}{5}\frac{\hbar^2}{2m}\left(\frac{3\pi^2}{2}\right)^{2/3} \times \frac{1}{2}$$

For neutron matter, Z=0 and I=1. Therefore,

$$F_{5/3}(I=1) = \frac{1}{2}\left[(2)^{5/3} + (0)^{5/3}\right] = 1.587$$

And

$$c = \frac{3}{5}\frac{\hbar^2}{2m}\left(\frac{3\pi^2}{2}\right)^{2/3} \times 1.587$$

The symmetry energy comes from the difference between the symmetric nuclear matter and neutron matter [E/A], which is dependent on the factor $(F_{5/3}(I=1) - F_{5/3}(I=0)) = (1.587 - 0.5) = 1.087$. In this case,

$$c = \frac{3}{5}\frac{\hbar^2}{2m}\left(\frac{3\pi^2}{2}\right)^{2/3} \times 1.087$$

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