# Homework 3

PHYSICS 304
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1. (a) (The book has a typo and wrote H, but I'm going to assume it meant ${}^4_2\mathrm{He}$.)

$$\begin{aligned} \text{Radius } {}^4_2\mathrm{He} &= r_0 A^{1/3} = (1.2\,\mathrm{fm})\,(4)^{1/3} \\ &= 1.90\,\mathrm{fm} \end{aligned}$$

   (b)

$$\begin{aligned} \text{Radius } {}^{238}_{92}\mathrm{U} &= (1.2\,\mathrm{fm})\,(238)^{1/3} \\ &= 7.43\,\mathrm{fm} \end{aligned}$$

   (c) The ratio is given as

$$\begin{aligned} k &= \left(\frac{A_2}{A_1}\right)^{1/3} \\ &= \left(\frac{238}{4}\right)^{1/3} \\ &= 3.90 \end{aligned}$$

2. For $10\,\mathrm{cm}^3$ of neutrons of radius $r_0$,

$$\begin{aligned} r &= r_0 N^{1/3} \\ \frac{4}{3}\pi r^3 &= \frac{4}{3}\pi r_0^3 N = 10\,\mathrm{cm}^3 \\ N &= \left(10\,\mathrm{cm}^3 \times \frac{1\,\mathrm{fm}^3}{1\times 10^{-39}\,\mathrm{cm}^3}\right)\frac{3}{4\pi r_0^3} \\ &= 1.38\times 10^{39} \text{ neutrons} \\ &= 2.31\times 10^{12}\,\mathrm{kg} \end{aligned}$$

4. (a) Using Table 13.2, for neutrons in the $B = 1\,\mathrm{T}$ field,

$$\begin{aligned} f &= \frac{2\mu B}{h} = \frac{-2(1.9135)\left(5.05\times 10^{-27}\,\mathrm{J}\cdot\mathrm{T}^{-1}\right)(1\,\mathrm{T})}{6.626\times 10^{-34}\,\mathrm{J}\cdot\mathrm{s}} \\ &= 29.2\,\mathrm{MHz} \end{aligned}$$

   Is it fine to omit the negative sign on a frequency?

   (b) For protons, it's the same but has a moment $\mu = 2.7928\mu_n$,

$$\begin{aligned} f &= \frac{2(2.7928)\left(5.05\times 10^{-27}\,\mathrm{J}\cdot\mathrm{T}^{-1}\right)(1\,\mathrm{T})}{6.626\times 10^{-34}\,\mathrm{J}\cdot\mathrm{s}} \\ &= 42.6\,\mathrm{MHz} \end{aligned}$$

   (c) For $B = 50\,\mu\mathrm{T}$,

$$\begin{aligned} f &= \frac{2(2.7928)\left(5.05\times 10^{-27}\,\mathrm{J}\cdot\mathrm{T}^{-1}\right)\left(50\times 10^{-6}\,\mathrm{T}\right)}{6.626\times 10^{-34}\,\mathrm{J}\cdot\mathrm{s}} \\ &= 2.13\,\mathrm{kHz} \end{aligned}$$

5. (a) Using the Coulomb potential for the silver atom ($Z = 79$, $q_{\text{Au}} = 79e$),

$$\begin{aligned}
0.5\,\text{MeV} &= \frac{q_\alpha q_{\text{Au}}}{4\pi\epsilon_0 r} \\
r &= \frac{q_\alpha q_{\text{Au}}}{4\pi\epsilon_0\,(0.5\,\text{MeV})} = \frac{158\left(1.602\times10^{-19}\,\text{C}\right)^2}{4\pi\left(8.85\times10^{-12}\,\text{F}\cdot\text{m}^{-1}\right)\left(0.5\,\text{MeV}\times\frac{1.602\times10^{-13}\,\text{J}}{1\,\text{MeV}}\right)} \\
&= 455.2\,\text{fm}
\end{aligned}$$

(b) From (a) and using classical kinetic energy,

$$\begin{aligned}
E_\alpha &= \frac{q_\alpha q_{\text{Au}}}{4\pi\epsilon_0 r} \\
&= \frac{158\left(1.602\times10^{-19}\,\text{C}\right)^2}{4\pi\left(8.85\times10^{-12}\,\text{F}\cdot\text{m}^{-1}\right)\left(300\times10^{-15}\,\text{m}\right)} \\
&= 1.21\times10^{-13}\,\text{J} \\
\frac{m_\alpha v^2}{2} &= 1.21\times10^{-13}\,\text{J} \\
v &= 6.05\times10^{6}\,\text{m}\cdot\text{s}^{-1}
\end{aligned}$$

7. The difference in energy between the normal and $B$-aligned state is,

$$\begin{aligned}
\Delta E &= |\mu||\mathbf{B}| \\
&= 2.7928\left(5.05\times10^{-27}\,\text{J}\cdot\text{T}^{-1}\right)(12.5\,\text{T}) \\
&= 1.76\times10^{-25}\,\text{J}
\end{aligned}$$

The total difference in energy between the two aligned states is then $2\Delta E$,

$$\begin{aligned}
2\Delta E &= 3.52\,\text{J} \\
&= 2.2\times10^{-6}\,\text{eV}
\end{aligned}$$

10. (a) For ${}^{12}_{6}\text{C}$,

$$\begin{aligned}
r &= (1.2\,\text{fm})\,12^{1/3} \\
&\approx 2.74\,\text{fm}
\end{aligned}$$

(b) I'm going to assume the distance from the other protons are given by the radius...

$$\begin{aligned}
|F_r| &= \left|-\frac{\partial}{\partial r}U_{\text{Coulomb}}\right| \\
&= \frac{5e^2}{4\pi\epsilon_0 r^2} \\
&\approx 153.7\,\text{N}
\end{aligned}$$

(c) It's basically (b) but without the additional $r$,

$$\begin{aligned}
W &= F_r\times r \\
&= 4.21\times10^{-13}\,\text{J} \\
&= 2.63\,\text{MeV}
\end{aligned}$$

(d)
- From 1(b), $r = 7.43\,\mathrm{fm}$.
- $F = \frac{92e^2}{4\pi\epsilon_0(7.43\,\mathrm{fm})^2} = 384\,\mathrm{N}$
- $W = 2.85 \times 10^{-12}\,\mathrm{J} = 17.8\,\mathrm{MeV}$

11. Using (13.4),

$$\begin{aligned} E_b &= [1.007\,825\,\mathrm{u} + 2 \times 1.008\,655\,\mathrm{u} - 3.016\,049\,\mathrm{u}] \times 931.494\,\mathrm{MeV} \cdot \mathrm{u}^{-1} \\ &= 8.48\,\mathrm{MeV} \end{aligned}$$

For the $A = 3$ nucleons,

$$\frac{8.48}{3} = 2.83\,\mathrm{MeV/nucleon}$$

12. Applying (13.4) to ${}^{56}_{26}\mathrm{Fe}$,

$$\begin{aligned} E_b &= [26(1.007825) + 30(1.008665) - 55.934939] \times 931.494 \\ &= 492.26\,\mathrm{MeV} \\ &= 8.79\,\mathrm{MeV/nucleon} \end{aligned}$$

14. (a) Using (13.4),

$$E_b = [8(1.007825) + 7(1.008665) - 15.003065] \times 931.494$$

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