Binding Energy of Atomic Nuclei

Homework 5 Due 1 March 2023

In home assignment 3, we used the Bethe-Weizsäcker mass formula to compute properties of several atomic nuclei. In this assignment, we will use this formula to compute the binding energy of isospin symmetric nuclei[2] with baryon (atomic mass) numbers A ranging from 1 and 240. The binding energy is given by (see home assignment 3)

$$E_B(Z,A) = -a_{\rm V} + a_{\rm S}A^{-1/3} + a_{\rm C}Z^2A^{-4/3} + a_{\rm A}(Z-A/2)^2A^{-2}\,, \tag{1}$$

where $a_{\rm V} = 15.8$ MeV, $a_{\rm S} = 18.3$ MeV, $a_{\rm C} = 0.71$ MeV, and $a_{\rm A} = 92.7$ MeV.

Task

Write a structured Fortran 90 program which computes $E_B(Z,A)$ for $1 \leq A \leq 240$.

Program Design

- Your program must contain a preamble.
- Your program must be well commented.
- There is no keyboard input.
- Treat A as a continuous (floating point) variable that runs from 1 in steps of $\Delta A = 0.01$ to 240. Hint: This can be accomplished with a `DO` loop.
- The binding energy as a function of A is to be written to an output file named `EBvsA.dat`.
- Using the `python` programming language (or any other graphical software of your choice such as `xmgrace`), create a plot that shows the results of your calculations graphically. The plot must contain all the information shown in this figure:

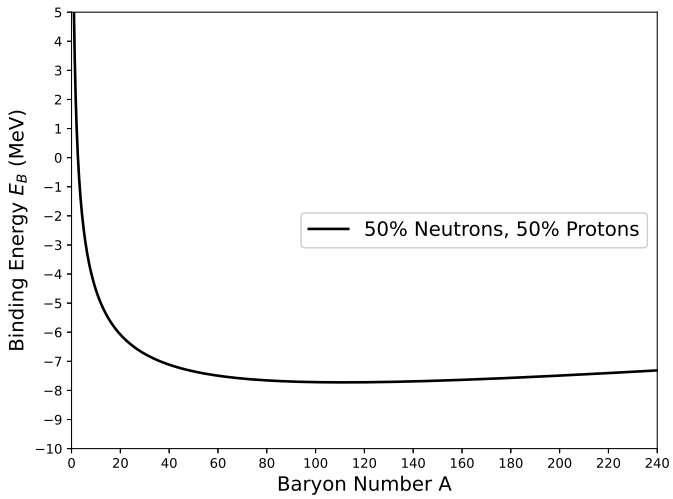

Figure 1: Binding energy of isospin symmetric nuclei.

The `python` program that produces the plot shown in Fig. 1 is listed on the next page. It can be downloaded from the class website. The name of the program is `python_hw5.py`

[2]Nuclei with $N = Z$ are called isospin symmetric.

```
# Python sample program ------------------------------------------------------------------
import numpy as np
import matplotlib.pyplot as plt

# Create a new figure of size 8x6 points, using 100 dots per inch
plt.figure(figsize=(8,6), dpi=100)
x, y = np.loadtxt('EBvsA.dat', unpack=True)

plt.plot(x,y, color='black', linewidth=2.0, linestyle='-', label='50% Neutrons, 50% Protons')

plt.xlabel('Baryon Number A', fontsize=15)
plt.ylabel('Binding Energy $E_B$ (MeV)', fontsize=15)

plt.legend(loc='center right', fontsize=15)

# Set x limits
plt.xlim(1,240)
# Set y limits
plt.ylim(-10,5)

# Set x and y ticks
plt.yticks(np.arange(-10,5.1,1))
plt.xticks(np.arange(0,251,50))

# Save plot as pdf file
plt.savefig('EBvsA.dat.pdf')

# Show plot on screen
plt.show()
# Python sample program ------------------------------------------------------------------
```

• To run the python program, execute `python3 python_hw5.py` in a terminal. This will create a `pdf` file of your data named `EBvsA.dat.pdf` and also shows the plot on the screen.

HOMEWORK SUBMISSION INSTRUCTIONS

1. Create a sub-directory `LastFirst_HW5`.

2. Copy the source code of your Fortran 90 program and the pdf file `EBvsA.dat.pdf` to `LastFirst_HW5`.

3. Create a gzipped archive file of your homework by typing
`tar -czvf LastFirst.tgz LastFirst_HW5/.`

4. Email the archive file `LastFirst.tgz` to `ewhart317@gmail.com`. Put `PHYS 317 HW 5` in the subject line.