Tutorial-2 [PHN-624]

Q1: Find the solutions for Rutherford scattering by solving the four coupled first order differential equations (using Runge Kutta Method) and show them in a two dimensional plot.

Q2: The semi-empirical mass formula for binding energy can be expressed as-

$$E_B = a_v A - a_s A^{2/3} - a_A \frac{(A-2Z)^2}{A} - a_c \frac{Z^2}{A^{1/3}} + \delta(A,Z), \tag{1}$$

where,

$$\delta(A,Z) = \begin{cases} \dfrac{a_p}{A^{3/4}} \rightarrow N, Z \;\; \text{even} \\ 0 \rightarrow A \;\; \text{odd} \\ -\dfrac{a_p}{A^{3/4}} \rightarrow N, Z \;\; \text{odd} \end{cases}$$

Using the binding energies per nucleon (E_n) for ^{10}Be, ^{14}C, ^{18}O, ^{26}Mg, and ^{30}Si, find the coefficients for volume term (a_v), surface term (a_s), asymmetry term (a_A), coulomb term (a_c), and paring term (a_p). [**Hint:** E_n(^{10}Be)= 6.498 MeV, E_n(^{14}C)= 7.520 MeV, E_n(^{18}O)= 7.767 MeV, E_n(^{26}Mg)= 8.334 MeV, E_n(^{30}Si)= 8.521 MeV]

Q3: Using the values of different coefficient as $a_v = 15.75$ MeV, $a_s = 17.80$ MeV, $a_c = 0.71$ MeV, $a_A = 23.70$ MeV, and $a_p = 33.50$ MeV, plot a graph for binding energy per nucleon with respect to the mass number ranging from 1 to 250.

Q4: Plot a N vs. Z graph for beta stability line, proton drip-line and neutron drip-line using the following expressions (with a_v= - 16 MeV; a_s= 20 MeV; a_c= 0.751 MeV; a_{asym}= 21.4 MeV) :

(i) For β-stability line:

$$N - Z = \frac{a_c A^{2/3} - (M_n - M_H)c^2}{(4a_{sym}/A) + (a_c/A^{1/3})}, \tag{2}$$

(ii) For proton drip-line:

$$Z = A\{(1+\beta) \pm \sqrt{[(1+\beta)^2 - \gamma]}\}, \tag{3}$$

where,

$$\beta = \frac{2a_c A^{2/3}}{a_c A^{2/3} + 12a_{sym}},$$

and

$$\gamma = \frac{a_v + 3a_{sym} - \frac{2}{3}a_s A^{-1/3}}{\frac{1}{3}a_c A^{2/3} + 4a_{sym}}.$$

(iii) For neutron drip-line:

$$N = A[1 \pm \sqrt{1-\alpha}], \tag{4}$$

where,

$$\alpha = \frac{a_v + 3a_{sym} - \frac{2}{3}\frac{a_s}{A^{1/3}} + \frac{a_c}{3}A^{2/3}}{\frac{a_c}{3}A^{2/3} + 4a_{sym}}.$$

Q5: Calculate the transmission probability (T) for alpha decay with energy $E = 5.0$ MeV for ^{238}U using the following expression:

$$T = \exp\{-2\int_{r1}^{r2}\sqrt{\frac{2m}{\hbar^2}[V(r)-E]}dr\}. \tag{5}$$

Here, $r1$ is the radius of the decaying nucleus ($1.07{\times}A^{1/3}$ fm), $r2$ is the outer radius of the Coulomb barrier (take $17.1{\times}A^{1/3}$ fm), and m is the mass of alpha particle. For $V(r)$, take the Coulomb potential as $\frac{1}{4\pi\epsilon_0}\frac{2Ze^2}{r}$.