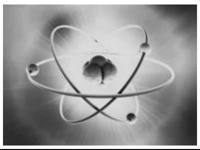
Khemis Miliana University
Faculty of Material Sciences and Computer Science
Department of Physics
L3 Fundamental Physics (2023/2024)



Nuclear Physics

Set of Exercises - 01

Chapter 01: The atomic nucleus

Useful data: $1uc^2 = 931.5[MeV]$; $m_p = 1.0073u$; $m_n = 1.0087u$; $R_0 = 1.2 \times 10^{-15} fm$;
$a_V = 14.64MeV, a_S = 14.08MeV, a_C = 0.64MeV, a_A = 21.07MeV, a_P = 11.54MeV$ *(Benzaid, NST 2020)*

Exercise 01:
By considering the nucleus as a spherical volume with a radius is given as a function of mass number: $R = R_0 A^{1/3}$
Find the density of the ${}^{12}_{6}C$ nucleus.

Exercise 02:
Find the repulsive electric force on a proton whose center is 2.4 fm from the center of another proton. Assume the protons are uniformly charged spheres of positive charge.

Exercise 03:
(a) Find the energy difference between the spin-up and spin-down states of a proton in a magnetic field of $B = 1.000\ T$ (which is quite strong).
(b) What is the Larmor frequency of a proton in this field?

Exercise 04:
(a) To penetrate the Coulomb barrier of a light nucleus, what should be the energy order of magnitude for the incoming proton.
Take the H nucleus as target and the characteristic distance $r = 1fm$.
(b) What will be this energy in the case of ${}_2He$ *or* ${}_3Li$ as a target?

Exercise 05:
The binding energy of the neon isotope ${}^{20}_{10}Ne$ is 160.647 MeV. Find its atomic mass

Exercise 06:
(a) Find the energy needed to remove a neutron from the nucleus of the calcium isotope ${}^{42}_{20}Ca$.
(b) Find the energy needed to remove a proton from this nucleus.
(c) Why are these energies different?
$\boldsymbol{M(20,42) = 41.958622, M(20,41) = 40.962278,}$
$\boldsymbol{M(19,41) = 40.961825}$

Exercise 07:
Find the energy needed to remove a neutron, proton, or an α particle from the following isotopes: ${}^{238}_{92}U$, ${}^{232}_{90}Th$
$\boldsymbol{M(92,238) = 238.050786, M(91,237) = 237.051023}$
$\boldsymbol{M(92,237) = 237.048728, M(90,234) = 234\ 043599}$
$\boldsymbol{M(90,232) = 232.038053, M(89,231) = 231.038393}$
$\boldsymbol{M(90,231) = 231.036302, M(88,228) = 228.031068}$

Exercise 08:
(a) The atomic mass of the zinc isotope ${}^{64}_{30}Zn$ is 63.929 u. Compare its binding energy with the Theoretical prediction:

$$\boldsymbol{E_B^{SEMF}(Z,A) = a_V A - a_S A^{\frac{2}{3}} - a_C \frac{Z(Z-1)}{A^{\frac{1}{3}}} - a_A \frac{(A-2Z)^2}{A} + a_P \frac{\delta}{A^{3/4}}}$$

(b) Do the same for the isotopes given in Ex.06.

Exercise 09:
Isobars are nuclides that have the same mass number A. Derive a formula for the atomic number of the most stable isobar of a given A and use it to find the most stable isobars for:

$$A = 12, 16, 25, 56, 107, 197, 238$$

Compare with available data.

Exercise 10:
What is the Coulomb repulsion energy of two protons in ${}^{3}_{2}He$ if it is assumed that they separated by a nuclear radius?

Exercise 11:
What is the difference between the binding energy of ${}^{3}_{2}He$ and ${}^{3}_{1}H$? Comment the result.

Exercise 12:
Compare the separation energy of a neutron from the following isotopes: ${}^{41}_{20}Ca$, ${}^{42}_{20}Ca$ and ${}^{43}_{20}Ca$
$\boldsymbol{M(20,43) = 42.958770}$

Exercise 13:
(a) "Mirror" nuclei have the same odd value of A, but the values of N and Z are interchanged. Determine the mass difference between two mirror nuclei which have $N - Z = 1$.

(b) the masses of ${}^{23}_{11}Na$ and ${}^{23}_{12}Mg$ are 22.989771u and 22.994125u, respectively. From these data determine the Coulomb coefficient a_C in the semiempirical formula.