M.Sc. Examination, 2019

Semester - II

Physics

Paper: MPC-25

(Nuclear Physics)

Time: Three Hours **Full Marks: 40**

Questions are of value as indicated in the margin.

Answer ***any four*** questions

1. (a) The following atomic masses have been determined (in amu):
(i) 7Li: 7.0182, 7Be: 7.0192
(ii) 13C: 13.0076, 13N 13.0100
(iii) 19F: 19.0045, 19Ne: 19.0080
(iv) 34P: 33.9983, 34S: 33.9978
Remembering that the mass of the electron is 0.00055 amu, indicate which nuclide of each pair is unstable, its mode(s) of decay, and the approximate energy released in the disintegration.

(b) For deuteron, the maximum value of the spin, $S = 1\hbar$. Give the possible values of the orbital angular momentum quantum number l ?

(c) At a center-of-mass energy of 5 MeV, the phase describing the elastic scattering of a neutron by a certain nucleus has the following values: $\delta_0=30^\circ$, $\delta_1=10^\circ$. Assuming all other phase shifts to be negligible, plot $d\sigma/d\Omega$ as a function of scattering angle. Explicitly calculate values at 30°, 45° and 90°. What is the total cross section σ ? [5+1+4]

2. (a) Describe briefly the energy spectra of alpha- and beta-particles emitted by radioactive nuclei. Emphasize the differences and qualitatively explain the reasons for them. Draw a schematic diagram of an instrument which can measure one of these spectra. Give numerical estimates of essential parameters and explain how they are chosen.

(b) To study nuclear properties, one employs electrons, protons and neutrons as probes. What are the criteria in selecting the probe ? Explain. What is your opinion using photons for this purpose ?

(c) Using Bohrś arguments, deduce a relation of stopping power with the velocity for a heavy charged particle while passing through a target material. [4+2+4]

3. (a) What is the size of a nucleus ? Mention the different methods of estimating the nuclear size and describe any one in detail.

(b) If the nuclear force is charge-independent and a neutron and proton form a bound state, why then there is no bound state for two neutrons ? What information does this provide on nucleon-nucleon force ?

(c) Chlorine-33 decays by positron emission with end-point energy of 4.3 MeV. Calculate the radius of the nucleus. [5+2+3]

4. (a) It is found from experiments that deuteron possesses both magnetic dipole moment and electric quadrupole moment. Give those values and write a note on its implication.

(b) Give evidences and/or arguments to prove that (i) the nuclear forces show saturation, (ii) the nuclear forces are of exchange type and are partly non-central.

(c) Determine the magnetic moment of the deuteron in $^3D_1$ state and show that a few percent admixture of this state into the $^3S_1$ state gives the measured magnetic moment.

[2.5+2.5+5]

P.T.O.

5. A more realistic nuclear charge distribution is given by the Fermi distribution:

$$\rho(r) = \rho_0 [1+\exp\{(r-R)/a\}]^{-1}.$$

(a) Sketch this distribution and find the value of a if $r = 2.3$ Fermi.

(b) What is the significance of the parameter R ?

(c) Show that the parameter $a = t/4.4$, where t is the radial distance between the points in the nucleus where charge densities are respectively, 10% and 90% of the maximum value.

(d) Evaluate $\langle r^2 \rangle$ according to Fermi charge distribution and spherical charge distribution. [2+1+3+4]

6. (a) Explain how the relationship between the alpha decay constant (λ) and energy $E(\lambda)$ is explained quantum-mechanically. Show also how it is possible to explain the extremely rapid dependence of λ on $E(\lambda)$.

(b) Use the uncertainty principle to estimate the minimum speed and kinetic energy of an alpha particle confined to the interior of a heavy nucleus.

(c) In Rutherfordś scattering experiment, the number of alpha particles is observed at a rate of 1 MHz at an angle of 10°. What will be the number observed at angles of 90° and 180° ?

[5+2.5+2.5]
