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3 (Sem–5/CBCS) PHY HE 5

2022

PHYSICS

(Honours Elective)

Paper : PHY–HE–5056

(Nuclear and Particle Physics)

Full Marks : 80

Time : Three hours

The figures in the margin indicate full marks for the questions.

1. Give short answers to the following questions : ***(any ten)*** 1×10=10

   (a) If the nuclear radius of ^{27}Al is 3·6 Fermi, find the approximate nuclear radius of ^{64}Cu in Fermi.

   (b) Which one is having maximum binding energy ^{56}Fe *or* ^{208}Pb ?

   (c) Is the nuclear force spin dependent ?

Contd.

(d) What is the meaning of non-zero value of quadrupole moment of a nucleus?

(e) Will there be any difference between energy spectra of electrons and positrons in β-decay process?

(f) What is radioactive decay represented by the following nuclear reaction

$${}^{A}_{Z}X \rightarrow {}^{A}_{Z-1}A + {}^{0}_{e}e + \nu \text{ ?}$$

(g) What would be the energy spectra of neutrino in electron capture process?

(h) What happens to atomic number, mass number and actual mass when a nucleus emits gamma ray photon?

(i) If the Q-value of a nuclear reaction is zero, what does it represent?

(j) Complete the nuclear reaction

$${}^{35}_{17}Cl + \_\_ \rightarrow {}^{32}_{16}S + {}^{4}_{2}He.$$

(k) What is the type of nuclear reaction represented by ${}^{16}_{8}O\left({}^{2}_{1}H,\ {}^{3}_{1}H\right){}^{15}_{8}O$?

(l) Why pair production cannot take place in free space?

(m) What is the minimum energy of gamma ray photon to undergo pair production?

(n) What does the asymmetry term in semi empirical mass formula represent?

(o) According to the meson field theory a neutron emits a π^- meson and is converted into a proton. Is the statement true?

(p) What is the significance of magic number?

(q) What is the strongest force in nature?

(r) What are the particles responsible for mediating strong and electromagnetic interaction?

2. Briefly answer the following questions : ***(any five)*** 2×5=10

(a) Calculate the binding energy of a deuteron nucleus? Given, mass of deuteron = 2·013553 *a.m.u* , mass of proton = 1.007276 *a.m.u*, and mass of neutron = 1.008665 *a.m.u*.

(b) What is the saturation property of nuclear force?

(c) Why neutron number exceeds proton number in the medium and heavy nuclei ?

(d) What is mass defect and packing fraction ?

(e) How are the energy spectra of alpha particle different from that of beta particle and why?

(f) A beam of mono energetic gamma rays is incident on an aluminum sheet of thickness 10 *cm*. The sheet reduces the intensity of the beam to 21 per cent of the original. Calculate the linear and mass absorption co-efficient, given density of $Al = 2700\, kg/m^3$.

(g) What is quenching of a GM counter ?

(h) What is Cherenkov radiation ?

(i) What are strange particles ? How are the strangeness quantum number, baryon number, and the third component of isotopic spin related to the charge of the elementary particle ?

(j) The quark composition of π^- is $\bar{u}d$ and that of proton is *uud*. Show that these compositions give the required charge, baryon number, strangeness and spin of the respective particles.

3. Answer ***any four*** of the following : 5×4=20

(a) How the release of large amount of energy during fission and fusion can be explained from binding energy per nucleon against mass number curve ?

(b) What are the characteristics of nuclear force ?

(c) (i) What is meson theory of nuclear force ?

(ii) How it can be established that mass of π meson is almost 275 times that of electron ?

(d) (i) Give a brief outline of the determination of the energy of α-particle experimentally.

(ii) An α-particle from radioactive nuclei travel along a semicircle of radius 20 cm in a magnetic field of flux density 1·763 web/m^2. Find the velocity and energy of the particles. Given, e/m for α-particle $= 4{\cdot}824 \times 10^7 Ckg^{-1}$, Mass of α-particle $= 6{\cdot}643 \times 10^{-27} kg$.

(e) How neutrino hypothesis explains continuous nature of β-spectrum?

(f) What are the *three* key features used in the detection of nuclear radiation?

(g) (i) What is the most serious limitation of the action of cyclotron?

(ii) What is the advantage of linear accelerator over cyclotron?

(h) (i) What are leptons?

(ii) How many leptons are there? Write their names.

4. Answer the following questions : ***(any four)*** 10×4=40

(a) (i) Write the semi empirical mass formula and explain its various terms.

(ii) Using semi empirical mass formula, show that the atomic number (Z) of the most stable nucleus (A) is given by

$$Z = \frac{A}{2 + 0{\cdot}0157\, A^{2/3}}$$

The best values of constants in semi-empirical mass formula, expressed in MeV are

$a_v = 15{\cdot}760$, $a_s = 17{\cdot}810$, $a_c = 0{\cdot}711$, $a_{asym} = 23{\cdot}702, \delta = 0$ 5+5=10

(b) (i) What are the significant similarities between a drop of liquid and an atomic nucleus?

(ii) What are the evidences of shell model of nucleus? 5+5=10

(c) (i) What is the range of alpha particles?

(ii) What is Geiger-Nuttall law?

(iii) Justify that the radioactive element of large decay constant emits high energy alpha particles.

(iv) Given that the range, in standard air, of the alpha particles from radium ($T_{1/2}$ = 1622 years) is 3·36 *cm.*, whereas, from polonium ($T_{1/2}$ = 138 days) his range is 3·85 *cm.* Calculate the half-life of *RaC* for which the alpha particle range is 6·97 *cm.*

2+2+2+4=10

(d) (i) What is alpha disintegration energy?

(ii) Calculate the kinetic energy of alpha particle in the following decay

$$Pu^{239} \rightarrow U^{235} + He^{4}$$

Given,

$M(Pu^{239})$ = 239·052158 *MeV,*

$M(U^{235})$ = 235·043925 *MeV,*

$M(He^{4})$ = 4·002603 *MeV*

(iii) Give the quantum mechanical explanation of alpha decay.

3+3+4=10

(e) (i) What are different types of nuclear reactions?

(ii) What are the conservation laws applicable to a nuclear reaction?

5+5=10

(f) (i) Define *Q*-value of a nuclear reaction?

(ii) What is exoergic and endoergic reaction?

(iii) Find the *Q*-value and threshold energy for the reaction

$$^{19}F(n, p)\ ^{19}O.$$

Given, atomic masses are

^{19}F = 18·99840 *amu,*

$^{1}_{1}H$ = 1·007825 *amu,*

^{19}O = 19·003577 *amu,* and

$^{1}_{0}n$ = 1·008665 *amu.*

4+2+4=10

(g) (i) What is dead time, resolving time, and recovery time of GM counter?

(ii) A GM counter has dead time 400 μs. What are the true counting rates when the observed rates are *(i)* 100 per minute, and *(ii)* 1000 per minute? 7+3=10

(h) (i) What is the basic resonance condition of a fixed frequency cyclotron ?

(ii) Why a cyclotron is not suitable for energizing an electron ?

(iii) What is the energy to which protons can be accelerated in a cyclotron with a dee-dia of 2 m and a magnetic field of flux density 0.72 Wb/m^2? Mass of proton = $1{\cdot}673\times10^{-27}kg$. 5+2½+2½=10

(i) (i) What are hadrons ?

(ii) A μ^- meson decays into an electron (e^-) and a pair of neutrinos $(\nu_\mu, \overline{\mu_e})$. Calculate the maximum available energy for the process and the average electron energy. Assume $m_e = 207m_\mu$.

(iii) Check if the reaction $\pi^- + p \rightarrow \Lambda^0 + K^0$ is allowed or forbidden ? 5+2½+2½= 10

(j) (i) What are fundamental interactions in nature?

(ii) What do you mean by quarks ? How many possible quarks are there ? Give the charge and quantum number associated with each quark. 5+5=10