2018

PHYSICS

(Major)

Paper : 6.1

(Nuclear Physics)

Full Marks : 60

Time : 3 hours

The figures in the margin indicate full marks for the questions

1. Give short answers to the following questions : 1×7=7

(a) Why do heavy nuclei have more neutrons than protons?

(b) Between the two given nuclei ${}_3X^7$ and ${}_3Y^4$, which one is more stable? Give reason.

(c) Which conservation law is violated in the nuclear reaction given below?

$${}_0n^1 \rightarrow {}_1H^1 + {}_{-1}e^0$$

(d) Why cannot electron-positron pair production process occur in vacuum?

(e) Give the names of the three processes which are mainly responsible for absorption of γ-rays.

(f) What is the reason for variation of cosmic ray intensities in the equatorial and polar regions of earth?

(g) Why are the nuclei so small as compared to the atoms?

2. Briefly answer the following questions : $2\times4=8$

(a) Why is it necessary to emit a neutrino in the process of β-disintegration from the point of view of statistics conservation?

(b) Show that the ratio of radii of nuclei ${}_{13}Al^{27}$ and ${}_{52}Te^{125}$ is approximately 6 : 10.

(c) In Compton scattering, incident γ-ray is scattered through an angle of 60°. Find the wavelength of incident γ-ray, if wavelength of scattered γ-ray is 0·250 Å.

(d) Give two successes of nuclear shell model.

3. Answer any *three* of the following : 5×3=15

(a) *(i)* What are magic numbers? Why are they so called? 2

(ii) Nuclei with magic number of protons and magic number of neutrons are found to be stable. Verify this by calculating proton separation energy S_p for ${}_{50}Sn^{120}$ and ${}_{51}Sb^{121}$. Given

$S^{119} = 118 \cdot 9058$ u, $Sn^{120} = 119 \cdot 902199$ u, and ${}_1H^1 = 1 \cdot 0078252$ u. 3

(b) *(i)* What are secondary cosmic rays? Give the compositions of secondary cosmic rays. 2

(ii) What are 'latitude effect' and 'longitude effect' of cosmic rays? 3

(c) *(i)* How does the emission of β-particles differ from that of α-particles in respect to the spectrum of the energies of the emitted particles? 2

(ii) "The electron line spectrum is related to the emission of γ-radiation rather than to the process of β-decay." Explain. 3

(d) If the counter-size and pressure are large enough for all proton energy to be absorbed, what will be the number of ion-pairs produced in a gas-filled detector by a 10 MeV proton? If the gas multiplication factor is 10^3, calculate the amount of charge flow in the counter when the proton is absorbed. If the pulse of current flows for 10^{-3} sec, and if the resistance is 10^4 ohm, find the pulse-height of the voltage pulse. Assume, energy required for the production of one ion-pair as 35 eV. 5

(e) Distinguish between nuclear fission and fusion. Why are neutrons moderated to thermal speed in nuclear reactor?

A reactor is developing energy at the rate of 32×10^6 watt. How many atoms of U^{235} undergo fission per second? Assume that on the average, an energy of 200 MeV is released per fission.

2+1+2=5

4. Answer any *three* of the following questions : 10×3=30

(a) What is meant by 'resonance acceleration' in cyclotron?

Show that the frequency of the applied high-frequency voltage is independent of the radius of the circular path, but proportional to magnetic induction field and specific charge of ion to be accelerated using a cyclotron.

A fixed frequency cyclotron has an oscillatory frequency of 12 MHz and dee radius of 0·55 m. If it is used to accelerate deuteron, what magnetic flux density is required? What will be the energy up to which a deuteron can be accelerated? Given, mass of deuteron is equal to $3 \cdot 34245 \times 10^{-27}$ kg.

Mention one of the limitations of fixed frequency cyclotron. 2+3+4+1=10

(b) What are mirror nuclei? Give two examples.

Derive an expression for β-disintegration energy of mirror nuclei using semi-empirical mass formula. How can you find the nuclear radius parameter from it?

Give an example of stable isobaric pair at odd mass number. 1+1+5+2+1=10

(c) Write short notes on any *two* of the following : 5×2=10

(i) Origin of cosmic rays

(ii) Nucleon-Nucleon forces

(iii) Liquid drop model of nucleus

(iv) β-ray spectrum

(v) Gamma rays and their origin

(d) (i) Show that nuclear matter density is a constant quantity.

Calculate the neutron and proton densities in a nucleus with $N = Z$. Given :

$$R_0 = 1 \cdot 2 \times 10^{-15} \text{m}$$ 2+2=4

(ii) Explain three terms of Bethe-Weizsäcker mass formula which contribute to the binding energy of a nucleus. 6

(e) (i) Discuss the principle of detection of charged particles.

Mention two processes by which a neutron can eject positively charged nuclei. 3+2=5

(ii) What are exoergic and endoergic nuclear reactions? Give examples. Write the equations of proton-proton chain of thermonuclear reaction. 2+1+2=5

(f) (i) Why is alpha decay a classically forbidden phenomenon? Draw a graph showing Coulomb potential barrier of α-decay. What is quantum mechanical tunnel effect? 2+2+2=6

(ii) What is nuclear energy level? What is meant by α-disintegration energy? Show that α-disintegration energy E_α can be expressed as

$$E_\alpha = \frac{1}{2} M v^2 \left(1 + \frac{M}{M_r}\right),$$

where M is the mass and v is the velocity of the α-particle, M_r is the mass of residual nucleus. 1+1+2=4

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