2023-24

Time - 3 hours

Full Marks - 80

*Answer **all groups** as per instructions.*
Figures in the right hand margin indicate marks.
Candidates are required to answer
in their own words as far as practicable.

GROUP - A

1. Answer (all) questions by choosing the correct answer from the given alternatives. [1 × 12

(a) Neutrino is :

(i) Chargless and has no spin

(ii) Chargless and has spin

(iii) Charged like electron and spin

(iv) Uncharged but has mass nearly that of proton

(b) The radius of a nucleus (r) depends on mass number A of the nucleus as :

(i) $r = r_0 A^{2/3}$ (ii) $r = r_0 A^{1/3}$

(iii) $r = r_0 A^{-1/3}$ (iv) $r = r_0 A^{-2/3}$

(c) The maximum energy of a proton beam that can be achieved using a cyclotron of radius 0.4 m and magnetic field of 1.5 weber/m^2 is (take mass of proton as 1.6×10^{-27} kg) :

(i) 5.2 MeV (ii) 8.5 MeV

(iii) 12.7 MeV (iv) 17.3 MeV

(d) In the process of electron capture :

(i) Neutron converts to a proton

(ii) Proton converts to a neutron

(iii) Neutron emits a positron

(iv) Proton emits a positron

(e) Determine which of the following reactions are possible ?

1. $\pi^+ + n^0 \rightarrow \Lambda^0 + K^+$

2. $\pi^+ + n^0 \rightarrow K^0 + K^+$

(i) Only reaction 1 is allowed.

(ii) Only reaction 2 is allowed.

(iii) Both reactions are allowed.

(iv) Both the reactions are not allowed.

(f) After 10 hours, the radioactivity of a nuclide is 1/8 times its original level. The half life of the sample is :

(i) 5 hours (ii) 2.5 hours

(iii) 1.25 hours (iv) 0.625 hours

(g) The approximate amount of energy that is obtained when mass of one proton is converted to energy :

(i) 200 MeV (ii) 511 MeV

(iii) 725 MeV (iv) 931 MeV

(h) A radioactive nucleus (initial mass number A and atomic number Z) emits three α-particles and two positrons. The ratio of the number of neutrons to that of protons in the final nucleus will be :

(i) $\frac{A-Z-8}{Z-4}$ (ii) $\frac{A-Z-4}{Z-8}$

(iii) $\frac{A-Z-12}{Z-4}$ (iv) $\frac{A-Z-4}{Z-2}$

(i) When $^{7}_{3}Li$ nuclei are bombarded by protons and the resultant nuclei and $^{8}_{4}Be$, the emitted particles will be :

(i) gamma photons (ii) neutrons

(iii) alpha particles (iv) beta particles

(j) A linear accelerator accelerating protons consists of 200 drift tubes. If the injection energy of each proton is 2 MeV, then the final energy attained by each proton is :

(i) 60 MeV (ii) 45 MeV

(iii) 32 MeV (iv) 24 MeV

(k) Which among the following is a massless boson ?

(i) Graviton (ii) Proton

(iii) Electron (iv) Meson

(l) The quadrupole moment of a spherical nuclei containing equal number of protons and neutrons and in which the protons are rotating in x-y plane is :

(i) Zero (ii) Positive

(iii) Negative

(iv) Can be positive or negative

GROUP - B

2. Answer any eight of the following within two or three sentences each. [2 × 8

(a) Write the factors that contribute to nuclear stability significantly.

(b) Outline two points of difference between shell model and liquid drop model.

(c) State important features of nuclear forces.

(d) State Geiger-Nuttal law.

(e) If a star can convert all the helium nuclei completely into oxygen nuclei, estimate the energy released per formation of a new oxygen nuclei (Take mass of He nucleus as 4.0026 amu and mass of oxygen nucleus as 15.9994 amu.)

(f) How do you define 'acitivity' in context of a radioactive element ? What is its SI unit ?

(g) What are Quarks ? What is the charge and spin of up (u) quark ?

(h) Write down the demerits of a linear accelerator ?

(i) State law of radioactive decay. Write down its mathematical form.

(j) What are the basic assumptions of Shell model ?

GROUP - C

3. Answer any eight of the following within 75 words each. [3 × 8

(a) What is the principle of working of a Cyclotron ? What are its demerits ?

(b) Explain how a semiconductor detector works ?

(c) Draw a graph showing variation of binding energy per nucleon as a function of mass number of nuclei and outline its importanrt features.

(d) What the term isospin indicates ? What is its importance ? Why isopin numbers are not associated with leptons ?

(e) What do you mean by parity ? In the processes involving what type of interactions the parity is seen to be conserved ?

(f) What do you mean by Q-value of a nuclear reaction ? Write down its expression ? How from Q-value, one can know the reaction to be endothermic or exothermic ?

(g) What is the principle of working of a Scintillation counter ? What are its advantages ?

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

(i) Though neutron is neutral, yet it has a magnetic moment. What is the value of this magnetic moment ? How can you give an account of it ?

(j) Theoretically quarks are supposed to be very heavy, much heavier than nucleons. But known properties of strongly interacting particles suggest that mass of quark is about one third of mass of proton. Give an account for this discrepancy.

GROUP - D

4. Answer any four of the following within 500 words each.

(a) State the semi-empirical mass formula explaining the significance of various terms. Use it to discuss stability limit of heavy nuclei. What are its limitations ? [4+2+1

(b) With a neat schematic diagram discuss the construction and working of a Van de Graff generator. [7

(c) Discuss the principle and working of a GM counter. What are its merits and demerits ? [7

(d) Give a brief outline on Shell model of the nucleus. Explain the role of magic numbers and quadrupole moments. [7

(e) Discuss Gamow's theory of α-decay and hence obtain the expression for transmission probability of α-particle from a nucleus. [7

(f) What are β-rays ? Discuss the important features of β-ray spectra emitted by radioactive nuclides. What is neutrino hypothesis in β-decay process and why it is required ? [1+4+2

(g) (i) Write a note on classification of elementary particles. [3½

(ii) Give a brief note on the different types of interactions that the elementary particles can undergo. [3½