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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 of any of the seven questions from the following : 1×7=7
- (a) What do you mean by exothermic and endothermic nuclear reactions?
 - (b) Give one evidence that nuclear force is saturative and short-ranged.
 - (c) How did the concept of non-central nuclear force conceive from the interaction between two particles?
 - (d) Explain why a cylindrical geometry is always preferred over parallel-plate geometry for making a gas detector.

- (e) Write two achievements of shell model over liquid-drop model.
- (f) Define elastic, inelastic and transfer reactions in terms of Q -values of a reaction.
- (g) Why can electron not exist inside the nucleus?
- (h) Draw a β -decay spectrum and locate the position of β -particle and neutrino (or anti-neutrino).

2. Briefly answer the following (any four) : $2 \times 4 = 8$

- (a) Write down the Compton's scattering formula for the energy of the scattered photons. Hence, calculate the Compton edge (in MeV) for an electron.
- (b) Write down the conditions for positive β -decay and negative β -decay. Also plot the nature of each spectrum.
- (c) Explain why out of ${}^6_2\text{He}$, ${}^6_4\text{Be}$ and ${}^6_3\text{Li}$, only the last one is stable.
- (d) What are the compositions of primary and secondary cosmic rays?
- (e) "To study a nuclear reaction, an accelerator is must." Explain the statement with an argument.

3. Answer any *three* of the following : $5 \times 3 = 15$

- (a) Consider the following mass formula for a nucleus with Z protons and $(A-Z)$ neutrons :

$$M(A, Z) = 0.99395A - 0.00084Z + 0.0144A^{2/3} + 0.021 \frac{(A-2Z)^2}{A} + 0.00063 \frac{Z^2}{A^{1/3}}$$

Based on this formula, show that the nucleus can spontaneously break into two identical nuclei each with $Z/2$ protons and $\frac{1}{2}(A-Z)$ neutrons provided $Z^2/A \geq 16$.

- (b) Show that nuclear density of proton (${}^1_1\text{H}$) is about 10^{14} times greater than the atomic density of proton (${}^1_1\text{H}$). Assume, the atom to have the radius of 1st Bohr orbit (i.e., 0.53 \AA).
- (c) Draw the circuit diagram of a gas-filled detector. Assume, a 5.486 MeV α -particle is placed in front of a gas detector and ion-pairs are formed and signals are seen in an oscilloscope. Find the pulse height generated across the anode of the detector (in m volts). Consider the energy needed for one ion-pair formation is about 30 eV and to capacitance of the circuit is 2 picofarad .

- (d) Explain the theory of Pauli's neutrino hypothesis during the decay of a neutron to proton, and vice versa. Explain their significance. Neutrino and neutron are both chargeless and massless particles. Do you think that a neutron detection technique is applicable for neutrino? Explain.

4. Answer any *three* of the following : $10 \times 3 = 30$

- (a) Explain the first three terms of Bethe-Weissacker semi-empirical mass formula. Also plot them in a graph for the variation of binding energy per nucleon (BE/A) as a function of atomic mass number. Which part is contributing more to the binding energy of the nucleus? Also, calculate the BE/A of a ${}^{40}_{20}\text{Ca}$ nuclei by using the semi-empirical formula. $3+3+1+3=10$

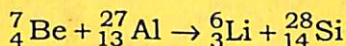
- (b) (i) Draw the pulse height characteristics of a gas-filled detector and explain significance of each region. 5

- (ii) Explain the working principle of a linear accelerator. If a particle with kinetic energy E_{in} is subjected to pass through a linear accelerator of drift tube length (L) of n numbers of such types, show that the energy of the incident particle at the outgoing part is \sqrt{n} times the incident energy (E_{in}). 5

(c) (i) Define the impact parameter during a nuclear reaction between a projectile and a target. Classify the types of nuclear reaction in terms of impact parameter, incident energy and incident angle. 5

(ii) Define fusion barrier between two nuclei. Draw the effective potential graph (Coulomb and nuclear) during the process of interaction. Calculate the Coulomb barrier energy between ${}^7_4\text{Be}$ and ${}^{27}_{13}\text{Al}$ nuclei.

Also, calculate the Q -value of the following reaction :



Given,

$$m({}^6\text{Li}) = 6.015123 \text{ u}$$

$$m({}^7\text{Li}) = 7.016004 \text{ u}$$

$$m({}^{27}\text{Al}) = 26.981541 \text{ u}$$

$$m({}^{28}\text{Si}) = 27.966928 \text{ u}$$

(d) (i) How does the energy production take place in sun or stars? Write down various steps involved in pp-chain reaction in sun and obtain the final balance equation for energy production. Do you think that a star can be generated in the laboratory? 5

4+1=5

- (ii) What are the basic differences between a charged particle and gamma radiation in terms of energy loss?

Explain in brief various processes that a gamma particle can interact with matter.

- (e) Write short notes on any *two* of the following :

- (i) Shell model
(ii) The East-West effect, altitude effect and longitude effect of cosmic rays
(iii) Yokawa's meson theory
(iv) Nuclear fission and nuclear reactor—as an alternative source of power

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