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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*) : 2×4=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 ${}^{6}_{2}\mathrm{He}$, ${}^{6}_{4}\mathrm{Be}$ and ${}^{6}_{3}\mathrm{Li}$, 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 : 5×3=15

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

$$M(A, Z) = 0{\cdot}99395A - 0{\cdot}00084Z + 0{\cdot}0144A^{2/3} + 0{\cdot}021\frac{(A-2Z)^2}{A} + 0{\cdot}00063\frac{Z^2}{A^{1/3}}$$

Based on this formula, show that the nucleus can spontaneously breaks 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 ($^1_1$H) is about 10^{14} times greater than the atomic density of proton ($^1_1$H). Assume, the atom to have the radius of 1st Bohr orbit (i.e., 0·53 Å).

(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 : 10×3=30

(a) Explain the first three terms of Bethe-Weisackar 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 ${}_{4}^{7}\mathrm{Be}$ and ${}_{13}^{27}\mathrm{Al}$ nuclei.

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

$$ {}_{4}^{7}\mathrm{Be} + {}_{13}^{27}\mathrm{Al} \rightarrow {}_{3}^{6}\mathrm{Li} + {}_{14}^{28}\mathrm{Si} $$

Given,

$$ m({}^{6}\mathrm{Li}) = 6 \cdot 015123\ u $$

$$ m({}^{7}\mathrm{Li}) = 7 \cdot 016004\ u $$

$$ m({}^{27}\mathrm{Al}) = 26 \cdot 981541\ u $$

$$ m({}^{28}\mathrm{Si}) = 27 \cdot 966928\ u $$

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(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? 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. 5

(e) Write short notes on any *two* of the following : 10

(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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