Jadavpur University
Master of Nuclear Engineering
First Semester Examination 2024
Subject : Concepts in Nuclear Science

Time : Three Hours | Full Marks : 100

All sections are compulsory

[20]

Section A

- **All questions are compulsory and carry equal marks (2 each).**

1.a Define the term "packing fraction".
1.b Define Atomic Mass Unit. What is the mass of ^{12}C in this system of unit.
1.c Explain the relevance of the term "wave packet".
1.d A 10 bit ADC can accept and analog signal of 0 – 5 V. What is the voltage binning capacity of the ADC.
1.e Define "W" value for a radiation detector.
1.f What is the highest energy to which a doubly charged Helium ion (q=2e) can be accelerated with a potential difference of 3 MV. Express your answer in Joule
1.g Why do X-rays have a lower energy compared to gamma-rays.
1.h How many 5 MeV alpha particles are required to deposit a total energy of 1 Joule.
1.i Define "cross section". What is it's unit.
1.j How is the nuclear radius related to the scattering cross section.

[20]

Section B

- **Attempt any 4 questions.**
- **All questions carry equal marks (5 marks each)**

2.a Calculate the energy of 1 MeV gamma photon after Compton scattering through 90^0.
2.b The BE for ^{238}U (Z=92) nucleus is 1760 MeV, given m_{proton} = 1.0078 a.m.u, $m_{neutron}$= 1.0086 a.m.u compute m_U (mass of ^{238}U) in a.m.u
2.c You are provided with a gas detector whose W value = 50 eV. A charged particle whose energy is 5 MeV is incident on this detector, which in turn is connected to a pre-amplifier whose capacitance is 20 pico-farad. Compute the voltage of the output pulse.
2.d Calculate the energy of the emitted alpha particle, using the following data : $^{232}_{92}U : mass = 232.037156\ u$; $^{228}_{90}Pa : mass = 228.028715\ u$; ; $^{4}_{2}He : mass = 4.002603\ u$
2.e How much energy would be required to assemble U_{92}^{238} nucleus, given m_U = 238.05078826 u, m_{proton}= 1.0078 a.m.u, $m_{neutron}$= 1.0086 a.m.u for individual and independent components. From this information compute the Packing fraction for this nucleus
2.f Prove that the nuclear density is identical for all nuclei (independent of "A"). If earth were to have the same density as that of the nucleus, and it's mass is $6 \times 10^{24}\ kg$, then compute the radius of the earth.

Section C

[60]

- **Attempt any 4 questions.**
- **Attempt all the sub-questions within a given question.**
- **All questions carry equal marks (15 marks each)**

3.a How is the mass of a particle related to its velocity. Prove that for $v \leq c$, the particle be considered classically *i.e* the mass does not depend on the velocity. [8]

3.b Prove that $p = \frac{1}{c}\sqrt{E_{total}^2 - E_{rest}^2}$, where "p" denotes the momentum. [4]

3.c Justify the statement "the nucleus is the central, massive, dense component of the atomic nucleus". [3]

4.a Justify in detail the statement "Semiconductor detector is a fully depleted reverse biased junction". [6]

4.b Draw and label the various components of a typical radiation counting system. [3]

4.c Explain in why the "amplifier" in a nuclear counting system is referred to as "shaping" amplifier. What is the typical SNR for the output of an amplifier. [4]

4.d What do you understand by the term "efficiency" of a radiation detector. What is the typical energy resolution for a scintillator detector. [2]

5.a Why do we have Nuclear Models. Name the two nuclear models which are routinely referred to in the study of the nucleus. Briefly discuss the Liquid Drop Model of the nucleus, and detail the expression for the Binding Energy for a nucleus based various terms of the Semi – Empirical Mass Formula of Bethe and Weizsacker. Explain why does certain terms have negative coefficients. [10]

5.b. Explain the occurrence of discrete energy levels for a nucleus. [3]

5.c Sketch the nuclear potential as a function of "r" [2]

6.a State de-Brogile's hypothesis. Why do microscopic particles have a considerable wave like property. [4]

6.b Based on the de-Brogile's hypothesis work out the wavelength for a thermal and fast neutron (7 MeV). [4]

6.c Plot the various operating regions of a gas detector. [4]

6.d Define the term "Activity" for a radioactive sample. Define 1 Curie. [3]

7.a Define the term "Exposure". What are the conventional and SI units for Exposure. Prove that 1 Roentgen of radiation is that quantity in which 83.8 ergs of energy is absorbed per gram of air. [11]

7.b How much time would a thermal neutron take to traverse a nucleus with A = 27. [4]

8.a Define the Law of Radioactive Decay and obtain an expression for the number of decayed atoms at time t, if N_0 , λ, represent the initial number of radioactive atoms and decay constant respectively. When do you expect all the radioactive atoms to decay, *i.e.* we have no surviving atoms. Show that after 6 half-lives most of the radioactive nuclei have decayed. [8]

8.b For a successive disintegration show that [7]

$$N_2 = \frac{N_0 * \lambda_1}{\lambda_2 - \lambda_1}\left\{e^{-\lambda_1 t} - e^{-\lambda_2 t}\right\}$$

Where the symbols have their usual meaning. What do you understand by the terms "secular" and "transient" equilibrium.