Saitech Informatics

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NUCLEAR PHYSICS

Class 12 - Physics

Time Allowed: 1 hour and 29 minutes **Maximum Marks: 45**

1. Why is neutron so effective as bombarding particles? **[1]**
2. What is the nuclear radius of Fe^{125}, if that of Al^{27} is 3.6 fermi? **[1]**
3. The isotope ${}^{16}_{8}O$ has 8 protons, 8 neutrons and 8 electrons while ${}^{8}_{4}Be$ has 4 protons, 4 neutrons and 4 electrons. Yet the ratio of their atomic masses is not exactly same. Why? **[1]**
4. Two nuclei have mass numbers in the ratio 1: 8. What is the ratio of their nuclear radii? **[1]**
5. Write the relation for binding energy (BE) (in MeV) of a nucleus of mass ${}^{A}_{Z}M$, atomic number (Z) and mass number (A) in terms of the masses of its constituents - neutrons and protons. **[1]**
6. Is the nuclear density the same for all elements? **[1]**
7. Name the quantities that are conserved in a nuclear reaction. **[1]**
8. Calculate the energy in the fusion reaction: **[1]**
   ${}^{2}_{1}\mathrm{H} + {}^{2}_{1}\mathrm{H} \longrightarrow {}^{3}_{2}\mathrm{He} + n$
   where BE of ${}^{2}_{1}\mathrm{H} = 2.23\mathrm{MeV}$ and ${}^{3}_{2}\mathrm{He} = 7.73\mathrm{MeV}$
9. The carbon isotope ${}^{12}_{6}C$ has a nuclear mass of $12 \cdot 000000u$. Calculate the binding energy of its nucleus. **[1]**
   Given $m_p = 1.007825u; m_n = 1.008665u$.
10. What is nuclear fusion? Explain, how such a large amount of energy is produced inside the sun through proton-proton cycle and carbon-carbon cycle. **[1]**
11. What is a moderator? Explain its action in slowing down the neutrons. **[3]**
12. i. Write the process of β^- decay. How can radioactive nuclei emit β^- particles even though they do not contain them? Why do all electrons emitted during β^- decay not have the same energy? **[3]**
    ii. A heavy nucleus splits into two lighter nuclei. Which one of the two-parent nuclei or the daughter nuclei has more binding energy per nucleon?
13. The nucleus ${}^{235}_{92}\mathrm{Y}$, initially at rest, decays into ${}^{231}_{90}\mathrm{X}$ by emitting an α-particle **[3]**
    ${}^{235}_{92}Y \rightarrow {}^{231}_{90}X + {}^{4}_{2}He + energy$
    The binding energies per nucleon of the parent nucleus, the daughter nucleus and α-particle are 7.8 MeV, 7.835 MeV and 7.07 MeV, respectively. Assuming the daughter nucleus to be formed in the unexcited state and neglecting its share in the energy of the reaction, find the speed of the emitted α-particle. (Mass of α-particle = 6.68×10^{-27} kg).
14. Draw a graph showing the variation of binding energy per nucleon with mass number of different nuclei. Write any two salient features of the curve. How does this curve explain the release of energy both in the processes of nuclear fission and fusion? **[3]**
15. Write symbolically the nuclear β^+ decay process of ${}^{11}_{6}C$. Is the decayed product X an isotope or isobar of ${}^{11}_{6}\mathrm{C}$? **[3]**
    Given the mass values $m\left({}^{11}_{6}\mathrm{C}\right)$ = 11.011434 u and m(X) = 11.009305 u. Estimate the Q-value in this process.
16. State the principle involved in a nuclear reactor. Draw a labelled diagram of a nuclear reactor and explain the **[5]**

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functions of moderator, control rods and coolant in it.

17. i. Draw the plot of binding energy per nucleon (BE/ A) as a function of mass number A. Write two important conclusions that can be drawn regarding the nature of nuclear force. **[5]**

ii. Use this graph to explain the release of energy in both the processes of nuclear fusion and fission.

iii. Write the basic nuclear process of neutron undergoing β-decay. Why is the detection of neutrinos found very difficult?

18. a. The observed decay products of a free neutron are a proton and an electron. The emitted electrons are found to have a continuous distribution of kinetic energy with a maximum of $(m_n - m_p - m_e)\, c^2$. Explain clearly why the presence of a continuous distribution of energy is a pointer to the existence of other unobserved products in the decay. **[5]**

b. If a neutron is unstable with a half-life of about 917 seconds, why don't all the neutrons of a nucleus decay eventually into protons? How can a nucleus of Z protons and (A - Z) neutrons ever remain stable, if the neutrons themselves are unstable?

19. Answer the following questions: **[5]**

a. Are the equations of nuclear reactions 'balanced' in the sense a chemical equation (e.g., $2H_2 + O_2 \rightarrow 2H_2O$) is? If not, in what sense are they balanced on both sides?

b. If both the number of protons and the number of neutrons are conserved in each nuclear reaction, in what way is mass converted into energy (or vice-versa) in a nuclear reaction?

c. A general impression exists that mass-energy interconversion takes place only in nuclear reaction and never in chemical reaction. This is strictly speaking, incorrect. Explain.

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