REV-01
MSP/34/17/20

2022/12

SET A

M.Sc. PHYSICS
THIRD SEMESTER
NUCLEAR PHYSICS
MSP – 303

[USE OMR SHEET FOR OBJECTIVE PART]

Duration : 3 hrs. **Full Marks : 70**

(Objective)

Time: 30 min. **Marks: 20**

Choose the correct answer from the following: ***1X20=20***

1. Which of the following about the nuclear force is true?
   a. It is a strong, short-range, attractive force between the nucleons.
   b. It is much weaker than the gravitational force.
   c. It is much weaker than the electromagnetic force.
   d. It is an attractive force between electrons and protons in an atom.

2. Which of the following nuclei is the most stable?
   a. $^{44}_{20}Ca$ b. $^{16}_{8}O$
   c. $^{60}_{28}Ni$ d. $^{204}_{82}Pb$

3. What is the approximate mass number of a nucleus whose radius is measured to be 4.8 fm ?
   a. 110 b. 90
   c. 64 d. 125

4. The contribution of the coulomb energy in the semi-empirical mass formula of a nucleus of mass number A and the atomic number Z is of the form (a is a constant)
   a. $aZA^{2/3}$ b. $\frac{aZ^2}{A^{2/3}}$
   c. $-\frac{a(A-2Z)^2}{A}$ d. $-\frac{aZ(Z-1)}{A^{1/3}}$

5. According to Fermi's theory of allowed beta decay, the energy remains conserved in the decay process, the available energy being shared among the electrons and neutrinos. At the end point i.e. $Q=T_e$, the neutrino energy
   a. becomes equal to the total energy released in the process
   b. becomes equal to the energy of the emitted electrons
   c. becomes equal to the energy of the daughter nucleus
   d. approaches to zero

6. The non conservation of parity in beta decay was first hinted by
   a. Wu and co-workers b. Bohr and Wheeler
   c. Lee and Yang d. Pauli and Fermi

7. The decay chain of the nucleus $^{238}_{92}U$ involves 8 alpha decays and 6 beta decays. The final nucleus at the end of the process will have
   a. $^{224}_{84}Po$
   b. $^{206}_{82}Pb$
   c. $^{206}_{88}Ra$
   d. $^{200}_{76}Os$

8. The missing particle in the following reaction is:
   $^{1}_{1}p \rightarrow {}^{1}_{0}n + ? + \nu$
   a. e^+
   b. e^-
   c. π^+
   d. μ^+

9. The total number of nucleons filling up the shells with energy $\frac{7}{2}\hbar\omega$ are
   a. 12
   b. 8
   c. 20
   d. 6

10. The degenerate states (n, l) corresponding to energy level $\frac{9}{2}\hbar\omega$ are
   a. (2,1)(1,3)
   b. (1,1)(1,2)
   c. (3,0)(2,2)
   d. (2,0)(1,2)

11. The total angular momentum of any shell with an even number of nucleons is
   a. 1
   b. +1/2
   c. 0
   d. -1/2

12. The ground state spin-parity of $^{4}_{2}He$ is
   a. $\frac{1}{2}^+$
   b. $\frac{1}{2}^-$
   c. 0^+
   d. 0^-

13. One way to initiate a fission reaction is to penetrate a large nucleus with a
   a. electron
   b. proton
   c. neutron
   d. photon

14. What is the type of the following nuclear reaction: $^{16}_{8}O + {}^{4}_{2}He \rightarrow {}^{1}_{0}n + {}^{19}_{10}Ne$
   a. (n, α)
   b. (α, n)
   c. (p, n)
   d. (α, p)

15. What is the Q-value of the folllowing reaction?
   $^{14}_{7}N$ (14.003074 u) + $^{4}_{2}He$ (4.002603 u) → $^{1}_{1}p$ (1.007825 u) + $^{17}_{8}O$ (16.999131 u)
   a. 1.191 MeV
   b. -1.191 MeV
   c. $1.279X10^{-3}$ MeV
   d. $-1.279X10^{-3}$ MeV

16. What is the mass of the products of a nuclear fission reaction compared to the mass of the original products?
   a. greater
   b. less
   c. the same
   d. varies according to the reaction

17. The fundamental gauge boson which mediates the strong interaction between two quarks is
   a. photon (γ)
   b. Z^0 boson
   c. Higgs boson (H)
   d. gluon (g)

18. For application of GM counter in cosmic ray studies, the operating point must be
    a. at the starting of the plateau region
    b. at the end of the plateau region
    c. at the middle of the plateau region
    d. outside the plateau region

19. Which of the following is not a magic number?
    a. 2
    b. 8
    c. 28
    d. 40

20. The decay $\pi^- + p \rightarrow \pi^- + K^+$ is forbidden. The conservation law violated here is
    a. conservation of parity
    b. conservation of strangenes
    c. conservation of baryon number
    d. conservation of charge

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Descriptive

Time : 2 hrs. 30mins. Marks : 50

[Answer question no.1 & any four (4) from the rest]

1. Explain in detail Fermi's theory of nuclear beta decay and hence derive an expression for the number of final state electrons in the momentum range p and $p+dp$. 10

2. a. Describe the graphical representation of binding energy per nucleon curve. 3+3+2+2 =10

   b. Write an expression for the semi-empirical mass formula based on liquid drop model explaining each term associated with it.

   c. Compute binding energy per nucleon for $^{235}_{92}U$. *Given mass of* $^{235}_{92}U = 235.04392\ u$, mass of proton, $m_p = 1.0072u$, mass of neutron, $m_n = 1.0086\ u$.

   d. The radius of a $^{60}_{27}Co$ is measured to be 4.8 fm. Calculate the radius of $^{22}_{11}Na$.

3. a. Calculate the total number of shell closure along with the degenerate states $(n.l)$ upto the energy level $\frac{9}{2}\hbar\omega$, and show it in tabular form. 2+4+2+2 =10

   b. Using the shell model, calculate the ground state spin-parity of $^{11}_{5}B$ and $^{16}_{8}O$.

   c. State two differences between nuclear fission and nuclear fusion reactions.

   d. Calculate the Q-value of the following nuclear reaction:
   $^{6}_{3}Li + ^{1}_{0}n \rightarrow ^{3}_{1}H + ^{4}_{2}He$.

4. Explain in detail the Wu's experiment of nuclear beta decay. What important information does it provide about beta decay processes? 8+2=10

5. a. Based on single particle shell model, show that the spin-orbit splitting of the two energy levels with $j = l + \frac{1}{2}$ and $j = l - \frac{1}{2}$ is given by (symbols have their usual meanings) 6+4=10
   $$\Delta\varepsilon_{ls} = \varepsilon_{ls}\left(l + \tfrac{1}{2}\right)\langle\phi(r)\rangle.$$

b. Sketch the sequence of the nuclear energy level for 50 numbers of nucleons according to shell model taking into account spin-orbit interaction.

6. Explain the Bohr-Wheeler theory of nuclear fission and hence derive the expression for critical energy of deformation for lighter nuclei. **10**

7. a. List the fundamental particles of nature with their symbols. Also mention their charge, spin, lepton number and baryon number. **8+2=10**

b. Check whether the following reaction is allowed or forbidden (Using conservation laws of charge, baryon number, lepton number etc):

$$\pi^0 + p \rightarrow \mu^+ + \nu_\mu + n$$

8. a. Draw the characteristic graph of a GM counter with proper labelling. **2+5+3 =10**

b. What do you mean by Townsend avalanche? Explain in detail.

c. Describe briefly the role of the quenching agent in a GM tube.

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