NUCLEAR AND PARTICLE PHYSICS SOLUTIONS

GATE-2010

Q1. The basic process underlying the neutron β-decay is

(a) $d \to u + e^- + \bar{\nu}_e$ (b) $d \to u + e^-$

(c) $s \to u + e^- + \bar{\nu}_e$ (d) $u \to d + e^- + \bar{\nu}_e$

Ans: (a)

Q2. In the nuclear shell model the spin parity of ^{15}N is given by

(a) $\frac{1^-}{2}$ (b) $\frac{1^+}{2}$ (c) $\frac{3^-}{2}$ (d) $\frac{3^+}{2}$

Ans: (a)

Solution: $Z = 7$; $(s_{1/2})^2$ $(p_{3/2})^4$ $(p_{1/2})^1$ and $N = 8$

$$l = 1,\ J = \frac{1}{2} \Rightarrow \text{parity} = (-1)^1 = -1, \quad \text{spin - parity} = \left(\frac{1}{2}\right)^-$$

Q3. Match the reactions on the left with the associated interactions on the right.

(a) $\pi^+ \to \mu^+ + \nu_\mu$ (i) Strong

(2) $\pi^0 \to \gamma + \gamma$ (ii) Electromagnetic

(3) $\pi^0 + n \to \pi^- + p$ (iii) Weak

(a) (1, iii), (2, ii), (3, i) (b) (1, i), (2, ii), (3, iii)

(c) (1, ii), (2, i), (3, iii) (d) (1, iii), (2, i), (3, ii)

Ans: (a)

Q4. The ground state wavefunction of deuteron is in a superposition of s and d states. Which of the following is NOT true as a consequence?

(a) It has a non-zero quadruple moment

(b) The neutron-proton potential is non-central

(c) The orbital wavefunction is not spherically symmetric

(d) The Hamiltonian does not conserve the total angular momentum

Ans: (d)

Q5. The first three energy levels of $^{228}Th_{90}$ are shown below

4^+ ——————— $187keV$
2^+ ——————— $57.5keV$
0^+ ——————— $0keV$

The expected spin-parity and energy of the next level are given by

(a) (6^+; 400 keV) (b) (6^+; 300 keV) (c) (2^+; 400 keV) (d) (4^+; 300 keV)

Ans: (a)

Solution: $\frac{E_2}{E_1}=\frac{J_2(J_2+1)}{J_1(J_1+1)}\Rightarrow\frac{E_6}{E_4}=\frac{6(6+1)}{4(4+1)}\Rightarrow E_6=393keV$

GATE-2011

Q6. The semi-empirical mass formula for the binding energy of nucleus contains a surface correction term. This term depends on the mass number A of the nucleus as

(a) $A^{-1/3}$ (b) $A^{1/3}$ (c) $A^{2/3}$ (d) A

Ans: (c)

Q7. According to the single particles nuclear shell model, the spin-parity of the ground state of $^{17}_{8}O$ is

(a) $\frac{1}{2}^-$ (b) $\frac{3}{2}^-$ (c) $\frac{3}{2}^+$ (d) $\frac{5}{2}^+$

Ans: (d)

Solution: $Z=8$ and $N=9$; $(s_{1/2})^2\ (p_{3/2})^4\ (p_{1/2})^2\ (d_{5/2})^1$

$l=2,\ J=\frac{5}{2}\Rightarrow \text{parity}=(-1)^2=+1,\quad \text{spin - parity}=\left(\frac{5}{2}\right)^+$

Q8. In the β-decay of neutron $n\rightarrow p+e^-+\bar{\nu}_e$, the anti-neutrino $\bar{\nu}_e$, escapes detection. Its existence is inferred from the measurement of

(a) energy distribution of electrons (b) angular distribution of electrons

(c) helicity distribution of electrons (d) forward-backward asymmetry of electrons

Ans: (a)

Q9. The isospin and the strangeness of Ω^- baryon are

(a) 1, -3 (b) 0, -3 (c) 1, 3 (d) 0, 3

Ans: (b)

GATE-2012

Q10. Deuteron has only one bound state with spin parity 1^+, isospin 0 and electric quadrupole moment 0.286 efm^2. These data suggest that the nuclear forces are having

(a) only spin and isospin dependence

(b) no spin dependence and no tensor components

(c) spin dependence but no tensor components

(d) spin dependence along with tensor components

Ans: (d)

Q11. The quark content of Σ^+, K^-, π^- *and* p is indicated:

$$\left|\Sigma^+\right\rangle = \left|uus\right\rangle; \left|K^-\right\rangle = \left|s\bar{u}\right\rangle; \left|\pi^-\right\rangle = \left|\bar{u}d\right\rangle; \left|p\right\rangle = \left|uud\right\rangle.$$

In the process, $\pi^- + p \to K^- + \Sigma^+$, considering strong interactions only, which of the following statements is true?

(a) The process, is allowed because $\Delta S = 0$

(b) The process is allowed because $\Delta I_3 = 0$

(c) The process is not allowed because $\Delta S \neq 0$ and $\Delta I_3 \neq 0$

(d) The process is not allowed because the baryon number is violated

Ans: (c)

Solution: $\pi^- + p \to k^- + \sum^+$

S: 0 0 −1 −1 (not conserved)

I_3: −1 $+\frac{1}{2}$ $-\frac{1}{2}$ +1 (not conserved)

For strong interaction S and I_3 must conserve. Therefore this process is not allowed under strong interaction

Q12. Which one of the following sets corresponds to fundamental particles?

(a) proton, electron and neutron

(b) proton, electron and photon

(c) electron, photon and neutrino

(d) quark, electron and meson

Ans: (a)

Q13. In case of a Geiger-Muller (GM) counter, which one of the following statement is CORRECT?

(a) Multiplication factor of the detector is of the order of 10^{10}

(b) Type of the particles detected can be identified

(c) Energy of the particles detected can be distinguished

(d) Operating voltage of the detector is few tens of Volts

Ans: (c)

Q14. Choose the CORRECT statement from the following

(a) Neutron interacts through electromagnetic interaction

(b) Electron does not interact through weak interaction

(c) Neutrino interacts through weak and electromagnetic interaction

(d) Quark interacts through strong interaction but not through weak interaction

Ans: (d)

GATE-2013

Q15. The decay process $n \to p^+ + e^- + \bar{\nu}_e$ violates

(a) Baryon number (b) lepton number (c) isospin (d) strangeness

Ans: (c)

Q16. The isospin (I) and baryon number (B) of the up quark is

(a) $I = 1, B = 1$ (b) $I = 1, B = 1/3$

(c) $I = 1/2, B = 1$ (d) $I = 1/2, B = 1/3$

Ans: (d)

Q17. In the β decay process, the transition $2^+ \to 3^+$, is

(a) allowed both by Fermi and Gamow-Teller selection rule

(b) allowed by Fermi and but not by Gamow-Teller selection rule

(c) not allowed by Fermi but allowed by Gamow-Teller selection rule

(d) not allowed both by Fermi and Gamow-Teller selection rule

Ans: (c)

Solution: According to Fermi Selection Rule:

$\Delta I = 0, \quad Parity = No\ Change$

According to Gammow-Teller Selection Rule:

$\Delta I = 0, \pm 1, \quad Parity = No\ Change$

In the β decay process, the transition $2^+ \to 3^+$,

$\Delta I = \pm 1, \quad Parity = No\ Change$.

GATE-2014

Q18. Which one of the following is a fermions'?

(a) α -particle (b) ${}_4Be^7$ nucleus

(c) Hydrogen atom (d) deuteron

Ans: (b)

Q19. Which one of the following three-quark states (qqq) denoted by X CANNOT be a possible baryon? The corresponding electric charge is indicated in the superscript.

(a) X^{++} (b) X^{+} (c) X^{-} (d) X^{--}

Ans: (d)

Solution: $X = qqq$

$X^{++}(uuu)\frac{2}{3}+\frac{2}{3}+\frac{2}{3}=\frac{6}{3}=2(\text{two unit positive charge})$

$X^{+}(uud)\frac{2}{3}+\frac{2}{3}-\frac{1}{3}=\frac{4}{3}-\frac{1}{3}=1(\text{single unit positive charge})$

$X^{-}(ddd)=-\frac{1}{3}-\frac{1}{3}-\frac{1}{3}=-1(\text{single unit negative charge})$

X^{--} [Not possible with qqq]. So the correct option is (d)

Q20. Consider the process $\mu^+ + \mu \to \pi^+ + \pi^-$. The minimum kinetic energy of the muons (μ) in the centre of mass frame required to produce the pion (π) pairs at rest is _____ MeV.

Ans: 81.7

Solution: Use conservation of energy and momentum in relativistic form.

Q21. A nucleus X undergoes a first forbidden β-decay to nucleus Y. If the angular momentum (I) and parity (P), denoted by I^P as $\frac{7^-}{2}$ for X, which of the following is a possible I^P value for Y?

(a) $\frac{1^+}{2}$ (b) $\frac{1^-}{2}$ (c) $\frac{3^+}{2}$ (d) $\frac{3^-}{2}$

Ans: (b)

GATE-2015

Q22. The decay $\mu^+ \to e^+ + \gamma$ is forbidden, because it violates

(a) momentum and lepton number conservations

(b) baryon and lepton number conservations

(c) angular momentum conservation

(d) lepton number conservation

Ans.: (d)

Solution: $\mu^+ \to e^+ + \gamma$. In this decay lepton number is not conserved.

Q23. A beam of X- ray of intensity I_0 is incident normally on a metal sheet of thickness $2\ mm$. The intensity of the transmitted beam is $0.025\ I_0$. The linear absorption coefficient of the metal sheet $(in\ m^{-1})$ is _____ (upto one decimal place)

Ans.: 1844.4

Solution: $I = I_0 e^{-\mu x} \Rightarrow \mu = \frac{1}{x}\ln\left(\frac{I_0}{I}\right) = \frac{1}{2\times10^{-3}}\ln\left(\frac{I}{0.025 I_0}\right) = \frac{1}{2\times10^{-3}}\ln(40)$

$\Rightarrow \mu = \frac{2.303}{2\times10^{-3}}[\log_{10} 40] = 1.151\times10^3[2\times0.3010+1] = 1844.4\ m^{-1}$

Q24. The mean kinetic energy of a nucleon in a nucleus of atomic weight A varies as A^n, where n is_____(upto two decimal places)

Ans.: -0.67

Solution: $< T >= \dfrac{\int_0^R -\dfrac{\hbar^2}{2m}\left(\dfrac{d^2}{dr^2}+\dfrac{2}{r}\dfrac{d}{dr}\right)4\pi r^2 dr}{\int_0^R 4\pi r^2 dr} = \dfrac{-\dfrac{\hbar^2}{2m}4\pi\int_0^R (2+2)\,dr}{\int_0^R 4\pi r^2 dr} = \dfrac{-\dfrac{\hbar^2}{2m}4\pi\times 4R}{4\pi R^3/3}$

$$\Rightarrow < T > \propto \frac{R}{R^3} \propto \frac{1}{R^2} = \frac{1}{\left(R_0 A^{\frac{1}{3}}\right)^2} = \frac{1}{A^{\frac{2}{3}}} = A^{-\frac{2}{3}} \Rightarrow n = -\frac{2}{3} = -0.667 = -0.67$$

Q25. The atomic masses of ${}^{152}_{63}Eu$, ${}^{152}_{62}Sm$, ${}^{1}_{1}H$ and neutron are 151.921749, 151.919756, 1.007825 and 1.008665 in atomic mass units (amu), respectively. Using the above information, the Q- value of the reaction ${}^{152}_{63}Eu + n \rightarrow {}^{152}_{62}Sm + p$ is _____ $\times 10^{-3}$ amu (upto three decimal places)

Ans.: 2.833

Solution: $Q = 152.930414 - (152.927581) = 2.833\times 10^{-3}\, a.m.u.$

Q26. In the nuclear shell model, the potential is modeled as $V(r) = \dfrac{1}{2}m\omega^2 r^2 - \lambda \vec{L}\cdot\vec{S},\ \lambda > 0$. The correct spin-parity and isospin assignments for the ground state of ${}^{13}C$ is

(a) $\dfrac{1^-}{2};\ \dfrac{-1}{2}$ (b) $\dfrac{1^+}{2};\ \dfrac{-1}{2}$ (c) $\dfrac{3^+}{2};\ \dfrac{1}{2}$ (d) $\dfrac{3^-}{2};\ \dfrac{-1}{2}$

Ans.: (a)

Solution: ${}^{13}C_6$, $N = 7, Z = 6$

For $N = 7$; $\left(1S_{\frac{1}{2}}\right)^2\left(1P_{\frac{3}{2}}\right)^4\left(P_{\frac{1}{2}}\right)^1 \Rightarrow j = \dfrac{1}{2}\ and\ \ l = 1$

Thus spin- parity is $\left(\dfrac{1}{2}\right)^-$.

GATE-2016

Q27. In the $SU(3)$ quark model, the triplet of mesons (π^+, π^0, π^-) has

(a) Isospin $= 0$, Strangeness $= 0$ (b) Isospin $= 1$, Strangeness $= 0$

(c) Isospin $= \frac{1}{2}$, Strangeness $= +1$ (d) Isospin $= \frac{1}{2}$, Strangeness $= -1$

Ans.: (b)

Solution: π^+, π^0, π^- are not strange particle thus strangness $= 0$

Since meson group contain 3 particles, thus $I = 1$

Q28. Consider the reaction ${}^{54}_{25}Mn + e^- \rightarrow {}^{54}_{24}Cr + X$. The particle X is

(a) γ (b) ν_e (c) n (d) π^0

Ans.: (b)

Q29. Which of the following statements is NOT correct?

(a) A deuteron can be disintegrated by irradiating it with gamma rays of energy $4\ MeV$.

(b) A deuteron has no excited states.

(c) A deuteron has no electric quadrupole moment.

(d) The ${}^1S_0$ state of deuteron cannot be formed.

Ans.: (c)

Q30. According to the nuclear shell model, the respective ground state spin-parity values of ${}^{15}_{8}O$ and ${}^{17}_{8}O$ nuclei are

(a) $\frac{1^+}{2}, \frac{1^-}{2}$ (b) $\frac{1^-}{2}, \frac{5^+}{2}$ (c) $\frac{3^-}{2}, \frac{5^+}{2}$ (d) $\frac{3^-}{2}, \frac{1^-}{2}$

Ans.: (d)

Solution: ${}^{15}_{8}O$; $Z = 8$ and $N = 7$; $N = 7 : (s_{1/2})^2 (p_{3/2})^4 (p_{1/2})^1$

$\Rightarrow j = \frac{1}{2}$ and $l = 1$. Thus spin and parity $= \left(\frac{1}{2}\right)^-$

${}^{17}_{8}O$; $Z = 8$ and $N = 9$; $N = 9 : (s_{1/2})^2 (p_{3/2})^4 (p_{1/2})^2 (d_{5/2})^1$

$\Rightarrow j = \frac{5}{2}$ and $l = 2$. Thus spin and parity $= \left(\frac{5}{2}\right)^+$