IIT-JAM CHEMISTRY 2023

TEST : ATOMIC STRUCTURE

Time 00 : 60 Hour **Date : 31-10-2022**

M.M. : 35

INSTRUCTION:

1. **Attempt all the questions.**
2. **PART-A contains 10 Multiple Choice Questions (MCQ). Each question has 4 choices (a), (b), (c) and (d), for its answer, out of which ONLY ONE is correct. From Q.1 to Q.5 carries 1 Mark and Q.6 to Q.10 carries 2 Marks each.**
3. **PART-B contains 05 Multiple Select Questions(MSQ). Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONE or MORE than ONE is/are correct. For each correct answer you will be awarded 2 marks.**
4. **PART-C contains 06 Numerical Answer Type (NAT) questions. Q.16 to Q.17 carry 1 Mark and Q.18 to Q.21 carries 2 Marks each. The answer of each (NAT) is a real number.**
5. **In all Parts, questions not attempted will result in zero mark. In PART–A (MCQ), wrong answer will result in negative marks. For all 1 mark questions, 1/3 marks will be deducted for each wrong answer. For all 2 marks questions, 2/3 marks will be deducted for each wrong answer. In PART–B (MSQ), there is no negative and no partial marking provisions. There is no negative marking in Section–C (NAT) as well.**

PART-A

Q.1 to Q.05: Carry 1 Mark each.

1. Commutator of the operators $5\hat{P}_z$ and $10z$ is

(a) $50\,i\hbar$ (b) $-50\,i\hbar$ (c) $-15\,i\hbar$ (d) $-i\hbar$

2. Wavefunction associated with ground state for a particle along x-direction in one dimentional box having length $-\ell$ to $+\ell$.

(a) $\psi = \sqrt{\frac{2}{\ell}}\cos\frac{\pi x}{\ell}$ (b) $\psi = \sqrt{\frac{2}{\ell}}\sin\frac{\pi x}{\ell}$ (c) $\psi = \sqrt{\frac{1}{\ell}}\sin\frac{\pi x}{2\ell}$ (d) $\psi = \sqrt{\frac{1}{\ell}}\cos\frac{\pi x}{2\ell}$

3. If the electron were spin 1 particles, instead of spin ½, then the number of electrons that can be accomodated in a level are

(a) 4 (b) 3 (c) 2 (d) 1

4. The de-Broglie wavelength of a particle of mass m, energy E and velocity v is

(a) $\frac{h}{\sqrt{2mE}}$ (b) $\frac{\hbar}{mv}$ (c) $\frac{\sqrt{2mE}}{h}$ (d) $\frac{mv}{h}$

5. Velocity of electron associated with 3rd Bohr's orbit of hydrogen atom

(a) $\frac{\hbar}{3ma_0}$ (b) $\frac{ma_0}{3\hbar}$ (c) $\frac{27\,\hbar}{ma_0}$ (d) $\frac{ma_0}{27\hbar}$

Q.6 to Q.10: Carry 2 Marks each.

6. The kinetic energy of a particle described by the wavefunction e^{-ikx} is

(a) $-\frac{h^2}{8\pi^2 m}\cdot k^2$ (b) 0 (c) $\frac{h^2}{8\pi^2 m}\cdot k^2$ (d) k^2

7. Benzene π-electrons are considered as particle in 2D-square box of infinite potential barrier having length ℓ. The energy associated with the lowest energy transition is

(a) $\frac{2h^2}{8m\ell^2}$ (b) $\frac{5h^2}{8m\ell^2}$ (c) $\frac{3h^2}{8m\ell^2}$ (d) $\frac{h^2}{8m\ell^2}$

8. What transition in the hydrogen spectrum would have the same wavelength as the Balmer transition (i.e. $n_1 = 4$ to $n_2 = 2$) of He^+ spectrum?

(a) $n_1 = 4$ to $n_2 = 2$ (b) $n_1 = 4$ to $n_2 = 1$ (c) $n_1 = 2$ to $n_2 = 1$ (d) $n_1 = 3$ to $n_2 = 2$

9. Which of the following electronic transition in hydrogen atom has minimum energy?

(a) $n = 1 \rightarrow n = 2$ (b) $n = 1 \rightarrow n = 10$ (c) $n = 2 \rightarrow n = 3$ (d) $n = 3 \rightarrow n = 5$

10. The spin angular momentum of 3p electron is

(a) $\frac{\sqrt{3}}{4\pi}h$ (b) 0 (c) $\frac{\sqrt{3}}{2}h$ (d) $\sqrt{2}\,h$

PART-B

Q.11 to Q.15: Carry 2 Marks each.

11. Which of the following functions is(are) quantum mechanically well behaved?

(a) $\psi(x) = e^{-\alpha x}\ (a > 0) \quad 0 < x < \alpha$ (b) $\psi(x) = \frac{1}{4-x} \quad 1 < x < 10$

(c) $\psi(x) = e^{-a|x|} \quad (a > 0) \quad -\infty < x < +\infty$ (d) $\psi(x) = e^{-x^2} \quad -\infty < x < +\infty$

12. An electron near the nucleons of an atom is strongly attracted by the nucleus and has/have

(a) low potential energy (b) high kinetic energy
(c) high potential energy (d) low velocity

13. A particle is placed in a one dimensional box of size L along x-axis $(0 < x < L)$ with potential $V(x) = 0$. Which of the following statements is/are TRUE.

(a) For an arbitrary state $|\psi_n\rangle$, the average location of particle is L/2.

(b) In the ground state the particle has exact location L/2

(c) In the ground state the probability of finding the particle in the interval (L/4 to L/2) is 41%

(d) On moveing in higher state probability distribution become uniform.

14. Which of the following statements is/are CORRECT.

(a) Both position $(\hat{x})$ and momentum $(\hat{p})$ operators commute with their commutator

(b) One dimensional square well with infinite potential has infinite number of states

(c) For hydrogenic atoms 3s and 3p orbitals are degenerate.

(d) Function *kx* is an eigen function of $\frac{\hat{d}}{dx}$ operator.

15. Which of the following statements is/are **TRUE** for Bohr's theory.
(a) When an electron moves from one orbit to another it either radiates or absorbs energy
(b) Angular momentum of an electron in particular orbit must be equal to a whole number *n* of quantum.
(c) For an electron to remain in its orbit, electrostatic attraction between electron and the nucleus which tends to pull the electron towards the nucleus must be equal to centrifugal force.
(d) For hydrogenic type atoms as atomic number increases electron moves to higher energy orbit.

PART-C

Q.16 to Q.17: Carry 1 Mark each.

16. The average value of the radius $\langle r \rangle$ in the 1s state of the hydrogen atom is _____Å. [Given: Bohr's first orbit is 0.529 Å]. (Round off upto three decimal places)

17. The electron of a hydrogen atom is in its first Bohr orbit having de-Broglie wavelength of 13.4 Å. The parameter of the orbit is _____Å. (Round off upto one decimal place)

Q.18 to Q.21: Carry 2 Marks each.

18. A certain particle carries 2.5×10^{-16} C of static electric charge. The number of electrons associated with this change is _____(Round off to nearest integer)

[Charge carry by an electron is 1.6×10^{-19} C).

19. For the particle in a cubic box, the degree of degeneracy of the energy levels with the value of $\frac{8ma^2E}{h^2}$ as 27 is _____(Round off to nearest integer)

20. In an atom, how many electrons can have quantum numbers n = 4, $m_l = 1$, $m_s = 1/2$ _____(Answer shoul be an integer).

21. For a particular state hydrogenic radial wavefunction with atomic number *Z*, is given as

$$R_{n,\ell}(r) = \frac{1}{(243)^{1/2}}\left(\frac{Z}{a_0}\right)^{3/2}\left(6 - \frac{6\,Zr}{na_0} + \frac{Z^2r^2}{n^2a_0^2}\right)\cdot e^{-\frac{Zr}{na_0}}$$

The number of radial nodes in this orbital will be _____(Answer should be an integer).

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PART - A

1. (b)	2. (d)	3. (b)	4. (a)	5. (a)	6. (a)	7. (c)
8. (c)	9. (d)	10. (a)				

PART - B

11. (c,d)	12. (a,b)	13. (a,c,d)	14. (a,b,c)	15. (a,b,c)

PART - C

16. (0.793 to 0.795)	17. (13.4)	18. (1560 to 1565)	19. (4)
20. (3)	21. (2)		