CAREER ENDEAVOUR
ACADEMY PRIVATE LIMITED
Best Institute for IIT-JAM|CSIR-UGC-NET/JRF|GATE

IIT-JAM CHEMISTRY-(CY) 2016

TEST : ATOMIC STRUCTURE

Time : 00:50 Hour **Date : 04-07-2015**
M.M. : 60

Instructions:

- **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. For each correct answer you will be awarded **3 marks**. For each incorrect answered **1 mark** will be deducted.
- **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,** there is no negative marking in this section.
- **Part-C** contains 10 Numerical Answer Type (NAT) questions which contain **2 Marks** for each, and there is no negative marking.

PART- A

1. A particle is moving in one dimensional box between $x = a$ and $x = b$. The potential energy is such that the particle can not be outside these limits and the wave function in between is $\psi = \frac{A}{x}$. The average value of x is:

(a) $\sqrt{\frac{ab}{b-a}}$ (b) $\sqrt{\frac{ab}{b-a}}\ell n\frac{b}{a}$ (c) $\frac{ab}{b-a}\ell n\frac{b}{a}$ (d) $\sqrt{\frac{ab}{b-a}}\ell n\frac{a}{b}$

2. An electron is confined in a 1-D box of 1 nm long. How many energy levels are there with energy less than 10 eV is:

(a) 5 (b) 10 (c) 15 (d) 16

3. Identify which of the following operators is not hermitian ?

(a) $\frac{\hbar}{i}\frac{d}{dx}$ (b) $i\frac{d^2}{dx^2}$ (c) $\frac{d^2}{dx^2}$ (d) x^2

4. TThe angle between the angular momentum $l = 2$ and the z-axis for $m_l = 2$ is:

(a) 35.3 (b) 65.9 (c) 114.1 (d) 144.7

5. A hydrogenic orbital with radial function of the form $r^{\alpha}\exp[-\beta r]$ and ϕ–part as $\exp[-3i\phi]$ corresponds to

(a) $n > 4, l > 3, m = 3$ (b) $n = 4, l = 3, m = -3$

(c) $n = 4,\ l > 3,\ m = 3$ (d) $n > 4,\ l = 3,\ m = -3$

6. A particle is in a one-dimensional box with a potential V_0 inside the box and infinite outside. An energy state corresponding to n = 0 (n : quantum number) is not allowed because

(a) the total energy becomes zero
(b) the average momentum becomes zero
(c) the wave function becomes zero everywhere
(d) the potential $V_0 \neq 0$

7. An eigenstate of energy satisfie $H\psi_n = E_n\psi_n$. In the presence of an extra constant potential V_0

(a) both E_n and ψ_n will change (b) both E_n and average kinetic energy will change

(c) only E_n will change, but not ψ_n (d) only ψ_n will change, but not E_n.

8. Compare the difference of energies of the first excited and ground states of a particle confined in (i) a 1-d box (Δ_1), (ii) a 2-d square box (Δ_2) and (iii) a 3-d cubic box (Δ_3). Assume the length of each of the boxes is the same. The correct relation between the energy differences Δ_1, Δ_2 and Δ_3 for the three states is

(a) $\Delta_1 > \Delta_2 > \Delta_3$ (b) $\Delta_1 = \Delta_2 = \Delta_3$ (c) $\Delta_3 > \Delta_2 > \Delta_1$ (d) $\Delta_3 > \Delta_1 > \Delta_2$

9. The correct statement about both the average value of position $(\langle x \rangle)$ and momentum $(\langle p \rangle)$ of a 1-d harmonic oscillator wavefunction is

(a) $\langle x \rangle \neq 0$ and $\langle p \rangle \neq 0$ (b) $\langle x \rangle = 0$ but $\langle p \rangle \neq 0$

(c) $\langle x \rangle = 0$ and $\langle p \rangle = 0$ (d) $\langle x \rangle \neq 0$ but $\langle p \rangle = 0$

10. The value of the commutator $[x, [x, p_x]]$ is

(a) $i\hbar x$ (b) $-i\hbar$ (c) $i\hbar$ (d) 0

PART- B

11. Analyse the function given , $\psi_{n,\ell,m} \propto \rho^2 e^{-\rho/3} \sin\theta \cos\theta \cos\phi$

The correct statement is

(a) Angular node corresponding to this function = 3 and radial node coresonding to this function = 0

(b) The z-component of angular momentum corresponding to the above function is $\frac{h}{2\pi}$

(c) Total angular momentum corresponding to this function $\frac{3h^2}{2\pi^2}$ and energy corresponding to this function is – 0.055 a.u.

(d) Average value of $\langle r \rangle$ corresponding to above function is $12a_0$.

12. Consider the statement. The ***correct*** statements are

(a) In the Bohr atom the angular momentum always had a non-zero value. While in the modern theory the angular momentum is zero in S state only

(b) In Schrodinger model n has nothing directly to do with angular momentum, while on Bohr model n was measure first of the angular momentum of the system.

(c) If a hydrogen atom in the ground 1s state absorb radiation, then it must be finally in 2s state.

(d) The virial theorem corresonding to H-atom is 2×total energy = – <potential energy)

13. The ***incorrect*** statement is

(a) The degeneracy corresponding to Li^{++} species having energy $-\frac{e^2}{72\pi \in_0 a_0}$ is 9

(b) The degeneracy corresponding to rotating a particle of mass 'm' having energy $\frac{5h^2}{2\pi^2 mr^2}$ is 7

(c) The energy corresponding to particle confined to move in 2D square box having energy $\frac{25h^2}{4\ell^2}$ is 2

(d) The negative value of energy eigenvalue $E\left(=\frac{-13.6z^2}{n^2}\right)$ corresponds to scattering states in which there is not enough energy for the electron to escape from the nucleus

14. $\psi = N\, r\left(6 - Z\, r\right)e^{-Zr/3}\cos\theta$, is a proposed hydrogenic wavefunction, where Z = atomic number, r = radial distance from the nucleus, θ = azimuthal angle, N is a constant. The **CORRECT** statement about ψ is
(a) $\psi = 0$ in the xy-plane
(b) two radial nodes are presenet in ψ
(c) one angular node is present in ψ
(d) the size of the orbital decreases with increase in atomic number

15. Among the following statements, which statements **TRUE** for a Hermitian operator are :
(a) The eigen values are real
(b) the eigen functions are orthogonal
(c) The represent observables
(d) The scalar product of two different eigen function is equal to one

PART- C

16. The wavelength associated with an electron moving with a velocity of $10^3\,\text{m sec}^-$ _____(-10^{-7} m).

17. The degenracy of the energy level $\frac{12h^2}{8ml^2}$ of a particle in a three dimensional cube of the length 'a' is _____

18. In the units of $\frac{h^2}{8ml^2}$, the energy difference between levels corresponding to 3 to 2 node eigen functions for a particle of mass m in a one dimensional box of length 'ℓ' is _____

19. For unnormalized wave-function, $\psi(r,\theta,\phi) = \sin\theta\cos\phi\left(\frac{2r}{a_0} - \left(\frac{r}{a_0}\right)^2\right)\exp\left(-\frac{r}{a_0}\right)$, the number of radial node(s) is_____

20. The wavelength of an electron accelerated through a potential of 100 kV is _____(Å)

21. The probability of finding the particle in one dimensional box of length L in the region between $\frac{L}{4}$ and $\frac{3L}{4}$ for quantum number n = 2 is _____ %

22. The ground state translational energy of a particle in one-dimensional box of 300pm length is about 4 eV. Suppose that the same particle is moving in a three-dimensional cubic box of 100 pm on the side. The ground state energy of the particle in the three-dimensional box is _____ (eV).

23. A cubic box of edge-length 1.2 nm contains 10 electrons. Applying the simple particle in a box theory, the value of ΔE for the first excited state of this system is _____(10^{-20} J)

24. For a particle of mass m confined in a box of length L, assume $\Delta x = L$. Assume further that $\Delta p(\text{min}) = \left\langle p^2 \right\rangle^{1/2}$. Use the uncertainity principle to obtain an estimate of the energy of the particle. The value will be _____ $\left(\frac{\hbar^2}{mL^2}\right)$.

25. The ground state energy of hydrogen atom is –13.598 eV. The expectation values of kinetic energy, $\langle T \rangle$ is _____ (in units of eV).

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ANSWER KEY

Part - A

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

Part - B

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

Part - C

16. (7.25)	17. (1)	18. (7)	19. (1)	20. (0.037)	21. (50)
22. (108)	23. (8.366)	24. (0.125)	25. (13.598)		