JEE Advanced Previous Year Questions on Atomic Structure

Question 1. Consider Bohr's model of a one-electron atom where the electron moves around the nucleus. In the following, List-I contains some quantities for the nth orbit of the atom and List-II contains options showing how they depend on n.

	List I		List II
(I)	Radius of the n^{th} orbit	(P)	$\propto n^{-2}$
(II)	Angular momentum of the electron in the n^{th} orbit	(Q)	$\propto n^{-1}$
(III)	Kinetic energy of the electron in the n^{th} orbit	(R)	$\propto n^{0}$
(IV)	Potential energy of the electron in the n^{th} orbit	(S)	$\propto n^{1}$
		(T)	$\propto n^{2}$
		(U)	$\propto n^{1/2}$

Which of the following options has the correct combination considering List-I and List-II?

A. (I), (T)

B. (II), (R)

C. (I), (P)

D. (II), (Q)

Solution: (A)

$r = 0.59 \times n^2 / z \Rightarrow r \propto n^2 \Rightarrow$ (I)(T)

$mvr = nh / 2\pi \Rightarrow (mvr) \propto n \Rightarrow$ (II)(S)

$K\,E = 13.6 \times z^2 / n^2 \Rightarrow K\,E \propto n^{-2} \Rightarrow$ (III)(P)

$P\,E = -2 \times 13.6 \times z^2 / n^2 \Rightarrow P\,E \propto n^{-2} \Rightarrow$ (IV)(P)

Question 2. A ball of mass 100g is moving with a velocity of 100 $msec^{-1}$. Find its wavelength.

A. 6.63×10^{-35} m

B. 6.63×10^{-30} m

C. 6.63×10^{-33} m

D. 6.63×10^{-32} m

Solution: (A)

Using De-broglie's equation, given m = 100g, v = 100 m/s

$\lambda = h / mv$

λ = De-broglie wavelength

M = 100g = 100 / 1000 kg = 0.1 kg

$v = 100\ ms^{-1}$

$\lambda = 6.626 \times 10^{-34} / 0.1 \times 100 = 6.626 \times 10^{-35}$ m

Question 3. The ground state energy of the hydrogen atom is –13.6 eV. Consider an electronic state ψ of He+ whose energy, azimuthal quantum number and magnetic quantum number are –3.4 eV, 2 and 0, respectively. Which of the following statement(s) is(are) true for the state ψ?

A. It is a 4d state

B. The nuclear charge experienced by the electron in this state is less than 2e, where e is the magnitude of the electronic charge

C. It has 2 angular nodes

D. It has 3 radial nodes

Solution: (A, C)

$E_{He+} = -13.6 \times (2)^2 / n^2 = -3.4 = -13.6 / 4$

$n^2 = 16$ so $n = 4$

Quantum number is

$n = 4, \ell = 2, m = 0$

So, subshell is = d

Angular node = $\ell = 2$

Radial node = $[n = \ell - 1] = 4 - 2 - 1 = 1$

Question 4. An electron in a hydrogen atom undergoes a transition from an orbit with quantum number ni to another with quantum number nf. V_i and V_f are respectively the initial and final potential energies of the electron. If $V_i / V_f = 6.25$, then the smallest possible n_f.

Solution: (5)

The potential energy of an electron in Bohr's modal is given by (assuming Coulombic force)

$U = -Kze^2 / \gamma$

Where, γ = radius

& radius for Bohr's orbital (for mono-electronic system) $= 0.529\ n^2 / z$

so, $U_i / U_r = \gamma_2 / \gamma_1 = n_2^2 / n_1^2$ …(1)

As, given $n_2 / n_1 = 6.25$

By comparing the above equation and equation (1).

$n_2 / n_1 = \sqrt{6.25}$

$n_2 / n_1 = 2.5$

So, $n_2 / n_1 = 5 / 2$

It can be written as,

$n_2 = 5\ n_1 = 2$

so the final value of $n_2 = 5$.

Question 5. A hydrogen atom in its ground state is irradiated by the light of wavelength 970 Å. Taking hc / e = 1.237 × 10^{-6} eV m and the ground state energy of hydrogen atom as -13.6eV the number of lines present in the emission spectrum is.

Solution: (6)

The electron in the ground state of the H-atom jumps to the nth state after absorbing the radiation.

Wavelength of the radiation, λ = 970 Å = 970 × 10^{-10}

Energy gained by the electron, E′ =

Thus the energy of the n^{th} state, E_n = −13.6 + 12.75 = −0.85eV

Using: $E_n = -13.6 / n^2$ eV

∴ -0.85 = $-13.6 / n^2$

⇒ n = 4

Number of (emission) spectral line, N = n(n – 1) / 2 = 4(4 – 1) / 2 = 6 lines.

Question 6. Consider a hydrogen atom with its electron in the nth orbital. Electromagnetic radiation of wavelength 90 nm is used to ionize the atom. If the kinetic energy of the ejected electron is 10.4 eV, then the value of n is (hc = 1242 eV nm).

Solution: (2)

Given, the wavelength of electromagnetic radiation = 90nm

The energy of the incident photon (E) = hc / λ ⇒ hc / 90

And, the energy of electron on n^{th} orbital for Hydrogen atom = $13.6 / n^2$

So,

The kinetic energy (K E) of ejected electron = (Energy of incident photon)-(Energy of electron on n^{th} orbital for Hydrogen atom)

K E = hc / 90 nm – $13.6 / n^2$ ………(1)

Given, K E = 10.4 eV and hc = 1242 eV nm

On putting the values in equation (1)

10 = 1242 / 90 – $13.6 / n^2$

$13.6 / n^2$ = 3.8

n = 2

Question 7. In a CO molecule, the distance between C (mass = 12 a.m.u.) and O (mass = 16 a.m.u.), where 1 a.m.u. = 5 / 3 × 10^{-27} kg, is close to.

A. 2.4 x 10^{-10} m

B. 1.9 x 10^{-10} m

C. 1.3 x 10^{-10} m

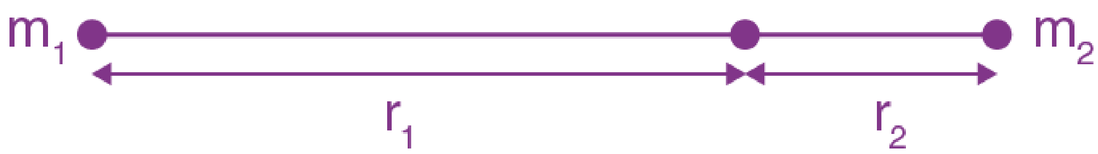
D. 4.4 x 10^{-11} m

Solution: (C)

$r_1 = m_2d / m_1 + m_2$ and $r_2 = m_1d / m_1 + m_2$

$I = m_1r_1^2 / m_2r_2^2$

$\therefore d = 1.3 \times 10^{-10}$ m



Question 8. The atomic masses of He and Ne are 4 and 20 amu respectively. The value of the de Broglie wavelength of He gas at -73°C is 'M' times that of the de Broglie wavelength of Ne at 727°C 'M' is.

Solution: (5)

de Broglie's wavelength of a particle when kinetic energy (K.E) and mass (m) are given:

$\lambda = h / \sqrt{2K.E\, m}$

Given:

Mass of He atom (m_{He}) = 4 amu

Mass of He atom (m_{Ne}) = 20 amu

The temperature of He(T_{He}) = -73°C = 200K

The temperature of Ne(T_{Ne}) = +727°C = 1000K

We know that;

$K.E \propto T$

$K.E_{He} / K.E_{Ne} = T_{He} / T_{Ne} = 200 / 1000 = 1/5$

Now, the ratio of de Broglie's wavelengths of Ne and He ($\lambda_{He} / \lambda_{Ne}$)

$\lambda_{He} / \lambda_{Ne} = \sqrt{2K.E_{Ne} m_{Ne}} / \sqrt{2K.E_{He} m_{He}} = \sqrt{5 / 1 \times 20 / 4} = 5$

$\therefore \lambda_{He} = 5 \times \lambda_{Ne}$

The value of m is 5.

Question 9. The maximum number of electrons that can have the principal quantum number, n = 3, and spin quantum number, ms = -½, is.

A. 3

B. 7

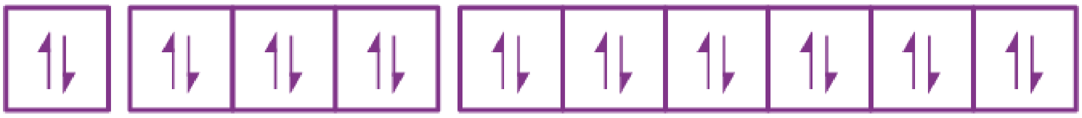
C. 9

D. 10

Answer: (C)

When n = 3, l = 0, 1, 2 i.e., there are 3s, 3p and 3d orbitals. If all these orbitals are completely occupied as shown in the figure.

Total 18 electrons, 9 electrons with s = + ½ and 9 with s = -½



Alternatively, in any n^{th} orbit, there can be a maximum of $2n^2$ electrons.

Hence, when n = 3, the number of maximum electrons =18. Out of these 18 electrons, 9 can have spin −½ and the remaining nine with spin = + ½

Question 10. Not considering the electronic spin, the degeneracy of the second excited state (n = 3) of the H atom is 9, while the degeneracy of the second excited state of H^- is.

Solution: (3)

H^- is a 2 electron system,

The three following rows show the ground state, 1st excited state and the second excited state.

$1s^2$

$1s^1$, $2s^1$

$1s^1$, $2p^1$

Since the excited electron is in the p orbital, it has 3 degenerate orbitals.

The most important idea here is that we just consider one electron undergoing these transitions.