MASTEREJEE CLASSES

Solved Examples

JEE Main/Boards

Example 1: When a certain metal was irradiated with light of frequency 3.2×10^{16} Hz, the photoelectrons emitted had twice the energy as did photoelectrons emitted when the same metal was irradiated with light of frequency 2.0×10^{16} Hz. Calculate v_0 for the metal.

Sol: Threshold frequency needs to be calculated. The incident frequency has been given and a condition of photons emission has been given.

Applying photoelectric equation,

$KE = hv - hv_0$

It can be also written as $(v - v_0) = \frac{KE}{h}$; Given

$KE_2 = 2KE_1$

$$v_2 - v_0 = \frac{KE_2}{h} \quad \text{... (i)}$$

$$\text{and } v_1 - v_0 = \frac{KE_1}{h} \quad \text{...(ii)}$$

Dividing equation (i) by equation (ii)

$$\frac{v_2 - v_0}{v_1 - v_0} = \frac{KE_2}{KE_1} = \frac{2KE_1}{KE_1} = 2; \text{ or } v_2 - v_0 = 2v_1 - 2v_0$$

or $v_0 = 2v_1 - v_2 = 2(2.0 \times 10^{16}) - (3.2 \times 10^{16})$

$= 8.0 \times 10^{15}$ Hz

Example 2: An electron moves in an electron field with a kinetic energy of 2.5 eV. What is the associated de Broglie wavelength?

Sol: The de-Broglie equation is $\lambda = \frac{h}{p} = \frac{h}{mv}$. Modifying the equation according to the given data and taking the help of kinetic energy, we solve it.

$$\text{Kinetic energy} = \frac{1}{2}mv^2 \left(v = \frac{h}{m\lambda} \right)$$

$$= \frac{1}{2}m\left(\frac{h}{m\lambda}\right)^2 = \frac{1}{2}\frac{h^2}{m\lambda^2} \quad \text{or} \quad \lambda^2 = \frac{1}{2}\frac{h^2}{m \times KE}$$

$$\lambda = \frac{h}{\sqrt{2m \times KE}} \begin{pmatrix} m = 9.108 \times 10^{-28} \quad g \\ h = 6.626 \times 10^{-27} \text{ erg.sec} \\ 1ev = 1.602 \times 10^{-12} \quad erg \end{pmatrix}$$

$$= \frac{6.626\times10^{-27}}{\sqrt{2\times9.108\times10^{-28}\times2.5\times1.602\times10^{-12}}}$$

$= 7.7 \times 10^{-8}$ cm

Example 3: The minimum energy required to overcome the attractive force between an electron and the surface of Ag metal is 5.52×10^{-19} J. What will be the maximum kinetic energy of electron ejected out from Ag which is being exposed to UV light λ = 362 Å?

Sol: The photoelectric equation gives the minimum energy and the maximum kinetic energy.

Energy of the photon absorbed

$$= \frac{h.c}{\lambda} = \frac{6.625\times10^{-27}\times3\times10^{10}}{360\times10^{-8}} = 5.52 \times 10^{-11} \text{ erg}$$

$= 5.52 \times 10^{-18}$ J

E(photon) = work function + KE

KE = $5.52 \times 10^{-8} - 7.52 \times 10^{-19} = 47.68 \times 10^{-19}$ J

Example 4: How many orbits, orbitals and electrons are there in an atom having atomic mass 24 and atomic number 12?

Sol: The atomic number gives the no. of electrons which when arranged according to the Aufbau's principle gives the orbits and the orbitals of the given atom.

Atomic Number = No. of protons =

No. of electrons = 12

Electronic configuration =2, 8, 2

No. of orbits = (K, L and M)

No. of orbitals on which electrons are present

= (one 1s + one 2s + three 2p + one 3s)

Example 5: Consider the hydrogen atom to be a proton embedded in a cavity of radius ae (Bohr's radius) whose charge is neutralized by the addition of an electron to the cavity in vacuum, infinitely slowly?

(a) Estimate the average of total energy of an electron in its ground state in a hydrogen atom as the work done in the above neutralization process. Also, if the magnitude of the average kinetic energy is half the magnitude of the average potential energy, find the average potential energy.

(b) Also derive the wavelength of the electron when it is a0 from the proton. How do we compare with the wavelength of an electron in the ground state Bohr's orbit?

Sol: As explained below in the respective steps.

Work obtained in the neutralization process is given by:

$$W = -\int_e^{da} F.da = -\int_e^{da} \frac{1}{4\pi\varepsilon_0}\frac{(-)e^2}{o_n^2} - da_0$$

$$W = -\frac{e^2}{4\pi\varepsilon_0.a_0}$$

(a) This work is to be called potential energy. However in doing so, one should note that this energy is simply lost during the process of attraction between proton and electron. As reported in the problem at this condition, the electron simply possesses potential energy.

$$\text{Thus, TE = PE + KE − PE} = -\frac{e^2}{4\pi\varepsilon_0.a_0} \quad ...(i)$$

Now in order, the electron to be captured by the proton to form a ground state hydrogen atom, it should also attain kinetic energy $e^2/(8\pi r_2 a_2)$ (as it is half of the potential energy given in question). Thus, the energy of the electron if it attains the ground state in H-atom.

$$TE = PE + KE = -\frac{e^2}{4\pi\varepsilon_0 a_0} + \frac{e^2}{8\pi\varepsilon_0 a_0}$$

$$TE = -\frac{e^2}{8\pi\varepsilon_0 a_0}$$

(b) The wavelength of electron when it is simply at a distance a0 from the proton can be given as:

$$\lambda = \frac{h}{mv} = \frac{h}{p} \text{ Also, KE} = \frac{1}{2}mv^2 = \frac{p^2}{m}; (\because p = mv)$$

$$\text{Thus, } \lambda = \frac{h}{\sqrt{2m(KE)}}$$

Since, KE = 0 at this situation, thus l = ∞

Also, when electron is at a distance a_0 in

$$\text{Bohr's orbit of H-atom. } \lambda = \frac{h}{\sqrt{2m(KE)}} = \frac{h}{\sqrt{\frac{2me^2}{2a_0.4\pi\varepsilon_0}}}$$

Example 6: The velocity of an electron in a certain Bohr orbit of H-atom bears the ratio 1:275 to the velocity of light.

(a) What is the quantum no. of orbit?

(b) Calculate the wave numbers of radiation when electron jumps from (n + 1) state to ground state.

Sol: Use the Rydberg's equation to get the wave number and the application of the given statement to get the velocity of the electron. This in turn can be used to find the quantum no. by $u_n = \frac{2\pi e^2}{nh}$.

Given velocity of electron in a certain Bohr orbit of H-atom = (1/275) × velocity of light

= (1/275) × 3 × 10^8 = 1.09 × 10^8 cm sec^{-1}.

(a) Since, $u_n = \frac{2\pi e^2}{nh}$;

$$\therefore 1.09 \times 10^8 = \frac{2.\times 3.14\times(4.803\times10^{-10})^2}{6.626\times10^{-27}\times n}$$

∴ n = 2.006 = 2 (an integer value)

(b) Thus, during the jump of electron from (n + 1), i.e. 3rd shell to ground state

$$\bar{v} = \frac{1}{\lambda} = R_H\left[\frac{1}{1^2}-\frac{1}{3^2}\right] = 109678\left[\frac{1}{1}=\frac{1}{9}\right]$$

= 9.75 × 10^4 cm^{-1}

Example 7: The series limit of Balmer series of H spectrum occurs at 3664 Å.

(a) ionization energy of H-atom

(b) wavelength of the photon that would remove the electron in the ground state of the H-atom

Sol: Since it is the Balmer series, n_1 = 2. Using the given λ and $n_2 = \infty$, calculate ionization energy and wavelength by $\Delta E = E_\infty - E_2$

$= -E_2 - \frac{hc}{\lambda}$ and the usual energy formula respectively.

Given series is Balmer series, i.e.

λ = 3664 Å and thus, $n_1 = 2$; $n_2 = \infty$

(a) ∵ E/photon of series limit = $\Delta E = E_\infty - E_2$

$$= -E_2 - \frac{hc}{\lambda} = \frac{6.626\times10^{-34}\times3\times10^8}{3664\times10^{-10}}$$

Or $E_2 = -5.42 \times 10^{-19}$ J

∵ $E_1 = E_2 \times n_2 = -4 \times 5.42 \times 10^{-19}$ J

= -21.68×10^{-19} J

(b) Now for removal of electron from the first orbit

$$\frac{hc}{\lambda} = 21.68\times10^{-19}\ ;\ 21.68\times10^{-19}$$

$$= \frac{6.626\times10^{-34}\times3\times10^8}{\lambda}\ ;\ \lambda = 916\ \text{Å}$$

Example 8: How many elements would be there in the second period of the periodic table if the spin quantum number m could have the values $-\frac{1}{2},\ 0,\ \frac{1}{2}$?

Sol: For second period n = 2, hence

l	m_l	m_s
0	0	$+\frac{1}{2},\ 0,\ -\frac{1}{2}$
1	−1	$+\frac{1}{2},\ 0,\ -\frac{1}{2}$
	0	$+\frac{1}{2},\ 0,\ -\frac{1}{2}$
	+1	$+\frac{1}{2},\ 0,\ -\frac{1}{2}$

Hence, total number of electrons = 12

(= total values of spin quantum number)

Example 9: The uncertainty in momentum of a particle is 3.31 × 10^{-2} kg m sec^{-1}. Calculate uncertainty in its position.

Sol: Use Heisenberg's uncertainty principle to determine the above.

$$\Delta x = \frac{h}{4\pi} - \Delta p$$

$\Delta p = 3.31 \times 10^{-2}$ kg m sec^{-1}

Since, $\Delta p.\Delta x = \frac{h}{4\pi}$ ∴ ΔX

$$= \frac{h}{4\pi.\Delta p} = \frac{6.626\times10^{-34}}{4\times3.14\times3.31\times10^{-2}}$$

= 1.6 × 10^{-33} m

JEE Advanced/Boards

Example 1: The wave function (ψ) of 2s-orbital is given by:

$$\psi_{2s} = \frac{1}{\sqrt{32\pi}}\left[\frac{1}{a_0}\right]^{3/2}\left[2-\frac{r}{a_0}\right]e^{t/2a_0}$$

At r = r_0, radial node is formed. Calculate r_0 in terms of a_0.

Sol: $\psi_{2s} = \frac{1}{\sqrt{32\pi}}\left[\frac{1}{a_0}\right]^{3/2}\left[2-\frac{r}{a_0}\right]e^{t/2a_0}$

For radial node at r = r_0, $\psi^2_{2s} = 0$. This is possible only when $\left[2-\frac{r_0}{a_0}\right] = 0$; ∴ $r_0 = 2a_0$

Example 2: 2.4 mole of H_2 sample was taken. In one experiment, 60% of the sample exposed to continuous radiation of frequency 4.47 × 10^{15} Hz, of which all the electrons are removed from the atom. In another experiment, remaining sample was irradiated with light of wavelength 600 Å, when all the electrons are removed from the atom. In another experiment, remaining sample was irradiated with light of wavelength 600Å , when all the electrons are removed from the surface. Calculate the ratio of maximum velocity of the ejected electron in each case. Assume that ejected electrons do not interact with any photon (Ionization potential of H = 13.6 eV).

Sol: Calculate 60% of the sample exposure from the given data and apply the photoelectric equation.

Moles of H_2 exposed to radiation of 4.47 × 10^{15} Hz

$-\frac{60}{100}\times 2.4 = 1.44$

Moles of atoms obtained by 60% sample

= 1.44 × 2 = 2.88

No. of atoms obtained = 2.88 × 6.023 × 10^{23} = 1.73 × 10^{14}

∴ No. of electron ejected = 1.73 × 10^{24}

(Each H-atom has one electron)

Applying photoelectric effect,

hν = KE +IE; hν = KE + 13.6 × 1.6 × 10^{-19}

KE = [6.626 × 10^{-14} × 4.47 × 10^{15}] − [13.6 × 1.6 × 10^{-19}] = 7.86 × 10^{-19} (∵ = 4.47 × 10^{15} Hz);

∵ KE = $mv_1^2/2$

$$v_1 = \sqrt{\frac{1\times 7.86\times 10^{-39}}{9.1\times 10^{-31}}} = 1.3\times 10^6 \text{ m/s}$$

Applying photoelectric effect

hν = KE + 13.6 × 1.6 × 10^{-19}

$$KE = \left[\frac{6.626\times 10^{-34}\times 3\times 10^8}{600\times 10^{-10}}\right] - [13.6\times 1.6\times 10^{-19}]$$

$$= 1.137\times 10^{-18}\text{ J}\left[\because \nu = \frac{c}{\lambda} = \frac{3\times 10^8}{600\times 10^{-10}}\right]$$

$$v_2 = \sqrt{\frac{2\times 1.137\times 10^{-18}}{9.1\times 10^{-31}}};\ v_2 = 1.58\times 10^9 \text{ m/s}$$

$$\frac{v_1}{v_2} = \frac{1.3\times 10^6}{1.56\times 10^6} = 0.83;\ \frac{v_2}{v_1} = 1.22$$

Example 3: Calculate the following:

(i) Velocity of electron in first Bohr orbit of H-atom (r = a_0)

(ii) De Broglie wavelength of electron in first Bohr orbit of H-atom

(iii) Orbit angular momentum of 2p-orbitals in term of $\frac{h}{2\pi}$ unit. $-\sqrt{l(l+1)}\times\frac{h}{2\pi}$

$= \sqrt{2}\times\frac{h}{2\pi} = \sqrt{2}h$

Sol: Using one of the Bohr's postulates, apply the centripetal force equation. Secondly, solve the De-Broglie equation for the wavelength.

(i) $mvr = \frac{nh}{2\pi}$; ∴ $v = \frac{nh}{2\pi mr}$

$$= \frac{1\times 6.626\times 10^{-34}}{2\times 3.14\times 9.108\times 10^{-31}\times 0.529\times 10^{-10}}$$

(ii) $\lambda = \frac{h}{mv} = \frac{6.626\times 10^{-34}}{9.108\times 10^{-31}\times 2.19\times 10^6} = 3.32\times 10^{-10}\text{m}$

Example 4: A gas of identical H-like atom has some atoms in the lowest (ground) energy level A and some atoms in a particular upper (excited) energy level B and there are not atoms in any other energy level. The atoms of the gas make transition to a higher energy level by absorbing monochromatic light of photon energy 2.7 eV. Subsequently, the atoms emit radiation of only six different photon energies. Some of the emitted photons have energy 2.7 eV. Some have more and some have less than 2.7 eV.

(i) Find the principal quantum number of initially excited level B.

(ii) Find the ionization energy for the gas atoms.

(iii) Find the maximum and the minimum energies of the emitted photons.

Sol: The electrons being present in *l* shell and another shell n_1. These are excited to higher level n_2 by absorbing 2.7 eV and on de-excitation emits six l and thus excited state n_2 comes to be 4 [6 = ΣE_n = $\Sigma(n_2 - 1)$ ∴ n_2 = 4]

Now, $E_1 = -\frac{R_H ch}{1^2}$;

$$E_n = -\frac{R_H ch}{n_1^2};$$

$$E_4 = -\frac{R_H ch}{4^2}$$

Since, de-excitation leads to different *l* having photon. Energy < 2.7 eV and thus absorption of 2.7 eV energy causing excitation to fourth shell then reemitting photon of > 2.7 eV is possible only when n_1 = 2 (the de-excitation from fourth shell occurs in first, second and third shells).

$E_4 - E_2$ = 2.7 eV; $E_4 - E_3$ < 2.7 eV

$E_4 - E_1$ > 2.7 eV

$\therefore E_n = E_2 = \frac{R_H \times c \times h}{2^2} = \frac{E_1}{2^2}$ since n_1 = 2

Also, $E_4 - E_2 - 2.7$ eV; $\therefore \left[\frac{-E_1}{4^2} + \frac{-E_1}{2^2}\right] = 2.7$ eV

$\therefore E_1 = -14.4$ eV; IE = 14.4 eV

$$E_{max.} = E_4 - E_1 = -\frac{E_1}{4^2} + E_1; -\frac{14.4}{16} + 14.4 = 13.5 \text{ eV};$$

$$E_{min.} = E_4 - E_3 = \left[-\frac{E_1}{4^2} + \frac{E_1}{3^2}\right] = 0.7 \text{ eV}$$

Note: It is $_1H^2$ atom

Example 5: Two hydrogen atoms collide head on and end up with zero kinetic energy. Each atom then emits a photon of wavelength 131.6 nm. Which transition leads to this wavelength? How fast were the hydrogen atoms travelling before collision?

[$R_H = 1.097 \times 10^7$ m^{-1} and $m_H = 1.67 \times 10^{-27}$ kg]

Sol: With the given data calculate the transition levels using the Rydberg equation and solve for velocity by equating kinetic energy and the energy of a photon.

Wavelength emitted in UV region and thus

n_1 = 1; For H-atom $\therefore \frac{1}{\lambda} = R_H\left[\frac{1}{1^2} - \frac{1}{n^2}\right]$

$$\frac{1}{121.6 \times 10^{-9}} = 1.097 \times 10^7 \left[\frac{1}{1^2} - \frac{1}{n^2}\right] \therefore n = 2$$

Also the energy released is due to collision and all the kinetic energy is released in the form of photon. Thus,

$$\frac{1}{2}mv^2 = \frac{hc}{\lambda}$$

Or $\frac{1}{2} \times 1.67 \times 10^{-27} \times v^2 = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{121.6 \times 10^{-3}}$

$\therefore$ v = 4.43×10^4 m sec^{-1}

Example 6: Let a light of wavelength λ and intensity T strike a metal surface to emit x electrons per second. Average energy of each electron is 'y' unit, What will happen to x and y when (a) λ is halved (b) intensity I is double?

Sol: (a) Rate of emission of electron is independent of wavelength. Hence, 'x' will be unaffected. Kinetic energy of photoelectron = absorbed energy − Threshold energy $y = \frac{hc}{\lambda} - w_0$

When I is halved, average energy will increases but it will not become double.

(b) Rate of emission of electron per second 'x' will become double when intensity I is double. Average energy of ejected electron, i.e. 'y' will be unaffected by increases in the intensity of light.

Example 7: The IP_1 of H is 13.6 eV. It is exposed to electromagnetic waves of 1028 Å and gives out induced radiation. Find the wavelength of these induced radiations:

Sol: From energy of H-atom, solve for the level. Thus, calculate the consecutive wavelength.

E_1 of H atom = −13.6 eV

Energy given to H atom

$$-\frac{6.625 \times 10^{-34} \times 3.0 \times 10^8}{1028 \times 10^{-10}} = 1.933 \times 10^{-18} \text{ J} = 12.07 \text{ eV}$$

$\therefore$ Energy of H atom after excitation

= −13.6 + 12.07 = −1.53 eV

$\therefore E_n = \frac{E_1}{n^2}; \therefore n^2 = \frac{-13.6}{-1.53} = 9; \therefore n = 3$

Thus, electron in H atom is excited to third shell.

$\therefore$ I induced $\lambda_1 = \frac{hc}{E_3 - E_1}$

$\therefore E_1$ = − 13.6 eV; E_3 = − 1.53 eV

$$\therefore \lambda_1 = \frac{6.625 \times 10^{-34} \times 3.0 \times 10^8}{(-1.53 + 13.6 \times 1.602) \times 10^{19}} = 1028 \times 10^{10} \text{ m}$$

$\therefore \lambda = 1028Å$;

$\therefore$ II induced $\lambda_2 = \dfrac{hc}{(E_2 - E_1)}$

$E_1 = -13.6$ eV; $E_2 = -\dfrac{13.6}{4}$eV

$$\therefore\ \lambda_2 = \frac{6.625 \times 10^{-14} \times 3.0 \times 10^{8}}{\left(-\dfrac{13.6}{4} + 13.6\right) \times 1.602 \times 10^{-19}}$$

$= 1216 \times 10^{-16}$ m = 1216 Å

$\therefore$ III induced $\lambda_3 = \dfrac{hc}{(E_2 - E_1)}$

$$\therefore \lambda_2 = -\frac{6.625 \times 10^{-34} \times 3.0 \times 10^{8}}{\left(-\dfrac{13.6}{9} + \dfrac{13.6}{4}\right) \times 1.602 \times 10^{-19}}$$

$= 6568 \times 10^{-10}$m = 6568 Å

Example 8: How many elements would be in the third period of the periodic table if the spin quantum number m_2 could have the value $-\dfrac{1}{2}$, 0 and $+\dfrac{1}{2}$?

Sol: Apply the data to the formulas of the quantum numbers.

n= 1, l = 0, m=0 $\qquad m_s = -1/2, 0, +1/2$

l=1; m = –1, 0, +1
- $m_s = -1/2, 0, +1/2$
- $m_s = -1/2, 0, +1/2$
- $m_s = -1/2, 0, +1/2$

l=2 ; m =–2, –1, 0, 0, +1, +2 $\left\{ m_f = -1/2, 0, +1/2 \right.$ for each value of magnetic quantum no. $\}$

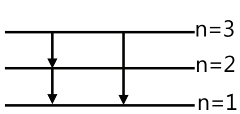
Number of elements = 3s(3e)

3p(9e)

3d(15e)

$\therefore$ 27 elements will be there in third period of periodic table.

Example 9: Consider the following two electronic transition possibilities in a hydrogen atom as pictured below:



(a) The electron drops from third Bohr orbit to second Bohr orbit followed with the next transition from second to first Bohr orbit.

(b) The electron drops from third Bohr orbit to first Bohr orbit directly. Show that the sum of energies for the transitions n = 3 to n = 2 and n = 2 to n = 1 is equal to the energy of transition for n =3 to n = 1.

Sol: Applying $\Delta E = R_H\left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$

For n = 3 to n = 2

$$\Delta E_{3\to 2} = R_H\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R_H \times \frac{5}{36} \qquad \text{... (i)}$$

For n = 2 to n = 1

$$\Delta E_{2\to 1} = R_H\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = R_H \times \frac{3}{4} \qquad \text{... (ii)}$$

For n = 3 to n = 1;

$$\Delta E_{3\to 1} = R_H\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = R_H \times \frac{8}{9} \qquad \text{... (iii)}$$

Adding equation (i) and (ii)

$$\left(\frac{5}{36} + \frac{3}{4}\right) = R_H\left(\frac{5 + 27}{36}\right) = R_H \times \frac{8}{9}$$

Thus, $\Delta E_{3\to 1}\ \Delta E_{3\to 2} + \Delta E_{2\to 1}$

Example 10: Consider the hydrogen atom to be a proton embedded in a cavity of radius a_0 (Bohr radius) whose charge is neutralized by the addition of an electron to the cavity in vacuum infinitely slowly. Estimate the average total energy of an electron in its ground state in a hydrogen atom as the work done in the above neutralization process. Also, if the magnitude of average KE is half the magnitude of average potential energy, find the average potential energy.

Sol: Coulombic force of attraction = Centrifugal force

$$\frac{1}{4\pi \in_0}\frac{Ze \times e}{a_0^2} = \frac{m\upsilon^2}{a_0}$$

Where, υ = velocity of electron

a_0 = distance between electron and nucleus

$$\frac{1}{4\pi \in_0}\frac{Ze^2}{a_0} = m\upsilon^2$$

$$KE = \frac{1}{2}m\upsilon^2 = \frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{2a_0}$$

$$PE = -2 \times KE = -2 \times \frac{1}{4\pi\varepsilon_0} \times \frac{Ze^2}{2a_0} = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{a_0}$$

JEE Main/Boards

Exercise 1

Q.1 In an oil drop experiment, the following charges (in arbitrary units) were found on a series of oil droplets: 4.5×10^{-18}, 3.0×10^{-18}, 6.0×10^{-18}, 7.5×10^{-18}, 9.0×10^{-18}. What is the charge on electron (in the same unit)?

Q.2 Arrange electron (e), proton (p), neutron (n) and α-particle (a) in the increasing order of their specific charges.

Q.3 With what velocity should an α-particle travel towards the nucleus of a copper atom so as to arrive at a distance 10^{-13} m from the nucleus of the copper atom? Atomic number of copper is 29. Mass of alpha particle is 4 amu.

Q.4 The wavelength of the Kα line for an element of atomic number 57 is λ. What is wavelength of the Kα line for the element of atomic number 29.

Q.5 The wavelength of an electromagnetic radiation is 600 nm. What is its frequency?

Q.6 Calculate the energy per quanta of an electron magnetic radiation of wavelength 6626Å.

Q.7 Calculate the Rydberg constant R_H if He^+ ions are known to have the wave length difference between first (of the longest wavelength) lines of Balmer and Lyman series equal to 133.7 nm.

Q.8 Suppose 10^{-17} J of light energy is needed by the interior of the human eye to see an object. How many photons of green light (λ = 550 nm) are needed to generate this minimum amount of energy?

Q.9 The bond energy of H−H bond is 104 kcal/mol. What is the largest wavelength of electromagnetic radiation needed to dissociate H_2 molecules? Assume that one photon may dissociate only one molecule.

Q.10 The work function of potassium is 2.25 eV. Would photoelectron emit when red light of 660 nm falls on potassium surface? If yes, what would be the maximum kinetic energy of electron liberated?

Q.11 The threshold frequency of a metal is 1.8×10^{14} Hz. Calculate the maximum kinetic energy of photoelectron liberated when the metal is irradiated by an electromagnetic radiation of wavelength 4000Å.

Q.12 A particle of mass 'm' moves along a circular orbit in a centro-symmetrical potential field U(r) = $Kr^2/2$. Using the Bohr quantization condition, find the permissible orbital radii of that particle.

Q.13 Light of wave length 2000Å falls on an aluminium surface (work function of aluminium 4.2 eV). Calculate (a) The kinetic energy of the fastest and slowest emitted photo electrons (b) Stopping potential. (c) Cut-off wavelength for Aluminium.

Q.14 Calculate the speed of electron revolving in the 3^{rd} orbit of hydrogen atom.

Q.15 An electron is revolving at a distance of 4.761 Å from the hydrogen nucleus. Determine its speed.

Q.16 Calculate the ratio of time period of electron in the 2nd orbit of H-atom to that in the 3^{rd} orbit of He^+ ion.

Q.17 Calculate the angular frequency of an electron occupying the second Bohr orbit of He^+ ion.

Q.18 Calculate the first four energy levels for electron in hydrogen atom.

Q.19 The dissociation energy of H_2 is 103.2 k cal mole^{-1}. Suppose H_2 molecules are irradiated with wavelength, λ = 2537Å. Assume that one photon is absorbed by and dissociated one molecule of H_2. How much of the photon energy is converted into kinetic energy of the dissociated atoms.

Q.20 Calculate the kinetic, potential and total energy of electron in the 3^{rd} orbit of He^+ ion.

Q.21 Calculate the excitation energy of Li^{2+} ion in the ground state.

Q.22 Calculate the binding energy of electron in the ground state of He^+ ion.

Q.23 Electromagnetic radiation of wavelength 24 nm is just sufficient to ionize sodium atom. Calculate the ionization energy of sodium atom.

Q.24 A beam of electron accelerated with 4.64 V is passed through a tube containing mercury vapours. As a result of absorption, electronic changes occurred with mercury atoms and light was emitted if the full energy of single electron was converted into light, what was the wave number of emitted light?

Q.25 A proton and an electron, both at rest initially, combine to form a hydrogen atom in the ground state. A single photon is emitted in this process. What is its wavelength?

Q.26 Calculate the frequency of the radiation absorbed in the transition n = 2 to n = 4 in hydrogen atom.

Q.27 When electromagnetic radiations of wavelength λ nm fall on hydrogen atoms, electron excite from the ground state to a particular upper energy state. Subsequently, the atoms emit the radiations of six different wavelengths. Calculate the value of λ.

Q.28 The wavelength of H line in the Balmer series of hydrogen spectrum is 660 nm. What is the wavelength of H-line of this series

Q.29 Calculate the momentum of a photon of wavelength 10 Å.

Q.30 Electrons which have absorbed 10.20 eV and 12.09 eV in hydrogen atom can cause radiations to be emitted when they come back to ground state. Calculate in each come back to ground state. Calculate in each case the principal quantum no. of the orbit to which electron goes and the wavelength of the radiations emitted if it drops back to ground state.

Exercise 2

Single Correct Choice Type

Q.1 Which of the following does not characterize x-rays?

(A) The radiation can ionize gases

(B) It causes ZnS to show fluorescence

(C) Deflected by electric and magnetic fields

(D) Have wavelength shorter than ultraviolet rays.

Q.2 Which of the following is false regarding Bohr's model

(A) It introduces the idea of stationary states

(B) It explains the line spectrum of hydrogen

(C) It gives the probability of the electron near the nucleus

(D) It predicts that the angular momentum of electron in H-atom = $nh/2\pi$.

Q.3 The energy of an orbit in a hydrogen atom is given by the relation $E = \frac{\text{Constant}}{n^2}(\text{kJ mol}^{-1})$. Which of the following properties represents the constant in the above relation

(A) Electron affinity (B) Ionization energy

(C) Electro negativity (D) Bond energy

Q.4 The ratio of the energy of a photon of 2000Å wavelength radiation to that of 4000Å radiation is

(A) 1/4 (B) 4 (C) ½ (D) 2

Q.5 The energy of electron is maximum at

(A) Nucleus

(B) Ground state

(C) First excited state

(D) Infinite distance from the nucleus

Q.6 Which quantum number is not related with Schrödinger equation?

(A) Principal (B) Azimuthal

(C) Magnetic (D) Spin

Q.7 The shortest wavelength of He atom in Balmer series is X, then longest wavelength in the Paschen series of Li^{+2} is

(A) $\frac{36x}{5}$ (B) $\frac{16x}{7}$ (C) $\frac{36x}{5}$ (D) $\frac{5x}{9}$

Q.8 An electron in a hydrogen atom in its ground state absorbs energy equal to the ionization energy of Li^{+2}. The wavelength of the emitted electron is:

(A) 3.32×10^{-10} m (B) 1.17 Å

(C) 2.32×10^{-9} nm (D) 3.33 pm

Q.9 Given ΔH for the process $Li(g) \rightarrow Li^{+3}(g) + 3e^-$ is 19800 kJ/mole and IE_1 for Li is 520 then IE_2 and IE_3 of Li+ are respectively (approx. value)

(A) 11775, 7505 (B) 19280, 520

(C) 11775, 19280 (D) Data insufficient

Q.10 The ratio of difference in wavelengths of 1st and 2nd lines of Lyman series in H-like atom to difference in wavelength for 2nd and 3rd lines of same series is:

(A) 2.5: 1 (B) 3.5: 1 (C) 4.5: 1 (D) 5.5: 1

Q.11 The ratio of the radii of the first three Bohr orbit is

(A) 1: 0.5: 033 (B) 1: 2: 3

(C) 1: 4: 9 (D) 1: 8: 27

Q.12 Which combination of quantum number n, *l*, m, s for the electron in an atom does not provide a permissible solution of the wave equation?

(A) 3, 2, −2, +1/2 (B) 3, 3, 1, − ½

(C) 3, 2, 1, +1/2 (D) 3, 1, 1, −1/2

Q.13 The ratio of the energy of a photon of 2,000 Å wavelength radiation to that of 4,000 Å radiation is

(A) 1/4 (B) 4 (C) 1/2 (D) 2

Q.14 The orbital angular momentum of an electron in 2s orbital is

(A) $+\frac{1}{2}\left(\frac{h}{2\pi}\right)$ (B) Zero (C) $h/2\pi$ (D) $\sqrt{2}\times\frac{h}{2\pi}$

Q.15 If n and *l* are respectively the principal and azimuthal quantum number, then the expression for calculating the total number of electrons in any energy level is

(A) $\sum_{i=0}^{\ell-n-\ell} 2(2\ell+1)$ (B) $\sum_{i=0}^{\ell-n-\ell} 2(2\ell+1)$

(C) $\sum_{i=0}^{\ell-n+\ell} 2(2\ell+1)$ (D) $\sum_{i=0}^{\ell-n-\ell} 2(2\ell\times1)$

Q.16 The wavelength of a tennis ball of mass 6.0×10^{-2} kg moving at a speed of about 140 miles per hour is ($h = 6.63 \times 10^{-27}$ erg s)

(A) 1.8×10^{-30} cm (B) 1.8×10^{-32} cm

(C) 1.8×10^{-34} cm (D) None of these

Q.17 If radius of second stationary orbit (in Bohr's atom) is R. Then radius of third orbit will be

(A) R/3 (B) 9R (C) R/9 (D) 2.25 R

Q.18 The ratio of wave length of photon corresponding to the α-line of Lyman series in H-atom and β-line of Balmer series in He^+ is

(A) 1: 1 (B) 1: 2 (C) 1: 4 (D) 3: 16

Q.19 The value of $(n_2 + n_1)$ and for He^+ ion in atomic spectrum are 4 and 8 respectively. The wavelength of emitted photon when electron jump from n_2 to n_1 is

(A) $\frac{32}{9}R_H$ (B) $\frac{9}{32}R_H$ (C) $\frac{9}{32R_H}$ (D) $\frac{32}{9R_H}$

Q.20 Number of possible spectral lines which may be emitted in bracket series in H atom if electron present in 9th excited level returns to group level, are

(A) 21 (B) 6 (C) 14 (D) 7

Q.21 The first use of quantum theory to explain the structure of atom was made by:

(A) Heisenberg (B) Bohr

(C) Planck (D) Einstein

Q.22 The wavelength associated with a golf weighing 200 g and moving at a speed of 5 m/h of the order

(A) 10^{-10} m (B) 10^{-20} m

(C) 10^{-30} m (D) 10^{-40} m

Q.23 The longest wavelength of He^+ in Paschen series is "m", then shortest wavelength of Be^{+3} in Paschen series is (in terms of m):

(A) $\frac{5}{36}m$ (B) $\frac{64}{7}m$ (C) $\frac{53}{8}m$ (D) $\frac{7}{64}m$

Q.24 Consider the following nuclear reactions involving X and Y.

$X \rightarrow Y + {}_2^4He\,;\ Y \rightarrow {}_8O^{18} + {}_1H^1$

If both neutrons as well as protons in both the sides are conserved in nuclear reaction then moles of neutrons in 4.6 gm of X

(A) 2.4 NA (B) 2.4

(C) 4.6 (D) 0.2 NA

Q.25 Electromagnetic radiations having λ = 310Å are subjected to a metal sheet having work function = 12.8 eV. What will be the velocity of photoelectrons with maximum Kinetic energy

(A) 0, no emission will occur (B) 2.15×10^6 m/s

(C) $2.18\sqrt{2}\times10^{6}$ m / s (D) 8.72 × 106 m/s

Q.26 Assuming Heisenberg Uncertainty Principle to be true what could be the minimum uncertainty in de-Broglie wavelength of a moving electron accelerated by Potential Difference of 6V whose uncertainty in position is 7/22 n.m.

(A) 6.25Å (B) 6Å

(C) 0.625 Å (D) 0.3125 Å

Q.27 Correct statement(s) regarding 3P, orbital is/are

(A) Angular part of wave function is independent of angles θ and ϕ)

(B) No. of maxima when a curve is plotted between $4\pi r^2R^2(r)$ vs. r are '2'

(C) 'rz' plane acts as nodal plane

(D) Magnetic quantum number must be '−1'.

Q.28 Choose the incorrect statement(s):

(A) Increasing order of wavelength is Micro waves > Radio waves > IR waves > visible waves > UV waves

(B) The order of Bohr radius is (r_n: where n is orbit number for a given atom) $r_1 < r_2 < r_3 < r_4$

(C) The order of total energy is (E_n: where n is orbit number for a given atom)

(D) The order of velocity of electron in H, He^+, Li^+, Be^{3+} species in second Bohr orbit is

$Be^{1+} > Li^{+2} > He^+ > H$

Q.29 Which is/are correct statement.

(A) The difference in angular momentum associated with the electron present in consecutive orbits of H-atom is $(n - 1)\dfrac{h}{2\pi}$

(B) Energy difference between energy levels will be changed if, PE. At infinity assigned value of other than zero.

(C) Frequency of spectral line in a H-atom is in the order of $(2 \rightarrow 1) < (3 \rightarrow 1) < (4 \rightarrow 1)$

Previous Years' Questions

Q.1 Who discovered neutron ***(1982)***

(A) James Chadwick (B) William Crooks

(C) J.J. Thomson (D) Rutherford

Q.2 The radius of an atom is of the order of ***(1985)***

(A) 10^{-10} cm (B) 10^{-13} cm

(C) 10^{-15} cm (D) 10^{-8} cm

Q.3 Which one of the following constitutes a group of the isoelectronic species ***(2008)***

(A) NO^+, C_2^{2-}, CN^-, N_2 (B) CN^-, N_2, O_2^{2-}, C_2^{2-}

(C) N_2, O_2^-, NO^+, CO (D) C_2^{2-}, O^-_2, CO, NO

Q.4 Which one of the following groupings represents a collection of isoelectronic species ***(2003)***

(A) Na^+, Ca^{2+}, Mg^{2+} (B) $N3^-$, F^-, Na^+

(C) Be, A^{3+}, Cl^- (D) Ca^{2+}, Cs^+, Br

Q.5 The radius of which of the following orbit is same as that of the first Bohr's orbit of hydrogen atom ***(2004)***

(A) He^+ (n = 2) (B) Li^{2+} (n = 2)

(C) Li^{2+} (n = 3) (D) Be^{3+} (n = 2)

Q.6 The wavelength of the radiation emitted, when a hydrogen atom electron falls from infinity to stationary state 1, would be (Rydberg constant = 1.097×10^7 m^{-1}) ***(2004)***

(A) 406 nm (B) 192 nm

(C) 91 nm (D) 9.1×10^{-8} nm

Q.7 The ionization enthalpy of hydrogen atom is 1.313×10^6 J mol^{-1}. The energy required to excite the electron in the atom from n = 1 to n = 2 is ***(2008)***

(A) 6.56×10^5 J mol^{-1} (B) 7.56×10^5 J mol^{-1}

(C) 9.84×10^{-5} J mol^{-1} (D) 8.51×10^5 J mol^{-1}

Q.8 A gas absorbs a photon of 355 nm and emits at two wavelengths. If one of the emissions is at 680 nm, the other is at ***(2011)***

(A) 1035 nm (B) 325 nm

(C) 743 nm (D) 518 nm

Q.9 Calculate the wavelength (in nanometer) associated with a proton moving at $1.0 \times 10^3\ ms^{-1}$ (Mass of proton $= 1.67 \times 10^{-27}$ kg and $h = 6.63 \times 10^{-34}$ Js): ***(2009)***

(A) 0.032 nm (B) 0.40 nm

(C) 2.5 nm (D) 14.0 nm

Q.10 In an atom, an electron is moving with a speed of 600 m/s with an accuracy of 0.005%. Certainty with which the position of the electron can be located is ($h = 6.6 \times 10^{-34}$ kg $m^2 s^{-1}$, mass of electron $m = 9.1 \times 10^{-31}$ kg) ***(2009)***

(A) 1.52×10^{-4} m (B) 5.10×10^{-3} m

(C) 1.92×10^{-3} m (D) 3.84

Q.11 Which of the following sets of quantum number represents the highest energy of an atom? ***(2007)***

(A) n = 3, l = 1, m = 1, s = ±1/2

(B) n = 3, l = 2, m=1, s = −1/2

(C) n = 4, l = 0, m = 0, s = ±1/2

(D) n = 3, l = 0, m = 0, s = ±1/2

Q.12 In a multi-electron atom, which of the following orbital's described by the three quantum numbers will have the same energy in the absence of magnetic and electric fields

(1) n = 1, l = 0, m = 0 (2) n = 2, l = 0, m = 0

(3) n = 2, l = 1, m= 1 (4) n = 3, l = 2, m = 0

(5) n = 3, l = 2, m = 1 ***(2005)***

(A) (1) and (2) (B) (2) and (3)

(C) (3) and (4) (D) (4) and (5)

Q.13 The electronic configuration of an element is $1s^2\ 2s^2\ 3p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$. This represent its ***(2000)***

(A) Excited sate (B) Ground state

(C) Cationic form (D) Anionic form

Q.14 Which of the following sets of quantum number is correct for an electron in 4f orbital? ***(2004)***

(A) n = 4, l = 3, m = +1, s = +1/2

(B) n = 4, l = 4, m = −4, s = −1/2

(C) n = 4, l = 3, m = +4, s = +1/2

(D) n = 3, l = 2, m = −2, s = +1/2

Q.15 The electrons identified by quantum numbers n and λ ***(2012)***

(1) n = 4, λ = 1 (2) n = 4, λ = 0

(3) n = 3, λ = 2 (4) n = 3, λ = 1

Can be placed in order of increasing energy as

(A) (3) < (4) < (2) < (1) (B) (4) < (2) < (3) < (1)

(C) (2) < (4) < (1) < (3) (D) (1) < (3) < (2) < (4)

Q.16 In an atom, an electron is moving with a speed of 600m/s with an accuracy of 0.005%. Certainity with which the position of the electron can be located is $\left(h = 6.6\times10^{-34}\ kg\ m^2\ s^{-1} \text{ mass of electron, } e_m = 9.1\times10^{-31}\ kg\right)$ ***(2009)***

(A) 1.52×10^{-4} m (B) 5.10×10^{-3} m

(C) 1.92×10^{-3} m (D) 3.84×10^{-3} m

Q.17 Calculate the wavelength (in nanometer) associated with a proton moving at $1.0 \times 10^3\ ms^{-1}$ (Mass of proton $= 1.67 \times 10^{-27}$ kg and $h = 6.63 \times 10^{-34}$ Js): ***(2009)***

Q.18 The energy required to break one mole of Cl–Cl bonds in Cl_2 is 242 kJ mol^{-1}. The longest wavelength of light capable of breaking a single Cl – Cl bond is $\left(c = 3\times10^8\ ms^{-1} \text{ and } N_A = 6.02\times10^{23}\ mol^{-1}\right)$ ***(2010)***

(A) 594 nm (B) 640 nm

(C) 700 nm (D) 494 nm

Q.19 Ionisation energy of He^+ is 1.96×10^{-18} J $atom^{-1}$. The energy of the first stationary state (n = 1) of Li^{2+} is ***(2010)***

(A) 4.41×10^{-16} J $atom^{-1}$

(B) -4.41×10^{-17} J $atom^{-1}$

(C) -2.2×10^{-15} J $atom^{-1}$

(D) 8.82×10^{-17} J $atom^{-1}$

Q.20 Which of the following is the energy of a possible excited state of hydrogen? ***(2015)***

(A) +13.6 eV (B) –6.8 eV

(C) –3.4 eV (D) +6.8 eV

JEE Advanced/Boards

Exercise 1

Q.1 What is the relationship between the eV and the wavelength in meter of the energetically equivalent photon?

Q.2 What electronic transition in the He^+ would emit the radiation of the same wavelength as that of the first Lyman transition of hydrogen (i.e., for an electron jumping from n = 2 to n = 1)? Neglect the reduced – mass effect. Also calculate second ionization potential of He and first Bohr orbit for He^+. (e = 1.65×10^{-19} coulomb, m = 9.1×10^{-31} kg, h = 6.626×10^{-34} J, sec c = 2.997×10^8 meter/sec and $e_0 = 8.854 \times 10^{-12}$ columb^2/newton metre^2)

Q.3 What acceleration potential is needed to produce an electron beam with an effective wavelength of 0.090 Å?

Q.4 In view of the uncertainty principle explain that the motion of an electron cannot be described in terms of orbit as proposed by Bohr.

Q.5 With what velocity should an α-particle travel towards the nucleus of a Cu-atom so as to arrive at distance 10^{-13} meter from the nucleus of the Cu-atom? (Cu = 29, e = 1.6×10^{-19}C $a_0 = 8.85 \times 10^{-12}$ J^{-1} C^{-1} C^2m^{-1} $m_0 = 9.1 \times 10^{-31}$ kg)

Q.6 Calculate the velocity of an electron in the third orbit of the hydrogen atom. Also calculate the number of revolutions per second made by this electron around the nucleus.

Q.7 According to Bohr theory, the electronic energy of hydrogen atom in the n^{th} Bohr atom is given by $E = \frac{-21.76 \times 10^{-19}}{n^2}$ J. Calculate the longest wavelength of light that will be needed to remove an electron from the third Bohr orbit of the He^+ ion.

(h = 6.626×10^{-34} J sec, c = 3×10^8 m sec^{-1})

Q.8 Why the concept of orbit has been replaced by probability picture?

Q.9 What is meant by atomic orbital? Explain the concept of orbital in terms of probability density?

Q.10 Explain hydrogen spectrum.

Q.11 The λ of H_α line of Balmer series of 6500 Å. What is the l of H_β line of Balmer series.

Q.12 Calculate the frequency of the spectral line emitted when the electron in n = 3 in H atom de excites to ground state R_H = 109737 cm^{-1}.

Q.13 Estimate the difference in energy between 1^{st} and 2^{nd} Bohr orbit for a H atom. At what minimum atomic no., a transition from n = 2 to n = 1 energy level would result in the emission of X-ray with $\lambda = 3.0 \times 10^8$ m. Which hydrogen atom like species does this atomic no. corresponds to?

Q.14 What does the shape of an atomic orbital represent?

Q.15 How many nodes and spherical nodes are there in p_x orbital?

Q.16 Why is the electronic configuration $1s^2\ 2s^2\ 2p^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^4$ not correct for chromium? What is the its correct configuration (Atomic number of Cr is 24). Give proper explanation.

Q.17 The photo electric emission requires a threshold frequency v_0 for a certain metal λ_1 = 2200Å and λ_2 = 1900Å produce electrons with maximum kinetic energy KE_1 and KE_2. If $KE_2 = 2KE_1$ calculate v_0 and corresponding value.

Q.18 A near ultraviolet photon of 300 nm is absorbed by a gas and then re-emitted as two photons? One photon is red with wavelength 760 nm. What would be the wavelength of the second photon?

Q.19 Show that the wavelength of a 150 rubber ball moving with a velocity 50 m sec^{-1} is short enough to be observed.

Q.20 When a certain metal was irradiated with light frequency 1.6×10^{16} Hz, the photo electrons emitted had twice the kinetic energy as did photoelectrons emitted when the same metal was irradiated with light of frequency 1.0×10^{16} Hz. Calculate v_0 (threshold frequency) for metal.

Q.21 Magnetic moment of X^{st} ion of 3d series is B.M. What is atomic number of X^{34}?

Q.22 Iodine molecule dissociates into atoms after absorbing light of 4500 Å if one quantum of radiation is absorbed by each molecule. Calculate the kinetic energy of iodine?

Q.23 Energy required to stop the ejection of electron from Cu plate is 0.24 eV. Calculate the work function when radiations of λ = 253.7 nm strikes the plate.

Q.24 Calculate the energy emitted when electrons of 1.0 g atom of hydrogen undergo transition giving the spectral lines lowest energy in the visible region of its atomic spectra

$R_H = 1.1 \times 10^3\ m^{-1}$, $C = 3 \times 10^8$ m sec^{-1} and $h = 6.62 \times 10^{-34}$ Js.

Q.25 The characteristics X-rays wavelength for the lines of the K_α series in elements X and Y are 9.87 Å and 2.29 Å respectively. If Moseley's equation $v = 4.9 \times 10^7 (Z - 0.75)$ is followed, what are atomic numbers of X and Y

Q.26 In the Balmer series of atomic spectra of hydrogen there is a line corresponding to wavelength 4744 Å. Calculate the number of higher orbits from which the electron drops to generate other line [$R \times C = 3.289 \times 10^{13}$]

Q.27 Assuming a spherical second and third Bohr orbits of the hydrogen atom is -5.42×10^{-12} ergs and -2.41×10^{-11} ergs respectively. Calculate the wavelength of the emitted radiation when the electron drops from third to second orbit.

Q.28 Assuming a spherical shape for the F nucleus, calculate the radius and the nuclear density of F nucleus of mass number 19.

Q.29 What conclusion may be drawn from the following results of? If a 10×10^{-1} kg body is traveling along the x-axis at 1 meter/sec within 0.01 meter/sec. Calculate the theoretical uncertainty in its position.

Q.30 What conclusion may be drawn from the following of? If an electron is traveling at 100 meter/sec. within 1 meter/sec. Calculate the theoretical uncertainty in its position.

[$h = 6.63 \times 10^{-34}$ J s, mass of electron = 9.109×10^{-31} kg]

Exercise 2

Single Correct Choice Type

Q.1 Bohr's concept of an orbit in an atom contradicts

(A) de Broglie's equation (B) Pauli's principle

(C) Uncertainty principle (D) Hund's rule

Q.2 It is a data sufficiency problem in which it is to be decided on the basis of given statements whether given question can be answered or not. No matter whether the answer is yes or no.

Question: Is the orbital of hydrogen atom $3p_x$?

Statement-I: The radial function of the orbital is

$$R(r) = \frac{1}{9\sqrt{6}a_0^{3/2}}(4-\sigma)\sigma e^{-\sigma/2}, \sigma = \frac{r}{2}$$

Statement-II: The orbital has 1 radial node and 0 angular mode.

(A) Statement-I alone is sufficient.

(B) Statement-II alone is sufficient

(C) Both together is sufficient.

(D) Neither is sufficient

Comprehension Type

Paragraph 1: The only electron in the hydrogen atom resides under ordinary conditions on the first orbit. When energy is supplied, the electron moves to higher energy orbit depending on the amount of energy absorbed. When this electron returns to any of lower orbits, it emits energy. Lyman series is formed when the electron returns to the lowest orbit while Balmer series is formed when the electron returns to second orbit. Similarly, Paschen, Brackett and Pfund series are formed when electron returns to the third, fourth and fifth orbits from higher energy orbits respectively.

Maximum number of lines produced when an electron jumps from nth level to ground level is equal to $\frac{n(n-1)}{2}$. For example, in the case of n = 4, number of lines produced is 6.

(4 → 3, 4 → 2, 4 → 1, 3 → 2, 3 → 1, 2 → 1). When an electron returns from n_2 to n_1 state, the number of lines in the spectrum will be equal to $\frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$

If the electron comes back from energy level having energy E_2 to energy level having energy E_1, then the difference may be expressed in terms of energy of photon as:

$E_2 - E_1 = \Delta E, \lambda = \frac{hc}{\Delta E}$

Since h and c are constants, DE corresponds to definite energy, thus each transition from one energy level to another will produce a light of definite wavelength. This is actually observed as line in the spectrum of hydrogen atom. Wave number of line is given by the formula $\bar{v} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ Where R is a Rydberg's constant ($R = 1.1 \times 10^7\ m^{-1}$)

Q.3 The energy photon emitted corresponding to transition n = 3 to n = 1 is [$h = 6\ 0 \times 10^{-34}$ J −sec]

(A) 1.76×10^{-18} J
(B) 1.98×10^{-18} J
(C) 1.76×10^{-17} J
(D) None of these

Q.4 In a collection of H-atom, electrons make transition from 5th excited state to 2nd excited state then maximum number of different types of photons observed are

(A) 3 (B) 4 (C) 6 (D) 15

Q.5 The difference in the wavelength of the 1st line of Lyman series and 2nd line of Balmer series in a hydrogen atom is

(A) $\frac{9}{2R}$
(B) $\frac{4}{R}$
(C) $\frac{88}{15R}$
(D) None of these

Q.6 The wave number of electromagnetic radiation emitted during the transition of electron in between two levels of Li^{2+} ion whose principal quantum number sum is 4 and difference is 2 is

(A) 3.5 R
(B) 4R
(C) 8R
(D) $\frac{8}{9}R$

Paragraph 2: In the Rutherford's experiment, α-particles were bombarded towards the copper atoms so as to arrive at a distance of 10^{-13} meter from the nucleus of copper and then getting either deflected or traversing back. The α-particles did not move further closer.

Q.7 The velocity of the α-particles must be

(A) 8.32×10^8 cm/sec
(B) 6.32×10^8 cm/sec
(C) 6.32×10^8 m/sec
(D) 6.32×10^8 km/sec

Q.8 Which of the following metals can be used instead of gold in α-scattering experiment

(A) Pt (B) Na (C) K (D) Cs

Q.9 From the Rutherford's α-particle scattering, it can be concluded that

(A) $N \propto \sin^4 \frac{\theta}{2}$
(B) $N \propto \frac{1}{\sin^4 \theta}$
(C) $N \propto \frac{1}{\sin^4 \theta / 2}$
(D) $N = \sin\frac{\theta}{2}$

Q.10 Rutherford observed that

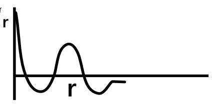
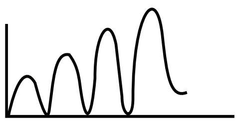
(A) 50% of the α-particles got deflected
(B) 99% of the α-particles got deflected
(C) 99% of the α-particles went straight without suffering any deflection.
(D) Nucleus is negatively charged.

Match the Columns

Q.11 Match the entries in column I with entries in column II

Column I	Column II
(A) Electron moving in 2nd orbit in He^+ ion electron is	(p) Radius of orbit in which moving is 0.529Å
(B) Electron moving in 3rd orbit in H-atom	(q) Total energy of electron is (−)13.6 × 9eV
(C) Electron moving in 1st orbit in Li^{+2} ion	(r) Velocity of electron is $\frac{2.188 \times 10^8}{3}$ m / sec
(D) Electron moving in 2nd orbit is Be^{+3} ion	(s) De-broglie wavelength of Electron is $\sqrt{\frac{150}{13.6}}$Å

Q.12 Column I and column II contain data on Schrodinger Wave–Mechanical model, where symbols have their usual meanings. Match the columns.

Column I	Column II
(A) Ψ_r 	(p) 4s
(B) $\Psi_r^2 4\pi r^2$ 	(q) $5p_x$
(C) $\psi(\theta, \phi)$ = K (independent of θ and ϕ)	(r) 3s
(D) at least one angular node is present	(s) 6d

True/False Type

Q.13 Statement-I: Emitted radiations will fall in the visible range when an electron jumps from higher level to n = 2 in Li^{+2} ion.

Statement-II: Balmer series radiations belong to visible range in all H-like atoms.

(A) Statement-I true; Statement-II is true; Statement-II is the correct explanation of Statement-I.

(B) Statement-I true; Statement-II is true; Statement-II is not the correct explanation of Statement-I.

(C) Statement-I is true; Statement-II is false.

(D) Statement-I is false; Statement-II is true.

Previous Years' Questions

Q.1 The increasing order (lowest first) for the values of e/m (charges/mass) for electron (e), proton (p) ***(1984)***

(A) e, p, n α (B) n, p, e, α

(C) n, p, α, e (D) n, α, p, e

Q.2 Which of the following does not characterize X-rays ***(2000)***

(A) The radiation can ionize gases

(B) It causes ZnS to fluoresce

(C) Deflected by electric and magnetic fields

(D) Have wavelengths shorter than ultraviolet rays

Q.3 The number of nodal planes in a px orbital is ***(2001)***

(A) One (B) Two (C) Three (D) Zero

Q.4 If the nitrogen atom had electronic configuration $1s^1$ it would have energy lower than that of the normal ground state configuration $1s^2$ $2s^2$ $2p^3$, because the electrons would be closer to the nucleus, yet $1s^7$ is not observed because it violates ***(2002)***

(A) Heisenberg uncertainty principle

(B) Hund's rule

(C) Pauli exclusion principle

(D) Bohr postulate of stationary orbits

Q.5 Which hydrogen like species will have same radius as that of Bohr orbit of hydrogen atom? ***(2003)***

(A) n = 2, Li^{2+} (B) n = 2, Be^{3+}

(C) n = 2, He^+ (D) n = 3, Li^{2+}

Q.6 The number of radial nodes in 3s and 2p respectively are ***(2005)***

(A) 2 and 0 (B) 0 and 2

(C) 1 and 2 (D) 2 and 1

Q.7 When alpha particles are sent through a thin metal foil, most of them go straight through the foil because ***(1984)***

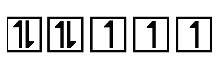
(A) Alpha particles are much heavier than electrons

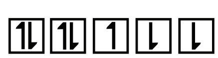
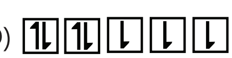
(B) Alpha particles are positively charged

(C) Most part of the atom is empty space

(D) Alpha particles move with high velocity

Q.8 The ground state electronic configuration of nitrogen atom can be represented by ***(2004)***

(A)  (B) 

(C)  (D) 

Read the following questions and answer as per the direction given below:

(A) Statement-I true; Statement-II is true; Statement-II is the correct explanation of Statement-I.

(B) Statement-I true; Statement-II is true; Statement-II is not the correct explanation of Statement-I.

(C) Statement-I is true; Statement-II is false.

(D) Statement-I is false; Statement-II is true.

Q.9 Statement-I: The first ionization energy of Be is greater than that of B.

Statement-II: 2p orbital is lower in energy than 2s. ***(2000)***

Paragraph 1: The hydrogen-like species Li^{2+} is in a spherically symmetric state S_1 with one radial node. Upon absorbing light the ion undergoes transition to a state S_2 has one radial node and its energy is equal to the ground state energy of the hydrogen atom. ***(2010)***

Q.10.1 The state S_1 is

(A) 1s (B) 2s (C) 2p (D) 3s

Q.10.2 Energy of the state S_1 in units of the hydrogen atom ground state energy is

(A) 0.75 (B) 1.50 (C) 2.25 (D) 4.50

Q.10.3 The orbital angular momentum quantum number of the state S_2 is

(A) 0 (B) 1 (C) 2 (D) 3

Q.11 According to Bohr's theory En = total energy

K_n = Kinetic energy K_n = Kinetic energy

V_n = Potential energy R_n = Radius of nth orbit

Match the following: ***(2006)***

Column I	**Column II**
(A) V_n/K_n =	(p) V_n/K_n =
(B) If radius of nth orbit $\propto E^x_n$, x=	(q) −1
(C) Angular momentum is lowest orbital	(r) −2
(D) $\frac{1}{r^n} \propto Z^y, y = ?$	(s) 1

Q.12 Match the entries in Column I with the correctly related quantum number (s) in column II. ***(2008)***

Column I	**Column II**
(A) Orbital angular momentum of the electron in a hydrogen-like atomic orbital	(p) Principal quantum number
(B) A hydrogen-like one-electron wave function obeying Pauli's principle	(q) Azimuthal quantum number
(C) Shape, size and orientation of hydrogen-like atomic orbital	(r) Magnetic quantum number
(D) Probability density of electron at the nucleus in Hydrogen-like atom	(s) Electron spin quantum number

Q.13 The maximum number of electrons that can have principal quantum number, n = 3 and spin quantum number, $m_s = -\frac{1}{2}$ is ***(2011)***

Q.14 The work function (Φ) of some metals is listed below. The number of metals which will show photoelectric effect when light of 300 nm wavelength falls on the metal is ***(2011)***

Metal	Li	Na	K	Mg	Cu	Ag	Fe	Pt	W
Ö(eV)	2.4	2.3	2.2	3.7	4.8	4.3	4.7	6.3	4.75

Q.15 (a) The Schrodinger wave equation for hydrogen atom is: $\psi_{2s} = \frac{1}{4(2\pi)^{1/2}}\left(\frac{1}{a_0}\right)^{3/2}\left(2-\frac{r}{a_0}\right)e^{-r/2a_0}$

Where, a_0 is Bohr's radius. Let the radial node in 2s be at r_0. Then find r in terms of a_0.

(b) A baseball having mass 100 g moves with velocity 100 m/s. Find out the value of wavelength of baseball. ***(2004)***

Q.16 (a) Calculate velocity of electron in first Bohr orbit of hydrogen atom (Given, $r = a_0$)

(b) Find de-Broglie wavelength of the electron in first Bohr orbit

(c) Find the orbital angular momentum of 2p-orbital in terms of $h/2\pi$ units. ***(2005)***

Q.17 The atomic masses of He and Ne are 4 and 20 a.m.u., 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 ***(2013)***

Q.18 Not considering the electronic spin, the degeneracy of the second excited state(n = 3) of H atom is 9, while the degeneracy of the second excited state of H^- is ***(2015)***

Q.19 The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is [is Bohr radius] ***(2015)***

(A) $\frac{h^2}{4\pi^2 ma_0^2}$ (B) $\frac{h^2}{16\pi^2 ma_0^2}$

(C) $\frac{h^2}{32\pi^2 ma_0^2}$ (D) $\frac{h^2}{64\pi^2 ma_0^2}$

MasterJEE Essential Questions

JEE Main/Boards

Exercise 1

Q.1 Q.4 Q.9
Q.13 Q.16 Q.27

Exercise 2

Q.5 Q.7 Q.18
Q.19 Q.28

Previous Years' Questions

Q.7 Q.15

JEE Advanced/Boards

Exercise 1

Q.1 Q.7 Q.17
Q.19

Exercise 2

Q.4 Q.6 Q.9
Q.12

Previous Years' Questions

Q.8 Q.10.3 Q. 11

Answer Key

JEE Main/Boards

Exercise 1

Q.1 [1.5×10^{-18} unit.]

Q.2 [$n < \alpha < p < e$]

Q.3 [6.35×10^{6} m/s]

Q.4 [$\lambda_1 = 4\lambda$]

Q.5 [$5 \times 10^{14}\ s^{-1}$]

Q.5 [3×10^{-19}]

Q.7 1.095 x $10^{5}\ cm^{-1}$

Q.8 [≈28]

Q.9 [2741 Å]

Q.10 [No photoelectron will emit]

Q.11 [3.78×10^{-19} J]

Q.12 [$r = \left(\frac{n^2h^2}{4\pi^2mk}\right)^{1/4}$]

Q.13 (A) 2.0 eV; (B) 2V; (C) 2970Å

Q.14 7.293 ×10^{5} m/s

Q.15 7.293 × 10^{5} m/s

Q.16 32/27

Q.17 2.09 × $10^{16}\ s^{-1}$

Q.18 $E_a = E_1/n^2$

Q.19 6 ×10^{-20} J

Q.20 −6.044eV; + 6.044 eV; −12.088 eV.

Q.21 91.8 eV

Q.22 54.4eV

Q.23 494.73 kJ/mol

Q.24 3.75×10^4 cm^{-1}

Q.25 912.37 Å

Q.26 1.01×10^{15} Hz

Q.27 97.86 nm

Q.28 488.89 nm

Q.29 6.626×10^{-25} kg ms^{-1}

Q.30 n = 2 and 3; λ = 1216 Å; λ = 1020Å

Exercise 2

Single Correct Chioce Type

Q.1 C	**Q.2** C	**Q.3** B	**Q.4** D	**Q.5** D	**Q.6** D	**Q.7** B
Q.8 B	**Q.9** A	**Q.10** B	**Q.11** C	**Q.12** B	**Q.13** D	**Q.14** B
Q.15 A	**Q.16** D	**Q.17** D	**Q.18** A	**Q.19** C	**Q.20** A	**Q.21** B
Q.22 C	**Q.23** D	**Q.24** B	**Q.25** C	**Q.26** B	**Q.27** B	**Q.28** A
Q.29 C						

Previous Years' Questions

Q.1 A	**Q.2** D	**Q.3** A	**Q.4** B	**Q.5** D	**Q.6** C	**Q.7** C
Q.8 C	**Q.9** B	**Q.10** C	**Q.11** B	**Q.12** D	**Q.13** B	**Q.14** A
Q.15 B	**Q.16** C	**Q.17** B	**Q.18** A	**Q.19** B	**Q.20** C	

JEE Advanced/Boards

Exercise 1

Q.1 1eV = 1.24×10^{-6} meter

Q.2 $n_1 = 2$, $n_2 = 4$, I.P. = 8.67×10^{-18} J,
r = 2.64×10^{-11} volts

Q.3 1.86×10^3 volts

Q.5 6.34×10^6 m/sec

Q.6 2.4×10^{14} sec^{-1}

Q.7 2.055×10^{-7} m/s

Q.11 4814.8 Å

Q.12 2.92×10^{15}

Q.13 Z = 2 He^+

Q.17 $v_0 = 1.148 \times 10^{15}$ sec^{-1}; λ_0 = 2614.6 Å

Q.18 495 nm

Q.19 8.84×10^{-35} m

Q.20 $v_0 = 4\times10^{15}$ Hz

Q.21 26

Q.22 2.2×10^{-20} J

Q.23 4.65 eV

Q.24 182.5 kJ

Q.25 $Z_x = 12$, $Z_y = 24$

Q.26 5

Q.27 $\lambda = 6.6 \times 10^3$ Å

Q.28 Volume = 2×10^{-37} cm^3 Density of molecules = 1.44×10^{14} gm/cm^3

Q.29 $\Delta n = 3 \times 10^{-30}$ m

Q.30 $\Delta n = 3 \times 10^{-5}$ m

This shows uncertainty in positions for larger particles is less whereas the uncertainty in position for smaller particles is larger. Hence for macro particles uncertainty in positions is not significant

Exercise 2

Single Correct Chioce Type

Q.1 C　**Q.2** B

Comprehension Type

Paragraph 1: **Q.3** A B　**Q.4** C　**Q.5** B　**Q.6** C

Paragraph 2: **Q.7** B　**Q.8** A　**Q.9** C　**Q.10** C

Match the Columns

Q.11 A → s; B → r; C → q; D → p　**Q.12** A → p; B → p, q, s; C → p, r; D → q, s

Assertion Reasoning Type

Q.13 D

Previous Years' Questions

Q.1 D　**Q.2** C　**Q.3** A　**Q.4** C　**Q.5** B　**Q.6** A　**Q.7** A, C

Q.8 A, D　**Q.9** C　**Q.10.1** B　**Q.10.2** C　**Q.10.3** B

Q.11 A → r; B → q; C → p; D → s　**Q.12** A → q; B → p, q, r, s; C → p, q, r; D → p, q, r

Q.13 9　**Q.14** 4　**Q.15** (A) Ro = 2ro, (B) 6.625×10^{-25} Å

Q.16 (A) 2.18×10^6 ms^{-1} (B) 3.3 Å (C) $\sqrt{2}\left(\frac{h}{2\pi}\right)$　**Q.17** 5　**Q.18** 3　**Q.19** C

Solutions

JEE Main/Boards

Exercise 1

Sol 1: In an oil drop experiment, the obtained charges will be integral multiples of charge of electron.

Let charge of electron be u

u = GCD (4.5×10^{-18}, 3×10^{-18}, 6×10^{-18}, 7.5×10^{-18}, 9×10^{-18}) and we know that

GCD (4.5, 3.6, 7.5, 9) = 1.5

∴ Charge of electron = u = 1.5×10^{-18} C

Sol 2: Let charge of electron be 'e_0' and mass of proton and neutron = m_0

$$SC_e = \frac{|e_0|}{\frac{m_0}{1837}} = 1837\frac{|e_0|}{m_0}$$

$$SC_p = \frac{|e_0|}{m_0}$$

$$SC_n = \frac{0}{m_0} = 0$$

$$SC_\infty = \frac{|2e_0|}{4m_0} = \frac{1}{2}\frac{|e_0|}{m_0}$$

[since α particle = He^{2+}]

$\therefore SC_n < SC_\alpha < SC_p < SC_e$

i.e. $[n < \alpha < p < e]$.

Sol 3: By conservation of energy

$\Delta PE = \Delta KE$

$$\Rightarrow \frac{1}{4\pi \epsilon_0} \times \frac{q_1 q_2}{r} = \frac{1}{2} mv^2$$

q_1 = charge of copper nucleus

q_2 = charge of α-particle

$$\Rightarrow \frac{9\times10^9 \times 29\times1.6\times10^{-19}\times2\times1.6\times10^{-19}}{10^{-13}}$$

$$= \frac{1}{2} \times 4 \times 1.67 \times 10^{-27} \times v^2$$

$$v^2 = \frac{133.6}{3.3} \times 10^{12} \Rightarrow v = 6.34 \times 10^6 \text{ m/s}$$

Sol 4: By Moseley's law

$E = (10.2 \text{ eV}) (2 - 1)^2$

$$\lambda \propto \frac{1}{E} \Rightarrow \lambda \propto \frac{1}{(Z-1)^2}$$

$$\frac{\lambda_{29}}{\lambda_{57}} = \frac{(57-1)^2}{(29-1)^2} = \frac{56^2}{28^2} = 4$$

$$\Rightarrow \lambda_{29} = 4\lambda_{57} \Rightarrow \lambda' = 4\lambda.$$

Sol 5: Frequency, $\nu = \frac{c}{\lambda} = \frac{3\times10^8}{600\times10^{-9}}$

$= 5 \times 10^{14}$ /sec

Sol 6: $E = \frac{hc}{\lambda} = \frac{6.66\times10^{-34}\times3\times10^8}{6626\times10^{-10}} = 3 \times 10^{-19}$ J

Sol 7: First line of Lyman is He^{2+}

$$\frac{1}{\lambda} = R_H \times Z^2 \left[\frac{1}{1^2} - \frac{1}{2^2}\right] = R_H \times 4\left(\frac{3}{4}\right)$$

$$\frac{1}{\lambda} = 3R_H \qquad \lambda = \frac{1}{3R_H}$$

$$\therefore \Delta\lambda = \frac{1}{R_H}\left(\frac{9}{5} - \frac{1}{3}\right) = \frac{22}{15R_H} = 133.7 \times 10^{-17} \text{ cm}$$

$\therefore R_H = 1.085 \times 10^5 \text{ cm}^{-1}$

First line of Balmer is He^{2+}

$$\frac{1}{\lambda} = R_H \times Z^2 \left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R_H \times Z^2\left(\frac{5}{36}\right)$$

$$\frac{1}{\lambda} = \frac{5R_H}{9}$$

$$\lambda = \frac{9}{5R_H}$$

$\therefore R_H = 1.095 \times 10^5 \text{ cm}^{-1}$

Sol 8: Energy of each photon = $E_0 = \frac{hC}{\lambda}$

$$= \frac{6.6\times10^{-34}\times3\times10^8}{550\times10^{-9}} = 3.6 \times 10^{-19} \text{ J}$$

Number of photon required $= \frac{E}{E_0} = \frac{10^{-17}}{3.6\times10^{-19}}$

≈ 27.7

So we need 28 ph otons.

Sol 9: Energy required of H_2 molecule is

$$E_0 = \frac{104\times10^3\times4.2 \text{ J}}{6\times10^{2.3}} = 72.8 \times 10^{-20}$$

$= 7.28 \times 10^{-19}$ J

$$E_0 = \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E_0} = \frac{6.6\times10^{-34}\times3\times10^8}{7.28\times10^{-19}}$$

$= 2.74 \times 10^{-7}$ m = 2740 Å

Sol 10: Energy of photon = $\frac{hc}{\lambda}$

$$= \frac{6.6\times10^{-34}\times3\times10^8}{660\times10^{-9}} = 3 \times 10^{-19} \text{ J}$$

Work function = $2.25 \times 1.6 \times 10^{-19}$ J

$\approx 3.6 \times 10^{-19}$ J

As work function is greater than energy of photon, no photoelectron will be emitted.

Sol 11: Energy of photon = $\frac{hc}{\lambda}$

$$= \frac{6.6\times10^{-34}\times3\times10^8}{4\times10^3\times10^{-10}} = 4.95 \times 10^{-19} \text{ J}$$

Work function = $h\nu_0$

$= 6.6 \times 10^{-34} \times 1.8 \times 10^{14} = 1.18 \times 10^{-19}$ J

and $KE_{max} = E_{photon}$ − work function

$= 3.78 \times 10^{-19}$ J

Sol 12: According to Bohr,

$mvr = \frac{nh}{2\pi}$ and for equilibrium of electron.

$\frac{mv^2}{r} = F$

$F = \frac{\partial U}{\partial r} = \frac{d\left(\frac{1}{2}kr^2\right)}{dr} = kr$

$\frac{mv^2}{r} = kr$ ...(i)

and from first equation

$mvr = \frac{nh}{2\pi}$

$\Rightarrow m^2v^2r^2 = \frac{n^2h^2}{4\pi^2}$ ...(ii)

If we equate v_2 in both the equations

$\Rightarrow \frac{kr^2}{m} = \frac{n^2h^2}{4\pi^2m^2r^2} \Rightarrow r^4 = \frac{n^2h^2}{4\pi^2mk}$

$\Rightarrow r = \left(\frac{n^2h^2}{k4\pi^2m}\right)^{1/4}$

Sol 13: Energy of photon $= \frac{hc}{\lambda}$

$= \frac{6.6\times10^{-34}\times3\times10^8}{2\times10^3\times10^{-10}}$

$\approx 9.9 \times 10^{-19}$ J

$\approx \frac{9.9\times10^{-19}}{1.6\times10^{-19}}$ eV = 6.2 eV

(a) For fastest moving electron

$KE = \frac{hc}{\lambda} - E_0$ = 6.2 eV − 4.2 eV = 2.0 eV

for slowest moving electron

KE = 0

(b) Stopping potential $= \frac{KE_{max}}{e} = \frac{2eV}{e} = 2V$

(c) Cut-off wavelength $= \lambda_0 = \frac{hc}{E_0}$

$= \frac{6.6\times10^{-34}\times3\times10^8}{4.2\times1.6\times10^{-19}}$

$\approx 2.97 \times 10^{-7}$ m = 2970 Å

Sol 14: Speed of an electron in H-atom in nth orbit is

$v_n = \frac{2\pi ke^2}{h}\times\frac{Z}{n} = 2.18 \times 10^6 \times \frac{1}{n}$ and n = 3

$\therefore$ v = 7.29×10^5 m/s

Sol 15: Radius of nth orbit in H is

$r_n = 0.529 \times n^2$ Å

$\Rightarrow 0.529\ n^2 = 4.761 \Rightarrow n^2 = 9 \Rightarrow n = 3$

$v^3 = \frac{2.18\times10^6}{3} = 7.29 \times 10^5$ m/s

Sol 16: Time period of electron $= \frac{2\pi r}{v}$

$\therefore t \propto \frac{n^2/Z}{Z/n} \Rightarrow t \propto \frac{n^3}{Z^2}$

$\therefore \frac{T_1}{T_2} = \frac{\frac{2^3}{1^2}}{\frac{3^3}{2^2}} = \frac{2^5}{3^3} = \frac{32}{27}$

Sol 17: Angular frequency of an electron in an orbit is

$f = \frac{2\pi}{T} = \frac{V}{2\pi r}\times 2\pi = \frac{2.18\times10^6\times\frac{2}{2}}{2\times3.14\times0.529\times\frac{2^2}{2}\times10^{-10}} \times$

2×3.14

2.08×10^{16} /sec

Sol 18: Energy of nth orbit in H atom is

$E = \frac{-2\pi^2k^2me^4}{n^2h^2} = \frac{-13.6}{n^2}$ eV

E_1 = −13.6 eVE_2 = −3.4 eV

E_3 = −1.51 eVE_4 = −0.85 eV

Sol 19: Energy of photon $= \frac{hC}{\lambda}$

$= \frac{6.6\times10^{-34}\times3\times10^8}{2.537\times10^{-7}} = 7.8 \times 10^{-19}$ J

Energy needed to dissociate 1 molecule of H_2

$= \frac{103.2\times10^3\times4.2}{6\times10^{23}} = 7.22 \times 10^{-19}$ J

$\therefore$ KE = (7.8 − 7.2) × 10^{-19} J = 6 × 10^{-20} J

Sol 20: TE of 3rd orbit of He+ ion

$= 13.6 \times \frac{Z^2}{n^2}$ eV and Z = 2, n = 3

$\therefore$ TE = −13.6 × $\frac{4}{9}$ = −6.044 eV

PE = 2TE = −12.088 eV

KE = −TE = 6.044 eV

Sol 21: Excitation energy = Energy of 2nd orbit − Energy of 1st orbit

$$E_{ex} = \frac{-13.6 \times Z^2}{2^2} - \left(\frac{-13.6 \times Z^2}{1^2}\right) \text{ and } Z = 3$$

$$\Rightarrow E_{ex} = 13.6 \times 9 \left(\frac{3}{4}\right) = 91.8 \text{ eV}$$

Sol 22: BE of electron in ground of He^{2+} ion

= − total energy of electron in that orbit.

$\therefore$ BE = −TE

$$= -\left(-13.6 \times \frac{Z^2}{n^2}\right) = 13.6 \times 4 = 54.4 \text{ eV}$$

Sol 23: IE of Na = Energy of photon × N

$$= \frac{hC}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{242 \times 10^{-9}} \times N$$

= 8.18 × 10^{-19} × 6 × 10^{23}

= 4.9 × 10^3 J/mol = 4.9 kJ/mole

Sol 24: E_0 = Energy of electron = 4.64 eV

= 4.64 × 1.6 × 10^{-19} J

Energy of photon = $hc\bar{\nu}$

$$\Rightarrow \bar{\nu} = \frac{E}{hc} \Rightarrow \bar{\nu} = \frac{4.64 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34} \times 3 \times 10^8}$$

= 3.74 × 10^4 /cm

Sol 25: Change in energy = TE_H = −13.6 eV

$$\Rightarrow 13.6 \text{ eV} = \frac{hc}{\lambda}$$

$$\Rightarrow \lambda = \frac{hc}{13.6 \text{eV}}$$

$$= \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{13.6 \times 1.6 \times 10^{-19}} = 9.12 \times 10^{-8} \text{ m}$$

≈ 912 Å

Sol 26: Energy absorbed in the transition

= $E_4 - E_2$

$$= \frac{-13.6}{4^2} - \left(\frac{13.6}{2^2}\right) = 13.6\left[\frac{1}{4} - \frac{1}{16}\right]$$

$$= \frac{5 \times 13.6}{16} = 4.2 \text{ eV}$$

Energy of photon = hν

$$\Rightarrow \nu = \frac{E}{h}$$

$$= \frac{4.2 \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34}} = 1.01 \times 10^{15} \text{ Hz}$$

Sol 27: Assume that the electron excites to orbit no. 'n'.

No. of subsequent emissions

$$= \frac{(\Delta H)(\Delta n + 1)}{2} = \frac{(n-1)(n-1+1)}{2}$$

Given no. of subsequent emission = 6

$$\Rightarrow \frac{n(n-1)}{2} = 6 \Rightarrow n = 4$$

$$\Rightarrow \frac{hc}{\lambda} = 13.6\left[\frac{1}{1^2} - \frac{1}{4^2}\right]$$

$$\Rightarrow \lambda = \frac{13.6 \times \frac{15}{16} \times 1.6 \times 10^{-19}}{6.6 \times 10^{-34} \times 3 \times 10^8}$$

= 9.78 × 10^{-8} m = 97.8 nm.

Sol 28: $\lambda_{H_\alpha} = \frac{hc}{E} = \frac{hc}{13.6\left[\frac{1}{2^2} - \frac{1}{3^2}\right]}$

$$\lambda_{H_\beta} = \frac{hc}{13.6\left[\frac{1}{2^2} - \frac{1}{4^2}\right]}$$

$$\Rightarrow \frac{\lambda_{H_\beta}}{\lambda_{H_\alpha}} = \frac{\left[\frac{1}{4} - \frac{1}{9}\right]}{\left[\frac{1}{4} - \frac{1}{16}\right]}$$

$$\Rightarrow \lambda_{H_\beta} = 660 \times \frac{\frac{5}{36}}{\frac{3}{16}} = 488.8\ \overset{\circ}{A}$$

Sol 29: Momentum of a photon = P = $\frac{h}{\lambda}$

$$= \frac{6.6\times10^{-34}}{10\times10^{-10}} = 6.6 \times 10^{-25}\ \text{kg m/s}$$

Sol 30: Energy of 2nd orbit of H = $\frac{-13.6}{2^2}$ = −3.4 eV

given transitions have energies greater than

3.4 eV.

So $n_1 = 1$.

$$10.2 = 13.6\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$$

$$\Rightarrow \frac{3}{4} = \frac{1}{1^2}-\frac{1}{n_2^2}$$

$$\Rightarrow \frac{1}{n_2^2} = \frac{1}{4} \Rightarrow n_2 = 2$$

$$\lambda = \frac{hC}{E} \text{ or } \frac{912\text{Å}}{\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]}$$

$$= \frac{912\text{Å}}{\frac{1}{1^2}-\frac{1}{2^2}} = 912 \times \frac{4}{3} = 1216\ \text{Å}$$

For 12.09 eV

$$12.09 = 13.6\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$$

$$\frac{1}{1^2}-\frac{1}{n_2^2} = \frac{8}{9}$$

$$\Rightarrow n_2 = 3$$

$$\therefore \lambda = \frac{912\ \text{Å}}{\left[\frac{1}{1^2}-\frac{1}{3^2}\right]} = \frac{912\times9}{8} = 1020\ \text{Å}$$

Exercise 2

Single Correct Choice Type

Sol 1: (C) (A) As x-rays are high energetic photons, it can ionise gases.

(B) ZnS shows fluorescence in x-rays.

(C) As x-rays are photons, they are neither deflected by electric nor magnetic fields

(D) $E_{rays} > E_{uv\text{-}rays}$, so $\lambda_{x\text{-}rays} < \lambda_{uv\text{-}rays}$

Sol 2: (C) Bohr's model doesn't say anything about probability of finding an electron near nucleus. It gives discrete orbitals as locus for finding electrons.

Sol 3: (B) If we put x = 1 in E = $\frac{\text{constant}}{n^2}$ kJ/mole.

Constant is the negative of energy an electron first orbit.

So, it also the ionisation energy of H-atom.

Sol 4: (D) E = $\frac{hc}{\lambda}$

$$\text{So } \frac{E_1}{E_2} = \frac{hc/\lambda_1}{hc/\lambda_2} = \frac{\lambda_2}{\lambda_1} = \frac{4000}{2000} = 2$$

Sol 5: (D) Let's assume that the electron is at a distance 'r' from nucleus.

$$E_{electron} = \frac{-k.Z_e.e}{r}$$

as the energy is negative, the energy is maximum when $r \to \infty$, $E \to 0$.

Sol 6: (D) Schrodinger's equation depends on radius, shape and orbital orientation. So, it depends on n, ℓ, m.

But it doesn't depend on spin of the electron.

∴ So Schrondinger's equation is not related spin quantum number.

Sol 7: (B) $\frac{1}{x} = R_H \times Z^2\left[\frac{1}{2^2}-\frac{1}{n^2}\right]$

Z = 2

and shortest wavelength comes when $n \to \infty$

$$\Rightarrow \frac{1}{x} = R_H \times 4\left[\frac{1}{4}\right] = R_H$$

∴ Let x' be longest wavelength is Paschen of Li^{2+}.

Longest wavelength: $3 \rightarrow 4$

$$\frac{1}{x'} = R_H \times Z^2 \left[\frac{1}{3^2} - \frac{1}{4^2}\right]$$

$$\Rightarrow \frac{1}{x'} = R_H \times 9 \left[\frac{1}{9} - \frac{1}{16}\right] = \frac{7R_H}{16}$$

$$\frac{1}{x'} = \frac{7}{x16} \Rightarrow x' = \frac{16x}{7}$$

Sol 8: (B) $\frac{1}{\lambda} = R_H \times Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$$\Rightarrow \lambda = \frac{912\,Å}{9\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]}$$

∴ E = 13.6 × 9 eV

Ionisation energy of H = 13.6 eV

KE of e^- = 13.6 × 8 eV

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mkE}}$$

$$= \frac{6.6 \times 10^{-34}}{\sqrt{2 \times 9.1 \times 10^{-31} \times 13.6 \times 8 \times 1.6 \times 10^{-19}}}$$

$$= \frac{6.6 \times 10^{-34}}{6 \times 10^{-24}} ; \approx 1.17\,Å$$

Sol 9: (A) IE_3 of Li is $Li^{2+} \xrightarrow{\Delta E} Li^{+3}$

$\Delta E = 13.6 \times Z^2$ eV per atom per mole.

$$IE_3 = \frac{13.6 \times 9 \times 1.6 \times 10^{-19} \times 6 \times 10^{23}}{1 \times 10^3} \text{ kJ/mole}$$

= 11775 kJ/mole

IE_2 = 19800 − 11775 − 520 = 7505 kJ/mole

Sol 10: (B) $\Delta_1 = \frac{912}{\left[\frac{1}{1^2} - \frac{1}{2^2}\right]} - \frac{912}{\left[\frac{1}{1^2} - \frac{1}{3^2}\right]}$

1st line $1 \rightarrow 2$

2nd line $1 \rightarrow 3$

3rd line $1 \rightarrow 4$

$$= 912\left(\frac{4}{3} - \frac{9}{8}\right) = 912\left(\frac{5}{24}\right)$$

$$\Delta_2 = \frac{912}{\left[\frac{1}{1^2} - \frac{1}{3^2}\right]} - \frac{912}{\left[\frac{1}{1^2} - \frac{1}{4^2}\right]}$$

$$= 912\left[\frac{9}{8} - \frac{16}{15}\right] = 912\left(\frac{7}{120}\right)$$

$$\Delta_1 : \Delta_2 = \frac{5}{24} \times \frac{120}{7} = \frac{25}{7}$$

≈ 3.5

Sol 11: (C) $r_n = 0.529 \times n^2$ Å $\Rightarrow r_n \propto n^2$

$\therefore r_1 : r_2 : r_3 = 1 : 2^2 : 3^2$

Sol 12: (B) For a permissible solution of n, ℓ, m, s

$n - 1 \geq \ell, m \leq |\ell|, s = \pm\frac{1}{2}$

∴ 3, 3, 1, $-\frac{1}{2}$ is not permissible.

Sol 13: (D) $E \propto \frac{1}{\lambda}$

$$\Rightarrow \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1} = 2$$

Sol 14: (B) Orbital angular momentum of an orbital is

$$L = \frac{h}{2\pi}\sqrt{\ell(\ell+1)}$$

For 2s, $\ell = 0$

∴ L = 0

Sol 15: (A) For each value of 'ℓ'

We have $2\ell + 1$ orbitals

∴ No. of electrons = $\sum_{\ell=0}^{n-1} 2(2\ell+1)$

Sol 16: (D) $\lambda = \frac{h}{mv} = \frac{6.63 \times 10^{-27}}{6 \times 10^{-2} \times 1.4 \times 1.6 \times 10^2 \times \frac{5}{18}}$

$= 1.8 \times 10^{-27}$ m $= 1.8 \times 10^{-25}$ cm

Sol 17: (D) Given

$R = 0.529 \times \frac{n^2}{Z}$ Å

$\Rightarrow R = \frac{0.529}{Z} \times 4$

$R' = \frac{0.529 \times 3^2}{Z} = \frac{R}{4} \times 9 = \frac{9R}{4} = 2.25R$

Sol 18: (A) $\lambda_1 = R_H \times 1^2 \left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$\lambda_2 = R_H \times 2^2 \left[\frac{1}{2^2} - \frac{1}{4^2}\right] = RH \left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$\Rightarrow \lambda_1 : \lambda_2 = 1 : 1$

Sol 19: (C) $n_1 + n_2 = 4$

$n_2^2 - n_1^2 = 8$

$\Rightarrow (n_2 + n_1)(n_2 - n_1) = 8$

$\Rightarrow n_2 - n_1 = 2$

$\Rightarrow n_1 = 1$

$n_2 = 3$

$\frac{1}{\lambda} = \frac{1}{R_H \times Z^2} \times \frac{1}{\left[\frac{1}{1} - \frac{1}{3^2}\right]} = \frac{9}{32R_H}$

Sol 20: (A) Brackett series $n_1 = 4$

n_2 can be from 9 to 5

∴ No. of lines in Brackett series are 9 − 4 = 5

Sol 21: (B) Bohr used quantum theory for quantising the angular momentum of electron in atom.

Sol 22: (C) $\lambda = \frac{h}{mv}$

$= \frac{6.6 \times 10^{-34}}{2 \times 10^{-1} \times 5 \times \frac{5}{18} \times 1.6} = 10^{-33}\left(\frac{6.6 \times 18}{3.2 \times 25}\right)$

It's in the order of 10^{-30} s.

Sol 23: (D) Paschen series → $n_1 = 3$

Longest wavelength → 3 → 4, Shortest 3 → ∞

$\Rightarrow \frac{1}{m'} = R_H \times 4^2 \left[\frac{1}{3^2} - \frac{1}{\infty^2}\right]$

$\Rightarrow \frac{1}{m} = R_H \times Z^2 \left[\frac{1}{3^2} - \frac{1}{4^2}\right]$

$\Rightarrow \frac{m'}{m} = \frac{2^2}{4^2} \frac{7/144}{1/9} = \frac{7}{64}$

$\Rightarrow m' = \frac{7m}{64}$

Sol 24: (B) $Y \rightarrow {}_9F^{19}$[since protons = 2s + 1, mass = 18 + 1]

$\Rightarrow X = {}_{11}Na^{23} \rightarrow$ 11 protons, 12 neutrons

23 g ⇒ 12 N neutrons

4.6 g → $\frac{12 \times 4.6}{23}$ = 2.4 moles of neutron

Sol 25: (C) Energy of photon

$E = \frac{hC}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3.1 \times 10^{-8}} = 6.3 \times 10^{-18}$ J

Work function= $12.8 \times 1.6 \times 10^{-19} = 2.04 \times 10^{-18}$ J

$KE_{max} = 4.26 \times 10^{-18}$ J

$V = \sqrt{2KE_{max}/m_e} = 2.18\sqrt{2} \times 10^6$ m/s

Sol 26: (B) By de-Broglie hypothesis

$\lambda = \frac{h}{p} \Rightarrow |\Delta\lambda| = \frac{h}{p^2}.|\Delta p|....(i) \left[\because \frac{d\lambda}{dp} = \frac{-h}{p^2}\right]$

and by Uncertainity principle

$\Delta x.\Delta p = \frac{\hbar}{2} \Rightarrow \Delta p \Rightarrow \frac{h}{4\pi\Delta x}$ and give $\Delta x = \frac{7}{22}$ nm

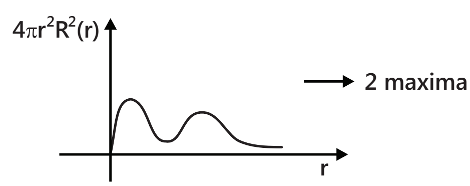
Put this in (i)

We get minimum Δλ as

$|\Delta\lambda| = \frac{h}{p^2}.\frac{1}{4\pi\Delta x} = \frac{h^2}{4\pi p^2 \Delta x}$

Sol 27: (B) For $3p_y$

ψ is not independent of θ, φ



$2 \rightarrow$ nodal plane

m can be 1 or 0 or −1.

Sol 28: (A) $\lambda_{radio} > \lambda_{micro}$

$r_n \propto n^2 \Rightarrow r_1 < r_2 < r_3 < r_4$

$E \propto -\frac{1}{n}$

$\therefore E_1 < E_2 < E_3 < E_4$ and $V \propto \frac{Z}{n}$

$\therefore Be^{+3} > Li^{+2} > He^{2+} > H$

Sol 29: (C) $L = \frac{nh}{2\pi}$

$L_n - L_{n-1} = \frac{h}{2\pi}$

ΔE doesn't depend on potential at ∞.

$KE \propto \frac{1}{r^2}$

$\therefore$ KE decreases on moving away from nucleus.

Previous Years' Questions

Sol 1: (A) James Chadwick discovered neutron ($_0n^1$).

Sol 2: (D) The radius of an atom is of the order of 10^{-8} cm

Sol 3: (A)

NO^+	C_2^{2-}	CN^-	N_2
$14e^-$	$14e^-$	$14e^-$	$14e^-$

Sol 4: (B) N^{3-}, F^- and Na^+ (These three ions have e^- = 10, hence they are isoelectronic)

Sol 5: (D) $r_H = 0.529 \frac{n^2}{z}$ Å

For hydrogen ; n = 1 and z = 1 therefore

$r_H = 0.529$ Å

For Be^{3+} : Z = 4 and n = 2 Therefore

$$r_{Be^{3+}} = \frac{0.529 \times 2^2}{4} = 0.529 Å$$

Sol 6: (C) $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$$\frac{1}{\lambda} = 1.097 \times 10^7 m^{-1}\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]$$

$\therefore l = 91 \times 10^{-9}$

We known 10^{-9} = 1 nm So, λ = 91 nm

Sol 7: (C) $\Delta E = 1.312 \times 10^6\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$= 1.312 \times 10^6 \times \frac{3}{2} = 0.984 \times 10^6$ d

$= 9.84 \times 10^5$ J/mol.

Sol 8: (C) $E = E_1 + E_2$

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2} \Rightarrow \frac{1}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

$$\frac{1}{355} = \frac{1}{680} + \frac{1}{\lambda_2} \Rightarrow \lambda_2 = 742.76 nm$$

Sol 9: (B) As

$$\lambda = \frac{h}{m\upsilon} = \frac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 1 \times 10^3} = 3.97 \times 10^{-10} m$$

$= 0.397 \times 10^{-9}$ m = 0.40 nm.

Sol 10: (C) $\Delta x + \Delta p = \frac{h}{4x}$

$\Delta x \times [m\Delta\upsilon] = \frac{h}{4x}$; $\Delta u = \frac{600 \times 0.005}{100} = 0.03$

So, $\Delta x\,[9.1 \times 10^{-31} \times 0.03] = \frac{6.6 \times 10^{-34}}{4 \times 3.14}$

$$\Delta x = \frac{6.6 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 0.03 \times 10^{-31}} = 1.92 \times 10^{-3} m$$

Sol 11: (B) is the correct option because it has the maximum value of n + *l*

Sol 12: (D) (4) and (5) belong to 3d-orbital which are same energy.

Sol 13: (B) The electronic configuration is Cr (chromium element in the ground state) = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

Sol 14: (A) For 4f orbital electron n = 4

l = 3 (Because 0, 1, 2, 3)

s, p, d, f

m = + 3, +2, +1, 0, −1, −2, −3; s = +1/2

Sol 15: (B) 4p(2) 4s(3) 3d(4) 3p

According to (n + ℓ) rule, increasing order of energy

(4) < (2) < (3) < (1)

Sol 16: (C) $\Delta x.m\ \Delta v = \frac{h}{4\pi}$

$$\Delta x = \frac{h}{4\pi\ m\ \Delta\ v}$$

$$\Delta v = 600 \times \frac{0.005}{100} = 0.03$$

$$\Rightarrow \Delta x = \frac{6.625\times10^{-34}}{4\times3.14\times9.1\times10^{-31}\times0.03} = 1.92\times10^{-3}\ m$$

Sol 17: (B) $\lambda = \frac{h}{mv} = \frac{6.63\times10^{-34}}{1.67\times10^{-27}\times10^{3}} \equiv 0.40$ nm

Sol 18: (A) Energy required for 1 Cl_2 molecule

$= \frac{242\times10^{3}}{N_A}$ Joules.

This energy is contained in photon of wavelength 'λ'.

$$\frac{hc}{\lambda} = E \Rightarrow \frac{6.626\times10^{-34}\times3\times10^{8}}{\lambda}$$

$$= \frac{242\times10^{3}}{6.022\times10^{23}}$$

$\lambda = 4947\ \overset{0}{A} \approx 494$ nm

Sol 19: (B) $IE_{He^+} = 13.6\ Z_{He^+}^2\left[\frac{1}{1^2}-\frac{1}{\infty^2}\right] = 13.6\ Z_{He^+}^2$, where $\left(Z_{He^+} = 2\right)$

Hence, $13.6\times Z_{He^+}^2 = 19.6\times10^{-18}$ J atom^{-1}.

$$\left(E_1\right)_{Li^{+2}} = -13.6\ Z_{Li^{+2}}^2 \times \frac{1}{1^2}$$

$$= -13.6\ Z_{He^+}^2 \times \left[\frac{Z_{Li^{+2}}^2}{Z_{He^+}^2}\right]$$

$$= -19.6\times10^{-18}\times\frac{9}{4} = -4.41\times10^{-17}\ J/atom$$

Sol 20: (C) $\left(E_n\right)_H = -13.6\frac{1^2}{n^2}$eV

$n = 2 \Rightarrow E_2 = -3.4$ eV

JEE Advanced/Boards

Exercise 1

Sol 1: 1 eV = 1.6×10^{-19} J

Let λ be the wavelength of a photon of 1 eV energy.

$$E = \frac{hc}{\lambda}$$

$$\Rightarrow \lambda = \frac{hc}{E} = \frac{6.6\times10^{-34}\times3\times10^{8}}{1.6\times10^{-19}}$$

$= 12.3\times10^{-7}$ m

$= 1.23\times10^{-6}$ m

Sol 2: 1st line in Lyman series of H

$$\frac{1}{\lambda} = R_H \times 1^2\left[\frac{1}{1^2}-\frac{1}{2^2}\right]$$

In He^{2+}

$$\frac{1}{\lambda} = R_H \times Z^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$$

$$\Rightarrow \left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]\times2^2 = \frac{1}{1^2}-\frac{1}{2^2}$$

$$\Rightarrow \frac{1}{n_1^2}-\frac{1}{n_2^2} = \frac{1}{2^2}-\frac{1}{4^2}$$

$\Rightarrow n_1 = 2$, n = 4

IE_2 of He = $13.6\times Z^2$ eV/atom

$= 13.6\times4\times1.6\times10^{-19}$

$= 8.67\times10^{-18}$ J/atom

1st of He^{2+} → r = $0.529\times\frac{n^2}{Z}$ Å

n = 1, Z = 2

∴ r = 0.264 Å

Sol 3: $\lambda = \dfrac{h}{mv}$ and $eV = \dfrac{1}{2}mv^2$

$$\Rightarrow \lambda = \frac{h}{\sqrt{2meV}} \Rightarrow r = \frac{h^2}{2me\lambda^2}$$

$$= \frac{(6.6\times10^{-34})^2}{2\times9.1\times10^{-31}\times1.6\times10^{-18}\times(9\times10^{-12})^2}$$

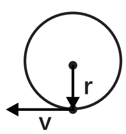
$= 10^5 \times 0.0186$

$= 1.86 \times 10^3$ Volts.

Sol 4: According to Heisenberg's Uncertainity principle, the position and momentum of a moving particle cannot be found exactly.

But according to Bohr, electrons move in a stationary circular orbit with a fixed velocity which contradicts Heisenberg principle.

According to Bohr,



if $\bar{r}$ is fixed, we can find $\bar{v}$ exactly.

Sol 5: Let it move with a velocity v.

From conservation of energy

$\Delta KE + \Delta PE = 0$

$$\Rightarrow \frac{1}{2}mv^2 = \frac{1}{4\pi\epsilon_0}.\frac{q_1q_2}{r}$$

$$\Rightarrow \frac{1}{2} \times 4 \times 1.67 \times 10^{-27} \times v^2$$

$$= \frac{9\times10^{11}\times29\times2\times(1.6\times10^{-18})^2}{10^{-13}}$$

$\Rightarrow v = \sqrt{4012} \times 10^5$ m/s $= 6.34 \times 10^6$ m/s

Sol 6: Velocity of electron in nth orbit of H atom is = $\dfrac{2.18\times10^6}{n}$ m/s

if n = 3

$v = 0.72 \times 10^6$ m/s

no. of revolutions per sec = $\dfrac{v}{2\pi r}$

$$= \frac{0.72\times10^6 \text{ m/s}}{2\times3.14\times0.529\times3^2\times10^{-10}} \text{ M}$$

$= 2.40 \times 10^{14}$ /sec

Sol 7: $E \propto \dfrac{Z^2}{n^2}$

Minimum energy of photon needed to remove electron in 3rd orbit of He+ is

$$-21.76 \times 10^{-19} \times \frac{2^2}{3^2} \text{ J}$$

$$\therefore \frac{hc}{\lambda} = +\,21.76 \times 10^{-19} \times \frac{4}{9} \text{ J}$$

$$\Rightarrow \lambda = \frac{6.6\times10^{-34}\times3\times10^8}{21.76\times4\times10^{-19}} \times 9 = 2.04 \times 10^{-7} \text{ m}$$

Sol 8: Bohr's theory has some failures

→ It can't explain the splitting of spectral lines in magnetic fields.

→ When the positions of electrons are recorded practically, the obtained results show that electrons don't move in a fixed and quantised orbit but they move in 3-dimensional orbitals which spread but nucleus to infinity.

But probability is high at Bohr's orbits compared to other regions

Sol 9: An atomic orbital is a mathematical function that describes the wave-like behaviours' of either one electron or a pair of electrons in an atom.

It gives us the probability of finding an electron at a certain point around the nucleus.

Each orbital in an atom is characterised by a unique set of values called quantum numbers they are

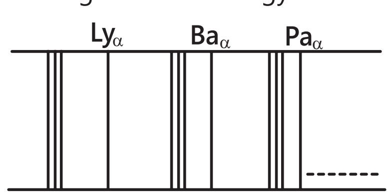
n → principle quantum number

l → Azimuthal quantum number

m → Magnetic quantum number

Sol 10: The emission spectrum of atomic hydrogen is divided into a number of spectral series with wavelength given by Rydberg's formula.

These observed spectral lines are due to electron moving between energy levels in the atom



Sol 11: $\frac{1}{\lambda} = R_H Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$$\frac{1}{6500\,\text{Å}} = R_H(1)\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

In Balmer, H_α - $2 \rightarrow 3$

H_β - $2 \rightarrow 4$

$$\frac{1}{\lambda'} = R_H(1)\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$$

$$\Rightarrow \frac{\lambda'}{6500} = \frac{\frac{1}{4} - \frac{1}{9}}{\frac{1}{4} - \frac{1}{16}} = \frac{\frac{5}{36}}{\frac{3}{16}} = \frac{20}{27}$$

λ' = 4814 Å

Sol 12: $\frac{1}{\lambda} = R_H \times Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

Frequency $= \frac{C}{\lambda} = CR_H Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$= 3 \times 10^8 \times 1.09 \times 10^7 \left(1 - \frac{1}{9}\right) = 2.9 \times 10^{15}$ Hz

Sol 13: $\Delta E = E_2 - E_1$

$= \frac{-13.6}{2^2} - \left(\frac{-13.6}{1^2}\right) = -3.4 + 13.6 = 10.2$ eV

Energy of X-ray $\rightarrow \frac{hC}{\lambda} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{3 \times 10^{-8}}$

$= 6.6 \times 10^{-18}$ J

$\Delta E = Z^2 \times 10.2$ eV $= Z^2 \times 10.2 \times 1.6 \times 10^{-19}$ J

and $\Delta E = \frac{hc}{\lambda} \Rightarrow Z^2 \times 10.2 \times 1.6 \times 10^{-19} = 6.6 \times 10^{-18}$

$\Rightarrow Z^2 = 4 \Rightarrow Z = 2$ i.e. He

Sol 14: The shape of an atomic orbital is the locus where there is a significant probability of finding an electron of that orbital. For example, if we take an s-orbital → there is a good probability of finding electrons around a spherical surface of certain radius and p-orbital has a shape of a dumbbell.

Sol 15: For any orbital

Spherical radial nodes = $n - \ell - 1$

Angular nodes/nodal planes = ℓ

Total nodes = $n - 1$

Sol 16: Atomic number of chromium. Actual chromium configuration is$1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 3d^5\, 4s^1$ but expected is [Ar] $4s^2\, 3d^4$. The deviation can be explained by 2 reasons

1 → No. of exchange pairs. More the number of exchange pairs, more is the stabilisation energy.

2 → Spherical symmetry in both 4s and 3d orbitals.

So, it will be more stable which is not the case in $4s^2\, 3d^4$.

Sol 17: As we know

Energy of photon = Work function → KE_{max}

$$\Rightarrow \frac{hc}{\lambda_1} = h\nu_0 + KE_1 \quad \text{...(i)}$$

$$\frac{hc}{\lambda_2} = h\nu_0 + KE_2 \quad \text{...(ii)}$$

Multiply (i) by (ii) and subtract from (ii)

$$\frac{2hc}{\lambda_1} - \frac{hc}{\lambda_2} = 2h\nu_0 - h\nu_0$$

$$\Rightarrow 3 \times 10^8 \left(\frac{2}{2.2 \times 10^{-7}} - \frac{1}{1.9 \times 10^{-7}}\right) = \nu_0$$

$$\Rightarrow \nu_0 = 3 \times 10^{15} \left(\frac{1}{1.1} - \frac{1}{1.9}\right) = 1.14 \times 10^5 \text{ Hz}$$

$$\lambda_0 = \frac{c}{\nu_0} = \frac{3 \times 10^8}{1.14 \times 10^{15}} = 2.61 \times 10^{-7} \text{ m}$$

Sol 18: By conservation of energy $E_0 = E_1 + E_2$

$\frac{hc}{\lambda_0} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$ where $\lambda_0 = 300$ nm

$\lambda_1 = 760$ nm

$$\Rightarrow \frac{1}{\lambda_0} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2} \Rightarrow \frac{1}{\lambda_2} = \frac{1}{\lambda_0} - \frac{1}{\lambda_1}$$

$$\Rightarrow \lambda_2 = \frac{\lambda_0\lambda_1}{\lambda_1 - \lambda_0} = \frac{300(760)}{760 - 300} = 495.6 \text{ nm}$$

Sol 19: By De-Broglie hypothesis

$$\lambda = \frac{h}{mv} = \frac{6.6\times10^{-34}}{0.15\times50} = 8.8 \times 10^{-35} \text{ m}$$

It is extremely low even compared to size of atoms. So, it's not observable.

Sol 20: According to conservation of energy $\frac{hc}{\lambda} = \omega_0 + KE_{max}$

when $\nu_1 = 1.6 \times 10^{16}$ Hz

$h\nu_1 = \omega_0 + KE_1$ .....(i)

when $\nu_2 = 10^{16}$ Hz and $KE_1 = 2KE_2$

$h\nu_2 = \omega_0 + KE_2$ .....(ii)

Multiply (ii) by 2 subtract (i) from it.

$2h\nu_2 - h\nu_1 = 2\omega_0 + 2KE_2 - (\omega_0 + KE_1) = \omega_0$

and $\omega_0 = h\nu_0$

$\Rightarrow 2h\nu_2 - h\nu_1 = h\nu_0$

$\Rightarrow \nu_0 = 2\nu_2 - 2\nu_1$

$= 2 \times 10^{16} - 1.6 \times 10^{16}$

$= 0.4 \times 10^{16}$

$= 4 \times 10^{15}$ Hz

Sol 21: The magnetic moment of an ion is

$M = \sqrt{n(n+2)}$ B.M. where n is the number of unpaired electron in the ion.

$\sqrt{n(n+2)} = \sqrt{35}$

$\Rightarrow n(n + 2) = 35 = 5 \times 7$

$\Rightarrow n = 5$

So, X^{3+} has 5 unpaired electron in 3d series.

$\therefore$ Atomic number = 18 + 5 + 3= 26

Sol 22: Bond energy of $I_2 \rightarrow$ 240 kJ/mole for 1 molecule

$$= \frac{240\times10^3}{6\times10^{23}} = 4 \times 10^{-19} \text{ J}$$

Energy of a photon = $\frac{hc}{\lambda}$

$$= \frac{6.66\times10^{-34}\times3\times10^8}{4.5\times10^{-7}} = 4.44 \times 10^{-19} \text{ J}$$

$\therefore$ KE of 2 Iodine atoms

$= 4.44 \times 10^{-19}$ J $- 4 \times 10^{-19}$ J

$= 0.44 \times 10^{-19}$ J

$\therefore$ KE of a single atom = $\frac{4.4\times10^{-20}}{2} = 2.2 \times 10^{-20}$ J

Sol 23: Energy of the incident photon, $E = \frac{hc}{\lambda}$

$$= \frac{6.6\times10^{-34}\times3\times10^8}{2.53\times10^{-7}} = 7.82 \times 10^{-19} \text{ J}$$

$$= \frac{7.82\times10^{-19}}{1.6\times10^{-19}} \text{ eV} = 4.89 \text{ eV}$$

$\therefore$ Work function = $\frac{hc}{\lambda} - KE_{max}$

$= 4.89 - 0.24 = 4.65$ eV

Sol 24: 1 g atm $\rightarrow$ 1 N atoms

Lowest energy of visible region $\rightarrow$ Lowest energy line of Balmer series i.e. $3 \rightarrow 2$

$$E = E_3 - E_2 = \frac{-13.6}{n_1^2} - \left(\frac{-13.6}{n_2^2}\right)$$

$$\Rightarrow 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 13.6\left(\frac{5}{36}\right) = 1.88 \text{ eV}$$

Total energy $= 6 \times 10^{23} \times 1.88$ eV

$= 6 \times 10^{23} \times 1.88 \times 1.6 \times 10^{-19}$ eV

$= 18.2 \times 10^4$ J

= 182 kJ per 1.0 gram atom

Sol 25: For X

$\lambda = 9.87$ Å. Moseley's law = $\sqrt{\nu} = k(Z - \alpha)$

$$\nu = \frac{c}{\lambda} = \frac{3\times10^8}{9.87\times10^{-10}}$$

$= 3.03 \times 10^{17}$

$\sqrt{\nu} = \sqrt{30.3\times10^{16}}$

$= 5.51 \times 10^8$

$\Rightarrow 5.51 \times 10^8 = 4.9 \times 10^7 (2 - 0.75)$

$\Rightarrow Z - 0.75 = 11.245$

$\Rightarrow Z \approx 12.$

For Y

$\lambda = 2.29$ Å

$\nu = \frac{c}{\lambda} = \frac{3\times10^{8}}{2.29\times10^{-10}}$

$= 1.31 \times 10^{18}$

$\sqrt{\nu} = 1.14 \times 10^{9}$

$\Rightarrow 1.14 \times 10^{9} = 4.9 \times 10^{7} (2 - 0.75)$

$\Rightarrow 2 - 0.75 = 23.35$

$\Rightarrow Z \approx 24$

Sol 26: $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$ and given that, its Balmer series so $n_1 = 2$

$\Rightarrow \frac{1}{\lambda} = R\left[\frac{1}{2^2}-\frac{1}{n_2^2}\right]$

$\Rightarrow \frac{1}{\lambda}\times\frac{1}{R} = \frac{1}{2^2}-\frac{1}{n_2^2}$

$\Rightarrow \frac{912\,Å}{4344\,Å} = \frac{1}{2^2}-\frac{1}{n_2^2}$

$\Rightarrow 0.209 = \frac{1}{4}-\frac{1}{n_2^2}$

$\Rightarrow \frac{1}{n_2^2} = 0.0400$

$\Rightarrow n_2^{\,2} = 25$

$\Rightarrow n_2 = 5$

Sol 27: Change in energy of electron = Energy of photon

$E = E_3 - E_2$

$= -2.41 \times 10^{-12} - (-5.42 \times 10^{-12})$

$= 3.01 \times 10^{-12}$ erg

$= 3.01 \times 10^{-19}$ J

$\lambda = \frac{hc}{E} = \frac{6.6\times10^{-34}\times3\times10^{8}}{3.01\times10^{-19}}$

$\approx 6.6 \times 10^{-7}$ m

$= 6.6 \times 10^{3}$ Å

Sol 28:

$r = r_0 . A^{1/3} = 1.4\times10^{-13}.A^{1/3}\text{cm}$

$= 1.4\times10^{-13}\times19^{1/3} = 5.07\times10^{-13}\,\text{cm}$

Vol of F. Nucleus $= \frac{4}{3}\pi r^3 = 7.17\times10^{-37}\,\text{cm}^3$

Density $= \frac{\text{Mass}}{\text{Volume}} = \frac{19}{6.02\times10^{23}\times7.17\times10^{-37}}$

$= 0.44\times10^{14}\,\text{gm cm}^{-3}$

Sol 29: From Heisenberg’s Uncertainty principle

$\Delta x\,.\Delta p \geq \frac{\hbar}{2}$

$\Rightarrow x.m\,\Delta V \geq \frac{h}{4\pi}$ $\Delta V = 2 \times 0.01$ m/s

$\therefore \Delta x = \frac{6.6\times10^{-34}}{4\times3.14\times10^{-3}\times10^{-2}\times2} = \frac{6.6\times10^{-29}}{12.56\times2}$

$\approx 3 \times 10^{-30}$ m

Though, there is some uncertainty in the position, it is extremely negligible, i.e. we cannot observe such deviations.

Sol 30: By Heisenberg's uncertainty principle and $\Delta V = 2$ m/s

$\Delta x.\Delta p \geq \frac{\hbar}{2}$

$\Rightarrow \Delta x \times 9.109 \times 10^{-31} \times 2 = \frac{6.6\times10^{-34}}{4\times3.14}$

$\Rightarrow \Delta x = 0.028 \times 10^{-3}$

$\approx 2.8 \times 10^{-5}$ m

Here, the uncertainty in position is quite high compared to size of an atom.

$\therefore$ From the above 2 problems, we can see that uncertainty in position for macroparticles is negligible, but there, is high uncertainty in case of micro particles.

Exercise 2

Single Correct Choice Type

Sol 1: (C) Bohr's model says that electron move in a stationary state with fixed velocities. So, it contradicts uncertainty principle.

Sol 2: (B) Statement-II seems to be irrelevant.

Comprehension Type

Paragraph 1:

Sol 3: (A, B) $E = 13.6\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$ eV

$= 13.6\left[\frac{1}{1^2}-\frac{1}{3^2}\right] \times 1.6 \times 10^{-19}$ J

$\approx 13.6 \times \frac{8}{9} \times 1.6 \times 10^{-19}$ J

$= 1.93 \times 10^{-18}$ J

Sol 4: (C) No. of lines = $\frac{(\Delta n)(\Delta n+1)}{2}$ where $\Delta n = n_1 - n_2$.

In this case

$n_1 = 6, n_2 = 3$

$\therefore$ lines = $\frac{3(4)}{2} = 6.$

Sol 5: (B) 1st line in Lyman

$\frac{1}{\lambda} = R \times 1^2 \times \left[\frac{1}{1^2}-\frac{1}{2^2}\right] \Rightarrow \lambda = \frac{4}{3R}$

2nd line in Balmer

$\frac{1}{\lambda} = R \times 1^2 \left[\frac{1}{2^2}-\frac{1}{4^2}\right] \Rightarrow \lambda = \frac{16}{3R}$

$\lambda = \frac{12}{3R} = \frac{4}{R}$

Sol 6: (C) Wave number = $\frac{1}{\lambda}$

$n_1 + n_2 = 4$

$n_2 - n_1 = 2$

$\Rightarrow n_1 = 1$

$n_2 = 3$

$\frac{1}{\lambda} = R \times Z^2 \left[\frac{1}{1^2}-\frac{1}{3^2}\right]$ and Z = 3

$= R(9)\left(\frac{8}{9}\right) = 8R$

Paragraph 2:

Sol 7: (B) $\Delta KE = \Delta PE$

$\Rightarrow \frac{1}{2}mv^2 = \frac{1}{4\pi \epsilon_0}\frac{q_1q_2}{r}$

$\Rightarrow \frac{1}{2} \times 4 \times 1.6 \times 10^{-27} \times v^2$

$= \frac{9\times10^{11}\times29\times2\times(1.6\times10^{-19})^2}{10^{-13}}$

$\Rightarrow v = \sqrt{4012} \times 10^5$ m/s

$= 6.33 \times 10^6$ m/s

$= 6.33 \times 10^8$ cm/sec

Sol 8: (A) Na, K, Cs can't be used as they are 1A group elements, they have only 1e⁻ in outer shell. So, they have less density and IE. So, Pt is suitable.

Sol 9: (C) This question is out of scope.

Though the value of N after several calculations comes out as

$N(\theta) = \frac{nt}{4r^2}\left(\frac{2Z}{2k}\right)^2\left(\frac{e^2}{4\pi \epsilon_0}\right)^2 \frac{1}{\sin^4 \theta/2}$

$\therefore N \propto \frac{1}{\sin^4 \theta/2}$ (need not be included in the syllabus)

Sol 10: (C) In Rutherford's α-ray scattering experiment, most of the α-particles doesn't undergo any deflection. Few particles deviate through some angle and negligible no. of α-particles deflect for more than 90°.

Match the Columns

Sol 11: A → s; B → r; C → q; D → p

(A) 2nd orbit in $He^+ \rightarrow r = 0.529 \times \frac{2^2}{2}$ Å

$\rightarrow E = -13.6 \times \frac{2^2}{2^2}$ eV

$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mE}}$

$= \frac{6.6\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times13.6\times1.6\times10^{-19}}} = \sqrt{\frac{150}{13.6}}$ Å

(B) 3rd orbit in H-atom, $V \propto \frac{Z}{n}$

$V = 2.18 \times \frac{Z}{n} = \frac{2.18}{3}$ m/s

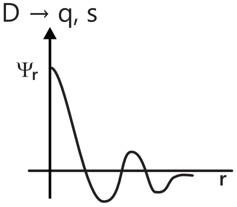
(C) 1st orbit Li^{2+} ion $\rightarrow E = -13.6 \times \frac{Z^2}{n^2} = (-13.6)\ 9$ eV

(D) 2nd orbit, Be^{3+} ion $\rightarrow r = 0.529 \times \frac{n^2}{Z}$

$= 0.529 \times \frac{2^2}{Z} = 0.529$ eV

Sol 12: A → p; B → p, q, s; C → p, r; D → q, s

(A) 4s, 5p, 6d, ... show similar ψ

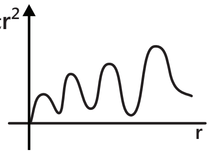


4s [since 3 maxima/minima locally]

$5p_x$, $6d_{xy}$ are not symmetric for all values of θ and ϕ.

4s, 5p, 6d, ...

(B) $\psi^2_r 4\pi r^2$



(C) $\psi(\theta, \phi)$ = k (i.e. independent of θ, ϕ)

only for circularly symmetric orbitals.

4s, 3s

(D) At one angular nodes for any orbital, no. of angular nodes = ℓ.

$5p_x$, $6d_{xy}$

Assertion Reasoning Type

Sol 13: (D) In Li^{2+}, if n_1 = 2, and n_2 > 2, then the line may not be in visible region, as energy of that line is 9 times the corresponding line H atom (which is in visible region). So, Statement-I is false.

Previous Years' Questions

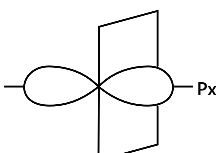
Sol 1: (D) Neutron has no charge, hence, e/m is zero for neutron. Next, α-particle (He^{2+}) has very high mass compared to proton and electron, therefore very small e/m ratio. Proton and electron have same charge (magnitude) but former is heavier, hence has smaller value of e/m.

e/m : n < α < p < e

Sol 2: (C) X-rays is electrically neutral, not deflected in electric or magnetic fields.

yz-plane, a nodal plane

Sol 3: (A) Nodal plane is an imaginary plane on which probability of finding an electron is minimum. Every p-orbital has one nodal plane:



YZ-plane, a nodal plane

Sol 4: (C) $1s^7$ violate Pauli exclusion principle, according to which an orbital cannot have more than two electrons.

Sol 5: (B) Expression for Bohr's orbit is $r_n = \frac{a_0 n^2}{Z} = a_0$

When n = 2, Z = 4.

Sol 6: (A) The number of radial nodes is given by expression (n − l − 1)

For 3s, number of nodes = 3 − 0 − 1 = 2

For 2p, number of nodes = 2 − 1 − 1 = 0

Sol 7: (A, C) Alpha particles passes mostly undeflected when sent through thin metal foil mainly because

(A) It is much heavier than electrons.

(C) Most part of atom is empty space.

Sol 8: (A, D) Then these electrons in the 2p orbital must have same spin, no matter up spin or down spin.

Sol 9 (C) Statement-I is correct, Be ($1s^2$, $2s^2$) has stable electronic configuration, removing an electron requires more energy than the same for B ($2p^1$). Reason is incorrect (Aufbau principle)

Sol 10.1: (B) S_1 is spherically symmetrical state, i.e., it corresponds to an s-orbital. Also, it has one radial node.

Number of radial nodes = n − l − 1

$\Rightarrow$ n − 0 − 1 = 1

(i) n = 2, i.e., S_1 = 2s orbital

Sol 10.2: (C) (ii) Ground state energy of electron in H-atom (E_H)

$$E_H = k\frac{Z^2}{n^2} = k(Z = 1, n = 1)$$

For S_1 state of Li^{2+}.

$$E = \frac{k(3)^2}{2^2} = \frac{9}{4}k = 2.25k$$

Sol 10.3: (B) (iii) In S_2 state, E(Li^{2+}) = k (given)

$$\Rightarrow k = \frac{9k}{n^2}$$

$\Rightarrow$ n = 3

Since, S_2 has one radial node.

3 − l − 1 = 1

$\Rightarrow$ l = 1

Sol 11: A → r; B → q; C → p; D → s

(A) $V_n = \frac{1}{4\pi \in_0}\left(\frac{Ze^2}{r}\right)$

$K_n = \frac{1}{8\pi \in_0}\left(\frac{Ze^2}{r}\right) \Rightarrow \frac{V_n}{K_n} = -2(R)$

(B) $E_n = -\frac{Ze^2}{8\pi \in_0 r} \propto r^{-1}$

$\Rightarrow x = -1(Q)$

(C) Angular momentum = $\sqrt{l(l+1)}\frac{h}{2\pi}$ = 0 in 1s orbital.

(D) $r_n = \frac{a_0 n^2}{Z} \Rightarrow \frac{1}{r_n} \propto Z(S)$

Sol 12: A → q; B → p, q, r, s; C → p, q, r; D → p, q, r

(A) Orbital angular momentum

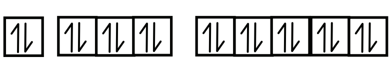
(L) = $\sqrt{l(l+1)}\frac{n}{2\pi}$ i.e,L depends on azimuthal quantum number only.

(B) To describe a one electron wave function, the quantum numbers n, *l* and m are needed. Further to abide by Pauli exclusion principle, spin quantum number (s) is also needed.

(C) For shape, size and orientation, only n, *l* and m are needed.

(D) Probability density (ψ^2) can be determined if n, *l* and m are known.

Sol 13: When n = 3, *l* = 0, 1, 2, i.e., there are 3s, 2p and 3d orbital. If all these orbitals are completely occupied as



Total 18 electrons, 9 electrons with s = + $\frac{1}{2}$ and 9 with s = $-\frac{1}{2}$

Alternatively: In any nth orbit, there can be a maximum of $2n^2$ electrons. Hence, when n = 3, number of maximum

Electrons − 18. Out of these 18 electrons, 9 can have spin −1 /2 and remaining nine with spin = + 1/2

Sol 14: Energy of photon

$$\frac{hc}{\lambda}J = \frac{hc}{e\lambda}eV = \frac{6.625\times10^{-34}\times3\times10^{8}}{300\times10^{-9}\times1.602\times10^{-19}} = 4.14eV$$

For photoelectric effect to occur, energy of incident photons must be greater than work function of metal. Hence, only Li, Na, K and Mg have work functions less than 4.14V.

Sol 15: At radial node, ψ_2 must vanish i.e.

$$\psi_{2r}^2 = 0 = \left[\frac{1}{4\sqrt{2\pi}}\right]^2\left(2-\frac{r_0}{a_0}\right)^2 e^{-\frac{r_n}{a_0}}$$

$\Rightarrow 2-\frac{r_0}{a_0} = 0$

$\Rightarrow r_0 = 2a_0$

(b) $\frac{h}{mv} = \frac{6.625\times10^{-34}}{100\times10^{-3}\times100} = 6.625\times10^{-35}m$

= 6.625×10^{-25} Å (negligibly small)

Sol 16: $mvr = \frac{nh}{2\pi}$

$$v = \frac{nh}{2\pi mr} = \frac{6.625\times10^{-34}}{2\times3.14\times9.1\times10^{-31}\times0.529\times10^{-10}}$$

= $2.18 \times 10^6\ ms^{-1}$.

(b) $\lambda = \frac{h}{mv} = \frac{6.625\times10^{-34}}{9.1\times10^{-31}\times2.18\times10^{6}}$

= 0.33×10^{-9} m = 3.3 Å

(c) Orbital angular momentum (L) = $\sqrt{l(l+1)}\frac{h}{2\pi}$

$= \sqrt{2}\left(\frac{h}{2\pi}\right)$ [∵ for p-orbital, *l* = 1]

Sol 17: Since, $\lambda = \frac{h}{mV} = \frac{h}{\sqrt{2M\,K.E.}}$ (since KE. ∝ T)

$\Rightarrow \lambda \propto \frac{1}{\sqrt{MT}}$

For two gases,

$$\frac{\lambda_{He}}{\lambda_{Ne}} = \sqrt{\frac{M_{Ne}\ T_{Ne}}{M_{He}\ T_{He}}} = \sqrt{\frac{20}{4}\times\frac{1000}{200}}$$

$= \sqrt{25} = 5$

Sol 18: Single electron species don't follow the $(n+l)$ rule but multi electron species do.

Ground state of H^- = $1s^2$

First excited state of H^- = $1s^1$, $2s^1$

Second excited state of H^- = $1s^1$, $2s^0$, $2p^1$

Sol 19: (C) As per Bohr's postulate,

$$mvr = \frac{nh}{2\pi}$$

$$\text{So, } v = \frac{nh}{2\pi mr}$$

$$KE = \frac{1}{2} mv^2$$

$$\text{So, } KE = \frac{1}{2} m\left(\frac{nh}{2\pi mr}\right)^2$$

$$\text{Since, } r = \frac{a_0 \times n^2}{z}$$

So, for 2nd Bohr orbit

$$r = \frac{a_0 \times 2^2}{1} = 4a_0$$

$$KE = \frac{1}{2}m\left(\frac{2^2h^2}{4\pi^2m^2 \times (4a_0)^2}\right)$$

$$KE = \frac{h^2}{32\pi^2 ma_0^2}$$