Solved Problems

Objective

Problem 1: ***Bohr's atomic model can explain***

(a) the spectrum of hydrogen atom only
(b) the spectrum of an atom or ion containing one electron only
(c) the spectrum of hydrogen molecule
(d) the solar spectrum

Solution: In Bohr's theory while calculating the energy of electron, the potential energy has been found out by considering only the attraction between the electron and nucleus. If there is another electron in the orbit, the potential energy would change due electron-electron repulsion. Therefore the Bohr's model is meant for all one-electron systems.

$\therefore$ **(b)**

Problem 2: ***The orbital angular momentum of an electron in 2s orbital is***

(a) 4 ***(b) 1***
(c) zero ***(d)*** $\frac{h}{2\pi}$

Solution: The orbital angular momentum of an electron is calculated as $\sqrt{\ell(\ell+1)}\,\frac{h}{2\pi}$,

$\sqrt{0(0+1)}\,\frac{h}{2\pi} = 0$

$\therefore$ **(c)**

Problem 3: **The ratio of the energies of photons of 2000Å to that of 4000Å is**

(a) 2 **(b) 4**
(c) $\frac{1}{2}$ **(d)** $\frac{1}{4}$

Solution: $E = \frac{hc}{\lambda},\ \therefore\ \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1} = \frac{4000}{2000} = 2$

$\therefore$ **(a)**

Problem 4: ***Which of the following postulates does not belong to Bohr's model of the atom?***

(a) Angular momentum is an integral multiple of $\frac{h}{2\pi}$
(b) The electron stationed in the orbit is stable
(c) The path of an electron is circular
(d) The change in the energy levels of electron is continuous

Solution: In Bohr's model, the energy are discrete and not continuous

$\therefore$ **(d)**

Problem 5: **The wave number of the first Balmer line of Li^{2+} ion is 1,36,800 cm^{-1} the wave number of the first line of Balmer series of hydrogen atom is (in cm^{-1})**

(a) 68,400 **(b) 15,200**
(c) 76,000 **(d) 30,800.**

Solution: Atomic number of Li^{2+} is 3

$$\frac{1}{\lambda} = R_H Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right], \quad 1,36,800 = R_H \times 9\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$$R_H\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{1,36,800}{9} = 15,200$$

$\therefore$ **(b)**

Problem 6: **If uncertainty in the position of an electron is zero the uncertainty in its momentum will be**

(a) $< \frac{h}{4\pi}$ **(b)** $> \frac{h}{4\pi}$
(c) zero **(d) infinite**

Solution: $\Delta x \times \Delta p \geq h/4\pi$

if $\Delta x = 0$, then ΔP will be infinite

$\therefore$ **(d)**

Problem 7: **The principle quantum number represents**

(a) shape of an orbital
(b) number of electrons in an orbit
(c) distance of an electron from the nucleus
(d) orientation of orbitals in space.

Solution: (c)

Problem 8: ***The energy of an electron of $2p_y$ orbital is***

(a) greater than 2p orbital
(b) less than $2p_x$ orbital
(c) equal to 2s orbital
(d) same as that of $2p_x$ and $2p_z$ orbitals.

Solution: All the 2p orbitals are degenerate

$\therefore$ **(d)**

Problem 9: ***If the following matter waves travel with equal velocity, the longest wavelength is that of a/an.***

(a) electron ***(b) proton***
(c) neutron ***(d) α – particle***

Solution: $\lambda = \frac{h}{mv}$

λ will be large if m is small

$\therefore$ **(a)**

Problem 10: ***Number of nodal planes (planes of zero electron density) in the*** d_{xy} ***orbital is***

(a) 1 *(b) 2*

(c) 0 *(d) 4*

Solution: xz and yz are planes with zero electron density for d_{xy} orbital.

$\therefore$ **(b)**

Problem 11: **If the speed of electron in the Bohr's first orbit of hydrogen atom is x the speed of the electron in the third Bohr's orbit is**

(a) x/9 **(b) x/3**

(c) 3x **(d) 9x**

Solution: According to Bohr's model for hydrogen and hydrogen like atoms the velocity of an electron in an atom is quantized and is given by $v = \frac{2\pi k ze^2}{nh}$

$\therefore$ (b)

Problem 11: **Which set of quantum number is not consistent with the quantum mechanical theory?**

(a) n = 2, l = 1, m = 1, s = ½ **(b) n = 4, l = 3, m = 2, s = –1/2**

(c) n = 3, l = 2, m = 3, s = +1/2 **(d) n = 4, l = 3, m = 3, s = +1/2.**

Solution: The e is a well defined co-relation between n, l, m and s quantum numbers in an atom. l = (n – 1), m will be $\pm$ ½, for n = 3 there cannot be m = 3. Highest value m will be 2.

$\therefore$ **(c)**

Problem 13: ***If the radius of first Bohr orbit be*** a_0***, then the radius of third Bohr orbit would be***

(a) $3 \times a_0$ *(b)* $6 \times a_0$

(c) $9 \times a_0$ *(d)* $1/9 \times a_0$

Solution: The radius as per Bohr's model $r \propto n^2$

$\therefore$ **(c)**

Problem 14: ***The quantum numbers of most energetic electron in Ne atom when it is in first excited state is***

(a) 2, 1, 0, $\pm 1/2$ *(b) 3, 1, 1,* $\pm$ *½*

(c) 3, 0, 0, $\pm 1/2$ *(d) 3, 1, 0,* $\pm 1/2$*.*

Solution: The electronic configuration of Ne atom is $1s^2 2s^2 2p^6$. In its first excitation state the electron from 2p will unpair and shift to 3s where its quantum numbers will be 3, 0, 0, ± ½.
$\therefore$ **(c)**

Problem 15: ***Of the following transitions in hydrogen atom, the one which gives an absorption line of lowest frequency is***
(a) n = 1 to n = 2 ***(b) n = 3 to n = 8***
(c) n = 2 to n = 1 ***(d) n = 8 to n = 3***

Solution: Absorption line in the spectra arise when energy is absorbed i.e., electron shifts from lower to higher orbit, out of a and b, b will have the lowest frequency as this falls in the Paschen series.
$\therefore$ **(b).**

Subjective

Problem 1: ***Which is larger, an He^+ ion with an electron in an orbit with n = 3 or Li^{2+} ion with an electron in an orbit with n = 5?***

Solution: Radius of the nth Bohr's orbit of the species of atomic number Z is given by

$$r_n = \frac{n^2 a_0}{Z}$$

Where $a_0 (= 0.529 Å)$ is called Bohr's radius.

i) $r_3(He^+, Z = 2) = \frac{9a_0}{2} = 4.5a_0$ ii) $r_5(Li^{2+}, Z = 3) = \frac{25a_0}{3} = 8.33a_0$

Problem 2: ***How many elements would be in the second period of the periodic table if the spin quantum number m_s could have the value $-\frac{1}{2}, 0, \frac{1}{2}$?***

Solution: For second period n = 2, hence,

1	m	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)

Problem 3: ***Calculate the wavelength of a soft ball of mass of 100 g traveling at a velocity of 35 m s^{-1}.***

Solution: Using de-Broglie's equation

$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}\,\text{J s}^{-1}}{\left(\frac{100}{1000}\right)\text{kg} \times 35\ \text{m s}^{-1}} = 1.893 \times 10^{-34}\ \text{m}$$

Problem 4: ***O_2 undergoes photochemical dissociation into 1 normal oxygen atom (O) and more energetic oxygen atom O*. If (O*) has 1.967 eV more energy (O) and normal dissociation energy of O_2 is 498 kJ mol^{-1}, what is the maximum wavelength effective for the photochemical dissociation of O_2?***

Solution: $O_2 \rightarrow O + O^*$

Dissociation energy $= 498\ \text{kJ mol}^{-1} = \frac{498 \times 1000}{6.02 \times 10^{23}}\ \text{J molecule}^{-1}$

$= 8.27 \times 10^{-19}\,\text{J molecule}^{-1}$

Excitation energy to form O^*

$= 1.967\ \text{eV atom}^{-1} = 1.967 \times 1.6 \times 10^{-19}\ \text{J atom}^{-1}$

$= 3.15 \times 10^{-19}\ \text{J atom}^{-1}$

Total energy $= 11.42 \times 10^{-19}\ \text{J}$

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

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

$= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{11.42 \times 10^{-19}} = 174 \times 10^{-9}\ \text{m} = 174\ \text{nm}$

Problem 5: ***The electron energy in hydrogen atom is given by $E = (-21.7 \times 10^{-12})/n^2$ ergs. Calculate the energy required to remove an electron completely from the n = 2 orbit. What is the longest wavelength (in cm) of light that can be used to cause this transition?***

Solution: $\Delta E = E_\infty - E_2 = [0] - \left[-\frac{21.7 \times 10^{-12}}{4}\right]$

Since $E_n = -\frac{21.7 \times 10^{-12}}{n^2}$ ergs, $= \frac{21.7 \times 10^{-12}}{4}$

$\Delta E = hv$

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

$\frac{21.7 \times 10^{-12}}{4} = 6.627 \times 10^{-27} \times \frac{3 \times 10^{10}}{\lambda}$

whence $\lambda = 3.67 \times 10^{-5}\,\text{cm}$.

Problem 6: ***The wave number of the first line in the Balmer series of hydrogen is 15200 cm^{-1}. What is the wave number of the first line in the Balmer series of Be^{3+}?***

Solution: $\bar{\nu}_H = R_H \left[\frac{1}{2^2} - \frac{1}{3^2}\right]$; Z = 1 for H-atom

$\bar{\nu}_{Be^{3+}} = R_H \times 16\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$; Z = 4 for Be^{3+}

Thus, $\bar{\nu}_{Be^{3+}} = 16\ \nu_H = 16 \times 152000\ cm^{-1}$

$= 2.432 \times 10^5\ cm^{-1}$

$= 4.16 \times 10^{-14}$.

Problem 7: ***Two 1.0 g carbon disks 1.00 cm apart have equal and opposite charges. If force of attraction between them is 1.00 × 10^{-5}N, calculate the ratio of excess electrons to total atoms on the negatively charged disk. (permittivity) constant is 9.0 × 10^9 N m^2 C^{-2}).***

Solution: $q_1 = \sqrt{\frac{Fr^2}{k}} = \sqrt{\frac{1.00\times10^{-5}\times(1.0\times10^{-2})^2}{9.0\times10^9}} = 3.33\times10^{-10}$ C on each disk,

Since charge on one electron $= 1.6\times10^{-19}$ C

hence, number of electron on the disk $= \frac{3.33\times10^{-10}}{1.6\times10^{-19}} = 2.08\times10^9$

number of atoms in 1.0 g carbon $= \frac{1}{12}\times6.02\times10^{23} = 5.0\times10^{22}$ atoms

Hence, ratio of electron to atoms $= \frac{2.08\times10^9}{5.00\times10^{22}}$

Problem 8: ***When a certain metal was irradiated with light of frequency 1.6 × 10^{16} Hz, the photoelectrons 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 ν_0 (threshold frequency) for the metal.***

Solution: $KE_1 = h(\nu_1 - \nu_0)$ … (i)

$KE_2 = h(\nu_2 - \nu_0)$ … (ii)

Dividing Eqs. (ii) by (i) we have

$\therefore \quad \frac{\nu_2 - \nu_0}{\nu_1 - \nu_0} = \frac{1}{2}$

$\frac{1.0\times10^{16} - \nu_0}{1.6\times10^{16} - \nu_0} = \frac{1}{2}$

$2.0\times10^{16} - 2\nu_0 = 1.6\times10^{16} - \nu_0$

$\nu_0 = 4\times10^{15}$ Hz

Problem 9: ***One mole of He^+ ion is excited. Spectral analysis showed the existence of 50% ions in 3rd level, 25% in 2nd level and remaining 25% in ground state. ionization energy of He^+ is 54.4 eV; calculate total energy evolved when all the ions return to ground state.***

Solution: $(\Delta E)_{3\to 1} = (54.4)\,\frac{N_0}{2}\left[\frac{1}{1^2}-\frac{1}{3^2}\right]$, for $\frac{N_0}{2}$ ions falling to ground state

$= 54.4\times\frac{4\times N_0}{9}\ \text{eV}$

and $(\Delta E)_{3\to 1} = (54.4)\,\frac{N_0}{4}\left[\frac{1}{1^1}-\frac{1}{2^2}\right]$, for $\frac{N_0}{4}$ ions falling to ground state

$= 54.4\times\frac{3\times N_0}{16}\ \text{eV}$

Hence, total energy $= 54.4\times N_0\left[\frac{4}{9}+\frac{3}{16}\right] = 54.4\times 6.02\times 10^{23}\times\frac{91}{144}\text{eV}$

$= 54.4\times 6.02\times 10^{23}\times\frac{91}{144}\times 1.6\times 10^{-19}\,\text{J} \ = 3.31\times 10^{6}\,\text{J}$

Problem 10: ***Consider the following two electronic transition possibilities in a hydrogen atom as pictured below:***

1) The electron drops from third Bohr's orbit to Second Bohr's orbit followed with the next transition from second to first Bohr's orbit.

2) The electron drops from third Bohr's orbit to first Bohr's orbit directly. Show that:

a) The sum of the 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.

b) Are wavelengths and frequencies of the emitted spectrum are also additive in the same ways as their energies are ?

Solution: a) $\Delta E = R_H\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

for 3 to 2 $\Delta E_{3\to 2} = R_H\left[\frac{1}{2^2}-\frac{1}{3^2}\right]$

for 2 to 1 $\Delta E_{2\to 1} = R_H\left[\frac{1}{1^1}-\frac{1}{2^2}\right]$

for 3 to 1 $\Delta E_{3\to 1} = R_H\left[\frac{1}{1^2}-\frac{1}{3^2}\right]$

It is evident from Eqs. (1), (2) and (3), that

$\Delta E_{3\to 1} = \Delta E_{3\to 2} + \Delta E_{2\to 1}$

b) Also E = hv; thus frequencies are also additive

but $E = \frac{hc}{\lambda}$ and thus wavelengths are not additive.

Problem 11: ***Ultraviolet light of wavelength 800Å and 700Å when allowed to fall on hydrogen atoms in their ground state is found to liberate electrons with kinetic energy 1.8 eV and 4.0 eV respectively. Find the value of Planck's constant.***

Solution: $KE_1 = h\nu_1 - W = h.\frac{c}{\lambda_1} - W$ … (i)

$KE_2 = h\nu_2 - W = h.\frac{c}{\lambda_2} - W$ … (ii)

Substracting equation (i) from equation (ii),

$(KE_2 - KE_1) = hc\left(\frac{1}{\lambda_2} - \frac{1}{\lambda_1}\right) = hc\left(\frac{\lambda_1 - \lambda_2}{\lambda_1\lambda_2}\right)$

or $h = \frac{(KE_2 - KE_1)\times\lambda_1\lambda_2}{c\times(\lambda_1 - \lambda_2)}$

$= \frac{(4.0eV - 1.8eV)\times 800\times 10^{-10}\times 700\times 10^{-10}}{3\times 10^8\times(800-700)\times 10^{-10}}$

$= \frac{(2.2\times 1.6\times 10^{-19} J)\times(56\times 10^{-16}\times m^2)}{(3\times 10^8 ms^{-1})\times(100\times 10^{-10} m)} = \frac{2.2\times 1.6\times 56\times 10^{-35}}{3} J-s$

$= 6.57\times 10^{-34} J-s$

Problem 12: ***The λ of H_α line of Balmer series is 6500Å. What is the λ of H_β line of Balmer series?***

Solution: For H_α lines of Balmer series $n_1 = 2, n_2 = 3$

For H_β line of Balmer series $n_1 = 2, n_2 = 4$

$\therefore \quad \frac{1}{\lambda_{H_\alpha}} = R_H\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$ … (1)

and $\frac{1}{\lambda_{H_\beta}} = R_H\left[\frac{1}{2^2} - \frac{1}{4^2}\right]$ … (2)

By Eqs. (1) and (2)

$\therefore \quad \frac{\lambda_\beta}{\lambda_\alpha} = \frac{\frac{1}{4} - \frac{1}{9}}{\frac{1}{4} - \frac{1}{16}}$

$\therefore \quad \lambda_\beta = \lambda_\alpha \times\left[\frac{80}{108}\right] = 6500\times\frac{80}{108} = 4814.8Å$

Problem 13: ***The IP_1 of H is 13.6 eV. It is exposed to electromagnetic waves of 1028Å and gives out induced radiations. Find the wavelength of these induced radiations.***

Solution: E_1 of H atom = –13.6 eV

Energy given to H atom $= \frac{6.625\times 10^{-34}\times 3.0\times 10^8}{1028\times 10^{-10}}$

$= 1.933\times 10^{-18} J = 12.07eV$

$\therefore$ Energy of H atom after excitation = –13.6 + 12.07

$= -1.53 \text{ eV}$

$\therefore \quad E_n = \frac{E_1}{n^2}$

$\therefore \quad n^2 = \frac{-13.6}{-1.53} = 9$

$\therefore \quad n = 3$

Thus, electron in H atom is excited to 3rd shell

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

$\therefore \quad E_1 = -13.6 \text{ eV}; E_3 = -1.53 \text{ eV}$

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

$= 1028 \times 10^{-10} \text{ m}$

$\therefore \quad \lambda = 1028 \text{ Å}$

$\therefore \quad \text{II induced } \lambda_2 = \frac{hc}{(E_2 - E_1)}$

$\therefore \quad E_1 = -13.6 \text{ eV}; E_2 = -\frac{13.6}{4} \text{ eV}$

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

$= 1216 \times 10^{-10} \text{ m} = 1216 \text{ Å}$

$\therefore \quad \text{III induced } \lambda_3 = \frac{hc}{E_3 - E_2}$

$\therefore \quad E_1 = -13.6 \text{eV}; E_2 = -\frac{13.6}{4} \text{eV}; E_3 = -\frac{13.6}{9} \text{ eV}$

$$\therefore \quad \lambda_3 = \frac{6.625 \times 10^{-34} \times 3.0 \times 10^8}{\left(-\frac{13.6}{9} + \frac{13.6}{4}\right) \times 1.602 \times 10^{-19}} = 6568 \times 10^{-10} \text{ m} = 6568 \text{ Å}$$

Problem 14: ***Calculate the wavelength in angstrom of the photon that is emitted when an electron in Bohr orbit n = 2 returns to the orbit n = 1 in the hydrogen atom. The ionization potential of the ground state of hydrogen atom is 2.17 $\times 10^{-11}$ erg per atom.***

Solution: In the ground state of H-atom the solitary electron occupies the first orbit and hence, the ionization potential of the ground state of the hydrogen atom is the energy of the electron of the first orbit, with sign reversed.

$E_1 = -2.17 \times 10^{-11} \text{erg}$

Thus, $E_2 = \frac{E}{n^2} \;\; = -\frac{2.17 \times 10^{11}}{2^2}$

$\therefore$ Energy of the radiation emitted,

$$\Delta E = E_2 - E_1$$

$$= -\frac{2.17\times10^{-11}}{2^2} - (-2.17\times10^{-11}) = 1.627\times10^{-11}\,\text{erg}$$

We know $\Delta E = hv = \frac{hc}{\lambda}$

Thus $\frac{hc}{\lambda} = 1.627\times10^{-11}$

$$\lambda = \frac{6.62\times10^{-27}\times3\times10^{10}}{1.627\times10^{-11}} = 1.22\times10^{-5}\,\text{cm}$$

$= 1220$ Å (1Å $= 10^{-8}$ cm)

Problem 15: ***Infrared lamps are used in restaurants and cafeterias to keep food warm. The infrared radiation is strongly absorbed by water raising its temperature and that of the food in which it is incorporated. How many photons per second of infrared radiation are produced by an infrared lamp that consumes energy at the rate of 100 watt (100 J*** s^{-1}) ***and is 12% efficient in converting this energy to infrared radiation? Assume that the radiation has a wavelength of 1500 nm.***

Solution: $E = Nh\,\nu = \frac{Nhc}{\lambda}$

$$= \frac{N\times6.626\times10^{-34}\times3\times10^{8}}{1500\times10^{-9}}$$

$$E = \frac{100\times12}{100}\,\text{watt (Js}^{-1}\text{)}$$

$$\therefore\quad 100\times\frac{12}{100} = \frac{N\times6.626\times10^{-34}\times3\times10^{8}}{1500\times10^{-9}}$$

$\therefore\quad N = 9.06\times10^{6}$ photons s^{-1}

Assignments (New Pattern)

SECTION – I **Single Choice Questions**

1. Photoelectric emission is observed from a surface of frequencies ν_1 and ν_2 of the incident radiation $(\nu_1 > \nu_2)$, if the maximum kinetic energies of the photoelectrons. In two cases are in the ratio of 1 : K then the threshold frequency ν_0 is given by:

(a) $\frac{\nu_1 - \nu_2}{K-1}$ (b) $\frac{K\nu_1 - \nu_2}{K-1}$

(c) $\frac{K\nu_2 - \nu_2}{K-1}$ (d) $\frac{\nu_1 - \nu_2}{K}$.

2. The radial distribution curve of the orbital with double dumbbell shape in the 4^{th} principle shell consists of `n' nodes, n is

(a) 2 (b) 0

(c) 1 (d) 3

3. The probability of finding an electron residing in a P_x orbital is zero in the

(a) yz plane (b) xy plane

(c) xz plane (d) y and z directions.

4. The first emission line in the atomic spectrum of hydrogen in the Balmer Series appears at

(a) $\frac{9R_H}{400} cm^{-1}$ (b) $\frac{7R_H}{144} cm^{-1}$

(c) $\frac{3R_H}{4} cm^{-1}$ (d) $\frac{5R_H}{36} cm^{-1}$.

5. The hydrogen line spectrum provides evidence for the

(a) Heisenberg Uncertainty Principle

(b) wave like properties of light

(c) Diatomic nature of H_2

(d) quantized nature of atomic energy states.

6. If λ_1 and λ_2 denote the de-Broglie wavelength of two particles with same masses but charges in the ratio of 1 : 2 after they are accelerated from rest through the same potential difference, then

(a) $\lambda_1 = \lambda_2$ (b) $\lambda_1 < \lambda_2$

(c) $\lambda_1 > \lambda_2$ (d) None of these.

7. The increasing order of the value of e/m (charge to mass ratio) for electron (e), proton (p), neutron (n) and alpha particle (α) is

(a) $e < p < n < \alpha$ (B) $n < p < e < \alpha$

(c) $n < p < \alpha < e$ (d) $n < \alpha < p < e$.

8. The energy of the second Bohr orbit in the hydrogen atom is –3.41eV. the energy of the second Bohr orbit of He^{+} ion would be
(a) –0.85 eV
(b) –13.64 eV
(c) –1.70 eV
(d) –6.82 eV

9. The amount of energy required to remove electron from a Li^{+2} ion in its ground state is how many times greater than the amount of energy needed to remove the electron from a H atom in its ground state?
(a) 9
(b) 6
(c) 4
(d) 3.

10. The velocity of electron of H-atom in its ground state is $2.2 \times 10^{6} ms^{-1}$. The de-Broglie wavelength of this electron would be
(a) 0.33 nm
(b) 23.3 nm
(c) 45.6 nm
(d) 100 nm.

11. The M shell of an atom contains
(a) only s-sub-shell
(b) both s and p sub-shell
(c) s, p and d sub-shell
(d) s, p, d and f sub-shell.

12. Which of the following sets of the four quantum numbers, n, l, m and m_s describes one of the outermost electrons in a ground state magnesium atom?
(a) $3, 1, 1, \frac{1}{2}$
(b) $3, 0, 0, -\frac{1}{2}$
(c) $3, 0, 1, \frac{1}{2}$
(d) $3, 1, 0, \frac{1}{2}$.

13. Which of the following statements concerning px orbitals is false?
(a) the electron density has two regions of high magnitude pointed in the +x and –x directions
(b) these two high probability regions are separated by a node passing through the nucleus
(c) the electrons stay half the time in one of these region and the remaining time in the other region
(d) none of these.

14. The wavelength associated with a golf ball weighing 200 g and moving at a speed of 5 m/h is of the order
(a) $10^{-10} m$
(b) $10^{-20} m$
(c) $10^{-30} m$
(d) $10^{-40} m$.

15. The quantum numbers of +1/2 and –1/2 for the electron spin represent
(a) Rotation of the electron in clockwise and anticlockwise direction respectively
(b) Rotation of the electron in anticlockwise and clockwise direction respectively
(c) Magnetic moment of the electron pointing up and down respectively
(d) Two quantum mechanical spin states which have no classical analogue.

16. What element has a H-like spectrum, whose lines have wavelengths four times shorter than those of atomic hydrogen?
(a) He (b) He^{+}
(c) H (d) Li^{+2}

17. The atomic spectrum of Li^{+2} arises due to the transition of an electron from n_2 to n_1. If $(n_1 + n_2) = 4$ and $(n_2 - n_1) = 2$ find the wavelength of the 3rd line of this series in Li^{+2} ion?
(a) 10.8 nm (b) 1.08 nm
(c) 108 nm (d) 100 nm

18. The second line of Lyman series of H coincides with the 6th line of Paschen series of an Ionic species X. Find X assuming R to be same for both H and X?
(a) He^{+} (b) Li^{+2}
(c) Li^{+} (d) H

19. The ratio of energy of the electron in ground state of hydrogen to the electron in first excited state of Be^{+3} is
(a) 4 : 1 (b) 1 : 4
(c) 1 : 8 (d) 8 : 1

20. In an atom two electrons move around the nucleus in circular orbits of radii R and 4R. The ratio of the time taken by them to complete one revolution is
(a) 1 : 4 (b) 4 : 1
(c) 1 : 8 (d) 8 : 1

21. The work function for a metal is 4 ev. To emit a photo electron of zero velocity from the surface of the metal, the wavelength of incident light should be;
(a) 2700Å (b) 1700Å
(c) 5900Å (d) 3100Å

22. An electron in a H-like atom is in an excited state. It has a total energy of –3.4 ev, calculate the de-Broglie's wavelength?
(a) 66.5Å (b) 6.66Å
(c) 60.6Å (d) 6.06Å

23. When the frequency of light incident on a metallic plate is doubled, the KE of the emitted photoelectron will be;
(a) doubled
(b) Halved
(c) Increased but more than doubled of the previous KE
(d) Remains unchanged

24. The ratio of the difference in energy of electron between the first and second Bohr's orbit to that between second and third Bohr's orbit is;
(a) $\frac{1}{3}$ (b) $\frac{27}{5}$
(c) $\frac{9}{4}$ (d) $\frac{4}{9}$

25. The approximate quantum no. of a circular orbit of diameter 20.6 nm of the hydrogen atom according to Bohr's theory is
(a) 10 (b) 14
(c) 12 (d) 16

SECTION – II	May be more than one choice

1. The electrons, identified by quantum numbers n and 1, (i) n = 4, l = 1 (ii) n = 4, l = 0 (iii) n = 3, l = 2 (iv) n = 3, l = 1 can be placed in order of increasing energy, from the lowest to highest, as
   (a) iv < ii < iii < I
   (b) ii < iv < i < iii
   (c) I < iii < ii < iv
   (d) iii < I < iv < ii.

2. The energy of an electron in the first Bohr orbit of H atom is –13.6 eV. The possible energy value(s) of the excited state(s) for electrons in Bohr orbits of hydrogen is (are)
   (a) –3.4 eV
   (b) –4/2 eV
   (c) –6.8 eV
   (d) + 6.8 eV.

3. Which of the following statement(s) is (are) incorrect?
   (a) The electronic configuration of Cr is $[Ar]3d^5 4s^1$. (Atomic No. of Cr = 24).
   (b) the magnetic quantum number may have a negative value.
   (c) In silver atom, 23 electrons have a spin of one type and 24 of the opposite type. (Atomic No. of Ag = 47).
   (d) The oxidation state of nitrogen in NH_3 is –3.

4. For a `d'-electron, the orbital angular momentum is
   (a) $\sqrt{6}h$
   (b) $\sqrt{2}\ h$
   (c) h
   (d) 2h.

5. The first use of quantum theory to explain the structure of atom was made by
   (a) Heisenberg
   (b) Bohr
   (c) Planck
   (d) Einstein.

6. The orbital angular momentum of an electron in 2s orbital is:
   (a) $+\frac{1}{2}.\frac{h}{2\pi}$
   (b) zero
   (c) $\frac{h}{2\pi}$
   (d) $\sqrt{2}.\frac{h}{2\pi}$

7. The wavelength of a spectral line for an electronic transition is inversely related to
   (a) The number of electrons undergoing the transition
   (b) The nuclear charge of the atom
   (c) The difference of the energy of the energy levels involved in the transition
   (d) The velocity of the electron under going the transition.

8. Bohr model can explain
   (a) the spectrum of hydrogen atom only
   (b) spectrum of an atom or ion containing one electron only
   (c) the spectrum of hydrogen molecule
   (d) the solar spectrum

9. The radius of an atomic nucleus is of the order of

(a) 10^{-10} cm (b) 10^{-13} cm

(c) 10^{-15} cm (d) 10^{-8} cm.

10. When alpha particles are sent through a thin metal foil, most of them go straight through the foil because:

(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 particle move with high velocity

11. The increasing order (lowest first) for the value of c/m (charge/mass) for electron (e), proton(p), neutron (n) and alpha particle (α) is:

(a) e, p, n, α (b) n, p, e, α

(c) n, p, a, α (d) n, α, p, e

12. Which electronic level would allow the hydrogen atom to absorb a photon but not to emit a photon?

(a) 3s (b) 2p

(c) 2s (d) 1s

13. Any p-orbital can accommodate upto

(a) four electrons (b) six electrons

(c) two electrons with parallel spins (d) two electrons with opposite spins

14. The principal quantum number of an atom is related to the

(a) size of the orbital (b) spin angular momentum

(c) orbital angular momentum (d) orientation of the orbital in space

15. If uranium (mass number 238 and atomic number 92) emits an α-particle, the product has mass no. and atomic no.

(a) 236 and 92 (b) 234 and 90

(c) 238 and 90 (d) 236 and 90

16. If the radius of first Bohr orbit is x, then the de-Broglie wavelength of electron in 3rd orbit is nearly;

(a) $2\pi x$ (b) $6\pi x$

(c) 9x (d) $\frac{x}{3}$

17. The angular momentum of electron of H-atom is proportional to;

(a) r^2 (b) $\frac{1}{r}$

(c) $\sqrt{r}$ (d) $\frac{1}{\sqrt{r}}$

18. With what velocity must an electron travel so that its momentum is equal to that of a photon of wavelength λ = 5200Å?

(a) 1400 ms^{-1} (b) 140 ms^{-1}

(c) 14 ms^{-1} (d) 1.4 ms^{-1}

19. The eyes of a certain member of reptile family pass a visual signal to the brain when the visual receptors are struck by photon of wavelength 850 nm. If a total of energy of 3.15×10^{-14} Joules is required to trip the signal, what is the minimum no. of photons that must strike the receptor?

(a) 1.37×10^5 photons
(b) 13.7×10^5 photons
(c) 4×10^4 photons
(d) 2×10^3 photons

20. A photon of 300 nm is absorbed by a gas and then re-emitted two photons. One re-emitted photon has wavelength 496 nm, the wavelength of second re-emitted photons is;

(a) 759
(b) 857
(c) 957
(d) 600

21. Which represents an possible arrangement

	n	ℓ	m	s
(a)	3	2	–2	1/2
(b)	4	0	0	1/2
(c)	3	2	–3	1/2
(d)	5	3	0	1/2

22. Which set of quantum number is consistent with theory

(a) $n = 2, \ell = 1, m = 0, s = -1/2$
(b) $n = 4, \ell = 3, m = 2, S = -1/2$
(c) $n = 3, \ell = 2, m = 3, S = +1/2$
(d) $n = 4, \ell = 3, m = 3, S = +1/2$

23. Which of the following statements are false:

(a) The uncertainty in position and momentum in Heisenberg's principle due to electron wave.
(b) The energy level order 4s < 3d < 4p < 5s may not hold good for all elements
(c) The quantum nature of light radiation is manifested in photoemission of electrons
(d) According to Bohr's theory the energy decreases as n increases.

24. Five valence electrons of $_{15}P$ are labeled as

Pq		x	y	z
3s			3P	

If the spin quantum number of q and z is $+\frac{1}{2}$

The group of electrons with three of the quantum number same are :

(a) Pq
(b) (xyz), (pq)
(c) (pq), (xyz), (pz)
(d) (pq), (xyz), (qy)

25. Which of the following is/are correct?

(a) the energy of an electron depends only on the principal quantum numbers not on the other quantum numbers
(b) the energy of an electron depends only on the principal quantum number in case of hydrogen and hydrogen like atoms.
(c) The difference in potential energies of any two energy level is always more than the difference in kinetic energies of these two levels.
(d) An electron in an excited state can always emit a photon or two but can not absorb a photon

SECTION – III	Comprehension Type Questions

Write-up I

An orbital is designated by certain values of first three quantum numbers (n, ℓ and m) and according to Pauli's Exclusion Principle, no two electron in an atom can have all the four quantum numbers equal. n, ℓ and m denote size, shape and orientation of the orbital. The permissible values of n are 1, 2, 3 …..∞ while that of ℓ are all possible integral values from 0 to n –1. Orbitals with same values of n and ℓ but different values of m (where m can have any integral values from –ℓ to +ℓ including zero) are of equal energy and are called degenerate orbitals. However degeneracy is destroyed in an inhomogeneous external magnetic field due to different extent of interaction between the applied field and internal electronic magnet of different orbitals differing in orientations. In octahedral magnetic field the external magnetic field are oriented along axes while in tetrahedral field the applied field acts more in between the axes than that on the axes themselves. For ℓ = 0, 1, 2, 3…, the states (called sub-shells) are denoted by the symbol s, p, d f …… respectively. After f, the subshells are denoted by the letters alphabetically. ℓ determines orbital angular motion (L) of electron as

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

On the otherhand, m determines Z – component of orbital angular momentum as

$$L_Z = m\left(\frac{h}{2\pi}\right)$$

Hund's rule states that in degenerate orbitals electrons do not pair up unless and until each such orbital has got an electron with parallel spins.

Besides orbital motion, an electron also possess spin-motion. Spin may be clock-wise and anti-clock wise. Both these spin motion are called two spin states of electron characterised by spin Q.N.(s): $s = +\frac{1}{2}$ and $s = -\frac{1}{2}$ respectively. The sum of spin Q.N. of all the electrons is called total spin (s) and (2s + 1) is called spin multiplicity of the configuration as a whole. The spin angular momentum of an electron is written as:

$$L_s = \sqrt{s(s+1)}\frac{h}{2\pi}$$

1. According to Hund's rule, the distribution of electron within the various orbitals of a given sub-shell is one which is associated with
   (a) Minimum spin multiplicity (b) Maximum spin multiplicity
   (c) Maximum energy (d) Minimum total spin

2. An orbital has n = 5 and its ℓ value is the maximum possible. The orbital angular momentum of the electron in this orbital will be
   (a) $\sqrt{2}\frac{h}{2\pi}$ (b) $\sqrt{6}\frac{h}{2\pi}$
   (c) $\sqrt{12}\frac{h}{2\pi}$ (d) $\sqrt{20}\left(\frac{h}{2\pi}\right)$

3. ℓ introduces quantisation in which of the following?
   (a) Energy of electron b) Shape of orbital

(c) Orbital angular momentum of orbital (d) All the three

4. What is the spin angular momentum of N-atom (Z = 7): EC = $1s^2 2s^2 2p^3$ (GS)

(a) Zero (b) $\sqrt{\frac{3}{4}}\left(\frac{h}{2\pi}\right)$

(c) $\sqrt{\frac{15}{4}}\left(\frac{h}{2\pi}\right)$ (d) $\frac{1}{2}\left(\frac{h}{2\pi}\right)$

✍ **Write-up II**

In H-spectrum, we get several spectral lines in different region like UV, visible and IR. The wave lengths of different spectral lines in a particular series are different and can be calculated by using Rydberg's formula.

$$\frac{1}{\lambda} = \bar{v} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

where, $R = 1.1 \times 10^7 \ m^{-1}$

In a particular series lines are very close to each other. In addition to this the energy gap between two energy levels are going to decrease from lower energy level to higher energy levels.

5. The significance of quantisation is going to be lost as

(a) The energy difference between consecutive energy levels are going to decrease.

(b) When we move from lower energy level to higher energy level, energy levels are trying to converge into a single line

(c) Both (a) and (b)

(d) None

6. A high Rydberg atom is characterisecd by a transition of electron from n = 100 to n = X level. The wavelength of emitted light is 4.49 cm. What is the value of X?

(a) X = 99 (b) X = 90

(c) X = 9 (d) X = 10

7. The atomic spectrum of Li^{2+} arises due to the transition of an electron from n_1 to n_2. If $(n_1 + n_2) = 4$ and $(n_2 - n_1) = 2$, then find the wavelength of the 3rd line of this series in Li^{2+} ion?

(a) 1.08 nm (b) 10.8 nm

(c) 108 nm (d) 1080 nm

✍ **Write-up III**

The single quantum number suggested by Neil's Bohr and the appearance of several spectral lines in a particular series of H-spectrum, suggest that there must be more than one quantum number to explain all the quantized properties of an electron in a particular energy level inside the atom.

In fact when the properties of the electron is transformed from Cartesian co-ordinate to polar co-ordinates then it becomes the function of r, θ, and ϕ suggesting three

independent quantum numbers. In addition to this a fourth quantum number is required to consider the spinning behaviour of an electron.
The principal quantum number n, suggest the orbit number in which electron revolves; Azimuthal quantum number l suggest the shape of orbitals, magnetic quantum number m, gives orientation of orbital in presence of external magnetic field, while spin quantum number s, gives direction of rotation of an electron about it's own axis.
$n \neq 0$ values of "l" ranges in between 0 to (n –1), while m depends upon l. Total number of values of m = 2l + l, and "m" ranges in between –l to +l including 0. For each electron spin will be $\pm\frac{1}{2}$.

$S = +\frac{1}{2}$ Clock wise spin

$S = -\frac{1}{2}$ Anti clock wise spin

8. The maximum number of electrons with n = 3, l = 3 is
(a) 14
(b) 10
(c) 6
(d) 0

9. If n = 3, l = 0, m = 0 then the possible atomic number may be
(a) 10, 11
(b) 11, 12
(c) 12, 13
(d) 13, 14

10. Two electrons A and B in an atom have the following set of quantum numbers; what is true for A and B
For A; n = 3, l = 2, m = –2, s = +1/2
For B; n = 3, l = 0, m = 0,s = +1/2
(a) A and B have same energy
(b) A has more energy than B
(c) B has more energy than A
(d) A and B represent the same electron

✍ **Write-up IV**
Rutherford's and Bohr's atomic model became defective as in those atomic models only particle nature of electron was considered. While according to wave mechanical concept an electron behaves as a wave as well as a particle. This is true for all the microscopic particles like nucleons, atoms, molecules and ions. de-Broglie established a relationship between wavelength momentum and kinetic energy of the electron

$$\lambda = \frac{h}{p} = \frac{h}{\sqrt{2mKE}}$$

Where h = Planck' constant, p = momentum, m = mass of electron & KE = Kinetic energy
Later on, Heisen-berg (1927) told that the location of an electron at particular point from nucleus is not possible. According to him "It is impossible to determine the momentum and position of moving electron or any microscopic particle simultaneously and exactly. If one will be certain then other will be uncertain.

According to Heisenberg

$$\Delta x.\Delta p \geq \frac{h}{4\pi}$$

Photoelectric effect, reflection of light suggest the particle nature of electron, while deffraction, polarization, interference, scattering of light suggest the wave nature of electron.

11. Determine de-Broglie wavelength of an electron having kinetic energy of 1.6×10^{-6} erg, $m_e = 9.11 \times 10^{-28}$ g, $h = 6.62 \times 10^{-27}$ erg sec.
(a) 1.22×10^{-10} cm
(b) 2.1×10^{-3} cm
(c) 5×10^{-5} cm
(d) 6.0 cm

12. Calculate the accelerating potential that must be imparted to a proton beam to give it an effective wave length of 0.005 nm.
(a) 30.85 volt
(b) 32.85 volt
(c) 25.0 volt
(d) 26.5 volts.

13. A green ball weighs 75 gm and comes travelling towards you at 400 cm/sec. A photon of light emitted from green ball has a wavelength of 5×10^{-5} cm. Assuming that error in position of ball is the same as wave length of itself, calculate the error in momentum of green ball.
(a) 1.055×10^{-23}
(b) 0.5×10^{-23}
(c) 2.3×10^{-23}
(d) 1.0

Write-up V

It is tempting to think that all possible transitions are permissible, and that an atomic spectrum arises from the transition of an electron from any initial orbital to any other orbital. However, this is not so, because a photon has an intrinsic spin angular momentum of $\sqrt{2}\frac{h}{2\pi}$ *corresponding to S = 1 although it has no charge and no rest mass. On the other hand, an electron has got two types of angular momentum: Orbital angular momentum,* $L == \sqrt{\ell(\ell+1)}\frac{h}{2\pi}$ *and spin angular momentum,* $L_s\left(=\sqrt{s(s+1)}\frac{h}{2\pi}\right)$ *arising from orbital motion and spin motion of electron respectively. The change in angular momentum of the electron during any electronic transition must compensate for the angular momentum carried away by the photon. To satisfy this condition the difference between the azimuthal quantum numbers of the orbitals within which transition takes place must differ by one. Thus, an electron in a d-orbital (ℓ = 2) cannot make a transition into an s-orbital (ℓ = 0) because the photon cannot carry away enough angular momentum. An electron as is well known, possess four quantum numbers n, ℓ, m and s. Out of these four ℓ determines the magnitude of orbital angular momentum (mentioned above) while m determines its Z-component as* $m\left(\frac{h}{2\pi}\right)$*. The permissible values of only integers right from $-\ell$ to $+\ell$. While those for ℓ are also integers starting from 0 to (n –1).*

The values of ℓ denotes the sub-shell. For ℓ = 0, 1, 2, 3, 4….. the sub-shells are denoted by the symbols s, p, d, f, g…. respectively.

14. To what orbitals may a 4d-electron make radioactive transitions?
(a) any of ns, np, nd and nf
(b) any of np and nf orbitals
(c) only 3s and 4p
(d) only 6f

15. Electronic transition from 4s to 3s orbital is forbidden meaning that it cannot occur because
(a) There will be no change in the orbital angular momentum of electron although the emitted photon has angular momentum.
(b) There will be change in the orbital angular momentum whereas the emitted photon has no momentum.
(c) Δm_ℓ values between 4s and 3s is not zero which is an important selection rule for allowed transition
(d) In 4s and 3s orbitals the wavelength of electron-wave are the same.

16. The maximum orbital angular momentum of an electron with n = 5 is
(a) $\sqrt{6}\frac{h}{2\pi}$
(b) $\sqrt{12}\frac{h}{2\pi}$
(c) $\sqrt{42}\frac{h}{2\pi}$
(d) $\sqrt{20}\frac{h}{2\pi}$

17. The orbital angular momentum of an electron in p-orbital makes an angle of 45° from Z-axis. Hence Z-component of orbital angular momentum of electron is:
(a) $\frac{h}{\pi}$
(b) $\left(\frac{h}{2\pi}\right)$
(c) $-\frac{h}{\pi}$
(d) $-\left(\frac{h}{2\pi}\right)$

18. The spin-only magnetic moment of a free ion is $\sqrt{8}$ B.M. The spin angular momentum of electron will be
(a) $\sqrt{2}\frac{h}{2\pi}$
(b) $\sqrt{8}\frac{h}{2\pi}$
(c) $\sqrt{6}\frac{h}{2\pi}$
(d) $\sqrt{\frac{3}{4}}\frac{h}{2\pi}$

SECTION – IV | Subjective Questions

LEVEL – I

1. i) Calculate the total number of electrons present in 1 mol of methane.
   ii) Find (a) the total number and (b) the total mass of neutrons in 7 mg of C–14. [Assume that mass of a neutron = 1.675×10^{-27} kg].
   iii) Find (a) the total number and (b) the total mass of protons in 34 mg of NH_3 at S.T.P. Will the answer change if the temperature and pressure are changed?

2. i) The energy associated with the first orbit in the hydrogen atom is -2.18×10^{-18} J atom^{-1}. What is the energy associated with the 5 orbit?
   ii) Calculate the radius of Bohr's fifth orbit for hydrogen atom.

3. What is the energy in joules, required to shift the electron of the hydrogen atom from the first Bohr orbit to the fifth Bohr orbit and what is the wavelength of the light emitted when the electron returns to the ground state? The ground state electron energy is -2.18×10^{-11} ergs.

4. i) An atomic orbital has n = 3. What are the possible value of ℓ and m?
   ii) List the quantum numbers (m and ℓ) of electrons for 3d orbital.
   iii) Which of the following orbitals are possible? 1p, 2s, 2p and 3f.

5. Two particles A and B are in motion; if wavelength of A is 5×10^{-8} m, calculate wavelength of B so that its momentum is double of A.

6. How much energy is required to move an electron from the ground state of the H-atom to the first excited state? Ionisation energy of H-atom is 13.6 eV.

7. If uncertainties in the measurement of position and momentum are equal, calculate uncertainty in the measurement of velocity.

8. Calculate the wavelength of a helium atom whose speed is equal to root mean-square speed at 293 K.

9. Fe^{x+} has magnetic moment of $\sqrt{35}$ B.M. Write its electronic configuration.

10. The kinetic energy of an electron in H like atom is 6.04 eV. Find the area of the third Bohr orbit to which this electron belong. Also report the atom.

LEVEL – II

1. Calculate the velocity of an electron placed in the third orbit of the hydrogen atom. Also calculate the no. of revolutions per second that this electron makes around the nucleus.

2. The uncertainty in the momentum of a particle is 2.5×10^{-16} g cm s^{-1} with what accuracy can its position be determined.

3. Calculate momentum of radiations of wavelength 0.33nm.

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

5. To what series does the spectral lines of atomic hydrogen belong if its wave number is equal to the difference between the wave numbers of the following two lines of the Balmer series. 486.1 and 410.2 nm? What is the wavelength of that line?

6. The angular momentum of an electron in a Bohr's orbit of H-atom is 4.2178×10^{-34} $kg\text{-}m^2/sec$. Calculate the spectral line emitted when electron from this level to next lower level.

7. Wavelength of the K_α characteristic X-ray of iron and potassium are 1.931×10^{-8} and 3.737×10^{-8} cm respectively. What is the atomic number and name of the element for which characteristic K_α wavelength is 2.289 $\times 10^{-8}$ cm?

8. The circumference of the second Bohr orbit of electron in hydrogen atom 600 nm. Calculate the potential difference to which the electron has to be subjected so that the electron stops. The electron had the de-Broglie wavelength corresponding to this circumference.

9. An electron in a hydrogen like species is in the excited state n_2. The wavelength for the transition n_2 to n_1 = 2 is 48.24 nm. The corresponding wavelength for the transition n_2 to n_1 = 3 is 142.46 nm. Find the value of n_2 and z?

10. What transition in the H-spectrum would have the same wavelength as the Balmer transition n = 4 to n = 2 of He^+ ion spectrum?

LEVEL – III (Judge yourself at JEE level)

1. Consider the hydrogen atom to be a proton embedded in a cavity of radius a_0 (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 a_0 from the proton. How does this compare with the wavelength of an electron in the ground state Bohr's orbit?

2. Calculate the wavelength of radiations emitted producing a line in Lyman series, when an electron falls from fourth stationary state in hydrogen atom. ($R_H = 1.1 \times 10^7 m^{-1}$).

3. A bulb emits light of λ 4500Å. The bulb is rated as 150 watt and 8% of the energy is emitted as light. How many photons are emitted by the bulb per second?

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

5. A gas to identical to 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 no 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 photons 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.

6. Find out the number of waves made by a Bohr electron in one complete revolution in its 3^{rd} orbit.

7. A compound of vanadium has a magnetic moment of 1.73 BM. Work out the electronic configuration of the vanadium ion in the compound.

8. What transition in the hydrogen spectrum would have the same wavelength as the Balmer transition n = 4 to n = 2 of He^{+} spectrum?

9. 1.8 g hydrogen atoms are excited to radiations. The study of spectra indicates that 27% of the atoms are in 3^{rd} energy level and 15% of atoms in 2^{nd} energy level and the rest in ground state. IP of H is 13.6 eV. Calculate:
a) No. of atoms present in III and II energy level.
b) Total energy evolved when all the atoms return to ground state.

10. Iodine molecule dissociates into atoms after absorbing light of 4500Å. If one quantum of radiation is absorbed by each molecule, calculate the kinetic energy of iodine atoms. (bond energy of $I_2 = 240 \text{ kJ mol}^{-1}$).

SECTION – V | Miscellaneous Questions

Match the following

1.

	LIST – I		LIST – II
a)	Orbital angular momentum = $\sqrt{2}\frac{h}{2\pi}$	1)	d–orbital.
b)	$mvr = \frac{nh}{2\pi}, n = 1, 2, 3....$	2)	Classical analogue of angular momentum.
c)	Orbital with five fold degeneracy but four lobes	3)	p–orbital
d)	N–shell	4)	No. of waves made by electron is 4.

Codes

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

The following questions (to) consists of two statements, one labelled as **ASSERTION (A)** and **REASON (R)**. Use the following key to chose the correct appropriate answer.
(a) If both (A) and (R) are correct, and (R) is the correct explanation of (A).
(b) If both (A) and (R) are correct, but (R) is not the correct explanation of (A).
(c) If (A) is correct, but (R) is incorrect.
(d) If (A) is incorrect, but (R) is correct.

2.	KE of photo electrons is directly proportional to the intensity of the incident radiation.	Each photon of light causes the emission of one photo electron.

Answers to Assignments

SECTION - I

1.	**(b)**	2.	**(d)**	3.	**(a)**	4.	**(d)**
5.	**(d)**	6.	**(c)**	7.	**(d)**	8.	**(b)**
9.	**(a)**	10.	**(a)**	11.	**(c)**	12.	**(b)**
13.	**(c)**	14.	**(c)**	15.	**(d)**	16.	**(b)**
17.	**(a)**	18.	**(b)**	19.	**(b)**	20.	**(c)**
21.	**(d)**	22.	**(b)**	23.	**(c)**	24.	**(b)**
25.	**(b)**						

SECTION - II

1.	**(a)**	2.	**(a)**	3.	**(c)**	4.	**(a)**
5.	**(a)**	6.	**(b)**	7.	**(c)**	8.	**(b)**
9.	**(b)**	10.	**(a, (c)**	11.	**(d)**	12.	**(d)**
13.	**(d)**	14.	**(a)**	15.	**(b)**	16.	**(b)**
17.	**(c)**	18.	**(a)**	19.	**(a)**	20.	**(a)**
21.	**(a), (b), (d)**	22.	**(a), (b), (d)**	23.	**(b), (d)**	24.	**(a), (b)**
25.	**(b), (d)**						

SECTION - III

1.	**(b)**	2.	**(d)**	3.	**(d)**	4.	**(c)**
5.	**(c)**	6.	**(a)**	7.	**(b)**	8.	**(d)**
9.	**(b)**	10.	**(b)**	11.	**(a)**	12.	**(b)**
13.	**(a)**	14.	**(b)**	15.	**(a)**	16.	**(d)**
17.	**(b)**	18.	**(a)**				

SECTION - IV

LEVEL – I

1. i) 6.022×10^{24} electrons
   ii) (a) 2.4088×10^{21} neutrons; (b) 4.0347×10^{-6} kg
   iii) (a) 1.2044×10^{22} protons; (b) 2.015×10^{-5} kg

2. i) 8.72×10^{-20}J
   ii) 1.3225 nm
3. 2.08×10^{-11} ergs, 956Å
4. i)

1	m_ℓ
0	0
1	–1, 0, + 1
2	–2, –1, 0, +1, +2

   ii) $l = 2$; $m_\ell = -2, -1, 0, +1, +2$
   iii) 2s, 2p
5. $\lambda_B = 2.5 \times 10^{-8}$m
6. 10.2 eV
7. 7.98×10^{12} m s^{-1}
8. 7.39×10^{-2} nm
9. [Ar] $3d^5$
10. 17.80×10^{-16} cm^2, He^+

LEVEL – II

1. 7.26×10^7 cm/sec, 2.4314×10^{14} r.p.s.
2. 2.11×10^{-12}cm
3. 2.01×10^{-24} kg m sec^{-1}
4. 28
5. 2.63×10^{-4} cm
6. 1.8×10^{-4} cm
7. z = 24, Cr
8. 1.675×10^{-5} V
9. 5, 310.

$n_1 = 1 \longleftarrow n_2 = 2$

LEVEL – III

1. (a) $-\frac{e^2}{4\pi\varepsilon_0 a_0}, -\frac{e^2}{8\pi\varepsilon_0 a_0}$; (b) $\lambda = \frac{h}{\sqrt{2m(KE)}}, \lambda = \frac{h}{\sqrt{\frac{e^2 m}{4\pi\varepsilon_0 a_0}}}$
2. 9.696×10^{-8} meter
3. 27.2×10^{-18}
4. 10.2 eV, 2, He^{+2}
5. (i) 2; (ii) 14.4 eV ; (iii) max = 13.5 eV; (iv) min = 0.7 eV
6. 3
7. ${}_{23}V^{4+} : 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^1$
8. $n_1 = 1$, $n_2 = 2$
9. (a) 292.68×10^{21} atoms, 162.62×10^{21} atoms, (b) 832.50 kJ
10. 2.186×10^{-20}J

SECTION - V

1. (a)
2. (d)