3 Atomic Structure

Fundamental particles of atom

(1) Atom consists of two parts

(a) *Nucleus:* Contains neutrons and protons.

(b) *Extra nuclear part:* Contains electrons.

(2) The characteristics of fundamental particles are given below :

Particle	Symbol	Mass in amu	Mass in kg	Charge in esu	Charge in coulomb
Electron	${}_{-1}e^0$	0.000548	9.1091×10^{-31}	-4.803×10^{-10}	-1.602×10^{-19}
Proton	${}_{+1}p^1$	1.00757	1.6725×10^{-27}	$+4.803\times10^{-10}$	$+1.602\times10^{-19}$
Neutron	${}_0n^1$	1.00893	1.6748×10^{-27}	0	0

Note : 1. The radius of electron is 4.28×10^{-14} cm

2. The radius of proton is 1.53×10^{-13}cm

Atomic number (*Z*):

$\because$ Z = No. of protons in the nucleus of an atom

= No. of electrons in the extra nuclear part of neutral atom.

Mass number (*A*): It is equal to sum of numbers of protons and no. of neutrons in an atom or the number of nucleons.

$$A = p + n \quad ...(1)$$

Size of the nucleus: (1) The size of the various nuclei (r) can be calculated from

$$\text{radius } (r) = (1.3\times10^{-13})A^{1/3} \quad ...(2)$$

where A is the mass no. and r is the radius of nucleus in cm.

(2) If nucleus is assumed to be spherical, the density of nucleus (d) may be expressed as

$$d = \frac{\text{Mass of nucleus}}{\text{Volume of nucleus}} = \frac{\text{Mass no.}}{\text{Avogadro's no.}} \times \frac{1}{4/3\pi r^3} ...(3)$$

(3) The dimensions of nucleus are of the order of 10^{-6} nm.

(4) The dimensions of atom are of the order of 10^{-1} nm.

(5) The density of nucleus $= 1.68\times10^{14}\,\text{g cm}^{-3}$

Theory of relativity and velocity of particle: According to the theory of relativity, the mass (m_1) of a particle (electron) at high speed is given by

$$m_1 = \frac{m}{\sqrt{\left[1-\left(\frac{u}{c}\right)^2\right]}} \quad ...(4)$$

where m is the mass in the rest; u is velocity and c is velocity of light

If $u = c$, then $m_1 = \infty$

Planck's quantum theory: Radiant energy is emitted or absorbed only in discrete units or packets of energy called photon (quantum). The energy 'E' associated with a quantum is given by $E = h\nu$ where h is Planck's constant and ν is frequency of radiations.

$$E = h\nu = \frac{hc}{\lambda} = hc\bar{\nu} \qquad \left(\because \frac{1}{\lambda} = \bar{\nu}\right) \quad ...(5)$$

$$h = 6.625\times10^{-34}\ \text{J-sec} = 6.625\times10^{-27}\ \text{erg-sec}$$

c is velocity of light $= 3.0\times10^8$ m sec^{-1}

$= 3.0\times10^{10}$ cm sec^{-1}

ν is frequency of light in sec^{-1}, $\bar{\nu}$ is wave no. in m^{-1} or cm^{-1}.

It is thus clear that energy of photon decreases with increase in λ.

Note : Energy 'E' associated with a photon can also be written as

$$E = \frac{12375}{\lambda}\text{eV}$$

where E is energy in eV and λ is wavelength of light in Å.

Bohr's model for H or H like atoms, *i.e.*, one electron systems

(1) The electrons are in continuous motions round the nucleus in closed orbits of definite energy level known as shells. Shells are named as K, L, M, N... or numbered as 1, 2, 3, 4, ... from the nucleus. As the distance of shell increases from the nucleus, energy level of shell increases.

(2) As long as an electron occupy a definite energy level, it does not radiate out energy. The emission or absorption of energy occurs only when electron jumps from one level to other

$$\Delta E = E_{n_2} - E_{n_1} = h\nu \quad ...(6)$$

If $n_2 > n_1$ emission spectra

If $n_2 < n_1$ absorption spectra

(3) The angular momentum of electron in closed shell is always quantized, *i.e.*, integer multiple of $h/(2\pi)$.

$$\text{Angular momentum} = n \cdot \frac{h}{2\pi} \quad \text{or} \quad mur = n \cdot \frac{h}{2\pi} \quad ...(7)$$

Some important results of Bohr's model

For H atom or H like atoms, *i.e.*, He^+, Li^{2+}...

Radius: $r_n = n^2 \times r_1$ and $r_n = \dfrac{n^2h^2}{4\pi^2me^2Z}$ ...(8)

where Z is at. no., e is charge on electron, m is mass of electron and n is no. of shell.

and for H atom $r_1 = 0.529$ Å ...(9)

Energy: $E_T = \text{PE} + \text{KE}$

where E_T is total energy of an electron in a shell.

$$\text{PE is potential energy} = -\frac{Ze^2}{r_n}$$

$$\text{KE is kinetic energy} = \frac{1}{2}\frac{Ze^2}{r_n}$$

$$\therefore \quad E_T = -\frac{Ze^2}{r_n} + \frac{1}{2}\frac{Ze^2}{r_n} = -\frac{Ze^2}{2r_n} \quad ...(10)$$

$$\therefore \quad E_T = \frac{1}{2}\text{PE} \quad ...(11)$$

$$\text{KE} = -\frac{\text{PE}}{2} \quad ...(12)$$

Also, by Eqs. (8) and (10), we get

$$E_T = -\frac{2\pi^2me^4Z^2}{n^2h^2} \quad ...(13)$$

$$\text{for H atom, } E_T = -\frac{21.72 \times 10^{-12}}{n^2}\ \text{erg}$$

$$= -\frac{21.72 \times 10^{-19}}{n^2}\ \text{joule} = -\frac{13.6}{n^2}\ \text{eV}$$

These equations also reveal that

$$E_n \propto -\frac{1}{n^2} \quad \text{and} \quad E_n = \frac{E_1}{n^2} \quad ...(14)$$

where E_n and E_1 are energy levels in nth shell and 1st shell.

$$\text{Also} \quad r_{\text{H like atom}} = \frac{r_{\text{for H}}}{Z} \quad ...(15)$$

$$\text{and} \quad E_{n\ \text{H like atom}} = E_{n\ \text{for H}} \times Z^2 \quad ...(16)$$

Velocity of electron in an orbit :

$$\text{For H like atom:} \quad u_n = \frac{2\pi Ze^2}{nh} \quad ...(17)$$

$$\text{For H atom:} \quad u_n = \frac{2\pi e^2}{nh} \quad ...(18)$$

$$\therefore \quad u_n = \frac{u_1}{n} \quad ...(19)$$

where u_1 is velocity of electron in 1st orbit.

Time required (T) to complete one revolution by an electron round the nucleus in an orbit :

$$T = \frac{2\pi r_n}{u_n} \quad ...(20)$$

Number of revolution per sec. made by an electron round the nucleus in an orbit :

$$\text{number of revolution} = \frac{u_n}{2\pi r_n} \quad ...(21)$$

Note: (1) The use of above formulae from Eqs. (8) to (21) is permitted only in CGS units. If MKS units are used: the factor $\dfrac{1}{4\pi\varepsilon_0}$ should be used accordingly.

In CGS $\dfrac{1}{4\pi\varepsilon_0} = 1$

In MKS $\dfrac{1}{4\pi\varepsilon_0} = 9 \times 10^9\ \text{Nm}^2\text{C}^{-2}$

(2) If +13.6 eV energy is given to H atom, the electron in H atom will be knocked out giving rise to the formation of H^+. That is why ionisation potential of H = 13.6 eV, *i.e.*, the energy level of 1st shell with a negative sign.

Frequency (ν), wavelength (λ) and wave number ($\bar{\nu}$) during electronic transition :

$$\Delta E = E_{n_2} - E_{n_1} = \frac{hc}{\lambda} = h\nu = hc\bar{\nu}$$

$$\text{or} \quad h\nu = \frac{hc}{\lambda} = \frac{2\pi^2me^4Z^2}{h^2}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\text{or} \quad \frac{1}{\lambda} = \bar{\nu} = \frac{2\pi^2mZ^2e^4}{ch^3}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\bar{\nu} = \frac{1}{\lambda} = Z^2R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \quad ...(22)$$

where λ is the wavelength of radiations during electronic transition from n_2 to n_1. R_H is Rydberg constant and is equal to 109678 cm^{-1}.

(1) When $n_1 = 1$ $n_2 = 2, 3, 4$ ...Lyman series in UV region

(2) When $n_1 = 2$ $n_2 = 3, 4, 5$ ...Balmer series in visible region

(3) When $n_1 = 3$ $n_2 = 4, 5, 6$ ...Paschen series in IR region

(4) When $n_1 = 4$ $n_2 = 5, 6, 7$ ...Brackett series in IR region

(5) When $n_1 = 5$ $n_2 = 6, 7, 8$ ...Pfund series in IR region

To derive no. of subshell in a shell

A result of Sommerfeld model suggests that

$$\frac{n}{k} = \frac{\text{length of major axis}}{\text{length of minor axis}} \quad ...(23)$$

e.g., if principal quantum no. $n = 4$

The values of k can be 1, 2, 3, 4 only, since k is an integer

$\therefore$ 4th shell have 4 subshells.

Total spin and magnetic moment: The total spin (s) of an atom is given by $s = \frac{1}{2} \times n$, where n is number of unpaired electrons.

The spin magnetic moment (μ) of electron (excluding orbital magnetic moment) in Bohr Magneton (B.M.) is given by:

$$\mu_{\text{effective}} = \sqrt{4s(s+1)} \quad ...(24)$$

If $$s = \frac{1}{2} \times n$$

$$\therefore \quad \mu_{\text{effective}} = \sqrt{n(n+2)}\ \text{B.M.} \quad ...(25)$$

To derive the possible no. of λ in line spectrum when an electron de-excites from one level to other.

If an electron jumps from n_2 into n_1 orbit then $\Delta n = (n_2 - n_1)$ and possible number of λ given out during the jump $= \Sigma\Delta n$ ...(26)

Say an electron is in 4th shell in H atom. It is to be de-excited to ground state level, *i.e.*, 1st shell.

The possible no. of λ given out $= \Sigma\Delta n = \Sigma(4-1)$

$= \Sigma 3 = 1 + 2 + 3 = 6$

Particle and wave nature of electron, *i.e.*, dual nature.

de Broglie proposed a relationship in between λ of a moving particle with its velocity on the basis of quantum theory.

$$\lambda = \frac{h}{mu} = \frac{h}{P} = \frac{h}{\sqrt{2m(\text{KE})}} \quad (\because \text{KE} = \frac{1}{2}mu^2) \quad ...(27)$$

where m is mass of moving particle

u is its velocity

P is momentum of particle equal to mu or $\sqrt{2m(\text{KE})}$

h is Planck's constant.

The circumference of the nth orbit (if closed) is equal to integer multiple of wavelength.

Thus, $$2\pi r_n = n\lambda$$

Also, Frequency (ν) of matter wave

$$= \frac{u}{\lambda} = \frac{u}{h/mu} = \frac{mu^2}{h} = \frac{2\text{KE}}{h} \quad ...(28)$$

Heisenberg's uncertainty principle:

According to this principle, it is impossible to determine momentum and position of a subatomic particle precisely and simultaneously.

$$\Delta p \cdot \Delta x \geq \frac{h}{4\pi} \quad ...(29)$$

$$m \cdot \Delta u\, \Delta x \geq \frac{h}{4\pi}$$

$$\Delta u \cdot \Delta x \geq \frac{h}{4\pi m} \quad ...(30)$$

where Δp is uncertainty in momentum, Δx is uncertainty in position and Δu is uncertainty in velocity.

The four quantum numbers: The four quantum numbers are results of Schrodinger wave equation.

(1) Principal quantum no.

(a) Denoted by 'n'

(b) The values of 'n' are from 1 to n

$n = 1$	K shell
$n = 2$	L shell
$n = 3$	M shell
$n = 4$	N shell

(c) 'n' signify for the size and energy level of major energy shell.

(2) Azimuthal or angular quantum no.

(a) Denoted by 'l'

(b) The values of 'l' are from 0 to $(n-1)$

$l = 0$	s subshell
$l = 1$	p subshell
$l = 2$	d subshell
$l = 3$	f subshell

(c) 'l' signify for shape and energy level of subshells.

(3) Magnetic quantum no.

(a) Denoted by 'm'

(b) The values of 'm' are from $\pm l$ to $\mp l$

Let $l = 1$ $m = -1$ 0 +1

p_x or p_y p_z p_y or p_x

Let $l = 2$ $m = -2$ -1 0 +1 +2

d_{xy} or $d_{x^2-y^2}$; d_{xz} or d_{yz}; d_{z^2}; d_{yz} or d_{xz}; $d_{x^2-y^2}$ or d_{xy}

(c) 'm' signify for the possible no. of orientations of subshells.

(4) Spin quantum no.

(a) Denoted by 's'

(b) The values of 's' are $+\frac{1}{2}$ and $-\frac{1}{2}$

(c) 's' signify for the direction of spin of electron in a sub-subshell or orbital.

Angular momentum

Angular momentum of an electron in an orbit $= n\frac{h}{2\pi}$ ...(31)

Angular momentum of an electron in an orbital

$$=\frac{h}{2\pi}\times\sqrt{[(l+1)l]} \quad ...(32)$$

Pauli exclusion principle

(1) It is impossible for two electrons of an atom to have all their four quantum no. same.

(2) *e.g.*,  is correct for $1s^2$

 is wrong for $1s^2$

(3) Following results have been obtained by Pauli exclusion principle.

(a) Maximum no. of electrons in a shell can be $2n^2$.

(b) Maximum no. of electrons in a subshell can be 2, 6, 10, 14, in *s, p, d, f* respectively.

(c) Maximum no. of electrons in a sub-subshell is 2 only.

Note: Electronic transition between subshells is possible only when $\Delta l = \pm 1$.

Aufbau principles

The electronic configuration is written on the basis of following rules.

(1) The electrons in a poly electronic atom are filled one by one in order of increasing energy level.

e.g., $_1$H: $1s^2$ is correct

$2s^2$ is wrong

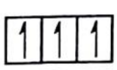
because energy level of $1s < 2s$.

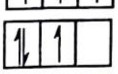
(2) Hund's rules:

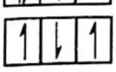
(a) In filling a group of orbitals of equal energy (or subshells) it is preferred to assign electrons to empty orbitals rather than pair them in a particular subshell, because the former arrangement leads to lower energy level.

(b) Same spin of unpaired electrons in sub-subshell also gives rise to lower energy level.

e.g., $_7$H: $1s^2, 2s^2 2p^3$

For $2p^3$  is correct

 is wrong (statement *a*)

 is wrong (statement *b*)

(3) $(n+l)$ rule:

(a) The subshell with lower values of $(n+l)$ possesses lower energy level and should be filled first.

e.g., $_{19}$K: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^1$ is wrong

$1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^1$ is correct

$n+l$ of $4s = 4+0 = 4$

$n+l$ of $3d = 3+2 = 5$

Thus, $4s$ should be filled first.

(b) If $(n+l)$ is same for two subshells, the one with lower values of n possess lower energy and should be filled first.

e.g., $_{21}$Sc: $1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2 4p^1$ is wrong

$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^1, 4s^2$ is correct

$n+l$ of $4p = 4+1 = 5$

$n+l$ of $3d = 3+2 = 5$

Thus, $3d$ should be filled first. $\because$ n of $3d < n$ of $4s$

(4) A subshell having nearly completely filled or nearly half filled configuration tends to acquire exactly completely filled or exactly half filled nature in order to attain stability, *i.e.*, lower energy level.

e.g., $_{24}$Cr: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^4, 4s^2$ is wrong

$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^1$ is correct

$_{29}$Cu: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^9, 4s^2$ is wrong

$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^1$ is correct

$_{46}$Pd: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^6 4d^8, 5s^2$ is wrong

$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^6 4d^{10}$ is correct

Photo Electric Effect

When a photon strikes the metallic surface, it gives up its energy to the electron. Part of this energy (say W) is used by the electrons to escape from the metal, the remaining imparts the kinetic energy $\left(\frac{1}{2}mu^2\right)$ to the photoelectrons. If the incident radiation has frequency ν, then its photons have energy $h\nu$, it follows from the conservation of energy principle that

$$h\nu = W + \left(\frac{1}{2}\right)mu^2 \quad ...(33)$$

or

$$\left(\frac{1}{2}\right)mu^2 = h\nu - W \quad ...(34)$$

The equation shows that if KE is plotted against frequency of incident radiations, a straight line is obtained with a slope equal to Planck's constant. The equation expresses the fact that if a photon strikes a metal then it can release an electron from the metal provided the photon energy (*i.e.*, $h\nu$) is greater than the binding energy or work function (W) of the electron in the metal. Further the released electron will escape out with kinetic energy equal to ($h\nu - W$).

Instead of irradiating a metal, one can irradiate atoms with photons of known frequency, the above equation may be written as: $h\nu = \text{IE} + \text{KE}$.

This suggests that the photon energy is partly used to knock out an electron from the atom (*i.e.*, IE) and the remainder shows up as the kinetic energy of the released photoelectron.

The potential applied on the surface to reduce the velocity of photo-electron to zero is known as stopping potential V_0, thus, kinetic energy $= eV_0$

Thus, $h\nu = W + (\text{Stopping potential} \times \text{charge})$

$$h\nu = W + eV_0 \quad ...(35)$$

where e is electronic charge and V_0 is stopping potential.

Number of Nodes

Total number of nodes in a shell $= (n - 1)$ ...(36)

Angular nodes $= l$ ...(37)

Spherical nodes $= n - l - 1$ ...(38)

Wave function of H atom in ground state:

$$\text{Wave function, } \psi_{1s} = \left[\frac{1}{\sqrt{\pi a_0^3}}\right] e^{-r/a_0} \quad ...(39)$$

• NUMERICAL PROBLEMS •

1. The mass-charge ratio for A^+ ion is 1.97×10^{-7} kg C^{-1}. Calculate the mass of A atom.
2. Calculate the force of attraction between an electron and a body having two proton charge when they are 0.529×10^{-8} cm apart. Charge on one electron and one proton is -1.6×10^{-19} C and $+1.6 \times 10^{-19}$ C.
3. Two carbon discs of 1.0 g each are 1.0 cm apart have equal and opposite charges. If forces of attraction between them is 1.00×10^{-5} N, calculate the ratio of excess electrons to total atoms on the negatively charged disc. (Permitivity constant is 9.0×10^9 N m^2C^{-2})
4. α-particles of 6 MeV energy is scattered back from a silver foil. Calculate the maximum volume in which the entire positive charge of the atom is supposed to be concentrated. (Z for silver = 47) $K = 9.0 \times 10^9$ Nm^2C^{-2}.
5. What is the relationship between eV and the wavelength in metre of the energetically equivalent photon?
6. What is the mass of one photon?
7. Write down the numerical value of h and its unit.
8. Calculate the energy per quantum associated with light of wavelengths,
   (a) 5890 Å (b) 250×10^{-9} m
   (c) 4.0×10^{-8} cm (d) 600 nm
   Also calculate the energy per mol of photon in case (*d*).
9. AIR service on Vividh Bharati is transmitted on 219 m band. What is its transmission frequency in Hertz?
10. A certain laser transition emits 6.37×10^{15} quanta per second per square metre. Calculate the power out put in joule per square metre per second. Given $\lambda = 632.8$ nm.
11. The dissociation energy of H_2 is 430.53 k J mol^{-1}. If H_2 is exposed to radiation energy of wavelength 253.7 nm, what % of radiant energy will be converted into kinetic energy?
12. 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 atoms. (Bond energy of $I_2 = 240$ k J mol^{-1}) **(IIT 1995)**
13. A bulb emits light of λ 4500 Å. 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? **(IIT 1995)**
14. Calculate the number of photons emitted in 10 hour by a 60W sodium lamp. ($\lambda_{photon} = 5893$ Å)
15. Calculate the energy required to excite one litre of hydrogen gas at 1 atm and 298 K to the first excited state of atomic hydrogen. The energy for the dissociation of H—H bond is 436 k J mol^{-1}. **(IIT 2000)**
    Also calculate the minimum frequency of photon to break this bond.
16. 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 ($\lambda = 550$ nm) are needed to generate this minimum amount of energy?
17. O_2 undergoes photochemical dissociation into one normal oxygen atom and one oxygen atom, 1.967 eV more energetic than normal. The dissociation of O_2 into two normal atoms of oxygen requires 498 k J mol^{-1}. What is the maximum wavelength effective for photochemical dissociation of O_2?
18. A certain dye absorbs light of $\lambda = 4530$ Å and then fluorescence light of 5080 Å. Assuming that under given conditions 47% of the absorbed energy is re-emitted out as fluorescence, calculate the ratio of quanta emitted out to the no. of quanta absorbed.
19. A photon of 300 nm is absorbed by a gas and then re-emits two photons. One re-emitted photon has wavelength 496 nm. Calculate energy of other photon re-emitted out.
20. Certain sun glasses having small crystals of AgCl incorporated in the lenses, on exposure to light of appropriate wavelength turns to gray colour to reduce the glare following the reaction:
    $$AgCl \xrightarrow{h\nu} \underset{\text{(Gray)}}{Ag} + Cl$$
    If the heat of reaction for the decomposition of AgCl is 248 k J mol^{-1}, what maximum wavelength is needed to induce the desired process?
21. Atomic radius is of the order of 10^{-8} cm and nuclear radius is of the order of 10^{-13} cm. Calculate what fraction of atom is occupied by nucleus?
22. Prove that $u_n = \sqrt{\left(\frac{Ze^2}{mr_n}\right)}$ where u is velocity of electron in a one electron atom of at. no. Z at a distance r_n from the nucleus, m and e are mass and charge of electron.
23. Calculate the velocity of an electron placed in III orbit of H atom. Also calculate the no. of revolution/sec round the nucleus.
24. Find out the energy of H atom in first excitation state. The value of permitivity factor $4\pi\varepsilon_0 = 1.11264 \times 10^{-10}$ C^2 $N^{-1}m^{-2}$.
25. 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. **(IIT 1996)**

(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?

26. What is the principal quantum no. of H atom orbital if the electron energy is -3.4 eV ? Also report the angular momentum of electron.

27. The velocity of electron in a certain Bohr's orbit of H atom bears the ratio 1 : 275 to the velocity of light :

(a) What is the quantum number (n) of orbit?

(b) Calculate the wave number of radiations emitted when electron jumps from $(n+1)$ state to ground state.

28. The ionisation energy of H atom is 13.6 eV. What will be ionisation energy of He^+ and Li^{2+} ions?

29. The ionisation energy of He^+ is 19.6×10^{-18} J atom^{-1}. Calculate the energy of first stationary state of Li^{2+}.

30. Electromagnetic radiations of wavelength 242 nm is just sufficient to ionise sodium atom. Calculate the ionisation energy of sodium in kJ mol^{-1}. **(Roorkee 1992)**

31. Calculate the shortest and longest wavelength in H spectrum of Lyman series. $R_H = 109678\ \text{cm}^{-1}$.

32. Convert the value of Rydberg constant ($R_H = 109678\ \text{cm}^{-1}$) into Rydberg an unit of energy (*i.e.*, 1 Rydberg (1 Rh) $= 2.18\times10^{-18}$ J).

33. How many spectral lines are emitted by atomic hydrogen excited to the nth energy level?

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

35. The λ of H_α line of Balmer series is 6500 Å. What is the λ of H_β line of Balmer series?

36. Calculate the longest wavelength which can remove the electron from I Bohr's orbit. Given $E_1 = 13.6$ eV.

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

38. Calculate the wavelength of radiations emitted producing *a* line in Lyman series, when an electron falls from fourth stationary state in hydrogen atom. ($R_H = 1.1\times10^7\ \text{m}^{-1}$) **(Roorkee 1995)**

39. The ionisation energy of a H like Bohr's atom in 4 Rydberg.

(a) Calculate the wavelength radiated when electron jumps from the first excited state to ground state.

(b) What is the radius of I orbit of this atom?

Given $1R_h = 2.18\times10^{-18}$ J.

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

41. Calculate λ of the radiations when the electron jumps from III to II orbit for H atom. The electronic energy in II and III Bohr's orbit of H atom are -5.42×10^{-12} and -2.41×10^{-12} erg respectively.

42. The energy E for an electron in H atom is $-\dfrac{21.7\times10^{-12}}{n^2}$ erg. Calculate the energy required to remove electron completely from $n=2$ orbit. Also calculate the longest wavelength of light that can be used to cause this transition.

43. Calculate the energy emitted when electrons of 1.0 g atom of hydrogen undergo transition giving the spectral lines of lowest energy in the visible region of its atomic spectra.
$R_H = 1.1\times10^7\ \text{m}^{-1}$, $c = 3\times10^8$ m sec^{-1} and $h = 6.62\times10^{-34}$ J sec. **(Roorkee 1993)**

44. Energy required for excitation of electron in 1 mole H atom from ground state to 2nd excited state is 2.67 times lesser than dissociation energy per mole of $H_2(g)$. Calculate the amount of energy needed to excite each H atom of $H_2(g)$ confined in 1.0 litre at 27°C and 1 bar pressure. $R = 0.083$ bar litre K^{-1} mol^{-1};
$R_H = 1.1\times10^7\ \text{m}^{-1}$.

45. 1.8 g hydrogen atoms are excited to radiations. The study of spectra indicates that 27% of the atoms are in IIIrd energy level and 15% of atoms in IInd 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 levels.

(b) total energy evolved when all the atoms return to ground state.

46. For He^+ and Li^{2+}, the energies are related to the quantum no. n, through an expression: $E_n = -\dfrac{Z^2B}{n^2}$; where Z is the atomic no. of species and $B = 2.179\times10^{-18}$ J.

(a) What is the energy of lowest level of a He^+ ion?

(b) What is the energy of III level of Li^{2+} ion?

47. What hydrogen like ion has the wavelength difference between the first lines of Balmer and Lyman series equal to 593 nm? $R_H = 109678\ \text{cm}^{-1}$.

48. Wavelength of high energy transition of H atom is 91.2 nm. Calculate the corresponding wavelength of He^+ ion. **(IIT 2003)**

49. Calculate the ratio of wavelengths of m^{th} line of Lyman series and Balmer series of H-atom.

50. 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?

51. A series of lines in the spectrum of atomic H lies at wavelengths 656.46, 486.27, 434.17, 410.29 nm. What is the wavelength of next line in this series?

52. A hydrogen-like atom (atomic number *Z*) is in a higher excited state of quantum number *n*. This excited atom can make a transition to the first excited state by successively emitting two photons of energies 10.20 eV and 17.00 eV respectively. Alternatively, the atom from the same excited state can make a transition to the second excited state by successively emitting two photons of energy 4.25 eV and 5.95 eV respectively. Determine the values of *n* and *Z*.

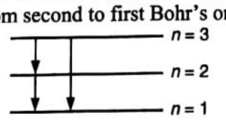
53. Estimate the difference in energy between 1st and 2nd Bohr's orbit for a H atom. At what minimum at. no., a transition from $n=2$ to $n=1$ energy level would result in the emission of *X*-rays with $\lambda = 3.0 \times 10^{-8}$ m? Which hydrogen atom like species does this atomic no. corresponds to? **(IIT 1993)**

54. What transition in the hydrogen spectrum would have the same wavelength as the Balmer transition $n=4$ to $n=2$ of He^+ spectrum? **(IIT 1993)**

55. Calculate the wavelength emitted during the transition of electron in between two levels of Li^{2+} ion whose sum is 4 and difference is 2.

56. Consider the following two electronic transition possibilities in a hydrogen atom as pictured given:

(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 way as their energies are?

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

58. Find the quantum no. '*n*' corresponding to the excited state of He^+ ion if on transition to the ground state that ion emits two photons in succession with wavelengths 108.5 and 30.4 nm.

59. A single electron atom has nuclear charge $+Ze$ where *Z* is atomic number and *e* is electronic charge. It requires 42.7 eV to excite the electron from the second Bohr's orbit to third Bohr's orbit. Find :

(a) the atomic number of element.

(b) the energy required for transition of electron from third to fourth orbit.

(c) the wavelength required to remove electron from first Bohr's orbit to infinity.

(d) the kinetic energy of electron in first Bohr's orbit.

60. Calculate the angular frequency of an electron occupying the second Bohr's orbit of He^+ ion.

61. Two hydrogen atoms collide head on and end up with zero kinetic energy. Each atom then emits a photon of wavelength 121.6 nm. Which transition leads to this wavelength? How fast were the hydrogen atoms travelling before collision?
($R_H = 1.097 \times 10^7 \text{ m}^{-1}$ and $m_H = 1.67 \times 10^{-27}$ kg.)

62. Calculate the wavelength of a 100 g rubber ball moving with a velocity 100 m sec^{-1}. Is the wavelength of ball short enough to be observed? **(IIT 2004)**

63. Calculate momentum of radiations of wavelength 0.33 nm.

64. How much will the kinetic energy and total energy of an electron in H atoms change if the atom emits a photon of wavelength 4860 Å?

65. Find out the number of waves made by a Bohr's electron in one complete revolution in its 3rd orbit. **(IIT 1994)**

66. Find out the following :

(a) The velocity of electron in first Bohr's orbit of H-atom ($r = a_0$).

(b) de Broglie wave length of the electron in first Bohr's orbit of H-atom.

(c) The orbital angular momentum of 2*p*-orbitals in terms of $\frac{h}{2\pi}$ units. **(IIT 2005)**

67. Calculate the wavelength of moving electron having 4.55×10^{-25} joule of kinetic energy.

68. Calculate the momentum of electron moving with 1/3rd velocity of light.

69. With what velocity must an electron travel so that its momentum is equal to that of a photon of wavelength of $\lambda = 5200$ Å?

70. Calculate u_{rms} for an electron at 27°C. Given $m_e = 9.108 \times 10^{-28}$ g.

71. Calculate the wavelength of helium atom whose speed is equal to its rms speed at 27°C.

72. An electron beam can undergo diffraction by crystals. Through what potential should a beam of electrons be accelerated so that its wavelength becomes equal to 1.54 Å? **(IIT May 1997)**

73. The vapours of Hg absorb some electrons accelerated by a potential difference of 4.5 volt as a result of which light is emitted. If the full energy of single incident electron is supposed to be converted into light emitted by single Hg atom, find the wave number $(1/\lambda)$ of the light.

74. Calculate the accelerating potential that must be imparted to a proton beam to give it an effective wavelength of 0.005 nm.

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

76. Show that de Broglie wavelength of electron accelerated through V volt is nearly given by:

$$\lambda_{(\text{in Å})} = \left[\frac{150}{V}\right]^{1/2}$$

77. A dust particle having mass equal to 10^{-11} g, diameter of 10^{-4} cm and velocity 10^{-4} cm sec^{-1}. The error in measurement of velocity is 0.1%. Calculate uncertainty in its position. Comment on the result.

78. Calculate the uncertainty in velocity of an electron if the uncertainty in its position is of the order of 1 Å.

79. Calculate the uncertainty in velocity of a cricket ball (mass = 0.15 kg) if its uncertainty in position is of the order of 1 Å.

80. What is the maximum precision with which the momentum of an electron can be known if the uncertainty in the position of electron is ±0.001 Å? Will there be any problem in describing the momentum if it has a value of $\frac{h}{2\pi a_0}$, where a_0 is Bohr's radius of first orbit, *i.e.*, 0.529 Å?

81. The position of a proton is measured with an accuracy of $\pm 1.0 \times 10^{-11}$ m. Find the uncertainty in the position of proton 1 second later. Assume u_{proton} = velocity of light.

82. An electron has a total energy of 2 MeV. Calculate the effective mass of the electron in kg and its speed. Assume rest mass of electron 0.511 MeV.

83. On the basis of Heisenberg's uncertainty principle, show that the electron cannot exist within the nucleus.

84. Energy required to stop the ejection of electrons from Cu plate is 0.24 eV. Calculate the work function when radiations of $\lambda = 253.7$ nm strike the plate.

85. A stationary He^+ ion emitted a photon corresponding to the first line (H_α) of the Lyman series. That photon liberated a photo electron from a stationary H atom in ground state. What is the velocity of photo electron? $R_H = 109678\ \text{cm}^{-1}$.

86. The photo electric emission requires a threshold frequency ν_0. For a certain metal $\lambda_1 = 2200$ Å and $\lambda_2 = 1900$ Å produce electrons with a maximum kinetic energy KE_1 and KE_2. If $KE_2 = 2KE_1$, calculate ν_0 and corresponding λ_0.

87. The minimum energy required to overcome the attractive forces between electron and the surface of Ag metal is 7.52×10^{-19} J. What will be the maximum kinetic energy of electron ejected out from Ag which is being exposed to U.V. light of $\lambda = 360$ Å?

88. The binding energy of electrons in a metal is 250 kJ mol^{-1}. What is the threshold frequency of metal?

89. 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 2.289×10^{-8} cm?

90. What is the significance of $\psi_{4,2,0}$?

91. Suggest the angular and spherical nodes in
(a) $4p$ (b) $3p$ (c) $3s$.

92. The wave function (ψ) of $2s$-orbital is given by:

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

At $r = r_0$, radial node is formed. Calculate r_0 in terms of a_0. **(IIT 2004)**

93. Nitrogen atom has at. no. 7 and oxygen has at. no. 8. Calculate total no. of electrons in nitrate ion.

94. A neutral atom of an element has $2K$, $8L$, $9M$ and $2N$ electrons. Find out the following:
(a) Atomic no.
(b) Total no. of s electrons
(c) Total no. of p electrons
(d) Total no. of d electrons
(e) Valency of element
(f) No. of unpaired electrons.

95. Oxygen consists of isotopes of O^{16}, O^{17} and O^{18} and carbon consists of isotopes of C^{12} and C^{13}. How many types of CO_2 molecules can be formed? Also report their molar masses.

96. The atomic masses of two isotopes of O are 15.9936 and 17.0036. Calculate in each atom:
(a) No. of neutrons (b) No. of protons
(c) No. of electrons (d) Mass no.

97. Write down electronic configuration of the following and report no. of unpaired electron in each.
(a) Mn^{+4} (b) Cr^{+2} (c) Fe^{+3} (d) Ni^{+2} (e) Cl^-
(f) Zn^{+2} (g) Fe^{+2} (h) Na (i) Mg (j) Cr^{+3}

98. Predict total spin for each configuration.

(a) $1s^2$ (b) $1s^2, 2s^2 2p^6$ (c) $1s^2, 2s^2 2p^5$

(d) $1s^2, 2s^2 2p^3$ (e) $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^2$.

99. A compound of vanadium has a magnetic moment of 1.73 BM. Work out the electronic configuration of the vanadium ion in the compound. **(IIT July 1997)**

100. Point out the angular momentum of an electron in

(a) 4*s* orbital (b) 3*p* orbital (c) 4*th* orbit

101. Given below are the sets of quantum numbers for given orbitals. Name these orbitals.

(a) $n=2$, $l=1$, $m=-1$ (b) $n=4$, $l=2$, $m=0$ (c) $n=3$, $l=1$, $m=\pm 1$ (d) $n=4$, $l=0$, $m=0$ (e) $n=3$, $l=2$, $m=\pm 2$

102. What values are assigned to quantum number *n*, *l*, *m* for

(a) $2s$ (b) $2p_z$ (c) $4d_{x^2-y^2}$ (d) $4d_{z^2}$?

103. Arrange the electrons represented by the following sets of quantum number in decreasing order of energy.

(1) $n=4$ $l=0$ $m_e=0$ $m_s=+\frac{1}{2}$

(1) $n=3$ $l=1$ $m_e=1$ $m_s=-\frac{1}{2}$

(1) $n=3$ $l=2$ $m_e=0$ $m_s=+\frac{1}{2}$

(1) $n=3$ $l=0$ $m_e=0$ $m_s=-\frac{1}{2}$

104. Write down the quantum numbers of all the electrons present in outermost orbit of Argon.

105. An oxide of nitrogen has vapour density 46. Find the total number of electrons in its 92 g.

106. Calculate the total number of electrons in

(a) 1.6 g CH_4

(b) one molecule of CO_2

(c) N_2 molecule.

107. $_4Be^7$ captures a *K* electron into its nucleus. What is the mass number and at. no. of the nucleide formed?

108. Write electronic configuration of $_{12}Mg$, $_{17}Cl$, $_{23}V$ and find out their period and groups in periodic table.

SOLUTIONS (Numerical Problems)

1. Given, $\frac{m}{e} = 1.97\times10^{-7}$ (since $e = 1.602\times10^{-19}$ C)

$\therefore$ $m = 1.97\times10^{-7}\times1.602\times10^{-19}$ kg

$m = \mathbf{3.16\times10^{-26}}$ **kg**

2. Force of attraction, $F = K\times\frac{q_1q_2}{d^2}$

where $K = 9.0\times10^9\ \text{Nm}^2\text{C}^{-2}$;

$d = 0.529\times10^{-8}\ \text{cm} = 0.529\times10^{-10}$ m

$$\therefore\ F = \frac{9.0\times10^9\times(-1.6\times10^{-19})\times2\times1.6\times10^{-19}}{(0.529\times10^{-10})^2}$$

$= \mathbf{1.65\times10^{-7}}$ **Newton**

3. $\because$ $F = K\frac{q_1q_2}{r^2}$

Also, $q_1 = q_2 = q$

$K = 9.0\times10^9\ \text{Nm}^2\text{C}^{-2}$ and $r = 1\times10^{-2}$ m

$$\therefore\ 1.0\times10^{-5} = \frac{9.0\times10^9\times q^2}{(1\times10^{-2})^2}$$

$q = 3.3\times10^{-10}$ C on each disc

Charge on one electron $= 1.602\times10^{-19}$ C

$\therefore$ Number of electrons on disc

$$= \frac{3.3\times10^{-10}}{1.602\times10^{-19}} = 2.08\times10^9$$

$\therefore$ Number of atoms in 1 g carbon

$$= \frac{6.02\times10^{23}}{12} = 5.0\times10^{22}$$

$$\therefore\ \text{Ratio of electrons to atoms} = \frac{2.08\times10^9}{5.0\times10^{22}}$$

$= \mathbf{4.17\times10^{-14}}$ **electron/atom**

4. $E = \frac{1}{4\pi\varepsilon_0}\frac{(Ze)(2e)}{r} = K\cdot\frac{(Ze)(2e)}{r}$

$$r = \frac{9\times10^9\times47\times2\times(1.6\times10^{-19})^2}{6\times10^6\times1.6\times10^{-19}} = 2.25\times10^{-14}\ \text{m}$$

$\therefore$ Maximum volume $= \frac{4}{3}\pi r^3 = \mathbf{48\times10^{-42}\ m^3}$

5.

$$E_{\text{photon}} = \frac{hc}{\lambda} = \frac{6.625\times10^{-34}\times3.0\times10^8}{\lambda_{(\text{in m})}}$$

Let $E_{\text{photon}} = 1\text{eV} = 1.602\times10^{-19}$ J

$$\therefore\ \lambda = \frac{6.625\times10^{-34}\times3.0\times10^8}{1.602\times10^{-19}} = \mathbf{12.40\times10^{-7}\ m}$$

6. **Photons are supposed to be massless bundles of energy. However, mass can be calculated by $\lambda = h/mu$**

7. $h = \mathbf{6.625\times10^{-27}}$ **erg sec** $= \mathbf{6.625\times10^{-34}}$ **joule sec**

The unit of h = **Joule sec or erg sec.** $\left(\begin{array}{l}\because\ h\nu = E\\ \therefore\ h = \frac{E}{\nu} = \frac{\text{erg}}{\text{sec}^{-1}}\end{array}\right)$

8.

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

where E is energy associated per photon of wavelength λ.

(a) $\therefore$ $E = \frac{6.625\times10^{-27}\times3.0\times10^{10}}{5890\times10^{-8}} = \mathbf{3.37\times10^{-12}}$ **erg**

(b) $E = \frac{6.625\times10^{-27}\times3.0\times10^{10}}{250\times10^{-7}} = \mathbf{7.95\times10^{-12}}$ **erg**

(c) $E = \frac{6.625\times10^{-27}\times3.0\times10^{10}}{4\times10^{-8}} = \mathbf{4.97\times10^{-9}}$ **erg**

(d) $E = \frac{6.625\times10^{-27}\times3.0\times10^{10}}{600\times10^{-7}} = \mathbf{3.3\times10^{-12}}$ **erg**

E/mol photon $= NE = 6.023\times10^{23}\times3.3\times10^{-12}$ erg

$= \mathbf{19.88\times10^{11}}$ **erg**

9. Given, $\lambda = 219$ m

Thus, $\nu = \frac{c}{\lambda}$ or $\nu = \frac{3.0\times10^8}{219} = \mathbf{1.37\times10^6}$ **Hz**

10. Energy falling per square metre per second

= No. of quanta falling per square metre per second × Energy of one quantum

$$= 6.37\times10^{15}\times\frac{hc}{\lambda} = 6.37\times10^{15}\times\frac{6.625\times10^{-34}\times3.0\times10^8}{632.8\times10^{-9}}$$

$= \mathbf{2\times10^{-3}\ Jm^{-2}\ sec^{-1}}$

11. Energy required to break H—H bond

$$= \frac{430.53\times10^3}{6.023\times10^{23}}\ \text{J/molecule} = 7.15\times10^{-19}\ \text{J}$$

Energy of photon used for this purpose $= \frac{hc}{\lambda}$

$$= \frac{6.625\times10^{-34}\times3.0\times10^8}{253.7\times10^{-9}} = 7.83\times10^{-19}\ \text{J}$$

$\therefore$ Energy left after dissociation of bond

$= (7.83-7.15)\times10^{-19}$

or Energy converted into KE $= 0.68\times10^{-19}$ J

$\therefore$ % of energy used in kinetic energy

$$= \frac{0.68\times10^{-19}}{7.83\times10^{-19}}\times100 = \mathbf{8.68\%}$$

12. Energy given to I_2 molecule

$$= \frac{hc}{\lambda} = \frac{6.626\times10^{-34}\times3.0\times10^8}{4500\times10^{-10}} = 4.417\times10^{-19}\ \text{J}$$

Also, energy used for breaking up of I_2 molecule

$$= \frac{240\times10^3}{6.023\times10^{23}} = 3.984\times10^{-19}\ \text{J}$$

$\therefore$ Energy used in imparting kinetic energy to two I atoms

$= [4.417-3.984]\times10^{-19}$ J

$\therefore$ KE/iodine atom $= [(4.417-3.984)/2]\times10^{-19}$

$= \mathbf{0.216\times10^{-19}}$ **J**

13. Energy of one photon $= \frac{hc}{\lambda}$

$$= \frac{6.625\times10^{-34}\times3.0\times10^{8}}{4500\times10^{-10}} \text{ J} = 4.42\times10^{-19} \text{ J}$$

Energy emitted by bulb $= 150\times\frac{8}{100}$ J/sec (watt = J/s)

$$\therefore \quad n\times4.42\times10^{-19} = 150\times\frac{8}{100}$$

(where n is no. of photons)

$$\therefore \quad \mathbf{n = 27.2\times10^{18}}$$

14. The energy of the photon

$$= \frac{hc}{\lambda} = \frac{6.625\times10^{-34}\times3.0\times10^{8}}{5893\times10^{-10}} \text{ joule}$$

$$= 3.37\times10^{-19} \text{ J}$$

Now, total energy emitted by Na lamp

= watt × time = 60 × 1 = 60 joule per second

$$\because \quad 3.37\times10^{-19} \text{ J energy} = 1 \text{ photon}$$

$$\therefore \quad 60 \text{ J energy} = \frac{60}{3.37\times10^{-19}} \text{ photon}$$

i.e., no. of photons emitted out in one second.

No. of photons emitted out in 10 hour

$$= 10\times3600\frac{60}{3.37\times10^{-19}} = \mathbf{6.40\times10^{24}}$$

15. Mole of H_2 present in one litre

$$= \frac{PV}{RT} = \frac{1\times1}{0.0821\times298} = 0.0409$$

Thus, energy needed to break H—H bonds in 0.0409 mole of H_2

$$= 0.0409\times436 = 17.83 \text{ kJ}$$

Also energy needed to excite one H atom from 1st to 2nd energy level

$$= 13.6\left(1-\frac{1}{4}\right) = 10.2 \text{ eV} = 10.2\times1.6\times10^{-19} \text{ J}$$

$\therefore$ Energy needed to excite $0.0409\times2\times6.02\times10^{23}$ atoms of H

$$= 10.2\times1.6\times10^{-19}\times0.0409\times2\times6.02\times10^{23} \text{ J}$$

$$= 80.36 \text{ kJ}$$

Thus, total energy needed = 17.83 + 80.36 = **98.19 kJ**

Energy required to break (H—H) bond $= \frac{436\times10^{3}}{6.023\times10^{23}}$ joule

$$\because \quad E = h\nu$$

$$\therefore \quad \frac{436\times10^{3}}{6.023\times10^{23}} = 6.625\times10^{-34}\,\nu$$

$$\therefore \quad \mathbf{\nu = 10.93\times10^{14}\ sec^{-1}\ or\ Hz}$$

16. The energy required to see object $= 10^{-17}$ joule

Energy of photon of $\lambda(550\times10^{-9}\text{ m}) = \frac{hc}{\lambda}$

$$= \frac{6.625\times10^{-34}\times3.0\times10^{8}}{550\times10^{-9}} = 3.61\times10^{-19} \text{ joule}$$

$$\because \quad 3.61\times10^{-19} \text{ J} = 1 \text{ photon}$$

$$\therefore \quad 10^{-17} \text{ J} = \frac{10^{-17}}{3.61\times10^{-19}} = 27.7 \text{ photon}$$

$\therefore$ No. of photons for generating minimum amount of energy = **28** (an integer value)

Note : The integer value should be reported in all such cases where minimum no. of photon is asked because fraction of a photon is never absorbed. Further more the number reported should be higher one and never lower one because lower integer will not provide minimum value.

17.

$$O_2 \xrightarrow{h\nu} O_{Normal} + O_{Excited}$$

$$O_2 \longrightarrow O_{Normal} + O_{Normal}$$

Energy required for simple dissociation of O_2 into two normal atoms

$$= 498\times10^{3} \text{ J mol}^{-1} = \frac{498\times10^{3}}{6.023\times10^{23}} \text{ J molecule}^{-1}$$

If one atom in excited state has more energy, *i.e.*, 1.967 eV

$$= 1.967\times1.602\times10^{-19} \text{ J}$$

The energy required for photochemical dissocaition of O_2

$$= \frac{498\times10^{3}}{6.023\times10^{23}} + 1.967\times1.602\times10^{-19}$$

$$= 82.68\times10^{-20} + 31.51\times10^{-20}$$

$$= 114.19\times10^{-20} \text{ joule}$$

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

$$114.19\times10^{-20} = \frac{6.625\times10^{-34}\times3.0\times10^{8}}{\lambda}$$

$$\lambda = 1740.52\times10^{-10} \text{ m} = \mathbf{1740.52\ \text{Å}}$$

18. E of light absorbed in one photon $= \frac{hc}{\lambda_{absorbed}}$

Let n_1 photons are absorbed, therefore,

$$\text{Total energy absorbed} = \frac{n_1 hc}{\lambda_{absorbed}}$$

Now, E of light re-emitted out in one photon $= \frac{hc}{\lambda_{emitted}}$

Let n_2 photons are re-emitted then,

$$\text{Total energy re-emitted out} = n_2\times\frac{hc}{\lambda_{emitted}}$$

As given $\quad E_{absorbed}\times\frac{47}{100} = E_{re\text{-}emitted\ out}$

$$\frac{hc}{\lambda_{absorbed}}\times n_1\times\frac{47}{100} = n_2\times\frac{hc}{\lambda_{emitted}}$$

$$\therefore \quad \frac{n_2}{n_1} = \frac{47}{100}\times\frac{\lambda_{emitted}}{\lambda_{absorbed}} = \frac{47}{100}\times\frac{5080}{4530}$$

$$\therefore \quad \frac{n_2}{n_1} = \mathbf{0.527}$$

19.

$$E_{photon\ absorbed} = \frac{6.625\times10^{-34}\times3.0\times10^{8}}{300\times10^{-9}} = 6.625\times10^{-19} \text{ J}$$

$$E_{photon\ re\text{-}emitted\ out} = \frac{6.625\times10^{-34}\times3.0\times10^{8}}{496\times10^{-9}} = 4.0\times10^{-19} \text{ J}$$

$$\therefore \quad E_{absorbed} = E_{I\ photon} + E_{II\ photon\ re\text{-}emitted\ out}$$

$$\therefore \quad E_{II\ photon} = 6.625\times10^{-19} - 4.0\times10^{-19}$$

$$= \mathbf{2.625\times10^{-19}\ joule}$$

20. Energy needed to change = 248×10^3 J/mol

If photon is used for this purpose, then according to Einstein law one molecule absorbs one photon. Therefore,

$$\therefore \quad N_A \cdot \frac{hc}{\lambda} = 248 \times 10^3$$

$$\lambda = \frac{6.625 \times 10^{-34} \times 3.0 \times 10^8 \times 6.023 \times 10^{23}}{248 \times 10^3}$$

$$= \mathbf{4.83 \times 10^{-7}\ m}$$

21. Volume of nucleus $= \frac{4}{3}\pi r^3 = \frac{4}{3}\pi(10^{-13})^3\ cm^3$

Volume of atom $= \frac{4}{3}\pi(10^{-8})^3\ cm^3$

$$\therefore \quad \frac{V_{Nucleus}}{V_{Atom}} = \frac{10^{-39}}{10^{-24}} = 10^{-15}$$

$$\therefore \quad V_{Nucleus} = \mathbf{10^{-15} \times V_{Atom}}$$

22. Kinetic energy of electron $= \frac{1}{2}mu^2$

Also, from Bohr's concept KE $= \frac{1}{2}\frac{Ze^2}{r_n}$

$$\frac{1}{2}mu^2 = \frac{1}{2}\frac{Ze^2}{r_n}$$

$$u = \sqrt{\left(\frac{Ze^2}{mr_n}\right)}$$

23. For CGS system $u_n = \sqrt{\left(\frac{Ze^2}{mr_n}\right)}$

For electron $\because \ e = 4.803 \times 10^{-10}$ esu

$$m = 9.108 \times 10^{-28}\ g$$

Radius of III orbit $= r_1 \times n^2 = \mathbf{0.529 \times 10^{-8} \times 9\ cm}$

$$\therefore \quad u_n = \sqrt{\left(\frac{1 \times (4.803 \times 10^{-10})^2}{9.108 \times 10^{-28} \times 0.529 \times 10^{-8} \times 9}\right)}$$

$$u_n = \mathbf{7.29 \times 10^7\ cm\ sec^{-1}}$$

Now, circumference of III orbit

$$= 2 \times \pi \times 0.529 \times 10^{-8} \times 9 = 29.93 \times 10^{-8}\ cm$$

$\therefore$ No. of revolutions/sec

$$= \frac{u_n}{2\pi r} = \frac{7.29 \times 10^7}{29.93 \times 10^{-8}} = \mathbf{2.44 \times 10^{14}}$$

24. In MKS system, $E_n = -\frac{2\pi^2 Z^2 me^4}{(4\pi\varepsilon_0)^2 n^2 h^2} \qquad \because \ n = 2$

$$= -\frac{2 \times (3.14)^2 \times (1)^2 \times 9.108 \times 10^{-31} \times (1.602 \times 10^{-19})^4}{(1.11264 \times 10^{-10})^2 \times (2)^2 \times (6.625 \times 10^{-34})^2}$$

$$= \mathbf{5.443 \times 10^{-19}\ joule}$$

25. (a) Work obtained in the neutralization process is given by

$$W = -\int_{\infty}^{a_0} F \cdot da = -\int_{\infty}^{a_0} \frac{1}{4\pi\varepsilon_0}\frac{(-)e^2}{a_0^2} \cdot da_0$$

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

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

$$TE = PE + KE = PE = -\frac{e^2}{4\pi\varepsilon_0 a_0} \qquad ...(1)$$

Now in order, the electron to be captured by the proton to form a ground state hydrogen atom, it should also attain kinetic energy $\frac{e^2}{8\pi\varepsilon_0 a_0}$ (as it is half of the potential energy given in question). Thus, the total energy of the electron if it attains the ground state in H atom,

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

(b) The wavelength of electron when it is simply at a distance a_0 from the proton can be given as:

$$\lambda = \frac{h}{mu} = \frac{h}{p}$$

Also, $\quad KE = \frac{1}{2}mu^2 = \frac{p^2}{2m} \qquad (\because p = mu)$

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

Since, KE = 0 at this situation, thus $\lambda = \infty$

Also when electron is at a distance a_0 in Bohr's orbit of H atom

$$\lambda = \frac{h}{\sqrt{2m(KE)}} = \frac{h}{\sqrt{\frac{2me^2}{2a_0 \cdot 4\pi\varepsilon_0}}}$$

$$\lambda = \frac{h}{\sqrt{\frac{e^2 m}{4\pi\varepsilon_0 a_0}}}$$

26. E_1 for H = −13.6eV

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

$$\therefore \quad -3.4 = \frac{-13.6}{n^2} \quad \therefore \ n = 2$$

Now, Angular momentum$(mur) = n \cdot \frac{h}{2\pi} = \frac{2 \times 6.626 \times 10^{-34}}{2 \times 3.14}$

$$= \mathbf{2.1 \times 10^{-34}\ J\text{-}sec^{-1}}$$

27. Velocity of electron $= \frac{1}{275} \times$ velocity of light

$$= \frac{1}{275} \times 3 \times 10^{10} = 1.09 \times 10^8\ cm\,sec^{-1}$$

Since, $\quad u_n = \frac{2\pi e^2}{nh}$

$$\therefore \quad 1.09 \times 10^8 = \frac{2 \times 3.14 \times (4.803 \times 10^{-10})^2}{6.625 \times 10^{-27} \times n}$$

$$\therefore \quad n = 20.06 \times 10^{-1} = \mathbf{2} \ \text{(an integer value)}$$

Also when electron jumps from $(n+1)$, *i.e.*, 3 to ground state

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

$$= \mathbf{9.75 \times 10^4\ cm^{-1}}$$

28. E_1 for $He^+ = E_1$ for $H \times Z^2 = 13.6 \times 4 = \mathbf{54.4\ eV}$

E_1 for $Li^{2+} = E_1$ for $H \times Z^2 = 13.6 \times 9 = \mathbf{122.4\ eV}$

29. E_1 for $Li^{2+} = E_1$ for $H \times 9$

E_1 for $He^+ = E_1$ for $H \times 4$

$\therefore$ E_1 for $Li^{2+} = E_1$ for $He^+ \times \frac{9}{4} = 19.6 \times 10^{-18} \times \frac{9}{4}$

$$= \mathbf{44.1 \times 10^{-18}\ J\ atom^{-1}}$$

30. Energy associated with a photon of 242 nm

$$= \frac{6.625 \times 10^{-34} \times 3.0 \times 10^8}{242 \times 10^{-9}} = 8.21 \times 10^{-19} \text{ joule}$$

$\because$ 1 atom of Na for ionisation requires $= 8.21 \times 10^{-19}$ J

$\therefore$ 6.023×10^{23} atoms of Na for ionisation requires

$$= 8.21 \times 10^{-19} \times 6.023 \times 10^{23} = 49.45 \times 10^4 \text{ J}$$

$$= \mathbf{494.5\ kJ\ mol^{-1}}$$

31. For Lyman series $n_1 = 1$

For shortest λ of Lyman series; energy difference in two levels showing transition should be maximum, *i.e.*, $n_2 = \infty$

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

$$\frac{1}{\lambda} = 109678$$

$$\therefore \quad \lambda = 911.7 \times 10^{-8} \text{ cm} = \mathbf{911.7\ \text{Å}}$$

For longest λ of Lyman series; energy difference in two levels showing transition should be minimum, *i.e.*, $n_2 = 2$

$$\therefore \quad \frac{1}{\lambda} = R_H\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = 109678 \times \frac{3}{4}$$

$$\therefore \quad \lambda = 1215.67 \times 10^{-8} \text{ cm} = \mathbf{1215.67\ \text{Å}}$$

32. Rydberg constant $= 109678\text{ cm}^{-1}$

$$E = h\nu = \frac{h.c}{\lambda} = hc\bar{\nu}$$

$\therefore$ $\bar{\nu}$ in cm^{-1} $\quad \therefore$ $\bar{\nu} = 109678\text{ cm}^{-1}$

$$\therefore \quad E = 6.626 \times 10^{-34} \times 3.0 \times 10^{10} \times 109678 \text{ J/atom}$$

$$E = 2.18 \times 10^{-18} \text{ J/atom} = \mathbf{1\ Rh}$$

Also, $\quad \boldsymbol{E = N \times \text{Rh J / mole}}$

33. Spectral lines emitted when electron jumps from n to 1 is $\Sigma(n-1)$ or $\Sigma\Delta n$

$$\because \quad \Sigma n = n\frac{(n+1)}{2}$$

$\therefore$ If $\quad n = n - 1$

Then $\quad \Sigma(n-1) = (n-1)\frac{(n-1+1)}{2} = \mathbf{\frac{1}{2} n(n-1)}$

34. $\frac{1}{\lambda_1} = Z^2R_H\left[\frac{1}{2^2} - \frac{1}{3^2}\right]; \quad \therefore \lambda_1 = \frac{36}{5R_HZ^2}$

$\frac{1}{\lambda_2} = Z^2R_H\left[\frac{1}{1^2} - \frac{1}{2^2}\right]; \quad \therefore \lambda_2 = \frac{4}{3R_HZ^2}$

$$\lambda_1 - \lambda_2 = 133.7 \times 10^{-9} \quad \text{and} \quad Z = 2$$

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

35. For H_α line of Balmer series $n_1 = 2, n_2 = 3$

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

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

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

By Eqs. (1) and (2) $\quad \frac{\lambda_\beta}{\lambda_\alpha} = \frac{\frac{1}{4} - \frac{1}{9}}{\frac{1}{4} - \frac{1}{16}}$

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

36. The photon capable of removing electron from I Bohr's orbit must possess energy

$$= 13.6\text{eV} = 13.6 \times 1.602 \times 10^{-19}\text{ J} = 21.787 \times 10^{-19}\text{ J}$$

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

$$21.787 \times 10^{-19} = \frac{6.625 \times 10^{-34} \times 3.0 \times 10^8}{\lambda}$$

$$\therefore \quad \lambda = 912.24 \times 10^{-10} \text{ m} = \mathbf{912.24\ \text{Å}}$$

This is longest λ because a photon having λ higher than this will possess energy lesser then required, as $E \propto \frac{1}{\lambda}$.

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

$$\therefore \quad \frac{c}{\lambda} = \nu = R_H \cdot c\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= 109737 \times 3.0 \times 10^{10}\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$$

$$= \mathbf{2.92 \times 10^{15}\ sec^{-1}}$$

38. $\because \quad \frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

Given $R_H = 1.1 \times 10^7$; for Lyman series $n_1 = 1$ and $n_2 = 4$ (given)

$$\therefore \quad \frac{1}{\lambda} = 1.1 \times 10^7\left[\frac{1}{1^2} - \frac{1}{4^2}\right]$$

$$\therefore \quad \lambda = \mathbf{0.9696 \times 10^{-7}\ metre}$$

39. Energy of I orbit of H like atom

$$= 4R_h = 4 \times 2.18 \times 10^{-18} \text{ joule}$$

E_1 for $H = -2.18 \times 10^{-18}$ J

$\because \quad E_{\text{H like atom}} = E_{1\,\text{H}} \times Z^2$

$-4\times 2.18\times10^{-18} = -2.18\times10^{-18}\times Z^2$

$\therefore \quad Z = 2$

i.e., Atomic no. of H like atom is 2 or it is He^+.

(a) For de-excitation of 'e' in He^+ from $n_2 = 2$ to $n_1 = 1$

$$E_2 - E_1 = \frac{hc}{\lambda}$$

Now $\quad E_1 = -4R_h$

$\therefore \quad E_2 = -\frac{4R_h}{4} = -R_h \quad \left(\because E_2 = \frac{E_1}{n^2}\right)$

$\therefore \quad E_2 - E_1 = 3R_h = 3\times 2.18\times10^{-18}$ J

$\therefore \quad E_2 - E_1 = \frac{hc}{\lambda}$

$\therefore \quad \lambda = \frac{6.625\times10^{-34}\times3.0\times10^8}{3\times2.18\times10^{-18}} = 303.89\times10^{-10}$ m

$= \mathbf{303.89\ Å}$

(b) Radius (r_1) of H like atom $= \frac{r_H}{Z} = \frac{0.529\times10^{-8}}{2}$

$= \mathbf{2.645\times10^{-9}\ cm}$

40. $\quad E_1$ of H atom $= -13.6$eV

Energy given to H atom $= \frac{6.625\times10^{-34}\times3.0\times10^8}{1028\times10^{-10}}$

$= 1.933\times10^{-18}$ J $= 12.07$eV

$\therefore$ Energy of H atom after excitation

$= -13.6 + 12.07 = -1.53$eV

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

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

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

$\because \quad E_1 = -13.6$eV; $E_3 = -1.53$eV

$\therefore \quad \lambda_1 = \frac{6.625\times10^{-34}\times3.0\times10^8}{(-1.53+13.6)\times1.602\times10^{-19}} = 1028\times10^{-10}$ m

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

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

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

$\therefore \quad \lambda_2 = \frac{6.625\times10^{-34}\times3.0\times10^8}{\left(-\frac{13.6}{4}+13.6\right)\times1.602\times10^{-19}}$

$= 1216\times10^{-10}$ m $= \mathbf{1216\ Å}$

$\therefore$ III induced $\lambda_3 = \frac{hc}{(E_3 - E_2)}$

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

$\therefore \quad \lambda_3 = \frac{6.625\times10^{-34}\times3.0\times10^8}{\left(-\frac{13.6}{9}+\frac{13.6}{4}\right)\times1.602\times10^{-19}}$

$= 6568\times10^{-10}$ m $= \mathbf{6568\ Å}$

41. $\quad E_3$ for H $= -2.41\times10^{-12}$ erg

E_2 for H $= -5.42\times10^{-12}$ erg

$\therefore$ For a jump from III to II shell

$$\Delta E = E_3 - E_2 = \frac{hc}{\lambda}$$

$\therefore \quad \lambda = \frac{hc}{E_3 - E_2}$

$= \frac{6.625\times10^{-27}\times3.0\times10^{10}}{-2.41\times10^{-12}+5.42\times10^{-12}}$

$= 6602.9\times10^{-8}$ cm $= \mathbf{6603\ Å}$

42. $\quad E_n = -\frac{21.7\times10^{-12}}{n^2}$ erg

$\therefore \quad E_2 = -\frac{21.7\times10^{-12}}{4} = -5.425\times10^{-12}$ erg

$\therefore$ For removal of electron $E_2 = \frac{hc}{\lambda}$; E_2 should be given to remove electron, *i.e.*, +ve.

$\therefore \quad \lambda = \frac{6.625\times10^{-27}\times3.0\times10^{10}}{5.425\times10^{-12}}$

$= 3663.6\times10^{-8}$ cm $= \mathbf{3663.6\ Å}$

So, the longest wavelength is **3663.6 Å.**

43. For visible line spectrum, *i.e.*, Balmer series $n_1 = 2$. Also for minimum energy transition $n_2 = 3$.

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

$\therefore \quad \frac{1}{\lambda} = R_H\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = 1.1\times10^7\left[\frac{1}{4} - \frac{1}{9}\right]$

$= 1.1\times10^7\times\frac{5}{36}$

$\therefore \quad \lambda = 6.55\times10^{-7}$ metre

Now $\quad E = \frac{hc}{\lambda} = \frac{6.62\times10^{-34}\times3.0\times10^8}{6.55\times10^{-7}}$

$= 3.03\times10^{-19}$ joule

if N electrons show this transition in 1 g-atom of H then

Energy released $= E\times N = 3.03\times10^{-19}\times6.023\times10^{23}$

$= 18.25\times10^4$ J

$= \mathbf{182.5\ kJ}$

44. $\quad$ Total mole of $H_2 = \frac{1\times1}{300\times0.083} = 0.040$

$\therefore$ Total mole of H atoms $= 0.040\times2 = 0.08$

Energy needed to excite 1 mole H atom from $n = 1$ to $n = 3$ is:

$$E = \frac{h\cdot c}{\lambda} = hc\cdot R_H\left[\frac{1}{1^2} - \frac{1}{3^2}\right]\times N_A$$

$E = 6.625\times10^{-34}\times3.0\times10^8\times1.1\times10^7\times\frac{8}{9}\times6.023\times10^{23}$

$= 11.71\times10^5$ J/mol

Energy required for dissociation of 1 mole H_2 molecules to H atoms

$= 11.71\times10^5\times2.67 = 31.25\times10^5$ J/mol

∴ Total energy needed

= Excitation energy for 0.08 mole H atom + Dissociation energy for 0.04 mole H_2

$= 11.71\times10^5 \times 0.08 + 31.25\times10^5 \times 0.04$

$= 9.37\times10^4 + 12.5\times10^4$

$= \mathbf{21.87\times10^4\ J}$

45. 1 g H contains = N atoms

∴ 1.8 g contains = $N\times1.8$ atoms

$= 6.023\times10^{23}\times1.8 = 10.84\times10^{23}$ atoms

(a) ∴ No. of atoms in III shell $= \dfrac{10.84\times10^{23}\times27}{100}$

$= \mathbf{292.68\times10^{21}}$ **atoms**

∴ No. of atoms in II shell $= \dfrac{10.84\times10^{23}\times15}{100}$

$= \mathbf{162.6\times10^{21}}$ **atoms**

and No. of atoms in I shell $= \dfrac{10.84\times10^{23}\times58}{100}$

$= \mathbf{628.72\times10^{21}}$ **atoms**

(b) When all the atoms return to I shell, then

$E' = (E_3 - E_1)\times292.68\times10^{21}$

$= \left(-\dfrac{13.6}{9}+13.6\right)\times1.602\times10^{-19}\times292.68\times10^{21}$

$= 5.668\times10^5$ joule

$E'' = (E_2 - E_1)\times162.6\times10^{21}$

$= \left(-\dfrac{13.6}{4}+13.6\right)\times1.602\times10^{-19}\times162.6\times10^{21}$

$= 2.657\times10^5$ joule

∴ $E = E' + E'' = 5.668\times10^5 + 2.657\times10^5$ joule

$= \mathbf{832.50\ kJ}$

46. (a) E_1 for He $= -\dfrac{2^2\times2.179\times10^{-18}}{1^2} = \mathbf{-8.716\times10^{-18}\ J}$

(b) E_3 for $Li^{2+} = -\dfrac{3^2\times2.179\times10^{-18}}{3^2} = \mathbf{-2.179\times10^{-18}\ J}$

47. We have $\dfrac{1}{\lambda} = R_H\, Z^2\left[\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right]$

For I line of Balmer series:

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

or $\lambda_B = \dfrac{36}{5\cdot R_H\cdot Z^2}$ ...(1)

For I line of Lyman series:

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

or $\lambda_L = \dfrac{4}{3R_H\cdot Z^2}$ ...(2)

Given, $\lambda_B - \lambda_L = 59.3\times10^{-7}$ cm

or $\dfrac{36}{5R_H\cdot Z^2} - \dfrac{4}{3R_H\cdot Z^2} = 59.3\times10^{-7}$

$\dfrac{1}{R_H\cdot Z^2}[7.2-1.333] = 59.3\times10^{-7}$

or $Z^2 = \dfrac{5.867}{R_H\times59.3\times10^{-7}} = \dfrac{5.867}{109678\times19.3\times10^{-7}}$

∴ $\mathbf{Z = 3}$

∴ H like atom is $\mathbf{Li^{2+}}$.

48. For H atom: $\dfrac{1}{\lambda_H} = R_H\left[\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right]$ ...(1)

For He^+ ion: $\dfrac{1}{\lambda_{He^+}} = R_H\cdot Z^2\left[\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right]$ ...(2)

By Eqs. (1) and (2), $\dfrac{\lambda_{He^+}}{\lambda_H} = \dfrac{1}{Z^2}$

or $\lambda_{He^+} = \lambda_H\times\dfrac{1}{Z^2} = 91.2\times\dfrac{1}{2^2} = \mathbf{22.8\ nm}$

49. m^{th} line of Lyman series $n_1 = 1, n_2 = (m+1)$

∴ $\dfrac{1}{\lambda_L} = R_H\left[\dfrac{1}{1^2}-\dfrac{1}{(m+1)^2}\right]$ ...(1)

Similarly m^{th} line of Balmer series, $n_1 = 2, n_2 = m+2$

∴ $\dfrac{1}{\lambda_B} = R_H\left[\dfrac{1}{2^2}-\dfrac{1}{(m+2)^2}\right]$ ...(2)

∴ $\dfrac{\lambda_B}{\lambda_L} = \dfrac{[(m+1)^2-1][4\times(m+2)^2]}{(m+1)^2[(m+2)^2-4]}$

50. Given, $\lambda_1 = 486.1\times10^{-9}$, m $= 486.1\times10^{-7}$ cm

$\lambda_2 = 410.2\times10^{-9}$, m $= 410.2\times10^{-7}$ cm

$$\bar{\nu} = \bar{\nu}_2 - \bar{\nu}_1 = \frac{1}{\lambda_2}-\frac{1}{\lambda_1} = R_H\left[\frac{1}{2^2}-\frac{1}{n_2^2}\right] - R_H\left[\frac{1}{2^2}-\frac{1}{n_1^2}\right]$$

$\bar{\nu} = R_H\left[\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right]$ ...(1)

For I case of Balmer series:

$$\frac{1}{\lambda_1} = R_H\left[\frac{1}{2^2}-\frac{1}{n_1^2}\right] = 109678\left[\frac{1}{2^2}-\frac{1}{n_1^2}\right]$$

or $\dfrac{1}{486.1\times10^{-7}} = 109678\left[\dfrac{1}{2^2}-\dfrac{1}{n_1^2}\right]$

∴ $n_1 = 4$

For II case of Balmer series:

$$\frac{1}{\lambda_2} = \frac{1}{410.2\times10^{-7}} = 109678\left[\frac{1}{2^2}-\frac{1}{n_2^2}\right]$$

∴ $n_2 = 6$

Thus, given transition occurs from 6th level to 4th level.

Also by Eq. (1) $\bar{\nu} = \dfrac{1}{\lambda} = 109678\left[\dfrac{1}{4^2}-\dfrac{1}{6^2}\right]$

∴ $\mathbf{\lambda = 2.63\times10^{-4}\ cm}$

51. The given series lies in the visible region and thus appears to be Balmer series.

Therefore, $n_1 = 2$ and $n_2 = ?$ for next line

Furthermore if $\lambda = 410.29 \times 10^{-7}$ cm and $n_1 = 2$ then n_2 may be calculated by

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

$$\frac{1}{410.29 \times 10^{-7}} = 109678\left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]$$

$\therefore$ $\quad n_2 = 6$

Thus, next line will be obtained during the jump of electron from 7th to 2nd shell, *i.e.*,

$$\frac{1}{\lambda} = R_H \left[\frac{1}{2^2} - \frac{1}{7^2}\right] = 109678\left[\frac{1}{4} - \frac{1}{49}\right]$$

$\therefore$ $\quad \lambda = 397.2 \times 10^{-7}$ cm

$\lambda = \mathbf{397.2\ nm}$

52. Total energy liberated during transition of electron from nth shell to first excited state (*i.e.*, 2nd shell)

$= 10.20 + 17.0 = 27.20\,\text{eV} = 27.20 \times 1.602 \times 10^{-12}$ erg

$$\because \quad \frac{hc}{\lambda} = R_H \times Z^2 hc\left[\frac{1}{2^2} - \frac{1}{n^2}\right]$$

$$\therefore \quad 27.20 \times 1.602 \times 10^{-12} = R_H \times Z^2 \times h \times c\left[\frac{1}{2^2} - \frac{1}{n^2}\right] \quad ...(1)$$

Similarly, total energy liberated during transition of electron from nth shell to second excited *i.e.*, 3rd shell)

$= 4.25 + 5.95 = 10.20\,\text{eV} = 10.20 \times 1.602 \times 10^{-12}$ erg

$$\therefore \quad 10.20 \times 1.602 \times 10^{-12} = R_H \times Z^2 \times h \times c\left[\frac{1}{3^2} - \frac{1}{n^2}\right] \quad ...(2)$$

Dividing Eq. (1) by Eq. (2), $\boldsymbol{n = 6}$

On substituting the value of n in Eqs. (1) or (2),

$\boldsymbol{Z = 3}$

53. E_1 for H $= -13.6$ eV

$$E_2 \text{ for H} = -\frac{13.6}{2^2} = -\frac{13.6}{4} = -3.4\,\text{eV}$$

$\therefore$ $\quad E_2 - E_1 = -3.4 - (-13.6) = +10.2\,\text{eV}$

$\therefore$ Difference in two levels $=$ **10.2 eV**

Also for transition of H like atom

$\lambda = 3.0 \times 10^{-8}$ m

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

$[\because R_H = 109677\,\text{cm}^{-1} = 109677 \times 10^2\ \text{m}^{-1}]$

$$\therefore \quad \frac{1}{3 \times 10^{-8}} = 109677 \times 10^2 \times Z^2\left[\frac{3}{4}\right]$$

$\therefore$ $\quad Z^2 = 4 \quad \therefore \quad \boldsymbol{Z = 2}$

54. For He^+,
$$\frac{1}{\lambda} = R_H \cdot Z^2\left[\frac{1}{2^2} - \frac{1}{4^2}\right]$$

For H,
$$\frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Since λ is same

$$\therefore \quad Z^2\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$\because$ $\quad Z = 2$

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

$\therefore$ $\quad \boldsymbol{n_1 = 1}$ and $\boldsymbol{n_2 = 2}$

55. Let the transition occurs in between the levels n_1 and n_2. Thus, if $n_2 > n_1$, then given

$n_1 + n_2 = 4$

$n_2 - n_1 = 2$

$\therefore$ $\quad n_1 = 1$ and $n_2 = 3$

$$\text{Therefore,} \quad \frac{1}{\lambda} = R_H \times Z^2\left[\frac{1}{1^2} - \frac{1}{3^2}\right]$$

$$= 109678 \times 3^2 \times \left[\frac{8}{9}\right] \quad (\because Z = 3 \text{ for Li})$$

$\therefore$ $\quad \boldsymbol{\lambda = 1.14 \times 10^{-6}}$ **cm**

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

For 3 to 2 $\quad \Delta E_{3\to2} = R_H\left[\frac{1}{2^2} - \frac{1}{3^2}\right] \quad ...(1)$

For 2 to 1 $\quad \Delta E_{2\to1} = R_H\left[\frac{1}{1^2} - \frac{1}{2^2}\right] \quad ...(2)$

For 3 to 1 $\quad \Delta E_{3\to1} = R_H\left[\frac{1}{1^2} - \frac{1}{3^2}\right] \quad ...(3)$

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

$$\Delta E_{3\to1} = \Delta E_{3\to2} + \Delta E_{2\to1}$$

(b) Also $E = h\nu$; thus, frequencies are also additive.

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

57. Given, $\quad mur = \frac{nh}{2\pi}$

$$\therefore \quad \frac{nh}{2\pi} = 4.2178 \times 10^{-34}$$

$$\text{or} \quad n = \frac{4.2178 \times 10^{-34} \times 2 \times 3.14}{6.625 \times 10^{-34}} = 4$$

$$\text{Thus,} \quad \frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

The transition spectral line for 4th to 3rd shell is

$$\frac{1}{\lambda} = 109678\left[\frac{1}{3^2} - \frac{1}{4^2}\right]$$

$\therefore$ $\quad \boldsymbol{\lambda = 1.8 \times 10^{-4}}$ **cm**

58. Given, $\lambda_2 = 30.4 \times 10^{-7}$ cm

$\lambda_1 = 108.5 \times 10^{-7}$ cm

Let excited state of He^+ be n_2. It comes from n_2 to n_1 and then n_1 to 1 to emit two successive photon

$$\frac{1}{\lambda_2} = R_H . Z^2\left[\frac{1}{1^2} - \frac{1}{n_1^2}\right]$$

$$\frac{1}{30.4 \times 10^{-7}} = 109678 \times 4\left[\frac{1}{1^2} - \frac{1}{n_1^2}\right]$$

$\therefore \quad n_1 = 2$

Now for $\lambda_1 : n_1 = 2$ and n_2 : ?

$$\frac{1}{\lambda_1} = R_H\ Z^2\left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]$$

$$\frac{1}{108.5 \times 10^{-7}} = 109678 \times 4\left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]$$

$\therefore \quad n_2 = 5$

Thus, excited state for He is **5th orbit.**

59. (a) $\because \quad 1\text{eV} = 1.602 \times 10^{-12}$ erg

Also, $\Delta E = \frac{hc}{\lambda} = E_3 - E_2 = R_H \cdot c \cdot h \cdot Z^2\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$

$$42.7 \times 1.602 \times 10^{-12} = 109678 Z^2\left[\frac{1}{2^2} - \frac{1}{3^2}\right] \times 3 \times 10^{10} \times 6.626 \times 10^{-27}$$

$\therefore \quad Z^2 = 22.6 \quad \therefore\ Z \approx 5$

(b) $\Delta E = E_4 - E_3 = R_H \cdot c \cdot h \cdot Z^2\left[\frac{1}{3^2} - \frac{1}{4^2}\right]$

$$= 109678 \times 3 \times 10^{10} \times 6.626 \times 10^{-27} \times 5^2 \times \frac{7}{16 \times 9}$$

$= \mathbf{26.5 \times 10^{-12}}$ **erg**

(c) $\frac{1}{\lambda} = R_H \cdot Z^2\left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]$

$\frac{1}{\lambda} = 109678 \times 25$

$\therefore \quad \lambda = 3.65 \times 10^{-7}$ cm

(d) $\text{KE} = \frac{1}{2}mu^2 = \frac{1}{2}m\left(\frac{2\pi Ze^2}{nh}\right)^2 = \frac{2\pi^2 Z^2 e^4 m}{n^2 h^2}$

$$= \frac{2 \times (3.14)^2 \times 5^2 \times (4.803 \times 10^{-10})^4 \times 9.108 \times 10^{-28}}{1^2 \times (6.625 \times 10^{-27})^2}$$

$= \mathbf{5.45 \times 10^{-10}}$ **erg**

60. Velocity of electron in He^+ ion in an orbit $(u) = \frac{2\pi Ze^2}{nh}$

Radius of He^+ ion in an orbit $(r_n) = \frac{n^2h^2}{4\pi^2 me^2 Z}$

$\therefore$ Angular frequency or angular velocity ω

$$= \frac{u}{r_n} = \frac{2\pi Ze^2 \times 4\pi^2 me^2 Z}{nh \times n^2h^2} = \frac{8\pi^3 Z^2 me^4}{n^3h^3}$$

$\because \quad n = 2, \quad m = 9.108 \times 10^{-28}$ g, $\quad Z = 2, h = 6.625 \times 10^{-27}$

$$\therefore w = \frac{8 \times (22/7)^3 \times (2)^2 \times 9.108 \times 10^{-28} \times (4.803 \times 10^{-10})^4}{(2)^3 \times (6.625 \times 10^{-27})^3}$$

$= \mathbf{2.067 \times 10^{16}\ sec^{-1}}$

61. Wavelength emitted in U.V. region and thus $n_1 = 1$; For H atom

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

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

$\therefore \quad n = 2$

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

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

or $\quad \frac{1}{2} \times 1.67 \times 10^{-27} \times u^2 = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{121.6 \times 10^{-9}}$

$\therefore \quad \mathbf{u = 4.43 \times 10^4\ m\ sec^{-1}}$

62. According to de Broglie equation $\lambda = \frac{h}{mu}$

$\because \quad m = 100\text{g} = 100 \times 10^{-3}$ kg, $u = 100\ \text{m sec}^{-1}$

$\therefore \quad \lambda = \frac{6.625 \times 10^{-34}}{100 \times 100 \times 10^{-3}} = 6.625 \times 10^{-35}$ m

63. We have $\quad \lambda = \frac{h}{mu}$

$\therefore \quad mu = \frac{h}{\lambda}$

i.e., Momentum $= \frac{6.625 \times 10^{-34}}{0.33 \times 10^{-9}} = \mathbf{2.01 \times 10^{-24}\ kg\ m\ sec^{-1}}$

64. Energy emitted out in form of photon

$$= \frac{hc}{\lambda} = \frac{6.625 \times 10^{-27} \times 3 \times 10^{10}}{4860 \times 10^{-8}}$$

$= 4.089 \times 10^{-12}$ erg $= 4.089 \times 10^{-19}$ J $= 2.553$ eV

The total energy loss of electron for atom = **2.553 eV**

Also we have total energy = – Kinetic energy (from Bohr's equation).

$\therefore$ Kinetic energy of electron in atom changes by (increases)

= **2.553 eV**

65. r_n for H $= r_1 \times n^2$

r_3 for H $= 0.529 \times 9 \times 10^{-8}$ cm $\quad (\because r_1 = 0.529\ \text{Å})$

Also, $\quad u_n = \frac{u_1}{n}$

$\therefore \quad u_3 = \frac{2.19 \times 10^8}{3}$ cm sec^{-1}

$(\because u_1 = 2.19 \times 10^8$ cm sec$^{-1})$

$\therefore$ No. of waves in one round

$$= \frac{2\pi r_3}{\lambda} = \frac{2\pi r_3}{h/mu_3} = \frac{2\pi r_3 \times u_3 \times m}{h}$$

$$= \frac{2 \times 22 \times 0.529 \times 9 \times 10^{-8} \times 2.19 \times 10^8 \times 9.108 \times 10^{-28}}{7 \times 3 \times 6.62 \times 10^{-27}} = 3$$

66. (a) $\because$ $mur = \frac{n \cdot h}{2\pi}$

$\therefore$ $u = \frac{n \cdot h}{2\pi mr}$

$= \frac{1 \times 6.626 \times 10^{-27}}{2 \times 3.14 \times 9.108 \times 10^{-28} \times 0.529 \times 10^{-8}}$

$= 2.19 \times 10^8$ cm/sec

(b) $\lambda = \frac{h}{mu}$

$= \frac{6.626 \times 10^{-27}}{9.108 \times 10^{-28} \times 2.19 \times 10^8} = 3.32 \times 10^{-8}$ cm

$= 3.32$ Å

(c) Orbital angular momentum of 2*p*-orbital

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

$= \frac{h}{2\pi}\sqrt{1(1+1)}$ $(\because l = 1)$

$= \frac{h}{2\pi} \times \sqrt{2} = \sqrt{2} \times \hbar \left(\hbar = \frac{h}{2\pi}\right)$

67. Kinetic energy $= \frac{1}{2}mu^2 = 4.55 \times 10^{-25}$ J

$\therefore$ $u^2 = \frac{4.55 \times 10^{-25} \times 2}{9.108 \times 10^{-31}}$

$\therefore$ $u = 10^3$ m sec^{-1}

Now, $\lambda = \frac{h}{mu} = \frac{6.625 \times 10^{-34}}{9.108 \times 10^{-31} \times 10^3}$

$= \mathbf{7.27 \times 10^{-7}}$ **metre**

68. Momentum of electron $= m' \cdot u$

where m' is mass of electron in motion $= \frac{m}{\sqrt{1 - \left(\frac{u}{c}\right)^2}}$

Also, $u = c/3$

$\therefore$ Momentum $= \frac{9.108 \times 10^{-28}}{\sqrt{1 - \left(\frac{c}{3 \times c}\right)}} \times \frac{3 \times 10^{10}}{3}$

$= \frac{9.108 \times 10^{-28} \times 3 \times 10^{10}}{0.94 \times 3}$

$= \mathbf{9.69 \times 10^{-18}}$ **g cm sec^{-1}**

69. $\because$ $\lambda = \frac{h}{mu}$

$\therefore$ Momentum, $mu = \frac{h}{\lambda} = \frac{6.625 \times 10^{-34}}{5200 \times 10^{-10}}$ kg m sec^{-1} ...(1)

Also momentum of electron $= mu = 9.108 \times 10^{-31} \times u$ ...(2)

Since, both are same, therefore, by Eqs. (1) and (2)

$9.108 \times 10^{-31} \times u = \frac{6.625 \times 10^{-34}}{5200 \times 10^{-10}}$

$\therefore$ $u = \mathbf{1400}$ **m sec^{-1}**

70. $u_{rms} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3 \times 8.314 \times 300}{9.108 \times 10^{-31} \times 6.023 \times 10^{23}}}$

$= \mathbf{11.68 \times 10^4}$ **m/sec**

71. u_{rms} of He $= \sqrt{\frac{3RT}{m}} = \sqrt{\frac{3 \times 8.314 \times 100}{4 \times 10^{-3}}} = \mathbf{1367.7}$ **ms^{-1}**

Now, $\lambda = \frac{h}{mu} = \frac{6.625 \times 10^{-34}}{\frac{4 \times 10^{-3} \times 1367.7}{6.023 \times 10^{23}}} = \mathbf{7.29 \times 10^{-11}}$ **m**

72. For an electron, $\frac{1}{2}mu^2 = e.V$

and $\lambda = \frac{h}{mu}$

Thus, $\frac{1}{2}m\frac{h^2}{m^2\lambda^2} = e.V$

or $V = \frac{1}{2}\frac{h^2}{m\lambda^2 \cdot e}$

$= \frac{1 \times (6.62 \times 10^{-34})^2}{2 \times 9.108 \times 10^{-31} \times (1.54 \times 10^{-10})^2 \times 1.602 \times 10^{-19}}$

$= \mathbf{63.3}$ **volt**

73. Energy of an accelerated electron

$= Q.V = 1.602 \times 10^{-19} \times 4.5 = 7.209 \times 10^{-19}$ J

This energy is completely converted into light.

i.e., $\frac{hc}{\lambda} = 7.209 \times 10^{-19}$

$\frac{6.625 \times 10^{-34} \times 3.0 \times 10^8}{\lambda} = 7.209 \times 10^{-19}$

$\therefore$ $\frac{1}{\lambda}$ = wave no. $= \mathbf{3.63 \times 10^6}$ **metre^{-1}**

74. For proton,

$u = \frac{h}{m\lambda}$; $\because$ mass of proton $= 1.67 \times 10^{-27}$ kg

$u = \frac{6.625 \times 10^{-34}}{1.67 \times 10^{-27} \times 0.005 \times 10^{-9}} = 7.94 \times 10^4$ metre sec^{-1}

Now accelerating potential is *V*, then velocity (*u*) acquired by the charge particle having charge *Q* and mass *m*.

$\because$ $Q.V = \frac{1}{2}mu^2$

$u = \sqrt{\left(\frac{2QV}{m}\right)} = \sqrt{\left(\frac{2 \times 1.602 \times 10^{-19} \times V}{1.67 \times 10^{-27}}\right)}$

or $7.94 \times 10^4 = \sqrt{\left(\frac{2 \times 1.602 \times 10^{-19} \times V}{1.67 \times 10^{-27}}\right)}$

$\therefore$ $V = \mathbf{32.85}$ **volt**

75. $\text{KE} = \frac{1}{2}mu^2 = \frac{1}{2}m\left[\frac{h}{m\lambda}\right]^2$

$\text{KE} = \frac{1}{2}\frac{h^2}{m\lambda^2}$

$\therefore$ $\lambda^2 = \frac{h^2}{2m\text{KE}}$

$\therefore$ $\lambda = \sqrt{\frac{h^2}{2m\text{KE}}} = \frac{6.626 \times 10^{-27}}{\sqrt{2 \times 9.108 \times 10^{-28} \times 2.5 \times 1.602 \times 10^{-12}}}$

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

76. $\lambda = \frac{h}{mu} = \frac{h}{\sqrt{2eVm}}$ $(\because eV = 1/2\, mu^2)$

$= \frac{6.626\times10^{-34}}{\sqrt{2\times1.6\times10^{-19}\times V\times9.1\times10^{-31}}}$

$= \frac{6.626\times10^{-34}}{5.396\times10^{-25}[V]^{1/2}} = \frac{1.227\times10^{-9}}{[V]^{1/2}}$ metre

$= \frac{12.27\times10^{-10}}{[V]^{1/2}}$ metre $= \frac{12.27}{[V]^{1/2}}$ Å

$= \left[\frac{\mathbf{150}}{\mathbf{V}}\right]^{1/2}$ **Å**

77. $\Delta u = \frac{0.1\times10^{-4}}{100} = 1\times10^{-7}\ \text{cm sec}^{-1}$

$\because \quad \Delta u\cdot\Delta x = \frac{h}{4\pi m}$

$\therefore \quad \Delta x = \frac{6.625\times10^{-27}}{4\times3.14\times10^{-11}\times1\times10^{-7}} = 5.27\times10^{-10}$ cm

The uncertainty in position as compared to particle size

$= \frac{\Delta x}{\text{diameter}} = \frac{5.27\times10^{-10}}{10^{-4}} = \mathbf{5.27\times10^{-6}}$ **cm**

The factor being small and almost being negligible for microscopic particles.

78. According to Heisenberg's uncertainty principle

$\Delta u\cdot\Delta x \approx \frac{h}{4\pi m}$

$\Delta u \approx \frac{h}{4\pi m\cdot\Delta x}$

$= \frac{6.625\times10^{-34}}{4\times\frac{22}{7}\times9.108\times10^{-31}\times10^{-10}}$

$= \mathbf{5.8\times10^{5}}$ **m sec^{-1}**

79. $\Delta u\cdot\Delta x \approx \frac{h}{4\pi m}$

$\Delta u = \frac{h}{4\pi m\cdot\Delta x} = \frac{6.625\times10^{-34}}{4\times\frac{22}{7}\times0.15\times10^{-10}}$

$= \mathbf{3.51\times10^{-24}}$ **m sec^{-1}**

80. $\Delta x\cdot\Delta p = \frac{h}{4\pi}$

$\because \quad \Delta x = 0.001\ \text{Å} = 10^{-13}$ m

$\therefore \quad \Delta p = \frac{6.625\times10^{-34}}{2\times3.14\times10^{-13}} = \mathbf{5.27\times10^{-22}}$ **Ns**

Now if the given momentum $= \frac{h}{2\pi a_0}$

$= \frac{6.625\times10^{-34}}{2\times3.14\times0.529\times10^{-10}}$

$= \mathbf{2\times10^{-24}}$ **Ns**

The uncertainty in momentum seems to be about $\left(\frac{5.27\times10^{-22}}{2\times10^{-24}}\right)$ or 263.5 times as large as the momentum itself is. Because of this reason, the concept of Bohr's orbit has been replaced by probabilities of locating electron cloud.

81. $\Delta x_0\cdot\Delta u = \frac{h}{4\pi m}$

$\therefore \quad \Delta u = \frac{h}{4\pi m\cdot\Delta x_0}$

or $\Delta u = \frac{\Delta x}{t}$ *i.e.*, the distance travelled by proton in time *t*.

$\therefore \quad \Delta x = \frac{t\cdot h}{4\pi m\cdot\Delta x_0}$

$= \frac{6.626\times10^{-34}\times1}{4\times3.14\times1.672\times10^{-27}\times1.0\times10^{-11}}$

$= \mathbf{3.15\times10^{3}}$ **m**

82. Mass of electron in motion $= \frac{2}{931}$ amu

$= \frac{2}{931}\times1.66\times10^{-27}$ kg

$(\because 1\,\text{amu} = 931\,\text{MeV})$

$= \mathbf{35.6\times10^{-31}}$ **kg**

Also, $m_e = \frac{m_e^0}{\sqrt{1-\left[\frac{u}{c}\right]^2}}$

or $35.6\times10^{-31} = \frac{\frac{0.511}{931}\times1.66\times10^{-27}}{\sqrt{1-\left[\frac{u}{3\times10^{10}}\right]^2}}$

$\therefore \quad u = \mathbf{2.9\times10^{10}}$ **cm sec^{-1}**

83. Radius of the nucleus is of the order of 10^{-13} cm and thus uncertainty in position of electron, *i.e.*, (Δx), if it is within the nucleus will be 10^{-13} cm.

Now, $\Delta x\cdot\Delta u \geq \frac{h}{4\pi m}$

$\therefore \quad \Delta u = \frac{6.626\times10^{-27}}{4\times3.14\times9.108\times10^{-28}\times10^{-13}}$

$= \mathbf{5.79\times10^{12}}$ **cm / sec**

i.e., order of velocity of electron will be 100 times greater than the velocity of light which is impossible. Thus, possibility of electron to exist within the nucleus is zero.

84. Energy of photon = work function $+1/2\, mu^2$

Energy of photon = work function $+ eV_0$ ...(1)

where *e* is electronic charge and V_0 is stopping potential and eV_0 is equal to energy required to stop the ejection of electron.

$\because \quad E_{\text{photon}} = \frac{hc}{\lambda} = \frac{6.625\times10^{-34}\times3.0\times10^{8}}{253.7\times10^{-9}}$

$= 7.834\times10^{-19}$ J

$= \frac{7.834\times10^{-19}}{1.602\times10^{-19}}$ eV $= 4.89$ eV

$\therefore$ By Eq. (1) 4.89 = work function + 0.24

Work function = **4.65 V**

85. Energy of photon liberated from He^+ during emission of H_α line of Lyman series $= hc \cdot R_H Z^2 \left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$$= 6.625 \times 10^{-27} \times 3 \times 10^{10} \times 109678 \times 2^2 \left[\frac{3}{4}\right]$$

$$= 6.54 \times 10^{-11} \text{ erg}$$

This energy is used in liberating electron from H atom from ground state, therefore,

$$6.54 \times 10^{-11} = E_1 \text{ of H} + \frac{1}{2}mu^2$$

$$= 13.6 \times 1.602 \times 10^{-12} + \frac{1}{2}mu^2$$

$$\frac{1}{2}mu^2 = 6.54 \times 10^{-11} - 2.179 \times 10^{-11}$$

$$= 4.361 \times 10^{-11} \text{ erg}$$

$$u^2 = \frac{4.361 \times 10^{-11} \times 2}{9.108 \times 10^{-28}}$$

$$\therefore \quad \mathbf{u = 3.09 \times 10^8 \text{ cm sec}^{-1}}$$

86. Energy of photon

= Kinetic energy of photo electron + Threshold frequency

$\therefore \quad h\nu_1 = KE_1 + h\nu_0 \quad ...(1)$

and $\quad h\nu_2 = KE_2 + h\nu_0 \quad ...(2)$

Multiplying Eq. (1) by 2 and subtracting Eq. (2) from it

$2h\nu_1 - h\nu_2 = h\nu_0 \quad (\because 2KE_1 = KE_2)$

or $\quad (2\nu_1 - \nu_2) = \nu_0$

$$\therefore \quad \nu_0 = \left[\frac{2c}{\lambda_1} - \frac{c}{\lambda_2}\right] = \frac{3 \times 10^8}{10^{-10}}\left[\frac{2}{2200} - \frac{1}{1900}\right]$$

$(1 \text{ Å} = 10^{-10} \text{ m})$

$$\mathbf{\nu_0 = 1.1483 \times 10^{15} \text{ sec}^{-1}}$$

Also, $\quad \lambda_0 = \frac{c}{\nu_0} = \frac{3 \times 10^8}{1.1483 \times 10^{15}} = 2.6126 \times 10^{-7} \text{ m}$

$$= \mathbf{2612.6 \text{ Å}}$$

87. Energy absorbed $= \frac{hc}{\lambda}$

$$= \frac{6.625 \times 10^{-27} \times 3.0 \times 10^{10}}{360 \times 10^{-8}} = 5.52 \times 10^{-11} \text{ erg}$$

$$= 5.52 \times 10^{-18} \text{ joule}$$

Now this energy is used in overcoming forces of attraction between surface of metal and imparting velocity to electron, therefore,

$E_{absorbed} = E$ used in attractive forces + Kinetic energy of electron

$\therefore$ Kinetic energy $= 5.52 \times 10^{-18} - 7.52 \times 10^{-19}$ joule

$$= \mathbf{47.68 \times 10^{-19} \text{ joule}}$$

88. Binding energy of electron = 250 kJ mol^{-1}

$\therefore$ Binding energy of one electron $= \frac{250 \times 10^3}{6.023 \times 10^{23}}$ J

$$= 4.15 \times 10^{-19} \text{ J}$$

Also, $\quad$ Binding energy $= h\nu_0$

Where ν_0 is threshold frequency.

$$\therefore \quad 4.15 \times 10^{-19} = 6.625 \times 10^{-34} \times \nu_0$$

$$\therefore \quad \mathbf{\nu_0 = 6 \times 10^{14} \text{ sec}^{-1}}$$

89. The frequency of emitted X-rays is given by

$$\sqrt{\nu} = a(Z - b)$$

(according to Mosley's law, where a and b are characteristic constants)

or $\quad \sqrt{\frac{c}{\lambda}} = a(Z-b) \quad$ (where c is velocity of light)

Thus, for $_{26}$Fe$(\because Z = 26) \therefore \quad \sqrt{\frac{c}{\lambda_1}} = a(26-b) \quad ...(1)$

For $_{19}$K $(\because Z = 19) \quad \therefore \quad \sqrt{\frac{c}{\lambda_2}} = a(19-b) \quad ...(2)$

By Eqs. (1) and (2) $\quad \sqrt{\frac{\lambda_2}{\lambda_1}} = \frac{26-b}{19-b}$

$$\lambda_1 = 1.931 \times 10^{-8} \text{ cm}, \ \lambda_2 = 3.737 \times 10^{-8} \text{ cm}$$

$$\sqrt{\frac{3.737 \times 10^{-8}}{1.931 \times 10^{-8}}} = \frac{26-b}{19-b}$$

$$1.39 = \frac{26-b}{19-b}$$

or $\quad 26.41 - 1.39b = 26 - b \quad$ or $\quad b = 1.05 \quad ...(3)$

By Eqs. (1) and (3)

$$\sqrt{\frac{3.0 \times 10^{10}}{1.931 \times 10^{-8}}} = a(26 - 1.05)$$

$$\therefore \quad a = 5 \times 10^7$$

Now, if $\lambda = 2.289 \times 10^{-8}$ cm, then

$$\sqrt{\frac{3.0 \times 10^{10}}{2.289 \times 10^{-8}}} = 5 \times 10^7 \ (Z - 1.05)$$

$\therefore \quad \mathbf{Z = 24} \quad (\because Z$ is integer)

Therefore, atomic no. of element is **24** and so it is **chromium.**

90. ψ value represents an orbital. The given value is for $4d_{z^2}$ $(n = 4, l = 2, m = 0)$.

91. Angular nodes $= l$, spherical node $= n - l - 1$

(a) 1, 2 (b) 1, 1 (c) 0, 2

92.
$$\psi_{2s} = \frac{1}{2\sqrt{32\pi}} \cdot \left[\frac{1}{a_0}\right]^{3/2} \cdot \left[2 - \frac{r}{a_0}\right] \cdot e^{-r/2a_0}$$

For radial node at $r = r_0$, $\psi^2_{2s} = 0$. This is possible only when

$$\left[2 - \frac{r_0}{a_0}\right] = 0 \quad \text{or} \quad 2 = \frac{r_0}{a_0} \quad \text{or} \quad \mathbf{r_0 = 2a_0}$$

93. Formula of nitrate ion $= NO_3^-$

$\therefore$ No. of electron in NO_3 = Electrons in N + 3 × Electrons in O + 1 (due to negative charge)

$$= 7 + 3 \times 8 + 1 = \mathbf{32}$$

94. Electronic configuration of neutral atom:

$$\underset{K}{1s^2}, \ \underset{L}{2s^2 2p^6}, \ \underset{M}{3s^2 3p^6 3d^1}, \ \underset{N}{4s^2}$$

(a) At. no. = Total no. of electron in neutral atom = **21**

(b) Total no. of s electrons = **8**
(c) Total no. of p electrons = **12**
(d) Total no. of d electrons = **1**
(e) Valency of element **+2** and **+3** (due to no. of electrons in outer shell and penultimate d sub-shell)
(f) No. of unpaired 'e' = **1** (of $3d$)

95. Total no. of molecules of CO_2 = 12

(1) $C^{12}O^{16}O^{16}$ Molar mass = **44 g mol^{-1}**
(2) $C^{12}O^{17}O^{17}$ Molar mass = **46 g mol^{-1}**
(3) $C^{12}O^{18}O^{18}$ Molar mass = **48 g mol^{-1}**
(4) $C^{12}O^{16}O^{17}$ Molar mass = **45 g mol^{-1}**
(5) $C^{12}O^{16}O^{18}$ Molar mass = **46 g mol^{-1}**
(6) $C^{12}O^{17}O^{18}$ Molar mass = **47 g mol^{-1}**

Similarly six molecules with C^{13} isotope.

96.

	I isotope of O	II isotope of O
Atomic masses are	15.9936	17.0036
∴ Mass no. are	**16**	**17** (Integer values)
∴ No. of neutrons	= 16 − 8 = **8**	= 17 − 8 = **9**
and No. of electrons	= **8**	= **8**

∵ Mass No. − At. No. = No. of neutrons

97.

	Electronic configuration	No. of unpaired (e)
(a)	$_{25}Mn^{+4}$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^3$	3
(b)	$_{24}Cr^{+2}$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^4$	4
(c)	$_{26}Fe^{+3}$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5$	5
(d)	$_{28}Ni^{+2}$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^8$	2
(e)	$_{17}Cl^-$: $1s^2, 2s^2 2p^6, 3s^2 3p^6$	0
(f)	$_{30}Zn^{+2}$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}$	0
(g)	$_{26}Fe^{+2}$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^6$	4
(h)	$_{11}Na$: $1s^2, 2s^2 2p^6, 3s^1$	1
(i)	$_{12}Mg$: $1s^2, 2s^2 2p^6, 3s^2$	0
(j)	$_{24}Cr^{+3}$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^3$	3

Note : In case of writing electronic configuration of cation, first write configuration of neutral atom and then take out desired electrons from outermost shell, *e.g.*,

$_{25}Mn$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^2$

$_{25}Mn^+$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^1$

98. Count unpaired electrons in each.

$$\text{Total spin} = \text{No. of unpaired electron} \times \left(\pm\frac{1}{2}\right)$$

∴ (a) Total spin in $1s^2 = \mathbf{0} \times \left(\pm\frac{1}{2}\right) = \mathbf{0}$

(b) Total spin in $1s^2, 2s^2 2p^6 = \mathbf{0} \times \left(\pm\frac{1}{2}\right) = \mathbf{0}$

(c) Total spin in $1s^2, 2s^2 2p^5 = \mathbf{1} \times \left(\pm\frac{1}{2}\right) = \pm\frac{1}{2}$

(d) Total spin in $1s^2, 2s^2 2p^3 = \mathbf{3} \times \left(\pm\frac{1}{2}\right) = \pm\frac{3}{2}$

(e) Total spin in $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^2$

$$= \mathbf{5} \times \left(\pm\frac{1}{2}\right) = \pm\frac{5}{2}$$

99. No. of unpaired electrons are given by

Magnetic moment = $\sqrt{[n(n+2)]}$

where n is no. of unpaired electrons

or $1.73 = \sqrt{[n(n+2)]}$ or $1.73 \times 1.73 = n^2 + 2n$ ∴ $n = 1$

Now vanadium atom must have one unpaired electron and thus its configuration is

$_{23}V^{4+}$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^1$

100. Angular momentum in an orbital = $\frac{h}{2\pi}\sqrt{[(l+1)\times l]}$

(a) $l = 0$ for $4s$ orbital

∴ Angular momentum = 0

(b) $l = 1$ for $3p$ orbital

∴ Angular momentum = $\frac{h}{\sqrt{2}\pi}$

(c) Angular momentum in an orbit = $\frac{nh}{2\pi}$

$n = 4$ for 4th orbit

∴ Angular momentum = $\frac{2h}{\pi}$

101. (a) ∵ $n = 2$ and $l = 1$ ∴ $2p$

Also $m = -1$ ∴ $\mathbf{2p_x}$ or $\mathbf{2p_y}$

(b) $\mathbf{4d_{z^2}}$
(c) $\mathbf{3p_x}$ or $\mathbf{3p_y}$
(d) **4s**
(e) $\mathbf{3d_{x^2-y^2}}$ or $\mathbf{3d_{xy}}$

102.

(a)	**2s**	: $n = 2$	$l = 0$	$m = 0$
(b)	$\mathbf{2p_z}$	: $n = 2$	$l = 1$	$m = 0$
(c)	$\mathbf{4d_{x^2-y^2}}$	: $n = 4$	$l = 2$	$m = -2$ or $+2$
(d)	$\mathbf{4d_{z^2}}$	: $n = 4$	$l = 2$	$m = 0$

103. Find $(n + l)$ for each set

(1) Lower is the value of $(n + l)$, lower is energy level.
(2) If $(n + l)$ are same then orbital with lower values of n possess lower energy.

∵ Decreasing order of energy **3 > 1 > 2 > 4.**

104. $_{18}Ar$: $1s^2, 2s^2 2p^6, 3s^2 3p^6$

Quantum numbers for $3p^6$ electrons

$n = 3$	$l = 1$	$m = -1$ or $+1$	$s = +\frac{1}{2}$ or $-\frac{1}{2}$
$n = 3$	$l = 1$	$m = 0$	$s = +\frac{1}{2}$ or $-\frac{1}{2}$
$n = 3$	$l = 1$	$m = +1$ or -1	$s = +\frac{1}{2}$ or $-\frac{1}{2}$
$n = 3$	$l = 1$	$m = -1$ or $+1$	$s = -\frac{1}{2}$ or $+\frac{1}{2}$
$n = 3$	$l = 1$	$m = 0$	$s = -\frac{1}{2}$ or $+\frac{1}{2}$
$n = 3$	$l = 1$	$m = +1$ or -1	$s = -\frac{1}{2}$ or $+\frac{1}{2}$

105. Let oxide of nitrogen be N_2O_a

Molar mass of $N_2O_a = 46 \times 2 = 92\,g\,mol^{-1}$

$\therefore \quad 2 \times 14 + 16(a) = 92$

$\therefore \quad a = 4$

$\therefore$ Oxide is N_2O_4

$92\,g\,N_2O_4 = 1\,\text{mole of}\,N_2O_4 = N$ molecules of N_2O_4

$\because$ 1 molecule of N_2O_4 has 46 electrons

$\therefore$ N molecules of N_2O_4 have $46 \times N$ electrons

where N is Avogadro's number.

106. (a) 16 g CH_4 has N molecules

1.6 g CH_4 has $\frac{N}{10}$ molecules

Now 1 molecule of CH_4 has $(6+4)e = 10e$

$\therefore$ $N/10$ molecules of CH_4 have $= N$ **electrons**

(b) No. of electrons in 1 molecule of $CO_2 = 6 + 16 = \mathbf{22}$

(c) No. of electrons in 1 molecule of $N_2 = 7 + 7 = \mathbf{14}$

107. $_4Be^7 + _{-1}e^0 \longrightarrow {}_3Li^7$

$\therefore$ At. No. = **3**; Mass No. = **7**

108. $_{12}Mg$: $1s^2, 2s^2 2p^6, 3s^2$

$_{17}Cl$: $1s^2, 2s^2 2p^6, 3s^2 3p^5$

$_{23}V$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^3, 4s^2$

To locate periods: The no. of outermost shell suggest the period of element. Therefore, **Mg** in **III** period, **Cl** in **III** period, **V** in **IV** period.

To locate groups: First locate block and then group as given below:

(a) *s*-Block: (1) The configuration ns^1 or ns^2 followed with $(n-1)s^2 p^6$ represents *s*-block.

(2) In *s*-block ns^1 represents for I gp.

ns^2 represents for II gp.

Therefore, **Mg is *s*-block element of II group.**

(b) *p*-Block: (1) The configuration $ns^2 np^{1\text{ to }6}$ represent *p*-block.

(2) In *p*-block no. of $(ns + np)$ electrons represent group.

ns^2np^1 = III gp. $ns^2\ np^4$ = VI gp.

ns^2np^2 = IV gp. $ns^2\ np^5$ = VII gp.

ns^2np^3 = V gp. $ns^2\ np^6$ = zero gp.

Therefore, **Cl is *p*-block element of VII group.**

(c) *d*-Block: (1) The configuration ns^1 or ns^2 followed with $(n-1)s^2\ p^6\ d^{1-10}$ represents *d*-block.

(2) In *d*-block = [No. of '*e*' in outer shell penultimate + No. of '*e*' in penultimate shell] $-8 = \Delta$ = group number

$\Delta = 3$	III group
$\Delta = 4$	IV group
$\Delta = 5$	V group
$\Delta = 6$	VI group
$\Delta = 7$	VII group
$\Delta = 8$, $\Delta = 9$, $\Delta = 10$	VIII group
$\Delta = 11$	I group
$\Delta = 12$	II group

$\therefore$ **$_{23}V$ is *d*-block element of V group.**

• SINGLE INTEGER ANSWER PROBLEMS •

1. The ratio of speeds of electron in I orbit of H-atom to IV orbit of He^+-ion is.....
2. The transition of electron occurs in H-atom from 6th to 3rd orbit. The no. of spectral lines given are .....
3. The no. of waves made by an electron during its revolution in 5th orbit is.....
4. Energy of an electron in an orbit of H-atom is $-\frac{R_H}{4}$. The no. of degenerate orbitals in this orbit are .....
5. The number of revolutions/sec made by an electron in II orbit is 8 times of the number of revolution/sec made by electron in nth orbit. The value of n is .....
6. A transition of electron from an higher orbit to 2nd orbit produces 10 spectral lines. The higher orbit no. is .....
7. A transition for H atom from II to I orbit has same wavelength as from nth orbit to 2nd orbit for He^+ ion. The value of 'n' is .....
8. Suppose 3.1×10^{-18} J energy is needed by the interior of the human eye to see an object. How many photon of light of $\lambda = 400$ nm will be needed to see the object? ($h = 6.6 \times 10^{-34}$ Js)
9. Humphry series is obtained when electron in H-atom jumps from a higher orbit to n orbit. The value of n is .....
10. The total values of m for each orbital in M shell are .....
11. No. of elliptical orbitals in 5th shell are .....
12. No. of nodal planes in 3d orbitals are .....
13. The magnetic moment of $_{41}Nb$ is found to be 5.916. Total no. of unpaired electron are .....
14. An absorption of 12.088 eV energy by an electron in ground state of H-atom brings in the excitation of electron to which orbit?
15. Total no. of degenerate orbital in $\psi_{4,2,0}$ orbital of H-atom.
16. The ratio of the time required for an electron taking one round of 2nd orbit of H-atom and He^+ ion respectively.
17. Total number of nodes in 3rd shell is ......
18. Number of unpaired electrons in V^{3+} ion is ......
19. Total spin of electrons in Cr atom is ......
20. Number of lobes in d_{z^2} orbital is ......
21. Possible number of molecules of H_2O using ^1_1H and all isotopes of oxygen.
22. If radius of I orbit of H-atom is 0.5×10^{-8} cm, the de Broglie wavelength of electron in I orbit is $a\,\pi$ Å. The closest value of a is.....
23. The energy required to stop the ejection of electrons from a metal plate in photoelectric effect is 0.89 eV. The radiations of 253.7 nm strike the metal plate to show ejection of electrons. The work function of metal in eV is.....
24. The wavelength ratio of two radiations is 1 : 5. The ratio of their energy is.....
25. The ratio of velocity of electrons in 1st orbit and 3rd orbit is.....
26. The wavelength of certain line in Balmer series is observed to be 4341Å. To what value of n_2 does this corresponds ?
27. Number of unpaired electrons in $_{28}Ni^{2+}$ ion is.....
28. An oil drop has 1.1214×10^{-18} coulomb charge. Number of electrons associated with this oil drop is .....
29. Number of orbitals not having spherical shape in 3rd shell is .....
30. n_2 values for II line of Humphry series corresponds to.....
31. Total spin of electrons in Mn^{3+} ion is $\pm a$. The value of a is.....
32. The lowest value of n which allows g-orbitals to exist is.....
33. Values of magnetic quantum numbers in an outer shell of an element are nine. What is the outermost shell of element ?
34. Which energy level in He^+ has same energy level as the 4th energy level of H ?
35. N and Ne both have same number of electrons having their spin in one direction. The maximum number of electrons having same spin orientation is.....
36. The magnetic moment of Mn^{a+} is 4.90 B.M. The value of a is.....
37. How many elements possess same number of s-electrons as p-electrons?
38. 10^{-18} J of energy is needed to carry out the reaction. How many photons of light of 450 nm are needed to generate this energy.
39. Cr^{n+} has magnetic moment equal to 5.916 BM. The value of n is ......
40. $E_n = -\frac{Z^2 B}{n^2}$ where Z is the atomic number of species and $B = 2.179 \times 10^{-18}$ J. If energy level of Li^{2+} ion in a particular shell is -2.179×10^{-18} J, the principal quantum number of shell is ......
41. The value of angular quantum number from which electron drops to emit I line of Lyman series.
42. The velocity of electron in a certain Bohr's orbit of H atom bears the ratio 1 : 275 to the velocity of light. The number of waves made by electron during one complete revolution round this orbit is ......

43. The binding energy of electrons in a metal is 2.5×10^a kJ mol^{-1} and threshold frequency of metal is $6 \times 10^{14} sec^{-1}$. The value of a is ......

44. Total number of molecules of CO_2 formed by using C–12 isotope and O-16, O-17 and O-18 isotopes are ......

45. Angular momentum in an orbit is $3\hbar$. The value of n is ......

46. Number of lobes present in d_{z^2} orbital is ......

47. The quantum number 6 corresponding to the excited state of He^+ ion if on deexcitation to the ground state that ion emits photons in succession with two wavelengths only. The quantum number of the shell in which the electron comes first before occupying ground state is ......

48. How many orbitals of He^+ ion possess same energy level in 2^{nd} shell?

49. The ratio of e/m for H^+ and He^{2+} is ......

50. H atom is in an excited state. It is subjected to radiation to excite further in next excited state. If photon of energy 1.89 eV is required to do show, the finally excited state of H atom is in ...... orbit.

51. The total values of magnetic quantum number of an electron when the value of $n = 2$ is ......

52. How many sets of four quantum numbers are possible for electrons present in He^{2-} ......

53. Number of electrons in the nucleus of an element of atomic number 14 is ......

54. If two electrons in an atom round the nucleus one each in circular orbit of R and $4R$. The time taken for one complete revolution in $4R$ shell is ...... times of R shell.

55. The maximum number of electrons that can have principal quantum no., $n = 3$ and spin quantum no. $m_s = -\frac{1}{2}$ is .... **(IIT 2011)**

56. 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 : **(IIT 2011)**

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

57. 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 : **[JEE (Advanced) I 2013]**

ANSWERS

1. Two	**2.** Six	**3.** Five	**4.** Four	**5.** Four	**6.** Six	**7.** Four	**8.** Seven	**9.** Six	**10.** Nine	**11.** Four	**12.** Two
13. Five	**14.** Three	**15.** Five	**16.** Four	**17.** Two	**18.** Two	**19.** Three	**20.** Two	**21.** Three	**22.** One	**23.** Four	**24.** Five
25. Three	**26.** Five	**27.** Two	**28.** Seven	**29.** Eight	**30.** Eight	**31.** Two	**32.** Five	**33.** Three	**34.** Eight	**35.** Five	**36.** Three
37. Two	**38.** Three	**39.** One	**40.** Three	**41.** One	**42.** Two	**43.** Two	**44.** Six	**45.** Three	**46.** Two	**47.** Two	**48.** Four
49. Two	**50.** Three	**51.** Four	**52.** Four	**53.** Zero	**54.** Eight	**55.** Nine	**56.** Four	**57.** Five			

OBJECTIVE PROBLEMS (One Answer Correct)

1. A Bohr orbit of H-atom having energy $= -\frac{Rh}{9}$ has degenerate levels :
(a) 2 (b) 4
(c) 5 (d) 9

2. If speed of an electron of mass 'm' in an orbit represents its wavelength, then its wavelength is given by :
(a) $\sqrt{\frac{m}{h}}$ (b) $\sqrt{\frac{h}{p}}$
(c) $\sqrt{\frac{h}{m}}$ (d) $\sqrt{\frac{h}{2k\varepsilon}}$

3. Out of which λ values are definitely observed during emission or absorption spectrum of H-atom?
(a) Lyman (b) Balmer
(c) Paschen (d) All of these

4. The wavelength of m^{th} line Balmer series for an orbital is 4103 Å. The value of m represents:
(a) 2 (b) 4
(c) 6 (d) 8

5. Spin angular momentum of electron is given by :
(a) $\frac{\sqrt{3}}{4}\frac{h}{\pi}$ (b) $\sqrt{\frac{3}{4}}\cdot\frac{h}{\pi}$
(c) $\sqrt{\frac{3h}{4\pi}}$ (d) $\sqrt{\frac{4h}{3\pi}}$

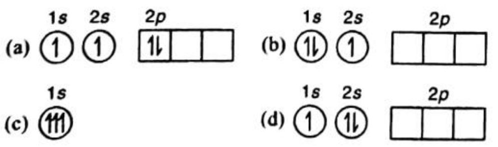
6. Which of the following does not contain same number of electrons in its outer shell as Pd has in its outer shell?
(a) Ag^+ (b) Cd^{2+}
(c) Cu^{2+} (d) Cu^+

7. Which of the following transitions are allowed in the normal electronic spectrum of H-atom?
(a) $4p$ to $3p$ (b) $4d$ to $3s$
(c) $4p$ to $3d$ (d) $3s$ to $2s$

8. The wavelength of an electron accelerated by a potential difference of 500 V is:
(a) 5.5×10^{-11} m (b) 3.89×10^{-11} m
(c) 5.5×10^{-10} m (d) 3.89×10^{-10} m

9. Completely filled or half filled set of d-orbitals is assumed to be spherically symmetrical. Which of the following has spherical symmetry?
(a) Pd^{2+} (b) O^{2-}
(c) Cr (d) Ni

10. In absence of Pauli principle, the configuration of $_3Li$ would have been:



11. A $3p$-orbital has:
(a) two spherical nodes
(b) two non-spherical nodes
(c) one spherical and one non-spherical node
(d) one spherical and two non-spherical node

12. Which has maximum number of unpaired electron?
(a) Mg^{2+} (b) Ti^{3+}
(c) V^{3+} (d) Fe^{2+}

13. For a d-electron, the orbital angular momentum is:
(a) $\sqrt{6}\,\hbar$ (b) $\sqrt{2}\,\hbar$
(c) $\hbar$ (d) $2\,\hbar$

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

15. The energy of an electron in the first orbit of H-atom is 13.6 eV. The possible value of excited state for electron in Bohr orbit of H-atom is :
(a) −3.4 eV (b) −4.2 eV
(c) −6.8 eV (d) +6.8 eV

16. The electrons, identified by quantum number n and l, (i) $n=4, l=1$; (ii) $n=4, l=0$; (iii) $n=3, l=2$; (iv) $n=3, l=1$ can be placed into 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)

17. Select the correct statement:
(a) The electron density in the XY plane of $3d_{X^2Y^2}$ orbital is zero.
(b) The energy of $3d$-orbitals is less than $4s$-orbital.
(c) The $3d$-orbitals are far away from nucleus than $4s$-orbital.
(d) Wave function of atomic orbital represents an orbital.

18. Select the correct statement:
(a) Electromagnetic waves with minimum wavelength is radiowave
(b) X-rays are deflected in electric and magnetic field
(c) $E = h\nu$ represents dual nature of electron
(d) No. of nodal planes in $3p$ sub-shell is one

19. The radius of first Bohr's orbit in H-atoms is r_1. The corresponding wavelength of an electron in 2nd orbit is:
(a) $6\pi r_1$ (b) $4\pi r_1$
(c) $2\pi r_1$ (d) $3\pi r_1$

20. The ratio of angular momentum of electron in two successive orbit is a ($a > 1$) and their difference is b. Then a / b is equal to :
(a) $\frac{n}{n+1}$ (b) $\frac{n+1}{n}$
(c) $\frac{n+1}{n}\cdot\frac{h}{2\pi}$ (d) $\frac{n+1}{n}\cdot\frac{2\pi}{h}$

21. The de Broglie wavelength of a particle of mass m and temperature T K is given by :

(a) $\frac{h}{\sqrt{2mkT}}$ (b) $\frac{h}{\sqrt{3mkT}}$

(c) $\frac{h}{\sqrt{4mkT}}$ (d) $\frac{h}{\sqrt{mkT}}$

22. A proton (p) a deutron (D) and an α-particle (α) possess same kinetic energy. The order of de Broglie wavelengths is :

(a) $\lambda_p > \lambda_\alpha > \lambda_D$ (b) $\lambda_D > \lambda_\alpha > \lambda_p$

(c) $\lambda_p > \lambda_D > \lambda_\alpha$ (d) $\lambda_\alpha > \lambda_D > \lambda_p$

23. Number of waves in a Bohr orbit of H-atom is 3. Its potential energy would be ....

(a) – 3.4 eV (b) – 3.02 eV

(c) –1.51 eV (d) – 13.6 eV

24. If a_0 be the radius of first Bohr orbit of H-atom, the de Broglie wavelength of an electron moving in the III Bohr orbit is :

(a) $6\pi a_0$ (b) $2\pi a_0$

(c) $4\pi a_0$ (d) πa_0

25. An electron during its transition shows a decrease in its kinetic energy by 1/4 value. The potential energy change during this transition will be :

(a) $\frac{1}{2}$KE (b) $\frac{3}{4}$KE

(c) $\frac{3}{5}$KE (d) $\frac{3}{8}$KE

26. The momentum of a photon is p, the energy associated with photon is given by :

(a) $\frac{p}{E}$ (b) $\frac{E}{p}$

(c) $p \cdot E$ (d) $\sqrt{\frac{E}{p}}$

27. The ratio of momentum of a proton and an α-particle which are accelerated from rest by a potential difference of 200 V. m_p and m_α are masses of proton and α-particles :

(a) $\sqrt{\frac{2m_p}{m_\alpha}}$ (b) $\sqrt{\frac{m_p}{2m_\alpha}}$

(c) $\frac{m_p}{2m_\alpha}$ (d) $\frac{2m_\alpha}{m_p}$

28. A source of light having wavelength λ ejects photo electron with maximum kinetic energy 1 eV. On irradiating same metal with wavlength $\lambda/3$, the ejected photoelectron possess kinetic energy of 4eV. The work function of metal is :

(a) 2 eV (b) 1 eV

(c) 3 eV (d) 0.5 eV

29. Nodal plane of $3p_y$ orbital lies along the plane :

(a) xy (b) yz

(c) zx (d) either of these

30. The frequency of revolution of electron II excited state He^+ and I excited state of H-atom :

(a) $\frac{27}{32}$ (b) $\frac{32}{27}$

(c) $\frac{1}{8}$ (d) $\frac{4}{1}$

31. When photon of energy 4.25 eV strikes the surface, the ejected electron has maximum kinetic energy T_A expressed in eV and de Broglie wavelength λ_A. The maximum kinetic energy of photoelectrons lilberated by another metal B by photons of 4.70 eV is T_B ($T_B = T_A - 1.5$ eV). If de Broglie wavelength of the electron is λ_B ($\lambda_B = 2\lambda_A$), then which is not correct?

(a) work function of A is 2.25 eV

(b) $T_B = 0.5$ eV

(c) work function of B is 1.20 eV

(d) $T_A = 2.0$ eV

32. The photoelectric work function for a metal surface is 4.125 eV. The cut of wavelength for this surface is :

(a) 3011 Å (b) 2062.5 Å

(c) 4125 Å (d) 6000 Å

33. A black body has maximum wavelength λ_m at 2000 K. Its corresponding wavelength at 3000 K will be :

(a) $\frac{3\lambda}{2}$ (b) $\frac{2\lambda}{3}$

(c) $\frac{16\lambda}{81}$ (d) $\frac{81\lambda}{16}$

34. If particles are moving with same velocity, then which has maximum de-Broglie wavelength?

(a) Proton (b) α-particle

(c) Neutron (d) β-particle

35. A metal surface on capable of showing photoelectric effect does not show this phenomenon on exposure to U.V. rays. The effect can be observed in exposure of surface to :

(a) IR rays (b) X-rays

(c) Radio wave (d) Micro wave

36. An electron is moving round the nucleus of a hydrogen atom in a circular orbit of radius r. The coulombic force $\vec{F}$ between the two is : $\left(K = \frac{1}{4\pi\varepsilon_0}\right)$

(a) $\frac{Ke^2}{r^2}$ (b) $-\frac{e^2}{Kr^2}$

(c) $\frac{e^2}{Kr^2}$ (d) $\frac{-Ke^2}{r^2}$

37. In which of the following systems will the radius of the first orbit is minimum?

(a) Doubly ionised lithium

(b) Singly ionised helium

(c) Deuterum atom

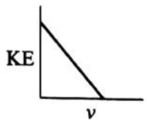
(d) Hydrogen atom

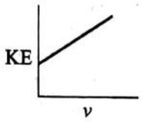
38. The mass number of nucleus is :

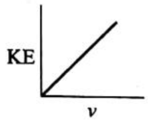
(a) always less than its atomic no.

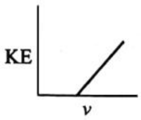
(b) always greater than its atomic no.
(c) some time equal to its atomic no.
(d) some times less than its atomic no.

39. According to Einstein photoelectric effect equation, the graph between the kinetic energy of photoelectron ejected and the frequency (v) of incidented radiations is :

(a) 

(b) 

(c) 

(d) 

40. In India electricity is supplied for domestic use at 220V. It is supplied in USA at 110V. If the resistance of a 60W bulb for use in India is R_1, the resistance of 60W bulb in USA will be :
(a) R (b) $2R$
(c) $\frac{R}{4}$ (d) $\frac{R}{2}$

41. Ionisation potential of hydrogen atom is 13.6 eV. If ground state of H-atom is excited by monochromatic radiations of 12.1 eV, then number of spectral lines emitted by H-atom on deexcitation will be :
(a) 1 (b) 2
(c) 3 (d) 4

42. The momentum of a photon of energy 1MeV in kg-m/s will be :
(a) 5×10^{-22} (b) 0.33×10^{6}
(c) 7×10^{-24} (d) 10^{-22}

43. When photons of energy $h\nu$ fall on an aluminium plate (of work function W_0), photoelectrons of maximum kinetic energy 'K' are ejected. If the frequency of radiation is doubled, the maximum kinetic energy of the ejected photoelectrons will be :
(a) $K+h\nu$ (b) $K+W_0$
(c) $2K$ (d) K

44. The angular momentum of an electron in a H-atom is proportional to (if r is radius of orbit) :
(a) $\frac{1}{\sqrt{r}}$ (b) $\frac{1}{r}$
(c) $\sqrt{r}$ (d) r^2

45. The work function of a photosensitive surface of a metal is 6.2 eV. The wavelength of incident radiation for which stopping potential is 5eV lies in the :
(a) IR region (b) X-ray region
(c) U.V. region (d) visible region

46. Monochromatic light of wavelength 667 mm is produced by helium-neon laser. The power emitted is 9mW. The average number of photons/sec. hitting the target exposed to this beam is :
(a) 9×10^{17} (b) 3×10^{16}
(c) 9×10^{15} (d) 3×10^{19}

47. The potential difference that must be applied to stop the fastest photoelectrons emitted by a nickel surface, having work function 5.01 eV, when U.V. light of 200 nm falls in it, must be :
(a) 2.4 eV (b) − 1.2 V
(c) −2.4 V (d) 1.2 V

48. The work functions for metals A, B and C respectively are 1.92 eV, 2.00 eV and 5.0 eV. Which of them will emit photo electrons if exposed to radiations of wavelength 4100 Å.
(a) A only (b) A and B only
(c) All of these (d) None of these

49. An electron in the ground state of hydrogen has an angular momentum L_1 and electron in the first orbit of Li^{2+} has angular momentum L_2, then
(a) $L_1=L_2$ (b) $L_1=3L_2$
(c) $3L_1=L_2$ (d) $L_1=6L_2$

50. If magnetic quantum number of a given electron in an atom is −3, then what will be its minimum principal quantum no.?
(a) 2 (b) 3
(c) 4 (d) 5

51. Out of a photon and electron, the equation $E=p\cdot c$ (where p is momentum and c is velocity of light) is valid for :
(a) photon only (b) electron only
(c) both (a) and (b) (d) none of these

52. The total number of electrons in one molecule of CO_2 is :
(a) 22 (b) 44
(c) 66 (d) 88

53. The number of neutrons in dipositive zinc ion, with mass number 70 is :
(a) 34 (b) 36
(c) 38 (d) 40

54. Rutherford's experiment on scattering of α-particles showed for the first time that the atom has :
(a) electrons (b) protons
(c) nucleus (d) neutrons

55. The number of unpaired electrons in Ni^{2+} are :
(a) 0 (b) 2
(c) 4 (d) 8

56. Any p-orbital can accommodate upto :
(a) four electrons
(b) six electrons
(c) two electrons with parallel spins
(d) two electrons with opposite spins

57. The principal quantum number of an atom is related to the :
(a) size of the orbital
(b) spin angular momentum
(c) orientation of the orbital in space
(d) orbital angular momentum

58. Rutherford's scattering experiment is related to the size of the :
(a) nucleus (b) atom
(c) electron (d) neutron

59. The increasing order (lowest first) for the values of e/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, α, e (d) n, α, p, e

60. Correct set of four quantum numbers for the valence (outermost) electron of rubidium (Z = 37) is :
(a) 5, 0, 0, + 1/2 (b) 5, 1, 0, + 1/2
(c) 5, 1, 1, + 1/2 (d) 6, 0, 0, + 1/2

61. Which electronic level would allow the hydrogen atom to absorb a photon but not to emit a photon?
(a) 3*s* (b) 2*p*
(c) 2*s* (d) 1*s*

62. Bohr's 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

63. 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

64. Electromagnetic radiation with maximum wavelength is :
(a) ultra violet (b) radio wave
(c) X-ray (d) infra-red

65. Rutherford's alpha particle scattering experiment eventually led to the conclusion that :
(a) mass and energy are related
(b) electrons occupy space around the nucleus
(c) neutrons are buried deep in the nucleus
(d) the point of impact with matter can be precisely determined

66. Which one of the following sets of quantum numbers represents an impossible arrangement?

	n	*l*	*m*	*s*		*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

67. The ratio of the energy of a photon of 2000 Å wavelength radiation to that of 4000 Å radiation is :
(a) 1/4 (b) 4
(c) 1/2 (d) 2

68. The sum of the numbers of neutron and proton in the isotope of hydrogen is :
(a) 6 (b) 5
(c) 4 (d) 3

69. The triad of nuclei that are isotones is :
(a) ${}^{14}_{6}C$, ${}^{15}_{7}N$, ${}^{17}_{9}F$ (b) ${}^{12}_{6}C$, ${}^{14}_{7}N$, ${}^{19}_{9}F$
(c) ${}^{14}_{6}C$, ${}^{14}_{7}N$, ${}^{17}_{9}F$ (d) ${}^{14}_{6}C$, ${}^{14}_{7}N$, ${}^{19}_{9}F$

70. 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 in the energy of the energy levels involved in the transition
(d) the velocity of the electron undergoing the transition

71. The orbital diagram in which the aufbau principle is violated :
(a) 2*s* [⇅] 2*p* [⇅][↑][ ] (b) 2*s* [↑] 2*p* [⇅][↑][↑]
(c) 2*s* [⇅] 2*p* [↑][↑][↑] (d) 2*s* [⇅] 2*p* [⇅][⇅][↑]

72. The correct ground state electronic configuration of chromium atom is :
(a) $[Ar]3d^5 4s^0$ (b) $[Ar]3d^4 4s^2$
(c) $[Ar]3d^6 4s^0$ (d) $[Ar]4d^5 4s^1$

73. The correct set of quantum numbers for the unpaired electron of chlorine atom is :

	n	*l*	*m*		*n*	*l*	*m*
(a)	2	1	0	(b)	2	1	−1 or +1
(c)	3	1	−1 or +1	(d)	3	0	0

74. If the speed of electron in the Bohr's first orbit of H-atom is *X*, the speed of the electron in the third orbit is :
(a) *X*/9 (b) *X*/3
(c) 3*X* (d) 9*X*

75. Which of the following does not characterise X-rays?
(a) The radiation can ionise gases
(b) It causes ZnS to fluorescence
(c) Deflected by electric and magnetic fields
(d) Have wavelengths shorter than ultraviolet rays

76. Which of the following relates to photons both as wave motion and as a stream of particles?
(a) Interference (b) $E = mc^2$
(c) Diffraction (d) $E = h\nu$

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

78. The wave no. for the shortest wavelength transition in the Balmer series of atomic hydrogen is :
(a) $27420\ cm^{-1}$ (b) $28420\ cm^{-1}$
(c) $29420\ cm^{-1}$ (d) $12186\ cm^{-1}$

79. The electron in He^+ ion is excited to next higher state. The ratio of area of shell of excited state to ground state is :
(a) 9 (b) 4
(c) 16 (d) 12

80. For an electron, α-particle and proton to have same de Broglie wavelength, their kinetic energy should be in the order :
(a) $E_\alpha > E_p > E_e$ (b) $E_e > E_p > E_\alpha$
(c) $E_p > E_\alpha > E_e$ (d) $E_p = E_\alpha = E_e$

81. During the transition of electron in H-atom from any lower to higher orbit, the angular momentum cannot be changed by :
(a) $\hbar$ (b) $\frac{\hbar}{2}$
(c) $2\hbar$ (d) $3\hbar$

82. The electronic configuration of an element is $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^1$. This represents its: **(IIT 2000)**
(a) excited state (b) ground state
(c) cationic form (d) anionic form

83. Number of nodal plane in p_x-orbital is: **(IIT 2000)**
(a) 1 (b) 2
(c) 3 (d) 0

84. The wavelength of a golf ball weighing 200 g and moving with a speed of 5 m / h is of the order: **(IIT 2001)**
(a) 10^{-10} m (b) 10^{-20} m
(c) 10^{-30} m (d) 10^{-40} m

85. If I is the intensity of absorbed light and C is the concentration of AB for the photochemical process $AB + h\nu \longrightarrow AB^*$. The rate of formation of AB^* is directly proportional to: **(IIT 2001)**
(a) C (b) I
(c) I^2 (d) $C.I$

86. Rutherford's experiment, which established the nuclear model of the atom, used a beam of: **(IIT 2002)**
(a) β-particles, which impinged on a metal foil and got absorbed
(b) γ-rays, which impinged on a metal foil and ejected electrons
(c) helium atoms, which impinged on a metal foil and got scattered
(d) helium nuclei, which impinged on a metal foil and got scattered

87. If the nitrogen atom and electronic configuration $1s^7$, 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: **(IIT 2002)**
(a) Heisenberg's uncertainty principle
(b) Hund's rule
(c) Pauli exclusion principle
(d) Bohr postulate of stationary orbits

88. The quantum numbers $+1/2$ and $-1/2$ for the electron spin represent: **(IIT 2001)**
(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 states which have no classical analogue

89. The radius of which of the following orbit is same as that of the first Bohr's orbit of hydrogen atom? **(IIT 2004)**
(a) $He^+ (n=2)$ (b) $Li^{2+} (n=2)$
(c) $Li^{2+} (n=3)$ (d) $Be^{3+} (n=2)$

90. The number of radial nodes of 3s and 2p-orbitals are respectively: **(IIT 2005)**
(a) 2, 0 (b) 0, 2
(c) 1, 2 (d) 2, 1

91. The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is : (a_0 is Bohr radius) **(IIT 2012)**
(a) $\frac{h^2}{4\pi^2 m a_0^2}$ (b) $\frac{h^2}{16\pi^2 m a_0^2}$
(c) $\frac{h^2}{32\pi^2 m a_0^2}$ (d) $\frac{h^2}{64\pi^2 m a_0^2}$

92. Energy of an electron is given by $E = -2.178 \times 10^{-18}\ J \left(\frac{Z^2}{n^2}\right)$. Wavelength of light required to excite an electron in an hydrogen atom from level $n = 1$ to $n = 2$ will be :
($h = 6.62 \times 10^{-34}$ Js and $c = 3.0 \times 10^8\ ms^{-1}$)
[JEE (Main) 2013]
(a) 6.500×10^{-7} m (b) 8.500×10^{-7} m
(c) 1.214×10^{-7} m (d) 2.816×10^{-7} m

SOLUTIONS (One Answer Correct)

1. (d) $E_n = -\frac{Rh}{n^2}$ $\therefore n = 3$ Thus, degenerate orbitals of 3rd energy level are $3s$, $3p_x$, $3p_y$, $3p_z$, $3d_{x^2-y^2}$, $3d_{xy}$, $3d_{z^2}$, $3d_{xy}$ and $3d_{yz}$.

2. (c) $\lambda = u$ then $\lambda = \frac{h}{mu}$ or $\lambda = \sqrt{\frac{h}{m}}$

3. (a) Electrons in atom lie in ground state.

4. (b) For Balmer series $\frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$,

$$\frac{1}{4103\times10^{-8}} = 109678\left[\frac{1}{2^2} - \frac{1}{(m+2)^2}\right]$$

$\therefore$ $m = 4$

Thus, m^{th} line represents 4^{th} line of Balmer series.

5. (a) Spin angular momentum $= \frac{h}{2\pi}\sqrt{m_s(m_s+1)}$

$$= \frac{h}{2\pi}\sqrt{\frac{1}{2}\left(\frac{1}{2}+1\right)} = \frac{h}{2\pi}\times\sqrt{\frac{3}{4}} = \frac{\sqrt{3}}{4}\frac{h}{\pi}$$

6. (c) Pd has 18 electrons in 4^{th} shell whereas Cu^{2+} has 17 electrons.

7. (c) Spectrum is observed only when $\Delta l = \pm 1$ and $\Delta m = 0, \pm 1$.

8. (a) $\lambda = \frac{h}{mu}$ and $\frac{1}{2}mu^2 = eV$, $\therefore u^2 = \frac{2eV}{m}$

$$\therefore \lambda = \frac{h}{m\times\sqrt{\frac{2eV}{m}}} = \frac{h}{\sqrt{2meV}}$$

$$= \frac{6.626\times10^{-34}}{\sqrt{2\times9.108\times10^{-31}\times1.602\times10^{-19}\times500}}$$

$= 5.5\times10^{-11}$ m

9. (c) Cr has $3d^5$ configuration.

10. (c) In absence of Pauli principle configuration of Li would have been $1s^3$.

11. (c) Spherical node $= n - l - 1 = 3 - 1 - 1 = 1$

Non-spherical node $= l = 1$

12. (d) Fe^{2+} has four unpaired electron ($1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^6$)

13. (a) Angular momentum in $3d$-orbital

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

$$= \sqrt{6}\frac{h}{2\pi} = \sqrt{6}\hbar\left(\hbar = \frac{h}{2\pi}\right)$$

14. (b) Bohr made use of Planck's quantum of theory to propose his model for atom.

15. (a) $E_n = \frac{E_1}{n^2} = \frac{-13.6}{2^2} = -3.4$ eV

16. (a) Higher is the value of $(n+l)$, more is the energy level of orbital. If $(n+l)$ is same, lower value of n decides lower energy level.

17. (d) Wave function ψ represents an orbital.

18. (c) $E = h\nu$ represents dual nature.

19. (b) $\lambda = \frac{2\pi r_n}{n} = \frac{2\pi\times n^2\times r_1}{n} = 2\pi r_1 \times n$

For H-atom if $n = 2$; $\lambda = 2\pi r_1 \times 2 = 4\pi r_1$

20. (d) Angular momentum in two successive orbitals are $\frac{nh}{2\pi}$ and $(n+1)\frac{h}{2\pi}$

$\therefore$ $a = \frac{n+1}{n}$ and $b = \frac{h}{2\pi}$

$\therefore$ $\frac{a}{b} = \frac{n+1}{n}.\frac{2\pi}{h}$

21. (b) $\lambda = \frac{h}{mu} = \frac{h}{m\sqrt{\frac{3kT}{m}}} = \frac{h}{\sqrt{3mkT}}$ $\quad\because \frac{3}{2}kT = \frac{1}{2}mu^2$

22. (c) $\lambda = \frac{h}{\sqrt{3mkT}}$ $\therefore$ $\lambda \propto \frac{1}{\sqrt{m}}$

23. (b) $P.E = -2\times E_{Total} = -\frac{2\times E_1}{n^2} = -\frac{2\times13.6}{3^2} = -3.02$ eV

24. (a) $\lambda = \frac{h}{mu_3} = \frac{h}{m\cdot\frac{u_1}{3}}$

$= \frac{3h}{mu_1} = \frac{3h}{h/2\pi a_0}$ $\quad\left(\text{Also } mur = \frac{nh}{2\pi}\right)$

$= 6\pi a_0$

25. (a) $\because$ K.E $= -\frac{P.E}{2}$

Let kinetic energy be initially E, then P.E. $= -2E$

New kinetic energy will be $E - \frac{E}{4} = \frac{3E}{4}$

$\therefore$ New potential energy will be $-\frac{3E}{2}$

$\therefore$ Change in potential energy $= 2E - \frac{3E}{2}$

(change is always + ve)

$= \frac{E}{2}$

26. (b) $E = mc^2$

$E = mc\cdot c$

$\therefore$ $c = \frac{E}{mc} = \frac{E}{p}$

27. (b) $QV = \frac{1}{2}mu^2$

(Q is charge, V is accelerating potential)

$\therefore$ $u = \sqrt{\frac{2Q.V}{m}}$

For proton

$u_p = \sqrt{\frac{2Q.V}{m_p}}$; $\therefore$ $m_p\cdot u_p = \sqrt{2Q.V.m_p}$

For α-particle

$$u_\alpha = \sqrt{\frac{2 \times 2QV}{m_\alpha}}; \quad \therefore m_\alpha \cdot u_\alpha = \sqrt{4Q.V.m_\alpha}$$

$$\therefore \frac{\text{momentum of proton}}{\text{momentum of } \alpha} = \sqrt{\frac{m_p}{2m_\alpha}}$$

Now momentum ratio $= \frac{p_p}{p_\alpha} = \frac{m_p \cdot u_p}{m_\alpha \cdot u_\alpha}$

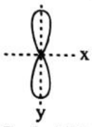
28. (d) $\frac{hc}{\lambda} = 1 + w$

$\frac{3hc}{\lambda} = 4 + w$

$\therefore 3(1 + w) = 4 + w$

$\therefore 2w = 1$

$w = 0.5$

29. (c) 

Probability of finding the electron along *xz*-plane is zero.

30. (b) Frequency (F) of revolution = No. of revolution/sec

$= \frac{u_1 \cdot Z^2}{r_1 n^3}$

(u_1 & r_1 are velocity of H-atom and radius of I orbit)

For H-atom : $Z = 1$, $n = 2$

$\therefore \quad F_H = \frac{u_1 \times 1^2}{r_1 \times 2^3} = \frac{u_1}{8}$

For He^+-atom : $Z = 2$, $n = 3$

$\therefore \quad F_{He^+} = \frac{u_1 \times 2^2}{r_1 \times 3^3} = \frac{4u_1}{27}$

$\frac{F_{He^+}}{F_H} = \frac{32}{27}$

31. (c) Let work function of A and B be W_A and W_B respectively, then

$4.25 = W_A + T_A$

$\therefore \quad T_A = 4.25 - W_A$ ...(i)

$T_B = 4.70 - W_B$ ...(ii)

$\therefore \quad T_B - T_A = 0.45 + W_A - W_B$

$\because \quad T_B - T_A = -1.5$

$\therefore \quad W_B - W_A = 1.95\,\text{eV}$ ...(iii)

Now, $\quad \lambda = \frac{h}{mu} = \frac{h}{\sqrt{2K \cdot m}} \quad \left(\text{KE} = \frac{1}{2}mu^2\right)$

$\therefore \quad \lambda \propto \frac{1}{\sqrt{K}}$ (K is kinetic energy)

$\frac{\lambda_B}{\lambda_A} = \sqrt{\frac{K_A}{K_B}} = 2$

$\therefore \quad \frac{K_A}{K_B} = 4 = \frac{T_A}{T_B}$ (KE $= T$)

or $\quad \frac{T_A}{T_A - 1.5} = 4$

$\therefore \quad T_A = 2\,\text{eV}$

$T_B = 0.5\,\text{eV}$

$W_A = 2.25\,\text{eV}$

$W_B = 4.2\,\text{eV}$

32. (a) Work function $= \frac{hc}{\lambda}$ and

$w = 4.125\,\text{eV} = 4.125 \times 1.6 \times 10^{-19}\,\text{J}$

$\lambda = \frac{6.625 \times 10^{-34} \times 3 \times 10^8}{4.125 \times 1.6 \times 10^{-19}}\,\text{Å} = 3011\,\text{Å}$

33. (b) By Wien's displacement law : $\lambda_{max} \cdot T = \text{constant}$

$\therefore \quad \lambda_1 T_1 = \lambda_2 T_2$

$\lambda \times 2000 = \lambda_2 \times 3000$

$\therefore \quad \lambda_2 = \frac{2\lambda}{3}$

34. (d) $\lambda = \frac{h}{mu} = \frac{K}{m}$ (*u* is same & *h* is a constant)

Lower is *m*, more will be λ.

35. (b) The light used should be of higher energy then UV region.

36. (d) $F = K\frac{Q_1 \times Q_2}{r^2}$

37. (a) $r_1 = \frac{r_H \times n^2}{Z} = \frac{0.529 \times n^2}{Z}$

$\therefore \quad r_1 \propto \frac{1}{Z}$

38. (c) ${}^1_1H$

39. (d) $hv = W + \text{K.E.} = hv_0 + \text{K.E.}$

$\therefore \text{K.E.} = hv - hv_0$

$v = mx + C$ (slope $= -h$ and intercept $= hv_0$)

40. (c) Power $= \frac{V^2}{R}$

$\therefore \frac{V_1^2}{R_1} = \frac{V_2^2}{R_2}$ or $\frac{(220)^2}{R_1} = \frac{(110)^2}{R_2}$

$\therefore R_2 = \frac{R_1}{4}$

41. (c) $E_n = -\frac{13.6}{n^2}$ Also $E = E_n - E_0$

$12.1 = -\frac{13.6}{n^2} + 13.6$

$\therefore \quad n = 3$

Thus, deexcitation will lead spectral lines $= \Sigma\Delta n$

$= \Sigma(3 - 1) = 3$

42. (a) $E = mc^2$

$E = \text{momentum} \times c$

$\therefore$ momentum $= \frac{E}{c} = \frac{10^6 \times 1.6 \times 10^{-19}}{3 \times 10^8}$

$= 5.22 \times 10^{-22}$ kg-m/s^{-1}

43. (a) $hv = w_0 + K$

$2hv = w_0 + K_1$

$\therefore \quad K_1 = hv + K$

44. (c) $\frac{mu^2}{r} = \frac{ze^2}{r^2}$

$\therefore \quad u \propto \frac{1}{\sqrt{r}}$

Also angular momentum $= mur \propto m\frac{1}{\sqrt{r}} \times r \propto m\sqrt{r}$

45. (c) $hv = W + K_{max} = W + eV_0$

or $hv = hv_0 + eV_0$

$\frac{hc}{\lambda} = 6.2 + 5 = 11.2\,\text{eV}$

$\therefore \quad \lambda = \frac{6.625\times10^{-34}\times3\times10^8}{11.2\times1.6\times10^{-19}}$

$= 1.1\times10^{-7}$ m *i.e.*, U.V. region

46. (b) No. of photons emitted/sec $= \frac{E\cdot\lambda}{hc}$

$(\because E = nhv)$ and $E = W \times t$ (per sec.) $= W$

$= \frac{9\times10^{-3}\times6.67\times10^{-7}}{6.6\times10^{-34}\times3\times10^8} = 3\times10^{16}$

47. (d) $E = hv_0 + eV_0$

$hv = \frac{6.626\times10^{-34}\times3\times10^8}{200\times10^{-9}\times1.6\times10^{-19}}\,\text{eV}$

$= 6.2\,\text{eV}$

$\therefore \quad eV_0 = hv - hv_0 = hv - W$

$\therefore \quad eV_0 = 6.2 - 5.01 = 1.2$ eV

or $V_s = 1.2$ V

48. (b) $E = hv = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3.0\times10^8}{4100\times10^{-10}\times1.6\times10^{-19}}\,\text{eV}$

$= 3\,\text{eV}$

Work function should be lower than 3eV to eject electron.

49. (a) Angular momentum in the orbit is $\frac{nh}{2\pi}$

50. (c) For $m = -3, l = 3 \quad \therefore$ minimum value of $n = 4$

51. (a) For photon $E = mc^2$

52. (a) 6 of C and 16 of O; Total 22 electrons.

53. (d) $^{70}_{30}\text{Zn}$; $\therefore$ no. of neutrons in Zn or $Zn^{2+} = 40$

54. (c) All the positive charge concentrated in nucleus and thus scattering occurs.

55. (b) $_{28}\text{Ni}$:....................$3s^2 3p^6 3d^8, 4s^2$

Ni^{2+} :....................$3s^2 3p^6 3d^8$

56. (d) Pauli's exclusion principle. A p orbital contains maximum two electrons and that too with opposite spin.

57. (a) $r_1 \times n^2 = r_n$

where, r_n = radius of n^{th} shell and

n = principal quantum number.

58. (a) Rutherford α-scattering experiment led to discovery of nucleus.

59. (d) $(e/m)_n = \frac{0}{1.675\times10^{-27}\,\text{kg}}$;

$(e/m)_\alpha = \frac{2\times1.602\times10^{-19}\,\text{C}}{4\times1.675\times10^{-27}\,\text{kg}}$;

$(e/m)_p = \frac{1.602\times10^{-19}\,\text{C}}{1.675\times10^{-27}\,\text{kg}}$;

$(e/m)_e = \frac{1.602\times10^{-19}\,\text{C}}{9.108\times10^{-31}\,\text{kg}}$

60. (a) $_{37}Rb$ = 2, (2, 6) (2, 6, 10) (2, 6) (1)

$= 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^6, 5s^1$

Valence electron is $5s^1$.

$5s^1$ [↿]

$\therefore \quad n = 5, l = 0, m = 0, s = +\frac{1}{2}\left(\text{or } -\frac{1}{2}\right)$

61. (d) Ground state of hydrogen atom, *i.e.*, 1s.

62. (b) Bohr's model is based on one electron system

63. (b) $r_{nucleus}$ = ...$\times10^{-13}$ cm; r_{atom} = ...$\times10^{-8}$ cm

64. (b)

Radiation	**Wavelength (incm)**
UV	10^{-5} to 10^{-6}
Radio Wave	1 to 10^2
X-ray	10^{-6} and above
Infra-red	10^{-3} to 10^{-4}

65. (b) Rutherford thus proposed his model.

66. (c) For a given $n, l = 0$ to $n - 1$ and $m = -1$ to $+1$

67. (d) $E_1 = \frac{hc}{\lambda_1}$ and $E_2 = \frac{hc}{\lambda_2}$

$\frac{E_1}{E_2} = \frac{hc}{\lambda_1}\times\frac{\lambda_2}{hc} = \frac{\lambda_2}{\lambda_1} = \frac{4000}{2000} = 2$

68. (d) In ^3_1H

69. (a) All contain 8 neutrons. (Species containing same number of neutrons are called isotones).

70. (c) $\Delta E = \frac{hc}{\lambda_1}$ or $\Delta E \propto \frac{1}{\lambda}$

71. (b) According to aufbau's principle, electrons cannot be filled in $2p$ orbital till $2s$ orbital is incomplete.

72. (d) Half-filled sub-shells are more stable than incomplete sub-shell. Hence, $Cr_{24} = [\text{Ar}]\,3d^5, 4s^1$

73. (c) $_{17}\text{Cl} = 1s^2, 2s^2 2p^6, 3s^2 3p^5$

3s [⇅] 3p [⇅][⇅][↿]

For unpaired electron : $n = 3, l = 1, m = -1$ or $+1$.

74. (b) $u_n = \frac{u}{n}$

75. (c) X-rays are not deflected by electric and magnetic fields.

76. (d) For photon, $E = hv$ (in form of particle and wave)

77. (b) Orbital angular momentum $(mvr) = \frac{h}{2\pi}\sqrt{l(l+1)}$

For $2s$ orbital, l (azimuthal quantum number) = 0

$\therefore$ orbital angular momentum $= \frac{h}{2\pi}\sqrt{0(0+1)}$

$= \frac{h}{2\pi}\sqrt{0} = 0$

78. (a) For shortest wavelength $\Delta E = \frac{hc}{\lambda}$, ΔE should be maximum. Thus $n_1 = 2$ and $n_2 = \infty$

$\therefore \quad \bar{v} = \frac{1}{\lambda} R_H \left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] = 109677 \times \frac{1}{4^2}$

$= 27419.5 \text{ cm}^{-1}$

79. (c) $r_1 \text{ He}^+ = \frac{r_H}{2}$; $r_2 \text{ He}^+ = \frac{r_H \times 2^2}{2} = 2r_1 H$

$\therefore \frac{\text{Area of shell of } r_2 \text{He}^+}{\text{Area of shell of } r_1 \text{He}^+} = \frac{\pi \times (2r_1)^2}{\pi \times \left(\frac{r_1}{2}\right)^2} = 16$

80. (b) $\lambda = \frac{h}{\sqrt{2E \times m}}$

To have same wavelength $E \times m$ must be same

$\because m_e < m_p < m_\alpha$

$\therefore E_{\text{electron}} > E_{\text{proton}} > E_\alpha$

81. (b) Change in angular momentum during transition

$= (n_2 - n_1)\frac{h}{2\pi}$

$= (n_2 - n_1)\hbar$

Also n_1 and n_2 are integers

82. (b, c) The given electronic configuration is for ground state of $_{24}$Cr and of Mn^+. **This question was asked in single answer choice.**

83. (a) Nodal plane in p-orbital = $l = 1$

84. (c) $\lambda = \frac{h}{mu} = \frac{6.626 \times 10^{-27}}{200 \times 5} = 6.626 \times 10^{-30}$ m/h

85. (d) The rate of formation of excited molecule as a result of absorption of light is directly proportional to the intensity of radiations.

i.e., rate = KI (Lamberts law)

but if solution is used then

rate = K.I.C. (Beer's law)

86. (d) Because Rutherford used α-particles and one α-particle is represented as nucleus of helium with 2 protons and 2 electrons.

87. (c) Pauli proposed that s-orbitals cannot have more than two electrons.

88. (d) Spin quantum number was derived in quantum mechanics.

89. (d) $r_2 \text{Be}^{3+} = \frac{r_2 \text{H}}{Z} = \frac{r_1 \text{H} \times 2^2}{Z} = \frac{r_2 \text{H} \times 4}{4} = r_1 \text{H}$

90. (a) Number of radial nodes = $n - l - 1$

For $3s$ it is 2

For $2p$ it is 0

91. (c) As per Bohr's postulate, kinetic energy in II orbit

$= +\frac{e^2}{2r_2} = \frac{e^2}{2a_0 \times 2^2} \quad (\because r_2 = r_1 \times n^2)$

$= \frac{e^2}{8a_0}$

Since, $a_0 = \frac{h^2}{4\pi^2 me^2}$

$\therefore$ Kinetic energy in II orbit $= \frac{h^2}{4\pi^2 ma_0} \times \frac{1}{8a_0} = \frac{h^2}{32\pi^2 ma_0^2}$

92. (c) $E = \frac{hc}{\lambda} = 2.178 \times 10^{-18} \times z^2 \left[\frac{1}{1^2} - \frac{1}{2^2}\right] \quad (z = 1)$

$\therefore \lambda = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{2.178 \times 10^{-18}} \times \frac{4}{3} = 1.214 \times 10^{-7}$ m

OBJECTIVE PROBLEMS (More Than One Answer Correct)

1. If T is the time required by electron in taking one round in an orbit, n represents the number of waves in an orbit, r represents the radius of orbit, then which are correct?

(a) $\frac{r_{2(\text{H})}}{r_{4(\text{He}^+)}} = \frac{1}{2}$ (b) $\frac{T_{2(\text{H})}}{T_{4(\text{He}^+)}} = \frac{1}{2}$

(c) $\frac{n_{2(\text{H})}}{n_{4(\text{H})}} = \frac{1}{2}$ (d) $\frac{E_{2(\text{H})}}{E_{4(\text{He}^+)}} = \frac{1}{2}$

2. Select the correct sentences:

(a) An electron in an orbit can absorb only one photon and that too equivalent in energy to the energy difference between two orbits

(b) $3d$ sub-shell penetrates more towards nucleus than $4s$

(c) Green light is never emitted in black body radiations

(d) The energy change between two successive orbits increases with increasing value of n

3. A metal surface having ν_0 as threshold frequency is incidented by light of frequency ν, then which are correct?

(a) $u = \sqrt{\frac{2h \cdot c(\lambda_0 - \lambda)}{m \cdot \lambda \cdot \lambda_0}}$ (b) $u = \sqrt{\frac{2h(\nu - \nu_0)}{m}}$

(c) $u = \sqrt{\frac{2h(\lambda_0 - \lambda)}{m}}$ (d) $u = \sqrt{\frac{2(h\nu - w)}{m}}$

4. Select the correct statements if $\hbar = \frac{h}{2}$ and $\hbar = \frac{h}{2\pi}$:

(a) $\Delta p \cdot \Delta x = \frac{\hbar}{2\pi}$ (b) $\Delta p \cdot \Delta x = \frac{\hbar}{2}$

(c) $\Delta u_y \cdot \Delta x = \frac{\hbar}{2\pi m}$ (d) $\Delta u_x \cdot \Delta x = \frac{\hbar}{2\pi m}$

5. Which of the following are correct?

(a) Each atom has at least one orbital symmetrical about the nucleus

(b) Each orbit has at least one orbital symmetrical about the nucleus

(c) Number of electrons in Ne having their angular momentum equal to zero is four

(d) Number of waves made by an electron in an orbit is equal to number of orbit

6. Which of the following are correct?

(a) Only Lyman series is observed in emission and absorption spectrum both

(b) The continuum in line spectrum is noticed after a certain value of n

(c) The wavelength of m^{th} line of Balmer series is: $\frac{1}{\lambda} = R_H Z^2 \left[\frac{1}{2^2} - \frac{1}{m^2}\right]$

(d) The number of spectral lines given when electron drops from 5^{th} to 2^{nd} shell is six

7. Select the correct statements:

(a) The concept of shell was given by Bohr

(b) The concept of sub-shells within a shell was given by Pauli

(c) The degeneracy of orbitals exists in presence of magnetic field

(d) The splitting of a line in fine lines under the influence of magnetic field was proposed by Zeeman

8. An isotone of $^{76}_{32}\text{Ge}$ is :

(a) $^{77}_{32}\text{Ge}$ (b) $^{77}_{33}\text{As}$

(c) $^{77}_{34}\text{Se}$ (d) $^{78}_{34}\text{Se}$

9. Many elements have non-integral atomic masses because :

(a) they have isotopes

(b) their isotopes have non-integral masses

(c) their isotopes have different masses

(d) the constituents, neutrons, protons and electrons, combine to give fractional masses

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 particles move with high velocity

11. The atomic nucleus contains :

(a) protons (b) neutrons

(c) electrons (d) photons

12. Which of the following statement(s) is (are) correct?

(a) the electronic configuration of Cr is [Ar] $3d^5 4s^1$. (Atomic number 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 number of Ag = 47)

(d) The oxidation state of nitrogen in HN_3 is -3

13. Decrease in atomic number is observed during :

(a) alpha emission (b) beta emission

(c) positron emission (d) electron capture

14. Ground state electronic configuration of nitrogen atom can be represented by :

(a) [↑↓] [↑↓] [↑][↑][↑] (b) [↑↓] [↑↓] [↓][↓][↓]

(c) [↑↓] [↑↓] [↑][↓][↓] (d) [↑↓] [↑↓] [↑][↑][↓]

SOLUTIONS (More Than One Answer Correct)

1. (a,c) $r_n = r_1 \times n^2$

$r_{2(H)} = r_{1(H)} \times 2^2 = 4r_{1(H)}$

$r_{4He^+} = \frac{r_{1(H)} \times 4^2}{Z} = \frac{r_1 \times 4^2}{2}$

$\therefore \frac{r_{2(H)}}{r_{4He^+}} = \frac{1}{2}$

No. of waves in an orbit = No. of orbit

$\therefore \frac{n_{2H}}{n_{4H}} = \frac{2}{4} = \frac{1}{2}$

$E_n = \frac{E_1}{n^2} \times Z^2$

$E_{2H} = \frac{E_1}{4} \times 1^2$

$E_{4\,He^+} = \frac{E_1 \times 2^2}{4^2}$

$\therefore \frac{E_{2H}}{E_{4\,He^+}} = 1$

Now $T_{2H} = \frac{2\pi r_2}{u_2} = \frac{2\pi r_{1H} \times n^2 \times n}{u_1} = \frac{2\pi r_{1H} \times n^3}{2\pi e^2} \times h$

$= \frac{r_{1H} n^3 h}{e^2} = \frac{r_{1H}\, 2^3 h}{e^2}$

Similarly $T_{4He^+} = \frac{2\pi r_{4\,He^+}}{u_{4\,He^+}} = \frac{2\pi r_{4H} \times n^2}{Z \times u_{nH} \times Z}$

$= \frac{2\pi r_{1H} \times 4^2}{Z^2 \times \frac{u_{1H}}{4}} = \frac{2\pi r_{1H} \times 4^3}{2^2 \times \frac{2\pi r_{1H} e^2}{4 \times h}} = 4^3 \frac{r_{1H} \cdot h}{e^2}$

$T_{4He^+} = \frac{r_1 n^3 h}{e^2 z^2} \quad \therefore \frac{T_{2H}}{T_{4He^+}} = \frac{2^3}{4^3} = \frac{1}{8}$

2. (a,b,c) $E_2 - E_1 > E_3 - E_2 > E_4 - E_3 \ldots$

3. (a,b,d) $h\nu = h\nu_0 + \frac{1}{2}mu^2$

$\therefore u = \sqrt{\frac{2h(\nu - \nu_0)}{m}} = \sqrt{\frac{2hc[\lambda_0 - \lambda]}{m(\lambda_0 \times \lambda)}}$

$h\nu = w + \frac{1}{2}mu^2$

$\therefore u = \sqrt{\frac{2(h\nu - w)}{m}}$

4. (a,b,d) Heisenberg principle is $\Delta p \cdot \Delta x = \frac{h}{4\pi} = \frac{\hbar}{2\pi} = \frac{\hbar}{2}$

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

Note that the principle loses its significance if Δu and Δx are not considered along same axis.

5. (a,b,c,d) For emission of λ; Δn = any value, $\Delta l = \pm 1$, $\Delta m = 0, \pm 1$

Ne has 4 electrons in *s*-orbitals: $1s^2, 2s^2 2p^6$

For a given n, $l = 0$ to $(n-1)$

6. (a,b,d) m^{th} line, $\frac{1}{\lambda_B} = R_H \cdot Z^2 \left[\frac{1}{2^2} - \frac{1}{(m+2)^2}\right]$; ΔE of two successive orbits becomes almost constant after a certain value of n.

Number of lines = $\Sigma\Delta n = \Sigma 5 - 2 = \Sigma 3 = 6$

7. (a,d) In presence of magnetic field orbitals are non-degenerate, *i.e.*, possess different energy levels.

8. (b,d) $^{77}_{33}$As and $^{78}_{34}$Se have same number of neutrons (A–Z) as $^{72}_{36}$Ge.

9. (d) Mass of an atom is due to masses of p, n and 'e' which are not integers. (a), (b), (c) choices are for non-integral at. wt.

10. (c,d) α-particles pass through because most part of the atom is empty.

11. (a,b) Nucleus contains protons and neutrons.

12. (a,b,c)

(a) $_{24}Cr = 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^1$

$= [Ar]\, 3d^5 4s^1$

(b) For magnetic quantum number (m) negative values are possible.

For *s*-sub-shell : $l = 0$, hence $m = 0$

For *p*-sub-shell : $l = 1$, hence $m = -1, 0, +1$

(c) $_{47}Ag = 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^6 4d^{10}, 5s^1$

Hence, 23 electrons have a spin of one type and 24 of the opposite type.

(d) Oxidation state of N in HN_3 is $-\frac{1}{3}$.

13. (a,c,d)

$^{11}_{6}C \longrightarrow {}^{11}_{5}B + {}^{0}_{+1}e$ (Positron emission)

$^{133}_{56}Ba + {}^{0}_{-1}e \longrightarrow {}^{133}_{55}Cs$ + X-rays (K-electron capture)

$^{235}_{92}U \longrightarrow {}^{231}_{90}Th + {}^{4}_{2}He$ (α-emission)

14. (a,b) By Hund's rule

COMPREHENSION BASED PROBLEMS

Comprehension 1 : 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 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.

[1] The principal quantum number of initially excited level B is:
(a) 2 (b) 3
(c) 4 (d) 5

[2] The ionisation energy for the gas atoms.
(a) 14.0 eV (b) 14.4 eV
(c) 13.6 eV (d) 20.2 eV

[3] Find the maximum and the minimum energies of the emitted photons.
(a) 14.4, 13.6 eV (b) 13.4, 14.6 eV
(c) 13.5, 0.7 eV (d) 0.7, 13.5 eV

Comprehension 2 : Whenever an electron falls from a higher level of energy to lower level of energy, equivalent amount of energy is given out. The jump of electron not only depends on major energy shell but also on the nature of orbital. The emission of energy is derived from Bohr's model and the possibility of jump is decided by the selection rule. According to Bohr's theory E_1 for H-atom is 2.17×10^{-18} J/atom.

[1] In which of the following jump of electron is possible?
(a) $3d$ to $1s$ (b) $4d$ to $3s$
(c) $4f$ to $2s$ (d) $3p$ to $2s$

[2] The shortest frequency which can remove 2^{nd} electron of He atom with a velocity of 10^5 m / sec :
(a) 3.28×10^{15} Hz (b) 13.45×10^{15} Hz
(c) 23.21×10^{15} Hz (d) 4.5×10^{15} Hz

[3] The angular frequency of an electron occupying the second Bohr's orbit of He^+ is:
(a) 2.07×10^{16} sec^{-1} (b) 2.07×10^{17} sec^{-1}
(c) 2.07×10^{18} sec^{-1} (d) 2.07×10^{15} sec

[4] The wavelength of H_B-line of Balmer series of H-atom is:
(a) 386 nm (b) 486 nm
(c) 586 nm (d) 686 nm

[5] The corresponding H_B-line of He^+ ion has frequency:
(a) 18.64×10^{14} (b) 9.12×10^{14}
(c) 4.56×10^{14} sec^{-1} (d) 2.46×10^{15} Hz

[6] The longest wavelength of light which can remove electron completely from 2^{nd} orbit of H-atom.
(a) 4000 Å (b) 3000 Å
(c) 5060 Å (d) 3663.6 Å

Comprehension 3 : The hydrogen like species Li^{2+} is in a spherically symmetric state S_1 with one radial node. Upon absorbing light the ion undergoes to transition to a state S_2. The state S_2 has one radial node and its energy is equal to the ground state of the H-atom. **[IIT 2010]**

[1] The state S_1 is:
(a) $1s$ (b) $2s$
(c) $2p$ (d) $3s$

[2] Energy of the state S_1 in units of H-atom ground state energy is:
(a) 0.75 (b) 1.50
(c) 2.25 (d) 4.50

[3] The orbital angular momentum quantam number of the state S_2 is:
(a) 0 (b) 1
(c) 2 (d) 3

Comprehension 4 : The letters n, l, m proposed by Bohr, Sommerfeld and Zeeman respectively for quantisation of angular momentum in classical physics were later on obtained as the results of solution of Schrödinger wave equation based on quantum mechanics. The term n, l, m were named as principal quantum number, azimuthal quantum number and magnetic quantum number respectively. The fourth quantum number s was given the name spin quantum number on the basis of two spins of electrons. The first two quantum numbers also decides the nodes of an orbital.

[1] The numerical value $\psi_{4,3,0}$ denotes :
(a) $3d$-orbitals (b) $4f$-orbitals
(c) $2s$-orbitals (d) $4d$-orbitals

[2] The angular momentum of $3p$-orbitals in terms of $\hbar \left\{\hbar = \frac{h}{2\pi}\right\}$ is :
(a) $\sqrt{2}\,\hbar$ (b) $2\,\hbar$
(c) $\frac{\hbar}{\sqrt{2}}$ (d) $\frac{\hbar}{2\pi}$

[3] Which statement about energy level in H-atom is correct?
(a) Only n and l decides energy level
(b) Only 'l' decides energy level
(c) Only n decides energy level
(d) n, l and m decides energy level

[4] Δu_x is uncertainty in velocity of electron and Δx_y is uncertainty in position, then :
(a) $\Delta u_x \cdot \Delta x_y = \frac{h}{4\pi}$ (b) $\Delta u_x \cdot \Delta x_y = \frac{h}{4\pi m}$
(c) $\Delta u_x \cdot \Delta x_y \geq \frac{h}{4\pi m}$ (d) none of these

SOLUTIONS

Comprehension 1

[1] (a) The electrons being present in I 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 λ and thus excited state n_2 comes to be 4. $[6 = \Sigma \Delta n = \Sigma(n_2 - 1) \therefore n_2 = 4]$

Now $E_1 = -\frac{R_h \cdot c \cdot h}{1^2}$; $E_{n_1} = -\frac{R_h \cdot c \cdot h}{n_1^2}$;

$$E_4 = -\frac{R_h \cdot c \cdot h}{4^2}$$

Since, de-excitation leads to different λ having photon energy $\lesseqgtr 2.7$ eV and thus absorption of 2.7 eV energy causing excitation to IV shell and then re-emitting photons of $\lesseqgtr 2.7$ eV are possible only when $n_1 = 2$ (the de-excitation from IV shell occurs in I, II and III shell).

$$E_4 - E_2 = 2.7\text{eV}$$
$$E_4 - E_3 < 2.7\text{eV}$$
$$E_4 - E_1 > 2.7\text{eV}$$
$$\therefore \; E_{n_1} = E_2 = \frac{R_h \cdot c \cdot h}{2^2} = \frac{E_1}{2^2}$$

since $n_1 = 2$ (as obtained by discussion)

[2] (b) Also, $E_4 - E_2 = 2.7$eV

$\therefore \quad -\frac{E_1}{4^2} + \frac{E_1}{2^2} = 2.7$eV

$\therefore \quad E_1 = -14.4$ eV

$\therefore \quad$ **IP = 14.4 eV**

[3] (c) $E_{max} = E_4 - E_1 = -\frac{E_1}{4^2} + \frac{E_1}{1^2} = -\frac{14.4}{16} + 14.4 = \mathbf{13.5\ eV}$

$E_{min} = E_4 - E_3 = -\frac{E_1}{4^2} + \frac{E_1}{3^2} = \mathbf{0.7\ eV}$

Note: It is ${}_1H^2$ atom.

Comprehension 2

[1] (d) For a jump $\Delta l = \pm 1$ according to selection rule

[2] (a) Total $E_{needed} = E_{needed}$ to remove 2nd electron from He $+ \frac{1}{2}mu^2$

$$= E_{2_{He^+}} + \frac{1}{2} \times 9.108 \times 10^{-31} \times (10^5)^2 \text{ Joule}$$
$$= E_{2H} \times Z^2 + 4.554 \times 10^{-21}$$
$$= \frac{E_1}{n^2} \times Z^2 + 4.554 \times 10^{-21}$$
$$= 2.17 \times 10^{-18} + 4.554 \times 10^{-21} \qquad (n = 2; Z = 2)$$
$$E = 2.1746 \times 10^{-18} = h\nu$$
$$\therefore \; \nu = \frac{2.1746 \times 10^{-18}}{6.626 \times 10^{-34}} = \mathbf{3.28 \times 10^{15}\ Hz}$$

[3] (a) Velocity of electron in He^+ ion in an orbit $(u) = \frac{2\pi Z e^2}{nh}$

Radius of He^+ ion in an orbit $(r_n) = \frac{n^2 h^2}{4\pi^2 me^2 Z}$

∴ Angular frequency or angular velocity

$$\omega = \frac{u}{r_n} = \frac{2\pi Z e^2 \times 4\pi^2 me^2 Z}{nh \times n^2 h^2} = \frac{8\pi^3 Z^2 me^4}{n^3 h^3}$$

$\because \quad n = 2,\ m = 9.108 \times 10^{-28}$ g,

$Z = 2,\ h = 6.625 \times 10^{-27}$

$$\therefore w = \frac{8 \times (22/7)^3 \times (2)^2 \times 9.108 \times 10^{-28} \times (4.803 \times 10^{-10})^4}{(2)^3 \times (6.625 \times 10^{-27})^3}$$
$$= \mathbf{2.067 \times 10^{16}\ sec^{-1}}$$

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

$$= 109678 \times 1^2 \left[\frac{3}{16}\right]$$

$\therefore \quad \lambda = 4.86 \times 10^{-5}$ cm $= 4.86 \times 10^{-7}$ m

$= 486 \times 10^{-9}$ m $= 486$ nm

[5] (c) $\lambda_{He^+} = 1.216 \times 10^{-5}$ cm $\qquad \left(\lambda^+_{He} = \frac{\lambda_H}{Z^2}\right)$

$$\nu = \frac{c}{\lambda} = \frac{3 \times 10^{10}}{1.216 \times 10^{-5}} = \mathbf{2.467 \times 10^{15}\ Hz}$$

[6] (d) $E_n = -\frac{21.7 \times 10^{-12}}{n^2}$ erg

$\therefore \quad E_2 = -\frac{21.7 \times 10^{-12}}{4} = -5.425 \times 10^{-12}$ erg

∴ For removal of electron $E_2 = \frac{hc}{\lambda}$; E_2 should be given to remove electron, *i.e.*, + ve.

$$\therefore \quad \lambda = \frac{6.625 \times 10^{-27} \times 3.0 \times 10^{10}}{5.425 \times 10^{-12}}$$
$$= 3663.6 \times 10^{-8} \text{ cm} = \mathbf{3663.6\ Å}$$

So, the longest wavelength is **3663.6 Å.**

Comprehension 3

Energy in state S_2 of $Li^{2+} = E_1$ of $Li^{2+} = E_1$ of $H = -13.6$eV

Also, E_{S_2} of $Li^{2+} = \frac{E_{1H} \times z^2}{n^2} = \frac{-13.6 \times 3^2}{n^2}$

$\therefore \quad n = 3$

The state S_2 represents 3rd orbital with one radial node, *i.e.*, 3*p* radial node $= n - l - 1 = 1$

The state S_1 represents 2*s* (as $n - 1 - l = 1$). Also transition is possible from 2*s* to 3*p* $\Delta l = \pm 1$ and $E_{S_1} = \frac{E_{1H} \times 3^2}{2^2} = 2.25 \times E_{1H}$; For state S_2 (*i.e.*, 3*p*) $l = 1$

1. (b) 2. (c) 3. (b)

Comprehension 4

[1] (b) ψ represents an orbital and $\psi_{4,3,0}$, has $n = 4$, $l = 3$, *i.e.*, 4*f*-orbital.

[2] (a) Angular momentum in an orbital $= \sqrt{l(l+1)} \cdot \frac{h}{2\pi}$

$$= \sqrt{l(l+1)} \cdot \frac{h}{2\pi} = \sqrt{2} \times \hbar$$

[3] (c) Subshells of a shell in H-atom possess same energy level, *i.e.*, *l* does not specify for the energy level of an orbital in H-atom.

[4] (d) Heisenberg principle has no significance of Δu is along *X*-axis and ΔX along *Y*-axis are given.

STATEMENT EXPLANATION PROBLEMS

In each sub question given below a statement (S) and explanation (E) is given. Choose the correct answers from the codes (a), (b), (c) and (d) given for each question:

(a) S is correct but E is wrong
(b) S is wrong but E is correct
(c) Both S and E are correct and E is correct explanation of S
(d) Both S and E are correct but E is not correct explanation of S

1. S : Transition of electron between p_x and p_y would not lead to an spectral line.
E : p-orbitals are degenerate orbitals.

2. S : Number of sub-shells in a shell is equal to the number of shell.
E : According to Sommerfeld :
$$\frac{n}{k} = \frac{\text{Length of major axis}}{\text{Length of minor axis}}$$

3. S : Electronic configuration of $_{23}V^{3+}$ ion is $[Ar]^{18}\,3d^2$ and not $[Ar]^{18}\,3d^0\,4s^2$.
E : V^{3+} ion is diamagnetic in nature.

4. S : Bohr proposed that angular momentum of electron in an orbit is quantised.
E : de Broglie derived that : $mur = n\frac{h}{2\pi}$.

5. S : Number of waves in an orbit of atom is equal to number of that orbit.
E : Number of waves in an orbit is derived by $\frac{2\pi r_n}{\lambda}$.

6. S : Matter waves and electromagnetic waves differ from each other in many respect.
E : The matter waves possess lesser wave number than electromagnetic waves as well as cannot radiate in empty space.

7. S : A triply ionised Be-atom has the same radius of 2nd orbit as that of ground state of H-atom.
E : The radius of an orbit is $r_n = \frac{r_1 \times n^2}{Z}$.

8. S : Wavelength of I line of Humphrey series is more than I line of Lyman series in H-atom.
E : $\Delta E = \frac{hc}{\lambda}$.

9. S : The energy radiated per unit volume, *i.e.*, energy density in black body radiation depends upon the temperature.
E : Green light is never emitted in black body radiations.

10. S : The magnetic moment of Mg-atom is more than K-atom as the former has two electrons in outermost shell.
E : The magnetic moment of N-atom is more than magnetic moment of O-atom and former has more number of unpaired electrons.

11. S : An electron in an s-orbital has a non-zero probability of being found right at the nucleus.
E : $l = 0$ for s-orbitals and thus there is no orbital angular momentum to fling the electron away from the nucleus.

12. S : An electron in s-orbital is not circulating around the nucleus but simply as distributed around it whereas an electron in p-orbital can be thought of as circulating around the nucleus.
E : For s-orbital angular momentum is zero for a p-orbital angular momentum is non-zero.

13. S : All s-orbital in H-atom corresponds to a non-zero probability density at nucleus.
E : The probability density is given by : ψ^2 and $\psi \propto e^{-\frac{Zr}{2a_0}}$.

14. S : The location and momentum of an electron in an orbital are complementry to each other.
E : The statement is against Heisenberg uncertainty principle.

15. S : Studies on black body radiations led to Planck's hypothesis of quantisation of electromagnetic radiations.
E : Photoelectric effect provides evidence of the particle nature of electromagnetic radiation whereas diffraction provides evidence of its wave nature.

16. S : The minimum frequency of radiations to show photoelectric effect depends upon the work function.
E : The concept is used to determine identity of the metals.

17. S : The $3p$-orbital has higher energy level than $3s$ in He^+ ion.
E : The energy of an orbital depends upon n and l.

18. S : Specific charge of α-particles is twice to that of proton.
E : Specific charge is given by e/m.

19. S : d-orbitals are five fold non-degenerate in presence of magnetic field.
E : In presence of magnetic field the energy of orbitals becomes altogether different.

20. S : Electromagnetic radiations will be emitted for the transition of $2p$ to $2s$-orbital in H-atom.

E : Both have same energy level and thus, no transition.

21. S : The ψ_{640} represents an orbital.

E : The orbital may be 6 g.

22. S : Monochromatic X-rays fall on lighter elements such as carbon and show scattering under the name of Compton effect.

E : $\lambda_{scattered}$ light is always lower than $\lambda_{incident}$ light.

23. S : $_{24}Cr$ has more paramagnetic nature than $_{25}Mn$.

E : Cr has more number of unpaired electrons than Mn.

24. S : The possible number of orientations of a sub-shell is $(2l+1)$.

E : The possible number of electrons in a sub-shell is $(4l+2)$.

25. S : Aufbau rule is violated in writing electronic configuration of Pd.

E : Pd shows diamagnetic nature.

26. S : Humphrey series discovered in H atomic spectra has lowest energy radiations.

E : The series belongs to $n_1 = 6$.

27. S : $Cu^{+}_{(aq.)}$ has less stable nature than $Cu^{2+}_{(aq.)}$ but $Fe^{3+}_{(aq.)}$ is more stable than $Fe^{2+}_{(aq.)}$.

E : Half filled and completely filled, subshells are more stable.

28. S : $2p$-orbitals do not have any spherical node.

E : The number of spherical and angular node is equal to $(n-l-1)$ and l respectively.

29. S : Dipositive zinc ion exhibits paramagnetism due to the loss of two electrons from $3d$-orbitals of neutral atom.

E : Paramagnetism is due to the presence of unpaired electron.

30. S : As the distance of shell increases from the nucleus, its energy level increases.

E : The energy of a shell is $E_n \propto -1/n^2$.

31. S : Zn^{2+} is diamagnetic

E : The electrons are lost from $4s$ orbital from Zn^{2+}

32. S : A spectral line is seen when electron jumps from $4d$ to $3s$

E : A spectral line is seen when electron jumps from $4d$ to $3p$

33. S : H-atom has only one electron in its orbit, but several spectral lines are noticed

E : The H-spectra is observed in H_2 gas

34. S : All the d-orbitals are identical in shape.

E : All the p-orbitals are identical in shape.

35. S : Band gap in germanium is small. **(2007)**

E : The energy spread of each germanium atomic energy level is infinitesimally small.

ANSWERS (Statement Explanation Problems)

1. (c) Degenerate orbitals possess same energy and thus, transition between p_x and p_y will not radiate energy.
2. (c). $k = 1$ to n and cannot be zero
$\therefore$ For fourth shell $k = 1, 2, 3, 4$, *i.e.*, four sub-shells.
3. (a) $_{23}V:[Ar]3d^3, 4s^2; V^{3+}:[Ar]3d^2$. Also it is paramagnetic due to the presence of two unpaired electrons.
4. (d) Both are facts.
5. (c) On substituting $r_n \left(mur_n = \frac{n \cdot h}{2\pi}\right)$ and $\lambda \left(\lambda = \frac{h}{mu}\right)$ in $\frac{2\pi r_n}{\lambda}$, number of waves comes equal to n.
6. (c) Explanation is correct reason for statement.
7. (c) $r_n = \frac{r_1 \times n^2}{Z}$ for $r_{2_{Be^{3+}}} = \frac{r_1 \times 2^2}{4}$ and for $r_{1H} = \frac{r_1 \times 1^2}{1}$
8. (c) $\Delta E_1 = E_6 - E_5$ in Humphrey series and $\Delta E = E_2 - E_1$ for Lyman series
$\because \quad \Delta E > \Delta E_1$
$\therefore \quad \lambda_{Lyman} < \lambda_{Humphrey}$
9. (d) Both are facts.
10. (b) Magnetic moment depends upon number of unpaired electrons and given by $= \sqrt{n(n+2)}$, where n is no. of unpaired electrons.

	Valence electron	Unpaired electron
K	1	1
Mg	2	0
N	3	3
O	4	2

11. (c) Explanation is correct reason for statement.
12. (c) Explanation is correct reason for statement.
13. (c) $\psi \propto e^{-\frac{Zr}{2a_0}}$ at $r = 0$; $\psi^2 \propto e^{-0} \propto 1$
14. (a) The statement belongs to Heisenberg uncertainty principle.
15. (d) Both are facts.
16. (d) Both are facts.
17. (b) Higher is the value of $(n + l)$ more is the energy level of orbital for one electron systems energy of $3s = 3p$.
18. (b) Specific charge for proton $= \frac{e}{m}$ and
specific charge of $\alpha = \frac{2e}{4m} = \frac{e}{2m}$
19. (c) Presence of magnetic field shows different repulsions for micromagnetic character developed in d-orbitals due to different orientations.
20. (b) In H like atom energy, of an orbital is decided by 'n' only and not by 'l'.
21. (d) ψ represents an orbital ψ_{640} means $n = 6$, $l = 4$, $m = 0$, *i.e*, 6 g orbital.
22. (a) In Compton effect $\lambda_{scattered} > \lambda_{incident}$.
23. (c) $_{24}Cr$ has all six unpaired electrons whereas $_{25}Mn$ has five unpaired out of seven electrons. Both have 5 d-electrons.
24. (c) The values of m are $-l$ to $+l$ through zero, *i.e.*, total $(2l+1)$ orbitals and each orbital has two electrons.
25. (c) Pd being diamagnetic and thus, has $4d^{10}$ configuration rather than $4d^8 5s^2$.
26. (c) For Humphrey series $\Delta E = E_{n_2} - E_5$, *.i.e.*, very small.
27. (d) In Cu^+, no doubt outer shell has $3d^{10}$ or completely filled configuration but hydration energy of Cu^+(aq.) is more.
28. (c) Explanation is correct answer for statement.
29. (b) Zn^{2+} shows paramagnetism due to the presence of unpaired electrons but electrons are lost from Zn from 4s subshell.
30. (c) $E_n \propto -\frac{1}{n^2}$; thus if n increase; E_n increases.
31. (d) Zn : .....$3s^2 3p^6 3d^{10} 4s^2$
Zn^{2+} : .....$3s^2 3p^6 3d^{10}$ (diamagnetic due to no unpaired electron)
32. (b) For spectral line to be given $\Delta l = \pm 1$
33. (c) H_2 gas has so many molecules which are dissouated to from a large no. of H-atoms having different energy levels.
34. (b) One of the d-orbital has baby soother shape.
35. (c) Germanium, semi-conductor substance, has small band gap in comparison to insulator (non-metal).

MATCHING TYPE PROBLEMS

Type I : Only One Match Possible

1.

List-A	List-B
A. r_n	1. n^{-2}
B. E_n	2. n^2
C. U_n	3. n^{-1}
D. Angular momentum of orbit	4. n

2. According to Bohr's concept, E_n is total energy, K_n is kinetic energy, V_n is potential energy, r_n is radius of n^{th} orbit.

List-A	List-B
A. $\frac{V_n}{K_n}$	1. 0
B. $r_n \propto E_n^x$, then $x =$	2. −1
C. Angular momentum in lowest orbit	3. −2
D. $(r_n)^{-1} \propto u_n^Y$, then $Y =$	4. 1

3.

List-1	List-2
A. Number of electrons in a *p*-orbital	a. $4l+2$
B. Number of orbitals in a shell	b. $2l+1$
C. Number of orbital in a sub-shell	c. n
D. Number of electrons in a sub-shell	d. 2

4.

List-1	List-2
A. Orbital angular momentum of $4f$-sub-shell	a. zero
B. Total spin of 6 electrons in *p*-sub shell	b. $\frac{3h}{\pi}$
C. Angular momentum of electron in 6th shell	c. $\frac{\sqrt{3}}{4}\frac{h}{\pi}$
D. Spin angular momentum of $3d^8$ sub-shell	d. $\sqrt{3}\frac{h}{\pi}$

5.

List-1	List-2
A. Mass spectrum	a. Wave function
B. X-ray spectrum	b. Unpaired electrons
C. Paramagnetism	c. Atomic number
D. Orbital	d. Isotopes

Type II : More than one match are Possible

6.

List-A	List-B
A. Orbital angular momentum of the electron in a H-like atom	1. Principal quantum number
B. Wave function of a H-like atom obeying Pauli principle	2. Azimuthal quantum number
C. Shape, size and orientation of H-like orbitals	3. Magnetic quantum number
D. Probability density of electron at the nucleus in H-like atom	4. Electron spin quantum number

7.

List-A	List-B
A. 1 B.M	1. Spin magnetic moment
B. 1 NM	2. Nuclear magnetic moment
C. Doughnut structure	3. 9.27×10^{-24} J/T
D. ψ_{320}	4. 5.051×10^{-27} J/T
E. Two nodal planes	5. $3d_{z^2}$

8.

List-1	List-2
A. $3d_{z^2}$	a. Two angular mode
B. $3d_{x^2-y^2}$	b. Doughnut shape
C. $5f$	c. Zero node
D. $2s$	d. Four total nodes

9.

Column-I	Column-II
A. Diffraction	i. Wave motion
B. Interference	ii. Mass decay
C. Photoelectric effect	iii. Particle nature
D. $E = mc^2$	iv. Planck's theory
E. $E = h\nu$	v. Threshold frequency

Type III : Only one Match from each list

10.

List-A	List-B	List-C
(A) Density of nucleus	1. 10^{-15} m^3	a. Independent of mass number
(B) Nuclear radius	2. 10^{17} kg / m^3	b. Dependent of mass number
(C) Higher *e/m*	3. -1.76×10^{11} C kg^{-1}	c. Electron
(D) Lower *e/m*	4. 9.58×10^{7} C kg^{-1}	d. Proton
(E) $\lambda = 91.75\left[\frac{n^2}{n^2-1}\right]$	5. Balmer series	e. λ in Å
(F) $\lambda = 3647\left[\frac{n^2}{n^2-4}\right]$	6. Lyman series	f. λ in nm

ANSWERS

1. A–2; B–1; C–3; D–4
2. A–3; B–2; C–1; D–4
3. A–d; B–c; C–b; D–a
4. A–d; B–a; C–b; D–c
5. A–d; B–c; C–b; D–a
6. A–2; B–1; C–1, 2, 3; D–none
7. A–1, 3; B–2, 4; C–5; D–5; E–5.
8. A–b; B–a, b; C–d; D–c
9. A–i; B–i; C–iii, v; D–ii, iii; E–i, iii, iv
10. A–2– a; B–1–b; C–4–d; D–3–c; E–6–f; F–5–e