SOLVED EXAMPLES

Ex. 1 The orbital angular momentum of a d-electron is :-

(A) $\sqrt{6}\hbar$ **(B)** $\sqrt{2}\hbar$ **(C)** $\hbar$ **(D)** $2\hbar$

Sol. For d–electron, $\ell = 2$, orbital angular momentum $= \sqrt{\ell(\ell+1)}\hbar = \sqrt{2(2+1)}\hbar = \sqrt{6}\hbar$

So, **(A)** is the correct answer

Ex. 2 An orbital is correctly described by :-

(A) Ψ^2 **(B)** Ψ **(C)** $|\Psi^2|\Psi$ **(D)** none

Sol. **(A)**

Ex. 3 The wave-mechanical model of atom is based upon :-

(A) de Broglie concept of dual character of matter
(B) Heisenberg's uncertainty principle
(C) Schrodinger wave equation
(D) All the above three

Sol. **(D)**

Ex. 4 The electronic configuration of an element is $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5, 4s^1$. This represents its :-

(A) excited state **(B)** ground state **(C)** cationic form **(D)** anionic form

Sol. The given electronic configuration is ground state for chromium.
So, **(B)** is the correct answer

Ex. 5 Which of the following sets of quantum number is/are incorrect ?

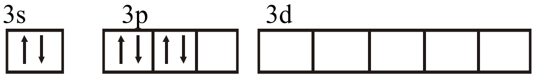
(A) $n = 3, \ell = 3, m = 0, s = \frac{1}{2}$ **(B)** $n = 3, \ell = 2, m = 2, s = -\frac{1}{2}$

(C) $n = 3, \ell = 1, m = 2, s = -\frac{1}{2}$ **(D)** $n = 3, \ell = 0, m = 0, s = +\frac{1}{2}$

Sol. When n = 3, ℓ cannot be 3, so **(A)** is incorrect when l = 1, m cannot be = +2.
So, **(C)** is incorrect
So, **(A)** and **(C)** is the correct answer.

Ex. 6 The following electron configuration of an atom in the ground state is not correct because :-

3s 3p 3d



(A) the energy of the atom is not minimum **(B)** Pauli's exclusion principle is violated
(C) Hund's rule is violated **(D)** Aufbau principle is not followed

Sol. **(C)** is the correct answer.

Ex. 7 In the first bohr orbit of H atom the energy of an electron is –13.6 eV. The possible energy value (s) of excited state (s) for electron in Bohr orbit of hydrogen is/are :-

(A) –3.4 eV **(B)** –4.2 eV **(C)** 6.8 eV **(D)** +6.8 eV

Sol. $E_n = \frac{-13.6}{n^2} eV$

For n = 2, $E_2 = \frac{-13.6}{4} = -3.4 eV$

So, **(A)** is the correct answer.

Ex. 8 Select the pairs of ions which have same electronic configuration ?

(A) Cr^{3+}, Fe^{3+} **(B)** Fe^{3+}, Mn^{2+} **C)** Fe^{3+}, Co^{3+} **(D)** Se^{3+}, Cr^{3+}

Sol. Fe^{3+} and Mn^{2+} have same electronic configuration

So **(B)** is the correct answer.

Ex. 9 If an electron in H atom has an energy of –78.4 kcal/mol. The orbit in which the electron is present is :-

(A) 1^{st} **(B)** 2^{nd} **(C)** 3^{rd} **(D)** 4^{th}

Sol. $E^n = \frac{-313.6}{n^2} \text{kcal / mol} \Rightarrow -78.4 = \frac{-313.6}{n^2} \quad \therefore n = 2$

Ex. 10 What transition in the hydrogen spectrum would have the same wavelength as the Balmer transition, n = 4 to n = 2 in the He^+ spectrum ?

(A) n = 4 to n = 2 **(B)** n = 3 to n = 2 **(C)** n = 3 to n = 1 **(D)** n = 2 to n = 1

Sol. $\bar{\nu} = \frac{1}{\lambda} = \left(\frac{1}{2^2} - \frac{1}{4^2}\right) RZ^2 = \frac{3}{4} R$

In H–spectrum for the same $\bar{\nu}$ or λ as Z = 1, n = 1, $n_2 = 2$

So, **(D)** is the correct answer.

Ex. 11 Difference between n^{th} and $(n + 1)^{th}$ Bohr's radius of H–atom is equal to its $(n – 1)^{th}$ Bohr's radius. The value of n is :-

(A) 1 **(B)** 2 **(C)** 3 **(D)** 4

Sol. $r_n \propto n^2$

But $r_n + 1 - r_n = r_n - 1$

$(n + 1)^2 - n^2 = (n - 1)^2$

n = 4

So **(D)** is the correct answer

Ex. 12 The dissociation energy of H_2 is 430.53 kJ mol^{-1}. If H_2 is dissociated by illumination with radiation of wavelength 253.7 nm. The fraction of the radiant energy which will be converted into kinetic energy is given by :-

(A) 8.86% **(B)** 2.33% **(C)** 1.3% **(D)** 90%

Sol. $\frac{hc}{\lambda} = \frac{430.53 \times 10^3}{6.023 \times 10^{23}} + \text{K.E.}$

$$\text{K.E.} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{253.7 \times 10^{-9}} - \frac{430.53 \times 10^3}{6.023 \times 10^{23}} = 6.9 \times 10^{-20}$$

$$\therefore \text{Fraction} = \frac{6.9 \times 10^{-20}}{7.83 \times 10^{-19}} = 0.088 = 8.86\%$$

Ex. 13 Principal, azimuthal and magnetic quantum numbers are respectively related to :-

(A) size, orientation and shape **(B)** size, shape and orientation

(C) shape, size and orientation **(D)** none of these

Sol. Principal gives size, i.e. azimuthal gives shape and magnetic quantum number gives the orientation.

So, **(B)** is the correct answer.

Ex. 14 If the radius of 2nd Bohr orbit of hydrogen atom is r_2. The radius of third Bohr orbit will be :-

(A) $\frac{4}{9}r_2$ **(B)** $4r_2$ **(C)** $\frac{9}{4}r_2$ **(D)** $9r_2$

Sol. $r = \frac{n^2h^2}{4\pi^2 mZe^2}$

$\therefore \frac{r_2}{r_3} = \frac{2^2}{3^2}$ $\therefore r_3 = \frac{9}{4}r_2$

So, **(C)** is the correct answer.

Ex. 15. Light of wavelength λ shines on a metal surface with intensity x and the metal emits Y electrons per second of average energy, Z. What will happen to Y and Z if x is doubled ?

(A) Y will be double and Z will become half **(B)** Y will remain same and Z will be doubled

(C) Both Y and Z will be doubled **(D)** Y will be doubled but Z will remain same

Sol. When intensity is doubled, number of electrons emitted per second is also doubled but average energy of photoelectrons emitted remains the same.

So, **(D)** is the correct answer.

Ex. 16 Which of the following is the ground state electronic configuration of nitrogen :-

(A) [↑↓] [↑↓] [↑|↑|↑] **(B)** [↑↓] [↑↓] [↑|↓|↑]

(C) [↑↓] [↑↓] [↑|↓|↓] **(D)** [↑↓] [↑↓] [↓|↓|↓]

Sol. In **(A)** and **(D)**, the unpaired electrons have spin in the same direction.

So, **(A)** and **(D)** are the correct answer.

Ex. 17 Select the wrong statement (s) from the following ?

(A) If the value of $\ell = 0$, the electron distribution is spherical

(B) The shape of the orbital is given by magnetic quantum number

(C) Angular momentum of 1s, 2s, 3s electrons are equal

(D) In an atom, all electrons travel with the same velocity

Sol. **(B)** is wrong because shape is given by azimuthal quantum number and magnetic quantum number tells the orientation. **(D)** is wrong because electrons in different shells travel with different velocities.

So, **(A)** and **(C)** are the correct answer.

Ex. 18 No. of wave in third Bohr's orbit of hydrogen is :-

(A) 3 **(B)** 6 **(C)** 9 **(D)** 12

Sol. Number of waves = $\frac{\text{Circumference}}{\text{Wavelength}}$

$$\frac{2\pi r}{\lambda} = \frac{2\pi r}{h/mv} = \frac{2\pi}{h}(mvr) = \frac{2\pi}{h} \times \frac{nh}{2\pi}$$

$\therefore n = 3$

So, **(A)** is the correct answer.

Ex. 19 In the hydrogen atoms, the electrons are excited to the 5^{th} energy level. The number of the lines that may appear in the spectrum will be :-

(A) 4 **(B)** 8 **(C)** 10 **(D)** 12

Sol. No. of lines produced for a jump from fifth orbit to 1^{st} orbit is given by

$$= \frac{n(n-1)}{2} = \frac{5(5-1)}{2} = 10$$

So, **(C)** is the correct answer.

Ex. 20 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 rational masses

Sol. Non-integral atomic masses are due to isotopes which have different masses.

So, **(A)** and **(C)** are the correct answer.

Ex. 21 Which of the following statement (s) is (are) correct ?

(A) The electronic configuration of Cr is $[Ar]3d^5, 4s^1$ (Atomic No. of Cr = 24)

(B) The magnetic quantum number may have a negative value

(C) In silver atom 23 electrons have spin of one type and 24 of the opposite type (Atomic No. of Ag = 47)

(D) The oxidation state of nitrogen in HN_3 is –3

Sol. Only **(D)** is wrong because oxidation state of N in HN_3 is –1/3.

So, **(A), (B)** and **(C)** are the correct answer.

Ex. 22 For the energy levels in an atom, which one of the following statement/s is/are correct ?

(A) There are seven principal electron energy levels

(B) The second principal energy level can have four sub-energy levels and contain a maximum of eight electrons

(C) The M energy level can have a maximum of 32 electrons.

(D) The 4s sub-energy level is at a lower energy than the 3d sub-energy level.

Sol. **(A)** and **(D)** are true. **(B)** is wrong because for $n = 2$, $\ell = 0, 1$ (two sub-energy levels). **(C)** is wrong because M shell means n = 3. Maximum electrons it can have = $2n^2 = 2 \times 3^2 = 18$

So, **(A)** and **(D)** is the correct answer.

Ex. 23 Find the wavelength emitted during the transition of electron in between two levels of Li^{2+} ion whose sum is 5 and difference is 3.

Sol. Let the transition occurs between the level n_1 and n_2 and $n_2 > n_1$

Given that $n_1 + n_2 = 5$

$n_2 - n_1 = 3$

$\therefore \quad n_1 = 1$ and $n_2 = 4$

$$\text{Therefore, } \frac{1}{\lambda} = R_h \times Z^2 \left[\frac{1}{(1)^2} - \frac{1}{(4)^2}\right] = 109678 \times (3)^2 \left[\frac{15}{16}\right]$$

$\therefore \quad \lambda = 1.08 \times 10^{-6}$ cm

Ex. 24 Find the wavelengths of the first line of He^+ ion spectral series whose interval with extreme lines is

$$\frac{1}{\lambda_1} - \frac{1}{\lambda_2} = 2.7451 \times 10^4 \text{ cm}^{-1}$$

Sol. Extreme lines means first and last

$$\frac{1}{\lambda_1} - \frac{1}{\lambda_2} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{\infty^2}\right] - RZ^2\left[\frac{1}{n_1^2} - \frac{1}{(n_1+1)^2}\right]$$

or $$\frac{1}{\lambda_1} - \frac{1}{\lambda_2} = \frac{RZ^2}{(n_1+1)^2}$$

$$2.7451 \times 10^4 = \frac{109677.76 \times 2^2}{(n_1+1)^2}$$

$(n_1 + 1) = 4$

$n_1 = 3$

Wavelength of first line,

$$\frac{1}{\lambda} = 109677.76 \times 2^2 \times \left[\frac{1}{3^2} - \frac{1}{4^2}\right]$$

$\lambda = 4689 \times 10^{-8} \text{ cm} = 4689 \text{ Å}$

Ex. 25 The Lyman series of the hydrogen spectrum can be represented by the equation.

$$v = 3.2881 \times 10^{15} \text{ s}^{-1}\left[\frac{1}{(1)^2} - \frac{1}{(n)^2}\right]$$

(where n = 2, 3,.....)

Calculate the maximum and minimum wavelength of lines in this series.

Sol. $$\bar{\nu} = \frac{1}{\lambda} = \frac{\nu}{c} = \frac{3.2881 \times 10^{15}}{3 \times 10^8} \text{ m}^{-1}\left[\frac{1}{(1)^2} - \frac{1}{n^2}\right]$$

Wavelength is maximum $(\bar{\nu}_{min})$ when n is minimum so that $\frac{1}{n^2}$ is maximum

$$\therefore \quad \bar{\nu}_{min} = \frac{1}{\lambda_{max}} = \frac{3.2881 \times 10^{15}}{3 \times 10^8}\left[\frac{1}{(1)^2} - \frac{1}{(2)^2}\right]$$

$$\therefore \quad \lambda_{max} = \frac{3 \times 10^8}{3.2881 \times 10^{15}} \times \frac{4}{3}$$

$$= 1.2165 \times 10^{-7} \text{ m} = 121.67 \text{ nm}$$

Wavelength is minimum $(\bar{\nu}_{max})$ when n is ∞

i.e. series converge

$$\therefore \quad \nu_{max} = \frac{1}{\lambda_{min}} = \frac{3.2881 \times 10^{15}}{3 \times 10^8}$$

$$\therefore \quad \lambda_{min} = 0.9124 \times 10^{-7} \text{m} \; 91.24 \text{ nm}$$

Ex. 26 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 ?

Sol. Wavelength is emitted in UV region and thus $n_1 = 1$

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

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

$\therefore \quad n = 2$

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

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

$$\therefore \quad \frac{1}{2} \times 1.67 \times 10^{-27} \times v^2 = \frac{6.625 \times 10^{-34} \times 3 \times 10^8}{121.6 \times 10^{-9}}$$

$\therefore \quad v = 4.43 \times 10^4$ m/sec

Ex. 27 When certain metal was irradiated with light frequency 0.4×10^{13} Hz the photo electrons emitted had twice the kinetic energy as did photo electrons emitted when the same metal was irradiated with light frequency 1.0×10^{13} Hz. Calculate threshold frequency (ν_0) for the metal.

Sol. $h\nu = h\nu_0 + KE$

$KE_1 = h(\nu_1 - \nu_0)$

$KE_2 = h(\nu_2 - \nu_0) = \frac{KE_1}{2}$

$$\therefore \quad \frac{\nu_2 - \nu_0}{\nu_1 - \nu_0} = \frac{1}{2} \Rightarrow \frac{1.0 \times 10^{13} - \nu_0}{0.4 \times 10^{13} - \nu_0} = \frac{1}{2} \Rightarrow \nu_0 = 1.6 \times 10^{13} \text{ Hz}$$

Ex. 28 Iodine molecule dissociates into atoms after absorbing light of 3000 Å. If one quantum of radiation is absorbed by each molecule, calculate the kinetic energy of iodine atoms. (Bond energy of I_2 = 240 kJ (mol).

Sol. Energy given to iodine molecule

$$\frac{hc}{\lambda} = \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{3000 \times 10^{-10}} = 6.62 \times 10^{-19} \text{ J}$$

Also energy used for breaking up

$$I_2 \text{ molecule} = \frac{240 \times 10^3}{6.023 \times 10^{23}} = 3.984 \times 10^{-19} \text{ J}$$

$\therefore$ Energy used in imparting kinetic to two atoms = $(6.62 - 3.984) \times 10^{-19}$ J

$$\therefore \quad \text{KE of iodine atom} = \frac{(6.62 - 3.984)}{2} \times 10^{-19} = 1.318 \times 10^{-19} \text{ J}$$

Ex. 29 An electron beam can undergo difraction by crystals. Through what potential should a beam of electrons be accelerated so that its wavelength becomes equal to 1.0 Å.

Sol. For an electron

$\frac{1}{2}mv^2 = eV$ where V is accelerating potential

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

$\therefore \quad \frac{1}{2}m\left(\frac{h}{m\lambda}\right)^2 = eV$

$\therefore \quad V = \frac{1}{2} \times \frac{h^2}{m\lambda^2 e} = \frac{1 \times \left(6.625 \times 10^{-34}\right)^2}{2 \times 9.108 \times 10^{-31} \times (1.0 \times 10^{-10})^2 \times 1.602 \times 10^{-19}} = 150.40$ volt

Ex. 30 The angular momentum of an electron in a Bohr's orbit of H-atom is 4.2178×10^{-34} kgm^2/sec. Calculate the wavelength of the spectral line emitted when electrons falls from this level to next lower level.

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

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

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

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

The wavelength for transition from n = 4 to n = 3

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

$\lambda = 1.8 \times 10^{-4}$ cm.

Ex. 31 Find the energy in kJ per mole of electronic charge accelerated by a potential of 2 volt.

Sol. Energy in joules = charge in coulombs × potential difference in volt

$= 1.6 \times 10^{-19} \times 6.02 \times 10^{23} \times 2 = 19.264 \times 10^4$ J or 192.264 kJ

Ex. 32 Which hydrogen like ionic species has wavelength difference between the first line of Balmer and first line of Lyman series equal to 59.3×10^{-9} m ? Neglect the reduced mass effect.

Sol. Wave number of first Balmer line of an species with atomic number Z is given by

$$\bar{\nu}' = RZ^2\left[\frac{1}{2^2}-\frac{1}{3^2}\right] = \frac{5RZ^2}{36}$$

Similarly wave number of $\bar{\nu}$ of first Lyman line is given by

$$\bar{\nu} = RZ^2\left[\frac{1}{1^2}-\frac{1}{2^2}\right] = \frac{3}{4}RZ^2 \;;\; \bar{\nu} = \frac{1}{\lambda} \text{ and } \bar{\nu}' = \frac{1}{\lambda'}$$

$$\therefore \quad \lambda' - \lambda = \frac{36}{5RZ^2} - \frac{4}{3RZ^2} = \frac{1}{RZ^2}\left[\frac{36}{5}-\frac{4}{3}\right] = \frac{88}{15RZ^2}$$

$$\therefore \quad Z^2 = \frac{88}{59.3\times10^{-9}\times15\times1.097\times10^7} = 9 \text{ or } Z = 3$$

$\therefore$ Ionic species is Li^{2+}

Ex. 33 **(i)** What is highest frequency photon that can be emitted from hydrogen atom ? What is wavelength of this photon ?

(ii) Find the longest wavelength transition in the Paschen series of Be^{3+}.

(iii) Find the ratio of the wavelength of first and the ultimate line of Balmer series of He^+ ?

Sol. **(i)** Highest frequency photon is emitted when electron comes from infinity to 1st energy level.

$$E = -\frac{13.6Z^2}{1^2} = -13.6 \text{ eV}$$

or, $13.6 \times 1.6 \times 10^{-19}$ Joule $= 2.176 \times 10^{-18}$ Joule

$E = h\nu$

$$\therefore \quad \nu = \frac{E}{h} = \frac{2.176\times10^{-18}\text{ J}}{6.626\times10^{-34}\text{ Js}} = 0.328 \times 10^{16} \text{ Hz}$$

$$\nu = \frac{c}{\lambda} \quad \therefore \lambda = \frac{3\times10^8}{0.328\times10^{16}} = 9.146 \times 10^{-8} \text{ m}$$

(ii)

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

For He ; Z = 4 ; For Paschen series $n_1 = 3$

For longest wavelength $n_2 = 4$

$$\frac{1}{\lambda} = 109678 \times (4)^2 \times \left[\frac{1}{3^2}-\frac{1}{4^2}\right] = 109678 \times 16 \times \left[\frac{1}{9}-\frac{1}{16}\right] = 109678 \times 16 \times \frac{7}{144}$$

$\lambda = 1172.20$ Å

(iii) Wave number of first line of Balmer,

$$\bar{\nu}_1 = RZ^2\left[\frac{1}{2^2}-\frac{1}{3^2}\right] = \frac{5\times4R}{36} = \frac{5R}{9}$$

$\therefore$ Wavelength of first line of Balmer $= \dfrac{9}{5R}$

Wave number of ultimate line of Balmer, $\bar{\nu}_2 = RZ^2\left[\frac{1}{2^2}-\frac{1}{\infty}\right] = \frac{4R}{4} = R$

$\therefore$ Wavelength of ultimate line of Balmer = $\frac{1}{R}$

$\therefore$ Ratio = $\frac{9}{5}$

Ex. 34 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 atom of oxygen requires 498 $kJmol^{-1}$. What is the maximum wavelength effective for photo chemical dissociation of O_2 ?

Sol. We know

$P_2 \xrightarrow{h\nu} O_{Normal} + O_{Excited}$

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

Energy required for simple dissociation of O_2 into two normal atoms = $498 \times 10^3 Jmol^{-1}$

$= \frac{498 \times 10^8}{6.023 \times 10^{23}} Jmol^{-1}$

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

$= 1.967 \times 1.602 \times 10^{-19}$ J

The energy required for photochemical dissociation of O_2

$= \frac{498 \times 10^3}{6.023 \times 10^{23}} + 1.967 \times 1.602 \times 10^{-19}$

$= 82.68 \times 10^{-20} + 31.51 \times 10^{-20} = 114.19 \times 10^{-20}$ Joule

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

$114.19 \times 10^{-20} = \frac{6.625 \times 10^{-34} \times 3 \times 10^8}{\lambda}$

$\lambda = 1740.2 \times 10^{-10}$ m = 1740.2 Å.

Ex. 35 The kinetic energy of an electron in H like atom is 6.04 eV. Find the area of the third Bohr orbit to which this electron belongs. Also report the atom.

Sol. K.E. = 6.04 in 3rd orbit

E_{total} = K.E. + P.E. = K.E. – 2 × K.E.

$\Rightarrow$ –K.E. = – 6.04 eV

E_1 for H = –13.6 eV and not for any orbit E = – 6.04 eV for H atom. Thus, atom for which K.E. is given is other than H.

E_n H like atom = $E_{nH} \times Z^2$

$\frac{E_1}{n^2} \times Z^2 \Rightarrow 6.04 = \frac{13.6}{3^2} \times Z^2$

$Z^2 = 3.99 \approx 4 \Rightarrow Z = 2$

$\therefore$ The atom is $He^+ \Rightarrow r_n = 0.529 \times \frac{n^2}{Z} = 0.529 \times \frac{3^2}{2} = 2.3805$ Å

Area, $\pi r^2 = \frac{22}{7} \times \left(2.3805 \times 10^{-8}\right)^2 = 17.8 \times 10^{-16}\ cm^2$

Ex. 36 What are the frequency and wavelength of a photon emitted during a transition from n = 5 state to the n = 2 state in the hydrogen atom ?

Sol. Since $n_i = 5$ and $n_f = 2$, this transition gives rise to a spectral line in the visible region of the Balmer series.

$$\Delta E = 2.18 \times 10^{-18}\,J\left[\frac{1}{5^2} - \frac{1}{2^2}\right] = -4.58 \times 10^{-19}\,J$$

It is an emission energy

The frequency of the photon (taking energy in terms of magnitude) is given by

$$\nu = \frac{\Delta E}{h} = \frac{4.58 \times 10^{-19}\,J}{6.626 \times 10^{-34}\,Js} = 6.91 \times 10^{14}\,Hz$$

$$\lambda = \frac{c}{\nu} = \frac{3.0 \times 10^{8}\,ms^{-1}}{6.91 \times 10^{14}\,Hz} = 434\,nm$$

Ex. 37 Photoelectrons are liberated by ultra violet light of wavelength 2000 Å from a metallic surface for which the photoelectric threshold is 4000 Å. Calculate the de Broglie wavelength of electrons emitted with maximum kinetic energy.

Sol. K.E. = Quantum Energy – Threshold energy

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{2000 \times 10^{-10}} - \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{4000 \times 10^{-10}}$$

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^{8}}{10^{-10}}\left(\frac{1}{2000} - \frac{1}{4000}\right)$$

$$= 4.969 \times 10^{-19}\ \text{Joule.}$$

$$\frac{1}{2}mv^2 = 4.969 \times 10^{-19} \Rightarrow m^2v^2 = 2 \times 4.969 \times 10^{-19} \times 9.1 \times 10^{-31}$$

$$mv = 9.51 \times 10^{-25} \Rightarrow \lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}}{9.51 \times 10^{-25}} = 0.696 \times 10^{-9}\,m$$

Ex. 38 Calculate the energy of a photon of sodium light of wave length 5.862×10^{-16} m in Joules.

Sol. $\lambda = 5.886 \times 10^{-16}\,m$

$c = 3 \times 10^{8}\,m\,sec^{-1}$

$$E = nh\nu \quad \text{or} \quad \frac{nhc}{\lambda} \qquad \{\because n = 1\}$$

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

$$E = \frac{1 \times 6.6 \times 10^{-34}\,\text{Jules} \times 3 \times 10^{8}\,\text{msec}^{-1}}{5.862 \times 10^{-16}\,m}$$

$$= \frac{6.6 \times 3}{5.862} \times 10^{-10}\ \text{Joules} = 3.38 \times 10^{-10}\ \text{Joules.}$$

Ex. 39 Calculate the frequency & energy of a photon of wave length 4000 Å

Sol. **(a)** Calculation of frequency :

$\lambda = 4000$ Å

$\lambda = 4000 \times 10^{-10}$ m

$\because \quad \nu = \dfrac{C}{\lambda}$

$\therefore \quad \nu = \dfrac{3 \times 10^{8} \text{ m / sec}}{4 \times 10^{-7} \text{ m}}$

$= 0.75 \times 10^{15} \text{ sec}^{-1}$

$= 7.5 \times 10^{14} \text{ sec}^{-1}$

(b) Calculation of energy :

$E = h\nu$

$= 6.626 \times 10^{-34} \text{ Joule} \times 7.5 \times 10^{14} \text{ sec}^{-1}$

$= 4.96 \times 10^{-19}$ Joule

Ex. 40 Calculate the λ and frequency of a photon having an energy of 2 electron volt

Sol. $\because$ $1\text{ev} = 1.602 \times 10^{-19}$ J

$\therefore$ $2\text{ev} = 3.204 \times 10^{-19} \text{ J} = E$

(a) Calculation of wavelength (λ) :

$$E = \frac{hc}{\lambda} \quad \text{or} \quad \lambda = \frac{hc}{E}$$

$$= \frac{6.626 \times 10^{-34} \text{ Js} \times 3 \times 10^{8} \text{ msec}^{-1}}{3.204 \times 10^{-19} \text{ J}}$$

$= 6.204 \times 10^{-7}$ m

(b) Calculation of frequency (ν) :

$$\nu = \frac{c}{\lambda} = \frac{3 \times 10^{8} \text{ msec}^{-1}}{6.204 \times 10^{-7} \text{ m}}$$

$= 0.48 \times 10^{15} \text{ sec}^{-1}$

$= 4.8 \times 10^{14} \text{ sec}^{-1}$

Ex. 41 Which has a higher energy ?

(a) A photon of violet light with wave length 4000 Å

or

(b) A photon of red light with wave length 7000 Å

Sol. **(a)** Violet light :

$$E_{violet} = \frac{hc}{\lambda}$$

$$= \frac{6.626 \times 10^{-34} \text{ Jsec} \times 3 \times 10^{8} \text{ msec}^{-1}}{4000 \times 10^{-10} \text{ m}}$$

$= 4.97 \times 10^{-19}$ Joule

(b) Red light :

$$E_{red} = \frac{hc}{\lambda}$$

$$= \frac{6.626 \times 10^{-34}\,\text{Jsec} \times 3 \times 10^{8}\,\text{msec}^{-1}}{7000 \times 10^{-10}\,\text{m}}$$

$= 2.8 \times 10^{-19}$ Joule

So, $E_{violet} > E_{red}$

Ex. 42 How many photons of lights having a wave length of 5000 Å are necessary to provide 1 Joule of energy.

Sol. $\because$ $E = \frac{nhc}{\lambda}$

$\therefore$ $n = \frac{E \times \lambda}{hc}$

$$= \frac{1\,\text{Joule} \times 5000 \times 10^{-10}\,\text{m}}{6.626 \times 10^{-34}\,\text{Joulesec} \times 3 \times 10^{8}\,\text{msec}^{-1}}$$

$= 2.5 \times 10^{18}$ photons

Ex. 43 Calculate the energy associated with the photon passing through vacuum with wavelength 9900 Å.

Sol. For vacuum, velocity of photon = 3×10^{8} m/sec

$h = 6.6 \times 10^{-34}$ Joule sec

$\lambda = 9900 \times 10^{-10}$ meter

$$E = h\nu = h\,\frac{c}{\lambda} = \frac{6.6 \times 10^{-34}\,\text{J.sec} \times 3 \times 10^{8}\,\text{msec}}{6600 \times 10^{-10}\,\text{m}} = \frac{19.8 \times 10^{-16}}{9900} = 2 \times 10^{-19}\ \text{Joule}$$

Exercise # 1

[Single Correct Choice Type Questions]

1. The approximate size of the nucleus of $^{64}_{28}Ni$ is :
(A) 3 fm **(B)** 4 fm **(C)** 5 fm **(D)** 2 fm

2. The element having no neutron in the nucleus of its atom is
(A) Hydrogen **(B)** Nitrogen **(C)** Helium **(D)** Boron

3. The ratio of the "e/m" (specific charge) values of a electron and an α-particle is -
(A) 2 : 1 **(B)** 1 : 1 **(C)** 1 : 2 **(D)** None of these

4. The fraction of volume occupied by the nucleus with respect to the total volume of an atom is
(A) 10^{-15} **(B)** 10^{-5} **(C)** 10^{-30} **(D)** 10^{-10}

5. Which of the following is iso-electronic with neon?
(A) O^{2-} **(B)** F^{-} **(C)** Mg **(D)** Na

6. Electromagnetic radiations of wavelength 242 nm is just sufficient to ionise Sodium atom. Then the ionisation energy of Sodium in kJ $mole^{-1}$ is.
(A) 494.65 **(B)** 400 **(C)** 247 **(D)** 600

7. Photon of which light has maximum energy :
(A) red **(B)** blue **(C)** violet **(D)** green

8. The MRI (magentic resonance imaging) body scanners used in hospitals operate with 400 MHz radio frequency. The wavelength corresponding to this radio frequency is
(A) 0.75 m **(B)** 0.75 cm **(C)** 1.5 m **(D)** 2 cm

9. The value of Planck's constant is 6.63×10^{-34} Js. The velocity of light is 3×10^{8} m/sec. Which value is closest to the wavelength of a quantum of light with frequency of 8×10^{15} sec^{-1} ?
(A) 5×10^{-18} m **(B)** 4×10^{-8} m **(C)** 3×10^{7} m **(D)** 2×10^{-25} m

10. A photon of energy $h\nu$ is absorbed by a free electron of a metal having work function $w < h\nu$. Then :
(A) The electron is sure to come out
(B) The electron is sure to come out with a kinetic energy $(h\nu - w)$
(C) Either the electron does not come out or it comes with a kinetic energy $(h\nu - w)$
(D) It may come out with a kinetic energy less than $(h\nu - w)$

11. Light of wavelength λ falls on metal having work function hc/λ_0. Photoelectric effect will take place only if :
(A) $\lambda \geq \lambda_0$ **(B)** $\lambda \geq 2\lambda_0$ **(C)** $\lambda \leq \lambda_0$ **(D)** $\lambda \leq \lambda_0/2$

12. A bulb of 40 W is producing a light of wavelength 620 nm with 80% of efficiency then the number of photons emitted by the bulb in 20 seconds are ($1 eV = 1.6 \times 10^{-19}$ J, hc = 12400 eV Å)
(A) 2×10^{18} **(B)** 10^{18} **(C)** 10^{21} **(D)** 2×10^{21}

13. If the value of $E_n = -78.4$ kcal/mole, the order of the orbit in hydrogen atom is :
(A) 4 **(B)** 3 **(C)** 2 **(D)** 1

14. Correct order of radius of the Ist orbit of H, He^{+}, Li^{2+}, Be^{3+} is :
(A) $H > He^{+} > Li^{2+} > Be^{3+}$ **(B)** $Be^{3+} > Li^{2+} > He^{+} > H$
(C) $He^{+} > Be^{3+} > Li^{2+} > H$ **(D)** $He^{+} > H > Li^{2+} > Be^{3+}$

15. What is likely to be orbit number for a circular orbit of diameter 20 nm of the hydrogen atom :
(A) 10 **(B)** 14 **(C)** 12 **(D)** 16

16. Which is the correct relationship :
(A) E_1 of H = 1/2 E_2 of He^+ = 1/3 E_3 of Li^{2+} = 1/4 E_4 of Be^{3+}
(B) $E_1(H) = E_2(He^+) = E_3(Li^{2+}) = E_4(Be^{3+})$
(C) $E_1(H) = 2E_2(He^+) = 3E_3(Li^{2+}) = 4E_4(Be^{3+})$
(D) No relation

17. If velocity of an electron in I orbit of H atom is V, what will be the velocity of electron in 3rd orbit of Li^{+2}
(A) V **(B)** V/3 **(C)** 3 V **(D)** 9 V

18. In a certain electronic transition in the hydrogen atoms from an initial state (1) to a final state (2), the difference in the orbital radius $(r_1 - r_2)$ is 24 times the first Bohr radius. Identify the transition.
(A) $5 \rightarrow 1$ **(B)** $25 \rightarrow 1$ **(C)** $8 \rightarrow 3$ **(D)** $6 \rightarrow 5$

19. The species which has its fifth ionisation potential equal to 340 V is
(A) B^+ **(B)** C^+ **(C)** B **(D)** C

20. Choose the correct relations on the basis of Bohr's theory.
(A) Velocity of electron $\propto$ n
(B) Frequency of revolution $\propto \frac{1}{n^2}$
(C) Radius of orbit $\propto n^2Z$
(D) Electrostatic force on electron $\propto \frac{1}{n^4}$

21. **S1 :** Potential energy of the two opposite charge system increases with the decrease in distance.
S2 : When an electron make transition from higher orbit to lower orbit it's kinetic energy increases.
S3 : When an electron make transtition from lower energy to higher energy state its potential energy increases.
S4 : 11eV photon can free an electron from the 1st excited state of He^+ -ion.
(A) T T T T **(B)** F T T F **(C)** T F F T **(D)** F F F F

22. **S1 :** Bohr model is applicable for Be^{2+} ion.
S2 : Total energy coming out of any light source is integral multiple of energy of one photon.
S3 : Number of waves present in unit length is wave number.
S4 : e/m ratio in cathode ray experiment is independent of the nature of the gas.
(A) F F T T **(B)** T T F F **(C)** F T T T **(D)** T F F F

23. Match the following

(A) Energy of ground state of He^+	(i) + 6.04 eV
(B) Potential energy of I orbit of H-atom	(ii) –27.2 eV
(C) Kinetic energy of II excited state of He^+	(iii) 54.4 V
(D) Ionisation potential of He^+	(iv) – 54.4 eV

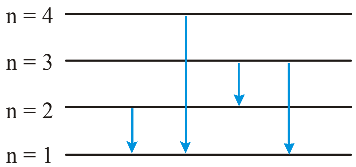
(A) A – (i), B – (ii), C – (iii), D – (iv)
(B) A – (iv), B – (iii), C – (ii), D – (i)
(C) A – (iv), B – (ii), C – (i), D – (iii)
(D) A – (ii), B – (iii), C – (i), D – (iv)

24. The wavelength of a spectral line for an electronic transition is inversely proportional to :
(A) number of electrons undergoing transition
(B) the nuclear charge of the atom
(C) the velocity of an electron undergoing transition
(D) the difference in the energy involved in the transition

25. Total no. of lines in Lyman series of H spectrum will be (where n = no. of orbits)
(A) n **(B)** n – 1 **(C)** n – 2 **(D)** n (n + 1)

26. The energy of hydrogen atom in its ground state is –13.6 eV. The energy of the level corresponding to n = 5 is:
(A) –0.54 eV **(B)** –5.40 eV **(C)** –0.85 eV **(D)** –2.72 eV

27. Suppose that a hypothetical atom gives a red, green, blue and violet line spectrum . Which jump according to figure would give off the red spectral line.



(A) $3 \rightarrow 1$ **(B)** $2 \rightarrow 1$ **(C)** $4 \rightarrow 1$ **(D)** $3 \rightarrow 2$

28. The difference between the wave number of 1st line of Balmer series and last line of paschen series for Li^{2+} ion is :
(A) $\frac{R}{36}$ **(B)** $\frac{5R}{36}$ **(C)** 4R **(D)** $\frac{R}{4}$

29. The spectrum of He^+ is expected to be similar to that of :
(A) Li^{2+} **(B)** He **(C)** H **(D)** Na

30. No. of visible lines when an electron returns from 5th orbit upto ground state in H spectrum :
(A) 5 **(B)** 4 **(C)** 3 **(D)** 10

31. In a sample of H-atom electrons make transition from 5th excited state upto ground state, producing all possible types of photons, then number of lines in infrared region are
(A) 4 **(B)** 5 **(C)** 6 **(D)** 3

32. In H-atom, if 'x' is the radius of the first Bohr orbit, de Broglie wavelength of an electron in 3rd orbit is :
(A) $3\pi x$ **(B)** $6\pi x$ **(C)** $\frac{9x}{2}$ **(D)** $\frac{x}{2}$

33. What possibly can be the ratio of the de Broglie wavelengths for two electrons each having zero initial energy and accelerated through 50 volts and 200 volts ?
(A) 3 : 10 **(B)** 10 : 3 **(C)** 1 : 2 **(D)** 2 : 1

34. The approximate wavelength associated with a gold-ball weighing 200 g and moving at a speed of 5 m/hr is of the order of
(A) 10^{-1} m **(B)** 10^{-20} m **(C)** 10^{-30} m **(D)** 10^{-40} m

35. The wavelength of a charged particle ________the square root of the potential difference through which it is accelerated :
(A) is inversely proportional to **(B)** is directly proportional to
(C) is independent of **(D)** is unrelated with

36. The uncertainty in the momentum of an electron is 1.0×10^{-5} kg m s^{-1} . The uncertainty in its position will be: ($h = 6.626 \times 10^{-34}$ Js)
(A) 1.05×10^{-28} m **(B)** 1.05×10^{-26} m **(C)** 5.27×10^{-30} m **(D)** 5.25×10^{-28} m

37. An α-particle is accelerated through a potential difference of V volts from rest. The de-Broglie's wavelength associated with it is
(A) $\sqrt{\frac{150}{V}}$ Å **(B)** $\frac{0.286}{\sqrt{V}}$ Å **(C)** $\frac{0.101}{\sqrt{V}}$ Å **(D)** $\frac{0.983}{\sqrt{V}}$ Å

38. de-Broglie wavelength of electron in second orbit of Li^{2+} ion will be equal to de-Broglie of wavelength of electron in
(A) n = 3 of H-atom (B) n = 4 of C^{5+} ion (C) n = 6 of Be^{3+} ion (D) n = 3 of He^+ ion

39. The total spin resulting from a d^7 configuration is :
(A) 1 (B) 2 (C) 5/2 (D) 3/2

40. Which of the following ions has the maximum number of unpaired d-electrons?
(A) Zn^{2+} (B) Fe^{2+} (C) Ni^{3+} (D) Cu^+

41. The orbital with zero orbital angular momentum is :
(A) s (B) p (C) d (D) f

42. Which of the following is electronic configuration of Cu^{2+} (Z = 29) ?
(A) $[Ar]4s^1 3d^8$ (B) $[Ar]4s^2 3d^{10} 4p^1$ (C) $[Ar]4s^1 3d^{10}$ (D) $[Ar] 3d^9$

43. Spin magnetic moment of X^{n+} (Z = 26) is $\sqrt{24}$ B.M. Hence number of unpaired electrons and value of n respectively are :
(A) 4, 2 (B) 2, 4 (C) 3, 1 (D) 0, 2

44. Consider the ground state of Cr atom (Z = 24). The numbers of electrons with the azimuthal quantum numbers, ℓ = 1 and 2 are, respectively :
(A) 16 and 5 (B) 12 and 5 (C) 16 and 4 (D) 12 and 4

45. Given is the electronic configuration of element X :

K	L	M	N
2	8	11	2

The number of electrons present with ℓ = 2 in an atom of element X is :
(A) 3 (B) 6 (C) 5 (D) 4

46. The orbital angular momentum of an electron in 2s-orbital is :
(A) $+\frac{1}{2}\frac{h}{2\pi}$ (B) zero (C) $\frac{h}{2\pi}$ (D) $\sqrt{2}\frac{h}{2\pi}$

47. The possible value of ℓ and m for the last electron in the Cl^- ion are :
(A) 1 and 2 (B) 2 and + 1 (C) 3 and – 1 (D) 1 and – 1

48. For an electron, with n = 3 has only one radial node. The orbital angular momentum of the electron will be
(A) 0 (B) $\sqrt{6}\frac{h}{2\pi}$ (C) $\sqrt{2}\frac{h}{2\pi}$ (D) $3\left(\frac{h}{2\pi}\right)$

49. The possible set of quantum no. for the unpaired electron of chlorine is :

	n	ℓ	m		n	ℓ	m
(A)	2	1	0	(B)	2	1	1
(C)	3	1	1	(D)	3	0	0

50. 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 positive values.
(C) In silver atom, 21 electrons have a spin of one type and 26 of the opposite type. (Atomic number of Ag = 47)
(D) None of these

51. The maximum probability of finding electron in the d_{xy} orbital is:
(A) Along the x-axis (B) Along the y-axis
(C) At an angle of 45^0 from the x and y axis (D) At an angle of 90^0 from the x and y axis.

52. The correct time independent Schrödinger's wave equation for an electron with E as total energy and V as potential energy is :

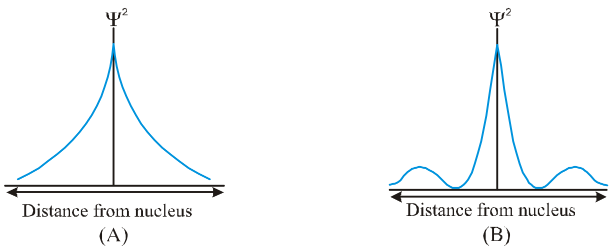
(A) $\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}+\frac{8\pi^2}{mh^2}(E-V)\psi=0$ **(B)** $\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}+\frac{8\pi m}{h^2}(E-V)\psi=0$

(C) $\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}+\frac{8\pi^2 m}{h^2}(E-V)\psi=0$ **(D)** $\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}+\frac{8\pi m^2}{h}(E-V)\psi=0$

53. The maximum radial probability in 1s-orbital occurs at a distance when : [r_0 = Bohr radius]

(A) $r = r_0$ **(B)** $r = 2r_0$ **(C)** $r = \frac{r_0}{2}$ **(D)** $2r = \frac{r_0}{2}$

54. Consider following figure A and B indicating distribution of charge density (electron probability Ψ^2) with distance r.



Select the correct statement :

(A) A and B both are for 1s **(B)** A and B both are for 2s
(C) A is for 2s, B is for 1s **(D)** A is for 1s, B is for 2s

55. The radial distribution curve of 2s sublevel consists of x nodes, x is :

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

56. $3p_y$ orbital has..........nodal plane :

(A) XY **(B)** YZ **(C)** ZX **(D)** All of these

57. A 3p-orbital has

(A) Two non-spherical nodes **(B)** Two spherical nodes
(C) One spherical and one non spherical nodes **(D)** One spherical and two non spherical nodes

58. According to Schrodinger model nature of electron in an atom is as :

(A) Particle only **(B)** Wave only
(C) Particle & wave nature both simultaneously **(D)** Sometimes waves and sometimes particle

59. Consider the following statements :

(A) Electron density in the XY plane in $3d_{x^2-y^2}$ orbital is zero

(B) Electron density in the XY plane in $3d_{z^2}$ orbital is zero.

(C) 2s orbital has one nodal surface

(D) for $2p_z$ orbital, YZ is the nodal plane.

Which of these are incorrect statements :

(A) a & c **(B)** b & c **(C)** Only b **(D)** a, b, d

60. d_{z^2} orbital has :

(A) Two lobe along Z axis & a ring in X-Y plane **(B)** A lobe & a ring along Z axis
(C) A lobe along Z axis and a ring in Y-Z plane **(D)** None of these

61. Pickout the correct statements :
(A) Negative β-decay decreases the proportion of neutrons and increases the proportion of proton.
(B) Positive β-decay increases the proportion of neutrons and decreases the proportion of proton.
(C) K-electron capture increases the proportion of neutrons and increases the proporiton of proton.
(D) Positrons and electrons quickly unite to produce photons.

62. ${}^{11}_{6}C$ on decay produces :
(A) Positron **(B)** β-particle **(C)** α-particle **(D)** none of these

63. Which consists of charged particles of matter?
(A) Inert gases **(B)** Neutrino **(C)** γ-rays **(D)** Anode rays

64. ${}^{60}_{27}Co$ is radioactive because :
(A) its atomic number is high **(B)** it has high p/n ratio
(C) it has high n/p ratio **(D)** none of these

65. Which of the following isotopes is likely to be most stable?
(A) ${}^{71}_{30}Zn$ **(B)** ${}^{66}_{30}Zn$ **(C)** ${}^{64}_{30}Zn$ **(D)** None of these

66. Consider α-particles, β-particles and γ-rays, each having an energy of 0.50 MeV. The increasing order of penetration power is :
(A) $\alpha < \beta < \gamma$ **(B)** $\alpha < \gamma < \beta$ **(C)** $\beta < \gamma < \alpha$ **(D)** $\gamma < \beta < \alpha$

67. ${}^{27}_{13}Al$ is a stable isotope. ${}^{29}_{13}Al$ is expected to disintegrate by :
(A) α-emission **(B)** β-emission **(C)** positron emission **(D)** proton emission

68. Which of the following nuclear emission will generate an isotope :
(A) β-emission **(B)** neutron emission **(C)** α-emission **(D)** positron emission

69. The total number of α- and β-particles given out during given nuclear transformation is :

$${}^{238}_{92}U \longrightarrow {}^{214}_{82}Pb$$

(A) 2 **(B)** 4 **(C)** 6 **(D)** 8

70. If wavelength is equal to the distance travelled by the electron in one second, then -
(A) $\lambda = \frac{h}{p}$ **(B)** $\lambda = \frac{h}{m}$ **(C)** $\lambda = \sqrt{\frac{h}{p}}$ **(D)** $\lambda = \sqrt{\frac{h}{m}}$

71. Which orbital is non-directional
(A) s **(B)** p **(C)** d **(D)** All

72. If n and ℓ are respectively the principal and azimuthal quantum numbers, then the expression for calculating the total number of electrons in any orbit is -
(A) $\sum_{\ell=1}^{\ell=n} 2(2\ell + 1)$ **(B)** $\sum_{\ell=1}^{\ell=n-1} 2(2\ell + 1)$ **(C)** $\sum_{\ell=0}^{\ell=n+1} 2(2\ell + 1)$ **(D)** $\sum_{\ell=0}^{\ell=n-1} 2(2\ell + 1)$

73. Uncertainty in position is twice the uncertainty in momentum. Uncertainty in velocity is :
(A) $\sqrt{\frac{h}{\pi}}$ **(B)** $\frac{1}{2m}\sqrt{\frac{h}{\pi}}$ **(C)** $\frac{1}{2m}\sqrt{\hbar}$ **(D)** $\frac{h}{4\pi}$

74. For which orbital angular probability distribution is maximum at an angle of 45° to the axial direction-

(A) $d_{x^2-y^2}$ **(B)** d_{z^2} **(C)** d_{xy} **(D)** P_x

75. The wave number of electromagnetic radiation emitted during the transition of electron in between two levels of Li^{2+} ion having sum of the principal quantum numbers 4 and difference is 2, will be : (R_H = Rydberg constant)

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

76. Consider an electron in the n^{th} orbit of a hydrogen atom in the Bohr model. The circumference of the orbit can be expressed in terms of the de Broglie wavelength λ of the electron as :

(A) (0.529) $n\lambda$ **(B)** $\sqrt{n}\ \lambda$ **(C)** (13.6) λ **(D)** $n\lambda$

77. The quantum numbers + 1/2 and – 1/2 for the electron spin represent -

(A) Rotation of the electron in clockwise and anticlockwise direction respectively.

(B) Rotation of the electron in anticlockwise and clockwise direction respectively.

(C) Magnetic moment of the electron pointing up and down respectively,

(D) Two quantum mechanical spin states which have no classical analogue.

78. A particle X moving with a certain velocity has a debroglie wave length of 1Å, If particle Y has a mass of 25% that of X and velocity 75% that of X, debroglies wave length of Y will be -

(A) 3 Å **(B)** 5.33 Å **(C)** 6.88 Å **(D)** 48 Å

79. De Broglie wavelength of an electron after being accelerated by a potential difference of V volt from rest is

(A) $\lambda = \frac{12.3}{\sqrt{h}}$ Å **(B)** $\lambda = \frac{12.3}{\sqrt{V}}$ Å **(C)** $\lambda = \frac{12.3}{\sqrt{E}}$ Å **(D)** $\lambda = \frac{12.3}{\sqrt{m}}$ Å

80. Let υ_1 be the frequency of the series limit of the Lyman series, υ_2 be the frequency of the first line of the Lyman series, and υ_3 be the frequency of the series limit of the Balmer series -

(A) $\upsilon_1 - \upsilon_2 = \upsilon_3$ **(B)** $\upsilon_2 - \upsilon_1 = \upsilon_3$ **(C)** $\upsilon_3 = 1/2\ (\upsilon_1 - \upsilon_3)$ **(D)** $\upsilon_1 + \upsilon_2 = \upsilon_3$

Exercise # 2 Part # I [Multiple Correct Choice Type Questions]

1. A hydrogen - like atom has ground state binding energy 122.4 eV. Then :

(A) its atomic number is 3

(B) a photon of 90 eV can excite it to a higher state

(C) a 80 eV photon cannot excite it to a higher state

(D) None

2. A sodium street light gives off yellow light that has a wavelength of 600 nm. Then

(For energy of a photon take $E = \frac{12400 \text{ eV Å}}{\lambda(\text{Å})}$)

(A) frequency of this light is 7×10^{14} s^{-1}

(B) frequency of this light is 5×10^{14} s^{-1}

(C) wavenumber of the light is 3×10^{6} m^{-1}

(D) energy of the photon is approximately 2.07 eV

3. The qualitative order of Debroglie wavelength for electron, proton and α particle is $\lambda_e > \lambda_p > \lambda\alpha$ if

(A) If kinetic energy is same for all particles

(B) If the accelerating potential difference **'V'** is same for all the particles (from rest)

(C) If velocities are same for all particles

(D) None of the above

4. If there are only two H-atoms, each is in 3^{rd} excited state then :

(A) Maximum number of different photons emitted is 4.

(B) Maximum number of different photons emitted is 3.

(C) Minimum number of different photons emitted is 1.

(D) Minimum number of different photons emitted is 2.

5. Which of the following statements is/are correct for an electron of quantum numbers n = 4 and m = 2?

(A) The value of ℓ may be 2.

(B) The value of ℓ may be 3.

(C) The value of s may be +1/2.

(D) The value of ℓ may be 0, 1, 2, 3.

6. Which is true about an electron ?

(A) Rest mass of electron is 9.1×10^{-28} g

(B) Mass of electron increases with the increase in velocity

(C) Molar mass of electron is 5.48×10^{-4} g/mole

(D) e/m of electron is 1.7×10^{8} coulomb/g

7. From the α-particle scattering experiment, Rutherford concluded that

(A) α-particle can come within a distance of the order of 10^{-14} m from the nucleus

(B) the radius of the nucleus is less than 10^{-14} m

(C) scattering followed Coulomb's law

(D) the positively charged parts of the atom move with extremely high velocities

8. Which of the following statement(s) are wrong ?

(A) Photons having energy 400 kJ will break 4 mole bonds of a molecule A_2 where A–A bond dissociation energy is 100kJ/mol.

(B) Two bulbs are emitting light having wavelength 2000Å & 3000Å respectively. If the bulbs A & B are 40 watt and 30watt respectively then the ratio of no. of photons emitted by A & B per day is 1 : 2.

(C) When an electron make transition from lower to higher orbit, photon is emitted.

(D) None of the above

9. In a H-like sample, electrons make transition from 4^{th} excited state upto 2^{nd} state. Then

(A) 10 different spectral lines are observed

(B) 6 different spectral lines are observed

(C) number of lines belonging to the balmer series is 3

(D) Number of lines belonging to paschen series is 2.

10. Identify the correct statement(s) :

(A) Wavelength associated with a 1 kg ball moving with the velocity 100 m/s can't be calculated.

(B) Wave nature of the running train is difficult to observe because wavelength is extremely small.

(C) Wavelength associated with the electron can be calculated using the formulae $E = \frac{hc}{\lambda}$

(D) If an electron is accelerated through 20 V potential difference if it has already 5eV kinetic energy then wavelength of the electron is approximately $\sqrt{6}$ Å.

11. 1^{st} excitation potential for the H-like (hypothetical) sample is 24 V. Then :

(A) Ionisation energy of the sample is 36 eV

(B) Ionisation energy of the sample is 32 eV

(C) Binding energy of 3^{rd} excited state is 2 eV

(D) 2^{nd} excitation potential of the sample is $\frac{32 \text{ x } 8}{9}$ V

12. If element $_{25}X^{+Y}$ has spin magnetic moment 1.732 B.M then

(A) number of unpaired electron = 1 **(B)** number of unpaired electron = 2

(C) Y = 4 **(D)** Y = 6

13. Isotone of $^{76}_{32}Ge$ is/are :

(A) $^{77}_{32}Ge$ **(B)** $^{77}_{33}As$ **(C)** $^{77}_{34}Se$ **(D)** $^{78}_{34}Se$

14. When alpha particles are sent towards 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 speed

15. In which of these options do both constituents of the pair have the same spin magnetic moment?

(A) Zn^{2+} and Cu^{+} **(B)** Co^{2+} and Ni^{2+} **(C)** Mn^{4+} and Co^{2+} **(D)** Mg^{2+} and Sc^{+}

16. In a hydrogen like sample two different types of photons A and B are produced by electronic transition. Photon B has it's wavelength in infrared region. If photon A has more energy than B, then the photon A may belong to the region

(A) ultraviolet **(B)** visible **(C)** infrared **(D)** None

17. Many elements have non-integral atomic masses because

(A) they have isotopes

(B) their isotopes have non-integral masses

(C) the constituents, neutrons, protons and electrons combine to give fractional masses

(D) none of these

18. Bohr's theory is not applicable to

(A) He **(B)** Li^{2+} **(C)** He^{2+} **(D)** the H-atom

19. In which transition, one quantum of energy is emitted ?

(A) $n = 4 \rightarrow n = 2$ **(B)** $n = 3 \rightarrow n = 1$ **(C)** $n = 4 \rightarrow n = 1$ **(D)** $n = 2 \rightarrow n = 1$

20. The magnitude of the spin angular momentum of an electron is given by

(A) $S = \sqrt{s(s+1)}\frac{h}{2\pi}$ **(B)** $S = s\frac{h}{2\pi}$ **(C)** $S = \frac{\sqrt{3}}{2} \times \frac{h}{2\pi}$ **(D)** $S = \pm\frac{1}{2} \times \frac{h}{2\pi}$

21. The change in angular momentum corresponding to an electron in Balmer transition inside a hydrogen atom can be

(A) $\frac{h}{4\pi}$ **(B)** $\frac{h}{\pi}$ **(C)** $\frac{h}{2\pi}$ **(D)** $\frac{h}{8\pi}$

22. Choose the correct configurations among the following :

(A) Cr (Z = 24) : [Ar] $3d^5 4s^1$ **(B)** Cu (Z = 29) : [Ar] $3d^{10} 4s^1$

(C) Pd (Z = 46) : [Kr] $4d^{10} 4s^0$ **(D)** Pt (Z = 78) : [Xe] $4d^{10} 4s^2$

23. The configuration [Ar] $3d^{10} 4s^2 4p^4$ is similar to that of

(A) boron **(B)** oxygen **(C)** sulphur **(D)** aluminium

24. What are the values of the orbital angular momentum of an electron in the orbitals 1s, 3s, 3d and 2p -

(A) $0, 0, \sqrt{6}\hbar, \sqrt{2}\hbar$ **(B)** $1, 1, \sqrt{4}\hbar, \sqrt{2}\hbar$ **(C)** $0, 1\sqrt{6}\hbar, \sqrt{3}\hbar$ **(D)** $0, 0\sqrt{20}\hbar, \sqrt{6}$

25. The value of the spin magnetic moment of a particular ion is 2.83 Bohr magneton. The ion is :

(A) Fe^{2+} **(B)** Ni^{2+} **(C)** Mn^{2+} **(D)** Co^{3+}

26. In an atom, two electrons move round the nucleus in circular orbits of radii R and 4R. The ratio of the time taken by them to complete one revolution is : (Consider Bohr model to be valid)

(A) 1 : 4 **(B)** 4 : 1 **(C)** 1 : 8 **(D)** 8 : 1

27. After np orbitals are filled, the next orbital filled will be :

(A) (n + 1) s **(B)** (n + 2) p **(C)** (n + 1) d **(D)** (n + 2) s

28. In Bohr's model of the hydrogen atom the ratio between the period of revolution of an electron in the orbit of n = 1 to the period of the revolution of the electron in the orbit n = 2 is -

(A) 1 : 2 **(B)** 2 : 1 **(C)** 1 : 4 **(D)** 1 : 8

29. Total number of electrons having $n + \ell = 3$ in Cr (24) atom in its ground state is :
(A) 8 (B) 10 (C) 12 (D) 6

30. The angular momentum of an electron in a given orbit is J, Its kinetic energy will be :
(A) $\frac{1}{2}\frac{J^2}{mr^2}$ (B) $\frac{Jv}{r}$ (C) $\frac{J^2}{2m}$ (D) $\frac{J^2}{2\pi}$

31. According to Bohr's model of hydrogen atom the electric current generated due to motion of electron in n^{th} orbit is:
(A) $\frac{4\pi^2mk^2e^4}{n^2h^2}$ (B) $\frac{4\pi^2mk^2e^5}{n^2h^2}$ (C) $\frac{n^2h^2}{4\pi^2mk^2e^5}$ (D) $\frac{4\pi^2mk^2e^5}{n^3h^3}$

32. The correct set of four quantum numbers for the valence electron of Rubidium (Z = 37) is
(A) $n = 5, \ell = 0, m = 0, s = +\frac{1}{2}$ (B) $n = 5, \ell = 1, m = 0, s = +\frac{1}{2}$
(C) $n = 5, \ell = 1, m = 1, s = +\frac{1}{2}$ (D) $n = 6, \ell = 0, m = 0, s = +\frac{1}{2}$

33. No. of visible lines when an electron returns from 5th orbit upto ground state in H spectrum :
(A) 5 (B) 4 (C) 3 (D) 10

34. If the shortest wave length of Lyman series of H atom is x, then the wave length of the first line of Balmer series of H atom will be :
(A) 9x/5 (B) 36x/5 (C) 5x/9 (D) 5x/36

35. Which of the given statement (s) is/are **false.**
I. Orbital angular momentum of the electron having n = 5 and having value of the azimuthal quantum number as lowest for this principle quantum number is $\frac{h}{\pi}$.
II. If $n = 3, \ell = 0, m = 0$, for the last valence shell electron, then the possible atomic number must be 12 or 13.
III. Total spin of electrons for the atom $_{25}Mn$ is $\pm\frac{7}{2}$.
IV. Spin magnetic moment of inert gas is 0 .
(A) I, II and III (B) II and III only (C) I and IV only (D) None of these

36. An electron in a hydrogen like atom makes transition from a state in which its de-Broglie wavelength is λ_1 to a state where its de-Broglie wavelength is λ_2 then wavelength of photon (λ) generated will be
(A) $\lambda = \lambda_1 - \lambda_2$ (B) $\lambda = \frac{4mc}{h}\left\{\frac{\lambda_1^2\lambda_2^2}{\lambda_1^2 - \lambda_2^2}\right\}$
(C) $\lambda = \sqrt{\frac{\lambda_1^2\lambda_2^2}{\lambda_1^2 - \lambda_2^2}}$ (D) $\lambda = \frac{2mc}{h}\left\{\frac{\lambda_1^2\lambda_2^2}{\lambda_1^2 - \lambda_2^2}\right\}$
where m is mass of the electron, c is speed of light in vaccum.

37. If first ionization potential of a hypothetical atom is 16 V, then the first excitation potential will be :
(A) 10.2 V (B) 12 V (C) 14 V (D) 16 V

38. Change in angular momentum when an electron makes a transition corresponding to the 3^{rd} line of the Balmer series in Li^{2+} ion is
(A) $\frac{h}{2\pi}$ (B) $\frac{2h}{2\pi}$ (C) $\frac{3h}{2\pi}$ (D) $\frac{4h}{2\pi}$

39. An α-particle has initial kinetic energy of 25 eV and it is accelerated through the potential difference of 150 volt. If a proton has initial kinetic energy of 25 eV and it is accelerated through the potential difference of 25 volt then find the approximate ratio of the final wavelengths associated with the proton and the α-particle.

(A) 5 **(B)** 4 **(C)** 3 **(D)** 2

40. Photon having energy equivalent to the binding energy of 4th state of He^+ atom is used to eject an electron from the metal surface of work function 1.4 eV. If electrons are further accelerated through the potential difference of 4V then the minimum value of De–broglie wavelength associated with the electron is :

(A) 1.1 Å **(B)** 5 Å **(C)** 9.15 Å **(D)** 11 Å

41. In a sample of H-atoms, electrons de-excite from a level 'n' to 1. The total number of lines belonging to Balmer series are two. If the electrons are ionised from level 'n' by photons of energy 13 eV. Then the kinetic energy of the ejected photoelectrons will be

(A) 12.15 eV **(B)** 11.49 eV **(C)** 12.46 eV **(D)** 12.63 eV

42. In case of $d_{x^2-y^2}$ orbital

(A) Probability of finding the electron along x-axis is zero.
(B) Probability of finding the electron along y-axis is zero.
(C) Probability of finding the electron is maximum along x and y-axis.
(D) Probability of finding the electron is zero in x-y plane

43. Match List-I with List-II and select the correct answer using the codes given below in the lists (n, ℓ and m are respectively the principal, azimuthal and magnetic quantum no.)

List-I		List-II
(A) Number of value of ℓ for an energy level(n)	(1)	0, 1, 2, ... (n - 1)
(B) Values of ℓ for a particular type of orbit	(2)	$+\ell$ to $-\ell$ through zero
(C) Number of value of m for $\ell = 2$	(3)	5
(D) Values of 'm' for a particular type of orbital	(4)	n

Code :

	A	B	C	D		A	B	C	D
(A)	4	1	2	3	**(B)**	4	1	3	2
(C)	1	4	2	3	**(D)**	1	4	3	2

44. When Z is doubled in an atom, which of the following statements are consistent with Bohr's theory?

(A) Energy of a state is doubled
(B) Radius of an orbit is doubled.
(C) Velocity of electron in an orbit is doubled.
(D) Energy of a state is halved

45. A photon of 300 nm is absorbed by a gas and then emits two photons. One photon has a wavelength 496 nm then the wavelength of second photon in nm is :

(A) 759 **(B)** 859 **(C)** 959 **(D)** 659

46. If the total energy of an electron in hydrogen like atom in an excited state is –3.4 eV, then the de-Broglie wavelength of the electron is :

(A) $\sqrt{\frac{150}{3.4}}$ Å **(B)** $\sqrt{\frac{150}{6.8}}$ Å **(C)** $\sqrt{\frac{150}{3.4}}$ nm **(D)** $\sqrt{\frac{150}{6.8}}$ nm

47. An electron, a proton and an alpha particle have kinetic energies of 16E, 4E and E respectively. What is the quantitative order of their de-Broglie wavelengths ?

(A) $\lambda_e > \lambda_p = \lambda_\alpha$ **(B)** $\lambda_p = \lambda_\alpha = \lambda_e$ **(C)** $\lambda_p > \lambda_e > \lambda_\alpha$ **(D)** $\lambda_e > \lambda_\alpha > \lambda_p$

48. The potential energy of the electron present in the ground state of Be^{3+} ion is represented by:

(A) $+\frac{e^2}{\pi \in_0 r}$ (B) $-\frac{e}{\pi \in_0 r}$ (C) $-\frac{e^2}{\pi \in_0 r^2}$ (D) $-\frac{e^2}{\pi \in_0 r}$

49. An ion Mn^{a+} has the spin magnetic moment equal to 4.9 BM. The value of a is : (atomic no. of Mn = 25)
(A) 3 (B) 4 (C) 2 (D) 5

50. d_{z^2} – orbital has :

(A) Two lobes along z-axis and a ring along xy-plane
(B) Two lobes along z-axis and two lobes along xy-plane
(C) Two lobes along z-axis and a ring along yz-plane
(D) Two lobes and a ring along z-axis

51. Photon having wavelength 310 nm is used to break the bond of A_2 molecule having bond energy 288 kJ mol^{-1} then % of energy of photon converted to the K.E. is [hc = 12400 evÅ , 1 ev = 96 kJ/mol]
(A) 25 (B) 50 (C) 75 (D) 80

52. In Balmer series of lines of hydrogen spectrum, the first line from the red end corresponds to which one of the following inter-orbit jumps of the electron for Bohr orbits in an atom of hydrogen ?
(A) $5 \rightarrow 2$ (B) $4 \rightarrow 1$ (C) $2 \rightarrow 5$ (D) $3 \rightarrow 2$

53. When an excited hydrogen atom returned to its ground state, some visible quanta were observed along with other quanta . Which of the following transitions must have occurred?
(A) $2 \rightarrow 1$ (B) $3 \rightarrow 1$ (C) $3 \rightarrow 2$ (D) $4 \rightarrow 2$

54. The radii of two of the first four Bohr's orbits of the hydrogen atom are in the ratio 1 : 4 The energy difference between them may be :
(A) Either 12.09 eV or 10.2 eV (B) Either 2.55 eV or 10.2 eV
(C) Either 13.6 eV or 3.4 eV (D) Either 3.4 eV or 0.85 eV

55. A proton and an α-particle are accelerated through the same potential difference from rest. Then the ratio of their de Broglie wavelength is :

(A) $\sqrt{2}$ (B) $\frac{1}{\sqrt{2}}$ (C) $2\sqrt{2}$ (D) $1/2\sqrt{2}$

56. Ionization energy of a hydrogen-like ion A is greater than that of another hydrogen like ion B. Let r, u, E and L represent the radius of the orbit, speed of the electron, total energy of the electron (with sign) and angular momentum of the electron respectively (for the same n). In ground state
(A) $r_A > r_B$ (B) $u_A > u_B$ (C) $E_A > E_B$ (D) $L_A > L_B$

57. There are two samples of H and He^+ atom. Both are in some excited state. In hydrogen atom total number of lines observed in Balmer series is 4 and in He^+ atom total number of lines observed in paschen series is 1. Electron in hydrogen sample make transitions to lower states from its excited state, then the photon corresponding to the line of maximum energy line of Balmer series of H sample is used to further excite the already excited He^+ sample. Then maximum excitation level of He^+ sample will be :
(A) n = 6 (B) n = 8 (C) n = 12 (D) n = 9

58. Which transition in Li^{2+} would have the same wavelength as the $2 \rightarrow 4$ transition in He^+ ion ?
(A) $4 \rightarrow 2$ (B) $2 \rightarrow 4$ (C) $3 \rightarrow 6$ (D) $6 \rightarrow 2$

59. Photons of equal energy were incident on two different gas samples. One sample containing H-atoms in the ground state and the other sample containing H-atoms in some excited state with a principal quantum number 'n'. The photonic beams totally ionise the H-atoms. If the difference in the kinetic energy of the ejected electrons in the two different cases is 12.75 eV. Then find the principal quantum number 'n' of the excited state.

(A) 1 **(B)** 2 **(C)** 3 **(D)** 4

60. The number of possible lines of Paschen series when electron jumps from 7^{th} excited state upto ground state (in hydrogen like atom) is :

(A) 2 **(B)** 5 **(C)** 4 **(D)** 3

61. Wavelength of radiations emitted when an electron jumps from a state A to C is 3000 Å and it is 6000 Å when the electron jumps from state B to C. Wavelength of the radiations emitted when an electron jumps from state A to B will be

(A) 2000 Å **(B)** 3000 Å **(C)** 4000 Å **(D)** 6000 Å

62. A certain dye absorbs light of $\lambda = 4000$ Å and then fluoresces light of 5000 Å. Assuming that under given conditions 50% of the absorbed energy is re-emitted out as fluorescence, calculate the ratio of number of quanta emitted out to the number of quanta absorbed.

(A) $\frac{5}{8}$ **(B)** $\frac{8}{5}$ **(C)** $\frac{3}{8}$ **(D)** $\frac{8}{3}$

63. The ratio of specific charge (e/m) of a proton and that of an α-particle is

(A) 2 : 1 **(B)** 1 : 2 **(C)** 1 : 4 **(D)** 1 : 1

64. The uncertainty in position and velocity of the particle are 0.1 nm and 5.27×10^{-27} ms^{-1} respectively. Then the mass of the particle is : ($h = 6.625 \times 10^{-34}$Js)

(A) 200 g **(B)** 300 g **(C)** 100 g **(D)** 1000 g

65. Last line of Lyman series for H–atom has wavelength λ_1 Å, 2^{nd} line of Balmer series has wavelength λ_2 Å then

(A) $\frac{16}{\lambda_1} = \frac{9}{\lambda_2}$ **(B)** $\frac{16}{\lambda_2} = \frac{3}{\lambda_1}$ **(C)** $\frac{4}{\lambda_1} = \frac{1}{\lambda_2}$ **(D)** $\frac{16}{\lambda_1} = \frac{3}{\lambda_2}$

66. The kinetic energy of the electron present in the ground state of Li^{2+} ion is represented by :

(A) $\frac{3e^2}{8\pi \in_0 r}$ **(B)** $-\frac{3e^2}{8\pi \in_0 r}$ **(C)** $\frac{3e^2}{4\pi \in_0 r}$ **(D)** $-\frac{3e^2}{4\pi \in_0 r}$

67. For the Hydrogen spectrum, last line of the Lyman series has frequency ν_1, last line of Lymen series of He^+ ion has frequency ν_2 and last line of Balmer series of He^+ ion has frequency ν_3 then

(A) $2(\nu_1 + \nu_3) = \nu_2$ **(B)** $\nu_1 = \nu_3$ **(C)** $4\nu_1 = \nu_2$ **(D)** $\nu_2 = \nu_3$

Part # II [Assertion & Reason Type Questions]

Each question has 5 choices (A), (B), (C), (D) and (E) out of which only one is correct.

(A) Statement-1 is True, Statement-2 is True; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True; Statement-2 is NOT a correct explanation for Statement-1.

(C) Statement-1 is True, Statement-2 is False.

(D) Statement-1 is False, Statement-2 is True.

(E) Statement-1 and Statement-2 both are False.

1. **Statement-1 :** Specific charge of α-particle is twice to that of proton.
Statement-2 : Specific charge is given by e/m.

2. **Statement-1 :** For n = 3, ℓ may be 0, 1 and 2 and 'm' may be 0, ± 1 and ± 2.
Statement-2 : For each value of n, there are 0 to (n – 1) possible values of ℓ; for each value of ℓ, there are 0 to ± ℓ values of m.

3. **Statement-1 :** The possible number of electrons in a subshell is $(4\ell + 2)$
Statement-2 : The possible number of orientations of a sub-shell are $(2\ell + 1)$

4. **Statement-1 :** If the potential difference applied to an electron is made 4 times, the de Broglie wavelength associated is halved. Initial kinetic energy of electron was zero.
Statement-2 : On making potential difference 4 times, velocity is doubled and hence λ is halved.

5. **Statement-1 :** Wave number of a spectral line for an electronic transition is quantised.
Statement-2 : Wave number is directly proportional to the velocity of electron undergoing the transition.

6. **Statement-1:** Humphry series discovered in H-atomic spectra has lowest energy radiations among all series.
Statement-2 : Lowest state for this series is $n_1 = 6$.

7. **Statement-1 :** A photon of energy 12 eV can break three molecules of A_2 into atoms which has bond dissociation energy of 4 eV/molecule.
Statement-2 : Total energy is conserved and interaction is always one to one between photon and molecule.

8. **Statement-1 :** Thomson's analysis of cathode ray experiment led him to conclude that electrons were fundamental particles.
Statement-2 : e/m ratio for particles in cathode rays was found to be independent of the nature of the gas taken in the tube.

9. **Statement-1 :** e/m ratio in case of anode ray experiment is different for different gases.
Statement-2 : The ion of gases formed after the ejection of electron are different if gas is different.

10. **Statement-I :** Nodal plane of p_x atomic orbital is yz plane.
Statement-II : In p_x atomic orbital electron density is zero in the yz plane.

11. **Statement-I :** No two electrons in an atom can have the same values of four quantum numbers.
Statement-II : No two electrons in an atom can be simultaneously in the same shell, same subshell, same orbitals and have same spin.

12. **Statement-I :** p-orbital has dumb-bell shape.
Statement-II : Electrons present in p-orbital can have one of three values for 'm', i.e. 0, +1, –1

13. **Statement-I :** The ground state configuration of Cr is $3d^5\ 4s^1$.
Statement-II : A set of exactly half filled orbitals containing parallel spin arrangement provide extra stability.

14. **Statement-I :** Mass numbers of most of the elements are fractional.

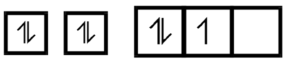
Statement-II : Mass numbers are obtained by comparing with the mass number of carbon taken as 12.

15. **Statement-I :** Limiting line in the balmer series has a wavelength of 36.4 μm.

Statement-II : Limiting lines is obtained for a jump of electron from n = ∞ to n = 2 for Balmer series.

16. **Statement-I :** The electronic configuration of nitrogen atom is represented as :

not as



Statement-II : The configuration of ground state of an atom is the one which has the greatest multiplicity.

17. **Statement-I :** The configuration of B atom cannot be $1s^2\ 2s^3$.

Statement-II : Hund's rule demands that the configuration should display maximum multiplicity.

18. **Statement-I :** 2p orbitals do not have spherical nodes.

Statement-II : The number of spherical nodes in p-orbitals is given by (n – 2).

19. **Statement-I :** In Rutherford's gold foil experiment, very few α– particles are deflected back.

Statement-II : Nucleus present inside the atom is heavy.

20. **Statement-I :** Each electron in an atom has two spin quantum numbers.

Statement-II : Spin quantum numbers are obtained by solving Schrodinger wave equation.

21. **Statement-I :** There are two spherical nodes in 3s-orbital.

Statement-II : There is no angular node in 3s-orbital.

Exercise # 3 Part # I [Matrix Match Type Questions]

1.

	Column I		Column II
(A)	Cathode rays	(p)	Helium nuclei
(B)	Dumb-bell	(q)	Uncertainty principle
(C)	Alpha particles	(r)	Electromagnetic radiation
(D)	Moseley	(s)	p-orbital
(E)	Heisenberg	(t)	Atomic number
(F)	X-rays	(u)	Electrons

2. Frequency = f, Time period = T, Energy of n^{th} orbit = E_n, radius of n^{th} orbit = r_n, Atomic number = Z, Orbit number = n

	Column I		Column II
(A)	f	(p)	n^3
(B)	T	(q)	Z^2
(C)	E_n	(r)	$\frac{1}{n^2}$
(D)	$\frac{1}{r_n}$	(s)	Z

3.

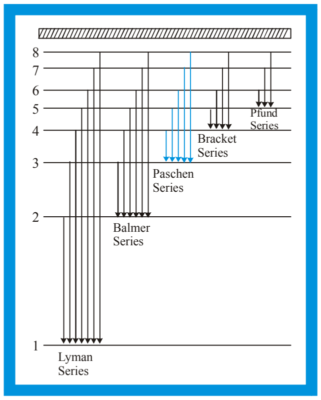
	Column I		Column II
(A)	Lyman series	(p)	maximum number of spectral line observed = 6
(B)	Balmer series	(q)	maximum number of spectral line observed = 2
(C)	In a sample of H-atom for 5 upto 2 transition	(r)	2^{nd} line has wave number $\frac{8R}{9}$
(D)	In a single isolated H-atom for 3 upto 1 transition	(s)	2^{nd} line has wave number $\frac{3R}{16}$
		(t)	Total number of spectral line is 10.

4.

	Column I		Column II
(A)	Aufbau principle	(p)	Line spectrum in visible region
(B)	de broglie	(q)	Maximum multiplicity of electron
(C)	Angular momentum	(r)	Photon
(D)	Hund's rule	(s)	$\lambda = h/(mv)$
(E)	Balmer series	(t)	Electronic configuration
(F)	Planck's law	(u)	mvr

Part # II [Comprehension Type Questions]

Comprehension # 1



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

Maximum number of lines produced when electrons jump from *n*th level to ground level is equal to $\frac{n(n-1)}{2}$.

For example, in the case of n = 4, number of lines produced is 6. ($4 \to 3, 4 \to 2, 4 \to 1, 3 \to 2, 3 \to 1, 2 \to 1$). When an electron returns from n_2 to n_1 state, the number of lines in the spectrum will be equal to

$$\frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

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

$$E_2 - E_1 = \Delta E, \qquad \lambda = \frac{hc}{\Delta E}, \qquad \Delta E = h\nu \ (\nu \text{ - frequency})$$

Since h and c are constants, ΔE corresponds to definite energy; thus each transition from one energy level to another will produce a light of definite wavelength. This is actually observed as a line in the spectrum of hydrogen atom.

Wave number of line is given by the formula $\bar{\nu} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$.

where R is a Rydberg constant ($R = 1.1 \times 10^7 \, m^{-1}$)

(i) First line of a series : It is called 'line of longest wavelength' or 'line of shortest energy'.

(ii) Series limit or last line of a series : It is the line of shortest wavelength or line of highest energy.

1. Last line of Brackett series for H–atom has wavelength λ_1 Å and 2nd line of lyman series has wavelength λ_2 Å, then

(A) $\frac{128}{\lambda_1} = \frac{9}{\lambda_2}$ **(B)** $\frac{16}{\lambda_1} = \frac{9}{\lambda_2}$ **(C)** $\frac{4}{\lambda_1} = \frac{1}{\lambda_2}$ **(D)** $\frac{128}{\lambda_1} = \frac{8}{\lambda_2}$

2. Consider the following statements

1. Spectral lines of He^+ ion belonging to Balmer series are not in visible range.
2. In the balmer series of H-atom maximum lines are in ultra violet region.
3. 2nd line of lyman series of He^+ ion has energy 48.4 eV

The above statements 1, 2, 3 respectively are (T = True, F = False)

(A) T F F **(B)** F T T **(C)** T F T **(D)** T T T

3. Wave number of the first line of Paschen series in Be^{3+} ion is

(A) $\frac{7R}{16}$ **(B)** $\frac{7R}{144}$ **(C)** $\frac{7R}{9}$ **(D)** $\frac{R}{144}$

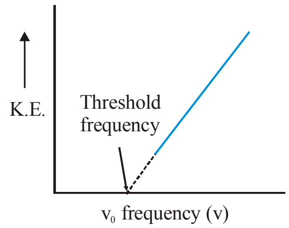
Comprehension # 2

In the photoelectric effect the electrons are emitted instantaneously from a given metal plate, when it is irradiated with radiation of frequency equal to or greater than some minimum frequency, called the threshold frequency. According to planck's idea, light may be considered to be made up of discrete particles called photons . Each photon carries energy equal to hν. When this photon collides with the electron of the metal, the electron acquires energy equal to the energy of the photon. Thus the energy of the emitted electron is given by :

$$h\nu = K.E_{maximum} + P.E. = \frac{1}{2}mu^2 + PE$$

If the incident radiation is of threshold frequency the electron will be emitted without any kinetic energy i.e. $h\nu_0 = PE$

$$\therefore \frac{1}{2}mu^2 = h\nu - h\nu_0$$



A plot of kinetic energy of the emitted electron versus frequency of the incident radiation yields a straight line given as

1. A beam of white light is dispersed into its wavelength components by a Quartz prism and falls on a thin sheet of potassium metal. What is the correct decreasing order of kinetic energy of maximum the electron emitted by the different light component.

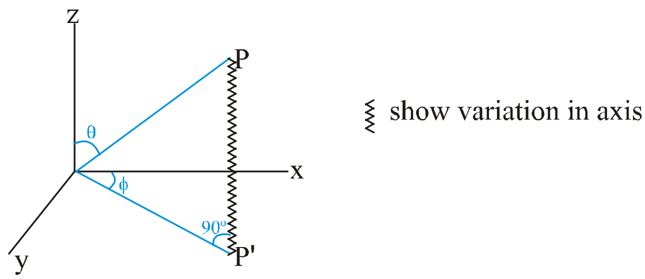
(A) blue > green > orange > yellow **(B)** violet > blue > orange > red
(C) yellow > green > blue > violet **(D)** orange > yellow > blue > violet

2. A laser producing monochromatic light is used to eject electron from the sheet of gold having threshold frequency $6.15 \times 10^{14}\ s^{-1}$ which of the following incident radiation will be suitable for the ejection of electron :
(A) 1.5 moles of photons having frequency $3.05 \times 10^{14}\ s^{-1}$
(B) 0.5 moles of photon of frequency $12.3 \times 10^{12}\ s^{-1}$
(C) One photon with frequency $5.16 \times 10^{15}\ s^{-1}$
(D) All of the above

3. The number of photoelectrons emitted depends upon :
(A) The intensity of the incident radiation
(B) The frequency of the incident radiation
(C) The product of intensity and frequency of incident radiation
(D) None of these

Comprehension # 3

After the failure of Bohr atomic theory but its ability to explain the atomic spectra a need was felt for the new model that could incorporate, the concept of stationary orbit, de Broglie concept, Heisenberg uncertainty principle. The concept that in corporate above facts is called quantum mechanics of the atomic model wave mechanical model. It includes set of quantum numbers and $|\psi^2|$a mathematical expression of the probability of finding an electron at all points in space. This probability function is the best indication available of how the electron behaves, for as a consequence of the Uncertainty Principle, the amount we can know about the electron is limited. While quantum mechanics can tell us the exact probability of finding an electron at any two particular points, it does not tell us how the electron moves from one of these points to the other. Thus the idea of an electron orbit is lost; it is replaced with a description of where the electron is most likely to be found. This total picture of the probability of finding an electron at various points in space is called an orbital.



There are various types of orbitals possible, each corresponding to one of the possible combinations of quantum numbers. These orbitals are classified according to the value of n and *l* associated with them. In order to avoid confusion over the use of two numbers, the numerical values of l are replaced by letters; electrons in orbitals with $l = 0$ are called s-electrons those occupying orbitals for which $l = 1$ are p-electrons and those for which $l = 2$ are called d-electrons. The numerical and alphabetical correspondences are summarized in table. Using the alphabetical notation for *l*, we would say that in the ground state of hydrogen atom ($n = 1, l = 0$) we have a 1s-electron, or that the electron moves in a 1s-orbital. The relation of the spherical polar co-ordinates r, θ and ϕ to Cartesian coordinates x, y and z. To make the concept of an orbital more meaningful, it is helpful to examine the actual solution of the wave function for the one-electron atom. Because of the spherical symmetry of the atom, the wave functions are most simply expressed in terms of a spherical polar-coordinate system, shown in fig., which has its orbit at the nucleus. It is found that the wave functions can be expressed as the product of two functions, one of which (the "angular part" X) depends only the angle θ and ϕ, the other of which (the "radial part" R) depends only on the distance from the nucleus. Thus we have

$$\psi(r, \theta, \phi) = R(\mathbf{r})\, X(\theta, \phi)$$

Angular and radial parts of hydrogen atom wave functions

Angular part $X(\theta, \phi)$	Radial part $R_{n,\ell}(\mathbf{r})$
$X(\mathbf{s}) = \left(\frac{1}{4\pi}\right)^{1/2}$	$R(1s) = 2\left(\frac{z}{a_0}\right)^{3/2} e^{-\sigma/2}$
$X(p_x) = \left(\frac{3}{4\pi}\right)^{1/2} \sin\theta \cos\phi$	$R(2s) = \frac{1}{2\sqrt{2}}\left(\frac{z}{a_0}\right)^{3/2} (2-\sigma)\, e^{-\sigma/2}$
$X(p_y) = \left(\frac{3}{4\pi}\right)^{1/2} \sin\theta \sin\phi$	$R(2p) = \frac{1}{2\sqrt{6}}\left(\frac{z}{a_0}\right)^{3/2} \sigma\, e^{-\sigma/2}$
$X(p_z) = \left(\frac{3}{4\pi}\right)^{1/2} \cos\theta$	
$X(d_{z^2}) = \left(\frac{5}{16\pi}\right)^{1/2} (3\cos^2\theta - 1)$	
$X(d_{xz}) = \left(\frac{15}{4\pi}\right)^{1/2} \sin\theta \cos\theta \cos\phi$	$R(3s) = \frac{1}{9\sqrt{3}}\left(\frac{z}{a_0}\right)^{3/2} (6 - 6\sigma + \sigma^2) e^{-\sigma/2}$

$$X(d_{yz}) = \left(\frac{15}{4\pi}\right)^{1/2} \sin\theta \cos\theta \sin\phi \qquad R(3p) = \frac{1}{9\sqrt{6}}\left(\frac{z}{a_0}\right)^{3/2} (4-\sigma)\sigma e^{-\sigma/2}$$

$$X(d_{x^2-y^2}) = \left(\frac{15}{4\pi}\right)^{1/2} \sin^2\theta \cos 2\phi \qquad R(3d) = \frac{1}{9\sqrt{30}}\left(\frac{z}{a_0}\right)^{3/2} \sigma^2 e^{-\sigma/2}$$

$$X(d_{xy}) = \left(\frac{15}{4\pi}\right)^{1/2} \sin^2\theta \sin 2\phi$$

$$\sigma = \frac{2Zr}{na_0}\ ;\ a_0 = \frac{h^2}{4\pi^2 me^2}$$

This factorization helps us to visualize the wave function, since it allows us to consider the angular and radial dependences separately. It contains the expression for the angular and radial parts of the one electron atom wave function. Note that the angular part of the wave function for an s-orbital it always the same, $(1/4\pi)^{1/2}$, regardless of principal quantum number. It is also true that the angular dependence of the p-orbitals and of the d-orbitals is independent of principle quantum number. Thus all orbitals of a given types (s, p, or d) have the same angular behaviour The table shows, however, that the radial part of the wave function depends both on the principal quantum number n and on the angular momentum quantum number l.

To find the wave function for a particular state, we simply multiply the appropriate angular and radial parts together called normalized wave function.

The probability of finding an electron at a point within an atom is proportional to the square of orbital wave function, i.e., ψ^2 at that point. Thus, ψ^2 is known as probability density and alwyas a positive quantity.

ψ^2 dV (or $\psi^2.4\pi r^2 dr$). represents the probability for finding electron in a small volume dV surrounding the nucleus.

1. The electron probability density for 1s-orbital is best represented by the relation

(A) $\frac{1}{2\sqrt{\pi}}\left(\frac{Z}{a_0}\right)^{3/2} \times e^{-\frac{r}{a_0}}$ **(B)** $\frac{1}{\pi}\left(\frac{Z}{a_0}\right)^{3} \times e^{-\frac{2zr}{a_0}}$

(C) $\frac{1}{\pi}\left(\frac{Z}{a_0}\right)^{3/2} e^{-\frac{r}{a_0}}$ **(D)** $\frac{2}{\pi}\left(\frac{Z}{a_0}\right)^{3} e^{-\frac{2zr}{a_0}}$

2. The wave function (Ψ) of 2s-orbital is given by :

$$\Psi_{2s} = \frac{1}{\sqrt{32\pi}}\left[\frac{1}{a_0}\right]^{3/2}\left[2-\frac{r}{a_0}\right]e^{-r/2a_0}$$, At $r = r_0$, radial node is formed.

Then which of the following is correct :

(A) $r_0 = a_0$ **(B)** $r_0 = 2a_0$ **(C)** $r_0 = 3a_0$ **(D)** None of these

3. The angular wave function of which orbital will not disturb by the variation with azimuthal angle only

(A) 1s and 2s **(B)** $2p_z$ and $2d_z{}^2$ **(C)** $2p_x$ and $3d_z{}^2$ **(D)** $2p_x$ and 2s

Comprehension # 4

Quantum numbers are assigned to get complete information of electrons regarding their energy, angular momentum, spectral lines etc. Four quantum numbers are known i.e. principal quantum numbers which tell the distance of electron from nucleus, energy of electron in a particular shell and its angular momentum. Azimuthal quantum number tells about the subshells in a given shell and of course shape of orbital. Magnetic quantum number deals with study of orientations or degeneracy of a subshell.

Spin quantum number which defines the spin of electron designated as $+\frac{1}{2}$ or $-\frac{1}{2}$ represented by ↿ and ⇂ respectively. Electron are filled in orbitals following Aufbau rule. Pauli's exclusion principal and Hund's rule of maximum multiplicity. On the basis of this answer the following questions.

1. Two unpaired electrons present in carbon atom are different with respect to their

(A) Principle quantum number **(B)** Azimuthul quantum number
(C) Magnetic quantum number **(D)** Spin quantum number

2. Number of electron having the quantum numbers n = 4, ℓ = 0, s = $-\frac{1}{2}$ in Zn^{+2} ion is/are :

(A) 1 **(B)** 0 **(C)** 2 **(D)** 5

3. Spin angular momentum for unpaired electron in sodium (Atomic No. = 11) is

(A) $\frac{\sqrt{3}}{2}$ **(B)** 0.866 h/2π **(C)** $-\frac{\sqrt{3}}{2}\frac{h}{2\pi}$ **(D)** None of these

Comprehension # 5

de Broglie proposed dual nature for electron by putting his famous equation $\lambda = \frac{h}{mv}$. Later on Heisenberg proposed uncertainty principle as $\Delta p. \Delta x \geq \frac{h}{4\pi}$. On the contrary, particle nature of electron was established on the basis of photoelectric effect. When a photon strikes the metal 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 and the remaining energy imparts kinetic energy ($1/2\ mv^2$) to the ejected photoelectron. The potential applied on the surface to reduce the velocity of photoelectron to zero is known as stopping potential.

1. Uncertainity in the position of an electron (mass 9.1×10^{-31} kg) moving with a velocity 300 ms^{-1}, accurate upto 0.001% will be : ($\frac{\hbar}{2m_e} = 5.8 \times 10^{-5}$)

(A) 19.2×10^{-2} m **(B)** 5.76×10^{-2} m **(C)** 3.84×10^{-2} m **(D)** 1.92×10^{-2} m

2. When a beam of photons of a particular energy was incident on a surface of a particular pure metal having work function = (40 eV), some emitted photoelectrons had stopping potential equal to 22 V, some had 12 V and rest had lower values. Calculate the wavelength of incident photons assuming that at least one photoelectron is ejected with maximum possible kinetic energy. .

(A) 310 Å **(B)** 298 Å **(C)** 238 Å **(D)** 200 Å

3. The circumference of third orbit of a single electron species is 3 nm. What may be the approximate wavelength of the photon required to just ionize electron from this orbit.

(A) 91.1 nm **(B)** 364.7 nm **(C)** 821 nm **(D)** 205 nm

Comprehension # 6

– Electrons in various suborbits of an orbit are filled in increasing order to their energies.

– Pairing of electrons in various orbitals of a suborbit takes place only after each orbital is half-filled.

– No two electrons in an atom can have the same set of quantum number.

1. Cr (Z = 24), Mn^{+} (Z = 25), Fe^{2+} (Z = 26) and Co^{3+} (Z = 27) are isoelectronic each having 24 electrons. Thus,

(A) all have configurations as [Ar] $4s^1$ $3d^5$

(B) Cr and Mn^{+} have configurations as [Ar] $4s^1$ $3d^5$ while Fe^{2+} and Co^{3+} have configurations as [Ar]$3d^5$.

(C) all have configurations as [Ar] $3d^6$

(D) all have configurations as [Ar] $4s^2$ $3d^6$

2. A compound of vanadium has a magnetic moment of 1.73 BM. Electronic configuration of the vanadium ion in the compound is :

(A) [Ar] $4s^0$ $3d^1$ **(B)** [Ar] $4s^2$ $3d^3$

(C) [Ar] $4s^1$ $3d^0$ **(D)** [Ar] $4s^0$ $3d^5$

3. Which of these ions are expected to be paramagnetic and coloured in aqueous solution ?

(A) Fe^{3+}, Ti^{3+}, Co^{3+} **(B)** Cu^{+}, Ti^{4+}, Sc^{3+}

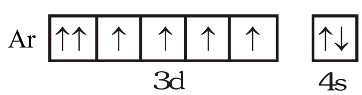
(C) Fe^{3+}, Ni^{2+}, V^{5+} **(D)** Cu^{+}, Cu^{2+}, Fe^{2+}

4. While writing the following electronic configuration of Fe some rules have been violated :

I : Aufbau rule,

II : Hund's rule

III : Pauli's exclusion principle



(A) I, II **(B)** II, III **(C)** I, III **(D)** I, II, III

5. How many elements would be in the second period of the periodic table if the spin quantum number (m_s) could have the value of $-\frac{1}{2}, 0, +\frac{1}{2}$?

(A) 8 **(B)** 10 **(C)** 12 **(D)** 18

6. The sub-shell that arises after *f* sub-shell is called g sub-shell.

(A) it contains 18 electrons and 9 orbitals

(B) it corresponds to ℓ = 4 and first occurs in 5th energy level

(C) a g-orbital can have maximum of two electrons

(D) all the above statements are true.

Exercise # 4 [Subjective Type Questions]

1. How long would it take a radio wave of frequency 6×10^3 sec^{-1} to travel from mars to the earth, a distance of 8×10^7 km ?

2. The energy levels of hypothetical one electron atom are shown below.

0 eV —— n = ∞
–0.50 eV —— n = 5
–1.45 eV —— n = 4
–3.08 eV —— n = 3
–5.3 eV —— n = 2
–15.6 eV —— n = 1

(a) Find the ionisation potential of atom?
(b) Find the short wavelength limit of the series terminating at n = 2 ?
(c) Find the wave no. of photon emitted for the transition made by the electron from third orbit to first orbit ?
(d) Find the minimum energy that an electron will have after interacting with this atom in the ground state, if the initial kinetic energy of the electron is (i) 6eV (ii) 11 eV ?

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

4. Find the number of photons of radiation of frequency 5×10^{13} s^{-1} that must be absorbed in order to melt one g ice when the latent heat of fusion of ice is 330 J/g.

5. The eyes of certain member of the reptile family pass a single visual signal to the brain when the visual receptors are struck by photons of wavelength 850 nm. If a total energy of 3.15×10^{-14} J is required to trip the signal, what is the minimum number of photons that must strike the receptor?

6. The wavelength of a certain line in the Paschen series is 1093.6 nm. What is the value of n_{high} for this line [$R_H = 1.0973 \times 10^{+7}$ m^{-1}].

7. Wavelength of the Balmer H_α line (first line) is 6565 Å. Calculate the wavelength of H_β (second line).

8. 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.

9. Calculate the energy emitted when electrons of 1.0 g atom of hydrogen undergo transition giving the spectral line of lowest energy in the visible region of its atomic spectrum.

10. A photon having λ = 854 Å causes the ionization of a nitrogen atom. Give the I.E. per mole of nitrogen in KJ.

11. Calculate energy of electron which is moving in the orbit that has its radius, Sixteen times the radius of first Bohr orbit for H-atom.

12. The electron energy in hydrogen atom is given by $E_n = \frac{-21.7 \times 10^{-12}}{n^2}$ ergs. Calculate the energy required to remove an e^- completely from n = 2 orbit. What is the largest wavelength in cm of light that can be used to cause this transition.

13. Calculate the wavelength in angstrom of photon that is emitted when an e^- in Bohr orbit n = 2 returns to the orbit n = 1. The ionization potential of the ground state of hydrogen atom is 2.17×10^{-11} erg/atom.

14. The velocity of e^- in a certain Bohr orbit of the hydrogen atom bears the ratio 1 : 275 to the velocity of light. What is the quantum no. "n" of the orbit and the wave no. of the radiation emitted for the transition form the quantum state (n + 1) to the ground state.

15. A doubly ionised lithium atom is hydrogen like with atomic number Z = 3. Find the wavelength of the radiation required to excite the electron in Li^{2+} from the first to the third Bohr orbit.

16. Estimate the difference in energy between I and II Bohr Orbit for a hydrogen 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 like species does this At. no. correspond to:

17. 1.8 g atoms of hydrogen are excited to radiations. The study of spectra indicates that 27% of the atoms are in 3rd energy level and 15% of atoms in 2nd energy level and the rest in ground state. If I.P. of H is 21.7×10^{-12} erg. Calculate.

(i) No. of atoms present in III & II energy level.

(ii) Total energy evolved when all the atoms return to ground state.

18. One mole He^+ ions are excited. Spectral analysis showed existence of 50% ions in 3rd orbit, 25% in 2nd and rest in ground state. Calculate total energy evolved when all the ions return to the ground state.

19. The energy of an excited H-atom is –3.4 eV. Calculate angular momentum of e^-.

20. The vapours of Hg absorb some electrons accelerated by a potential difference of 4.5 volt as a result of it light is emitted. If the full energy of single incident e^- is supposed to be converted into light emitted by single Hg atom, find the wave no. of the light.

21. The hydrogen atom in the ground state is excited by means of monochromatic radiation of wavelength x A^0. The resulting spectrum consists of 15 different lines. Calculate the value of x.

22. If the average life time of an excited state of H atom is of order 10^{-8} sec, estimate how many orbits an e^- makes when it is in the state n = 2 and before it suffers a transition to n = 1 state.

23. Calculate the frequency of e^- in the first Bohr orbit in a H-atom.

24. A single electron orbits around a stationary nucleus of charge +Ze where Z is a constant from the nucleus and e is the magnitude of the electric charge. The hydrogen like species required 47.2 eV to excite the electron from the second Bohr orbit to the third Bohr orbit. Find -

(i) the value of Z give the hydrogen like species formed.

(ii) the kinetic energy and potential energy of the electron in the first Bohr orbit.

25. A stationary He^+ ion emitted a photon corresponding to a first line of the Lyman series. The photon liberated a photoelectron from a stationary H atom in ground state. What is the velocity of photoelectron ?

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

27. A particle of charge equal to that of an electron and mass 208 times the mass of the electron moves in a circular orbit around a nucleus of charge +3e. Assuming that the Bohr model of the atom is applicable to this system, (a) derive an expression for the radius of the n^{th} bohr orbit, (b) find the value of n for which the radius of the orbit is approximately the same as that of the first Bohr orbit for the hydrogen atom, and (c) find the wavelength of the radiation emitted when the revolving particle jumps from the third orbit to the first.

28. A neutrons breaks into a proton and an electron. This decay of neutron is accompanied by release of energy. Assuming that 50% of the energy is produced in the form of electromagnetic radiation, what will be the frequency of radiation produced. Will this photon be sufficient to cause ionization of Aluminium. In case it is able to do so what will be the energy of the electron ejected from the Aluminum atom. IE_1 of Al = 577 kJ/mol.

29. Calculate the threshold frequency of metal if the binding energy is 180.69 kJ mol^{-1} of electron.

30. Calculate the binding energy per mole when threshold wavelength of photon is 240 nm.

31. A metal was irradiated by light of frequency 3.2×10^{15} s^{-1}. The photoelectron produced had its KE, 2 times the KE of the photoelectron which was produced when the same metal was irradiated with a light of frequency 2.0×10^{15} s^{-1}. What is work function ?

32. U.V. light of wavelength 800 A° & 700 A° falls on hydrogen atoms in their ground state & liberates electrons with kinetic energy 1.8 eV and 4 eV respectively. Calculate planck's constant.

33. A potential difference of 20 kV is applied across an X-ray tube. Find the minimum wavelength of X-ray generated.

34. The K.E. of an electron emitted from tungsten surface is 3.06 eV. What voltage would be required to bring the electron to rest.

35. What is de-Broglie wavelength of a He-atom in a container at room temperature. $\left(\text{Use } U_{avg.} = \sqrt{\dfrac{8kT}{\pi m}}\right)$

36. Through what potential difference must an electron pass to have a wavelength of 500 A°.

37. A proton is accelerated to one tenth of the velocity of light. If its velocity can be measured with a precision ± 1%. What must be its uncertainty in position ?

38. To what effective potential a proton beam be subjected to give its protons a wavelength of 1×10^{-10}m.

39. Calculate the number of exchange pairs of electrons present in configuration of Cu according to Aufbau principle considering 3d orbitals.

40. He atom can be excited to $1s^1\ 2p^1$ by λ = 58.44 nm. If lowest excited state for He lies 4857 cm^{-1} below the above. Calculate the energy for the lower excitation state.

41. A certain dye absorbs 4530 A° and fluoresence at 5080 A° these being wavelengths of maximum absorption that under given conditions 47% of the absorbed energy is emitted. Calculate the ratio of the no. of quanta emitted to the number absorbed.

42. The reaction between H_2 and Br_2 to form HBr in presence of light is initiated by the photo decomposition of Br_2 into free Br atoms (free radicals) by absorption of light. The bond dissociation energy of Br_2 is 192 kJ/mole. What is the longest wavelength of the photon that would initiate the reaction?

43. The quantum yield for decomposition of HI is 0.2. In an experiment 0.01 moles of HI are decomposed. Find the number of photons absorbed.

44. Calculate the wavelength of the radiation that would cause photo dissociation of chlorine molecule if the Cl – Cl bond energy is 243 kJ/mol.

45. The dissociation energy of H_2 is 430.53 kJ/mol. If H_2 is exposed to radiant energy of wavelength 253.7 nm, what % of radiant energy will be converted into K.E ?

46. Iodine molecule dissociates into atoms after absorbing light of 4500 A^0 If one quantum of radiation is absorbed by each molecule, calculate the K.E. of iodine atoms.
(Bond energy of I_2 = 240 kJ/mol)

47. X-rays emitted from a copper target and a molybdenum target are found to contain a line of wavelength 22.85 nm attributed to the K_α line of an impurity element. The K_α lines of a copper (Z = 29) and molybdenum (Z = 42) have wavelength 15.42 nm and 7.12 nm respectively. Using Moseley's law, $\gamma^{1/2} = a\,(Z - b)$. Calculate the atomic number of the impurity element.

48. What is de-Broglie wavelength associated with an e^- accelerated through P.D. = 100 kV ?

49. Calculate the de-broglie wavelength associated with motion of earth (mass 6×10^{24} kg) orbiting around the sun at a speed of 3×10^6 m/s.

50. A base ball of mass 200 g is moving with velocity 30×10^2 cm/s. If we can locate the base ball with error equal in magnitude to the λ of the light used (5000 Å), how will the uncertainty in momentum compared with the total momentum of base ball ?

51. An electron has a speed of 40 m/s, accurate up 99.99 %. What is the uncertainty in locating position?

52. To what series does the spectral lines of atomic hydrogen belong if its wave number is equal 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 this line ?

53. Energy required for the excitation of H-atom its ground state to the 2nd excited state is 2.67 times smaller than dissociation energy of H_2(g). If H_2 (g) placed in 1.0 litre flask at 27°Cand 1.0 bar is to be excited to their 2nd excited state, what will be the total energy consumption ?

54. Find the quantum number '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.

55. 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.
(a) Find the principal quantum number of initially excited level B.
(b) Find the ionisation energy for the gas atoms.
(c) Find the maximum and the minimum energies of the emitted photons.

56. 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 (ionisation energy of hydrogen atom = 13.6 eV).

57. Hydrogen atom in its ground state is excited by means of monochromatic radiation of wavelength 975 A°. How many different lines are possible in the resulting spectrum? Calculate the longest wavelength amongst them.

58. An alpha particle after passing through a potential difference of 2×10^6 volt falls on a silver foil. The atomic number of silver is 47. Calculate (i) the K.E. of the alpha-particle at the time of falling on the foil. (ii) K.E. of the α-particle at a distance of 5×10^{-14} m from the nucleus, (iii) the shortest distance from the nucleus of silver to which the α-particle reaches.

59. Suppose the potential energy between electron and proton at a distance r is given by $-\frac{ke^2}{3r^3}$. Use Bohr's theory to obtain energy of such a hypothetical atom.

60. An energy of 68 eV is required to excite a hydrogen like atom from its second Bohr orbit to the third. The nuclear charge is Ze. Find the value of Z, the kinetic energy of the electron in the first Bohr orbit and the wavelength of the radiation required to eject the electrons from the first Bohr orbit to infinity .

61. The ionisation energy of a H-like Bohr atom is 4 Rydbergs.

(i) What is the wavelength of radiation emitted when the e^- jumps from the first excited state to the ground state?

(ii) What is the radius of first Bohr orbit for this atom? [1 Rydberg = 2.18×10^{-18} J]

62. Photon having wavelength 12.4 nm was allowed to strike a metal plate having work function 25 eV. Calculate the

(a) Maximum kinetic energy of photoelectrons emitted in eV.

(b) Wavelength of electron with maximum kinetic energy in A°.

(c) Calculate the uncertainity in wavelength of emitted electron, if the uncertainity in the momentum is 6.62×10^{-28} kg m/sec.

63. Electron present in single electron species jumps from energy level 3 to 1. Emitted photons when passed through a sample containing excited He^+ ion causes further excitation to some higher energy level (Given $E_n = 13.6 \frac{Z^2}{n^2}$) Determine .

(i) Atomic number of single electron species.

(ii) Principal quantum number of initial excited level & higher energy of He^+

64. The angular momentum of an electron in a Bohr's orbit of H-atom is 3.1652×10^{-34} kg-m^2/sec. Calculate the wave number in terms of Rydberg constant (R) of the spectral line emitted when an electron falls from this level to the ground state. (Use $h = 6.626 \times 10^{-34}$ Js).

Exercise # 5 Part # I [Previous Year Questions] [AIEEE/JEE-MAIN]

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

(A) 91 nm **(B)** 192 nm **(C)** 406 **(D)** 9.1×10^{-6} nm

2. Which of the following set a of quantum numbers is correct for an electron in 4f orbital? **[AIEEE 2004]**

(A) n = 4, l =3, m = +4, s = +1/2 **(B)** n = 4, l = 4, m = –4, s = –1/2
(C) n = 4, l = 3, m = +1, s = +1/2 **(D)** n = 3, l=2, m =–2, s = +1/2

3. Consider the ground state of Cr atom (Z = 24). The numbers of electrons with the azimuthal quantum numbers, ℓ = 1 and 2 are, respectively **[AIEEE 2004]**

(A) 12 and 4 **(B)** 12 and 5 **(C)** 16 and 4 **(D)** 16 and 5

4. Which of the following statements in relation to the hydrogen atom is correct ? **[AIEEE 2005]**

(A) 3s, 3p and 3d orbitals all have the same energy
(B) 3s and 3p orbitals are of lower energy than 3d orbital
(C) 3p orbital is lower in energy than 3d orbital
(D) 3s orbital is lower in energy than 3p orbital

5. In a multi-electron atom, which of the following orbitals described by the three quantum numbers will have the same energy in the absence of magnetic and electric field ? **[AIEEE 2005]**

(i) n = 1, l = 0, m = 0 (ii) n =2, l = 0, m = 0 (iii) n = 2, l = 1, m = 1 (iv) n = 3, l = 2, m =1
(v) n = 3, l = 2, m = 0

(A) (iv) and (v) **(B)** (iii) and (iv) **(C)** (ii) and (iii) **(D)** (i) and (ii)

6. Uncertainity in the position of an electron (mass = 9.1×10^{-31} Kg) moving with a velocity 300 $m.sec^{-1}$, Accurate upto 0.001%, will be : (h = 6.63×10^{-34} J-s) **[AIEEE 2006]**

(A) 19.2×10^{-2} m **(B)** 5.76×10^{-2} m **(C)** 1.92×10^{-2} m **(D)** 3.84×10^{-2} m

7. According to Bohr's theory, the angular momentum to an electron in 5^{th} orbit is : **[AIEEE 2006]**

(A) $25\frac{h}{\pi}$ **(B)** $1.0\frac{h}{\pi}$ **(C)** $10\frac{h}{\pi}$ **(D)** $2.5\frac{h}{\pi}$

8. The 'spin-only' magnetic moment [in units of Bohr magneton (μ_β)] of Ni^{2+} in aqueous solution would be (Atomic number : Ni = 28) **[AIEEE 2006]**

(A) 2.84 **(B)** 4.90 **(C)** 0 **(D)** 1.73

9. Which of the following nuclear reactions will generate an isotope ? **[AIEEE 2007]**

(A) Neutron particle emission **(B)** Positron emission
(C) α-particle emission **(D)** β-particle emission

10. The ionisation enthalpy of hydrogen atom is 1.312×10^6 J mol^{-1}. The energy required to excite the electron in the atom from n_1 = 1 to n_2 = 2 is **[AIEEE 2008]**

(A) 8.51×10^5 J mol^{-1} **(B)** 6.56×10^5 J mol^{-1}
(C) 7.56×10^5 J mol^{-1} **(D)** 9.84×10^5 J mol^{-1}

11. Which of the following set of quantum numbers represents the highest energy of an atom ?

(A) n = 3, l = 0, m = 0, s = $+\frac{1}{2}$ **(B)** n = 3, l = 1, m =1, s = $+\frac{1}{2}$ **[AIEEE 2008]**

(C) n = 3, l = 2, m = 1, s = $+\frac{1}{2}$ **(D)** n = 4, l = 0, m = 0, s = $+\frac{1}{2}$

12. The energy required to break one mole of Cl – Cl bonds in Cl_2 is 242 kJ mol^{-1} . The longest wavelength of light capable of breaking a single Cl – Cl bond is **[AIEEE 2010]**
($c = 3 \times 10^8$ m s^{-1} and $N_A = 6.02 \times 10^{23}$ mol^{-1})
(A) 594 nm **(B)** 640 nm **(C)** 700 nm **(D)** 494 nm

13. Ionisation energy of He^+ is **[AIEEE 2010]**
19.6×10^{-18} J $atom^{-1}$. The energy of the first stationary state (n = 1) of Li^{2+} is :
(A) 4.41×10^{-16} J $atom^{-1}$ **(B)** -4.41×10^{-17} J $atom^{-1}$
(C) -2.2×10^{-15} J $atom^{-1}$ **(D)** 8.82×10^{-17} J $atom^{-1}$

14. A gas absorbs a photon of 355 nm and emits at two wavelengths. If one of the emission is at 680 nm, the other is at **[AIEEE 2011]**
(A) 1035 nm **(B)** 325 nm **(C)** 743 nm **(D)** 518 nm

15. The frequency of light emitted for the transition n = 4 to n = 2 of He^+ is equal to the transition in H atom corresponding to which of the following? **[AIEEE 2011]**
(A) n = 2 to n = 1 **(B)** n = 3 to n = 2 **(C)** n = 4 to n = 3 **(D)** n = 3 to n = 1

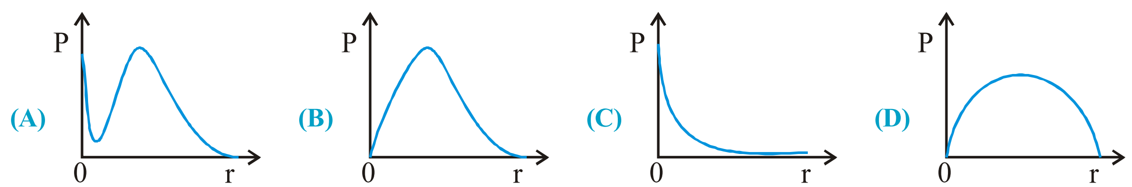
16. The electrons identified by quantum numbers n and ℓ : **[AIEEE 2012]**
(A) n = 4, $\ell = 1$ **(B)** n = 4, $\ell = 0$
(C) n = 3, $\ell = 2$ **(D)** n = 3, $\ell = 1$
can be placed in order of increasing energy as :
(A) (C) < (D) < (B) < (A) **(B)** (D) < (B) < (C) < (A)
(C) (B) < (D) < (A) < (C) **(D)** (A) < (C) < (B) < (D)

17. The correct set of four quantum numbers for the valence elections of rubidium atom (Z = 37) is : **[JEE MAIN 2014]**
(A) $5, 1, 1, +\frac{1}{2}$ **(B)** $5, 0, 1, +\frac{1}{2}$ **(C)** $5, 0, 0, +\frac{1}{2}$ **(D)** $5, 1, 0, +\frac{1}{2}$

18. Which of the following is the energy of a possible excited state of hydrogen? **[JEE MAIN 2015]**
(A) –3.4 eV **(B)** +6.8 eV **(C)** +13.6 eV **(D)** –6.8 eV

19. A stream of electrons from a heated filament was passed between two charged plates kept at potential difference V esu. If e and m are chage and mass of an electron respectivelly, then the value of h/λ (where λ is wavelength associated with electron wave) is given by : **[JEE MAIN 2016]**
(A) 2meV **(B)** $\sqrt{meV}$ **(C)** $\sqrt{2meV}$ **(D)** me V

20. P is the probability of finding the 1s electron of hydrogen atom in a spherical shell of infinitesimal thickness, dr, at a distance r from the nucleus. The volume of this shell is $4\pi r^2 dr$. The qualitative sketch of the dependence of P on r is **[JEE MAIN 2016]**



21. The radius of the second Bohr orbit for hydrogen atom is :
(Plank's Const. $h = 6.6262 \times 10^{-34}$ Js ; mass of electron = 9.1091×10^{-31} kg; charge of electron $e = 1.60210 \times 10^{-19}$ C; permittivity of vaccum $\epsilon_0 = 8.854185 \times 10^{-12}$ kg^{-1} $m^{-3}A^2$) **[JEE MAIN 2017]**
(A) 1.65 Å **(B)** 4.76 Å **(C)** 0.529 Å **(D)** 2.12 Å

Part # II [Previous Year Questions][IIT-JEE ADVANCED]

1. The orbit having Bohr radius equal to 1st Bohr orbit of H–atom is **[JEE 2004]**
(A) n = 2 of He^+ **(B)** n = 2 of B^{+4} **(C)** n = 3 of Li^{+2} **(D)** n = 2 of Be^{+3}

2. **(A)** The wave function of an electron in 2s orbital in hydrogen atom is given below : **[JEE 2004]**

$$\psi_{2s} = \frac{1}{4(2\pi)^{1/2}}\left(\frac{z}{a_0}\right)^{3/2}\left(2-\frac{r}{a_0}\right)\exp(-r/2a_0)$$

where a_0 is the Bohr radius. This wave function has a radial node at $r = r_0$. Express r_0 in terms of a_0.
(B) Calculate the wavelength of a ball of mass 100 g moving with a velocity of 100 ms^{-1}.
(C) $_{92}X^{238} \xrightarrow[-6\beta]{-8\alpha}$ Y. Find out atomic number, mass number of Y and identify it.

3. **(A)** Using Bohr's model for hydrogen atom, find the speed of electron in the first orbit if the Bohr's radius is $a_0 = 0.529 \times 10^{-10}$ m. Find deBroglie wavelength of the electron also. **[JEE 2005]**
(B) Find the orbital angular momentum of electron if it is in 2p orbital of H in terms of $\frac{h}{2\pi}$.

4. According to Bohr's theory,
E_n = Total energy , K_n = Kinetic energy
V_n = Potential energy, r_n = Radius of n^{th} orbit
Match the following: **[JEE 2006]**

Column I	Column II
(A) V_n/K_n = ?	**(p)** 0
(B) If radius of n^{th} orbit $\propto E_n^x$, x = ?	**(q)** – 1
(C) Angular momentum in lowest orbital	**(r)** – 2
(D) $\frac{1}{r_n} \propto Z^y$, y = ?	**(s)** 1

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

5. The state S_1 is : **[JEE 2010]**
(A) 1s **(B)** 2s **(C)** 2p **(D)** 3s

6. Energy of the state S_1 in units of the hydrogen atom ground state energy is : **[JEE 2010]**
(A) 0.75 **(B)** 1.50 **(C)** 2.25 **(D)** 4.50

7. The orbital angular momentum quantum number of the state S_2 is : **[JEE 2010]**
(A) 0 **(B)** 1 **(C)** 2 **(D)** 3

8. 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 **[JEE 2011]**

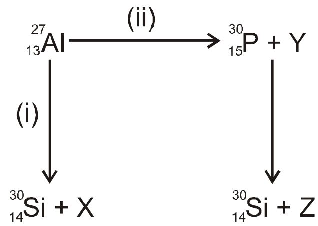
Metal	Li	Na	K	Mg	Cu	Ag	Fe	Pt	W
ϕ (eV)	2.4	2.3	2.2	3.7	4.8	4.3	4.7	6.3	4.75

9. The maximum number of electrons that can have principal quantum number, n = 3, and spin quantum number, $m_s = -1/2$, is **[JEE 2011]**

10. The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is [a_0 is Bohr radius] : **[JEE 2012]**

(A) $\frac{h^2}{4\pi^2 ma_0^2}$ **(B)** $\frac{h^2}{16\pi^2 ma_0^2}$ **(C)** $\frac{h^2}{32\pi^2 ma_0^2}$ **(D)** $\frac{h^2}{64\pi^2 ma_0^2}$

11. Bombardment of aluminum by α-particle leads to its artificial disintegration in two ways, (I) and (ii) as shown. Products **X**, **Y** and **Z** respectively are,



[JEE 2011]

(A) proton, neutron, positron **(B)** neutron, positron, proton
(C) proton, positron, neutron **(D)** positron, proton, neutron

12. The periodic table consists of 18 groups. An isotope of copper, on bombardment with protons, undergoes a nuclear reaction yielding element X as shown below. To which group, element X belongs in the periodic table?

$$^{63}_{29}Cu + ^{1}_{1}H \rightarrow 6^{1}_{0}n + \alpha + 2^{1}_{1}H + X$$ **[JEE 2012]**

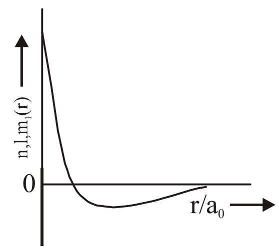
13. In an atom, the total number of electrons having quantum numbers n = 4, $|m_\ell| = 1$ and $m_s = -1/2$ is **[JEE 2014]**

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

Answer Q.15 to Q.17 by appropiately matching the information given in the three columns of the following table.

The wave function, ψ_{n,l,m_l} is a mathematical function whose value depends upon spherical polar coordinates (r, θ, ϕ) of the electron and characterized by the quantum numbers n, l and m_l. Here r is distance from nucleus, θ is colatitude and ϕ is azimuth. In the mathematical functions given in the Table, Z is atomic number a_0 is Bohr radius.

[JEE 2017]

Column I	Column 2	Column 3
(I) 1s orbital	**(i)** $\psi_{n,l,m_l} \propto \left(\frac{Z}{a_0}\right)^{\frac{3}{2}} e^{-\left(\frac{Zr}{a_0}\right)}$	**(P)** 
(II) 2s orbital	**(ii)** One radical node	**(Q)** nucleus per probability density $\propto \frac{1}{a_0^3}$
(IIII) $2p_z$ orbital	**(iii)** $\psi_{n,l,m_l} \propto \left(\frac{Z}{a_0}\right)^{\frac{5}{2}} re^{-\left(\frac{Zr}{2a_0}\right)} \cos\theta$	**(R)** nucleus per probability density is maximum
(IV) $3d_z{}^2$ orbital	**(iv)** *xy*-plane is a nodal plane	**(S)** Energy needed to excite electron from n = 2 state to n = 4 state is $\frac{27}{32}$ times the energy needed to excite electron from n = 2 state to n = 6 state

15. For He^+ ion, the only INCORRECT combination is
(A) (I) (i) (S) **(B)** (II) (ii) (Q) **(C)** (I) (iii) (R) **(D)** (I) (i) (R)

16. For the given orbital in Column I, the only CORRECT combination for any hydrogen - like species is
(A) (II) (ii) (P) **(B)** (I) (ii) (S) **(C)** (IV) (iv) (R) **(D)** (III) (iii) (P)

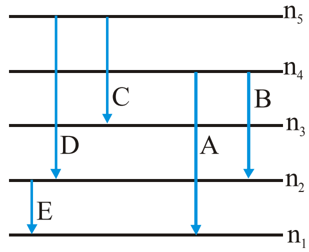
17. For hydrogen atom, the only CORRECT combination is
(A) (I) (i) (P) **(B)** (I) (iv) (R) **(C)** (II) (i) (Q) **(D)** (I) (i) (S)

MOCK TEST

SECTION - I : STRAIGHT OBJECTIVE TYPE

1. For a hypothetical H like atom which follows Bohr's model, some spectral lines were observed as shown. If it is known that line 'E' belongs to the visible region, then the lies possibly belonging to ultra violet region will be (n_1 is not necessarily ground state)

[Assume for this atom, no spectral series shows overlaps with other series in the emmission spectrum]



(A) B and D **(B)** D only **(C)** C only **(D)** A only

2. The number of photons emitted in 10 hours by a 60 W sodium lamp (λ of photon = 6000 Å)

(A) 6.50×10^{24} **(B)** 6.40×10^{23} **(C)** 8.40×10^{23} **(D)** 3.40×10^{23}

3. Ratio of frequency of revolution of electron in the 2nd excited state of He^+ and 2nd state of hydrogen is.

(A) $\frac{32}{27}$ **(B)** $\frac{27}{32}$ **(C)** 1/54 **(D)** 27/2

4. A proton accelerated from rest through a potential difference of 'V' volts has a wavelength λ associated with it. An alpha particle in order to have the same wavelength must be accelerated from rest through a potential difference of

(A) V volt **(B)** 4V volt **(C)** 2V volt **(D)** $\frac{V}{8}$ volt

5. If the wave number of 1st line of Balmer series of H-atom is 'x' then the wave number of 1st line of lyman series of the He^+ ion will be

(A) $\frac{36x}{5}$ **(B)** $\frac{12x}{5}$ **(C)** $\frac{108x}{5}$ **(D)** x

6. Consider the ground state of Cr atom (Z = 24). The number of electrons with the azimuthal quantum numbers, λ = 1 and 2 are, respectively :

(A) 16 and 5 **(B)** 12 and 5 **(C)** 16 and 4 **(D)** 12 and 4

7. 4000 Å photon is used to break the iodine molecule, then the % of energy converted to the K.E. of iodine atoms if bond dissociation energy of I_2 molecule is 246.5 kJ/mol

(A) 8% **(B)** 12% **(C)** 17% **(D)** 25%

8. Radius of 3rd orbnit of Li^{2+} ion is 'x' cm then de-broglie wavelength of electrons in the 1st orbit is

(A) $\frac{2\pi x}{3}$ cm **(B)** $6\pi x$ cm **(C)** $3\pi x$ cm **(D)** $\frac{2\pi x}{6}$ cm

9. When an electron makes a transition from (n + 1) state to n state, the frequency of emitted radiation is related to n according to (n > > 1)

(A) $\nu \propto n^{-3}$ **(B)** $\nu \propto\nu\ n^2$ **(C)** $\nu \propto n^3$ **(D)** $\nu \propto n^{2/3}$

10. If uncertainty in momentum is twice the uncertainty in position of an electron then uncertainty in velocity is :

$[\hbar = \frac{h}{2\pi}]$

(A) $\frac{1}{2m}\sqrt{\hbar}$ **(B)** $\frac{h}{4\pi m}$ **(C)** $\frac{1}{4m}\sqrt{h}$ **(D)** $\frac{1}{m}\sqrt{\hbar}$

SECTION - II : MULTIPLE CORRECT ANSWER TYPE

11. If the wave number of 1^{st} line of Balmer series of H-atom is 'x' then :

(A) wave number of 1^{st} line of lyman series of the He^+ ion will be $\frac{108x}{5}$

(B) wave number of 1^{st} line of lyman series of the He^+ ion will be $\frac{36x}{5}$

(C) the wave length of 2^{nd} line of lyman series of H-atom is $\frac{5}{32x}$

(D) the wave length of 2^{nd} line of lyman series of H-atom is $\frac{32x}{5}$

12. The wave functions of 3s and $3p_z$ orbitals are given by

$$\psi_{3s} = \frac{1}{9\sqrt{3}}\left(\frac{1}{4\pi}\right)^{1/2}\left(\frac{z}{a_0}\right)^{3/2}\left(6 - \frac{4zr}{a_0} + \frac{4}{9}.\frac{z^2r^2}{a_0^2}\right)e^{-zr/3a_0}$$

$$\psi_{3P_z} = \frac{1}{9\sqrt{6}}\left(\frac{3}{4\pi}\right)^{1/2}\left(\frac{z}{a_0}\right)^{3/2}\left(4 - \frac{2zr}{3a_0}\right)\left(\frac{2zr}{3a_0}\right)e^{-zr/3a_0}\cos\theta$$

from these we can conclude

(A) number of nodal surface for $3p_z$ & 3s orbitals are equal

(B) the angular nodal surface of $3p_z$ orbital has the equation $\theta = \pi/2$

(C) The radial nodal surfaces of 3s orbital and $3p_z$ orbitals are at equal distance from the nucles

(D) 3s electron have greater penetrating power into the nucleus in comparision to $3p_z$ electrons

13. A hydrogen like atom in ground state absorbs 'n' photons having the same energy and it emits exactly 'n' photons B has it's wavelength in infrared region if photon A has more energy than B, then the photon A may belong to the region.

(A) ultraviolet **(B)** visible **(C)** infrared **(D)** None

SECTION - III : ASSERTION AND REASON TYPE

14. **Statement-1**: 'He' has lowest ionisatioin energy among all the elements.

Statement - 2 : Addition of extra electrons even in fully filled orbitals releases energy

(A) Statement-1 is True, Statement-2 is True ; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True ; Statement- 2 is NOT a correct explanation for Statement-1.

(C) Statement-1 is True, Statement-2 is False

(D) Statement-1 is False, Statement-2 is True

15. **Statement-1**: If an electron is located within the range of 0.1 Å then the uncertainty in velocity is approximately 6×10^6 m/s.

Statement - 2 : Trajectory (path of motion) of above electron can be defined.

[$h = 6.6 \times 10^{-34}$, $m_e = 9.1 \times 10^{-31}$ kg]

(A) Statement-1 is True, Statement-2 is True ; Statement-2 is a correct explanation for Statement-1.

(B) Statement-1 is True, Statement-2 is True ; Statement- 2 is NOT a correct explanation for Statement-1.

(C) Statement-1 is True, Statement-2 is False

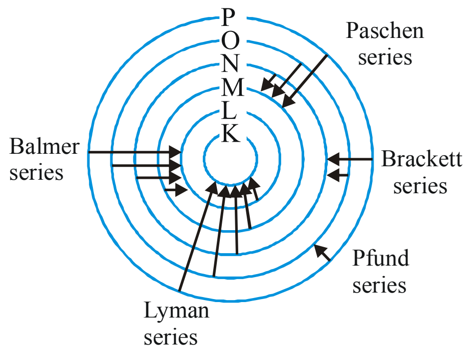
(D) Statement-1 is False, Statement-2 is True

SECTION - IV : COMPREHENSION TYPE

Read the following comprehensions carefully and answer the questions.

Comprehension # 1

The only electron in the hydrogen atom resides under ordinary conditions on the first orbit. When energy is supplied, the electron moves to higher energy orbit depending on the amount of energy absorbed. When this electron returns to any of the lower orbits, it emits energy. Lyman series is formed when the electron retursn to the lowest orbit while Balmer series is formed when the electron returns to second orbit. Similary, paschen, Brackett and Pfund series are formed when electron returns to the third, fourth and fifth orbits from higher energy orbits respectively (as shown in figure)



Maximum number of lines produced when an electron jumps from *n*th level to ground level is equal to $\frac{n(n-1)}{2}$. For example, in the case of n = 4, number of lines produced is 6. ($4 \to 3$, $4 \to 2$, $4 \to 1$, $3 \to 2$, $3 \to 1$, $2 \to 1$). When an electron returns from n_2 to n_1 state, the number of lines in the spectrum will be equal to

$$\frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

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

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

Since h and c are constants, ΔEcorresponds to definite energy, thus each transition from one energy level to another will produce a light of definite wavelength. This is actualy observed as a line in the spectrum of hydrogen atom.

Wave number of line is given by the formula $\bar{\nu} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$.

where R is a Rydberg constant ($R = 1.1 \times 10^7$)

(i) First line of a series : It is called 'line of longest wavelength' or 'line of shortest energy.

(ii) Series limit or last line of a series : It is the line of shortest wavelength or line of highest energy.

16. If the 2[nd] excitation potential for a Hydrogen like atom in a sample is 108.9 V. Then the series limit of the paschen series for this atom is .

(A) R **(B)** $\frac{R}{3^2}$ **(C)** $\frac{3^2 R}{4^2}$ **(D)** 3^2R

17. In a single isolated atom an electron make transition for 5[th] excited state to 2[nd] state then maximum number of different types of photons observed is

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

18. The difference in the wavelength of the 2nd line of Lyman sereis and last line of brackett seriesina hydrogen sample is

(A) $\frac{119}{8R}$ **(B)** $\frac{1271}{8R}$ **(C)** $\frac{219}{8R}$ **(D)** None

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

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

20. Let υ_1 be the frequency of the series limit of the Lyman series, υ_2 be the frequency of the first line of the Lyman series, and υ_3 be the frequency of the series limit of the Balmer series –

(A) $\upsilon_1 - \upsilon_2 = \upsilon_3$ **(B)** $\upsilon_2 - \upsilon_1 = \upsilon_3$ **(C)** $\upsilon_3 = 1/2\ (\upsilon_1 - \upsilon_3)$ **(D)** $\upsilon_1 + \upsilon_2 = \upsilon_3$

Comprehension # 2

If hydrogen atoms (in the ground state) are passed through an hiomogeneous magnetic field, the beam is split into two parts. This interaction with the magnetic field shows that the atoms must have magnetic moment. However, the moment cannot be due to the orbital angular momentum since $\ell = 0$. Hence one must assume existence of intrinsic angular momentum, which as the experiment shows, has only two permitted orientations.

Spin of the electron produces angular momentum equal to $S = \sqrt{s(s+1)}\frac{h}{2\pi}$ where $S = +\frac{1}{2}$.

Total spin of an atom $= +\frac{n}{2}$ or $-\frac{n}{2}$

where n is the number of unpaired electron.

The substance which contain species with unpaired electrons in their orbitals behave as paramagnetic substances. The paramagnetism is expressed in terms of magnetic moment.

The magnetic moment of an atom

$$\mu_s = \sqrt{s(s+1)}\frac{eh}{2\pi mc} = \sqrt{\frac{n}{2}\left(\frac{n}{2}+1\right)}\frac{eh}{2\pi mc} \qquad s = \frac{n}{2}$$

$$\Rightarrow \qquad \mu_s = \sqrt{n(n+2}\ \text{B.M.}$$

n – number of unpaired electrons

$$1\ .\ \text{B.M. (Bohr magneton)} = \frac{eh}{4\pi mc}$$

If magnetic momentt is zero the substance is di-magnetic.

21. Which of the following ion has highest magnetic moment

(A) Fe^{2+} **(B)** Mn^{2+} **(C)** Cr^{3+} **(D)** V^{3+}

22. If an ion of $_{25}Mn$ has a magnetic moment of 3.873 B.M. Then Mn is in which state.

(A) + 2 **(B)** + 3 **(C)** + 4 **(D)** + 5

23. Which of the following is a paramagnetic substance.

(A) Mg^{2+} **(B)** Cu^{+} **(C)** Mn^{+7} **(D)** Ti^{+2}

24. The number of unpaired electrons in Mn^{4+} (Z = 25) is –

(A) Four **(B)** Two **(C)** Five **(D)** Three

SECTION - V : MATRIX - MATCH TYPE

25. Match the following :

P_n = potential energy, E_n = total energy

f = frequency, Z = atomic number

V_n = velocity in n^{th} orbit

T_n = time period in n^{th} orbit

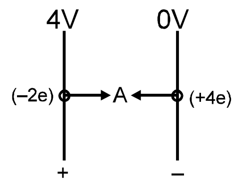
Column - I	Column - II
(A) $E_n \alpha r^y$, y = ?	**(p)** 1/2
(B) E_n / P_n	**(q)** 1
(C) $\frac{1}{f_n^{-x}} \alpha, z\ x = ?$	**(r)** 2
(D) $(V_n \times T_n)^t \alpha r_n$, t = ?	**(s)** – 1

26. Match the following :

List - I	List - II
(A) n = 6 → n = 3 (In H-atom)	(p) 10 lines in the spectrum
(B) n = 7 → n = 3 (In H-atom)	(q) Spectral lines in visible region
(C) n = 5 → n = 2 (In H-atom)	(r) 6 lines in the spectrum
(D) n = 6 → n = 2 (In H-atom)	(s) Spectral lines in infrared region

SECTION - VI : SUBJECTIVE TYPE

27. In the assembly as shown below, the potential difference across the plates is 4 volts. A positive particle of charge +4e is projected from the negative plate with an inital kinetic enerlgy of 4eV and the negative particle of charge (–2e) is projected from the positive plate. Both the particles reach point 'A' with zero kinetic energy. Find the initial kinetic energy of the negative particle in eV.



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

29. **(A)** Using Bohr's model for hydrogen atom, find the speed of electron in the first orbit if the Bohr's radius is $a_0 = 0.529 \times 10^{-10}$ m. Find deBroglie wavelength of the electron also.

(B) Find the orbital angular momentum of electron if it is in 2p orbital of H in terms of $\frac{h}{2\pi}$.

30. **(A)** The wave functioj of 2s electron is given by $\psi_{2s} = \frac{1}{4\sqrt{2\pi}}\left(\frac{1}{a_0}\right)^{3/2}\left(2-\frac{r}{a_0}\right).e^{-\frac{r}{a_0}}$

It has a node at $r = r_0$, find relation between r_0 and a_0.

(B) Find wavelength for 100 g particle moving with velocity 100 m/s.

31. Electrons in a sample of H-atoms make transitios from state n = x to some lower excited state. The emmission spectrum fro the sample is found to contain only the lines belonging to a particle series. If one of the photons had an energy of 0.6375 eV. Then find the value of x. [Tak $0.6375\text{ eV} = \frac{3}{4} \times 0.85\text{ eV}$]

32. A chemist has one mole of X-atoms. He finds that on absorption of 410 kJ, half of X-atoms transfer one electron to the other half. If all the resulting X^- ions are subsequently converted to X^+ ions, an addition of 735 kJ is required. Find the electron affinity of X.

ANSWER KEY

EXERCISE - 1

1. C	**2.** A	**3.** D	**4.** A	**5.** A	**6.** A	**7.** C	**8.** A	**9.** B	**10.** D	**11.** C	**12.** D	**13.** C
14. A	**15.** B	**16.** B	**17.** A	**18.** A	**19.** C	**20.** D	**21.** B	**22.** C	**23.** C	**24.** D	**25.** B	**26.** A
27. D	**28.** D	**29.** A	**30.** C	**31.** C	**32.** B	**33.** D	**34.** C	**35.** A	**36.** C	**37.** C	**38.** B	**39.** D
40. B	**41.** A	**42.** D	**43.** A	**44.** B	**45.** A	**46.** B	**47.** D	**48.** C	**49.** C	**50.** A	**51.** C	**52.** C
53. A	**54.** D	**55.** A	**56.** C	**57.** C	**58.** C	**59.** D	**60.** A	**61.** A	**62.** A	**63.** D	**64.** C	**65.** C
66. A	**67.** B	**68.** B	**69.** D	**70.** D	**71.** A	**72.** D	**73.** C	**74.** C	**75.** C	**76.** D	**77.** D	**78.** B
79. B	**80.** A											

EXERCISE - 2 : PART # I

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

25. B	**26.** C	**27.** A	**28.** D	**29.** A	**30.** A	**31.** D	**32.** A	**33.** C	**34.** B	**35.** A	**36.** D	**37.** B
38. C	**39.** A	**40.** B	**41.** A	**42.** C	**43.** B	**44.** C	**45.** A	**46.** A	**47.** A	**48.** D	**49.** A	**50.** A
51. A	**52.** D	**53.** A	**54.** B	**55.** C	**56.** B	**57.** C	**58.** C	**59.** D	**60.** B	**61.** D	**62.** A	**63.** A
64. C	**65.** B	**66.** A	**67.** C									

PART # II

1. D	**2.** A	**3.** A	**4.** A	**5.** C	**6.** A	**7.** D	**8.** A	**9.** A	**10.** A	**11.** A	**12.** B	**13.** A
14. E	**15.** A	**16.** A	**17.** B	**18.** A	**19.** B	**20.** E	**21.** B					

EXERCISE - 3 : PART # I

1. A $\rightarrow$ (u), B $\rightarrow$ (s), C $\rightarrow$ (p), D $\rightarrow$ (t), E $\rightarrow$ (q), F $\rightarrow$ (r)

2. A $\rightarrow$ (q), B $\rightarrow$ (p), C $\rightarrow$ (q, r), D $\rightarrow$ (r, s)

3. A $\rightarrow$ (r), B $\rightarrow$ (s), C $\rightarrow$ (p), D $\rightarrow$ (q)

4. A $\rightarrow$ (t), B $\rightarrow$ (s), C $\rightarrow$ (u), D $\rightarrow$ (q), E $\rightarrow$ (p), F $\rightarrow$ (r)

PART # II

Comprehension # 1 : **1.** A **2.** D **3.** C

Comprehension # 2 : **1.** B **2.** C **3.** A

Comprehension # 3 : **1.** B **2.** B **3.** A

Comprehension # 4 : **1.** C **2.** B **3.** B

Comprehension # 5 : **1.** D **2.** D **3.** C

Comprehension # 6 : **1.** B **2.** A **3.** A **4.** D **5.** C **6.** D

EXERCISE - 5 : PART # I

1. A **2.** C **3.** B **4.** A **5.** A **6.** C **7.** D **8.** A **9.** A **10.** D **11.** C **12.** D **13.** B
14. C **15.** A **16.** B **17.** C **18.** A **19.** C **21.** D

PART # II

1. D **2.** (a) $r = 2a_0$ (b) $\lambda = 6.66 \times 10^{-25}$ Å (c) $_{82}Y^{206}$; (Atomic no. 82, Mass no. 206)

3. (a) 2.18×10^6 m/s, 3.2×10^{-10} m ; (b) $\sqrt{2} \cdot \left(\frac{h}{2\pi}\right)$ **4.** [A – r]; [B – q]; [C – p] ; [D – s]

5. B **6.** C **7.** B **8.** 4 **9.** 9 **10.** C **11.** A **12.** 8 **13.** 6 **14.** 5 **15.** C **16.** A **17.** D

MOCK TEST

1. D **2.** A **3.** A **4.** D **5.** C **6.** B **7.** C **8.** A **9.** A **10.** D **11.** A,C **12.** A, B, D
13. A,B **14.** D **15.** C **16.** A **17.** B **18.** A **19.** C **20.** A **21.** B **22.** C **23.** D **24.** D
25. $A \rightarrow (s), B \rightarrow (p), C \rightarrow (p), D \rightarrow (q)$
26. $A \rightarrow (r, s), B \rightarrow (p, s), C \rightarrow (q, r), D \rightarrow p, q)$

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