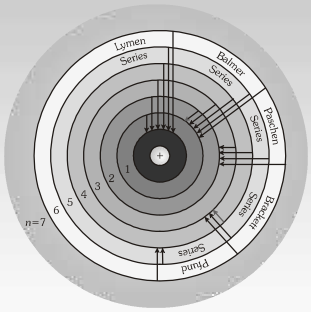


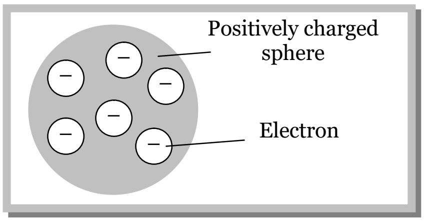
Atomic Structure

Important Atomic Models

(1) **Thomson's model**

J.J. Thomson gave the first idea regarding structure of atom. According to this model.

(i) An atom is a solid sphere in which entire and positive charge and it's mass is uniformly distributed and in which negative charge (*i.e.* electron) are embedded like seeds in watermelon.



Success and failure

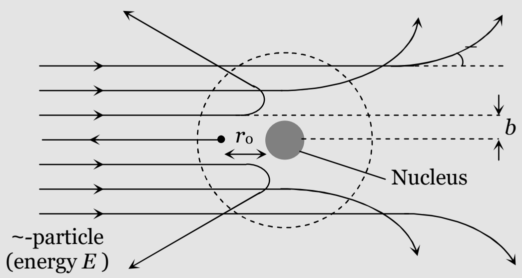
Explained successfully the phenomenon of thermionic emission, photoelectric emission and ionization.

The model fail to explain the scattering of ~- particles and it cannot explain the origin of spectral lines observed in the spectrum of hydrogen and other atoms.

(2) **Rutherford's model**

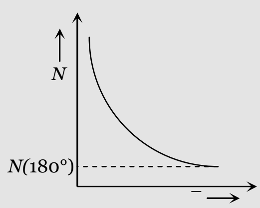
Rutherford's ~-particle scattering experiment

Rutherford performed experiments on the scattering of alpha particles by extremely thin gold foils and made the following observations



Number of scattered particles :

$$N \propto \frac{1}{\sin^4(\theta/2)}$$



(i) Most of the ~-particles pass through the foil straight away undeflected.

(ii) Some of them are deflected through small angles.

(iii) A few ~-particles (1 in 1000) are deflected through the angle more than 90^o.

(iv) A few ~ -particles (very few) returned back *i.e.* deflected by 180^o.

(v) Distance of closest approach (Nuclear dimension)

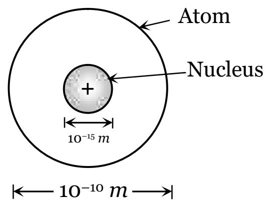
The minimum distance from the nucleus up to which the ~-particle approach, is called the distance of closest approach (r_o). From figure $r_0 = \frac{1}{4®£_0}.\frac{Ze^2}{E}$; $E = \frac{1}{2}mv^2$ = K.E. of ~-particle

(vi) Impact parameter (b) : The perpendicular distance of the velocity vector ($\vec{v}$) of the ~-particle from the centre of the nucleus when it is far away from the nucleus is known as impact parameter. It is given as

$$b = \frac{Ze^2 \cot(¯/2)}{4®£_0\left(\frac{1}{2}mv^2\right)} \Rightarrow b \propto \cot(¯/2)$$

Note : ❑ If t is the thickness of the foil and N is the number of ~-particles scattered in a particular direction (¯ = constant), it was observed that $\frac{N}{t}$ = constant $\Rightarrow \frac{N_1}{N_2} = \frac{t_1}{t_2}$.

After Rutherford's scattering of ~-particles experiment, following conclusions were made as regard as atomic structure:



Size of the nucleus = 1 Fermi = $10^{-15}\ m$
Size of the atom 1 Å = $10^{-10}\ m$

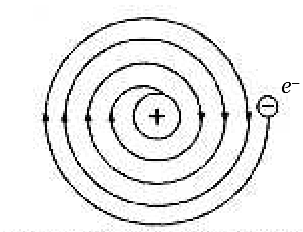
(a) Most of the mass and all of the charge of an atom concentrated in a very small region is called atomic nucleus.

(b) Nucleus is positively charged and it's size is of the order of $10^{-15}\ m \approx 1$ *Fermi*.

(c) In an atom there is maximum empty space and the electrons revolve around the nucleus in the same way as the planets revolve around the sun.

Draw backs

(i) Stability of atom: It could not explain stability of atom because according to classical electrodynamic theory an accelerated charged particle should continuously radiate energy. Thus an electron moving in an circular path around the nucleus should also radiate energy and thus move into smaller and smaller orbits of gradually decreasing radius and it should ultimately fall into nucleus.



Instability of atom

(ii) According to this model the spectrum of atom must be continuous where as practically it is a line spectrum.

(iii) It did not explain the distribution of electrons outside the nucleus.

(3) **Bohr's model**

Bohr proposed a model for hydrogen atom which is also applicable for some lighter atoms in which a single electron revolves around a stationary nucleus of positive charge Ze (called hydrogen like atom)

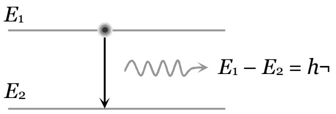
Bohr's model is based on the following postulates.

(i) The electron can revolve only in certain discrete non-radiating orbits, called stationary orbits, for which total angular momentum of the revolving electrons is an integral multiple of $\frac{h}{2®}$ $(= \hbar)$

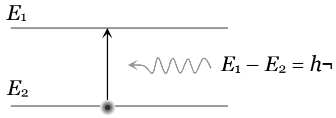
i.e. $L = n\left(\frac{h}{2®}\right) = mvr$; where n = 1, 2, 3, ...= Principal quantum number

(ii) The radiation of energy occurs only when an electron jumps from one permitted orbit to another.

When electron jumps from higher energy orbit (E_1) to lower energy orbit (E_2) then difference of energies of these orbits *i.e.* $E_1 - E_2$ emits in the form of photon. But if electron goes from E_2 to E_1 it absorbs the same amount of energy.



Emission



Absorption

Note : ❑ According to Bohr theory the momentum of an e^- revolving in second orbit of H_2 atom will be $\frac{h}{®}$

❑ For an electron in the n^{th} orbit of hydrogen atom in Bohr model, circumference of orbit $= nª$; where ª = de-Broglie wavelength.

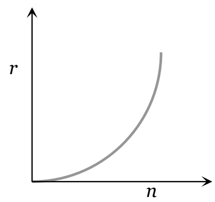
Bohr's Orbits (For Hydrogen and H_2-Like Atoms)

(1) **Radius of orbit**

For an electron around a stationary nucleus the electrostatics force of attraction provides the necessary centripetal force

i.e. $\frac{1}{4®£_0}\frac{(Ze)e}{r^2} = \frac{mv^2}{r}$ .... (i) also $mvr = \frac{nh}{2®}$ ....(ii)

From equation (i) and (ii) radius of n^{th} orbit



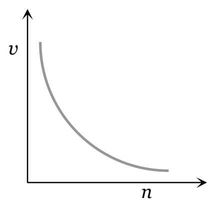
$$r_n = \frac{n^2h^2}{4®^2kZme^2} = \frac{n^2h^2£_0}{®mZe^2} = 0.53\frac{n^2}{Z}Å \quad \left[\text{where } k = \frac{1}{4®£_0}\right]$$

$$\Rightarrow \boldsymbol{r_n \propto \frac{n^2}{Z}}$$

Note : ❑ The radius of the innermost orbit (n = 1) hydrogen atom (z = 1) is called Bohr's radius a_0 *i.e.* $a_0 = 0.53 Å$.

(2) **Speed of electron**

From the above relations, speed of electron in n^{th} orbit can be calculated as



$$v_n = \frac{2®kZe^2}{nh} = \frac{Ze^2}{2£_0nh} = \left(\frac{c}{137}\right).\frac{Z}{n} = 2.2\times10^6\frac{Z}{n} m/sec$$

where (c = speed of light 3×10^8 m/s)

Note : ❑ The ratio of speed of an electron in ground state in Bohr's first orbit of hydrogen atom to velocity of light in air is equal to $\frac{e^2}{2£_0ch} = \frac{1}{137}$ (where c = speed of light in air)

(3) **Some other quantities**

For the revolution of electron in n^{th} orbit, some other quantities are given in the following table

Quantity	Formula	Dependency on n and Z
(1) Angular speed	$\omega_n = \frac{v_n}{r_n} = \frac{\pi m z^2 e^4}{2\varepsilon_0^2 n^3 h^3}$	$\omega_n \propto \frac{Z^2}{n^3}$
(2) Frequency	$\nu_n = \frac{\omega_n}{2\pi} = \frac{m z^2 e^4}{4\varepsilon_0^2 n^3 h^3}$	$\nu_n \propto \frac{Z^2}{n^3}$
(3) Time period	$T_n = \frac{1}{\nu_n} = \frac{4\varepsilon_0^2 n^3 h^3}{m z^2 e^4}$	$T_n \propto \frac{n^3}{Z^2}$
(4) Angular momentum	$L_n = m v_n r_n = n\left(\frac{h}{2\pi}\right)$	$L_n \propto n$
(5) Corresponding current	$i_n = e\nu_n = \frac{m z^2 e^5}{4\varepsilon_0^2 n^3 h^3}$	$i_n \propto \frac{Z^2}{n^3}$
(6) Magnetic moment	$M_n = i_n A = i_n(\pi r_n^2)$ (where $\mu_0 = \frac{eh}{4\pi m}$ = Bohr magneton)	$M_n \propto n$
(7) Magnetic field	$B = \frac{\mu_0 i_n}{2r_n} = \frac{\pi m^2 z^3 e^7 \mu_0}{8\varepsilon_0^3 n^5 h^5}$	$B \propto \frac{Z^3}{n^5}$

(4) **Energy**

(i) **Potential energy:** An electron possesses some potential energy because it is found in the field of nucleus potential energy of electron in n^{th} orbit of radius r_n is given by $U = k.\frac{(Ze)(-e)}{r_n} = -\frac{kZe^2}{r_n}$

(ii) **Kinetic energy :** Electron posses kinetic energy because of it's motion. Closer orbits have greater kinetic energy than outer ones.

As we know $\frac{mv^2}{r_n} = \frac{k.(Ze)(e)}{r_n^2} \Rightarrow$ Kinetic energy $K = \frac{kZe^2}{2r_n} = \frac{|U|}{2}$

(iii) **Total energy :** Total energy (E) is the sum of potential energy and kinetic energy *i.e.* $E = K + U$

$$\Rightarrow E = -\frac{kZe^2}{2r_n} \text{ also } r_n = \frac{n^2 h^2 \varepsilon_0}{\pi m z e^2}. \text{ Hence } E = -\left(\frac{me^4}{8\varepsilon_0^2 h^2}\right).\frac{z^2}{n^2} = -\left(\frac{me^4}{8\varepsilon_0^2 ch^3}\right)ch\frac{z^2}{n^2} = -Rch\frac{Z^2}{n^2} = -13.6\frac{Z^2}{n^2}eV$$

where $R = \frac{me^4}{8\varepsilon_0^2 ch^3}$ = Rydberg's constant = 1.09×10^7 *per metre*

Note : ❑ Each Bohr orbit has a definite energy

❑ For hydrogen atom ($Z = 1$) $\Rightarrow E_n = -\frac{13.6}{n^2} eV$

❑ The state with $n = 1$ has the lowest (most negative) energy. For hydrogen atom it is $E_1 = -13.6$ eV.

❑ Rch = Rydberg's energy $\simeq 2.17 \times 10^{-18} J \simeq 31.6\, eV$.

❑ $E = -K = \frac{U}{2}$.

(iv) **Ionisation energy and potential :** The energy required to ionise an atom is called ionisation energy. It is the energy required to make the electron jump from the present orbit to the infinite orbit.

Hence $E_{ionisation} = E_{\infty} - E_n = 0 - \left(-13.6\dfrac{Z^2}{n^2}\right) = +\dfrac{13.6Z^2}{n^2}eV$

For H_2-atom in the ground state $E_{ionisation} = \dfrac{+13.6(1)^2}{n^2} = 13.6\,eV$

The potential through which an electron need to be accelerated so that it acquires energy equal to the ionisation energy is called ionisation potential. $V_{ionisation} = \dfrac{E_{ionisation}}{e}$

(v) **Excitation energy and potential :** When the electron is given energy from external source, it jumps to higher energy level. This phenomenon is called excitation.

The minimum energy required to excite an atom is called excitation energy of the particular excited state and corresponding potential is called exciting potential.

$$E_{Excitation} = E_{Final} - E_{Initial} \text{ and } V_{Excitation} = \frac{E_{excitation}}{e}$$

(vi) **Binding energy (B.E.) :** Binding energy of a system is defined as the energy released when it's constituents are brought from infinity to form the system. It may also be defined as the energy needed to separate it's constituents to large distances. If an electron and a proton are initially at rest and brought from large distances to form a hydrogen atom, 13.6 *eV* energy will be released. The binding energy of a hydrogen atom is therefore 13.6 *eV*.

Note : ❑ For hydrogen atom principle quantum number $n = \sqrt{\dfrac{13.6}{(\text{B.E.})}}$.

(5) **Energy level diagram**

The diagrammatic description of the energy of the electron in different orbits around the nucleus is called energy level diagram.

Energy level diagram of hydrogen/hydrogen like atom

Principle quantum number	Orbit	Excited state	Energy for H_2 – atom	Energy for H_2 – like atom	Ionisation energy from this level (for H_2 – atom)
$n = \infty$	Infinite	Infinite	$E_{\infty} = 0\,eV$	$0\,eV$	$0\,eV$
$n = 4$	Fourth	Third	$E_4 = -0.85\,eV$	$-0.85\,Z^2$	$+0.85\,eV$
$n = 3$	Third	Second	$E_3 = -1.51\,eV$	$-1.51\,Z^2$	$+1.51\,eV$
$n = 2$	Second	First	$E_2 = -3.4\,eV$	$-3.4\,Z^2$	$+3.4\,eV$
$n = 1$	First	Ground	$E_1 = -13.6\,eV$	$-13.6\,Z^2$	$+13.6\,eV$

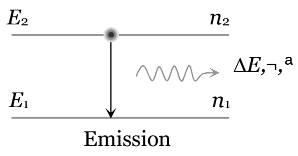
Note : ❑ In hydrogen atom excitation energy to excite electron from ground state to first excited state will be $-3.4-(-13.6) = 10.2\ eV$.

and from ground state to second excited state it is [$-1.51-(-13.6) = 12.09\ eV$].

❑ In an H_2 atom when e^- makes a transition from an excited state to the ground state it's kinetic energy increases while potential and total energy decreases.

(6) **Transition of electron**

When an electron makes transition from higher energy level having energy $E_2(n_2)$ to a lower energy level having energy E_1 (n_1) then a photon of frequency ν is emitted



(i) **Energy of emitted radiation**

$$\Delta E = E_2 - E_1 = \frac{-Rc\,h\,Z^2}{n_2^2} - \left(-\frac{Rch\,Z^2}{n_1^2}\right) = 13.6 Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(ii) **Frequency of emitted radiation**

$$\Delta E = h\nu \Rightarrow \nu = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h} = Rc\,Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(iii) **Wave number/wavelength**

Wave number is the number of waves in unit length $\bar{\nu} = \frac{1}{\lambda} = \frac{\nu}{c}$

$$\Rightarrow \frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = \frac{13.6 Z^2}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

(iv) **Number of spectral lines** : If an electron jumps from higher energy orbit to lower energy orbit it emits raidations with various spectral lines.

If electron falls from orbit n_2 to n_1 then the number of spectral lines emitted is given by

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

If electron falls from n^{th} orbit to ground state (*i.e.* $n_2 = n$ and $n_1 = 1$) then number of spectral lines emitted $\boldsymbol{N_E = \frac{n(n-1)}{2}}$

Note : ❑ Absorption spectrum is obtained only for the transition from lowest energy level to higher energy levels. Hence the number of absorption spectral lines will be $(n - 1)$.

(v) **Recoiling of an atom** : Due to the transition of electron, photon is emitted and the atom is recoiled

Recoil momentum of atom = momentum of photon $= \frac{h}{\lambda} = hRZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

Also recoil energy of atom $= \frac{p^2}{2m} = \frac{h^2}{2m\lambda^2}$ (where m = mass of recoil atom)

(7) **Draw backs of Bohr's atomic model**

(i) It is valid only for one electron atoms, *e.g.* : $H, He^+, Li^{+2}, Na^{+1}$ *etc.*

(ii) Orbits were taken as circular but according to Sommerfield these are elliptical.

(iii) Intensity of spectral lines could not be explained.

(iv) Nucleus was taken as stationary but it also rotates on its own axis.

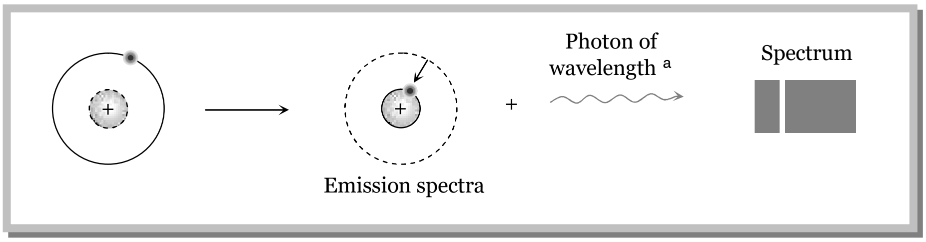
(v) It could not be explained the minute structure in spectrum line.

(vi) This does not explain the Zeeman effect (splitting up of spectral lines in magnetic field) and Stark effect (splitting up in electric field)

(vii) This does not explain the doublets in the spectrum of some of the atoms like sodium (5890Å & 5896Å)

Hydrogen Spectrum and Spectral Series

When hydrogen atom is excited, it returns to its normal unexcited (or ground state) state by emitting the energy it had absorbed earlier. This energy is given out by the atom in the form of radiations of different wavelengths as the electron jumps down from a higher to a lower orbit. Transition from different orbits cause different wavelengths, these constitute spectral series which are characteristic of the atom emitting them. When observed through a spectroscope, these radiations are imaged as sharp and straight vertical lines of a single colour.



Spectral series

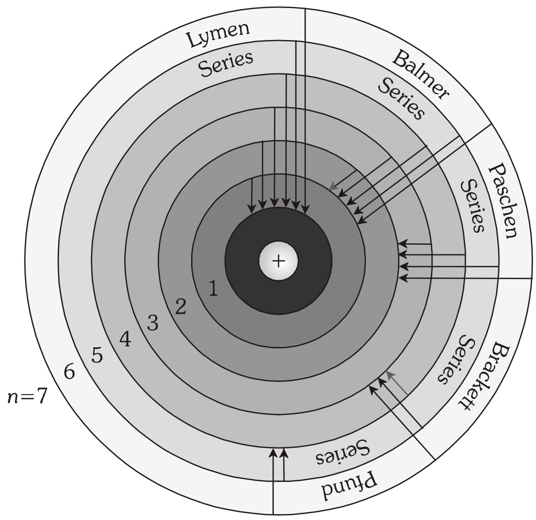
The spectral lines arising from the transition of electron forms a spectra series.

(i) Mainly there are five series and each series is named after it's discover as Lymen series, Balmer series, Paschen series, Bracket series and Pfund series.

(ii) According to the Bohr's theory the wavelength of the radiations emitted from hydrogen atom is given by

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

where n_2 = outer orbit (electron jumps from this orbit), n_1 = inner orbit (electron falls in this orbit)



(iii) First line of the series is called first member, for this line wavelength is maximum (a_{max})

(iv) Last line of the series ($n_2 = \infty$) is called series limit, for this line wavelength is minimum (a_{min})

Spectral series	Transition	**Wavelength (a)** $= \frac{n_1^2 n_2^2}{(n_2^2 - n_1^2)R} = \frac{n_1^2}{\left(1-\frac{n_1^2}{n_2^2}\right)R}$		$\frac{a_{max}}{a_{min}} = \frac{(n+1)^2}{(2n+1)}$	Region
		Maximum wavelength $(n_1 = n \text{ and } n_2 = n+1)$ $a_{max} = \frac{n^2(n+1)^2}{(2n+1)R}$	**Minimum wavelength** $(n_2 = \infty, n_1 = n)$ $a_{min} = \frac{n^2}{R}$		
1. Lymen series	$n_2 = 2, 3, 4 \ldots \infty$ $n_1 = 1$	$a_{max} = \frac{(1)^2(1+1)^2}{(2\times 1+1)R} = \frac{4}{3R}$	$n_1 = n = 1$ $a_{min} = \frac{1}{R}$	$\frac{4}{3}$	Ultraviolet region
2.Balmer series	$n_2 = 3, 4, 5 \ldots \infty$ $n_1 = 2$	$n_1 = n = 2,\ n_2 = 2+1 = 3$ $a_{max} = \frac{36}{5R}$	$a_{min} = \frac{4}{R}$	$\frac{9}{5}$	Visible region
3. Paschen series	$n_2 = 4, 5, 6 \ldots \infty$ $n_1 = 3$	$n_1 = n = 3, n_2 = 3+1 = 4$ $a_{max} = \frac{144}{7R}$	$n_1 = n = 3$ $a_{min} = \frac{9}{R}$	$\frac{16}{7}$	Infrared region
4. Bracket series	$n_2 = 5, 6, 7 \ldots \infty$ $n_1 = 4$	$n_1 = n = 4, n_2 = 4+1 = 5$ $a_{max} = \frac{400}{9R}$	$n_1 = n = 4$ $a_{min} = \frac{16}{R}$	$\frac{25}{9}$	Infrared region
5. Pfund series	$n_2 = 6, 7, 8 \ldots \infty$ $n_1 = 5$	$n_1 = a = 5, n_2 = 5+1 = 6$ $a_{max} = \frac{900}{11R}$	$a_{min} = \frac{25}{R}$	$\frac{36}{11}$	Infrared region

Quantum Numbers

An atom contains large number of shells and subshells. These are distinguished from one another on the basis of their size, shape and orientation (direction) in space. The parameters are expressed in terms of different numbers called quantum number.

Quantum numbers may be defined as a set of four number with the help of which we can get complete information about all the electrons in an atom. It tells us the address of the electron *i.e.* location, energy, the type of orbital occupied and orientation of that orbital.

(1) **Principal Quantum number (*n*) :** This quantum number determines the main energy level or shell in which the electron is present. The average distance of the electron from the nucleus and the energy of the electron depends on it. $E_n \propto \frac{1}{n^2}$ and $r_n \propto n^2$ (in *H*-atom)

The principal quantum number takes whole number values, $n = 1, 2, 3, 4, \ldots \infty$

(2) **Orbital quantum number (*l*) or azimuthal quantum number (*l*)**

This represents the number of subshells present in the main shell. These subsidiary orbits within a shell will be denoted as 1, 2, 3, 4 ... or *s*, *p*, *d*, *f* ... This tells the shape of the subshells.

The orbital angular momentum of the electron is given as $L = \sqrt{l(l+1)}\frac{h}{2®}$ (for a particular value of *n*).

For a given value of n the possible values of l are $l = 0, 1, 2, \ldots$ upto $(n-1)$

(3) **Magnetic quantum number (m_l):** An electron due to it's angular motion around the nucleus generates an electric field. This electric field is expected to produce a magnetic field. Under the influence of external magnetic field, the electrons of a subshell can orient themselves in certain preferred regions of space around the nucleus called orbitals.

The magnetic quantum number determines the number of preferred orientations of the electron present in a subshell.

The angular momentum quantum number m can assume all integral value between $-l$ to $+l$ including zero. Thus m_l can be $-1, 0, +1$ for $l = 1$. Total values of m_l associated with a particular value of l is given by $(2l + 1)$.

(4) **Spin (magnetic) quantum number (m_s) :** An electron in atom not only revolves around the nucleus but also spins about its own axis. Since an electron can spin either in clockwise direction or in anticlockwise direction. Therefore for any particular value of magnetic quantum number, spin quantum number can have two values, *i.e.* $m_s = \frac{1}{2}$ (Spin up) or $m_s = -\frac{1}{2}$ (Spin down)

This quantum number helps to explain the magnetic properties of the substance.

Electronic Configurations of Atoms

The distribution of electrons in different orbitals of an atom is called the electronic configuration of the atom. The filling of electrons in orbitals is governed by the following rules.

(1) **Pauli's exclusion principle**

"It states that no two electrons in an atom can have all the four quantum number (n, l, m_l and m_s) the same."

It means each quantum state of an electron must have a different set of quantum numbers n, l, m_l and m_s. This principle sets an upper limit on the number of electrons that can occupy a shell.

N_{max} in one shell = $2n^2$; Thus N_{max} in K, L, M, N .... shells are 2, 8, 18, 32,

Note : ❑The maximum number of electrons in a subshell with orbital quantum number l is $2(2l + 1)$.

(2) **Aufbau principle**

Electrons enter the orbitals of lowest energy first.

As a general rule, a new electron enters an empty orbital for which $(n + l)$ is minimum. In case the value $(n + l)$ is equal for two orbitals, the one with lower value of n is filled first.

Thus the electrons are filled in subshells in the following order (memorize)

1*s*, 2*s*, 2*p*, 3*s*, 3*p*, 4*s*, 3*d*, 4*p*, 5*s*, 4*d*, 5*p*, 6*s*, 4*f*, 5*d*, 6*p*, 7*s*, 5*f*, 6*d*, 7*p*, ...

(3) **Hund's Rule**

When electrons are added to a subshell where more than one orbital of the same energy is available, their spins remain parallel. They occupy different orbitals until each one of them has at least one electron. Pairing starts only when all orbitals are filled up.

Pairing takes place only after filling 3, 5 and 7 electrons in *p*, *d* and *f* orbitals, respectively.

Concepts

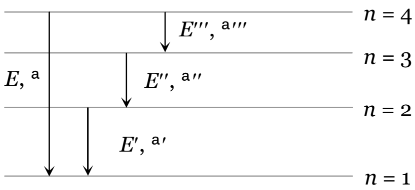
☞ *With the increase in principal quantum number the energy difference between the two successive energy level decreases, while wavelength of spectral line increases.*

$E' > E'' > E'''$

$a' < a'' < a'''$

$E = E' + E'' + E'''$

$\frac{1}{a} = \frac{1}{a'} + \frac{1}{a''} + \frac{1}{a'''}$



☞ ***Rydberg constant is different for different elements***

R(=1.09 ò 10^7 m^{-1}) is the value of Rydberg constant when the nucleus is considered to be infinitely massive as compared to the revolving electron. In other words, the nucleus is considered to be stationary.

In case, the nucleus is not infinitely massive or stationary, then the value of Rydberg constant is given as $\mathbf{R' = \frac{R}{1 + \frac{m}{M}}}$

where m is the mass of electron and M is the mass of nucleus.

☞ ***Atomic spectrum is a line spectrum***

Each atom has it's own characteristic allowed orbits depending upon the electronic configuration. Therefore photons emitted during transition of electrons from one allowed orbit to inner allowed orbit are of some definite energy only. They do not have a continuous graduation of energy. Therefore the spectrum of the emitted light has only some definite lines and therefore atomic spectrum is line spectrum.

☞ *Just as dots of light of only three colours combine to form almost every conceivable colour on T.V. screen, only about 100 distinct kinds of atoms combine to form all the materials in the universe.*

Example

***Example*: 1** The ratio of areas within the electron orbits for the first excited state to the ground state for hydrogen atom is

(a) 16 : 1 (b) 18 : 1 (c) 4 : 1 (d) 2 : 1

Solution : (a) For a hydrogen atom

Radius $r \propto n^2 \Rightarrow \frac{r_1^2}{r_2^2} = \frac{n_1^4}{n_2^4} \Rightarrow \frac{®r_1^2}{®r_2^2} = \frac{n_1^4}{n_2^4} \Rightarrow \frac{A_1}{A_2} = \frac{n_1^4}{n_2^4} = \frac{2^4}{1^4} = 16 \Rightarrow \frac{A_1}{A_2} = \frac{16}{1}$

***Example*: 2** The electric potential between a proton and an electron is given by $V = V_0 \ln \frac{r}{r_0}$, where r_0 is a constant. Assuming Bohr's model to be applicable, write variation of r_n with *n*, *n* being the principal quantum number

(a) $r_n \propto n$ (b) $r_n \propto 1/n$ (c) $r_n \propto n^2$ (d) $r_n \propto 1/n^2$

Solution : (a) Potential energy $U = eV = eV_0 \ln \frac{r}{r_0}$

$\therefore$ Force $F = -\left|\frac{dU}{dr}\right| = \frac{eV_0}{r}$. The force will provide the necessary centripetal force. Hence

$\frac{mv^2}{r} = \frac{eV_0}{r} \Rightarrow v = \sqrt{\frac{eV_0}{m}}$ .....(i) and $mvr = \frac{nh}{2®}$ .....(ii)

Dividing equation (ii) by (i) we have $mr = \left(\frac{nh}{2®}\right)\sqrt{\frac{m}{eV_0}}$ or $r \propto n$

***Example*: 3** The innermost orbit of the hydrogen atom has a diameter 1.06 $\AA$. The diameter of tenth orbit is

(a) 5.3 $\AA$ (b) 10.6 $\AA$ (c) 53 $\AA$ (d) 106 $\AA$

Solution : (d) Using $r \propto n^2 \Rightarrow \frac{r_2}{r_1} = \left(\frac{n_2}{n_1}\right)^2$ or $\frac{d_2}{d_1} = \left(\frac{n_2}{n_1}\right)^2 \Rightarrow \frac{d_2}{1.06} = \left(\frac{10}{1}\right)^2 \Rightarrow d = 106\,\AA$

***Example*: 4** Energy of the electron in n^{th} orbit of hydrogen atom is given by $E_n = -\frac{13.6}{n^2} eV$. The amount of energy needed to transfer electron from first orbit to third orbit is

(a) 13.6 eV (b) 3.4 eV (c) 12.09 eV (d) 1.51 eV

Solution : (c) Using $E = -\frac{13.6}{n^2} eV$

For $n = 1$, $E_1 = \frac{-13.6}{1^2} = -13.6\, eV$ and for $n = 3$ $E_3 = -\frac{13.6}{3^2} = -1.51\, eV$

So required energy $= E_3 - E_1 = -1.51 - (-13.6) = 12.09\, eV$

***Example*: 5** If the binding energy of the electron in a hydrogen atom is 13.6 *eV*, the energy required to remove the electron from the first excited state of Li^{++} is

(a) 122.4 eV (b) 30.6 eV (c) 13.6 eV (d) 3.4 eV

Solution : (b) Using $E_n = -\frac{13.6 \times Z^2}{n^2} eV$

For first excited state $n = 2$ and for Li^{++}, $Z = 3$

$\therefore\ E = -\frac{13.6}{2^2} \times 3^2 = -\frac{13.6 \times 9}{4} = -30.6\, eV$. Hence, remove the electron from the first excited state of Li^{++} be 30.6 *eV*

***Example*: 6** The ratio of the wavelengths for 2 → 1 transition in Li^{++}, He^+ and H is

(a) 1 : 2 : 3 (b) 1 : 4 : 9 (c) 4 : 9 : 36 (d) 3 : 2 : 1

Solution : (c) Using $\frac{1}{a} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow a \propto \frac{1}{Z^2} \Rightarrow a_{Li} : a_{He^+} : a_H = \frac{1}{9} : \frac{1}{4} : \frac{1}{1} = 4 : 9 : 36$

***Example*: 7** Energy E of a hydrogen atom with principal quantum number n is given by $E = \frac{-13.6}{n^2} eV$. The energy of a photon ejected when the electron jumps $n = 3$ state to $n = 2$ state of hydrogen is approximately

(a) 1.9 eV (b) 1.5 eV (c) 0.85 eV (d) 3.4 eV

Solution : (a) $\Delta E = 13.6\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 13.6 \times \frac{5}{36} = 1.9\, eV$

***Example*: 8** In the Bohr model of the hydrogen atom, let R, v and E represent the radius of the orbit, the speed of electron and the total energy of the electron respectively. Which of the following quantity is proportional to the quantum number n **[KCET 2002]**

(a) R/E (b) E/v (c) RE (d) vR

Solution : (d) Rydberg constant $R = \frac{£_0 n^2 h^2}{®mZe^2}$

Velocity $v = \frac{Ze^2}{2\varepsilon_0 nh}$ and energy $E = -\frac{mZ^2e^4}{8\varepsilon_0^2 n^2 h^2}$

Now, it is clear from above expressions $R.v \propto n$

***Example*: 9** The energy of hydrogen atom in nth orbit is E_n, then the energy in nth orbit of singly ionised helium atom will be

(a) $4E_n$ (b) $E_n/4$ (c) $2E_n$ (d) $E_n/2$

Solution : (a) By using $E = -\frac{13.6\,Z^2}{n^2} \Rightarrow \frac{E_H}{E_{He}} = \left(\frac{Z_H}{Z_{He}}\right)^2 = \left(\frac{1}{2}\right)^2 \Rightarrow E_{He} = 4E_n$.

***Example*: 10** The wavelength of radiation emitted is λ_0 when an electron jumps from the third to the second orbit of hydrogen atom. For the electron jump from the fourth to the second orbit of the hydrogen atom, the wavelength of radiation emitted will be

(a) $\frac{16}{25}\lambda_0$ (b) $\frac{20}{27}\lambda_0$ (c) $\frac{27}{20}\lambda_0$ (d) $\frac{25}{16}\lambda_0$

Solution : (b) Wavelength of radiation in hydrogen atom is given by

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \frac{1}{\lambda_0} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5}{36}R \quad .....(i)$$

and $$\frac{1}{\lambda'} = R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = R\left[\frac{1}{4} - \frac{1}{16}\right] = \frac{3R}{16} \quad .....(ii)$$

From equation (i) and (ii) $\frac{\lambda'}{\lambda} = \frac{5R}{36} \times \frac{16}{3R} = \frac{20}{27} \Rightarrow \lambda' = \frac{20}{27}\lambda_0$

***Example*: 11** If scattering particles are 56 for 90^o angle then this will be at 60^o angle

(a) 224 (b) 256 (c) 98 (d) 108

Solution : (a) Using Scattering formula

$$N \propto \frac{1}{\sin^4(\theta/2)} \Rightarrow \frac{N_2}{N_1} = \left[\frac{\sin\left(\frac{\theta_1}{2}\right)}{\sin\left(\frac{\theta_2}{2}\right)}\right]^4 \Rightarrow \frac{N_2}{N_1} = \left[\frac{\sin\left(\frac{90^\circ}{2}\right)}{\sin\left(\frac{60^\circ}{2}\right)}\right]^4 = \left[\frac{\sin 45^\circ}{\sin 30^\circ}\right]^4 = 4 \Rightarrow N_2 = 4N_1 = 4 \times 56 = 224$$

***Example*: 12** When an electron in hydrogen atom is excited, from its 4th to 5th stationary orbit, the change in angular momentum of electron is (Planck's constant: $h = 6.6 \times 10^{-34}\ J\text{–}s$)

(a) $4.16 \times 10^{-34}\ J\text{-}s$ (b) $3.32 \times 10^{-34}\ J\text{-}s$ (c) $1.05 \times 10^{-34}\ J\text{-}s$ (d) $2.08 \times 10^{-34}\ J\text{-}s$

Solution : (c) Change in angular momentum

$$\Delta L = L_2 - L_1 = \frac{n_2 h}{2\pi} - \frac{n_1 h}{2\pi} \Rightarrow \Delta L = \frac{h}{2\pi}(n_2 - n_1) = \frac{6.6 \times 10^{-34}}{2 \times 3.14}(5-4) = 1.05 \times 10^{-34}\ J\text{-}s$$

***Example*: 13** In hydrogen atom, if the difference in the energy of the electron in $n = 2$ and $n = 3$ orbits is E, the ionization energy of hydrogen atom is

(a) 13.2 E (b) 7.2 E (c) 5.6 E (d) 3.2 E

Solution : (b) Energy difference between $n = 2$ and $n = 3$; $E = K\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = K\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5}{36}K$ .....(i)

Ionization energy of hydrogen atom $n_1 = 1$ and $n_2 = \infty$; $E' = K\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = K$ .....(ii)

From equation (i) and (ii) $E' = \frac{36}{5} E = 7.2\, E$

***Example*: 14** In Bohr model of hydrogen atom, the ratio of periods of revolution of an electron in $n = 2$ and $n = 1$ orbits is

(a) 2 : 1 (b) 4 : 1 (c) 8 : 1 (d) 16 : 1

Solution : (c) According to Bohr model time period of electron $T \propto n^3 \Rightarrow \frac{T_2}{T_1} = \frac{n_2^3}{n_1^3} = \frac{2^3}{1^3} = \frac{8}{1} \Rightarrow T_2 = 8T_1$.

***Example*: 15** A double charged lithium atom is equivalent to hydrogen whose atomic number is 3. The wavelength of required radiation for emitting electron from first to third Bohr orbit in Li^{++} will be (Ionisation energy of hydrogen atom is 13.6 *eV*)

(a) 182.51 Å (b) 177.17 Å (c) 142.25 Å (d) 113.74 Å

Solution : (d) Energy of a electron in *n*th orbit of a hydrogen like atom is given by

$E_n = -13.6 \frac{Z^2}{n^2} eV$, and $Z = 3$ for *Li*

Required energy for said transition

$$\Delta E = E_3 - E_1 = 13.6 Z^2 \left(\frac{1}{1^2} - \frac{1}{3^2} \right) = 13.6 \times 3^2 \left[\frac{8}{9} \right] = 108.8\, eV = 108.8 \times 1.6 \times 10^{-19}\ J$$

Now using $\Delta E = \frac{hc}{ª} \Rightarrow ª = \frac{hc}{\Delta E} \Rightarrow ª = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{108.8 \times 1.6 \times 10^{-19}} = 0.11374 \times 10^{-7}\ m \Rightarrow ª = 113.74\ Å$

***Example*: 16** The absorption transition between two energy states of hydrogen atom are 3. The emission transitions between these states will be

(a) 3 (b) 4 (c) 5 (d) 6

Solution : (d) Number of absorption lines = $(n - 1) \Rightarrow 3 = (n - 1) \Rightarrow n = 4$

Hence number of emitted lines $= \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$

***Example*: 17** The energy levels of a certain atom for 1st, 2nd and 3rd levels are *E*, 4*E*/3 and 2*E* respectively. A photon of wavelength ª is emitted for a transition 3 → 1. What will be the wavelength of emissions for transition 2 → 1

(a) ª/3 (b) 4ª/3 (c) 3ª/4 (d) 3ª

Solution : (d) For transition 3 → 1 $\Delta E = 2E - E = \frac{hc}{ª} \Rightarrow E = \frac{hc}{ª}$ .....(i)

For transition 2 → 1 $\frac{4E}{3} - E = \frac{hc}{ª'} \Rightarrow E = \frac{3hc}{ª'}$ .....(ii)

From equation (i) and (ii) $ª' = 3ª$

***Example*: 18** Hydrogen atom emits blue light when it changes from $n = 4$ energy level to $n = 2$ level. Which colour of light would the atom emit when it changes from $n = 5$ level to $n = 2$ level

(a) Red (b) Yellow (c) Green (d) Violet

Solution : (d) In the transition from orbits $5 \to 2$ more energy will be liberated as compared to transition from 4 → 2. So emitted photon would be of violet light.

***Example*: 19** A single electron orbits a stationary nucleus of charge +*Ze*, where *Z* is a constant. It requires 47.2 *eV* to excited electron from second Bohr orbit to third Bohr orbit. Find the value of *Z*

(a) 2 (b) 5 (c) 3 (d) 4

Solution : (b) Excitation energy of hydrogen like atom for $n_2 \rightarrow n_1$

$$\Delta E = 13.6Z^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)eV \Rightarrow 47.2 = 13.6Z^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 13.6 \times \frac{5}{36}Z^2 \Rightarrow Z^2 = \frac{47.2 \times 36}{13.6 \times 5} = 24.98 \simeq 25$$

$\Rightarrow Z = 5$

Example: 20 The first member of the Paschen series in hydrogen spectrum is of wavelength 18,800 Å. The short wavelength limit of Paschen series is

(a) 1215 Å (b) 6560 Å (c) 8225 Å (d) 12850 Å

Solution : (c) First member of Paschen series mean it's $\lambda_{max} = \frac{144}{7R}$

Short wavelength of Paschen series means $\lambda_{min} = \frac{9}{R}$

Hence $\frac{\lambda_{max}}{\lambda_{min}} = \frac{16}{7} \Rightarrow \lambda_{min} = \frac{7}{16} \times \lambda_{max} = \frac{7}{16} \times 18{,}800 = 8225\ \mathring{A}$.

Example: 21 Ratio of the wavelengths of first line of Lyman series and first line of Balmer series is

(a) 1 : 3 (b) 27 : 5 (c) 5 : 27 (d) 4 : 9

Solution : (c) For Lyman series $\frac{1}{\lambda_{L_1}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}$ .....(i)

For Balmer series $\frac{1}{\lambda_{B_1}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5R}{36}$ .....(ii)

From equation (i) and (ii) $\frac{\lambda_{L_1}}{\lambda_{B_1}} = \frac{5}{27}$.

Example: 22 The third line of Balmer series of an ion equivalent to hydrogen atom has wavelength of 108.5 *nm*. The ground state energy of an electron of this ion will be

(a) 3.4 *eV* (b) 13.6 *eV* (c) 54.4 *eV* (d) 122.4 *eV*

Solution : (c) Using $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow \frac{1}{108.5 \times 10^{-9}} = 1.1 \times 10^7 \times Z^2\left(\frac{1}{2^2} - \frac{1}{5^2}\right)$

$$\Rightarrow \frac{1}{108.5 \times 10^{-9}} = 1.1 \times 10^7 \times Z^2 \times \frac{21}{100} \Rightarrow Z^2 = \frac{100}{108.5 \times 10^{-9} \times 1.1 \times 10^{-7} \times 21} = 4 \Rightarrow Z = 2$$

Now Energy in ground state $E = -13.6Z^2\ eV = -13.6 \times 2^2\ eV = -54.4\ eV$

Example: 23 Hydrogen (H), deuterium (D), singly ionized helium (He^+) and doubly ionized lithium (Li^{++}) all have one electron around the nucleus. Consider $n = 2$ to $n = 1$ transition. The wavelengths of emitted radiations are $\lambda_1, \lambda_2, \lambda_3$ and λ_4 respectively. Then approximately

(a) $\lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$ (b) $4\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$ (c) $\lambda_1 = 2\lambda_2 = 2\sqrt{2}\lambda_3 = 3\sqrt{2}\lambda_4$ (d) $\lambda_1 = \lambda_2 = 2\lambda_3 = 3\lambda_4$

Solution : (a) Using $\Delta E \propto Z^2$ ($\because n_1$ and n_2 are same)

$$\Rightarrow \frac{hc}{\lambda} \propto Z^2 \Rightarrow \lambda Z^2 = \text{constant} \Rightarrow \lambda_1 Z_1^2 = \lambda_2 Z_2^2 = \lambda_3 Z_3^2 = \lambda_4 Z^4 \Rightarrow \lambda_1 \times 1 = \lambda_2 \times 1^2 = \lambda_3 \times 2^2 = \lambda_4 \times 3^3$$

$\Rightarrow \lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$.

Example: 24 Hydrogen atom in its ground state is excited by radiation of wavelength 975 $\mathring{A}$. How many lines will be there in the emission spectrum

(a) 2 (b) 4 (c) 6 (d) 8

Solution : (c) Using $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \Rightarrow \frac{1}{975 \times 10^{-10}} = 1.097 \times 10^7 \left(\frac{1}{1^2} - \frac{1}{n^2}\right) \Rightarrow n = 4$

Now number of spectral lines $N = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$.

Example: 25 A photon of energy 12.4 eV is completely absorbed by a hydrogen atom initially in the ground state so that it is excited. The quantum number of the excited state is

(a) $n = 1$ (b) $n = 3$ (c) $n = 4$ (d) $n = \infty$

Solution : (c) Let electron absorbing the photon energy reaches to the excited state n. Then using energy conservation

$\Rightarrow -\frac{13.6}{n^2} = -13.6 + 12.4 \Rightarrow -\frac{13.6}{n^2} = -1.2 \Rightarrow n^2 = \frac{13.6}{1.2} = 12 \Rightarrow n = 3.46 \simeq 4$

Example: 26 The wave number of the energy emitted when electron comes from fourth orbit to second orbit in hydrogen is 20,397 cm^{-1}. The wave number of the energy for the same transition in He^+ is

(a) 5,099 cm^{-1} (b) 20,497 cm^{-1} (c) 40,994 cm^{-1} (d) 81,998 cm^{-1}

Solution : (d) Using $\frac{1}{\lambda} = \bar{\nu} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \Rightarrow \bar{\nu} \propto Z^2 \Rightarrow \frac{\bar{\nu}_2}{\bar{\nu}_1} = \left(\frac{Z_2}{Z_1}\right)^2 = \left(\frac{Z}{1}\right)^2 = 4 \Rightarrow \bar{\nu}_2 = \bar{\nu} \times 4 = 81588\ cm^{-1}$.

Example: 27 In an atom, the 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

(a) 1/4 (b) 4/1 (c) 8/1 (d) 1/8

Solution : (d) Time period $T \propto \frac{n^3}{Z^2}$

For a given atom (Z = constant) So $T \propto n^3$ .....(i) and radius $R \propto n^2$ .....(ii)

$\therefore$ From equation (i) and (ii) $T \propto R^{3/2} \Rightarrow \frac{T_1}{T_2} = \left(\frac{R_1}{R_2}\right)^{3/2} = \left(\frac{R}{4R}\right)^{3/2} = \frac{1}{8}$.

Example: 28 Ionisation energy for hydrogen atom in the ground state is E. What is the ionisation energy of Li^{++} atom in the 2nd excited state

(a) E (b) $3E$ (c) $6E$ (d) $9E$

Solution : (a) Ionisation energy of atom in nth state $E_n = \frac{Z^2}{n^2}$

For hydrogen atom in ground state (n = 1) and Z = 1 $\Rightarrow E = E_0$ .....(i)

For Li^{++} atom in 2nd excited state n = 3 and Z = 3, hence $E' = \frac{E_0}{3^2} \times 3^2 = E_0$ .....(ii)

From equation (i) and (ii) $E' = E$.

Example: 29 An electron jumps from n = 4 to n = 1 state in H-atom. The recoil momentum of H-atom (in eV/C) is

(a) 12.75 (b) 6.75 (c) 14.45 (d) 0.85

Solution : (a) The H-atom before the transition was at rest. Therefore from conservation of momentum

Photon momentum = Recoil momentum of H-atom or $P_{recoil} = \frac{h\nu}{c} = \frac{E_4 - E_1}{c} = \frac{-0.85 eV - (-13.6 eV)}{c} = 12.75 \frac{eV}{c}$

***Example*: 30** If elements with principal quantum number $n > 4$ were not allowed in nature, the number of possible elements would be

(a) 60 (b) 32 (c) 4 (d) 64

Solution : (a) Maximum value of $n = 4$

So possible (maximum) no. of elements

$N = 2\times 1^2 + 2\times 2^2 + 2\times 3^2 + 2\times 4^2 = 2 + 8 + 18 + 32 = 60$.

Tricky example: 1

If the atom ${}_{100}Fm^{257}$ follows the Bohr model and the radius of ${}_{100}Fm^{257}$ is n times the Bohr radius, then find n

(a) 100 (b) 200 (c) 4 (d) 1/4

Solution : (d) $(r_m) = \left(\frac{m^2}{Z}\right)(0.53\,\mathring{A}) = (n\times 0.53\,\mathring{A}) \Rightarrow \frac{m^2}{Z} = n$

$m = 5$ for ${}_{100}Fm^{257}$ (the outermost shell) and $z = 100$

$\therefore \quad n = \frac{(5)^2}{100} = \frac{1}{4}$

Tricky example: 2

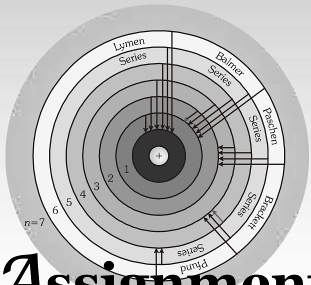
An energy of 24.6 eV is required to remove one of the electrons from a neutral helium atom. The energy (in eV) required to remove both the electrons from a neutral helium atom is

(a) 79.0 (b) 51.8 (c) 49.2 (d) 38.2

Solution : (a) After the removal of first electron remaining atom will be hydrogen like atom.

So energy required to remove second electron from the atom $E = 13.6 \times \frac{2^2}{1} = 54.4\, eV$

$\therefore$ Total energy required = 24.6 + 54.4 = 79 eV



Assignment

Atomic structure

1. The Bohr's model of atoms

(a) Assumes that the angular momentum of electrons is quantized

(b) Uses Einstein's photo-electric equation

(c) Predicts continuous emission spectra for atoms

(d) Predicts the same emission spectra for all types of atoms

2. In an orbital motion, the angular momentum vector is

(a) Along the radius vector (b) Parallel to the linear momentum

(c) In the orbital plane (d) Perpendicular to the orbital plane

3. The colour of the second line of Balmer series is

(a) Blue (b) Yellow (c) Red (d) Violet

4. If the ionization energy for the hydrogen atom is 13.6 *eV*, the energy required to excite it from the ground state to the next higher state is nearly

(a) 3.4 *eV* (b) 10.2 *eV* (c) 12.1 *eV* (d) 1.5 *eV*

5. If *r* is the radius of the lowest orbit of Bohr's model of hydrogen atom, the radius of next higher energy orbit is

(a) 4*r* (b) 9*r* (c) 16*r* (d) 2*r*

6. The kinetic energy of an electron revolving around a nucleus will be

(a) Four times of P.E. (b) Double of P.E. (c) Equal to P.E. (d) Half of its P.E.

7. Which state of triply ionised Beryllium (Be^{+++}) has the same orbital radius as that of the ground state of hydrogen

(a) $n = 1$ (b) $n = 2$ (c) $n = 3$ (d) $n = 4$

8. An ~-particle of energy 5 *MeV* is scattered through 180° by a fixed uranium nucleus. The distance of the closest approach is of the order of

(a) 1 Å (b) 10^{-10} *cm* (c) 10^{-12} *cm* (d) 10^{-15} *cm*

9. Dalton's atomic theory was in accordance with

(a) Conservation of energy (b) Conservation of mass (c) Conservation of charge (d) None of these

10. The energy of H_2 atom in its ground state is – 13.6 *eV*. The energy corresponding to first excitation state is

(a) – 3.4 *eV* (b) 3.4 *eV* (c) – 1.5 *eV* (d) 20.2 *eV*

11. The time of revolution of an electron around a nucleus of charge *Ze* in n^{th} Bohr orbit is directly proportional to

(a) n (b) $\frac{n^3}{Z^2}$ (c) $\frac{n^2}{Z}$ (d) $\frac{Z}{n}$

12. An electron in the $n = 1$ orbit of hydrogen atom is bound by 13.6 *eV* energy is required to ionize, it is

(a) 13.6 *eV* (b) 6.53 *eV* (c) 5.4 *eV* (d) 1.51 *eV*

13. In the lowest energy level of hydrogen atom, the electron has the angular momentum

(a) $®/h$ (b) $h/®$ (c) $h/2®$ (d) $2®/h$

14. According to Bohr's theory the moment of momentum of an electron revolving in second orbit of hydrogen atom will be

(a) $2®h$ (b) $®h$ (c) $\frac{h}{®}$ (d) $\frac{2h}{®}$

15. Which of the following transition will have highest emission wavelength

(a) $n = 2$ to $n = 1$ (b) $n = 1$ to $n = 2$ (c) $n = 2$ to $n = 5$ (d) $n = 5$ to $n = 2$

16. When the wave of hydrogen atom comes from infinity into the first orbit then the value of wave number is

(a) $109700\ cm^{-1}$ (b) $1097\ cm^{-1}$ (c) $109\ cm^{-1}$ (d) None of these

17. In which of the following systems will the radius of the first orbit ($n = 1$) be minimum

(a) Single ionized helium (b) Deuterium atom (c) Hydrogen atom (d) Double ionized lithium

18. Which of the following atoms has the lowest ionization potential

(a) ${}^{16}_{8}O$ (b) ${}^{14}_{7}N$ (c) ${}^{133}_{55}Cs$ (d) ${}^{40}_{18}Ar$

19. In the Bohr's model of hydrogen atom, the ratio of the kinetic energy to the total energy of the electron in nth quantum state is

(a) – 1 (b) + 1 (c) – 2 (d) 2

20. In the Bohr's hydrogen atom model, the radius of the stationary orbit is directly proportional to (n = principle quantum number)

(a) n^{-1} (b) n (c) n^{-2} (d) n^2

21. With the increase in principal quantum number, the energy difference between the two successive energy levels

(a) Increases (b) Decreases
(c) Remains constant (d) Sometimes increases and sometimes decreases

22. According to classical theory of Rutherford model the path of electron will be

(a) Parabolic (b) Hyperbolic (c) Circular (d) Elliptical

23. Bohr's theory was modified by

(a) Rutherford and Soddy (b) Planck (c) Hund (d) Somerfield

24. Minimum excitation potential of Bohr's first orbit in hydrogen atom is

(a) 13.6 V (b) 3.4 V (c) 10.2 V (d) 3.6 V

25. To explain his theory, Bohr used

(a) Conservation of linear momentum (b) Conservation of angular momentum
(c) Conservation of quantum frequency (d) Conservation of energy

26. A hydrogen atom and a Li^{++} ion are both in the second excited state. If l_H and l_{Li} are their respective electronic angular momenta, and E_H and E_{Li} their respective energies, then

(a) $l_H > l_{Li}$ and $|E_H| > |E_{Li}|$ (b) $l_H = l_{Li}$ and $|E_H| < |E_{Li}|$ (c) $l_H = l_{Li}$ and $|E_H| > |E_{Li}|$ (d) $l_H < l_{Li}$ and $|E_H| < |E_{Li}|$

27. The radius of the first orbit of the hydrogen atom is a_0. The radius of the second orbit will be

(a) $4a_0$ (b) $6a_0$ (c) $8a_0$ (d) $10a_0$

28. Energy of an electron in an excited hydrogen atom is – 3.4 eV. Its angular momentum will be ($h = 6.626 \times 10^{-34}\ J-s$)

(a) $1.11 \times 10^{34}\ J$ sec (b) $1.51 \times 10^{-31}\ J$ sec (c) $2.11 \times 10^{-34}\ J$ sec (d) $3.72 \times 10^{-34}\ J$ sec

29. Consider the spectral line resulting from the transition from n = 2 to n = 1 in atoms and ions given below. The shortest wavelength is produced by

(a) Hydrogen atom (b) Deuterium atom (c) Singly ionized helium (d) Doubly ionized lithium

30. Find the correct statement about Bohr atom model

(a) It could not explain about the spectral lines of hydrogen atoms

(b) Electrostatic force of attraction between the nucleus and the electron is $\frac{-z^2me^4}{8£_0^2n^2h^2}$

(c) Bohr used the planck's constant to explain his two postulates

(d) The centripetal force on the electron is $\frac{ze^2}{4®£_0 r_n^2}$

31. In a hydrogen atom what will be the radius of 5th orbit if the radius of the first orbit is 0.53$Å$

(a) 2.65 $Å$ (b) 5.3 $Å$ (c) 0.106 $Å$ (d) 13.25 $Å$

32. The velocity of an electron in the inner-most orbit of an atom is

(a) Zero (b) Highest (c) Lowest (d) Mean

33. An electron in revolving round a proton in an orbit of radius 5.3×10^{-9} cm. The speed of electron will be

(a) $2.2 \times 10^6\ m/s$ (b) $2.2 \times 10^8\ m/s$ (c) $2.2 \times 10^5\ m./s$ (d) $2.2 \times 10^4\ m/s$

34. If elements corresponding to $n > 5$ do not exist, the number of possible elements will be

(a) 60 (b) 5 (c) 75 (d) 110

35. The possible quantum number for 3d electron are

(a) $n = 3, l = 1, m_l = +1, m_s = -\frac{1}{2}$ (b) $n = 3, l = 2, m_l = +2, m_s = -\frac{1}{2}$

(c) $n = 3, l = 1, m_l = -1, m_s = -\frac{1}{2}$ (d) $n = 3, l = 0, m_l = +1, m_s = -\frac{1}{2}$

36. The ratio of speed of an electron in ground state in Bohrs first orbit of hydrogen atom to velocity of light in air is

(a) $\frac{e^2}{2£_0 hc}$ (b) $\frac{2e^2£_0}{hc}$ (c) $\frac{e^3}{2£_0 hc}$ (d) $\frac{2£_0 hc}{e^2}$

37. In hydrogen atom, when electron jumps from second to first orbit, then energy emitted is

(a) – 13.6 eV (b) – 27.2 eV (c) – 6.8 eV (d) None of these

38. The wavelength of light emitted from second orbit to first orbits in a hydrogen atom is

(a) $1.215 \times 10^{-7} m$ (b) $1.215 \times 10^{-5} m$ (c) $1.215 \times 10^{-4} m$ (d) $1.215 \times 10^{-3} m$

39. Whenever a hydrogen atom emits a photon in the Balmer series

(a) It need not emit any more photon (b) It may emit another photon in the Paschen series

(c) It must emit another photon in the Lyman series (d) It may emit another photon in the Balmer series

40. The frequency of 1st line of Balmer series in H_2 atom is $¬_0$. The frequency of line emitted by singly ionised He atom is

(a) $2¬_0$ (b) $4¬_0$ (c) $¬_0 / 2$ (d) $¬_0 / 4$

41. When the electron in the hydrogen atom jumps from 2nd orbit to 1st orbit, the wavelength of radiation emitted is a . When the electrons jump from 3rd orbit to 1st orbit, the wavelength of emitted radiation would be

(a) $\frac{27}{32}$ a (b) $\frac{32}{27}$ a (c) $\frac{2}{3}$ a (d) $\frac{3}{2}$ a

42. The Lyman series of hydrogen spectrum lies in the region

(a) Infrared (b) Visible (c) Ultraviolet (d) Of X-rays

43. The hydrogen atom can give spectral lines in the series, Lyman, Balmer and Paschen. Which of the following statements is correct

(a) Lyman series is in the infrared region
(b) Balmer series is in the visible region (partly)
(c) Balmer series is solely in the ultraviolet region
(d) Paschen series is in the visible region

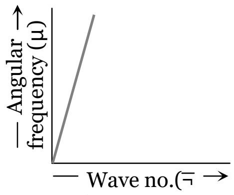
44. Ionization potential of hydrogen atom is 13.6 *eV*. Hydrogen atoms in the ground state are excited by monochromatic radiation of photon energy 12.1 *eV*. The spectral lines emitted by hydrogen atoms according to Bohr's theory will be

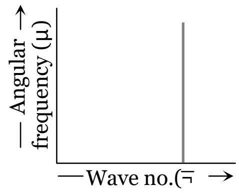
(a) One (b) Two (c) Three (d) Four

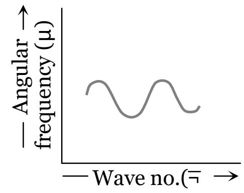
45. Minimum energy required to take out the only one electron from ground state of He^+ is

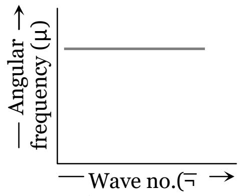
(a) 13.6 *eV* (b) 54.4 *eV* (c) 27.2 *eV* (d) 6.8 *eV*

46. The graph between wave number (¬) and angular frequency (µ) is

(a) 

(b) 

(c) 

(d) 

47. The energy of an electron in the n^{th} orbit of hydrogen is given by

(a) $E_n = -\frac{4®^2 mke^2}{n^2h^2}$
(b) $E_n = -\frac{n^2h^2}{4®^2 mke^2}$
(c) $E_n = -\frac{2®^2 mk^2e^4}{n^2h^2}$
(d) $E_n = -\frac{n^2h^2}{2®^2 mk^2e^2}$

48. If radiations of all wavelengths from ultraviolet to infrared are passed through hydrogen gas at room temperature, absorption lines will be observed in

(a) Lyman, Baklmer and Paschen series
(b) Both Lyman and Balmer series
(c) Lyman series
(d) Balmer series

49. In any excited state of hydrogen atom if $m = 5$, then value of n, i, m, s will be

(a) 5, 5, 5, –1/2 (b) 7, 7, 5, +1/2 (c) 6, 6, 5, –1/2 (d) 8, 7, 5, +1/2

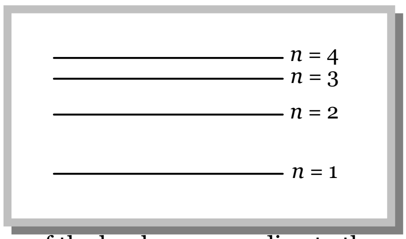
50. Which of the following is true for number of spectral lines in going form Lyman series to Pfund series

(a) Increases (b) Decreases (c) Unchanged (d) May decreases or increases

51. The first line in the Lyman series has wavelength ª. The wavelength of the first line in Balmer series is

(a) $\frac{2}{9}$ ª (b) $\frac{9}{2}$ ª (c) $\frac{5}{27}$ ª (d) $\frac{27}{5}$ ª

52. Four lowest energy levels of *H*-atom are shown in the figure. The number of possible emission lines would be



(a) 3
(b) 4
(c) 5
(d) 6

53. The energy of hydrogen atom in its ground state is – 13.6 *eV*. The energy of the level corresponding to the quantum number *n* is equal 5 is

(a) – 5.40 eV *(b) – 2.72 eV* *(c) – 0.85 eV* *(d) – 0.54 eV*

54. The ionisation potential of hydrogen is 13.6*eV*. Then the energy released when an electron jumps from $n = 3$ to $n = 2$ orbit, is

(a) 2.89 *eV* (b) 1.89 *eV* (c) 3.89 *eV* (d) 4.89 *eV*

55. The transition from the state n = 4 to n = 3 in a hydrogen-like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition

(a) $2 \to 1$ (b) $3 \to 2$ (c) $4 \to 2$ (d) $5 \to 4$

56. Orbital acceleration of electron is

(a) $\frac{n^2h^2}{4®^2m^2r^3}$ (b) $\frac{n^2h^2}{2n^2r^3}$ (c) $\frac{4n^2h^2}{®^2m^2r^3}$ (d) $\frac{4n^2h^2}{4®^2m^2r^3}$

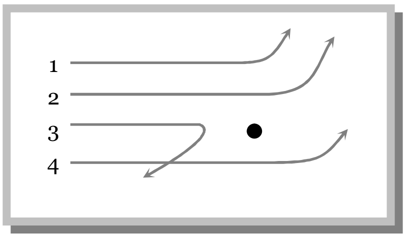
57. Which of the following transitions in a hydrogen atom emits photon of the highest frequency

(a) n = 1 to n = 2 (b) n = 2 to n = 1 (c) n = 2 to n = 6 (d) n = 6 to n = 2

58. Radius of the first orbit of the electron in a hydrogen atom is 0.53 *Å*. So, the radius of the third orbit will be

(a) 2.12 *Å* (b) 4.77 *Å* (c) 1.06 *Å* (d) 1.59 *Å*

59. The diagram shows the path of four ~-particles of the same energy being scattered by the nucleus of an atom simultaneously. Which of these are/is not physically possible



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

60. An electron jumps from 5th orbit to 4th orbit of hydrogen atom. Taking the Rydberg constant as 10^7 *per metre*. What will be the frequency of radiation emitted

(a) 6.75×10^{12} *Hz* (b) 6.75×10^{14} *Hz* (c) 6.75×10^{13} *Hz* (d) None of these

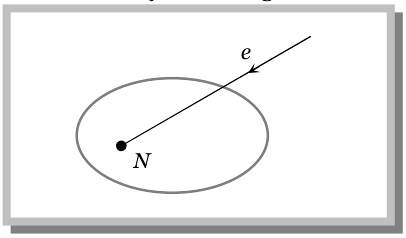
61. The electron in a hydrogen atom makes a transition $n_1 \to n_2$ where n_1 and n_2 are the principal quantum numbers of the two states. Assume the Bohr model to be valid. The time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are

(a) $n_1 = 4, n_2 = 2$ (b) $n_1 = 8, n_2 = 2$ (c) $n_1 = 8,. n_2 = 1$ (d) $n_1 = 6, n_2 = 3$

62. For principal quantum number $n = 3$, the possible values of orbital quantum number 'l' are

(a) 1, 2, 3 (b) 0, 1, 2, 3 (c) 0, 1, 2 (d) – 1, 0, + 1

63. An electron moves towards a nucleus at the focus of a an elliptical orbit with velocity *V*. Its angular momentum with respect to nucleus is



(a) Always zero
(b) Always remains constant
(c) Changes with time
(d) Can not determined

64. The total energy of the electron in the hydrogen atom in the ground state is –13.6 *eV*. The kinetic energy of this electron is

(a) – 13.6 *eV* (b) 0 (c) 6.8 *eV* (d) 13.6 *eV*

65. What change in energy per mole of atoms will be associated with an atomic transition giving rise to radiation at 1 *Hz*

(a) $0.399 \times 10^{-10}\ J\,mol^{-1}$ (b) $9.390 \times 10^{-10}\ J\,mol^{-1}$ (c) $3.990 \times 10^{-10}\ J\,mol^{-1}$ (d) None of these

66. According to Bohr's theory the radius of electron orbit is proportional to

(a) Z^2n^2 (b) $\frac{Z^2}{n^2}$ (c) $\frac{Z^2}{n}$ (d) $\frac{n^2}{Z}$

67. According to Bohr's postulate which of the following take discrete values

(a) Kinetic energy (b) Potential energy (c) Angular momentum (d) Linear momentum

68. Who indirectly determined of the mass of the electron by measuring the charge of the electrons

(a) Rutherford (b) Einstein (c) Thomson (d) Millikan

69. Who discovered spin quantum number

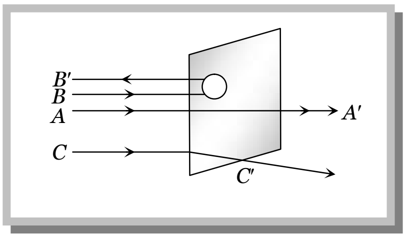
(a) Unlenbeck and Goudsmit (b) Neil's Bohr

(c) Zeeman (d) Sommerfield

70. In Rutherford scattering experiment, what will be the correct angle for ~ scattering for an impact parameter $b = 0$

(a) 90^o (b) 270^o (c) 0^o (d) 180^o

71. A beam of fast moving alpha particles were directed towards a thin film of gold. The parts A', B' and C' of the transmitted and reflected beams corresponding to the incident parts A, B and C of the beam, are shown in the adjoining diagram. The number of alpha particles in



(a) B' will be minimum and in C' maximum

(b) A' will be maximum and in B' minimum

(c) A' will be minimum and in B' maximum

(d) C' will be minimum and in B' maximum

72. The radius of hydrogen atom in its ground state is 5.3×10^{-11} m. After collision with an electron it is found to have a radius of 21.2×10^{-11} m. What is the principal quantum number n of the final state of the atom

(a) $n = 4$ (b) $n = 2$ (c) $n= 16$ (d) $n = 3$

73. The de-Broglie wavelength of thermal neutrons is of the order of the

(a) Distance between atoms in crystals (b) Size of the nucleus

(c) Bohr's radius (d) Size of a grain

74. As per Bohr model the minimum energy required to remove an electron from the ground state of doubly ionised $Li^{(z=3)}$ atom is

(a) 1.51 eV (b) 13.6 eV (c) 4.08 eV (d) 122.4 eV

75. The concept of stationary orbits was proposed by

(a) Neil Bohr (b) J.J. Thomson (c) Rutherford (d) I. Newton

76. The electron in a hydrogen atom makes a transition from an excited state to ground state. Which of the following statements is true

(a) Its kinetic energy increases and its potential and total energies decrease

(b) Its kinetic energy decreases, potential energy increases and its total energy remains same

(c) Its kinetic and total energies decrease and its potential energy increases

(d) Its kinetic, potential and total energies decrease

77. Imagine an atom made up of a proton and a hypothetical particle of double the mass of the electron but having same charge as the electron. Apply Bohr atom model and consider all possible transitions of this hypothetical particle to the first excited level. The longest wavelength photon that will be emitted has wavelength ª (given in the terms of Rydberg constant R for hydrogen atom) equal to

(a) $9/5\,R$ (b) $36/5\,R$ (c) $18/5\,R$ (d) $4/R$

78. According to the Rutherford's atomic model, the electrons inside the atom are

(a) Stationary (b) Not stationary (c) Centralized (d) None of these

79. The radius of hydrogen atom in ground state is of the order

(a) 10^{-8} cm (b) 10^{-6} cm (c) 10^{-4} cm (d) 10^{-7} cm

80. The radius of the Bohr orbit in the ground state of hydrogen atom is 0.5 $\mathring{A}$. The radius of the orbit of the electron in the third excited state of He^+ will be

(a) 8 $\mathring{A}$ (b) 4 $\mathring{A}$ (c) 0.5 $\mathring{A}$ (d) 0.25 $\mathring{A}$

81. What will be the angular momentum of a electron, if energy of this electron in H-atom is 1.5 eV (in J-sec)

(a) 1.05×10^{-34} (b) 2.1×10^{-34} (c) 3.15×10^{-34} (d) -2.1×10^{-34}

82. The ratio of the longest to shortest wavelengths in Brackett series of hydrogen spectra is

(a) $\frac{25}{9}$ (b) $\frac{17}{6}$ (c) $\frac{9}{5}$ (d) $\frac{4}{3}$

83. The ratio of minimum to maximum wavelength in Balmer series is

(a) 5 : 9 (b) 5 : 36 (c) 1 : 4 (d) 3 : 4

84. When an electron jumps from the fourth orbit to the second orbit, one gets the

(a) Second line of Lyman series (b)Second line of Paschen series

(c) Second line of Balmer series (d)First line of Pfund series

85. Calculate the series limit of the Lyman series of hydrogen atom

(a) $9.1176 \times 10^{-6}\, cm$ (b) 10968 cm (c) $1.2157 \times 10^{-5}\, cm$ (d) 82259 cm

86. Which of the following phenomena suggests the presence of electron energy levels in atoms

(a) Radio active decay (b) Isotopes (c) Spectral lines (d) ~ -particles scattering

87. The ionisation potential of H-atom is 13.6 V when it is excited from ground state by monochromatic radiations of 970.6 Å, the number of emission lines will be (according to Bohr's theory)

(a) 10 (b) 8 (c) 6 (d) 4

88. Which of the following spectral series in hydrogen atom give spectral line of 4860 Å

(a) Lyman (b) Balmer (c) Paschen (d) Bracket

89. The energy required to excite an electron from the ground state of hydrogen atom to the first excited state, is

(a) $1.602 \times 10^{-14}\, J$ (b) $1.619 \times 10^{-16}\, J$ (c) $1.632 \times 10^{-18}\, J$ (d) $1.656 \times 10^{-20}\, J$

90. The ratio of longest wavelength and the shortest wavelength observed in the five spectral series of emission spectrum of hydrogen is

(a) $\frac{4}{3}$ (b) $\frac{525}{376}$ (c) 25 (d) $\frac{900}{11}$

91. If in Rutherford's experiment, the number of particles scattered at 90° angle are 28 per min, then number of scattered particles at an angle 60° and 120° will be

(a) 112/min., 12.5/min (b) 100/min., 200/min (c) 50/min., 12.5/min (d) 117/min., 25/min

92. When the hydrogen atom is changed from its ground state to excited state

(a) P.E. increases but K.E. decreases (b) K.E. increases but P.E. decreases

(c) P.E. increases (d) K.E. increases

93. The velocity of an electron in the second orbit of sodium atom (atomic number = 11) is v. the velocity of an electron in its fifth orbit will be

(a) v (b) $\frac{22}{5}v$ (c) $\frac{5}{2}v$ (d) $\frac{2}{5}v$

94. The ratio between potential energy and kinetic energy of the electron in $(n-1)^{th}$ orbit of hydrogen atom is

(a) – 2 (b) 2 (c) 1 (d) – 1

95. Which of the following transitions in hydrogen atom emits a photon of lowest frequency (n = quantum number)

(a) n = 2 to n =1 (b) n = 4 to n = 3 (c) n = 3 to n = 1 (d) n = 4 to n = 2

96. In hydrogen spectrum the shortest wavelength in Balmer series is ª. The shortest wavelength in Bracket series will be

(a) 2ª (b) 4ª (c) 9ª (d) 16ª

97. Which of the following statements is true regarding Bohr's model of hydrogen atom.

(I) Orbiting speed of electrons decreases as it falls to discrete orbits away from the nucleus.

(II) Radii of allowed orbits of electrons are proportional to the principal quantum number.

(III) Frequency with which electrons orbit around the nucleus in discrete orbits is inversely proportional to the principal quantum number.

(IV) Binding force with which the electron is bound to the nucleus increases as it shifts to outer orbits.

Select the correct answer using the codes given below

(a) I and III (b) II and IV (c) I, II and III (d) II, III and IV

98. The Rydberg constant R for hydrogen is

(a) $R=\left(\frac{1}{4®£_0}\right)\frac{2®^2me^2}{ch^2}$ (b) $R=\left(\frac{1}{4®£_0}\right)\frac{2®^2me^4}{ch^2}$ (c) $R=\left(\frac{1}{4®£_0}\right)^2\frac{2®^2me^4}{c^2h^2}$ (d) $R=\left(\frac{1}{4®£_0}\right)^2\frac{2®^2me^4}{ch^3}$

99. In the Bohr model of a hydrogen atom, the centripetal force is furnished by the coulomb attraction between the proton and the electron. If a_0 is the radius of the ground state orbit, m is the mass and e is charge on the electron and $£_0$ is the vacuum permittivity, the speed of the electron is

(a) 0 (b) $\frac{e}{\sqrt{£_0 a_0 m}}$ (c) $\frac{e}{\sqrt{4®£_0 a_0 m}}$ (d) $\sqrt{\frac{4®£_0 a_0 m}{e}}$

100. The 21 *cm* radio wave emitted by hydrogen in interstellar space is due to the interaction called the hyperline interaction in atomic hydrogen. The energy of the emitted wave is nearly

(a) 10^{-17} *Joule* (b) 1 *Joule* (c) 7×10^{-8} *Joule* (d) 10^{-24} *Joule*

101. Which one of the series of hydrogen spectrum is in the visible region

(a) Lyman series (b) Balmer series (c) Paschen series (d) Bracket series

102. Frequency of the series limit of Balmer series of hydrogen atom in terms of Rydberg constant R and velocity of light C is

(a) RC (b) $\frac{RC}{4}$ (c) $4RC$ (d) $\frac{4}{RC}$

103. Hydrogen atom excites energy level from the fundamental state to $n = 3$. Number of spectral lines, according to Bohr, is

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

104. Ionization energy of hydrogen is 13.6 *eV*. If $h = 6.6\times10^{31}$ *J-sec*, the value of R will be of the order of

(a) $10^{10}\ m^{1}$ (b) $10^{7}\ m^{-1}$ (c) $10^{4}\ m^{-1}$ (d) $10^{-7}\ m^{-1}$

105. In a hydrogen atom, which of the following electronic transitions would involve the maximum energy change

(a) From $n = 2$ to $n = 1$ (b) From $n = 3$ to $n = 1$ (c) From $n = 4$ to $n = 2$ (d) From $n = 3$ to $n = 2$

106. The Rutherford ~-particle experiment shows that most of the ~-particles pass through almost unscattered while some are scattered through large angles. What information does it give about the structure of the atom

(a) Atom is hollow

(b) The whole mass of the atom is concentrated in a small centre called nucleus

(c) Nucleus is positively charged

(d) All of the above

107. An ionic atom equivalent to hydrogen atom has wavelength equal to 1/4 of the wavelengths of hydrogen lines. the ion will be

(a) He^{+} (b) Li^{++} (c) Ne^{9+} (d) Na^{10+}

108. The required energy to detach one electron from Balmer series of hydrogen spectrum is

(a) 13.6 *eV* (b) 10.2 *eV* (c) 3.4 *eV* (d) – 1.5 *eV*

109. Number of spectral lines in hydrogen atom is

(a) 3 (b) 6 (c) 15 (d) Infinite

110. A hydrogen atom in its ground state absorbs 10.2 eV of energy. The orbital angular momentum is increased by (Given Planck constant $h = 6.6 \times 10^{-34}$ J - sec)

(a) 1.05×10^{-34} J - sec (b) 3.16×10^{-34} J - sec (c) 2.11×10^{-34} J- sec (d) 4.22×10^{-34} J- sec

111. The ratio of the frequencies of the long wavelength limits of Lyman and Balmer series of hydrogen spectrum is

(a) 27 : 5 (b) 5 : 27 (c) 4 : 1 (d) 1 : 4

112. An electron in hydrogen and one in singly ionised helium atom are excited to the state $n = 2$. A photon is emitted when these electrons jump back to the ground state in each case. Then

(a) Energy of photon is same in both

(b) Radiations emitted by helium ion are shifted towards the red as compared to radiation from hydrogen atom

(c) Radiations emitted by helium ion are shifted towards the violet as compared to radiations from hydrogen atom

(d) None of these

113. Ionisation potential of hydrogen atom is 13.6 eV. Hydrogen atoms in the ground state are excited by monochromatic radiation of photon energy 12.1 eV. The spectral lines emitted by hydrogen atoms according to Bohr's theory will be

(a) One (b) Two (c) Three (d) Four

114. According to classical physics, the electron orbit in the hydrogen atom is unstable because

(a) The electron is an unstable particle (b) The electron has very high kinetic energy

(c) An accelerated electron radiates out E.M. waves (d) An accelerated electron absorbs E.M. waves

115. According to Bohr's theory of the hydrogen atom, the diameter of the first orbit is about

(a) 0.1 $Å$ (b) 1 $Å$ (c) 13.6 $Å$ (d) 5890 $Å$

116. The splitting of line into groups under the effect of electric or magnetic field is called

(a) Zeeman's effect (b) Bohr's effect (c) Heisenberg's effect (d) Magnetic effect

117. The number of revolutions per second made by an electron in the first Bohr orbit of hydrogen atom is of the order of

(a) 10^{20} (b) 10^{19} (c) 10^{17} (d) 10^{15}

118. Which of the following statements about the Bohr model of the hydrogen atom is false

(a) Acceleration of electron in n = 2 orbit is less than that in n =1 orbit

(b) Angular momentum of electron in n = 2 orbit is more than that in n =1 orbit

(c) Kinetic energy of electron in n = 2 orbit is less than that in n =1 orbit

(d) Potential energy of electron in n = 2 orbit is less than that in n =1 orbit

119. An electron makes a transition from orbit n = 4 to the orbit n = 2 of a hydrogen atom. The wave number of the emitted radiations (R = Rydberg's constant) will be

(a) $\frac{16}{3R}$ (b) $\frac{2R}{16}$ (c) $\frac{3R}{16}$ (d) $\frac{4R}{16}$

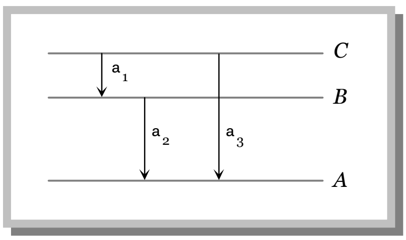
120. Energy levels A, B, C of a certain atom corresponding to increasing values of energy *i.e.*, $E_A < E_B < E_C$. If a_1, a_2, a_3 are the wavelengths of radiations corresponding to the transitions C to B, B to A and C to A respectively, which of the following statements is correct

(a) $a_3 = a_1 + a_2$

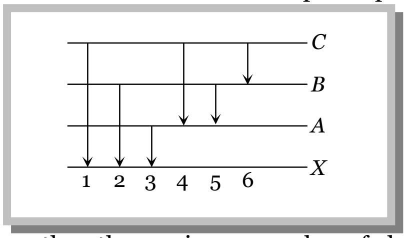
(b) $a_3 = \frac{a_1 a_2}{a_1 + a_2}$

(c) $a_1 + a_2 + a_3 = 0$

(d) $a_3^2 = a_1^2 + a_2^2$



121. The figure indicates the energy level diagram of an atom and the origin of six spectral lines in emission (*e.g.*, line no. 5 arises from the transition from level *B* to *A*). The following spectral lines will also occur in the absorption spectrum



(a) 1, 4, 6

(b) 4, 5, 6

(c) 1, 2, 3

(d) 1, 2, 3, 4, 5, 6

122. If in some atomic orbit, quantum numbers *n, l* and m_l are same, then the maximum number of electrons that can be present there are

(a) 2 (b) $2n^2$ (c) $(2l+1)$ (d) $2(2l+1)$

123. Which one of these is non-divisible

(a) Nucleus (b) Photon (c) Proton (d) Atom

124. The fact that protons carry energy was established by

(a) Doppler's effect (b) Compton's effect (c) Bohr's theory (d) Diffraction of light

125. The ratio of the speed of the electrons in the ground state of hydrogen to the speed of light in vacuum is

(a) 1/2 (b) 2/137 (c) 1/137 (d) 1/237

126. Bohr's model of *H*-atom predicts that the absorption spectra involves

(a) Accelerating electrons (b) Decelerating electrons

(c) Electron going to higher K.E. level (d) Electrons going to lower momentum levels

127. X-rays are not emitted from excited hydrogen atoms, because

(a) Hydrogen atoms contains only one electron

(b) Energy levels of the hydrogen atoms are very closed spaced

(c) There are no neutrons in the nucleus of the *H*-atom

(d) All of the above

128. Energy levels of the hydrogen atom are order of energy are –13.6, –3.40, –1.51, –0.85, –0.54,....., 0 *eV*. The ionisation potential for the atom in second excited state is

(a) 13.6 *volt* (b) 1.51 *V* (c) 1.51 *eV* (d) 13.6 *eV*

129. Which of the following is true

(a) Lyman series is a continuous spectrum

(b) Paschen series is a line spectrum in the infrared

(c) Balmer series is a line spectrum in the ultraviolet

(d) The spectral series formula can be derived from the Rutherford model of the hydrogen atom

130. Every series of hydrogen spectrum has an upper and lower limit in wavelength. The spectral series which has an upper limit of wavelength equal to 18752 Å is (Rydberg constant $R = 1.097 \times 10^7$ per metre)

(a) Balmer series (b) Lyman series (c) Paschen series (d) Pfund series

131. Hydrogen atom emits blue light when it changes from $n = 4$ energy level to the $n = 2$ level. Which colour of light would the atom emit when it changes from the $n = 5$ level to the $n = 2$ level

(a) Red (b) Yellow (c) Green (d) Violet

132. The wavelength of radiation emanating from transition of an atom

(i) From electronic state A to C and

(ii) From electronic state B to C are 1000 Å and 5000 Å respectively. What is the wavelength of radiation emanating from transition of the atom from state A to B

(a) 4000 Å (b) 2000 Å (c) 1250 Å (d) 500 Å

133. The ionization energy of hydrogen atom is 13.6 *eV*. Following Bohr's theory, the energy corresponding to a transition between 3rd and 4th orbit is

(a) 3.40 *eV* (b) 1.51 *eV* (c) 0.85 *eV* (d) 0.66 *eV*

134. Which of the following pairs, have identical atomic structure

(a) Li^+, Na^+ (b) He, Ne^+ (c) He, Li (d) C, N^+

135. As the electron in Bohr orbit of hydrogen atom passes from state n = 2 to n = 1, the KE (K) and PE (U) change as

(a) K two-fold, U also two-fold (b) K four-fold, U also four-fold (c) K four-fold, U two-fold (d) K two-fold, U four-fold

136. The ionisation energy of 10 times ionised sodium atom is

(a) 13.6 eV (b) 13.6 × 11 eV (c) $\frac{13.6}{11}$ eV (d) $13.6 \times (11)^2$ eV

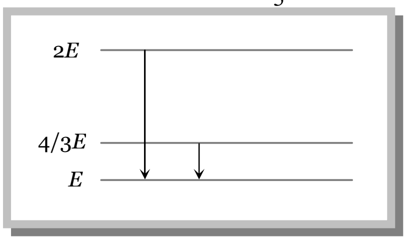
137. If the electron in H atom radiates a photon of wavelength 4860 Å, the KE of the electron

(a) Decreases by $2.0 \times 10^{-19} J$ (b) Increases by $4.1 \times 10^{-19} J$ (c) Decreases by $4.1 \times 10^{-19} J$ (d) Increases by $8.2 \times 10^{-19} J$

138. Assume that there exist an atom, according to Bohr model, whose first ionization potential is 20V, then the value of first excitation potential for this atom will be

(a) 5V (b) 10V (c) 15V (d) 25V

139. The following diagram indicates the energy levels of a certain atom when the system moves from 2E level to E. A photon of wavelength ª is emitted. The wavelength of photon produced during its transition from $\frac{4E}{3}$ level to E is



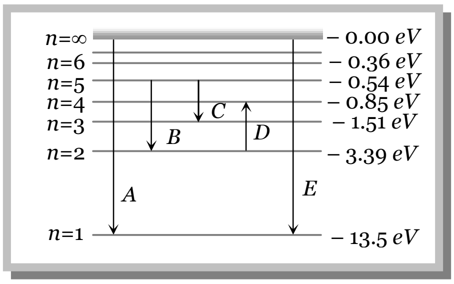
(a) ª / 3

(b) 3ª / 4

(c) 4ª / 3

(d) 3ª

140. The energy levels of the hydrogen spectrum is shown in figure. There are some transitions A, B, C, D and E. Transition A, B and C respectively represent



(a) First member of Lyman series, third spectral line of Balmer series and the second spectral line of Paschen series

(b) Ionization potential of hydrogen, second spectral line of Paschen series

(c) Series limit of Lyman series, third spectral line of Balmer series and second spectral line of Paschen series

(d) Series limit of Lyman series, second spectral line of Balmer series and third spectral line of Paschen series

141. The orbital quantum number of subshell which contains 7 orbitals is

(a) $l = 7$ (b) $l = 3$ (c) $l = 0$ (d) None of these

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

(a) Alpha particles are much heavier than electrons (b) Alpha particles are positively charged

(c) Most of the atom is empty space (d) Alpha particles move with high velocity

143. A hydrogen atom moving with velocity 4m/s absorbs a photon of wavelength ª and stops. The value of ª will be

(a) 1000 Å (b) 2000 Å (c) 3000 Å (d) 4000 Å

144. A hydrogen atom moving with velocity u collides inelastically with another hydrogen atom at rest. Both the atoms are in the ground state before collision. The minimum value of u, so that one of the atoms get excited, will be

(a) 3.12×10^6 m/s (b) 9.36×10^5 m/s (c) 6.24×10^4 m/s (d) 5×10^3 m/s

145. The angular momentum of electron in hydrogen atom is proportional to

(a) $\sqrt{r}$ (b) $1/r$ (c) r^2 (d) $1/\sqrt{r}$

146. The frequency of revolution of electron in nth orbit is f_n. If the electron makes a transition from nth orbit to $(n-1)$th orbit, then the relation between the frequency (¬) of emitted photon and f_n will be

(a) $¬ = f_n^2$ (b) $¬ = \sqrt{f_n}$ (c) $¬ = \frac{1}{f_n}$ (d) $¬ = f_n$

147. Two photons from excited atomic hydrogen are detected. Their energies are 10.2 eV and 1.9 eV. These photons must come from

(a) A single atom (b) Two different atoms

(c) Either a single atom or two atoms (d) None of these

148. Goudsmit and Uhelenbeck postulated the concept of electron spin in order to explain

(a) Hydrogen spectra (b) Fine structure of hydrogen spectra

(c) Doublet structure of Alkali metal spectra (d) Elliptical orbit motion of electrons in atom

149. The angular momenta of electrons in an atom produces

(a) Magnetic moment (b) Zeeman effect (c) Light (d) Nuclear fission

150. For an atom situated in a magnetic field, the number of possible orientations for orbit with $n = 3$ are

(a) 9 (b) 7 (c) 5 (d) 3

151. In Bohr model of hydrogen atom, the force on the electron depends on the principal quantum number as

(a) $F \propto 1/n^3$ (b) $F \propto 1/n^4$ (c) $F \propto 1/n^5$ (d) Does not depend on n

152. A proton and an electron, both at rest initially, combine to form a hydrogen atom in the ground state. A single photon is emitted in this process. Then the wavelength of this photon is

(a) 912 $Å$ (b) 3646 $Å$ (c) 8201 $Å$ (d) None of these

153. When a hydrogen atom emits a photon in going from $n = 5$ to $n = 1$, its recoil speed is almost

(a) $10^{-4}\ m/s$ (b) $2\times10^{-2}\ m/s$ (c) $4\ m/s$ (d) $8\times10^{2}\ m/s$

154. The ratio between total acceleration of the electron in singly ionized helium atom and doubly ionized lithium atom (both in ground state) is

(a) $\frac{2}{3}$ (b) $\frac{4}{9}$ (c) $\frac{8}{27}$ (d) 1

155. Suppose the potential energy between electron and proton at a distance r is given by $-\frac{ke^2}{3r^3}$. Application of Bohr's theory to hydrogen atom in this case shows that

(A) Energy in the nth orbit is proportional to n^6 (B) Energy is proportional to m^{-3} (m = mass of electron)

(a) Only (A) is correct (b) Only (B) is correct

(c) Both (A) and (B) are correct (d) None are correct

156. An electron with kinetic energy 5 eV is incident on a hydrogen atom in its ground state. The collision

(a) Must be elastic (b) May be partially elastic

(c) Must be completely inelastic (d) May be completely inelastic

157. Suppose, the electron in a hydrogen atom makes transition from $n = 3$ to $n = 2$ in $10^{-8}\ s$. The order of the torque acting on the electron in this period, using the relation between torque and angular momentum as discussed in the chapter on rotational mechanics is

(a) 10^{-34} N-m (b) 10^{-24} N-m (c) 10^{-42} N-m (d) 10^{-8} N-m

158. The distance of the closest approach of an alpha particle fired at a nucleus with momentum p is r_0. The distance of the closest approach when the alpha particle is fired at the same nucleus with momentum $2p$ will be

(a) $2r_0$ (b) $4r_0$ (c) $\frac{r_0}{2}$ (d) $\frac{r_0}{4}$

159. Radiations of wavelengths ª are incident on atoms of hydrogen in ground state. These atoms absorb fraction of these radiation. The excited atoms have ten different wavelengths in the emission spectrum. Then value of ª is

(a) 570 $\mathring{A}$ (b) 750 $\mathring{A}$ (c) 590 $\mathring{A}$ (d) 950 $\mathring{A}$

160. Potential energy between a proton and an electron is given by $U = \frac{Ke^2}{3R^3}$, then radius of Bohr's orbit can be given by

(a) $\frac{Ke^2m}{h^2}$ (b) $\frac{6®^3}{n^3}\frac{Ke^2m}{h^2}$ (c) $\frac{2®}{n}\frac{Ke^2m}{h^2}$ (d) $\frac{4®^2Ke^2m}{n^2h^2}$

161. The minimum kinetic energy of an electron, hydrogen ion, helium ion required for ionization of a hydrogen atom is E_1 in case electron is collided with hydrogen atom. It is E_2 if hydrogen ion is collided and E_3 when helium ion is collided. Then

(a) $E_1 = E_2 = E_3$ (b) $E_1 > E_2 > E_3$ (c) $E_1 < E_2 < E_3$ (d) $E_1 > E_3 > E_2$

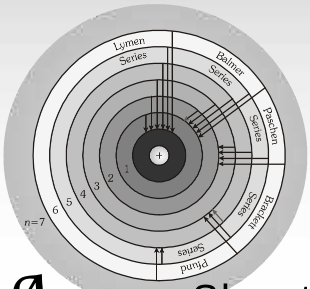
162. The wave number of first line of Balmer series in hydrogen atom is $1.52 \times 10^6\ m^{-1}$. The wave number of first line of Lyman series in Be^{3+} will be

(a) $2.43 \times 10^8\ m^{-1}$ (b) $1.31 \times 10^8\ m^{-1}$ (c) $5.44 \times 10^8\ m^{-1}$ (d) $6.83 \times 10^8\ m^{-1}$

163. A photon of energy 10.2 eV corresponds to light of wavelength ª$_0$. Due to an electron transition from n = 2 to n = 1 in a hydrogen atom, light of wavelength ª is emitted. If we take into account the recoil of the atom when the photon is emitted

(a) ª = ª$_0$ (b) ª < ª$_0$

(c) ª > ª$_0$ (d) The data is not sufficient to reach a conclusion



Answer Sheet

Assignments

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
a	d	a	b	a	d	b	c	b	a	b	a	c	c	a	a	d	c	a	d
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
b	c	d	c	b	b	a	c	d	d	d	b	a	d	b	a	d	a	c	b
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
a	c	b	c	b	a	c	c	d	b	d	d	d	b	d	a	b	b	d	c
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
a, d	c	a	d	c	d	c	d	a	d	b	b	c	d	a	a	c	b	a	b
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
c	a	a	c	a	c	c	b	c	d	a	a	d	a	b	b	a	d	c	d
101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120
b	b	b	b	b	d	a	c	d	a	a	c	c	c	b	a	d	d	c	b
121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140
c	a	b	c	c	d	b	b	b	c	d	c	d	d	b	d	c	c	d	c
141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160
b	c	a	c	a	d	c	c	b	a	b	a	c	c	c	a	b	d	d	d
161	162	163																	
c	b	c																	