ATOMIC STRUCTURE & NUCLEAR CHEMISTRY

CONTENTS

JEE(Advanced) SYLLABUS

Bohr model, spectrum of hydrogen atom, quantum numbers; Wave-particle duality, de Broglie hypothesis; Uncertainty principle; Qualitative quantum mechanical picture of hydrogen atom, shapes of s, p and d orbitals; Electronic configurations of elements (up to atomic number 36); Aufbau principle; Pauli's exclusion principle and Hund's rule.

JEE(Main) SYLLABUS

Thomson and Rutherford atomic models and their limitations; Nature of electromagnetic radiation, photoelectric effect; Spectrum of hydrogen atom, Bohr model of hydrogen atom. Its postulates, derivation of the relations for energy of the electron and radii of the different orbits, limitations of Bohr's model; Dual nature of matter, de-Broglie's relationship, Heisenberg uncertainty principle. Elementary ideas of quantum mechanics, quantum mechanical model of atom, its important features. Concept of atomic orbitals as one electron wave functions; Variation of ψ and ψ^2 with r for 1s and 2s orbital's; various quantum numbers (principal, angular momentum and magnetic quantum numbers) and their significance; shapes of s, p and d-orbitals, electron spin and spin quantum number; Rules for filling electrons in orbitals - aufbau principle, Pauli's exclusion principle and Hund's rule, electronic configuration of elements, extra stability of half-filled and completely filled orbitals.

ATOMIC STRUCTURE & NUCLEAR CHEMISTRY

Section (A) : Discovery of sub atomic particles, Atomic models, nucleus

Introduction:

Structure of Atom

Rutherford's Model | Bohr's Model | Wave mechanical model

Dalton’s concept of the indivisibility of the atom was completely discredited by a series of experimental evidences obtained by scientists. A number of new phenomena were brought to light and man’s idea about the natural world underwent a revolutionary change. The discovery of electricity and spectral phenomena opened the door for radical changes in approaches to experimentation. It was concluded that atoms are made of three particles: electrons, protons and neutrons. These particles are called the fundamental particles of matter.

Earlier efforts to reveal structure of atom:

CATHODE RAYS - DISCOVERY OF ELECTRON

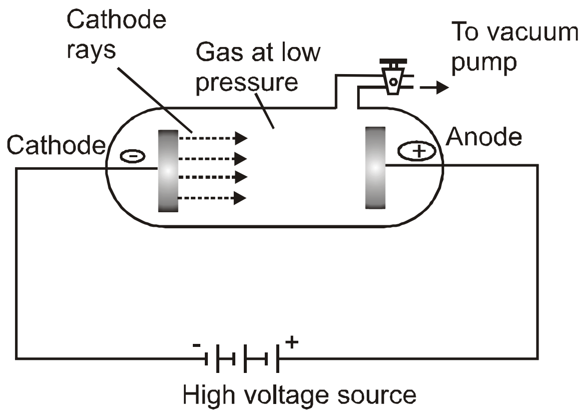


Figure-1

In 1859 **Julius Plucker** started the study of conduction of electricity through gases at low pressure (10^{-4} atm) in a discharge tube. When a high voltage of the order of 10,000 volts or more was impressed across the electrodes, some sort of invisible rays moved from the negative electrode to the positive electrode, these rays are called as cathode rays.

PROPERTIES OF CATHODE RAYS:

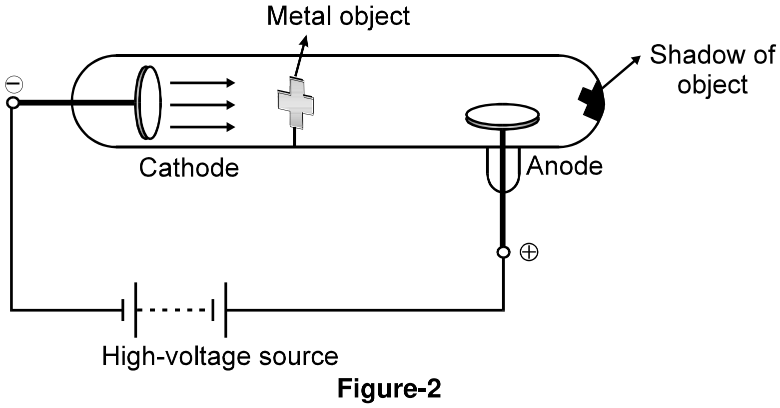


Figure-2

Cathode rays have the following properties.

(i) Cathode rays travel at a very high velocity on a straight path as it produces shadow of an object placed in its path.

(ii) Cathode rays produce mechanical effects. If small light paddle wheel is placed between the electrodes, it rotates. This indicates that the cathode rays consist of material particles.

(iii) When electric and magnetic fields are applied to the cathode rays in the discharge tube. The rays are deflected thus establishing that they consist of charged particles. The direction of deflection showed that cathode rays consist of negatively charged particles called **electrons**.

(iv) They produce a green glow when strike the glass wall beyond the anode. Bright spot is developed when they strike the zinc sulphide screen.

(v) Cathode rays penetrate through thin sheets of aluminum and metals.

(vi) They affect the photographic plates

(vii) The ratio of charge(e) to mass(m) i.e. charge/mass is same for all cathode rays irrespective of the gas used in the tube. e/m = 1.76×10^{11} Ckg^{-1}

Thus, it can be concluded that electrons are basic constituent of all the atoms.

(viii) Cathode rays are invisible.

PRODUCTION OF ANODE RAYS (DISCOVERY OF PROTON):

Goldstein (1886) repeated the experiment with a discharge tube filled with a perforated cathode and found that new type of rays came out through the hole in the cathode.

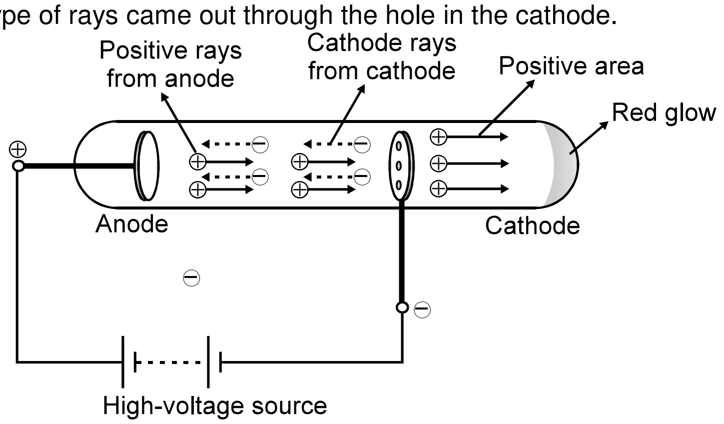


Figure-3

When this experiment is conducted, a faint red glow is observed on the wall behind the cathode. Since these rays originate from the anode, they are called anode rays (canal rays).

PROPERTIES OF ANODE RAYS :

- ***Anode rays travel along straight paths*** and hence they cast shadows of object placed in their path.
- ***They rotate a light paddle wheel placed in their path.*** This shows that anode rays are made up of material particles.
- They are deflected towards the negative plate of an electric field. This shows that these rays are positively charged.
- For different gases used in the discharge tube, the charge to mass ratio (e/m) of the positive particles constituting the positive rays is different. When hydrogen gas is taken in the discharge tube, the e/m value obtained for the positive rays is found to be maximum. Since the value of charge (e) on the positive particle obtained from different gases is the same, the value of m must be minimum for the positive particles obtained from hydrogen gas. Thus, the positive particle obtained from hydrogen gas is the lightest among all the positive particles obtained from different gases. This particle is called the proton.

DISCOVERY OF NEUTRON :

Later, a need was felt for the presence of electrically neutral particles as one of the constituent of atom. These particles were discovered by Chadwick in 1932 by bombarding a thin sheet of Beryllium with α-particles, when electrically neutral particles having a mass slightly greater than that of the protons were emitted. He named these particles as neutrons.

$$^{9}_{4}Be + ^{4}_{2}He \longrightarrow ^{12}_{6}C + ^{1}_{0}n$$

The NUCLEUS :

Electrons, protons & neutrons are the fundamental particles present in all atoms,(except hydrogen)

Table : 1

Particles	Symbol	Mass	Charge	Discoverer
Electron	$_{-1}e^0$ or β	9.10939×10^{-31} kg 0.00054 u	-1.6022×10^{-19} Coulombs -4.803×10^{-10} esu	J.J. Thomson Stoney Lorentz 1887
Proton	$_1H^1$	1.6722×10^{-27} kg 1.00727 u	$+1.6022 \times 10^{-19}$ Coulombs $+4.803 \times 10^{-10}$ esu	Goldstein Rutherford1907
Neutron	$_0n^1$	1.67493×10^{-27} kg 1.00867 u 1 amu $\approx 1.66 \times 10^{-27}$ kg	Neutral 0	James Chadwick 1932

ATOMIC MODELS :

(A) Thomson's Model of the atom :

An atom is electrically neutral. It contains positive charges (due to the presence of protons) as well as negative charges (due to the presence of electrons). It assumes that mass is equally distributed in the atom. Hence, J.J. Thomson assumed that an atom is a uniform sphere of positive charges with electrons embedded in it.

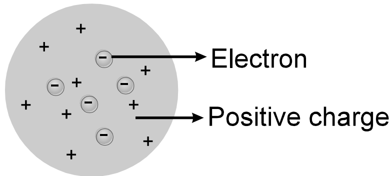


Figure-4

(B) Rutherford's Experiment :

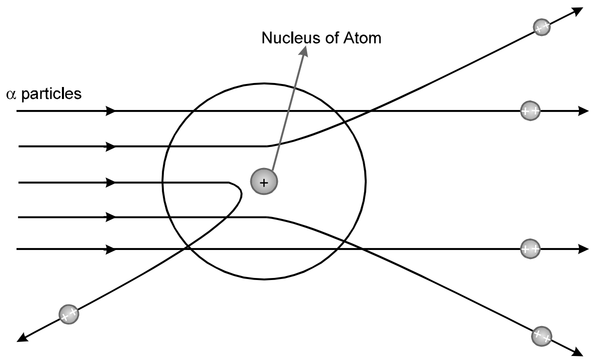


Figure-5

Observation :

1. Most of the α-particles passed straight through the gold foil undeflected.
2. A few of them were deflected through small angles, while a very few were deflected to a large extent.
3. A very small percentage (1 in 20000) was deflected through angles ranging from nearly 180°.

Rutherford's nuclear concept of the atom.

(i) The atom of an element consists of a small positively charged 'nucleus' which is situated at the centre of the atom and which carries almost the entire mass of the atom.

(ii) The electrons are distributed in the empty space of the atom around the nucleus in different concentric circular paths, called orbits.

(iii) The number of electrons in orbits is equal to the number of positive charges (protons) in the nucleus. Hence, the atom is electrically neutral.

(iv) The volume of the nucleus is negligibly small as compared to the volume of the atom.

(v) Most of the space in the atom is empty.

DRAWBACKS OF RUTHERFORD'S MODEL :

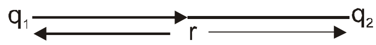
1. This was not according to the classical theory of electromagnetism proposed by Maxwell. According to this theory, every accelerated charged particle must emit radiations in the form of electromagnetic waves and loses it total energy.
   Since energy of electrons keep on decreasing, so radius of the circular orbits should also decrease and ultimately the electron should fall in nucleus.
2. It could not explain the line spectrum of H-atom.
3. It says nothing about the electronic structure of atom i.e. how the e^- are distributed around the nucleus and what are the energies of these e^-.

PROPERTIES OF CHARGE :

F1 1. Q = ne (charge is quantized)

2. Charge are of two types :
   (i) Positive charge (ii) Negative Charge
   $e = -1.6 \times 10^{-19}$
   $p = +1.6 \times 10^{-19}C$

This does not mean that a proton has a greater charge but it implies that the charge is equal and opposite.
Same charge repel each other and opposite charges attract each other.
3. Charge is a SCALAR Qty. and the force between the charges always acts along the line joining the charges.



The magnitude of the force between the two charge placed at a distance 'r' is given by

$$F_E = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r^2}$$

(electrical force)

4. If two charge q_1 and q_2 are separated by distance r then the potential energy of the two charge system is given by.

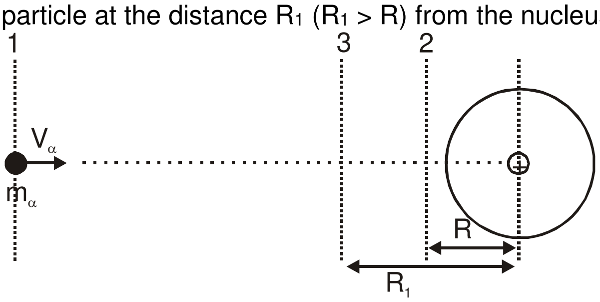
F2 $$P.E. = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$$

5. If a charged particle q is placed on a surface of potential V then the potential energy of the charge is q × V.

Estimation of closest distance of approach (derivation)

Der.1 An α-particle is projected from infinity with the velocity V_0 towards the nucleus of an atom having atomic number equal to Z then find out (i) closest distance of approach (R) (ii) what is the velocity of the α-particle at the distance R_1 ($R_1 > R$) from the nucleus.

Sol.



From energy conservation $P.E_1 + KE_1 = P.E_2 + KE_2$

$$\Rightarrow \quad 0 + \frac{1}{2}m_\alpha V_\alpha^2 = \frac{K(Ze)(2e)}{R} + 0$$

$$R = \frac{4KZe^2}{m_\alpha V_\alpha^2} \quad \text{(closest distance of approach)}$$

Let velocity at R_1 is V_1.
From energy conservation $P.E_1 + KE_1 = P.E_3 + KE_3$

$$\Rightarrow \quad 0 + \frac{1}{2}m_\alpha V_\alpha^2 = \frac{K(Ze)(2e)}{R_1} + \frac{1}{2}m_\alpha V_1^2$$

Size of the nucleus:

The volume of the nucleus is very small and is only a minute fraction of the total volume of the atom. Nucleus has a diameter of the order of 10^{-12} to 10^{-13} cm and the atom has a diameter of the order of 10^{-8} cm.

Thus, diameter (size) of the atom is 100,000 times the diameter of the nucleus.

The radius of a nucleus is proportional to the cube root of the number of nucleons within it.

F3 $R = R_0\,(A)^{1/3}$ cm

where R_0 can be 1.1×10^{-13} to 1.44×10^{-13} cm ; A = mass number ; R = Radius of the nucleus.

Nucleus contains protons & neutrons except hydrogen atoms which does not contain neutron in the nucleus.

ATOMIC NUMBER (Z) AND MASS NUMBER (A) :

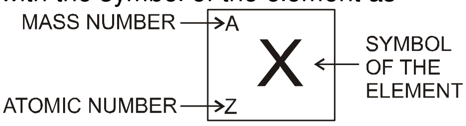
D1 ❍ **Atomic number (Z) of an element**

= Total number of protons present in the nucleus
= Total number of electrons present in the atom

- Atomic number is also known as proton number.
- Since the electrons have negligible mass, the entire mass of the atom is mainly due to protons and neutrons only. Since these particles are present in the nucleus, therefore they are collectively called **nucleons**.
- As each of these particles has one unit mass on the atomic mass scale, therefore the sum of the number of protons and neutrons will be nearly equal to the mass of the atom.

F4 ❍ **Mass number of an element = No. of protons (Z) + No. of neutrons (n).**

- The mass number of an element is nearly equal to the atomic mass of that element. However, the main difference between the two is that mass number is always a whole number whereas atomic mass is usually not a whole number.
- The atomic number (Z) and mass number (A) of an element 'X' are usually represented along with the symbol of the element as



e.g. ${}^{23}_{11}Na$, ${}^{35}_{17}Cl$ and so on.

D2 1. **Isotopes:** Such atoms of the same element having same atomic number but different mass numbers are called isotopes.

${}^{1}_{1}H$, ${}^{2}_{1}D$ and ${}^{3}_{1}T$ named as protium, deuterium (D) and tritium (T) respectively. Ordinary hydrogen is protium.

D3 2. **Isobars :** Such atoms of different elements which have same mass numbers (and of course different atomic numbers) are called isobars. e.g. ${}^{40}_{18}Ar$, ${}^{40}_{19}K$, ${}^{40}_{20}Ca$.

D4 3. **Isotones :** Such atoms of different elements which contain the same number of neutrons are called isotones. e.g. ${}^{14}_{6}C$, ${}^{15}_{7}N$, ${}^{16}_{8}O$.

D5 4. **Isoelectronic :** The species (atoms or ions) containing the same number of electrons are called isoelectronic. e.g., O^{2-}, F^{-}, Na^{+}, Mg^{2+}, Al^{3+}, Ne all contain 10 electrons each and hence they are isoelectronic.

Solved Examples

Example-1. Complete the following table :

Particle	Mass No.	Atomic No.	Protons	Neutrons	Electrons
Nitrogen atom	–	–	–	7	7
Calcium ion	–	20	–	20	–
Oxygen atom	16	8	–	–	–
Bromide ion	–	–	–	45	36

Solution. **For nitrogen atom.**

No. of electron = 7 (given)
No. of neutrons = 7 (given)
$\therefore$ No. of protons = Z = 7 ($\therefore$ atom is electrically neutral)
Atomic number = Z = 7
Mass No. (A) = No. of protons + No. of neutrons = 7 + 7 = 14

For calcium ion.

No. of neutrons = 20 (Given)
Atomic No. (Z) = 20 (Given)
$\therefore$ No. of protons = Z = 20 ;
No. of electrons in calcium atom = Z = 20
But in the formation of calcium ion, two electrons are lost from the extra nuclear part according to the equation $Ca \rightarrow Ca^{2+} + 2e^-$ but the composition of the nucleus remains unchanged.
$\therefore$ No. of electrons in calcium ion = 20 – 2 = 18
Mass number (A) = No. of protons + No. of neutrons = 20 + 20 = 40.

For oxygen atom.

Mass number (A) = No. of protons + No. of neutrons = 16 (Given
Atomic No. (Z) = 8 (Given)
No. of protons = Z = 8,
No. of electrons = Z = 8
No. of neutrons = A – Z = 16 – 8 = 8

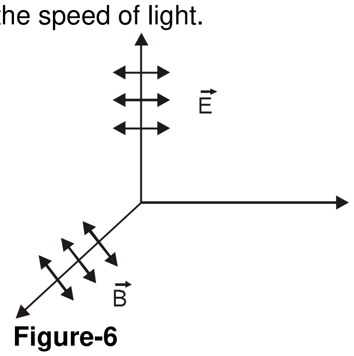
For bromide ion.

No. of neutrons = 45 (given)
No. of electrons = 36 (given)
But in the formation of bromide ion, one electron is gained by extra nuclear part according to equation
$Br + e^- \rightarrow Br^-$, But the composition of nucleus remains unchanged.
$\therefore$ No. of protons in bromide ion = No. of electrons in bromine atom = 36 – 1 = 35
Atomic number (Z) = No. of protons = 35
Mass number (A) = No. of neutrons + No. of protons = 45 + 35 = 80.

Section (B) : Quantum theory of light & Photoelectric Effect

Electromagnetic wave radiation :

D6 The oscillating electrical/magnetic field are electromagnetic radiations.
Experimentally, the direction of oscillations of electrical and magnetic field are perpendicular to each other.
These rays don't require medium for their propagation.
In vacuum all types of EM radiations, regardless of λ, travel at the same speed i.e., 2.997925×10^8 m/s called the speed of light.



$\vec{E}$ = Electric field, $\vec{B}$ = Magnetic field

Figure-6

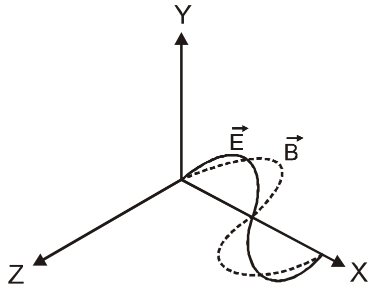


Figure-7

Some important characteristics of a wave :

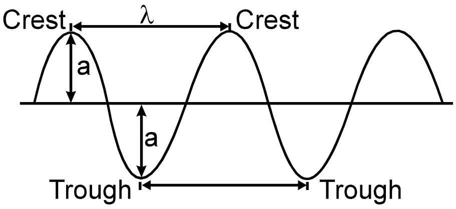


Figure-8

D7 **Wavelength** of a wave is defined as the distance between any two consecutive crests or troughs. It is represented by λ (lambda) and is expressed in Å or m or cm or nm (nanometer) or pm (picometer).

$1\ Å = 10^{-8}\ cm = 10^{-10}\ m$

$1\ nm = 10^{-9}\ m,\ 1\ pm = 10^{-12}\ m$

D8 **Frequency** of a wave is defined as the number of waves passing through a point in one second. It is represented by ν (nu) and is expressed in Hertz (Hz) or cycles/sec or simply sec^{-1} or s^{-1}.

1 Hz = 1 cycle/sec

D9 **Velocity** of a wave is defined as the linear distance travelled by the wave in one second. It is represented by v and is expressed in cm/sec or m/sec (ms^{-1}).

D10 **Amplitude** of a wave is the height of the crest or the depth of the trough. It is represented by 'a' and is expressed in the units of length.

D11 **Wave number** is defined as the number of waves present in 1 cm length. Evidently, it will be equal to the reciprocal of the wavelength. It is represented by $\bar{\nu}$ (read as nu bar).

F5 $\bar{\nu} = \dfrac{1}{\lambda}$

If λ is expressed in cm, $\bar{\nu}$ will have the units cm^{-1}.

Relationship between velocity, wavelength and frequency of a wave. As frequency is the number of waves passing through a point per second and λ is the length of each wave, hence their product will give the velocity of the wave.

F6 $v = \nu \times \lambda$

Order of wavelength in Electromagnetic spectrum

Cosmic rays < γ – rays < X-rays < Ultraviolet rays < Visible < Infrared < Micro waves < Radio waves.

Particle Nature of Electromagnetic Radiation: Planck's Quantum Theory

Some of the experimental phenomenon such as diffraction and interference can be explained by the wave nature of the electromagnetic radiation. However, following are some of the observations which could not be explained

(i) The nature of emission of radiation from hot bodies (black - body radiation)

(ii) Ejection of electrons from metal surface when radiation strikes it (photoelectric effect)

(iii) Variation of heat capacity of solids with respect to temperature.

(iv) Line spectrum of Hydrogen.

Black Body Radiation:

When solids are heated they emit radiation over a wide range of wavelengths.

The ideal body, which emits and absorbs all frequencies, is called a black body and the radiation emitted by such a body is called black body radiation. The exact frequency distribution of the emitted radiation (i.e., intensity versus frequency curve of the radiation) from a black body depends only on its temperature.

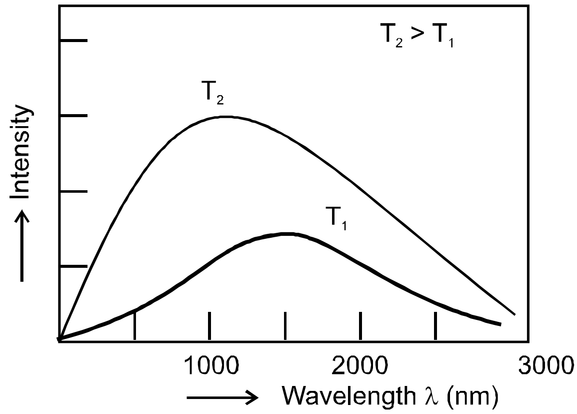


Figure-9

In the graph, there's a peak intensity but as per the Rayleigh-Jeans law (A mathematical formula for waves), there must be an infinite peak. So, the wave theory failed to explain this experimental graph.

Later, Plank's equation, which considered that atoms and molecules could emit (or absorb) energy only in discrete quantities (called quantum) and not in continuous manner, tallied with the graph proving even the particle nature of light.

QUANTUM THEORY OF LIGHT:

D12 The smallest quantity of energy that can be emitted or absorbed in the form of electromagnetic radiation is called as quantum of light.

According to Planck, the light energy coming out from any source is always an integral multiple of a smallest energy value called quantum of light.

Let quantum of light be = E_0(J), then total energy coming out is = nE_0 (n = Integer)

Quantum of light = Photon (Packet or bundle of energy)

Energy of one photon is given by

F7 $E_0 = h\nu$ (ν - Frequency of light)

$h = 6.626 \times 10^{-34}$ J-Sec (h - Planck const.)

F8 $E_0 = \dfrac{hc}{\lambda}$ (c - speed of light)

(λ - wavelength)

Order of magnitude of $E_0 = \dfrac{10^{-34} \times 10^{8}}{10^{-10}} = 10^{-16}$ J

Solved Examples

Example-2. Certain sun glasses having small of AgCl incorporated in the lenses, on exposure to light of appropriate wavelength turns to gray colour to reduce the glare following the reactions:

$$AgCl \xrightarrow{h\nu} Ag(Gray) + Cl$$

If the heat of reaction for the decomposition of AgCl is 248 kJ mol^{-1}, what maximum wavelength is needed to induce the desired process?

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

If photon is used for this purpose, then according to Einstein law one molecule absorbs one photon. Therefore, $\therefore$ $N_A \cdot \dfrac{hc}{\lambda} = 248 \times 10^3$

$$\lambda = \frac{6.626 \times 10^{-34} \times 3.0 \times 10^{8} \times 6.023 \times 10^{23}}{248 \times 10^{3}} = 4.83 \times 10^{-7} \text{ m}$$

D13 **One electron volt (e.v.) :** Energy gained by an electron when it is accelerated from rest through a potential difference of 1 volt.

Note: Positive charge always moves from high potential to low potential and –ve charge always. Moves from low potential to high potential if set free.

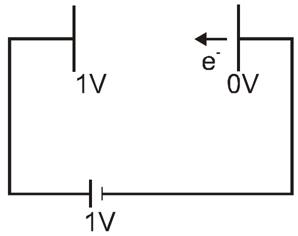


Figure-10

Der.2 From Energy conservation principle, $P.E._i + K.E._i = P.E._f + K.E._f$

$(-e)\,0 + 0 = (-e)\,(1V) + \frac{1}{2}mV_f^2$; $K.E. = \frac{1}{2}mV_f^2 = e\,(1 \text{ volt})$

If a charge 'q' is accelerated through a potential difference of 'V' volt then its kinetic energy will be increased by q.V.

$1eV = 1.6 \times 10^{-19}$ C x 1 volt $\therefore$ $1eV = 1.6 \times 10^{-19}$J

Photoelectric Effect :

D14 When certain metals (for example Potassium, Rubidium, Caesium etc.) were exposed to a beam of light electrons were ejected as shown in Fig.

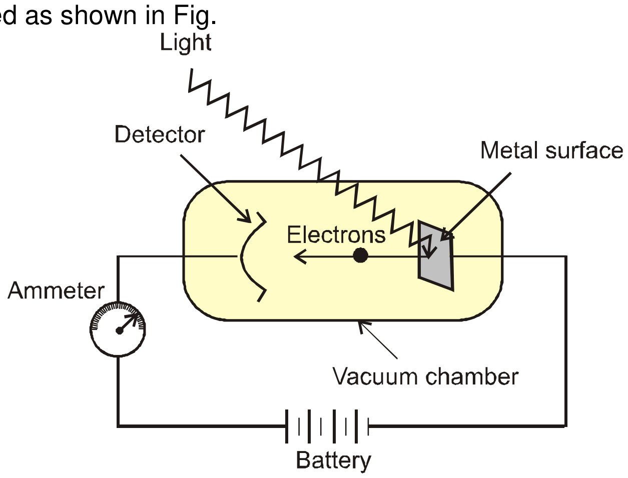


Figure-11

The phenomenon is called **Photoelectric effect**. The results observed in this experiment were :

(i) The electrons are ejected from the metal surface as soon as the beam of light strikes the surface, i.e., there is no time lag between the striking of light beam and the ejection of electrons from the metal surface.

(ii) The number of electrons ejected is proportional to the intensity or brightness of light.

(iii) For each metal, there is a characteristic minimum frequency, ν_0 (also known as **threshold frequency**) below which photoelectric effect is not observed. At a frequency $\nu > \nu_0$, the ejected electrons come out with certain kinetic energy. The kinetic energies of these electrons increase with the increase of frequency of the light used.

When a photon of sufficient energy strikes an electron in the atom of the metal, it transfers its energy instantaneously to the electron during the collision and the electron is ejected without any time lag or delay. Greater the energy possessed by the photon, greater will be transfer of energy to the electron and greater the kinetic energy of the ejected electron. In other words, kinetic energy of the ejected electron is proportional to the frequency of the electromagnetic radiation. Since the striking photon has energy equal to $h\nu$ and the minimum energy required to eject the electron is $h\nu_0$ (is also called work function, W_0) then the difference in energy $(h\nu - h\nu_0)$ is transferred as the kinetic energy of the photoelectron. Following the conservation of energy principle, the kinetic energy of the ejected electron is given by the equation

F9 $h\nu = h\nu_0 + \frac{1}{2}m_e v^2$

where m_e is the mass of the electron and v is the velocity associated with the ejected electron.

(iv) A more intense beam of light (consists of larger number of photons), ejected more e^- so it proved particle nature of light.

Solved Examples

Example-3. The threshold frequency ν_0 for a metal is 6×10^{14} s^{-1}. Calculate the kinetic energy of an electron emitted when radiation of frequency $\nu = 1.1 \times 10^{15}$ s^{-1} hits the metal.

Solution. K.E. = $\frac{1}{2}m_e V^2 = h(\nu - \nu_0)$

$\therefore$ K.E. = $(6.626 \times 10^{-34})(1.1 \times 10^{15} - 6 \times 10^{14})$

$\therefore$ K.E. = $(6.626 \times 10^{-34})(5 \times 10^{14}) = 3.313 \times 10^{-19}$ J

Section (C) : Bohr Model

BOHR'S ATOMIC MODEL : It is based on quantum theory of light.

Assumptions of Bohr's model :

- There are certain orbits around the nucleus such that if electron will be revolving in these orbit, then it does not emit any electromagnetic radiation. These are called stationary orbit for the e^-. The necessary centripetal force is produced by attraction forces of nucleus.

F10 $\frac{mv^2}{r} = \frac{Ke^2Z}{r^2}$

- Angular momentum of the electron in these stationary orbit is always an integral multiple of $\frac{h}{2\pi}$.

F11 $mvr = \frac{nh}{2\pi}$

- Electron can make jump from one stationary orbit to another stationary orbit by absorbing or emitting a photon of energy equal to difference in the energies of the stationary orbit i.e. energy change does not take place in continuous manner.

F12 $\frac{hc}{\lambda} = \Delta E$ ΔE – difference in the energy of orbit

F13 $\upsilon = \frac{\Delta E}{h}$ This is Bohr's frequency rule.

Mathematical forms of Bohr's Postulates :

Der.3 **Calculation of the radius of the Bohr's orbit :** Suppose that an electron having mass 'm' and charge 'e' revolving around the nucleus of charge 'Ze' (Z is atomic number & e = charge) with a tangential/linear velocity of 'v'. Further consider that 'r' is the radius of the orbit in which electron is revolving.

According to Coulomb's law, the electrostatic force of attraction (F) between the moving electron and nucleus is :

$F = \frac{KZe^2}{r^2}$ where : K = constant = $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ Nm^2/C^2

and the centrifugal force $F = \frac{mv^2}{r}$

For the stable orbit of an electron both the forces are balanced.

i.e $\dfrac{mv^2}{r} = \dfrac{KZe^2}{r^2}$

then $v^2 = \dfrac{KZe^2}{mr}$ .... (i)

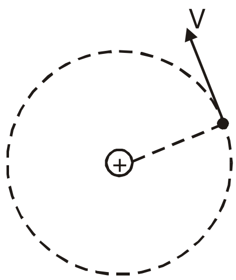


Figure-12

From the postulate of Bohr,

$mvr = \dfrac{nh}{2\pi}$ $\Rightarrow$ $v = \dfrac{nh}{2\pi mr}$

On squaring $v^2 = \dfrac{n^2h^2}{4\pi^2m^2r^2}$ .... (ii)

From equation (i) and (ii)

$$\frac{KZe^2}{mr} = \frac{n^2h^2}{4\pi^2m^2r^2}$$

On solving, we will get

F14 $r = \dfrac{n^2h^2}{4\pi^2mKZe^2}$

On putting the value of e, h, m the radius of n^{th} Bohr orbit is given by :

F15 $r_n = 0.529 \times \dfrac{n^2}{Z}$ Å

Solved Examples

Example-4. Calculate radius ratio for 2^{nd} orbit of He^+ ion & 3^{rd} orbit of Be^{3+} ion.

Solution. r_1 (radius of 2^{nd} orbit of He^+ ion) $= 0.529\left(\dfrac{2^2}{2}\right)$ Å

r_2 (radius of 3^{rd} orbit of Be^{3+} ion) $= 0.529\left(\dfrac{3^2}{4}\right)$ Å

Therefore $\dfrac{r_1}{r_2} = \dfrac{0.529 \times 2^2/2}{0.529 \times 3^2/4} = \dfrac{8}{9}$

Der.4 Calculation of velocity of an electron in Bohr's orbit :

Angular momentum of the revolving electron in n^{th} orbit is given by

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

$v = \dfrac{nh}{2\pi mr}$ .... (iii)

put the value of 'r' in the equation (iii)

then, $v = \dfrac{nh \times 4\pi^2mZe^2K}{2\pi mn^2h^2}$

F16 $v = \dfrac{2\pi Ze^2K}{nh}$

on putting the values of π, e^-, h and K

F17 velocity of electron in n^{th} orbit $v_n = 2.18 \times 10^6 \times \dfrac{Z}{n}$ m/sec; $v \propto Z$; $v \propto \dfrac{1}{n}$

F18 T, Time period of revolution of an electron in its orbit $= \dfrac{2\pi r}{v}$

F19 f, Frequency of revolution of an electron in its orbit = $\frac{v}{2\pi r}$

Der.5 Calculation of energy of an electron :

The total energy of an electron revolving in a particular orbit is

T.E. = K.E. + P.E.

where : P.E. = Potential energy , K.E. = Kinetic energy , T.E. = Total energy

The K.E. of an electron = $\frac{1}{2}mv^2$

and the P.E. of an electron $= -\frac{KZe^2}{r}$

Hence, T.E. $= \frac{1}{2}mv^2 - \frac{KZe^2}{r}$

We know that, $\frac{mv^2}{r} = \frac{KZe^2}{r^2}$ or $mv^2 = \frac{KZe^2}{r}$

Substituting the value of mv^2 in the above equation:

$$T.E. = \frac{KZe^2}{2r} - \frac{KZe^2}{r} = -\frac{KZe^2}{2r}$$

So, T.E. $= -\frac{KZe^2}{2r}$

Substituting the value of 'r' in the equation of T.E.

Then $$T.E. = -\frac{KZe^2}{2} \times \frac{4\pi^2 Ze^2 m}{n^2h^2} = -\frac{2\pi^2 Z^2 e^4 m\ K^2}{n^2h^2}$$

Thus, the total energy of an electron in n^{th} orbit is given by

F20 $$T.E. = E_n = -\frac{2\pi^2 me^4 k^2}{h^2}\left(\frac{z^2}{n^2}\right) \quad \text{... (iv)}$$

Putting the value of m, e, h and π we get the expression of total energy

F21 $E_n = -13.6\frac{Z^2}{n^2}$ eV / atom $\qquad n\uparrow$ T.E. $\uparrow$; $Z\uparrow$ T.E.$\downarrow$

F22 $E_n = -2.18 \times 10^{-18}\frac{Z^2}{n^2}$ J/atom

F23 T.E. $= \frac{1}{2}$ P.E.

F24 T.E. = – K.E.

Note: The P.E. at the infinite = 0; The K.E. at the infinite = 0

Conclusion from equation of energy :

(a) The negative sign of energy indicates that there is attraction between the negatively charged electron and positively charged nucleus.

(b) All the quantities on R.H.S. in the energy equation are constant for an element having atomic number Z except 'n' which is an integer such as 1, 2, 3, etc. i.e. the energy of an electron is constant as long as the value of 'n' is kept constant.

(c) The energy of an electron is inversely proportional to the square of 'n' with negative sign.

(d) Negative charge of the energy of e^- in the atom indicates that the energy of e^- in the atom is at lower energy than the energy of a free e^- at rest (which is taken to be zero).

Solved Examples

Example-5 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 ?

Solution. 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

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

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

Failures / limitations of Bohr's theory:

(a) He could not explain the line spectra of atoms containing more than one electron.

(b) He also could not explain the presence of doublet i.e. 2 closely spaced lines.

(c) He was unable to explain the splitting of spectral lines in magnetic field (Zeeman effect) and in electric field (Stark effect)

(d) No conclusion was given for the principle of quantisation of angular momentum.

(e) He was unable to explain the de-Broglie's concept of dual nature of matter.

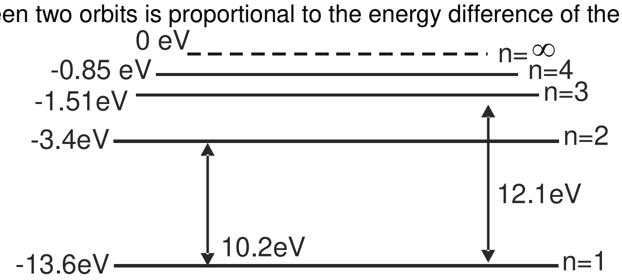
(f) He could not explain Heisenberg's uncertainty principle.

(g) Could't explain the ability of atoms to form molecules by chemical bonds.

Energy Level Diagram :

(i) Orbit of lowest energy is placed at the bottom, and all other orbits are placed above this.

(ii) The gap between two orbits is proportional to the energy difference of the orbits.



Energy level diagram of H-atom

Figure-13

DEFINITION VALID FOR SINGLE ELECTRON SYSTEM :

D15 (i) Ground state :

Lowest energy state of any atom or ion is called ground state of the atom. For it n = 1.

Ground state energy of H–atom = – 13.6 eV

Ground state energy of He^+ Ion = – 54.4 eV

D16 (ii) Excited State :

States of atom other than the ground state are called excited states :

n = 2	first excited state
n = 3	second excited state
n = 4	third excited state
n = n + 1	n^{th} excited state

D17 (iii) Ionisation energy (IE) :

Minimum energy required to move an electron from ground state to n = ∞ is called ionisation energy of the atom or ion.

Ionisation energy of H–atom = 13.6 eV

Ionisation energy of He^+ ion = 54.4 eV
Ionisation energy of Li^{+2} ion = 122.4 eV

D18 (iv) Ionisation Potential (I.P.) :

Potential difference through which a free electron must be accelerated from rest, such that its kinetic energy becomes equal to ionisation energy of the atom is called ionisation potential of the atom.
I.P. of H atom = 13.6 V, I.P. of He^+ Ion= 54.4 V

D19 (v) Excitation Energy :

Energy required to move an electron from ground state of the atom to any other state of the atom is called
excitation energy of that state.
Excitation energy of 2nd state = excitation energy of 1st excited state = 1st excitation energy = 10.2 eV.

D20 (vi) Excitation Potential :

Potential difference through which an electron must be accelerated from rest to so that its kinetic energy
become equal to excitation energy of any state is called excitation potential of that state.
Excitation potential of third state = excitation potential of second excited state = second excitation potential = 12.09 V.

D21 (vii) Binding Energy 'or' Separation Energy :

Energy required to move an electron from any state to $n = \infty$ is called binding energy of that state.
Binding energy of ground state = I.E. of atom or Ion.

Solved Examples

Example-6 A single electron system has ionization energy 11180 kJ mol^{-1}. Find the number of protons in the nucleus of the system.

Solution. I.E. = $\dfrac{Z^2}{n^2} \times 21.69 \times 10^{-19}$ J

$$\frac{11180 \times 10^3}{6.023 \times 10^{23}} = \frac{Z^2}{1^2} \times 21.69 \times 10^{-19}$$

Ans. Z = 3

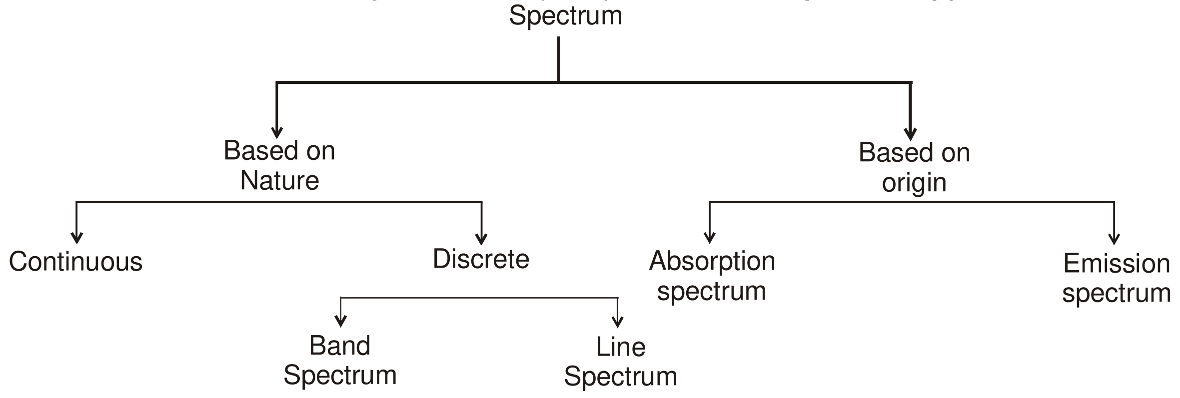
Section (D) : Spectrum

HYDROGEN SPECTRUM :

Study of Emission and Absorption Spectra :

An instrument used to separate the radiation of different wavelengths (or frequencies) is called spectroscope or a spectrograph. Photograph (or the pattern) of the emergent radiation recorded on the film is called a spectrogram or simply a spectrum of the given radiation.

D22 The branch or science dealing with the study of spectra is called **spectroscopy**.



D23 **Emission spectra :**

When the radiation emitted from some source e.g. from the sun or by passing electric discharge through a gas at low pressure or by heating some substance to high temperature etc., is passed directly through the prism and then received on the photographic plate, the spectrum obtained is called 'Emission spectrum'.

Depending upon the source of radiation, the emission spectra are mainly of two type :

D24 **(a) Continuous spectra :**

When white light from any source such as sun, a bulb or any hot glowing body is analysed by passing through a prism it is observed that it splits up into seven different wide band of colours from violet to red. These colours are so continuous that each of them merges into the next. Hence the spectrum is called continuous spectrum.

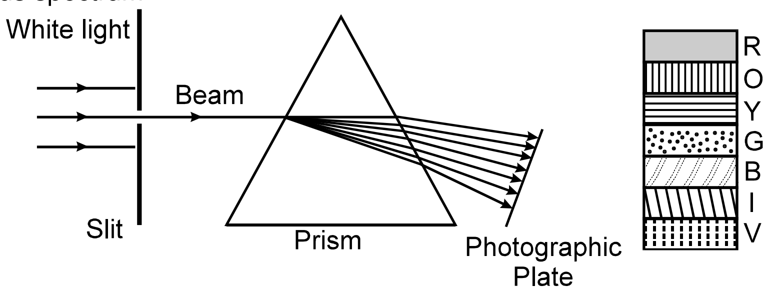


Figure-14

(b) Discrete spectra : It is of two type

(i) Band spectrum

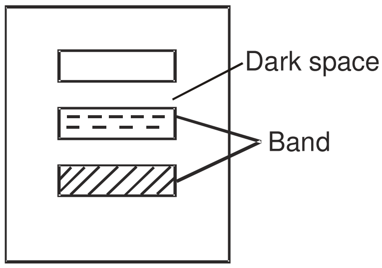


Figure-15

Band spectrum contains colourful continuous bands sepearted by some dark space.
Generally, molecular spectrum are band spectrum.

(ii) Line Spectrum :

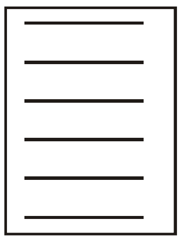


Figure-16

D25 This is the ordered arrangement of lines of particular wavelength separated by dark space eg. Hydrogen spectrum.
Line spectrum can be obtained from atoms.

D26 **Absorption spectra :**

When white light from any source is first passed through the solution or vapours of a chemical substance and then analysed by the spectroscope, it is observed that some dark lines are obtained in the continuous spectrum. These dark lines are supposed to result from the fact that when white light (containing radiations of many wavelengths) is passed through the chemical substance, radiations of certain wavelengths are absorbed, depending upon the nature of the element.

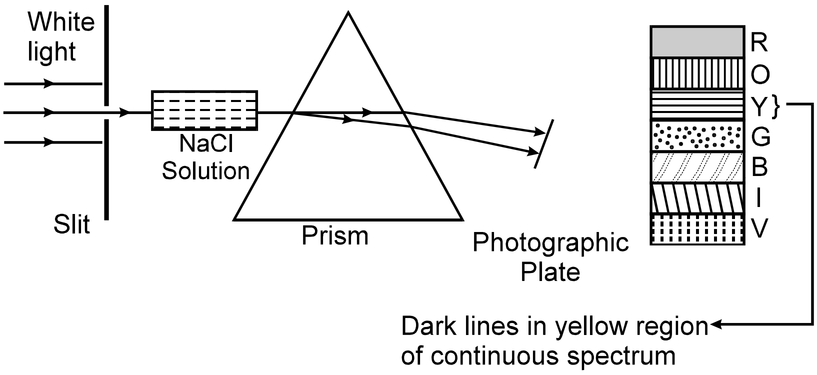


Figure-17

D27 EMISSION SPECTRUM OF HYDROGEN :

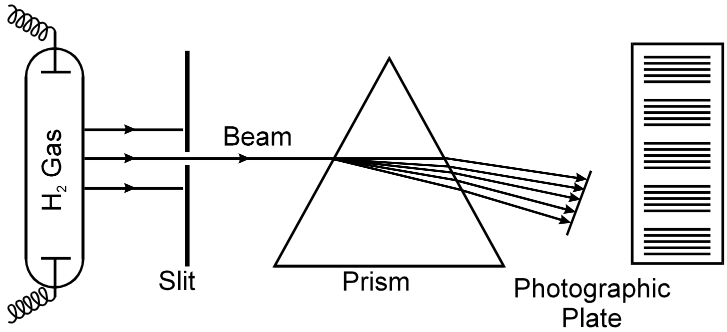


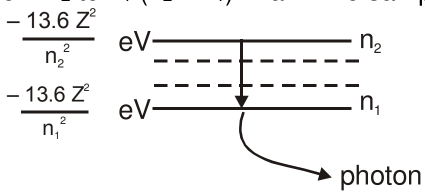
Figure-18

When hydrogen gas at low pressure is taken in the discharge tube and the light emitted on passing electric discharge is examined with a spectroscope, the spectrum obtained is called the emission spectrum of hydrogen.

Line Spectrum of Hydrogen :

Line spectrum of hydrogen is observed due to excitation or de-excitation of electron from one stationary orbit to another stationary orbit

Let electron make transition from n_2 to n_1 ($n_2 > n_1$) in a H-like sample



Der.6 Energy of emitted photon $= (\Delta E)_{n_2 \to n_1} = \dfrac{-13.6Z^2}{n_2^2} - \left(\dfrac{-13.6Z^2}{n_1^2}\right) = 13.6Z^2\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

Wavelength of emitted photon

$$\lambda = \frac{hc}{(\Delta E)_{n_2 \to n_1}}$$

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

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

F25 Wave number, $\dfrac{1}{\lambda} = \bar{\nu} = RZ^2\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

R = Rydberg constant = $1.09678 \times 10^7 m^{-1}$; $R \approx 1.1 \times 10^7\ m^{-1}$; $R = \frac{13.6eV}{hc}$; R ch = 13.6 eV

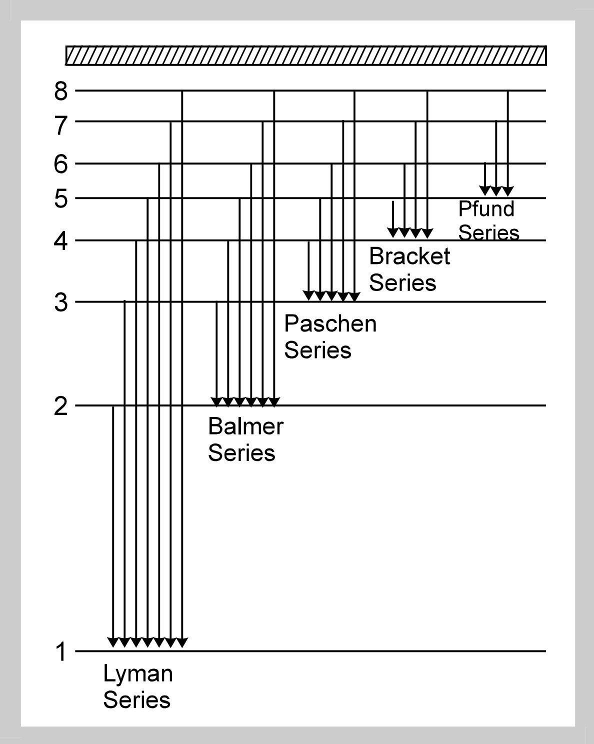


Figure-19

Solved Examples

Example-7 Calculate the wavelength of a photon emitted when an electron in H- atom maker a transition from n = 2 to n = 1

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

$\therefore\ \frac{1}{\lambda} = R(1)^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$\therefore\ \frac{1}{\lambda} = \frac{3R}{4}$ or $\lambda = \frac{4}{3R}$

SPECTRA LINES OF HYDROGEN ATOM :

LYMAN SERIES

* It is first spectral series of H.
* It was found to be in ultraviolet region by Lyman in 1898.
* For it value of $n_1 = 1$ and $n_2 = 2, 3, 4$ where 'n_1' is ground state and 'n_2' is called excited state of electron present in a H - atom.
* $\frac{1}{\lambda} = R_H\left[\frac{1}{1^2} - \frac{1}{n_2^2}\right]$ where $n_2 > 1$ always.
* The wavelength of marginal line (i.e. $n_2 = \infty$) = $\frac{n_1^2}{R_H}$ for all series. So for Lyman series $\lambda = \frac{1}{R_H}$.
* I[st] line of lyman series $\Rightarrow 2 \rightarrow 1$
  II[nd] line of lyman series = $3 \rightarrow 1$
  Last line of lyman series = $\infty \rightarrow 1$
  [$10.2\ eV \le (\Delta E)_{lyman} \le 13.6\ eV$]

$\dfrac{12400}{13.6} \le \lambda_{lyman} \le \dfrac{12400}{10.2}$ Å

* **Longest line :** longest wavelength line $\lambda_{longest}$ or $\lambda_{max.} = \dfrac{12400}{(\Delta E)_{min}}$
* **Shortest line :** shortest wavelength line $\lambda_{shortest}$ or $\lambda_{min} = \dfrac{12400}{(\Delta E)_{max}}$
* First line of any spectral series is the longest (λ_{max}) line.
* Last line of any spectral series is the shortest (λ_{min}) line.

Series limit :

It is the last line of any spectral series.

Wave no of Ist line of Lyman series $= \dfrac{1}{\lambda} = \bar{\nu} = R \times 1^2 \left(\dfrac{1}{1^2} - \dfrac{1}{2^2}\right)$

$$\bar{\nu} = R \times 1^2 \left(\frac{4-1}{4}\right)$$

$$\bar{\nu} = \frac{R \times 3}{4} = \frac{3R}{4}$$

$$\therefore \quad \left[\lambda = \frac{4}{3R}\right]$$

Wave no of last line of Lyman series

$$\bar{\nu} = R \times 1^2 \left(\frac{1}{1^2} - \frac{1}{\infty^2}\right)$$

$$\bar{\nu} = R$$

For Lyman series,

$$\lambda_{\ longest} = \frac{12400}{(\Delta E)_{2-1}}, \quad \lambda_{shortest} = \frac{12400}{(\Delta E)_{\infty \to 1}}$$

BALMER SERIES :

* It is the second series of H-spectrum.
* It was found to be in visible region by Balmer in 1892.
* For it value of $n_1 = 2$ and $n_2 = 3, 4, 5,$.............
* The wavelength of marginal line of Balmer series $= \dfrac{n_1^2}{R_H} = \dfrac{2^2}{R_H} = \dfrac{4}{R_H}$
* $\dfrac{1}{\lambda} = R_H \left(\dfrac{1}{2^2} - \dfrac{1}{n_2^2}\right)$ where $n_2 > 2$ always.

$1.9 \le (\Delta E)_{balmer} \le 3.4$ eV.

All the lines of balmer series in H spectrum are not in the visible range. Infact only Ist 4 lines belongs to visible range.

$\dfrac{12400}{3.4}$ Å $\le \lambda_{balmer} \le \dfrac{12400}{1.9}$ Å

3648 Å $\le \lambda_{\ balmer} \le$ 6536 Å

Lines of balmer series (for H atom) lies in the visible range.

Ist line of balmer series = $3 \to 2$

last line of balmer series = $\infty \to 2$

$(\bar{\nu})$ 1st line $= R \times 1 \left(\dfrac{1}{2^2} - \dfrac{1}{3^2}\right) = \dfrac{5R}{36}$

$(\bar{\nu})$ last line $= R\left(\dfrac{1}{2^2} - \dfrac{1}{\infty^2}\right) = \dfrac{R}{4}$

PASCHEN SERIES :

(a) It is the third series of H - spectrum.

(b) It was found to be in infrared region by Paschen.

(c) For it value of $n_1 = 3$ and $n_2 = 4, 5, 6$ ....

(d) The wavelength of marginal line of Paschen series = $\frac{n_1^2}{R_H} = \frac{3^2}{R_H} = \frac{9}{R_H}$.

(e) $\frac{1}{\lambda} = R_H\left[\frac{1}{3^2} - \frac{1}{n_2^2}\right]$ where $n_2 > 3$ always.

BRACKETT SERIES :

(a) It is fourth series of H - spectrum.

(b) It was found to be in infrared region by Brackett.

(c) For it value of $n_1 = 4$ and $n_2 = 5, 6, 7$ ....

(d) The wavelength of marginal line of brackett series = $\frac{n_1^2}{R_H} = \frac{4^2}{R_H} = \frac{16}{R_H}$

(e) $\frac{1}{\lambda} = R_H\left[\frac{1}{4^2} - \frac{1}{n_2^2}\right]$ where $n_2 > 4$ always.

PFUND SERIES :

(a) It is fifth series of H- spectrum.

(b) It was found to be in infrared region by Pfund.

(c) For it value of $n_1 = 5$ and $n_2 = 6, 7, 8$ .... where n_1 is ground state and n_2 is excited state.

(d) The wavelength of marginal line of Pfund series = $\frac{n_1^2}{R_H} = \frac{5^2}{R_H} = \frac{25}{R_H}$

(e) $\frac{1}{\lambda} = R_H\left[\frac{1}{5^2} - \frac{1}{n_2^2}\right]$ where $n_2 > 5$ always.

HUMPHRY SERIES :

(a) It is the sixth series of H-spectrum.

(b) It was found to be in infrared region by Humphry.

(c) For it value of $n_1 = 6$ and $n_2 = 7, 8, 9$ ....

(d) The wavelength of marginal line of Humphry series = $\frac{n_1^2}{R_H} = \frac{6^2}{R_H} = \frac{36}{R_H}$

(e) $\frac{1}{\lambda} = R_H\left[\frac{1}{6^2} - \frac{1}{n_2^2}\right]$ where $n_2 > 6$.

Solved Examples

Example-8 Calculate wavelength for 2nd line of Balmer series of He^+ ion

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

$n_1 = 2 \quad n_2 = 4$

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

$\frac{1}{\lambda} = \frac{3R}{4} \qquad \lambda = \frac{4}{3R}$ **Ans.**

No. of photons emitted by a sample of H atom :

If an electron is in any higher state n = n and makes a transition to ground state, then total no. of different photons emitted = $\frac{n \times (n-1)}{2}$.

F26 If an electron is in any higher state $n = n_2$ and makes a transition to another excited state $n = n_1$, then total no. of different photons emitted = $\frac{\Delta n \ \ (\Delta n + 1)}{2}$, where $\Delta n = n_2 - n_1$

F27 **Note:** In case of single isolated atom if electron make transition from n^{th} state to the ground state then max. number of spectral lines observed = (n-1)

Solved Examples

Example-9 If electron make transition from 7^{th} excited state to 2^{nd} state in H atom sample find the max. number of spectral lines observed.

Solution. $\Delta n = 8 - 2 = 6$

spectral lines = $6\left(\frac{6+1}{2}\right) = 6 \times \frac{7}{2} = 21$

Section (E) : De-broglie wavelength and Heisenberg uncertainity principle

Dual nature of electron (de-Broglie Hypothesis):

(a) Einstein had suggested that light can behave as a wave as well as like a particle i.e. it has dual character.

(b) In 1924, de-Broglie proposed that an electron behaves both as a material particle and as a wave.

(c) This proposed a new theory, the wave mechanical theory of matter. According to this theory, the electrons protons and even atom when in motion possess wave properties.

(d) According to de-Broglie, the wavelength associated with a particle of mass m, moving with velocity v is given by the relation,

F28 $\lambda = \frac{h}{mv}$

where h is Planck's constant

Der.7 (e) This can be derived as follows according to Planck's equation.

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

Energy of photon on the basis of Einstein's mass energy relationship

$E = mc^2$ or $\lambda = \frac{h}{mc}$

Equating both we get

$\frac{h.c}{\lambda} = mc^2$ or $\lambda = \frac{h}{mc}$

Which is same as de - Broglie relation.

This was experimentally verified by Davisson and Germer by observing diffraction effects with an electron beam.

Let the electron is accelerated with a potential of V then the K.E. is

Der.8 $\frac{1}{2}mv^2 = eV$

$m^2v^2 = 2emV$

$mv = \sqrt{2emV}$ = p (momentum)

F29 $\lambda = \frac{h}{\sqrt{2emV}}$

If we associate Bohr's theory with de - Broglie equation then

$2\pi r = n\lambda$ or $\lambda = \frac{2\pi r}{n}$

From de-Broglie equation

$\lambda = \dfrac{h}{mv}$ therefore $\dfrac{h}{mv} = \dfrac{2\pi r}{n}$

so, $mvr = \dfrac{nh}{2\pi}$

m = dynamic mass = $\dfrac{m_0}{\sqrt{1-\left(\dfrac{v}{c}\right)^2}}$

m_0 = rest mass of particle
Depended on velocity
c = velocity of light
If velocity of particle is zero then :
Dynamic mass = rest mass
Rest mass of photon is zero that means photon is never at rest

* K.E. = $\dfrac{1}{2}mv^2$

m (K.E.) = $\dfrac{1}{2}m^2v^2$ multiplied by mass on both side

⇒ m.v. = $\sqrt{2m(K.E.)}$

$\lambda = \dfrac{h}{\sqrt{2m(K.E.)}}$

If a charge q is accelerated through a potential difference of 'V' volt from rest then K.E. of the charge is equal to: " q.V"

⇒ $\lambda = \dfrac{h}{\sqrt{2m(q.V)}}$

* If an electron is accelerated through a potential difference of 'V' volt from rest then:

⇒ $\lambda = \dfrac{h}{\sqrt{2m_e(eV)}}$

⇒ $\lambda = \left(\dfrac{150}{V}\right)^{\frac{1}{2}}$ Å (on putting values of h, m_e and e)

F30 $\lambda = \dfrac{12.3}{\sqrt{V}}$ Å (V in volt)

* $mvr = n \times \dfrac{h}{2\pi}$

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

$mv = \dfrac{h}{\lambda}$ putting this in $mvr = \dfrac{nh}{2\pi}$

∴ $\dfrac{h}{\lambda}r = \dfrac{nh}{2\pi} \Rightarrow \left[\lambda = \dfrac{2\pi r}{n}\right]$ de Broglie wavelength

Solved Examples

Example-10 What will be the wavelength of a ball of mass 0.1 kg moving with a velocity of 10 m s^{-1} ?

Solution. According to de Broglie equation

$\lambda = \dfrac{h}{mv} = \dfrac{(6.626 \times 10^{-34} Js)}{(0.1\,kg)\ \ (10\ ms^{-1})}$ = 6.626 × 10^{-34} m (J = kg m^2 s^{-2}).

Heisenberg's Uncertainty Principle :

The exact position and momentum of a fast moving particle cannot be calculated precisely at the same moment of time. If Δx is the error in the measurement of position of the particle and if Δp is the error in the measurement of momentum of the particle, then:

F31 $\Delta x.\Delta p \geq \frac{h}{4\pi}$ or $\Delta x.(m\Delta v) \geq \frac{h}{4\pi}$

where, Δx = uncertainty in position, Δp = uncertainty in momentum
h = Plank's constant, m = mass of the particle
Δv = uncertainty in velocity

Der.9 If the position of a particle is measured precisely, i.e. $\Delta x \to 0$ then $\Delta p \to \infty$.
If the momentum of the particle is measured precisely. i.e. $\Delta p \to 0$ then $\Delta x \to \infty$.
This is because of a principle of optics that if a light of wavelength 'λ' is used to locate the position of a particle then maximum error in the position measurement will be $\pm\lambda$. i.e. $\Delta x = \pm\lambda$
If $\Delta x \to 0$; $\lambda \to 0$

But, $p = \frac{h}{\lambda} \Rightarrow p \to \infty$

So, to make $\Delta x \to 0$, $\lambda \to 0$ a photon of very high energy is used to locate it.
When this photon will collide with the electron then momentum of electron will get changed by a large amount.

* $\Delta p.\Delta x \geq \frac{h}{4\pi}$ (multiplied & divided by Δt)

$\frac{\Delta P}{\Delta t}\Delta t.\Delta x \geq \frac{h}{4\pi}$ ($\frac{\Delta P}{\Delta t}$ = rate of change in momentum = F)

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

$\Delta E.\Delta t \geq \frac{h}{4\pi}$

$\Delta E \longrightarrow$ uncertainty in energy

$\Delta t \longrightarrow$ uncertainty in time

☞ In terms of uncertainty in energy ΔE, and uncertainty in time Δt, this principle is written as,

F32 $\Delta E.\Delta t \geq \frac{h}{4\pi}$.

☞ Heisenberg replaced the concept of definite orbits by the concept of probability.

Solved Examples

Example-11 A golf ball has a mass of 40 g, and a speed of 45 m/s. If the speed can be measured within accuracy of 2%, calculate the uncertainty in the position.

Solution. The uncertainty in the speed is 2%, i.e., $45 \times \frac{2}{100} = 0.9\ m\ s^{-1}$.

Using the equation, $\Delta x = \frac{h}{4\pi m\Delta v} = \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 40 \times 10^{-3}\ (0.9\ ms^{-1})} = 1.46 \times 10^{-33}$ m

This is nearly ~10^{18} times smaller than the diameter of a typical atomic nucleus. As mentioned earlier for large particles, the uncertainty principle sets no meaningful limit to the precision of measurements.

Section (F) : Quantum mechanical model of atom, Shrodinger wave equation and orbital concept

Orbital :

D28 An orbital may be defined as the region of space around the nucleus where the probability of finding an electron is maximum (90% to 95%)

Orbitals do not define a definite path for the electron, rather they define only the probability of the electron being in various regions of space around the nucleus.

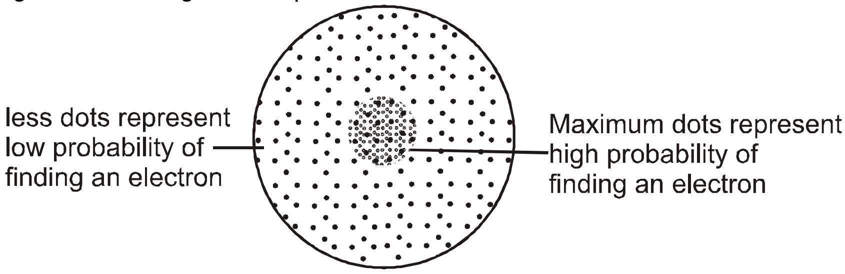


Figure-20

Difference between orbit and orbitals

	Orbit	**Orbitals**
1	It is well defined circular path followed by revolving electrons around the nucleus.	It is the region of space around the nucleus where electron is most likely to be found.
2	It represents planar motion of electron.	It represents 3 dimensional motion of an electron around the nucleus.
3	The maximum no. of electron in an orbits is $2n^2$ where n stands for no. of orbit.	Orbitals cannot accommodate more than 2 electrons.
4	Orbits are circular in shape.	Orbitals have different shape e.g. s-orbital is spherical, p-orbital is dumb-bell shaped.
5	Orbit are non-directional in character. Hence, they cannot explain shape of molecules.	Orbitals (except s-orbital) have directional character. Hence, they can account for the shape of molecules.
6	Concept of well-defined orbit is against Heisenberg's uncertainty principle.	Concept of orbitals is in accordance with Heisenberg's principle.

Shape of the orbitals :

Shape of the orbitals are related to the solutions of Schrodinger wave equation, and gives the space in which the probability of finding an electron is maximum.

s-orbital : **Shape $\rightarrow$ spherical**

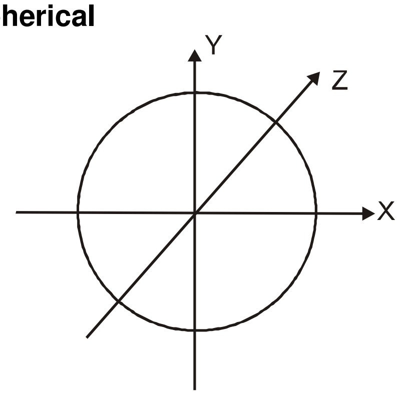


Figure-21

s-orbital is non directional and it is closest to the nucleus, having lowest energy.

s-orbital can accommodate maximum no. of two electrons.

$\boxed{\uparrow\downarrow}$

n s

p-orbital : Shape → dumb bell

Dumb bell shape consists of two lobes which are separated by a region of zero probability called node.

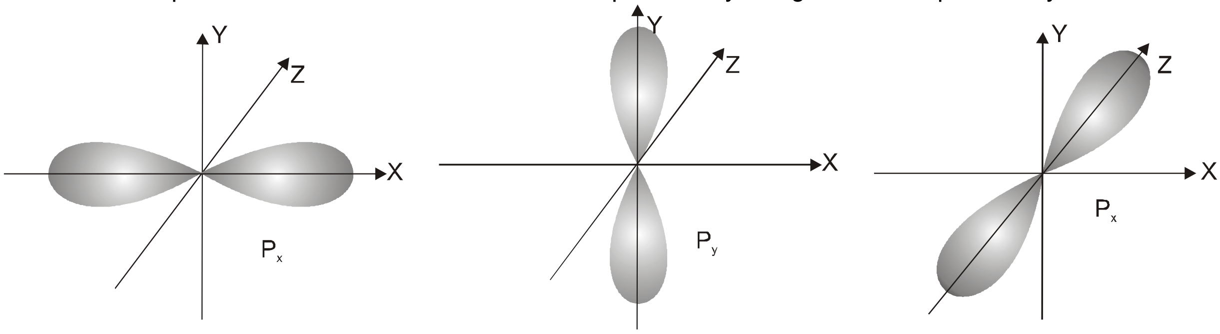


Figure-22

p-subshell can accomodate maximum no. of six electrons.

↑↓	↑↓	↑↓
p_x	p_y	p_z

d-Orbital : Shape → double dumb bell

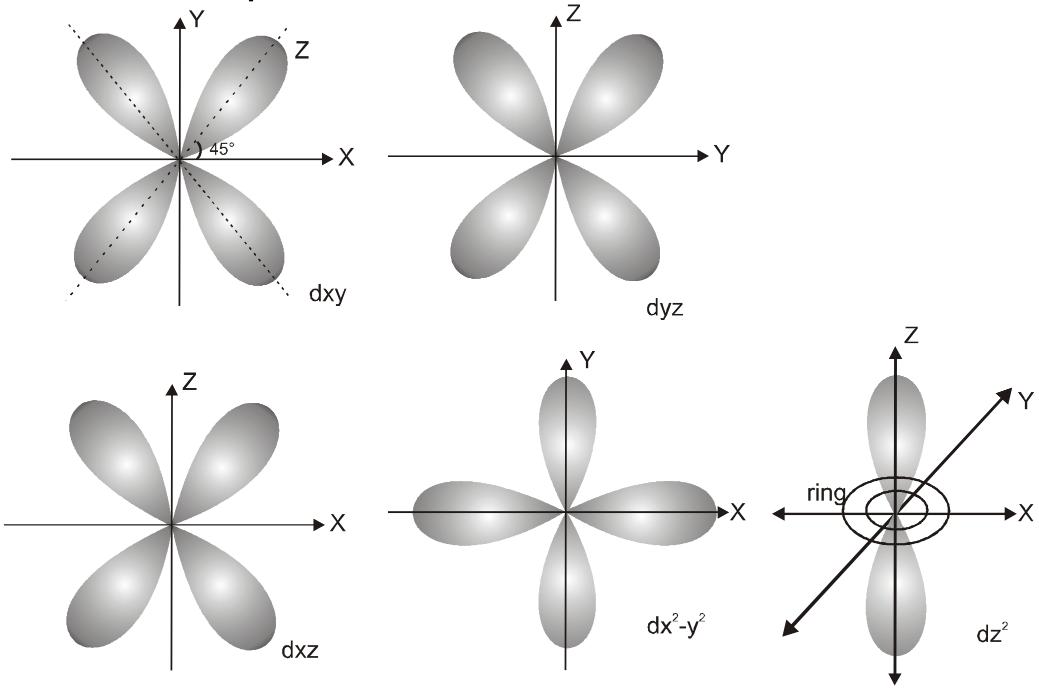


Figure-23

d-subshell can accommodate maximum no. of 10 electrons.

↑↓	↑↓	↑↓	↑↓	↑↓
dxy	dyz	dz^2	dx^2-y^2	dxz

f-orbital : Shape → leaf like

↑↓	↑↓	↑↓	↑↓	↑↓	↑↓	↑↓

f-subshell can accommodate maximum no. of 14 electrons.

Schrodinger Wave Mechanical model

Ervin Schrodinger developed a model which is based on the particle and wave nature of the electron, known as Wave Mechanical Model of atom. The equation determines the behaviour of the wave function that describes the wave like properties of subatomic system. It is solved to find the different energy levels of the system.

Schrodinger applied the equation to the hydrogen atom and predicted many of its properties with remarkable accuracy. The differential wave equation is as follows :

F-33 $$\frac{\delta^2\psi}{\delta x^2} + \frac{\delta^2\psi}{\delta y^2} + \frac{\delta^2\psi}{\delta z^2} + \frac{8\pi^2 m}{h^2}(E - V)\,\psi = 0$$

where m is mass of electron, ψ is wave function, E is total energy of electron, V is potential energy and h is Planck's constant.

- Wave function has no actual physical meaning but the value of ψ^2 describes the probability distribution of an electron.
- When we solve the Schrodinger equation, it is observed that for some region of space, the value of ψ is positive and for other, it is negative. But the probability must be positive, so it is proper to use ψ^2 in place of ψ.
- The Schrodinger equation is said to have been solved for a particular atomic system. The details of, how this is done, are beyond the syllabus, but the consequences of its solution are extremely important to us.

The important point of the solution of this equation is that it provides a set of numbers called quantum numbers. Quantum numbers are required to describe the distribution of electrons in atoms. Quantum numbers derived from the solution of Schrodinger equation are called principal quantum number, azimuthal quantum number and magnetic quantum number. These quantum numbers are used to describe the atomic orbitals.

Orbital : The locations in space at which the probability of finding the electron is maximum.

Node and Nodal Plane : Node represents the region where probability of finding an electron is zero (i.e., ψ and ψ^2 = 0). Similarly nodal plane represents the plane having zero probability of finding electron.

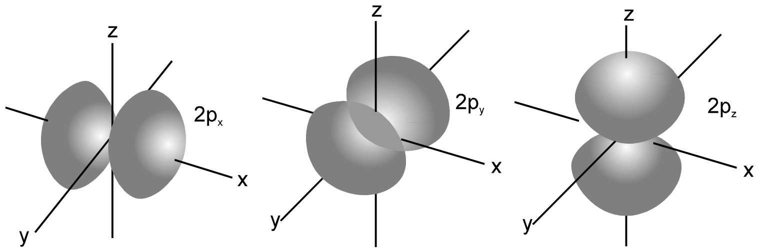
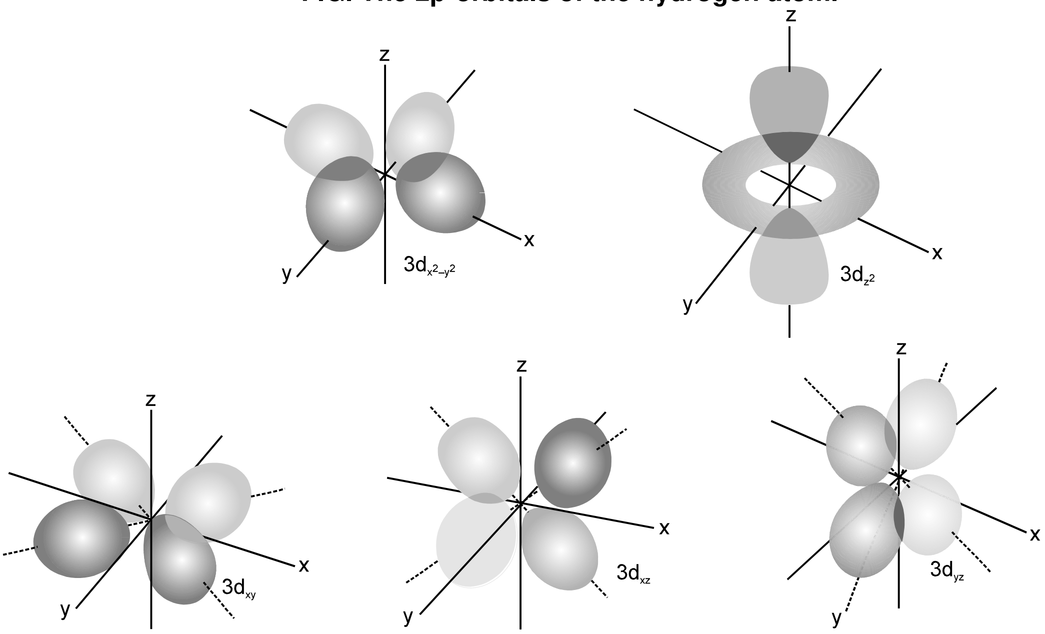


FIG. The 2p-orbitals of the hydrogen atom.



The 3d-orbitals of the hydrogen atom. Note the relation between the labeling of the d-orbitals and their orientations in space.

Nodes are of two types : (a) Radial node (b) Angular node
A radial node is the spherical region around nucleus having ψ and ψ^2 equal to zero. An orbital having higher number of nodes has more energy.

Calculation of number of nodes :

F34 Radial nodes = $n - \ell - 1$,

F35 Angular nodes = ℓ,

F36 Total nodes = $n - 1$, where n and ℓ are principal and azimuthal quantum numbers.

e.g. In 3p-orbital, Radial nodes = 3 – 1 – 1 = 1 (= $n - \ell - 1$)
Angular nodes = 1 (= ℓ)
Total nodes = 2 (one radial, one angular)

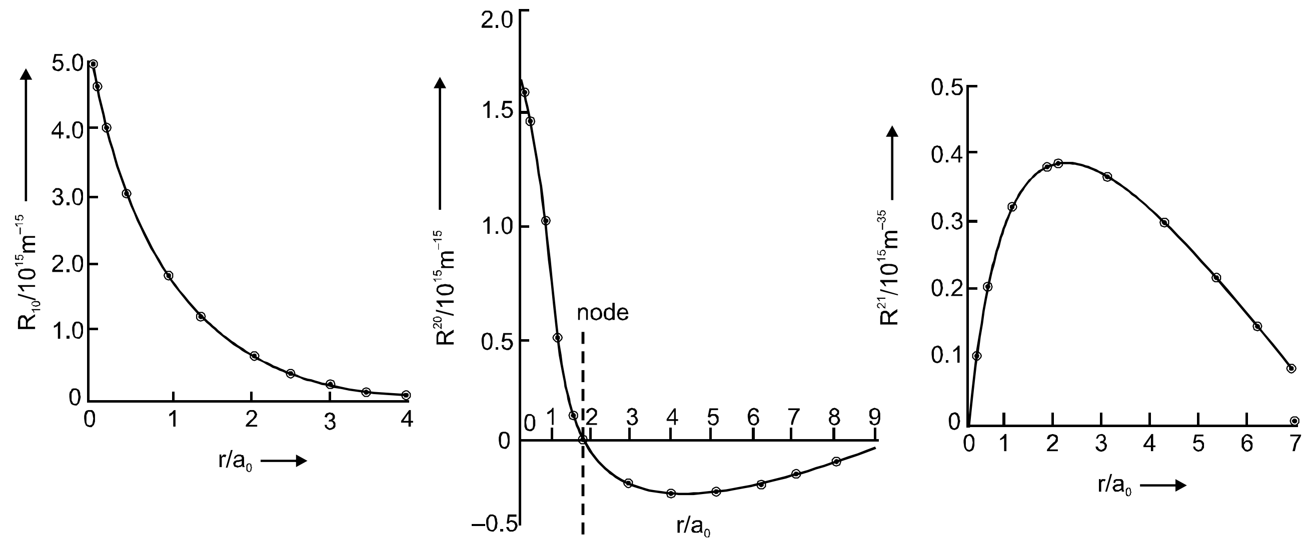
- $\psi_{(r)}$ i.e. radial part of wave function depends upon quantum number n and l and decides the size of an orbital.
- Angular part of wave function $\psi_{(\theta-\phi)}$, depends upon quantum numbers l and m and describes the shape of orbital.

For the sake of convenience the $\psi_{(r)}$ vs. r and $\psi_{(\theta,\phi)}$ vs. angle are plotted separately.

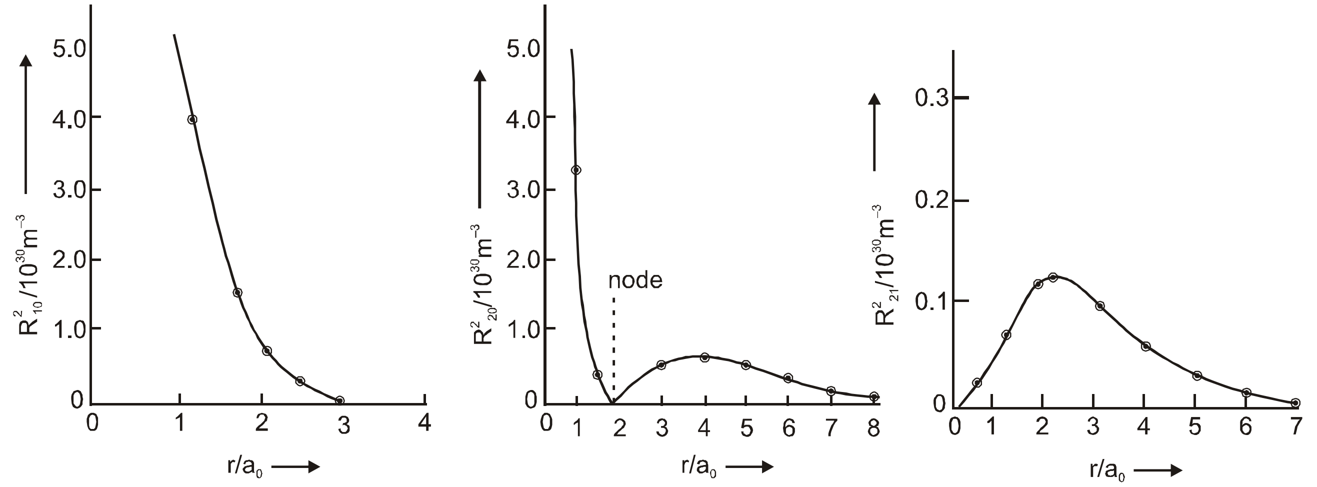
An atomic orbital is a one electron wave function Ψ (r, θ, ϕ) obtained from the solution of the Schrodinger equation. The orbital wave function Ψ has no physical significance but its square (Ψ^2) has a physical significance it measures the electron probability density at a point in an atom.

Plots of the Radial wave function R : The plots of the radial wave function R, radial probability density R^2 and radial probability function $4\pi r^2R^2$ for 1s, 2s & 2p atomic orbitals as a function of the distance r from the nucleus are shown in fig.

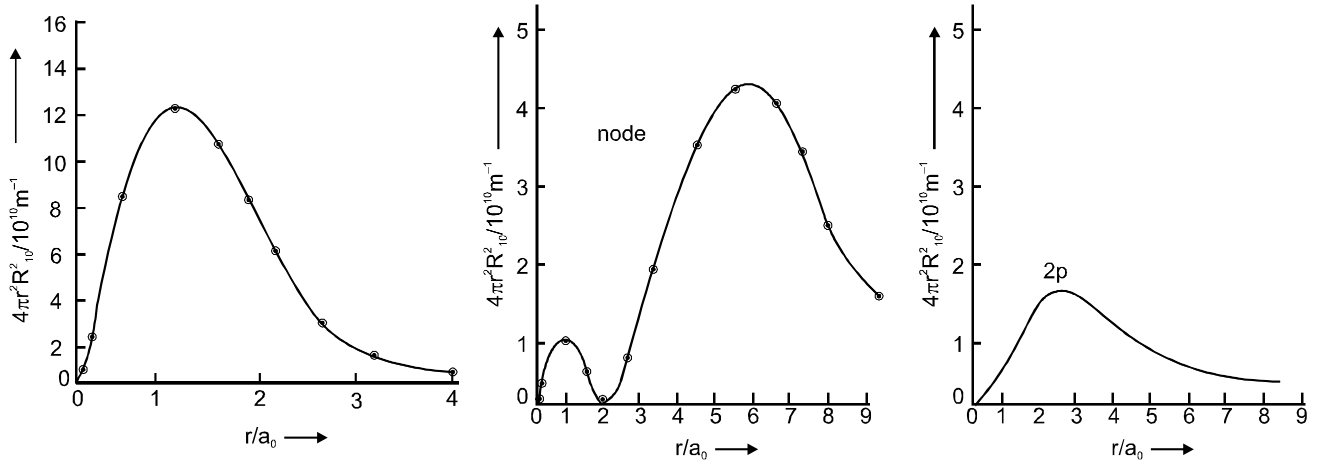
(i) Radial wave function (R) [Fig. (A)] : In all cases R approaches zero as r approaches infinity. We finds that there is a node in the 2s radial function. At the node the value of the radial function changes from positive to negative. In general, it has been found that ns-orbitals have (n–1) radial nodes and np-orbitals have (n–2) radial nodes etc.

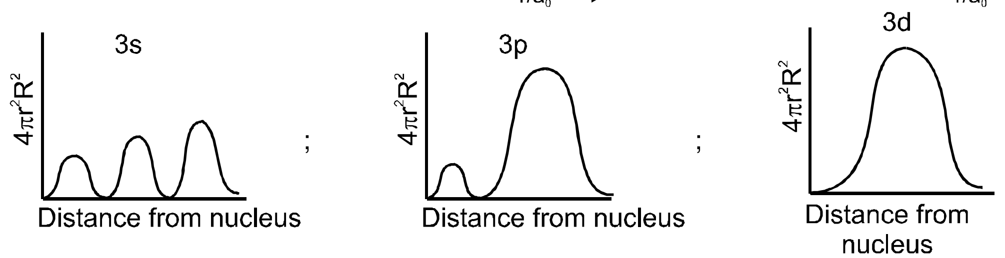


(ii) Radial Probability density (R^2) [Fig. (B)] : The radial density R^2 gives the probability density of finding the electron at a point along a particular radius line. Plots in fig. (B) give useful information about probability density or relative electron density at a point as a function of radius. It may be noted that for s-orbitals the maximum electron density is at the nucleus while all other orbitals have zero electron density at the nucleus. Its zero value ($R^2 = 0$) indicates zero probability of finding an electron.

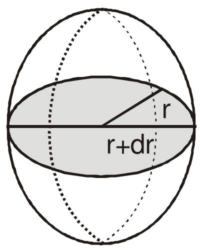


(iii) Radial probability function $4\pi r^2R^2$ [Fig.(C)] : Since the atoms have spherical symmetry, It is more useful to discuss the probability of finding the electron in a spherical shell between the spheres of radius (r + dr) and r. The volume of the shell is equal to $4/3\pi(r + dr)^3 - 4/3\pi r^3 = 4\pi r^2dr$.





This probability which is independent of direction is called radial probability and is equal to $[4\pi r^2drR^2]$. It gives the probability of finding the electron at a distance r from the nucleus regardless of direction.



Section (G) : Quantum numbers & Electronic configuration

D29 QUANTUM NUMBERS :

The set of four numbers required to define an electron completely in an atom are called quantum numbers. The first three have been derived from Schrodinger wave equation.

(i) Principal quantum number (n) : (Proposed by Bohr)

It describes the size of the electron wave and the total energy of the electron. It has integral values 1, 2, 3, 4 ...., etc., and is denoted by K, L, M, N. ..., etc.

F37 Number of subshell present in n^{th} shell = n

n	**subshell**
1	s
2	s, p
3	s, p, d
4	s, p, d, f

F38 Number of orbitals present in n^{th} shell = n^2 .

F39 The maximum number of electrons which can be present in a principal energy shell is equal to $2n^2$. No energy shell in the atoms of known elements possesses more than 32 electrons.

F40 Angular momentum of any orbit $= \dfrac{nh}{2\pi}$

(ii) Azimuthal quantum number (ℓ) : (Proposed by Sommerfield)

It describes the shape of electron cloud and the number of subshells in a shell.

* It can have values from 0 to (n – 1)

*

value of ℓ	**subshell**
0	s
1	p
2	d
3	f

F41 Number of orbitals in a subshell = $2\ell + 1$

F42 Maximum number of electrons in particular subshell = $2 \times (2\ell + 1)$

F43 Orbital angular momentum $L = \dfrac{h}{2\pi}\sqrt{\ell(\ell+1)} = \hbar\sqrt{\ell(\ell+1)}$ $\left[\hbar = \dfrac{h}{2\pi}\right]$

i.e. Orbital angular momentum of s orbital = 0, Orbital angular momentum of p orbital = $\sqrt{2}\dfrac{h}{2\pi}$,

Orbital angular momentum of d orbital = $\dfrac{\sqrt{6}h}{2\pi}$

(iii) Magnetic quantum number (m) : (Proposed by Linde)

It describes the orientations of orbitals with respect to standard set of coordinate axes. It can have values from $-\ell$ to $+\ell$ including zero, i.e., total $(2\ell + 1)$ values. Each value corresponds to an orbital. s-subshell has one orbital, p-subshell three orbitals (p_x, p_y and p_z), d-subshell five orbitals $(d_{xy}, d_{yz},\ d_{zx},\ d_{x^2-y^2},\ d_{z^2})$ and f-subshell has seven orbitals.

F44 The total number of orbitals present in a main energy level is 'n^2'.

(iv) Spin quantum number (s) : (Proposed by Goldsmith & Uhlenbeck)

It describes the spin of the electron. It has values +1/2 and –1/2. Signifies clockwise spinning and anticlockwise spinning.

F45 Spin magnetic moment $\mu_s = \dfrac{eh}{2\pi mc}\sqrt{s(s+1)}$ or $\mu = \sqrt{n(n+2)}$ B.M. (n = no. of unpaired electrons)

F46 It represents the value of spin angular momentum which is equal to $\dfrac{h}{2\pi}\sqrt{s(s+1)}$.

F47 Maximum spin of atom = $\dfrac{1}{2}$ × No. of unpaired electron.

Electronic configuration :

Pauli's exclusion principle :

No two electrons in an atom can have the same set of all the four quantum numbers, i.e., an orbital cannot have more than 2 electrons and the three quantum numbers (principal, azimuthal and magnetic) at the most may be same but the fourth must be different, i.e. their spins must be in opposite directions.

Aufbau principle :

Aufbau is a German word meaning building up. The electrons are filled in various orbitals in order of their increasing energies. An orbital of lowest energy is filled first. The sequence of orbitals in order of their increasing energy is :

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

The energy of the orbitals is governed by $(n + \ell)$ rule.

$(n + \ell)$ Rule :

The relative order of energies of various sub-shell in a multi electron atom can be predicated with the help of '$n + \ell$' rule

❖ The sub-shell with lower value of $(n + \ell)$ has lower energy and it should be filled first.

eg. 3d — $(n + \ell) = 3 + 2 = 5$ 4s — $(n + \ell) = 4 + 0 = 4$

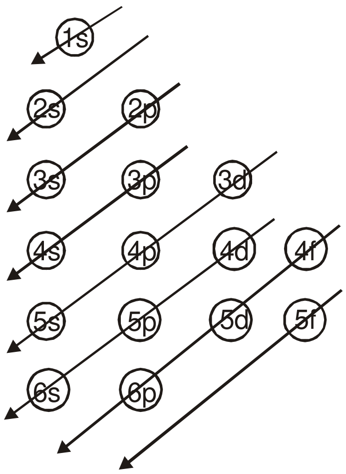
Since, $(n + \ell)$ value of 3d is more than 4s therefore, 4s will be filled before 3d.

❖ If two sub-shell has same value of $(n + \ell)$ then the sub-shell with lower value of n has lower energy and it should be filled first.

eg. 3d — $(n + \ell) = 3 + 2 = 5$ 4p — $(n + \ell) = 4 + 1 = 5$

3d is filled before 4p.

MEMORY MAP :



Hund's rule :

No electron pairing takes place in the orbitals in a sub - shell until each orbital is occupied by one electron with parallel spin. Exactly half filled and fully filled orbitals are observed to be more stable, i.e., p^3, p^6, d^5, d^{10}, f^7 and f^{14} configuration are most stable probably because of the following reasons :

(i) relatively small shielding
(ii) larger exchange energy
(iii) smaller coulombic repulsion energy.

Solved Examples

Example-12 Write the electronic configuration and find the no. of unpaired electrons as well as total spin for the following atoms :

(i) $_6C$ (ii) $_8O$ (iii) $_{15}P$
(iv) $_{21}Sc$ (v) $_{26}Fe$ (vi) $_{10}Ne$

Solution. (i) $_6C \rightarrow 1s^2, 2s^2, 2p^2$

$\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow}\boxed{\uparrow}\boxed{}$

No. of unpaired electrons $\rightarrow$ 2.

Total spin = $\frac{+2}{2}$ or $\frac{-2}{2}$

(ii) $_8O \rightarrow 1s^2, 2s^2, 2p^4$

$\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}$

1s 2s 2p

$\therefore$ No. of unpaired electrons = 2

Total spin = $\frac{+2}{2}$ or $\frac{-2}{2}$

(iii) $_{15}P \rightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^3$

$\boxed{\uparrow\downarrow}$ $\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

3s 3p

$\therefore$ No. of unpaired electrons = 3

Total spin = $\frac{+3}{2}$ or $\frac{-3}{2}$

(iv) $_{21}Sc \rightarrow 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^1$

or [Ar] $4s^2\ 3d^1$

[Ar] $3d^1\ 4s^2$

$\boxed{\uparrow}\boxed{}\boxed{}\boxed{}\boxed{}$ $\boxed{\uparrow\downarrow}$

3d 4s

$\therefore$ No. of unpaired electrons = 1

$\therefore$ Total spin = $\frac{+1}{2}$ or $\frac{-1}{2}$

(v) $_{26}Fe \rightarrow 1s^2, 2s^2\ 2p^6, 3s^2, 3p^6, 4s^2\ 3d^6$

or [Ar] $4s^2, 3d^6$

$\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}\boxed{\uparrow}$

4s 3d

No. of unpaired electrons = 4

$\therefore$ Total spin = $\frac{+4}{2}$ or $\frac{-4}{2}$

(vi) $_{10}Ne \rightarrow 1s^2, 2s^2\ 2p^6$

$\boxed{\uparrow\downarrow}$ $\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}\boxed{\uparrow\downarrow}$

No. of unpaired electrons = 0

Total spin = 0

Example-13 Write down the four quantum numbers for fifth and sixth electrons of carbon atom.

Solution. $_6C : 1s^2, 2s^2\ 2p^2$

fifth electron : $n = 2$ $\ell = 1$ $m = -1$ or $+1$ $s = +\frac{1}{2}$ or $-\frac{1}{2}$

sixth electron : $n = 2$ $\ell = 1$ $m = 0$ $s = +\frac{1}{2}$ or $-\frac{1}{2}$

Example-14 Calculate total spin, magnetic moment for the atoms having at. no. 7, 24 and 36.

Solution. The electronic configuration are

$_7N$	:	$1s^2, 2s^2\ 2p^3$	unpaired electron = 3
$_{24}Cr$	:	$1s^2, 2s^2\ 2p^6, 3s^2\ 3p^6\ 3d^5, 4s^1$	unpaired electron = 6
$_{36}Kr$	:	$1s^2, 2s^2\ 2p^6, 3s^2\ 3p^6\ 3d^{10}, 4s^2\ 4p^6$	unpaired electron = 0

$\therefore$ Total spin for an atom = $\pm 1/2 \times$ no. of unpaired electron

For $_7N$, it is = ± 3/2 ; For $_{24}Cr$, it is = ± 3 ; For $_{36}Kr$, it is = 0

Also magnetic moment = $\sqrt{n\,(n+2)}$

For $_7N$, it is = $\sqrt{15}$; For $_{24}Cr$, it is = $\sqrt{48}$; For $_{36}Kr$, it is = $\sqrt{0}$.

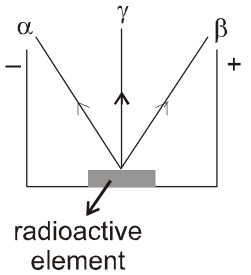
EXCEPTIONS :

(1) $_{24}Cr$ = [Ar] $4s^2, 3d^4$ (Not correct)
[Ar] $4s^1, 3d^5$ (correct : as d^5 structure is more stable than d^4 structure)

(2) $_{29}Cu$ = [Ar] $4s^1, 3d^{10}$ (correct : as d^{10} structure is more stable than d^9 structure).

Section (H) : Nuclear chemistry

D30 Spontaneous disintegration of nuclei due to emission of radiations like α, β, γ is called radioactivity.
Radioactivity is a nuclei phenomenon.
Radioactivity is not dependent on external conditions like temperature, pressure etc.
Radioactivity of a substance is independent to its physical state.
x(s), x(l), x(g), $(x)^+(g)$, $(x)^-(g)$ in all form, x is radioactive.
$^{14}CO_2$, $^{14}{}_6C(s)$, $^{14}{}_6C(g)$ is radioactive.



Radiations :

α : $_2He^4$ ($_2{}^4He^{2+}$) (nucleus of He-atom)
β or β^- : $_{-1}e^0$ (fast moving electron emitted from nucleus)
γ : $_0\gamma^0$ (electromagnetic radiation (waves) of high frequency)
speed : $\gamma > \beta > \alpha$
penetrating power : $\gamma > \beta > \alpha$
ionisation power : $\alpha > \beta > \gamma$

	Emission of rays	Usual condition	Effect	Process representation / example
1.	α	$Z > 83$	n/p ratio increases	$_ZX^A \rightarrow {}_{Z-2}X'^{A-4} + {}_2He^4$ $_{92}U^{238} \rightarrow {}_{90}Th^{234} + {}_2He^4$
2.	β	If $\frac{n}{p}$ ratio is high.	$\frac{n}{p}$ ratio decreases	$_ZY^A \rightarrow {}_{Z+1}Y^A + {}_{-1}e^0$
	eg.	$_6C^{12}$ (stable) $\frac{n}{p} = \frac{6}{6}$		$_6C^{14} \rightarrow {}_7N^{14} + {}_{-1}e^0$
		$_6C^{14}$ (radioactive) $\frac{n}{p} = \frac{8}{6}$ (high)		$\frac{n}{p} = \frac{8}{6}$ $\frac{n}{p} = \frac{7}{7}$
	eg.	$_{11}Na^{24}$ (radioactive) $\frac{n}{p} = \frac{13}{11}$ (high)		$_0n^1 \rightarrow {}_1p^1 + {}_{-1}e^0$ (from nucleus)
		$_{11}Na^{23}$ (stable) $\frac{n}{p} = \frac{12}{11}$		
		$_{11}Na^{22}$ $\frac{n}{p} = \frac{11}{11}$ ($\frac{n}{p}$ ratio low)		
3.	γ	If nucleus energy level is high	nucleus energy level decreases	$_{43}Tc^{99} \rightarrow {}_{43}Tc^{99} + \gamma$ high nucleus energy (metastable) → low nucleus energy

4. **(a)** Positron emission ($_{+1}e^0$) — If $\frac{n}{p}$ ratio is low — $\frac{n}{p}$ ratio increases

$_ZY^A \rightarrow _{Z-1}Y'^A + _{+1}e^0$

$_{11}Na^{22} \rightarrow _{10}Ne^{22} + _{+1}e^0$

$_1p^1 \rightarrow _0n^1 + _{+1}e^0$ (from nucleus)

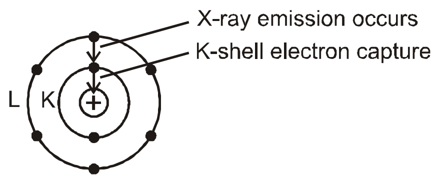
(b) Electron capture (EC) or K-shell — If $\frac{n}{p}$ ratio is low — $\frac{n}{p}$ ratio increases

$_ZX'^A + \underset{\text{K-shell}}{_{-1}e^0} \rightarrow _{Z-1}X''^A$

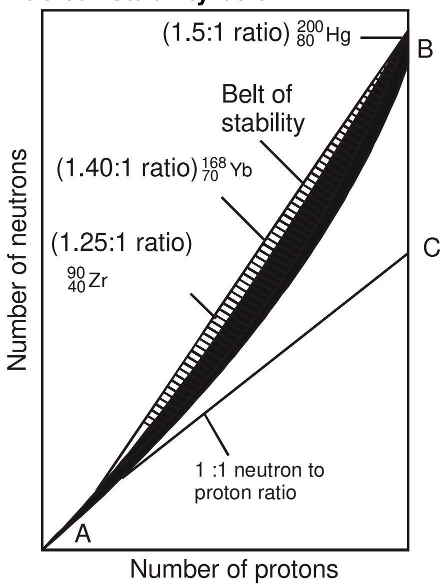
$_{80}Hg^{197} + _{-1}e^0 \rightarrow _{79}Au^{197}$

Electron capture

$$\boxed{_1p^1 + \underset{\text{(K – shell)}}{_{-1}e^0} \longrightarrow _0n^1}$$



Nuclear stability belt :



β-emission

$_0n^1 \rightarrow _1p^1 + _{-1}e^0$

* Z upto 20 : nuclei stable with n/p ratio nearly 1 : 1
* Z > 20 : n/p ratio increases with Z in stable nuclei region.
* More number of neutrons are required to reduce repulsion between protons.
* $_{83}Bi^{209}$: Stable with largest n/p ratio

$$\frac{n}{p} = \frac{1.52}{1}$$

Even-odd rule :

no. of n	no. of p	no. of stable nuclei
even	even	155 (max)
even	odd	55
odd	even	50
odd	odd	5 (min)

* Expected pairing of nucleus

Magic Numbers :

Nuclei in which nucleons have magic no. (2, 8, 20, 28, 50 ....) are more stable.

e.g. $_2He^4$, $_8O^{16}$

Group displacement law : (Given by Soddy and Fajan)

* When 1α emission takes place from a nuclei, new formed nuclei occupy two position left in periodic table.
* When 1β emission takes place from a nuclei, new formed nuclei occupy one position right in periodic table.

Due to emission of 1β particle; isobars are formed.
Due to emission of 1α particle; isodiaphers are formed.
Due to emission of 1α and 2β ; isotopes are formed.

Isotopes :	same number of proton	eg. $_6C^{14}$ and $_6C^{12}$
Isobars :	same mass number	eg. $_6C^{14}$ and $_7N^{14}$
Isotones :	same number of neutron	eg. $_2He^4$ and $_1H^3$

D31 **Isodiaphers :** Same (n – p) difference
e.g. $_9F^{19}$ and $_{19}K^{39}$; (n – p) = 10

D32 **Isosters :** Same number of atoms and electrons
e.g. N_2 and CO
N_2O and CO_2

Artifical nuclear reaction :

(α , p)
striking particle ← → emitted particle

* specific nuclei + stricking particle $\longrightarrow$ New nuclei + emitted particle

eg.

1.	(α, p type)	$_7N^{14}$	+	$_2He^4$ (s.p.)	$\longrightarrow$	$_8O^{17}$	+	$_1p^1$ (e.p.)	(or $_1H^1$)
2.	(n, γ type)	$_{11}N^{23}$	+	$_1n^0$	$\longrightarrow$	$_{11}Na^{24}$	+	γ	
3.	(D, p type)	$_{13}Al^{27}$	+	$_1H^2$	$\longrightarrow$	$_{13}Al^{28}$	+	$_1H^1$	
4.	(p, α type)	$_3Li^7$	+	$_1H^1$	$\longrightarrow$	$_2He^4$	+	$_2He^4$	

Nuclear fission and nuclear fusion:
In both processes, large amount of heat evolved due to conversion of some mass into energy.

D33 **Nuclear fission:** Is a process where heavy nuclei splits into large nuclei.

$$_{92}U^{235} + {_0n^1} \longrightarrow {_{92}U^{*236}} \longrightarrow \text{various nuclie and neutrons}$$

eg. atom bomb is based on fission.

D34 **Nuclear fusion :**
Is a process where light nuclei fused together to form heavy nuclei.

$$_1H^2 + {_1H^3} \longrightarrow {_2He^4} + {_0n^1}$$
$$_1H^2 + {_1H^2} \longrightarrow {_2He^4}$$

Hydrogen bomb is based on fusion. Very high temperature is required in this process.

Solved Examples

Example-15 ^{23}Na is the most stable isotope of Na. Find out the process by which $^{24}_{11}Na$ can undergo radioactive decay.

Solution. n/p ratio of ^{24}Na is 13/11 and thus greater than one. It will therefore decay following β-emission.

$$^{24}_{11}Na \longrightarrow {^{24}_{12}Mg} + {^{0}_{-1}e}$$

Example-16 The number of β-particle emitted during the change ${}^{c}_{a}X \longrightarrow {}^{b}_{d}Y$ is :

(A) $\frac{a-b}{4}$ (B) $d+\left(\frac{a-b}{2}\right)+c$ (C) $d+\left(\frac{c-b}{2}\right)-a$ (D) $d+\left(\frac{a-b}{2}\right)-c$

Solution. ${}^{c}_{a}X \longrightarrow {}^{b}_{d}Y + m\,{}^{4}_{2}He + n\,{}^{0}_{-1}e$

$\therefore$ $c = b + 4m$ ......(i)

and $a = d + 2m - n$ ......(ii)

by (i) & (ii)

$n = d + \left(\frac{c-b}{2}\right) - a$. **Ans. (C)**

Example-17 The decay product of ${}^{13}_{7}N$ is :

(A) ${}^{13}_{8}O + {}^{0}_{-1}e$ (B) ${}^{13}_{6}C + {}^{0}_{+1}e$

(C) ${}^{13}_{6}C$ + K electron capture (D) ${}^{9}_{5}Be + {}^{4}_{2}He$

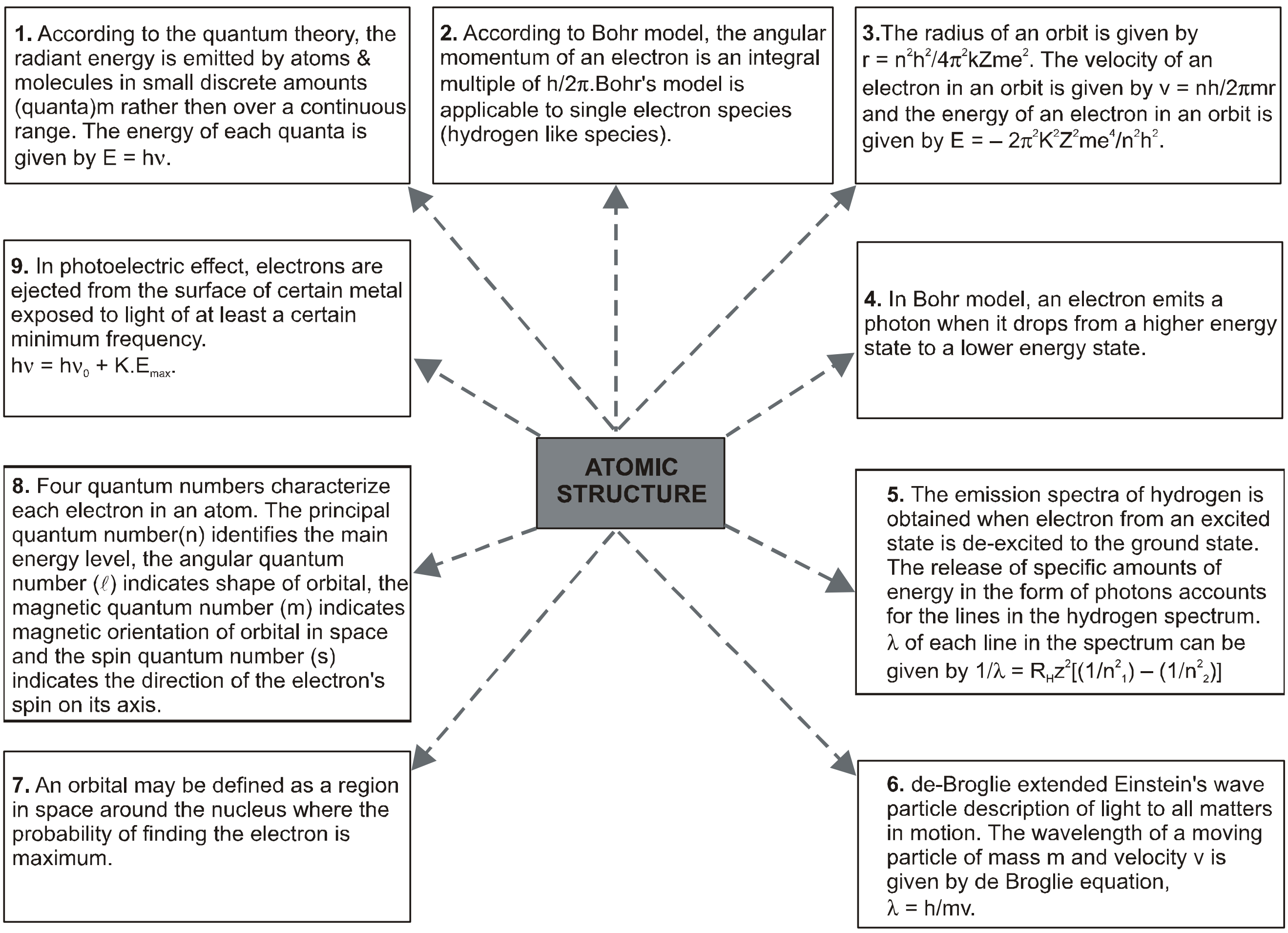
Solution. ${}^{13}_{7}N$ is positron emitter ; $\frac{n}{p}$ ratio is low. **Ans. (B)**

Example-18 A radioactive element X has an atomic numbers of 100. It decays directly into an element Y which decays directly into an element Z. In both processes a charged particle is emitted. Which of the following statement would be true?

(A) Y has an atomic number of 102. (B) Z has an atomic number of 101.

(C) Z has an atomic number of 97. (D) Z has an atomic number of 99.

Solution. X and Y can decay one α each or one β each or X-decays, 1 α, Y-decays 1 β or X-decays 1 β or Y-decays 1 α. In either case (A), (B) and (C) cannot be true. **Ans. (D)**



MISCELLANEOUS SOLVED PROBLEMS (MSPs)

1. The ratio of ($E_2 - E_1$) to ($E_4 - E_3$) for He^+ ion is approximately equal to (where E_n is the energy of n^{th} orbit)

(A) 10 (B) 15 (C) 17 (D) 12

Sol. $$\frac{13.6\ (2)^2\left[\frac{1}{(1)^2}-\frac{1}{(2)^2}\right]}{13.6\ (2)^2\left[\frac{1}{(3)^2}-\frac{1}{(4)^2}\right]} = 15$$ **Ans. (B)**

2. If the binding energy of 2^{nd} excited state of a hydrogen like sample is 24 eV approximately, then the ionisation energy of the sample is approximately

(A) 54.4 eV (B) 24 eV (C) 122.4 eV (D) 216 eV

Sol. $\frac{13.6(Z)^2}{(3)^2} = 24$

I.E. = $13.6(Z)^2 = (24 \times 9) = 216$ eV **Ans. (D)**

3. The ionisation energy of H atom is 21.79×10^{-19} J. Then the value of binding energy of second excited state of Li^{2+} ion

(A) $3^2 \times 21.7 \times 10^{-19}$ J (B) 21.79×10^{-19} J

(C) $\frac{1}{3} \times 21.79 \times 10^{-19}$ J (D) $\frac{1}{3^2} \times 21.79 \times 10^{-19}$ J

Sol. B.E. = $\frac{21.79 \times 10^{-19}(3)^2}{(3)^2} = 21.79 \times 10^{-19}$ J **Ans. (B)**

4. The wave number of the first line in the Balmer series of hydrogen is 15200cm^{-1}. What would be the wavenumber of the first line in the Lyman series of the Be^{3+} ion?

(A) 2.4 x 10^5cm^{-1} (B) 24.3 x 10^5cm^{-1} (C) 6.08 x 10^5cm^{-1} (D) 1.313 x 10^6 cm^{-1}

Sol. Given $15200 = R(1)^2\left[\frac{1}{(2)^2}-\frac{1}{(3)^2}\right]$ ..... (1)

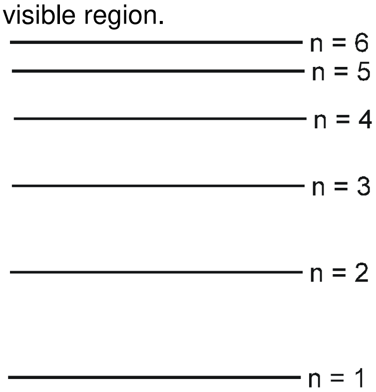
Then $\bar{\nu} = R(4)^2\left[\frac{1}{(1)^2}-\frac{1}{(2)^2}\right]$ ..... (2)

from (1) and (2) equation

$\bar{\nu} = 1.313 \times 10^6$ cm^{-1} **Ans. (D)**

5. What would be the maximum number of emission lines for atomic hydrogen that you would expect to see with the naked eye if the only electronic energy levels involved are those as shown in the Figure?

Hint: Balmer series lines lies in visible region.



(A) 4 (B) 6 (C) 5 (D) 15

Sol. Only four lines are present in visible region, $6 \rightarrow 2$, $5 \rightarrow 2$, $4 \rightarrow 2$ & $3 \rightarrow 2$.

Ans. (A)

6. The de Brogile wavelength of an electron moving in a circular orbit is λ. The minimum radius of orbit is

(A) $\frac{\lambda}{\pi}$ (B) $\frac{\lambda}{2\pi}$ (C) $\frac{\lambda}{4\pi}$ (D) $\frac{\lambda}{3\pi}$

Sol. We know, $2\pi r = n\lambda$

For minimum radius n = 1

$2\pi r_{min} = \lambda$

$r_{min} = \frac{\lambda}{2\pi}$ **Ans. (B)**

7. Uncertainty in position of a hypothetical subatomic particle is 1Å and uncertainty in velocity is $\frac{3.3}{4\pi} \times 10^5$ m/s then the mass of the particle is approximately [h = 6.6×10^{-34} Js]

(A) 2×10^{-28} kg (B) 2×10^{-27} kg (C) 2×10^{-29} kg (D) 4×10^{-29} kg

Sol. $\Delta x \times m \times \Delta v \geq h/4\pi$

$1 \times 10^{-10} \times m \times \frac{3.3}{4\pi} \times 10^5 \geq \frac{6.6 \times 10^{-34}}{4 \times \pi}$ m = 2×10^{-29} kg **Ans. (C)**

8. Which of the following set of quantum numbers is not valid.

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

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

Sol. Not valid **Ans. (D)**

9. What is the total spin value in case of $_{26}Fe^{3+}$ ion.

(A) +1 or –1 (B) +2 or –2 (C) + 2.5 or – 2.5 (D) +3 or –3

Sol. Total spin = no. of unpaired e^- $\times \left(\pm\frac{1}{2}\right) = 5 \times \left(\pm\frac{1}{2}\right) = \pm\frac{5}{2}$

Ans. (C)

CHECK LIST

Definitions (D)

D1 Atomic number (Z) of an element ☐
D2 Isotopes ☐
D3 Isobars ☐
D4 Isotones ☐
D5 Isoelectronic ☐
D6 Electromagnetic wave radiation ☐
D7 Wavelength ☐
D8 Frequency ☐
D9 Velocity ☐
D10 Amplitude ☐
D11 Wave number ☐
D12 Quantum of light ☐
D13 One electron volt (e.v.) ☐
D14 Photoelectric Effect ☐
D15 Ground state ☐
D16 Excited State ☐
D17 Ionisation energy (IE) ☐
D18 Ionisation Potential (I.P.) ☐
D19 Excitation Energy ☐
D20 Excitation Potential ☐
D21 Binding Energy 'or' Separation Energy ☐
D22 Spectroscopy ☐
D23 Emission spectra ☐
D24 Continuous spectra ☐
D25 Line spectrum ☐
D26 Absorption spectra ☐
D27 Emission spectrum of Hydrogen ☐
D28 Orbital ☐
D29 Quantum Numbers ☐
D30 Radioactivity ☐
D31 Isodiaphers ☐
D32 Isosters ☐
D33 Nuclear fission ☐
D34 Nuclear fusion ☐

Formule (F)

F1 Quantization of charge ☐
F2 Potential energy of two point charges ☐
F3 Size of nucleus ☐
F4 Mass number of an element ☐
F5 Wave number ☐
F6 Energy of emf waves ☐
F7 Speed of light ☐
F8 Energy in terms of wavelength (λ) ☐
F9 Photoelectric effect ☐
F10 Centripetal force ☐
F11 Angular momentum of a Bohr orbit ☐
F12 Photo energy ☐
F13 Frequency ☐
F14 Radius of Bohr orbit ☐
F15 Radius of Bohr orbit in term of calculation. ☐
F16 Velocity of electron in Bohr orbit (expanded) ☐
F17 Velocity of electron in Bohr orbit ☐
F18 Time period of a Bohr orbit ☐
F19 Frequency in a Bohr orbit ☐
F20 Total energy of a Bohr orbit ☐
F21 Total energy of in eV/atom ☐
F22 Total energy of in J/atom ☐
F23 Relation between total energy and potential energy ☐
F24 Relation between total energy and kinetic energy ☐
F25 Wave number
F26 Number of spectral lines ☐
F27 Single isolated atom maximum number of spectral lines ☐
F28 de-Broglie Wavelength in form of velocity ☐
F29 de-Broglie Wavelength in term of kinetic energy ☐
F30 de-broglies in terms of voltage ☐
F31 Heisenberg principle ☐
F32 Heisenberg in terms of ΔE & ΔT ☐
F33 Schordinger's equation ☐
F34 Radial nodes ☐
F35 Angular nodes ☐
F36 Total nodes ☐
F37 Number of subshell present in n^{th} shell ☐
F38 Number of orbitals present in n^{th} shell ☐
F39 The maximum number of electrons in a principal energy shell ☐
F40 Angular momentum of any orbit ☐
F41 Number of orbitals in a subshell ☐
F42 Maximum number of electrons in particular subshell ☐
F43 Angular orbital momentum ☐
F44 Orbitals present in a main energy level is 'n^2'. ☐
F45 Magnetic moment ☐
F46 Spin angular momentum ☐
F47 Maximum spin of atom ☐

Derivations (Der.)

Der1 Distance of closest approach ☐
Der2 Value of one electron volt ☐
Der3 Calculation of the radius of the Bohr's orbit ☐
Der4 Calculation of velocity of an electron in Bohr's orbit ☐
Der5 Calculation of energy of an electron ☐
Der6 Wave number ☐
Der7 de-Broglie wavelength ☐
Der8 de-Broglie wavelength in relation to voltage ☐
Der9 Heisenberg principle In terms of uncertainty in energy ΔE & Δt ☐

Exercise-1

Marked questions are recommended for Revision.

PART - I : SUBJECTIVE QUESTIONS

Section (A) : Discovery of sub atomic particles, Atomic models, nucleus

Commit to memory :

Q = ne (charge is quantized)

$$P.E. = \frac{1}{4\pi\varepsilon_0}\frac{q_1q_2}{r}$$

Mass number of an element = No. of protons (Z) + No. of neutrons (n).

$$\text{Closest distance } (r) = \frac{4KZe^2}{m_\alpha v_\alpha^2}$$

A-1. Complete the following table :

Particle	Atomic No.	Mass No.	No. of electrons	No. of protons	No. of neutrons
Sodium atom	11	---	---	---	12
Aluminium ion	---	27	10	---	---
Chloride ion	---	---	18	---	18
Phosphorus atom	---	31	---	15	---
Cuprous ion	---	---	28	---	35

A-2. If radius of the nucleus is 3.5×10^{-15} m then find the space or volume occupied by the nucleus.

A-3. The approximate radius of a H-atom is 0.05 nm, and that of proton is 1.5×10^{-15} m. Assuming both the hydrogen atom and the proton to be spherical, calculate fraction of the space in an atom of hydrogen that is occupied by the nucleus.

A-4. (A) Find the radius of nucleus of an atom having atomic mass number equal to 125. (Take $R_0=1.3\times10^{-15}$ m)
(B) Find the distance of closest approch when an α particle is projected towards the nucleus of silver atom having speed v. (mass of α particle = m_α, atomic number of Ag = 47)

A-5. Write the conclusions of observations of Rutherford's experiment.

Section (B) : Quantum theory of light & Photoelectric Effect

Commit to memory :

Q = ne (charge is quantized)

$$\bar{\nu} = \frac{1}{\lambda}$$

$$v = \nu \times \lambda$$

$E_0 = h\nu$ (ν - Frequency of light)

$E_0 = \dfrac{hc}{\lambda}$ (c - speed of light)

$$h\nu = h\nu_0 + \frac{1}{2}m_e v^2$$

B-1. Calculate the energy of 100 photons if the wavelength of the light is 2000Å.

B-2. How many photons are emitted per second by a 5 mW laser operating at 620 nm?

B-3. The Vividh Bharati Station of All India Radio, Delhi broadcasts on a frequency of 1368 kHz (kilo hertz). Calculate the wavelength and wave number of the electromagnetic radiation emitted by the transmitter.

B-4. One quantum is absorbed per gaseous molecule of Br_2 for converting into Br atoms. If light absorbed has wavelength 5000 Å, calculate energy required in kJ/mol.

B-5. The eyes of a certain member of the reptile family pass a 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? ($h = 6.6 \times 10^{-34}$)

B-6. Two bulbs 'A' and 'B' emit red light and yellow light at 8000 Å and 4000Å respectively. The number of photons emitted by both the bulbs per second is the same. If the red bulb is labelled as 100 watts, find the wattage of the yellow bulb.

B-7. If a light with frequency 4×10^{16} Hz emitted photoelectrons with double the maximum kinetic energy as are emitted by the light of frequency 2.5×10^{16} Hz from the same metal surface, then what is the threshold frequency (ν_0) of the metal ?

Section (C) : Bohr Model

Commit to memory :

- $\frac{mv^2}{r} = \frac{Ke^2Z}{r^2}$
- $mvr = \frac{nh}{2\pi}$
- $\frac{hc}{\lambda} = \Delta E$
- $\upsilon = \frac{\Delta E}{h}$
- $r = \frac{n^2h^2}{4\pi^2 mKZe^2}$
- $r_n = 0.529 \times \frac{n^2}{Z}$ Å
- $v = \frac{2\pi Ze^2K}{nh}$
- $v_n = 2.18 \times 10^6 \times \frac{Z}{n}$ m/sec
- $T = \frac{2\pi r}{v}$
- $f = \frac{v}{2\pi r}$
- T.E. = $E_n = -\frac{2\pi^2 me^4k^2}{h^2}\left(\frac{z^2}{n^2}\right)$
- $E_n = -13.6 \frac{Z^2}{n^2}$ eV/atom
- $E_n = -2.18 \times 10^{-18} \frac{Z^2}{n^2}$ J/atom
- T.E. = $\frac{1}{2}$ P.E.
- T.E. = – K.E.

C-1. Which state of the triply ionized Beryllium (Be^{3+}) has the same orbit radius as that of the ground state of hydrogen atom ?

C-2. If the velocity of the electron in first orbit of H atom is 2.18×10^6 m/s, what is its value in third orbit ?

C-3. Consider Bohr's theory for hydrogen atom. The magnitude of angular momentum, orbit radius and velocity of the electron in n^{th} energy state in a hydrogen atom are ℓ, r & v respectively. Find out the value of 'x', if product of v, r and ℓ ($vr\ell$) is directly proportional to n^x.

C-4. Find the ratio of the time period of 2^{nd} Bohr orbit of He^+ amd 4^{th} Bohr orbit of Li^{2+}.

C-5. Consider three electron jumps described below for the hydrogen atom

x : n = 3 to n = 1
y : n = 4 to n = 2
z : n = 5 to n = 3

The photon emitted in which transition x, y or z will have shortest wavelength.

C-6. A hydrogen sample is prepared in a particular excited state. Photons of energy 2.55 eV get absorbed into the sample to take some of the electrons to a further excited state B. Find orbit numbers of the states A and B. Given the allowed energies of hydrogen atom :

$E_1 = -13.6$ eV, $E_2 = -3.4$ eV, $E_3 = -1.5$ eV, $E_4 = -0.85$ eV, $E_5 = -0.54$ eV

C-7. A single electron ion has nuclear charge + Ze where Z is atomic number and e is electronic charge. It requires 16.52 eV to excite the electron from the second Bohr orbit to third Bohr orbit. Find
(a) The atomic number of element?
(b) The energy required for transition of electron from first to third orbit?
(c) Wavelength of photon required to remove electron from first Bohr orbit to infinity?
(d) The kinetic energy of electron in first Bohr orbit?

C-8. The excitation energy of first excited state of a hydrogen like atom is 40.8 eV. Find the energy needed to remove the electron to form the ion.

Section (D) : Spectrum

Commit to memory :

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

  R = Rydberg constant = $1.09678 \times 10^7\ m^{-1}$
- Number of different line produce = $\frac{\Delta n\ \ (\Delta n + 1)}{2}$, where $\Delta n = n_2 - n_1$

  n_2 = higher energy orbit, n_1 = lower energy orbit
- For single isolated atom max. number of spectral lines observed = (n – 1)

D-1. Calculate the two longest wavelengths of the radiation emitted when hydrogen atoms make transitions from higher states to n = 2 state.

D-2. What electron transition in the He^+ spectrum would have the same wavelength as the first Lyman transition of hydrogen?

D-3. Calculate the frequency of light emitted for an electron transition from the sixth to second orbit of the hydrogen atom. In what region of the spectrum does this light occur?

D-4. At what atomic number would a transition from n = 2 to n = 1 energy level result in emission of photon of $\lambda = 3 \times 10^{-8}$ m.

D-5. In a container a mixture is prepared by mixing of three samples of hydrogen, helium ion (He^+) and lithium ion (Li^{2+}). In sample all the hydrogen atoms are in 1st excited state and all the He^+ ions are in third excited state and all the Li^{2+} ions are in fifth excited state. Find the total number of spectral lines observed in the emission spectrum of such a sample, when the electrons return back upto the ground state.

Section (E) : De-broglie wavelength and Heisenberg uncertainity principle

Commit to memory

- $\lambda = \frac{h}{mv}$
- $\lambda = \frac{h}{\sqrt{2emV}}$
- $\lambda = \frac{12.3}{\sqrt{V}}$ Å
- $\Delta x\ .\ \Delta p \geq \frac{h}{4\pi}$ or $\Delta x.(m\Delta v) \geq \frac{h}{4\pi}$
- $\Delta E.\Delta t \geq \frac{h}{4\pi}$.

E-1. An electron in a H-atom in its ground state absorbs 1.5 times as much energy as the minimum required for its escape (13.6 eV) from the atom. What is wavelength of the emitted electron.

E-2. Deduce the condition when the De-Broglie wavelength associated with an electron would be equal to that associated with a proton if a proton is 1836 times heavier than an electron.

E-3. An electron, practically at rest, is initially accelerated through a potential difference of 100 volts. It then has a de Broglie wavelength = λ_1 Å. It then get retarded through 19 volts and then has a wavelength λ_2 Å. A further retardation through 32 volts changes the wavelength to λ_3Å, What is $\frac{\lambda_3 - \lambda_2}{\lambda_1}$?

E-4. If an electron having kinetic energy 2 eV is accelerated through the potential difference of 2 Volt. Then calculate the wavelength associated with the electron.

E-5. The uncertainty in position and velocity of the particle are 0.1 nm and 5.27×10^{-24} ms^{-1} respectively then find the mass of the particle. ($h = 6.625 \times 10^{-34}$Js)

Section (F) : Quantum mechanical model of atom, Shrodinger wave equation and orbital concept

Commit to memory :

- $\frac{\delta^2\psi}{\delta x^2} + \frac{\delta^2\psi}{\delta y^2} + \frac{\delta^2\psi}{\delta z^2} + \frac{8\pi^2 m}{h^2}(E - V)\,\psi = 0$
- Radial nodes = $n - \ell - 1$,
- Angular nodes = ℓ,
- Total nodes = $n - 1$

F-1. Find : (a) The number of radial nodes of 5s atomic orbital
(b) The number of angular nodes of $3d_{yz}$ atomic orbital
(c) The sum of angular nodes and radial nodes of $4d_{xy}$ atomic orbital
(d) The number of angular nodes of 3p atomic orbital

F-2. An electron in a hydrogen atom finds itself in the fourth energy level.
(i) Write down a list of the orbitals that it might be in.
(ii) Can it be in all of these orbitals at once ?
(iii) Can you tell which orbital it is in ?

Section (G) : Quantum numbers & Electronic configuration

Commit to memory :

- Number of subshell present in n^{th} shell = n
- Number of orbitals present in n^{th} shell = n^2.
- The maximum number of electrons in a principal energy shell = $2n^2$.
- Angular momentum of any orbit = $\frac{nh}{2\pi}$
- Number of orbitals in a subshell = $2\ell + 1$
- Maximum number of electrons in particular subshell = $2 \times (2\ell + 1)$
- $L = \frac{h}{2\pi}\sqrt{\ell(\ell+1)} = \hbar\sqrt{\ell(\ell+1)}$ $\left[\hbar = \frac{h}{2\pi}\right]$
- Orbitals present in a main energy level is 'n^2'.
- $\mu = \sqrt{n(n+2)}$ B.M.
- Spin angular momentum = $\frac{h}{2\pi}\sqrt{s(s+1)}$
- Maximum spin of atom = $\frac{1}{2}$ × No. of unpaired electron.

G-1. How many unpaired electrons are there in Ni^{+2} ion if the atomic number of Ni is 28.

G-2. Write the electronic configuration of the element having atomic number 56.

G-3. Given below are the sets of quantum numbers for given orbitals. Name these orbitals.

(a)	(b)	(c)	(d)	(e)
n = 3	n = 5	n = 4	n = 2	n = 4
ℓ = 1	ℓ = 2	ℓ = 1	ℓ = 0	ℓ = 2

G-4. Point out the angular momentum of an electron in,
(a) 4s orbital (b) 3p orbital (c) 4^{th} orbit (according to Bohr model)

G-5. Which of the following sets of quantum numbers are impossible for electrons? Explain why in each case.

Set	n	ℓ	m	s
(i)	1	0	1	$+\frac{1}{2}$
(ii)	3	0	0	$-\frac{1}{2}$
(iii)	1	2	2	$+\frac{1}{2}$
(iv)	4	3	–3	$+\frac{1}{2}$
(v)	5	2	1	$-\frac{1}{2}$
(v)	3	2	1	0

G-6. Find the total spin and spin magnetic moment of following ion.
(i) Fe^{+3} (ii) Cu^{+}

Section (H) : Nuclear chemistry

Commit to memory :
- α : $_2He^4$ ($_2{}^4He^{2+}$) (nucleus of He-atom)
- β or β^- : $_{-1}e^0$ (fast moving electron emitted from nucleus)
- γ : $_0\gamma^0$ (electromagnetic radiation (waves) of high frequency)
- $\Delta E = \Delta m \times 931.478$ MeV

H-1. Calculate the loss in mass during the change:

$$^{7}_{3}Li + ^{1}_{1}H \longrightarrow 2\,^{4}_{2}He + 17.25\text{ MeV}$$

H-2. When ^{24}Mg is bombarded with neutron then a proton is ejected. Complete the equation and report the new element formed.

H-3. Write equations for the following transformation :
(a) $^{14}_{7}N$ (n, p) (b) $^{39}_{19}K$ (n, α)

H-4. Explain with reason the nature of emitted particle by :
(a) $^{38}_{20}Ca$ (b) $^{35}_{18}Ar$ (c) $^{80}_{32}Ge$ (d) $^{40}_{20}Ca$

H-5. For the given series reaction in n^{th} step, find out the number of produced neutrons & energy.

$$^{238}_{92}U \longrightarrow Ba + Kr + 3\,_0n^1 + \text{Energy (E)}$$

PART - II : ONLY ONE OPTION CORRECT TYPE

Section (A) : Discovery of sub atomic particles, Atomic models, nucleus

A-1. The element having no neutron in the nucleus of its atom is
(A) Hydrogen (B) Nitrogen (C) Helium (D) Boron

A-2. The mass of cathode ray particle is :
(A) Same for different gases (B) Different for different gases
(C) Minimum for H_2 gas (D) Different for same gases

A-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

A-4. Rutherford's alpha particle scattering experiment eventually led to the conclusion that
(A) mass and energy are related
(B) electrons occupy space around the nucleus
(C) neutrons are buried deep in the nucleus
(D) the point of impact with matter can be precisely determined

A-5. 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}

A-6. The approximate size of the nucleus of $^{64}_{28}Ni$ is :
(A) 3 fm (B) 4 fm (C) 5 fm (D) 2 fm

Section (B) : Quantum theory of light & Photoelectric Effect

B-1. 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

B-2. Photon of which light has maximum energy :
(A) red (B) blue (C) violet (D) green

B-3. 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

B-4. 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 ($1eV = 1.6 \times 10^{-19}$ J, hc = 12400 eV Å)
(A) 2×10^{18} (B) 10^{18} (C) 10^{21} (D) 2×10^{21}

B-5. 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) $\lambda \leq \lambda_0/2$

B-6. 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 $(h\nu - w)$

Section (C) : Bohr Model

C-1. 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) $He^+ > H > Li^{2+} > Be^{3+}$

C-2. 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

C-3. 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

C-4. 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

C-5. 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) $6 \rightarrow 5$

C-6. 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)

C-7. **S_1 :** Potential energy of the two opposite charge system increases with the decrease in distance.
S_2 : When an electron make transition from higher orbit to lower orbit it's kinetic energy increases.
S_3 : When an electron make transtition from lower energy to higher energy state its potential energy increases.
S_4 : 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

Section (D) : Spectrum

D-1. 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

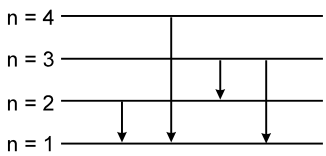
D-2. The wavelength of a spectral line for an electronic transition is inversely proportional to :
(A) number of electrons undergoing transition
(B) the nuclear charge of the atom
(C) the velocity of an electron undergoing transition
(D) the difference in the energy involved in the transition

D-3. 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

D-4. 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)

D-5. 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

D-6. 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) $3 \rightarrow 2$

D-7. 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) $\frac{R}{4}$

Section (E) : De-broglie wavelength and Heisenberg uncertainity principle

E-1. 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

E-2. 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

E-3. 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) $\frac{x}{2}$

E-4. 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

E-5. 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

E-6. 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

E-7. 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

Section (F) : Quantum mechanical model of atom, Shrodinger wave equation and orbital concept

F-1. The correct time independent Schrödinger's wave equation for an electron with E as total energy and V as potential energy is :

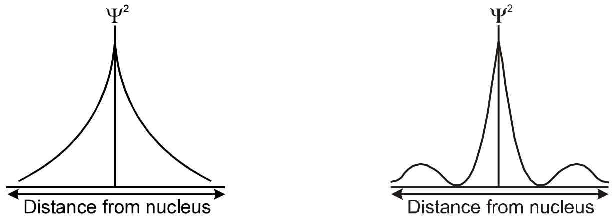
(A) $\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}+\frac{8\pi^2}{mh^2}(E-V)\psi=0$ (B) $\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}+\frac{8\pi m}{h^2}(E-V)\psi=0$

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

F-2. 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) $2r = \frac{r_0}{2}$

F-3. Consider following figure A and B indicating distribution of charge density (electron probability Ψ^2) with distance r.



(A) (B)

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

F-4. 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.

F-5. $3p_y$ orbital has..........nodal plane :

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

F-6. 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

F-7. According to Schrodinger model nature of electron in an atom is as :
(A) Particle only (B) Wave only
(C) Particle and wave nature simultaneous (D) Sometimes waves and sometimes particle

F-8. 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, XY is the nodal plane.
Which of these are incorrect statements:
(A) a & c (B) b & c (C) Only b (D) a, b

F-9. Which of the following d-orbitals has dough-nut shape ?
(A) d_{xy} (B) d_{yz} (C) $d_{x^2-y^2}$ (D) d_{z^2}

F-10. The permissible solution to the schrodinger wave equation gave an ideal of .... Quantum number
(A) 4 (B) 3 (C) 2 (D) 1

Section (G) : Quantum numbers & Electronic configuration

G-1. The orbital with zero orbital angular momentum is :
(A) s (B) p (C) d (D) f

G-2. 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) $[Ar] 3d^9$

G-3. 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

G-4. Which of the following ions has the maximum number of unpaired d-electrons?
(A) Zn^{2+} (B) Fe^{2+} (C) Ni^{3+} (D) Cu^{+}

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

G-6. 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

G-7. 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

G-8. 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) $\sqrt{2}\frac{h}{2\pi}$

G-9. 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

G-10. 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

Section (H) : Nuclear chemistry

H-1. $^{11}_{6}C$ on decay produces :

(A) Positron (B) β-particle (C) α-particle (D) none of these

H-2. $^{60}_{27}Co$ 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

H-3. 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) $\gamma < \beta < \alpha$

H-4. $^{27}_{13}Al$ is a stable isotope. $^{29}_{13}Al$ is expected to disintegrate by :

(A) α-emission (B) β-emission (C) positron emission (D) proton emission

H-5. Which of the following nuclear emission will generate an isotope :

(A) β-emission (B) neutron emission (C) α-emission (D) positron emission

H-6. 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

PART - III : MATCH THE COLUMN

1. **List-I** and **List-II** contains six entries each. Entries of **List-I** are to be matched with some entries of **List-II**.

	List-I		**List-II**
(i)	Cathode rays	(a)	Helium nuclei
(ii)	Dumb-bell	(b)	Uncertainty principle
(iii)	Alpha particles	(c)	Electromagnetic radiation
(iv)	Moseley	(d)	p-orbital
(v)	Heisenberg	(e)	Atomic number
(vi)	X-rays	(f)	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

	List-I		**List-II**
(i)	f	(p)	n^3
(ii)	T	(q)	Z^2
(iii)	E_n	(r)	$\frac{1}{n^2}$
(iv)	$\frac{1}{r_n}$	(s)	Z

3. **List-I** and **List-II** contains six entries each. Entries of **List-I** are to be matched with some entries of **List-II**.

	List-I		**List-II**
(i)	Aufbau principle	(p)	Line spectrum in visible region
(ii)	de broglie	(q)	Maximum multiplicity of electron
(iii)	Angular momentum	(r)	Photon
(iv)	Hund's rule	(s)	$\lambda = h/(mv)$
(v)	Balmer series	(t)	Electronic configuration
(vi)	Planck's law	(u)	mvr

4. 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)	(p)	0, 1, 2, ... (n - 1)
(B)	Values of ℓ for a particular type of orbit	(q)	$+\ell$ to $-\ell$ through zero
(C)	Number of value of m for $\ell = 2$	(r)	5
(D)	Values of 'm' for a particular type of orbital	(s)	n

Exercise-2

✍ **Marked questions are recommended for Revision.**

PART - I : ONLY ONE OPTION CORRECT TYPE

1. Which is not true with respect to cathode rays ?
(A) A stream of electrons (B) Charged particles
(C) Move with same speed as that of light (D) Can be deflected by electric field

2.✍ The mass to charge ratio (m/e) for a cation is 1.5×10^{-8} kg/C. What is the mass of this atom ?
(A) 2.4×10^{-19} g (B) 2.4×10^{-27} g (C) 2.4×10^{-24} g (D) None of these

3. An oil drop has 6.39×10^{-19} C charge. Find out the number of electrons in this oil drop.
(A) 2 (B) 4 (C) 6 (D) 8

4.✍ Which of the following statement is true in the context of photoelectic effect ?
(A) The kinetic energy of ejected electron is independent of the intensity of a radiation.
(B) The number of photoelectrons ejected depends upon the intensity of the incident radiation.
(C) The kinetic energy of the emitted electrons depends on the frequency of the incident radiation.
(D) All of these

5.✍ A light source of wavelength λ illuminates a metal and ejects photo-electrons with $(K.E.)_{max}$ = 1 eV
Another light source of wavelength $\frac{\lambda}{3}$, ejects photo-electrons from same metal with $(K.E.)_{max}$ = 4eV
Find the value of work function ?
(A) 1 eV (B) 2 eV (C) 0.5 eV (D) None of these

6.✍ 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

7.✍ 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

8. 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) $\frac{J^2}{2\pi}$

9.✍ The potential energy of the electron present in the ground state of Be^{3+} ion is represented by:
(A) $+\frac{e^2}{\pi \epsilon_0 r}$ (B) $-\frac{e}{\pi \epsilon_0 r}$ (C) $-\frac{e^2}{\pi \epsilon_0 r^2}$ (D) $-\frac{e^2}{\pi \epsilon_0 r}$

10.✍ The kinetic energy of the electron present in the ground state of Li^{2+} ion is represented by :
(A) $\frac{3e^2}{8\pi \epsilon_0 r}$ (B) $-\frac{3e^2}{8\pi \epsilon_0 r}$ (C) $\frac{3e^2}{4\pi \epsilon_0 r}$ (D) $-\frac{3e^2}{4\pi \epsilon_0 r}$

11. 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) $6 \rightarrow 2$

12. 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) $\upsilon_1 + \upsilon_2 = \upsilon_3$

13. 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

14. 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

15. 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

16. 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

17. The ratio of the de-broglie wavelength of a proton and α-particles will be 1 : 2 if their :
(A) velocity are in the ratio 1 : 8. (B) velocity are in the ratio 8 : 1.
(C) kinetic energy are in the ratio 1 : 64. (D) kinetic energy are in the ratio 1 : 256.

18. 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

19. 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) $\lambda = \sqrt{\frac{h}{m}}$

20. 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) $\frac{h}{4\pi}$

21. 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) $(13.6)\ \lambda$ (D) $n\lambda$

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

23. 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

24. In an atomic orbital, the sign of lobes indicates the :
(A) sign of the probability distribution (B) sign of charge
(C) sign of the wave function (D) presence or absence of electron

25. The correct set of four quantum numbers for the valence electron of Rubidium (Z = 37) is :

(A) n = 5, ℓ = 0, m = 0, s = $+\frac{1}{2}$ (B) n = 5, ℓ = 1, m = 0, s = $+\frac{1}{2}$

(C) n = 5, ℓ = 1, m = 1, s = $+\frac{1}{2}$ (D) n = 6, ℓ = 0, m = 0, s = $+\frac{1}{2}$

26. 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+}

27. 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, $\sqrt{20}\,\hbar$, $\sqrt{6}$

28. 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

29. 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) $\sum_{\ell=0}^{\ell=n-1} 2(2\ell+1)$

30. 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.

31. The number of α and β particles lost when $^{238}_{92}U$ changes to $^{206}_{82}Pb$:
(A) $8\alpha, 6\beta$ (B) $6\alpha, 6\beta$ (C) $6\alpha, 8\beta$ (D) $4\alpha, 4\beta$

PART - II : SINGLE AND DOUBLE VALUE INTEGER TYPE

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

2. Compare the energies of two radiation one with a wavelength of 300 nm and other with 600 nm.

3. The latent heat of fusion of ice is 330 J/g. Calculate the number of photons of radiation of frequency 5×10^{13} s^{-1} to cause the melting of 1 mole of ice. Take h = 6.6×10^{-34} J.S. Express your answer as X × 10^{22}, what is the value of 'X'.

4. The work function for a metal is 40 eV. To emit photo electrons of zero velocity from the surface of the metal the wavelength of incident light should be x nm.

5. Electrons in a sample of H-atoms make transition from state n = x to some lower excited state. The emission spectrum from the sample is found to contain only the lines belonging to a particular series. If one of the maximum energy photons has an energy of 0.6375 eV, find the value of x.

[Take 0.6375 eV = $\frac{3}{4} \times 0.85$ eV]

6. If first ionization potential of a hypothetical atom is 16 V, then the first excitation potential will be :

7. In hydrogen atom an orbit has a diameter of about 16.92Å. What is the maximum number of electrons that can be accommodated.

8. Electrons in the H-atoms jump from some higher level upto 3rd energy level. If six spectral lines are possible for the transition, find the initial position of electron.

9. 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 :

10. An electron in Li^{2+} ion makes a transition from higher state n_2 to lower state $n_1 = 6$. The emitted photons is used to ionize an electron in H–atom from 2nd excited state. The electron on leaving the H–atom has a de–Broglie wavelength $\lambda = 12.016$ Å. Find the value of n_2.

Note : Use $(12.016)^2 = \frac{150 \times 144}{13.6 \times 11}$, $\lambda_{Å} = \sqrt{\frac{150}{KE_{eV}}}$.

11. The radial distribution curve of 2s sublevel consists of x nodes, Find out value of x.

12. The wave function of atomic orbital of H like atoms is given as under

$$\psi_{2s} = \frac{1}{4\sqrt{2\pi}} z^{3/2} [2 - Zr]e^{Zr/2}$$

Given that the radius is in Å, then which of the following is radius for nodal surface for He^+ ion ?

13. How many of these orbitals have maximum orbital angular probability distribution is maximum at an angle of 45° to the axial direction.
d_{xy}, $d_{x^2-y^2}$, d_{yz}, d_{xz}, d_{z^2} , P_x, P_y, P_z, s

14. Total number of electrons having $n + \ell = 3$ in Cr (24) atom in its ground state is :

15. An ion Mn^{a+} has the spin magnetic moment equal to 4.9 BM. The value of a is : (atomic no. of Mn = 25)

16. The number of neutrons accompanying the formation of $^{139}_{54}Xe$ and $^{94}_{38}Sr$ from the absorption of a slow neutron by followed by nuclear fision is :

PART - III : ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

1. Isotone of $^{76}_{32}Ge$ is/are :
(A) $^{77}_{32}Ge$ (B) $^{77}_{33}As$ (C) $^{77}_{34}Se$ (D) $^{78}_{34}Se$

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

3. 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

4. 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

5. 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) wave number of the light is 3×10^6 m^{-1}.
(D) energy of the photon is approximately 2.07 eV.

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

7. Choose the correct relations on the basis of Bohr's theory.
(A) Velocity of electron $\propto \frac{1}{n}$
(B) Frequency of revolution $\propto \frac{1}{n^3}$
(C) Radius of orbit $\propto n^2 Z$
(D) Electrostatic force on electron $\propto \frac{1}{n^4}$

8. 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 $\frac{32 \times 8}{9}$ V

9. 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) $n = 2 \rightarrow n = 1$

10. 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.

11. 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) $\frac{h}{8\pi}$

12. 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

13. 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.

14. 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

15. 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) $S = \pm\frac{1}{2} \times \frac{h}{2\pi}$

16. 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 negative values.
(C) In silver atom, 23 electrons have a spin of one type and 24 of the opposite type. (Atomic number of Ag = 47)
(D) None of these

17. The configuration [Ar] $3d^{10}\,4s^2\,4p^4$ is similar to that of
(A) boron (B) oxygen (C) sulphur (D) aluminium

18. Which consists of charged particles of matter?
(A) α-particle (B) β-particle (C) γ-rays (D) Anode rays

19. Which of the following does not occur ?
(A) $^{40}_{20}Ca + ^{1}_{0}n \rightarrow ^{40}_{19}K + ^{1}_{1}H$ (B) $^{24}_{12}Mg + ^{4}_{2}He \rightarrow ^{27}_{14}Si + ^{1}_{0}n$
(C) $^{113}_{48}Cd + ^{1}_{0}n \rightarrow ^{112}_{48}Cd + ^{0}_{-1}e$ (D) $^{43}_{20}Ca + ^{4}_{2}He \rightarrow ^{46}_{21}Sc + ^{1}_{1}H$

20. 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 proportion of proton.
(D) Positrons and electrons quickly unite to produce photons.

PART - IV : COMPREHENSION

Read the following passage carefully and answer the questions.

Comprehension # 1

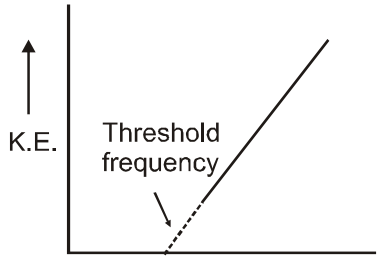
In the photoelectric effect the electrons are emitted instantaneously from a given metal plate, when it is irradiated with radiation of frequency equal to or greater than some minimum frequency, called the threshold frequency. According to planck's idea, light may be considered to be made up of discrete particles called photons. Each photon carries energy equal to $h\nu$. 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. $h\nu_0 = PE$

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

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



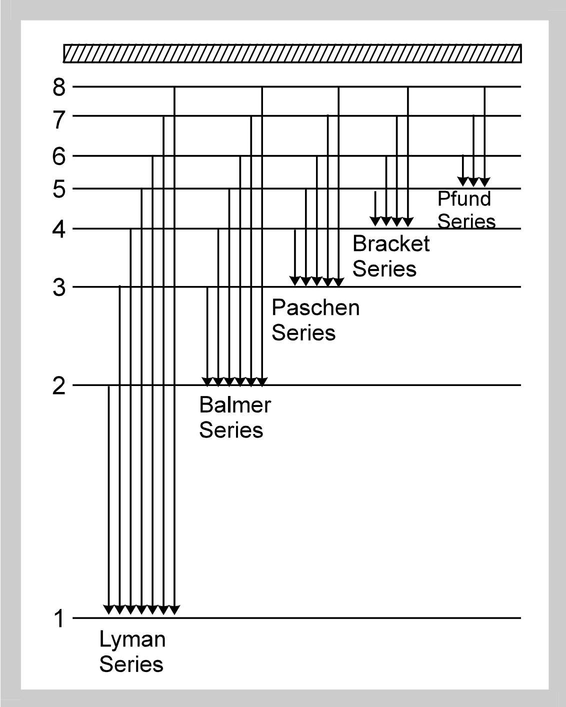
1. A beam of white light is dispersed into its wavelength components by a Quartz prism and falls on a thin sheet of potassium metal. What is the correct decreasing order of maximum kinetic energy of the electron emitted by the different light component?
(A) blue > green > orange > yellow (B) violet > 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 # 2

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. ($4 \rightarrow 3$, $4 \rightarrow 2$, $4 \rightarrow 1$, $3 \rightarrow 2$, $3 \rightarrow 1$, $2 \rightarrow 1$). 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 :

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

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.

4. Last line of Brackett series for H-atom has wavelength λ_1Å and 2^{nd} line of lyman series has wavelength λ_2Å, 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) $\frac{128}{\lambda_1} = \frac{8}{\lambda_2}$

5. 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. 2^{nd} 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

6. 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 # 3

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.

7. 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

8. 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.

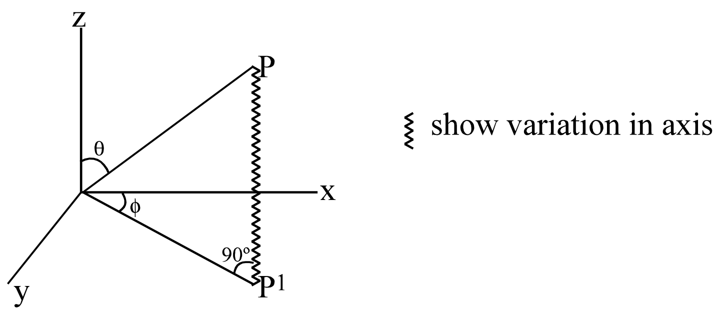
(A) 310 Å (B) 298 Å (C) 238 Å (D) 200 Å

9. 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 # 4

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 $\psi(r, \theta, \phi) = R(r)\, X(\theta, \phi)$.

Angular and radial parts of hydrogen atom wave functions

Angular part $X(\theta, \phi)$	Radial part $R_{n,\ell}(r)$
$X(s) = \left(\frac{1}{4\pi}\right)^{1/2}$	$R(1s) = 2\left(\frac{z}{a_0}\right)^{3/2} e^{-\sigma/2}$
$X(p_x) = \left(\frac{3}{4\pi}\right)^{1/2} \sin\theta \cos\phi$	$R(2s) = \frac{1}{2\sqrt{2}}\left(\frac{z}{a_0}\right)^{3/2} (2-\sigma)\, e^{-\sigma/2}$
$X(p_y) = \left(\frac{3}{4\pi}\right)^{1/2} \sin\theta \sin\phi$	$R(2p) = \frac{1}{2\sqrt{6}}\left(\frac{z}{a_0}\right)^{3/2} \sigma\, e^{-\sigma/2}$
$X(p_z) = \left(\frac{3}{4\pi}\right)^{1/2} \cos\theta$	
$X(d_{z^2}) = \left(\frac{5}{16\pi}\right)^{1/2} (3\cos^2\theta - 1)$	
$X(d_{xz}) = \left(\frac{15}{4\pi}\right)^{1/2} \sin\theta \cos\theta \cos\phi$	$R(3s) = \frac{1}{9\sqrt{3}}\left(\frac{z}{a_0}\right)^{3/2} (6 - 6\sigma + \sigma^2)\, e^{-\sigma/2}$
$X(d_{yz}) = \left(\frac{15}{4\pi}\right)^{1/2} \sin\theta \cos\theta \sin\phi$	$R(3p) = \frac{1}{9\sqrt{6}}\left(\frac{z}{a_0}\right)^{3/2} (4-\sigma)\, \sigma e^{-\sigma/2}$
$X(d_{x2-y2}) = \left(\frac{15}{4\pi}\right)^{1/2} \sin^2\theta \cos 2\phi$	$R(3d) = \frac{1}{9\sqrt{30}}\left(\frac{z}{a_0}\right)^{3/2} \sigma^2 e^{-\sigma/2}$
$X(d_{xy}) = \left(\frac{15}{4\pi}\right)^{1/2} \sin^2\theta \sin 2\phi$	

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

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 always 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.

10. 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) $\frac{2}{\pi}\left(\frac{Z}{a_0}\right)^{3} e^{-\frac{2zr}{a_0}}$

11. 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 # 5

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 $\uparrow$ and $\downarrow$ 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.

12. 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

13. 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

14. 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 # 6

15, 16 and 17 by appropriately matching the information given in the three columns of the following table.

Electrons are filled in orbitals following Auf-bau rule, Paulli exclusion principle and Hund's rule of maximum multiplicity.

Column 1	Column 2	Column 3
(I) Cu^{+}	(i) Number of unpaired electrons are 4	(P) Magnetic moment is $\sqrt{15}$ B.M.
(II) Fe^{+3}	(ii) Number of electron related to n + l = 5 are 3	(Q) Number of electrons related to n + ℓ=5 are 6.
(III) Cr^{+3}	(iii) Total spin = $\pm\frac{5}{2}$	(R) Number of electrons to ℓ + m = 0 are 12
(IV) Co^{+3}	(iv) Number of electrons related to ℓ = 2 are 10	(S) Magnetic moment is $\sqrt{35}$ B.M.

15. Ion which have maximum number of full filled orbital then the only correct combination is
(A) (I) (iv) (R) (B) (II) (iii) (P) (C) (III) (i) (S) (D) (IV) (ii) (Q)

16. For the given ion in column I. The only correct combination.
(A) (I) (iv) (S) (B) (II) (i) (R) (C) (III) (ii) (P) (D) (IV) (iii) (Q)

17. For Co^{+3} ion, the only correct combination is
(A) (IV) (ii) (P) (B) (IV) (iii) (S) (C) (IV) (iv) (R) (D) (IV) (i) (Q)

Exercise-3

* **Marked Questions may have more than one correct option.**

PART - I : JEE (ADVANCED) / IIT-JEE PROBLEMS (PREVIOUS YEARS)

1. The orbit having Bohr radius equal to 1st Bohr orbit of H–atom is : **[JEE 2004, 3/144]**
(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 :

$$\psi_{2s} = \frac{1}{4(2\pi)^{1/2}}\left(2-\frac{r}{a_0}\right)\exp(-r/2a_0)$$ **[JEE 2004, 4/60]**

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, 4/144]**
(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 ,6/184]**

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

Paragraph for Question Nos. 5 to 7

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, 3/163]**
(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, 3/163]**
(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, 3/163]**
(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, 4/180]**

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, 4/180]**

10. 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, 3/180]**

$$\begin{tikzcd} {}^{27}_{13}Al \arrow[r, "(ii)"] \arrow[d, "(i)"'] & {}^{30}_{15}P + Y \arrow[d] \\ {}^{30}_{14}Si + X & {}^{30}_{14}Si + Z \end{tikzcd}$$

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

11. The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is [a_0 is Bohr radius] : **[JEE 2012, 3/136]**

(A) $\dfrac{h^2}{4\pi^2 m a_0^2}$ (B) $\dfrac{h^2}{16\pi^2 m a_0^2}$ (C) $\dfrac{h^2}{32\pi^2 m a_0^2}$ (D) $\dfrac{h^2}{64\pi^2 m a_0^2}$

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? ${}^{63}_{29}Cu + {}^{1}_{1}H \rightarrow 6{}^{1}_{0}n + {}^{4}_{2}\alpha + 2{}^{1}_{1}H + X$ **[JEE 2012, 4/136]**

13.* In the nuclear transmutation

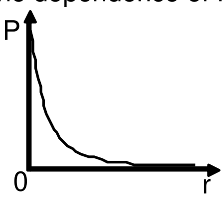
$${}^{9}_{4}Be + X \longrightarrow {}^{8}_{4}Be + Y$$

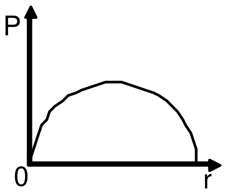
(**X, Y**) is (are) : **[JEE(Advanced) 2013, 3/120]**
(A) (γ, n) (B) (p, D) (C) (n, D) (D) (γ, p)

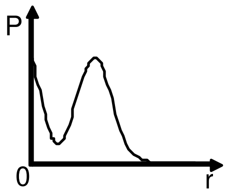
14. In an atom, the total number of electrons having quantum numbers n = 4, $|m_\ell| = 1$ and $m_s = -1/2$ is **[JEE(Advanced) 2014, 3/120]**

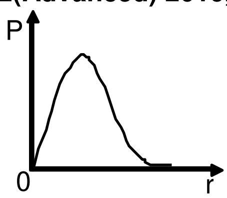
15. Not considering the electronic spin, the degeneracy of the second excited state (n = 3) of H atom is 9, while the degeneracy of the second excited state of H^- is : **[JEE(Advanced) 2015, 4/168]**

16. 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(Advanced) 2016, 3/124]**

(A) 

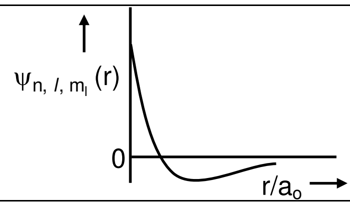
(B) 

(C) 

(D) 

Answer Q.17, Q.18 and Q.19 by appropriately 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 and a_o is Bohr radius.

Column 1	Column 2	Column 3
(I) 1s orbital	(i) $\psi_{n,l,m_l} \propto \left(\dfrac{Z}{a_o}\right)^{\frac{3}{2}} e^{-\left(\frac{Zr}{a_o}\right)}$	(P) 

(II) 2s orbital	(ii) One radial node	(Q) Probability density at nucleus $\propto \frac{1}{a_o^3}$
(III) $2p_z$ orbital	(iii) $\psi_{n, l, m_l} \propto \left(\frac{Z}{a_o}\right)^{\frac{5}{2}} re^{-\left(\frac{Zr}{2a_o}\right)}\cos\theta$	(R) Probability density is maximum at nucleus
(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

17. For He^+ ion, the only **INCORRECT** combination is **[JEE(Advanced) 2017, 3/122]**
(A) (I) (i) (S) (B) (II) (ii) (Q) (C) (I) (iii) (R) (D) (I) (i) (R)

18. For the given orbital in Column 1, the only **CORRECT** combination for any hydrogen-like species is **[JEE(Advanced) 2017, 3/122]**
(A) (II) (ii) (P) (B) (I) (ii) (S) (C) (IV) (iv) (R) (D) (III) (iii) (P)

19. For hydrogen atom, the only **CORRECT** combination is **[JEE(Advanced) 2017, 3/122]**
(A) (I) (i) (P) (B) (I) (iv) (R) (C) (II) (i) (Q) (D) (I) (i) (S)

PART - II : JEE (MAIN) / AIEEE PROBLEMS (PREVIOUS YEARS)

OFFLINE JEE-MAIN

1. Which of the following ions has the maximum magnetic moment? **[AIEEE 2002, 3/225]**
(1) Mn^{+2} (2) Fe^{+2} (3) Ti^{+2} (4) Cr^{+2}.

2. Energy of H-atom in the ground state is –13.6 eV, hence energy in the second excited state is : **[AIEEE 2002, 3/225]**
(1) – 6.8 eV (2) – 3.4 eV (3) – 1.51 eV (4) – 4.53 eV

3. Uncertainity in position of a particle of 25 g in space is 10^{-15} m. Hence, Uncertainity in velocity (in m.sec^{-1}) is: (plank's constant, h = 6.6×10^{-34} Js) **[AIEEE 2002, 3/225]**
(1) 2.1×10^{-18} (2) 2.1×10^{-34} (3) 0.5×10^{-34} (4) 5.0×10^{-24}

4. The de-Broglie wavelength of a tennis ball of mass 60 g moving with a velocity of 10 m/s is approximately (planck's constant, h = 6.63×10^{-34} J-s) **[AIEEE 2003, 3/225]**
(1) 10^{-33} m (2) 10^{-31} m (3) 10^{-16} m (4) 10^{-25} m

5. In Bohr series of lines of hydrogen spectrum, the third line from the red end corresponds to which one of the following inner-orbit jumps of the electron for Bohr orbits in an atom of hydrogen ? **[AIEEE 2003, 3/225]**
(1) $3 \rightarrow 2$ (2) $5 \rightarrow 2$ (3) $4 \rightarrow 1$ (4) $2 \rightarrow 5$

6. The numbers of d-electrons retained in Fe^{2+} (atomic number Fe = 26) ion is **[AIEEE 2003, 3/225]**
(1) 3 (2) 4 (3) 5 (4) 6

7. The orbital angular momentum for an electron revolving in an orbit is given by $\sqrt{\ell(\ell+1)}\,\frac{h}{2\pi}$. This momentum for an s-electron will be given by **[AIEEE 2003, 3/225]**
(1) $+\frac{1}{2}\cdot\frac{h}{2\pi}$ (2) Zero (3) $\frac{h}{2\pi}$ (4) $\sqrt{2}\cdot\frac{h}{2\pi}$

8. 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, 3/225]**
(1) 91 nm (2) 192 nm (3) 406 (4) 9.1×10^{-6} nm

9. Which of the following set a of quantum numbers is correct for an electron in 4f orbital? **[AIEEE 2004, 3/225]**
(1) n = 4, l =3, m = +4, s = +1/2 (2) n = 4, l = 4, m = –4, s = –1/2
(3) n = 4, l = 3, m = +1, s = +1/2 (4) n = 3, l=2, m =–2, s = +1/2

10. 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, 3/225]**
(1) 12 and 4 (2) 12 and 5 (3) 16 and 4 (4) 16 and 5

11. 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, 3/225]**
(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
(1) (iv) and (v) (2) (iii) and (iv) (3) (ii) and (iii) (4) (i) and (ii)

12. Which of the following statements in relation to the hydrogen atom is correct ? **[AIEEE 2005, 4½/225]**
(1) 3s, 3p and 3d orbitals all have the same energy
(2) 3s and 3p orbitals are of lower energy than 3d orbital
(3) 3p orbital is lower in energy than 3d orbital
(4) 3s orbital is lower in energy than 3p orbital

13. 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, 3/165]**
(1) 19.2×10^{-2} m (2) 5.76×10^{-2} m (3) 1.92×10^{-2} m (4) 3.84×10^{-2} m

14. According to Bohr's theory, the angular momentum to an electron in 5th orbit is : **[AIEEE 2006, 3/165]**
(1) $25\frac{h}{\pi}$ (2) $1.0\frac{h}{\pi}$ (3) $10\frac{h}{\pi}$ (4) $2.5\frac{h}{\pi}$

15. 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, 3/165]**
(1) 2.84 (2) 4.90 (3) 0 (4) 1.73

16. Which of the following nuclear reactions will generate an isotope ? **[AIEEE 2007, 3/120]**
(1) Neutron particle emission (2) Positron emission
(3) α-particle emission (4) β-particle emission

17. 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, 3/105]**
(1) 8.51×10^5 J mol^{-1} (2) 6.56×10^5 J mol^{-1} (3) 7.56×10^5 J mol^{-1} (4) 9.84×10^5 J mol^{-1}

18. Which of the following set of quantum numbers represents the highest energy of an atom ?
(1) n = 3, l = 0, m = 0, s = $+\frac{1}{2}$ (2) n = 3, l = 1, m =1, s = $+\frac{1}{2}$
(3) n = 3, l = 2, m = 1, s = $+\frac{1}{2}$ (4) n = 4, l = 0, m = 0, s = $+\frac{1}{2}$

19. 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 : (c = 3×10^8 m s^{-1} and N_A = 6.02×10^{23} mol^{-1}) **[AIEEE 2010, 4/144]**
(1) 594 nm (2) 640 nm (3) 700 nm (4) 494 nm

20. Ionisation energy of He^+ is 19.6×10^{-18} J atom^{-1}. The energy of the first stationary state (n = 1) of Li^{2+} is: **[AIEEE 2010, 4/144]**
(1) 4.41×10^{-16} J atom^{-1} (2) -4.41×10^{-17} J atom^{-1}
(3) -2.2×10^{-15} J atom^{-1} (4) 8.82×10^{-17} J atom^{-1}

21. 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, 4/120]**
(1) 1035 nm (2) 325 nm (3) 743 nm (4) 518 nm

22. The frequency of light emitted for the transition n = 4 to n = 2 of He^+ isequalto the transition in H atom corresponding to which of the following? **[AIEEE 2011, 4/120]**
(1) n = 2 to n = 1 (2) n = 3 to n = 2 (3) n = 4 to n = 3 (4) n = 3 to n = 1

23. The electrons identified by quantum numbers n and ℓ : **[AIEEE 2012, 4/120]**
(a) n = 4, ℓ = 1 (b) n = 4, ℓ = 0 (c) n = 3, ℓ = 2 (d) n = 3, ℓ = 1
can be placed in order of increasing energy as :
(1) (c) < (d) < (b) < (a) (2) (d) < (b) < (c) < (a) (3) (b) < (d) < (a) < (c) (4) (a) < (c) < (b) < (d)

24. Energy of an electron is given by $E = -2.178 \times 10^{-18}\,J\left(\frac{Z^2}{n^2}\right)$. Wavelength of light required to excite an electron in an hydrogen atom from level n = 1 to n = 2 will be: (h=6.62 × 10^{-34} Js and c=3.0 × 10^{8} ms^{-1}) **[JEE(Main)2013, 4/120]**
(1) 1.214 × 10^{-7} m (2) 2.816 × 10^{-7} m (3) 6.500 × 10^{-7} m (4) 8.500 × 10^{-7} m

25. The correct set of four quantum numbers for the valence electrons of rubidium atom (Z = 37) is : **[JEE(Main)2014, 4/120]**
(1) 5, 0, 0, $+\frac{1}{2}$ (2) 5, 1, 0, $+\frac{1}{2}$ (3) 5,1, 1, $+\frac{1}{2}$ (4) 5, 0, 1, $+\frac{1}{2}$

26. Which of the following is the energy of a possible excited state of hydrogen ? **[JEE(Main) 2015, 4/120]**
(1) +13.6 eV (2) –6.8 eV (3) –3.4 eV (4) +6.8 eV

27. A stream of electrons from a heated filament was passed between two charged plates kept at a potential difference V esu. If e and m are charge and mass of an electron, respectively, then the value of $\frac{h}{\lambda}$ (where λ is wavelength associated with electron wave) is given by: **[JEE(Main) 2016, 4/120]**
(1) 2meV (2) $\sqrt{meV}$ (3) $\sqrt{2meV}$ (4) meV

28. The radius of the second Bohr orbit for hydrogen atom is :
(Planck's Const. h = 6.6262 × 10^{-34} Js; mass of electron = 9.1091 × 10^{-31} kg; charge of electron e = 1.60210 × 10^{-19} C; permittivity of vacuum ϵ_0 = 8.854185 × 10^{-12} $kg^{-1}m^{-3}A^2$) **[JEE(Main) 2017, 4/120]**
(1) 4.76 Å (2) 0.529 Å (3) 2.12 Å (4) 1.65 Å

ONLINE JEE-MAIN

1. The energy of an electron in first Bohr orbit of H-atom is –13.6 eV. The energy value of electron in the excited state of Li^{2+} is : **[JEE(Main) 2014 Online (09-04-14), 4/120]**
(1) – 27.2 eV (2) 30.6 eV (3) – 30.6 eV (4) 27.2 eV

2. If λ_0 and λ be the threshold wavelength and wavelength of incident light, the velocity of photoelectron ejected from the metal surface is : **[JEE(Main) 2014 Online (11-04-14), 4/120]**
(1) $\sqrt{\frac{2h}{m}(\lambda_0 - \lambda)}$ (2) $\sqrt{\frac{2hc}{m}(\lambda_0 - \lambda)}$ (3) $\sqrt{\frac{2hc}{m}\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)}$ (4) $\sqrt{\frac{2h}{m}\left(\frac{1}{\lambda_0} - \frac{1}{\lambda}\right)}$

3. Based on the equation: $\Delta E = 2.0 \times 10^{-18}\,J\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right)$
the wavelength of the light that must be absorbed to excite hydrogen electron from level n = 1 to level n = 2 will be : (h = 6.625 × 10^{-34} Js, C = 3 × 10^{8} ms^{-1}) **[JEE(Main) 2014 Online (09-04-14), 4/120]**
(1) 1.325 × 10^{-7} m (2) 1.325 × 10^{-10} m (3) 2.650 × 10^{-7} m (4) 5.300 × 10^{-10} m

4. If m and e are the mass and charge of the revolving electron in the orbit of radius r for hydrogen atom, the total energy of the revolving electron will be : **[JEE(Main) 2014 Online (12-04-14), 4/120]**

(1) $\frac{1}{2}\frac{e^2}{r}$ (2) $-\frac{e^2}{r}$ (3) $\frac{me^2}{r}$ (4) $-\frac{1}{2}\frac{e^2}{r}$

5. The de-Broglie wavelength of a particle of mass 6.63 g moving with a velocity of 100 ms^{-1} is : **[JEE(Main) 2014 Online (12-04-14), 4/120]**

(1) 10^{-33} m (2) 10^{-35} m (3) 10^{-31} m (4) 10^{-25} m

6. Excited hydrogen atom emits light in the ultraviolet region at 2.47×10^{15} Hz With thi frequency, the energy of a single photon is : (h = 6.63×10^{-34} Js) **[JEE(Main) 2014 Online (12-04-14), 4/120]**

(1) 8.041×10^{-40} J (2) 8.041×10^{-19} J (3) 1.640×10^{-18} J (4) 6.111×10^{-17} J

7. Ionization energy of gaseous Na atom is 495.5 kJ mol^{-1}. The lowest possible frequency of light that ionizes a sodium atom is (h = 6.626×10^{-34} Js, $N_A = 6.022 \times 10^{23}$ mol^{-1}) **[JEE(Main) 2014 Online (19-04-14), 4/120]**

(1) 7.50×10^{4} s^{-1} (2) 4.76×10^{14} s^{-1} (3) 3.15×10^{15} s^{-1} (4) 1.24×10^{15} s^{-1}

8. If the principal quantum number n = 6, the correct sequence of filling of electrons will be : **[JEE(Main) 2015 Online (10-04-15), 4/120]**

(1) ns→np→(n – 1)d→(n – 2)f (2) ns→(n – 1)d→(n – 2)f→np
(3) ns→(n – 2)f→np→(n – 1)d (4) ns→(n – 2)f→(n – 1)d→np

9. At temperatuere T, the average kinetic energy of any particle is $\frac{3}{2}$KT. The de Broglie wavelength follows the order : **[JEE(Main) 2015 Online (11-04-15), 4/120]**

(1) Visible photon > Thermal neutron > Thermal electron
(2) Thermal proton > Thermal electon > Visible photon
(3) Thermal proton > Visible photon > Thermal electron
(4) Visible photon > Thermal electron > Thermal neutron

10. The total number of orbitals associated with the principal quantum number 5 is: **[JEE(Main) 2016 Online (09-04-16), 4/120]**

(1) 5 (2) 20 (3) 25 (4) 10

11. Aqueous solution of which salt will not contain ions with the electronic configuration $1s^22s^22p^63s^23p^6$? **[JEE(Main) 2016 Online (10-04-16), 4/120]**

(1) NaCl (2) CaI_2 (3) NaF (4) KBr

12. If the shortest wavelength in Lyman series of hydrogen atom is A, then the longest wavelength in Paschen series of He^+ is : **[JEE(Main) 2017 Online (08-04-17), 4/120]**

(1) $\frac{36A}{5}$ (2) $\frac{9A}{5}$ (3) $\frac{5A}{9}$ (4) $\frac{36A}{7}$

13. The electron in the hydrogen atom undergoes transition from higher orbitals to orbitals of radius 211.6 pm. This transition is associated with : **[JEE(Main) 2017 Online (09-04-17), 4/120]**

(1) Paschen series (2) Brackett series (3) Lyman series (4) Balmer series

14. Ejection of the photoelectron from metal in the photoelectric effect experiment can by stopped by applying 0.5 V when the radiation of 250 nm is used. The work function of the metal is : **[JEE(Main) 2018 Online (15-04-18), 4/120]**

(1) 4 eV (2) 5.5 eV (3) 4.5 eV (4) 5 eV

15. The de-Broglie's wavelength of electron present in first Bohr orbit of 'H' atom is : **[JEE(Main) 2018 Online (15-04-18), 4/120]**

(1) 0.529 Å (2) $2\pi \times 0.529$ Å (3) $\frac{0.529}{2\pi}$ Å (4) 4×0.529 Å

16. Which of the following statements is **false** ? **[JEE(Main) 2018 Online (16-04-18), 4/120]**

(1) Splitting of spectral lines in electrical field is called Stark effect.
(2) Frequency of emitted radiation from a black body goes from a lower wavelength of higher wavelength as the temperature increases.
(3) Photon has momentum as well as wavelength.
(4) Rydberg constant has unit of energy.

17. For emission line of atomic hydrogen from $n_i = 8$ to $n_f = n$, the plot of wave number $(\bar{\nu})$ against $\left(\frac{1}{n^2}\right)$ will be (The Rydberg constant, R_H is in wave number unit) **[JEE(Main) 2019 Online (09-01-19), 4/120]**

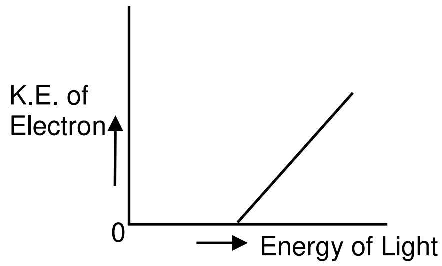
(1) Linear with intercept $-R_H$ (2) Linear with slope $-R_H$
(3) Non linear (4) Linear with slope R_H

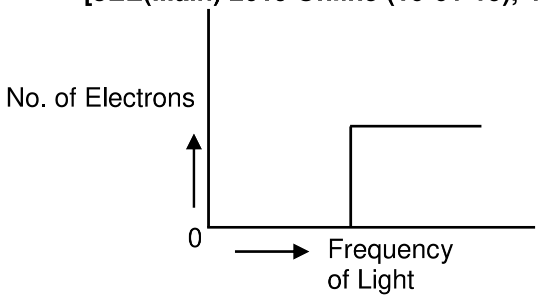
18. Which of the following combination of statements is true regarding the interpretation of the atomic orbitals? **[JEE(Main) 2019 Online (09-01-19), 4/120]**

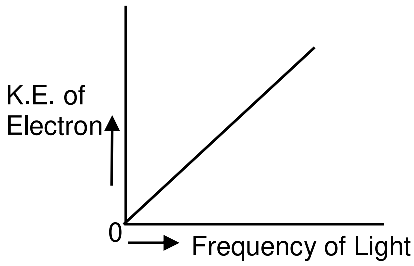
(a) An electron in an orbital of high angular momentum stays away from the nucleus than an electron in the orbitals of lower angular momentum.
(b) For a given value of the principal quantum number, the size of the orbit is inversely proportional to the azimuthal quantum number.
(c) According to wave mechanics, the ground state angular momentum is equal to $\frac{h}{2\pi}$.
(d) The plot of Ψ Vs r for various azimuthal quantum numbers, show peak shifting towards higher value.

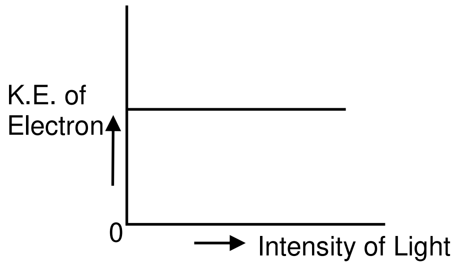
(1) (b), (c) (2) (a), (c) (3) (a), (d) (4) (a), (b)

19. Which of the graphs shown below does not represent the relationship between incident light and the electron ejected from metal surface ? **[JEE(Main) 2019 Online (10-01-19), 4/120]**

(1)


(2)


(3)


(4)


20. The ground state energy of hydrogen atom is –13.6 eV. The energy of second excited state of He^+ ion eV is: **[JEE(Main) 2019 Online (10-01-19), 4/120]**

(1) –27.2 (2) –54.4 (3) –3.4 (4) –6.04

21. Heat treatment of muscular pain involves radiation of wavelength of about 900 nm. Which spectral line of H-atom is suitable for this purpose ?
[$R_H = 1 \times 10^5$ cm^{-1}, $h = 6.6 \times 10^{-34}$ Js, $c = 3 \times 10^8$ ms^{-1}] **[JEE(Main) 2019 Online (11-01-19), 4/120]**

(1) Paschen, $\infty \to 3$ (2) Paschen, $5 \to 3$ (3) Balmer, $\infty \to 2$ (4) Lyman, $\infty \to 1$

22. The de Broglie wavelength (λ) associated with a photoelectron varies with the frequency (ν) of the incident radiation as, [ν_0 is threshold frequency] : **[JEE(Main) 2019 Online (11-01-19), 4/120]**

(1) $\lambda \propto \frac{1}{(\nu - \nu_0)^{\frac{3}{2}}}$ (2) $\lambda \propto \frac{1}{(\nu_0 - \nu_0)}$ (3) $\lambda \propto \frac{1}{(\nu - \nu_0)^{\frac{1}{2}}}$ (4) $\lambda \propto \frac{1}{(\nu - \nu_0)^{\frac{1}{4}}}$

23. What is the work function of the metal if the light of wavelength 4000Å generates photoelectrons of velocity 6×10^{5} ms^{-1} from it ? (Mass of electron = 9×10^{-31} kg, Velocity of light = 3×10^{8} ms^{-1}, Plank's constant = 6.626×10^{-34} Js, Charge of electron = 1.6×10^{-19} JeV^{-1})
[JEE(Main) 2019 Online (12-01-19), 4/120]

(1) 3.1 eV (2) 0.9 eV (3) 4.0 eV (4) 2.1 eV

24. If the de Broglie wavelength of the electron in n^{th} Bohr orbit in a hydrogenic atom is equal to 1.5 πa_0 (a_0 is Bohr radius), then the value of n/z is: **[JEE(Main) 2019 Online (12-01-19), 4/120]**

(1) 0.75 (2) 0.40 (3) 1.0 (4) 1. 50

Answers

EXERCISE - 1

PART - I

A-1.

Particle	Atomic No.	Mass No.	No. of electrons	No. of protons	No. of neutrons
Sodium atom	11	23	11	11	12
Aluminium ion	13	27	10	13	14
Chloride ion	17	35	18	17	18
Phosphorus atom	15	31	15	15	16
Cuprous ion	29	64	28	29	35

A-2. $1.8 \times 10^{-43}\ m^3$ **A-3.** 2.7×10^{-14} **A-4.** (A) 6.5×10^{-15} m , (B) $\frac{188\ Ke^2}{m_\alpha v^2}$

A-5. 1. Most of the α-particles passed straight through the gold foil undeflected.
2. A few of them were deflected through small angles, while a very few were deflected to a large extent.
3. A very small percentage (1 in 20000) was deflected through angles ranging from nearly 180°.

B-1. 621.1 eV. **B-2.** 1.56×10^{16} **B-3.** 219.3 m, $4.56 \times 10^{-3}\ m^{-1}$

B-4. 239.4 KJ/mol. **B-5.** 1.35×10^5 photons **B-6.** 200 watt.

B-7. 1×10^{16} Hz **C-1.** n = 2 **C-2.** 7.27×10^5 m/s

C-3. x = 2 **C-4.** $\frac{9}{32}$ **C-5.** 'x' **C-6.** A = 2, B = 4

C-7. (a) Z = 3, (b) 108.8 eV, (c) 1.013×10^{-8} m , (d) 122.4 eV **C-8.** 54.4 eV

D-1. 6561 Å, 4863 Å (Approx) **D-2.** n = 4 to n = 2

D-3. $v = 7.3 \times 10^{14}$ Hz, visible spectrum **D-4.** z = 2 **D-5.** 20

E-1. 4.71 Å **E-2.** $v_e = 1836\ v_p$ **E-3.** $\frac{20}{63}$ **E-4.** 6.15 Å

E-5. ≈ 100 gm **F-1.** a = 4 ; b = 2 ; c = 3 ; d = 1

F-2. (i) 4s , 4P , 4d , 4f
(ii) No, it will only be in one of them.
(iii) No. For the hydrogen atom, all orbitals with the same principal quantum number have the same energy (they are degenerate).

G-1. 2 **G-2.** $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^{10}\ 4p^6\ 5s^2\ 4d^{10}\ 5p^6\ 6s^2$.

G-3. 3p, 5d, 4p, 2s, 4d **G-4.** (a) 0, (b) $\frac{h}{\sqrt{2}\pi}$, (c) $\frac{2h}{\pi}$

G-5. Impossible sets of quantum numbers are (i), (iii), and (vi)

G-6. (i) + 5/2 or – 5/2, spin magnetic moment = $\sqrt{35}$ B.M. (ii) 0, 0

H-1. $\Delta m = 3.07 \times 10^{-26}$ g

H-2. $^{24}_{12}Mg + ^{1}_{0}n \longrightarrow ^{24}_{11}Na + ^{1}_{1}H$

H-3. (a) $^{14}_{7}N + ^{1}_{0}n \longrightarrow ^{14}_{6}C + ^{1}_{1}H$

(b) $^{39}_{19}K + ^{1}_{0}n \longrightarrow ^{36}_{17}Cl + ^{4}_{2}He$

H-4. (a) $^{38}_{20}Ca$: It has $\frac{n}{p} = \frac{18}{20} = 0.9$, Which lies below the belt of stability and thus positron emitter.

$$^{38}_{20}Ca \longrightarrow ^{38}_{19}K + ^{0}_{+1}e$$

(b) $^{35}_{18}Ar$: It has $\frac{n}{p} = \frac{17}{18} = 0.994$, which lies below the belt of stability and thus, positron emitter

$$^{35}_{18}Ar \longrightarrow ^{35}_{17}Cl + ^{0}_{+1}e$$

If $\frac{n}{p} < 1$ and nuclear charge is high the nuclide may show K-electron capture.

(c) $^{80}_{32}Ge$: It has $\frac{n}{p} = \frac{48}{32} = 1.5$, which lies above the belt of stability and thus β-emitter.

$$^{80}_{32}Ge \longrightarrow ^{80}_{33}As + ^{0}_{-1}e$$

(d) $^{40}_{20}Ca$: It has both magic numbers p = 20, n = 20 and thus, stable.

H-5. 3^n, $3^{n-1}E$

PART - II

A-1.	(A)	**A-2.**	(A)	**A-3.**	(D)	**A-4.**	(B)	**A-5.**	(A)
A-6.	(C)	**B-1.**	(A)	**B-2.**	(C)	**B-3.**	(A)	**B-4.**	(D)
B-5.	(C)	**B-6.**	(D)	**C-1.**	(A)	**C-2.**	(B)	**C-3.**	(B)
C-4.	(A)	**C-5.**	(A)	**C-6.**	(C)	**C-7.**	(B)	**D-1.**	(A)
D-2.	(D)	**D-3.**	(C)	**D-4.**	(B)	**D-5.**	(C)	**D-6.**	(D)
D-7.	(D)	**E-1.**	(C)	**E-2.**	(D)	**E-3.**	(B)	**E-4.**	(C)
E-5.	(B)	**E-6.**	(A)	**E-7.**	(C)	**F-1.**	(C)	**F-2.**	(A)
F-3.	(D)	**F-4.**	(C)	**F-5.**	(C)	**F-6.**	(C)	**F-7.**	(C)
F-8.	(D)	**F-9.**	(D)	**F-10.**	(B)	**G-1.**	(A)	**G-2.**	(D)
G-3.	(A)	**G-4.**	(B)	**G-5.**	(D)	**G-6.**	(A)	**G-7.**	(B)
G-8.	(B)	**G-9.**	(D)	**G-10.**	(C)	**H-1.**	(A)	**H-2.**	(C)
H-3.	(A)	**H-4.**	(B)	**H-5.**	(B)	**H-6.**	(D)		

PART - III

1. (i – f) ; (ii – d) ; (iii – a) ; (iv – e) ; (v – b) ; (vi – c)

2. (i – q) , (ii – p), (iii – q, r) , (iv – r, s). **3.** (i – t) ; (ii – s) ; (iii – u) ; (iv – q) ; (v – p) ; (vi – r)

4. (A – s) ; (B – p) ; (C – r) ; (D – q)

EXERCISE - 2

PART - I

1.	(C)	**2.**	(C)	**3.**	(B)	**4.**	(D)	**5.**	(C)
6.	(D)	**7.**	(C)	**8.**	(A)	**9.**	(D)	**10.**	(A)
11.	(C)	**12.**	(A)	**13.**	(C)	**14.**	(B)	**15.**	(A)
16.	(B)	**17.**	(B)	**18.**	(B)	**19.**	(D)	**20.**	(C)
21.	(D)	**22.**	(A)	**23.**	(C)	**24.**	(C)	**25.**	(A)
26.	(B)	**27.**	(A)	**28.**	(A)	**29.**	(D)	**30.**	(D)
31.	(A)								

PART - II

1.	2	**2.**	2	**3.**	18	**4.**	31 nm	**5.**	8
6.	12	**7.**	32	**8.**	6	**9.**	5 Å	**10.**	12
11.	1	**12.**	1Å	**13.**	3	**14.**	8	**15.**	+3
16.	3								

PART - III

1.	(BD)	**2.**	(AB)	**3.**	(AC)	**4.**	(ABC)	**5.**	(BD)
6.	(AC)	**7.**	(ABD)	**8.**	(BCD)	**9.**	(ABCD)	**10.**	(BCD)
11.	(BC)	**12.**	(ABC)	**13.**	(ABC)	**14.**	(AD)	**15.**	(AC)
16.	(ABC)	**17.**	(BC)	**18.**	(ABD)	**19.**	(C)	**20.**	(ABD)

PART - IV

1.	(B)	**2.**	(C)	**3.**	(A)	**4.**	(A)	**5.**	(D)
6.	(C)	**7.**	(D)	**8.**	(D)	**9.**	(C)	**10.**	(B)
11.	(A)	**12.**	(C)	**13.**	(B)	**14.**	(B)	**15.**	(A)
16.	(C)	**17.**	(D)						

EXERCISE - 3

PART - I

1. (D) **2.** (a) $r = 2a_0$; (b) $\lambda = 6.626 \times 10^{-25}$ Å ; (c) ${}_{82}Y^{206}$; (Atomic no. 82, Mass no. 206)

3. (a) 2.18×10^6 m/s, 3.32×10^{-10} m (b) $\sqrt{2}\,.\left(\frac{h}{2\pi}\right)$ **4.** [A – r]; [B – q]; [C – p]; [D – s]

5.	(B)	**6.**	(C)	**7.**	(B)	**8.**	4	**9.**	9
10.	(A)	**11.**	(C)	**12.**	8	**13.***	(AB)	**14.**	6
15.	3	**16.**	(D)	**17.**	(C)	**18.**	(A)	**19.**	(D)

PART - II

OFFLINE JEE-MAIN

1.	(1)	**2.**	(3)	**3.**	(1)	**4.**	(1)	**5.**	(2)
6.	(4)	**7.**	(2)	**8.**	(1)	**9.**	(3)	**10.**	(2)
11.	(1)	**12.**	(1)	**13.**	(3)	**14.**	(4)	**15.**	(1)
16.	(1)	**17.**	(4)	**18.**	(3)	**19.**	(4)	**20.**	(2)
21.	(3)	**22.**	(1)	**23.**	(2)	**24.**	(1)	**25.**	(1)
26.	(3)	**27.**	(3)	**28.**	(3)				

ONLINE JEE-MAIN

1.	(3)	**2.**	(3)	**3.**	(1)	**4.**	(4)	**5.**	(1)
6.	(3)	**7.**	(4)	**8.**	(4)	**9.**	(4)	**10.**	(3)
11.	(3)	**12.**	(4)	**13.**	(4)	**14.**	(3)	**15.**	(2)

16. (2) **17.** NTA answer was (2), but correct answer is (4).

18. NTA answer was (3), but correct answer is (2). **19.** (3) **20.** (4)

21. (1) **22.** (3) **23.** (4) **24.** ss(1)

Additional Problems For Self Practice (APSP)

✍ Marked questions are recommended for Revision.

This Section is not meant for classroom discussion. It is being given to promote self-study and self testing amongst the Resonance students.

PART - I : PRACTICE TEST-1 (IIT-JEE (MAIN Pattern))

Max. Time : 1 Hr. **Max. Marks : 120**

Important Instructions

1. The test is of **1 hour** duration.

2. The Test Booklet consists of **30** questions. The maximum marks are **120.**

3. Each question is allotted **4 (four)** marks for correct response.

4. Candidates will be awarded marks as stated above in Instructions No. 3 for correct response of each question.
¼ (one fourth) marks will be deducted for indicating incorrect response of each question. No deduction from the total score will be made if no response is indicated for an item in the answer sheet.

5. There is only one correct response for each question. Filling up more than one response in any question will be treated as wrong response and marks for wrong response will be deducted accordingly as per instructions 4 above.

1.✍ A 5g orbital has
(1) Zero angular node and zero radial node (2) Zero radial node and two angular nodes
(3) 4 radial nodes and 4 angular nodes (4) Zero radial node and 4 angular nodes

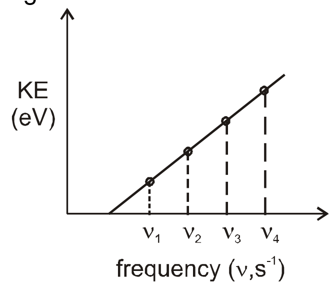
2. The threshold wavelength (λ_0) of sodium metal is 6500Å. If UV light of wavelength 360Å is used, what will be kinetic energy of the photoelectron in ergs?
(1) 55.175×10^{-12} (2) 3.056×10^{-12} (3) 52.119×10^{-12} (4) 48.66×10^{-10}

3.✍ An electron beam can undergo diffraction by crystals. Through what potential should a beam of electrons be accelerated so that its wavelength becomes equal to 1.54 Å?
(1) 54.3 volt (2) 63.3 volt (3) 66.2 volt (4) None of these

4.✍ Radiation corresponding to the transition n = 4 to n = 2 in hydrogen atoms falls on a certain metal (work function = 2.5 eV). The maximum kinetic energy of the photo-electrons will be :
(1) 0.55 eV (2) 2.55 eV (3) 4.45 eV (4) None of these

5. Calculate the number of photons emitted by a 100 W yellow lamp in 1.0 s. Take the wavelength of yellow light as 560 nm and assume 100 percent efficiency.
(1) 6.8×10^{20} (2) 4×10^{12} (3) 4×10^{20} (4) 2.8×10^{20}

6.✍ In a photoelectric experiment, kinetic energy of photoelectrons was plotted against the frequency of incident radiation (ν), as shown in figure. Which of the following statements is correct?



(1) The threshold frequency is ν_1.
(2) The slope of this line is equal to Plank's constant.
(3) As the frequency of incident wavelength increases beyond threshold frequency, kinetic energy of photoelectrons decreases.
(4) It is impossible to obtain such a graph.

7. Which of the following process not lead to formation of isobars ?
(1) 1α particle and 2β particles are emitted (2) Positron emission
(3) β particle ($_{-1}e^0$) emission (4) K-electron capture

8. If the value of $E_n = -78.4$ kcal/mole, the order of the orbit in hydrogen atom is :
(1) 2 (2) 3 (3) 1 (4) 4

9. In what region of the electromagnetic spectrum would you look for the spectral line resulting from the electronic transition from the tenth to the fifth electronic level in the hydrogen atoms? ($R_H = 1.10 \times 10^5$ cm^{-1})
(1) Microwave (2) Infrared (3) Visible (4) Ultraviolet

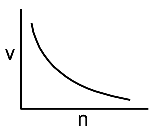
10. Consider Xenon (Z = 54). The maximum number of electrons in this atom that can have the values for their quantum numbers as n = 4, $\ell = 3$ and s = $\frac{1}{2}$ in its ground state is :
(1) Zero (2) 7 (3) 9 (4) 14

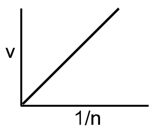
11. The increasing order for the values of e/m (charge/mass) is :
(1) e, p, n, α (2) n, p, e, α (3) e, α, e (4) n, α, p, e

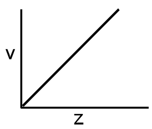
12. An electron in an atom jumps in such a way that its kinetic energy changes from x to $\frac{x}{4}$. The change in potential energy will be :
(1) $+\frac{3}{2}x$ (2) $-\frac{3}{8}x$ (3) $+\frac{3}{4}x$ (4) $-\frac{3}{4}x$

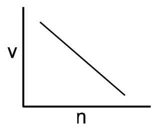
13. What atomic number of an element "X" would have to become so that the 4th orbit around X would fit inside the 1st Bohr orbit of Hydrogen ?
(1) 3 (2) 4 (3) 16 (4) 25

14. Select the incorrect graph for velocity of e^- in an orbit VS. Z, $\frac{1}{n}$ and n :

(1) 

(2) 

(3) 

(4) 

15. Which of the following is discreted in Bohr's theory?
(1) Potential energy (2) Kinetic energy (3) Velocity (4) Angular momentum

16. The mass of a proton is 1836 times more than the mass of an electron. It a sub-atomic particle of mass (m') 207 times the mass of electron is captured by the nucleus, then the first ionization potential of H :
(1) decreases (2) increases
(3) remains same (4) may be decrease or increase

17. In any subshell, the maximum number of electrons having same value of spin quantum number is :
(1) $\sqrt{\ell\ (\ell+1)}$ (2) $\ell + 2$ (3) $2\ell + 1$ (4) $4\ell + 2$

18. Which quantum number defines the orientation of orbital in the space around the nucleus ?
(1) Principal quantum number (n) (2) Angular momentum quantum number
(3) Magnetic quantum number (m_ℓ) (4) Spin quantum number (m_s)

19. For similar orbitals having different values of n :
(1) the most probable distance increases with increase in n
(2) the most probable distance decreases with increase in n
(3) the most probable distance remains constant with increase in n
(4) none of these

20. Maximum number of total nodes is present in :
(1) 5s (2) 5p (3) 5d (4) All have same number of nodes

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

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

22. Which of the following has the maximum number of unpaired electrons ?
(1) Mn (2) Ti (3) V (4) Al

23. The angular velocity of an electron occupying the second Bohr orbit of He^+ ion is (in sec^-):
(1) 2.067×10^{16} (2) 3.067×10^{16} (3) 1.067×10^{18} (4) 2.067×10^{17}

24. An excited state of H-atom emits a photon of wavelength λ and returns in the ground state, the principal quantum number of excited state is given by :
(1) $\sqrt{\lambda R(\lambda R-1)}$ (2) $\sqrt{\frac{\lambda R}{(\lambda R-1)}}$ (3) $\sqrt{\lambda R(\lambda R-1)}$ (4) $\sqrt{\frac{(\lambda R-1)}{\lambda R}}$

25. Light of wavelength λ strikes a metal surface with intensity X and the metal emits Y electrons per second of average energy Z. What willl happen to Y and Z if X is havled?
(1) Y will be halved (2) Y will double
(3) Y will be remain same (4) Z will be halved

26. Neutron scattering experiments have shown that the radius of the nucleus of an atom is directly proportional to the cube root of the number of nucleons in the nucleus. From ${}^{7}_{3}Li$ to ${}^{189}_{76}Os$, the radius is:
(1) Halved (2) the same (3) Doubled (4) Tripled

27. The nucleus of an atom is located at x = y = z = 0. If the probability of finding an electron in $d_{x^2-y^2}$ orbital in a tiny volume around x = a, y = 0, z = 0 is 1×10^{-5}, what is the probablility of finding the electron in the same size volume around x = 0, y = a, z = 0 ?
(1) 1×10^{-5} (2) $1 \times 10^{-5} \times a$ (3) $-1 \times 10^{-5} \times a$ (4) zero

28. The energy of a I, II and III energy levels of a certain atom are E, $\frac{4E}{3}$ and 2E respectively. A photon of wavelength λ is emitted during a transition from III to I. What will be the wavelength of emission for transition II to I ?
(1) $\lambda/2$ (2) λ (3) 2λ (4) 3λ

29. A compound of vanadium has a magnetic moment of 1.73 BM. What will be the electronic configurations:
(1) $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 3d^1$ (2) $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 3d^2$
(3) $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 3d^3$ (4) $1s^2\, 2s^2\, 2p^6\, 3s^2\, 3p^6\, 3d^4$

30. Calculate the minimum and maximum number of electrons which may have magnetic quantum number, m = +1 and spin quantum number, s = $-\frac{1}{2}$ in chromium (Cr) :
(1) 0, 1 (2) 1, 2 (3) 4, 6 (4) 2, 3

Practice Test-1 (IIT-JEE (Main Pattern))

OBJECTIVE RESPONSE SHEET (ORS)

Que.	1	2	3	4	5	6	7	8	9	10
Ans.										
Que.	11	12	13	14	15	16	17	18	19	20
Ans.										
Que.	21	22	23	24	25	26	27	28	29	30
Ans.										

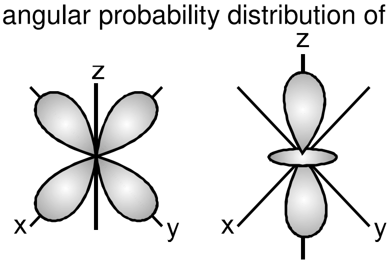
PART-II : NATIONAL STANDARD EXAMINATION IN CHEMISTRY (NSEC) STAGE-I

1. Which of the following pair of electrons is excluded from an atom ? **[NSEC-2000]**
(A) $n = 2, \ell = 0, m = 0, s = +½$ and $n = 2, \ell = 0, m = 0, s = +½$
(B) $n = 2, \ell = 1, m = +1, s = +½$ and $n = 2, \ell = 1, m = -1, s = +½$
(C) $n = 1, \ell = 0, m = 0, s = +½$ and $n = 1, \ell = 0, m = 0, s = -½$
(D) $n = 3, \ell = 2, m = -2, s = +½$ and $n = 3, \ell = 0, m = 0, s = +½$

2. The splitting of spectral lines under the influence of an electric field is called **[NSEC-2000]**
(A) Raman effect (B) Zeeman effect (C) Compton effect (D) Stark effect

3. The de Broglie wavelength associated with particle is **[NSEC-2000]**
(A) inversely proportional to its momentum (B) inversely proportional to its energy
(C) directly proportional to its velocity (D) directly proportional to its momentum.

4. The following figures show the angular probability distribution of **[NSEC-2000]**



(A) d_{xy} and d_{yz} orbitals (B) $d_{x^2-y^2}$ and d_{z^2} orbitals
(C) d_{xy} and d_{xz} orbitals (D) None of these

5. $^{37}_{18}Ar$ captures a K-electron into its nucleus. The product atom formed is **[NSEC-2000]**
(A) $^{37}_{17}Cl$ (B) $^{38}_{18}Ar$ (C) $^{36}_{18}Ar$ (D) $^{38}_{17}Cl$

6. Which of the following ions will show highest magnetic moment (Z values for neutral atoms are as follows: N = 7, Cr = 24, Fe = 26 & Co = 27) **[NSEC-2000]**
(A) Fe^{3+} (B) Cr^{3+} (C) N^{3+} (D) Co^{3+}

7. The equation $E = h\nu$ indicates that **[NSEC-2000]**
(A) photons have both particle and wave nature
(B) photons are waves
(C) photons are stream of particles
(D) no such inference can be drawn from the given equation

8. An isotone of $^{76}_{32}Ge$: **[NSEC-2001]**
(A) $^{77}_{34}Se$ (B) $^{77}_{33}As$ (C) $^{76}_{32}Ge$ (D) $^{79}_{34}Se$

9. Planck's constant value in joules-sec is : **[NSEC-2001]**
(A) 6.6252×10^{-34} (B) 6.6252×10^{-27} (C) 6.023×10^{-23} (D) 3.1444×10^{-10}

10. Which of the pair of orbitals have electronic density along the axis : **[NSEC-2001]**
(A) d_{xz}, d_{yz} (B) $d_{x^2-y^2}, d_{z2}$ (C) d_{xy}, d_{yz} (D) d_{xy}, d_{z2}

11. The radius of the first Bohr orbit of hydrogen atom is r. The radius of the 3rd orbit will be **[NSEC-2002]**
(A) 3 r (B) 4.5 r (C) 9 r (D) 27 r

12. In a given atom no two electrons can have the same values for all the four quantum numbers. This ruls is called **[NSEC-2002]**
(A) Hund's rule (B) Pauli's principle (C) Aufbau principle (D) selection rule.

13. According to Heisenburg's uncertainty principle **[NSEC-2002]**
(A) $\Delta x. \Delta P \geq \frac{h}{4\pi}$ (B) $\Delta x. \Delta v \geq \frac{h}{4\pi}$ (C) $\Delta x. \Delta m \geq \frac{h}{4\pi}$ (D) $\Delta x . \Delta E \geq \frac{h}{4\pi}$

14. The total number of orbitals in 3rd orbit is : **[NSEC-2002]**
(A) 3 (B) 5 (C) 4 (D) 9

15. Which of the quantum number describe shape of electron cloud ? **[NSEC-2002]**
(A) Principal quantum number (B) Azimuthal quantum number
(C) Magnetic quantum number (D) Spin quantum number.

16. Correct set of all four quantum number for an unpaired electron for $3d^9$ is : **[NSEC-2002]**
(A) 3, 2, + 2, + 1/2 (B) 3, 2, –2, – 1/2 (C) 3, 3, + 2 + 1/2 (D) 3, 3, + 2, – ½

17. The species which has its fifth ionisation potential equal to 340 eV is **[NSEC-2003]**
(A) B^+ (B) C^+ (C) B (D) C

18. Consider a 20 W light source that emits monochromatic light of wavelength 600 nm. The number of photons ejected per second in terms of Avogadro`s constant (N_A) is approximately **[NSEC-2003]**
(A) N_A (B) $10^{-2}\,N_A$ (C) $10^{-4}\,N_A$ (D) $10^{-5}\,N_A$

19. $^{235}_{92}U + ^{1}_{0}n \longrightarrow ^{236}_{92}U \longrightarrow X + ^{90}_{38}Sr + Y$
In the above nuclear fusion reaction, products are **[NSEC-2003]**
(A) $X = ^{140}_{56}B$, $Y = 3\,^{1}_{0}n$ (B) $X = ^{144}_{55}Cs$, $Y = 3\,^{1}_{0}n$ (C) $X = ^{143}_{54}Xe$, $Y = 3\,^{1}_{0}n$ (D) $X = ^{145}_{54}Xe$, $Y = 3\,^{1}_{0}n$

20. The ratio of the energy of a photon of wavelength 2000 Å to that of one with wavelength 4000 Å is **[NSEC-2004]**
(A) 1/4 (B) 4 (C) 1/2 (D) 2.

21. The phenomenon which suggested that light is emitted in packets (quanta) is **[NSEC-2004]**
(A) electron diffraction (B) photoelectric effect
(C) diffraction of light (D) black body radiation.

22. Wave length associated with electron motion **[NSEC-2005]**
(A) increases with increase in the speed of electron
(B) remains same irrespective of the speed of electron
(C) decreases with increase of the speed of electron
(D) changes with the atomic number of the atom to which it belong.

23. The number of unpaired electrons in the scandium atom is **[NSEC-2006]**
(A) 1 (B) 2 (C) 0 (D) 3.

24. The set of quantum numbers n = 2, ℓ = 2, m_ℓ = 0 for an atomic system **[NSEC-2006]**
(A) is not allowed (B) refers to an electron in 2d orbital
(C) denotes a 2p electron (D) describes one of the 7f orbitals.

25. The three quantum numbers n, ℓ, m corresponding to the valence electron in rubidium (Z=37) are **[NSEC-2006]**
(A) 5,0,0 (B) 5,1,0 (C) 5,0,1 (D) 5,1,1

26. The radiation having the highest amount of energy has **[NSEC-2006]**
(A) $\lambda = 3$ nm (B) $\lambda = 3$ pm (C) $\lambda = 3$ Å (D) $\upsilon = 3 \times 10^8\ s^{-1}$.

27. Which of the following pairs represents isoelectronic ions? **[NSEC-2006]**
(A) Mn^{3+} and Fe^{2+} (B) Mn^{2+} and Fe^{3+} (C) Cr^{3+} and Mn^{2+} (D) Fe^{2+} and Co^{2+}.

28. Mass of a typical star is 1.0×10^{30} kg. Assume that a star is typically 3/4 hydrogen and 1/4 helium by mass. The estimated number of protons (which are present in H as well as He) in a typical star is approximately **[NSEC-2006]**
(A) 0.5×10^{57} (B) 1×10^{56} (C) 1×10^{58} (D) 0.5×10^{55}.

29. In 1919, Rutherford bombarded nitrogen with α - particles. He observed emission of α positively charged particle. Such a particle was observed earlier by Wien. Rutherford named this particle as proton. What is the species X in the following ? $^{14}N + He \rightarrow X + {}^{1}H$. **[NSEC-2006]**
(A) ^{17}N (B) ^{18}N (C) ^{16}O (D) ^{17}O.

30. The Bohr radius of the first orbit of hydrogen atom is 0.530 Å units. The radius of the third orbit will be: **[NSEC-2008]**
(A) 1.06 Å (B) 4.77 Å (C) 2.12 Å (D) 1.59 Å

31. An impossible arrangement of the set of quantum number is : **[NSEC-2008]**

	n		m	s
(A)	3	2	–2	1/2
(B)	4	0	0	1/2
(C)	3	2	–3	1/2
(D)	1	0	0	–1/2

32. The fundamental particle responsible for keeping the nucleus together is, **[NSEC-2009]**
(A) meson (B) muon (C) positron (D) hyperon

33. The maximum number of electrons in $3\,d_{z^2}$ orbital is – **[NSEC-2009]**
(A) 2 (B) 4 (C) 5 (D) 10

34. The magnetic moment of a transition metal ion is found to be 3.87 Bohr Magneton (BM). The number of unpaired electrons present in it is : **[NSEC-2009]**
(A) 2 (B) 3 (C) 4 (D) 5

35. The velocity of an electron in the second Bohr orbit of an atom of an element is 1.1×10^{6} m sec^{-1}. Its velocity in the third orbit is **[NSEC-2010]**
(A) 3.3×10^{6} m sec^{-1} (B) 2.2×10^{6} m sec^{-1} (C) 7.333×10^{5} m sec^{-1} (D) 3.666×10^{5} m sec^{-1}

36. The sum of all the quantum numbers of hydrogen atom is **[NSEC-2010]**
(A) –1 (B) 0 (C) +1/2 (D) 3/2

37. The wavelength of a moving body of mass 0.1 mg is 3.31×10^{-29} m. The kinetic energy of the body in J would be : **[NSEC-2011]**
(A) 2.0×10^{-6} (B) 1.0×10^{-3} (C) 4.0×10^{-3} (D) 2.0×10^{-3}

38. The widest range over which electronic excitations in organic compounds occur, is **[NSEC-2012]**
(A) 200 nm - 780 nm (B) 220 nm- 500nm (C) 250 nm- 700 nm (D) 290 nm -1000nm

39. If the radius of the first Bohr orbit is r, then the deBroglie wavelength in the third Bohr orbit is **[NSEC-2012]**
(A) $2\pi r$ (B) 9r (C) r/3 (D) $6\pi r$

40. The quantum numbers for the 19[th] electron of Cr (Z = 24) are : **[NSEC-2012]**
(A) n = 3, l = 0, m = 0, s = + ½ (B) n = 4, l = 0, m = 0, s = + ½
(C) n = 3, l = 2, m = 2, s = + ½ (D) n = 4, l = 2, m = 2, s = + ½

41. The number of unpaired electrons in Ni^{2+} is **[NSEC-2013]**
(A) 0 (B) 2 (C) 3 (D) 4

42. The electronic level which allows the hydrogen atom to absorb, but not emit a photon is **[NSEC-2013]**
(A) 1s (B) 2s (C) 2p (D) 3s

43. The number of unpaired electrons in Ni^{2+} ion is 2, therefore its spin multiplicity is **[NSEC-2013]**
(A) 2 (B) 1 (C) 3 (D) 4

44. 4s orbital has lesser energy than 3d orbital because it has **[NSEC-2013]**
(A) Greater value of n (B) Lesser value of l
(C) Lesser value of (n +l) (D) l = 0

45. The magnetic moment of a divalent ion of an element with atomic number 24 in an aqueous solution is **[NSEC-2014]**
(A) 4.9BM (B) 2.45BM (C) 2.83BM (D) 1.73BM

46. From the following species that are isoelectronic are **[NSEC-2014]**
I . NH_3 II. CH_3^+ III. NH_2^- IV. NH_4^+
(A) (I), (II), (III) (B) (II), (III), (IV) (C) (I), (II), (IV) (D) (I), (III), (IV)

47. The set of quantum numbers that cannot be allotted to an electron in an atom is **[NSEC-2014]**
(A) $n = 3, l = 2, m_1 = +2, m_2 = -1/2$ (B) $n = 2, l = 0, m_1 = +1, m_s = +1/2$
(C) $n = 1, l = 0, m_1 = 0, m_s = +1/2$ (D) $n = 4, l = 3, m_1 = 0, m_s = -1/2$

48. If the energy of an electron in the 1st and 2nd energy levels of an H atom are –13.6 eV and –3.4 eV, respectively, the energy required in eV to excite an electron from the 1st to the 2nd energy level is **[NSEC-2014]**
(A) 17.0 (B) –17.0 (C) 10.2 (D) –10.2

49. The element X formed in the following nuclear reaction is ${}^{53}_{24}Cr + {}^{4}_{2}\alpha \rightarrow {}^{1}_{0}n + X$ **[NSEC-2014]**
(A) ${}^{56}_{26}Fe$ (B) ${}^{55}_{25}Mn$ (C) ${}^{56}_{25}Mn$ (D) ${}^{55}_{25}Fe$

50. If λ_0 and λ are the threshold wavelength and the wavelength of the incident light, respectively on a metal surface, the velocity of the photoelectron ejected from the metal surface is (m_e = mass of electron, h = Planck's constant, c = speed of light) **[NSEC-2015]**
(A) $\sqrt{\frac{2h(\lambda_0 - \lambda)}{m_e}}$ (B) $\sqrt{\frac{2hc(\lambda_0 - \lambda)}{m_e}}$ (C) $\sqrt{\frac{2hc}{m_e}\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)}$ (D) $\sqrt{\frac{2h}{m_e}\left(\frac{1}{\lambda_0} - \frac{1}{\lambda}\right)}$

51. The energy of an electron in the first Bohr orbit is –13.6 eV. The energy of Be^{3+} in the first excited state is **[NSEC-2015]**
(A) –30.6 eV (B) –40.8 eV (C) –54.4 eV (D) +40.8 eV

52. The de Brogile wavelength of an object of mass 33 g moving with a velocity of $200ms^{-1}$ is of the order of : **[NSEC-2015]**
(A) 10^{-31}m (B) 10^{-34}m (C) 10^{-37}m (D) 10^{-41}m

53. Imagine that in any atom about 50% of the space is occupied by the atomic nucleus. If a silver foil is bombarded with α-particles, majority of the α-particles would **[NSEC-2015]**
(A) be scattered (B) be absorbed by the nuclei
(C) pass through the foil undeflected (D) get converted into photons

54. For an electron whose x-positional uncertainty is 1.0 x 10^{-10} m, the uncertainty in the x. Component of the velocity in m s^{-1} will be of the order of **[NSEC-2015]**
(A) 10^6 (B)10^9 (C)10^2 (D) 10^{15}

55. The ionization energy of a certain element is 412 kJ mol^{-1}. When the atoms of this element are in the first excited state, however, the ionization energy is only 126 kJ mol^{-1}. The region of the electromagnetic spectrum in which the wavelenght of light emitted in a transition from the first excited state to the ground state is **[NSEC-2016]**
(A) Visible (B) UV (C) IR (D) X-ray

56. The kinetic energy of an electron that has a wavelength of 10 nm is **[NSEC-2016]**
(A) 2.4×10^{-21} J (B) 4.8×10^{-21} J (C) 2.4×10^{-29} J (D) 4.8×10^{-29} J

57. When a certain metal was irradiated with light of frequency 3.2×10^{16} Hz, the photoelectrons emitted had twice the kinetic energy as did the photoelectrons emitted when the same metal was irradiated with light of frequency 2.0×10^{16} Hz. The v_0 of the metal is : **[NSEC-2016]**
(A) 2.4×10^{16} Hz (B) 8.0×10^{16} Hz (C) 8.0×10^{15} Hz (D) 7.2×10^{16} Hz

58. An electron beam can undergo diffraction by crystals which proves the wave nature of electrons. The potential required for a beam of electrons to be accelerated so that its wavelength becomes equal to 0.154 nm is : **[NSEC-2016]**
(A) 63.5 V (B) 31.75 V (C) 635 V (D) 127 V

59. The ratio of the energy of the electron in ground state of hydrogen atom to that of the electron in the first excited state of Be^{3+} is **[NSEC-2016]**
(A) 1 : 4 (B) 1 : 8 (C) 1 : 16 (D) 4 : 1

60. The electrons identified by quantum number n and l, (i) n = 4, l = 1, (ii) n = 4, l = 0, (iii) n = 3, l = 2, (iv) n = 3, l = 1 can be placed in order of increasing energy from lowest to highest as : **[NSEC-2016]**
(A) (iv) < (ii) < (iii) < (i) (B) (ii) < (iv) < (i) < (iii) (C) (i) < (iii) < (ii) < (iv) (D) (iii) < (i) < (iv) < (ii)

61. The energy of an electron in Bohr's orbit of hydrogen atom is –13.6eV. The total electronic energy of a hypothetical' He atom is which there are no electron– electron repulsions is **[NSEC-2017]**
(A) 27.2 eV (B) –27.2 eV (C) –108.8 eV (D) 108.eV

62. The energy of an electron in the ground state of H atom is -13 6eV.
The negative sign indicates that **[NSEC-2017]**
(A) electrons are negatively charged.
(B) H atom is more stable than a free electron.
(C) energy of the electron in the H atom is lower than that of a free electron.
(D) work must be done to make a H atom from a free electron and proton.

63. Which of the following elements will exhibit photoelectric effect with light of the longest wavelength? **[NSEC-2018]**
(A) K (B*) Rb (C) Mg (D) Ca

64. If the radius of the hydrogen atom is 53 pm, the radius of the He^+ ion is close to **[NSEC-2018]**
(A) 75 pm (B) 38 pm (C) 106 pm (D*) 27 pm

65. An orbital among the following that has two radial nodes and two angular nodes is **[NSEC-2018]**
(A) 3d (B) 4p (C) 4f (D*) 5d

PART - III : HIGH LEVEL PROBLEMS (HLP)

SUBJECTIVE QUESTIONS

1. Why cathode ray tube experiment is not conducted at atmospheric pressure ?

2. The threshold frequency for the ejection of electrons from potasium metal is $5.3 \times 10^{14}\ s^{-1}$. Will the photon of a radiation having energy 3.3×10^{-19} J exhibit photoelectric effect ? ($h = 6.626 \times 10^{-34}$ Js)

3. If the work function (w) of an arbitrary metal is 3.1 eV, find its threshold wavelength and the maximum kinetic energy of the electron emitted when radiation of 300 nm strike the metal surface. (Take hc = 12400 eVÅ)

4. Calculate the speed of an electron in the ground state of He^+ ion. What fraction of speed of light is this value? How long does it take for the electron to complete one revolution around the nucleus. How many times does the electron travel around the nucleus in one second ?

5. When an electron falls from (n + 2) state to (n) state in a He^+ ion the photon emitted has energy 6.172×10^{-19} joules. What is the value of n.

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

0 eV ——— n = ∞
– 0.50 eV ——— n = 5
– 1.45eV ——— 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 ?

7. Calculate the energy emitted when electrons of 1.0 g atom of hydrogen undergo transition giving the spectral lines of lowest energy in the visible region of its atomic spectra.
$R_H = 1.1 \times 10^7$ mol^{-1}, c = 3×10^8 m sec^{-1} and h = 6.62×10^{-34} J sec.

8. An electron moving near an atomic nucleus has a speed of $6 \times 10^6 \pm 1\%$ m/s. What is the uncertainty in its position ?

9. Calculate the energy required to excite one litre Hydrogen gas at 1 atm and 298 K to first excited state of atomic hydrogen. The energy for the dissociation of H-H bond is 436 kJ mol^{-1}.

10. The wave function of 3s electron is given by

$$\Psi_{3s} = \frac{1}{81\sqrt{3}\Pi}\left(\frac{1}{a_0}\right)^{3/2}\left[27-18\left(\frac{r}{a_0}\right)+2\left(\frac{r}{a_0}\right)^2\right]e^{-r/3a_0}$$

It has a node at r = r_0, Find out the relation between r_0 and a_0

ONLY ONE OPTION CORRECT TYPE

11. 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

12. **S_1 :** Bohr model is applicable for Be^{2+} ion.
S_2 : Total energy coming out of any light source is integral multiple of energy of one photon.
S_3 : Number of waves present in unit length is wave number.
S_4 : 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

13. If uncertainties in the measurement of position and momentum are equal for electron, calculate uncertainty in the measurement of velocity? (Given that : $\sqrt{\frac{h}{4\pi}} = 0.726 \times 10^{-17}$)
(A) 7.98×10^{12} ms^{-1} (B) 7.98×10^{10} ms^{-1} (C) 8.42×10^{12} ms^{-1} (D) 6×10^6 ms^{-1}

14. A photon of frequency ν causes photo electric emission from a surface with threshold frequency ν_0. The de-Broglies wavelength (λ) of the photo electron emitted is given by :
(A) $\Delta\nu = \frac{h}{2m\lambda}$ (B) $\Delta\nu = \frac{h}{\lambda}$ (C) $\frac{mc^2}{h} = \left[\frac{1}{\nu_0} - \frac{1}{\nu}\right]$ (D) $\lambda = \sqrt{\frac{h}{2m\Delta\nu}}$

15. Choose the incorrect statement from among the following :
(A) A node is a point in space where the wave function (ψ) has zero amplitude.
(B) The number of peaks in radial distribution is $n - \ell$.
(C) Radial probability density $\pi_{n,\ell(r)} = 4\pi r^2 R^2_{n,\ell(r)}$.
(D) ψ^2 represent the atomic orbital.

16. Which of the d orbitals not lies in the xy-plane.
(A) $d_{x^2-y^2}$ (B) d_{xy} (C) d_{xz} (D) d_{xy} and $d_{x^2-y^2}$

17. Which of the following does not characterise X-rays ?
(A) The radiation can ionise the gas (B) It causes fluoresce effect on ZnS
(C) Deflected by electric and magnetic fields (D) Have wavelength shorter than ultraviolet rays

18. The increasing order for the values of e/m (charge/mass) is :
(A) e, p, n, α (B) n, p, e, α (C) e, α, e (D) n, α , p, e

19. The ratio of slopes of K_{max} Vs v and V_0 Vs v curves in the photoelectric effect gives (v = frequency, K_{max} = maximum kinetic energy, V_0 = stopping potential) :
(A) charge of electron
(B) Planck's constant
(C) work function
(D) the ratio of Planck's constant of electronic charge

20. From the α-particle scattering experiment, Rutherford concluded that
(A) α-particles can come within a distance of the order of 10^{-14} m of the nucleus
(B) the radius of the nucleus is less than 10^{-14} m
(C) scattering follows Coulomb's law
(D) All of these

21. 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) $\frac{4\pi^2mk^2e^5}{n^3h^3}$

22. An electron is continuously accelerated in vacuum tube by applying potenital difference. If its de-broglie wavelength is decreased by 1 %. The change in kinetic energy of the electron is nearly.
(A) Decreased by 1 % (B) Increased by 2 % (C) Increased by 1 % (D) Decreased by 2 %

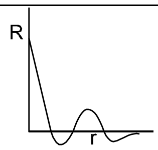
23. An electron in a hydrogen like atom makes transition from a state in which its de-Broglie wavelength is λ_1 to a state where its de-Broglie wavelength is λ_2 then wavelength of photon (λ) generated will be
(A) $\lambda = \lambda_1 - \lambda_2$ (B) $\lambda = \frac{4mc}{h}\left\{\frac{\lambda_1^2\ \lambda_2^2}{\lambda_1^2 - \lambda_2^2}\right\}$ (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.

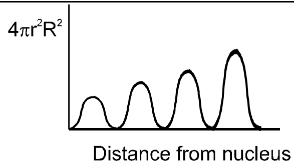
24. The radial probability is the probability of finding electrons in a small spherical shell around the nucleus at a particular distance (r). Hence radial probability is :
(A) $4\ \pi r^2\ dr\ \psi^2$ (B) $\frac{4}{3}\pi r^2\ dr\ \psi^2$ (C) $2\ \pi r^2\ dr\ \psi^2$ (D) $4\ \pi r\ dr\ \psi$

25. 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.
II. If n = 3, ℓ = 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

MATCH THE COLUMN

26. **Column-I** and **Column-II** contains four entries each. Entries of **Column-I** are to be matched with some entries of **Column-II**. One or more than one entries of **Column-I** may have the matching with the same entries of **Column-II**.

	Column-I		Column-II
(A)		(p)	4s

(B)		(q)	$5p_y$
(C)	Angular probability is dependent of θ and ϕ	(r)	3s
(D)	Atleast one angular node is present	(s)	$6d_{xy}$

SINGLE AND DOUBLE VALUE INTEGER TYPE

27. How many of the following statements are true about the cathode rays ?
(i) Path of travelling is straight from the cathode with a very high velocity as it produces shadow of an object placed in its path.
(ii) rays consist of material particle.
(iii) They deflect towards negative end of the electrode.
(iv) They produce yellow glow when the glass will beyond anode.
(v) Cathode rays penetrate through thin sheets of aluminium and metals.
(vi) They affect the photographic plates
(vii) The ratio of charge(e) to mass(m) i.e. charge/mass is same for all cathode rays irrespective of the gas used in the tube. e/m = 1.76×10^{11} Ckg^{-1}
(viii) cathode rays are visible at low voltage.

28. When a certain metal was irradiated with light frequency 1.6×10^{16} Hz, the photo electrons emitted had twice the kinetic energy as did photoelectrons emitted with frequency 1×10^{16} Hz when the same metal was irradiated with light, then threshold frequency $x \times 10^{15}$ Hz. Find "x".

29. A radio station is broadcasting programme at 100 MHz frequency. If the distance between the radio station and the receive set is 300 KM. How long the signal would take to reach the set from the radio station in term of 10^{-3} sec.

30. A single electron system has ionization energy 20902.2 kJ/mole. Find the number of protons in the nucleus of the system.

31. 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 :

32. An element undergoes a reaction as shown:

$x + e^- \rightarrow x^-$ energy released = 30.87 eV

If the energy released, is used to dissociate 12 g of H_2 molecules, equally into H^+ and H^*, where H^* is an excited state, in which the electron travels a path length equal to four times it's debroglie wavelength. Determine the least amount (in moles) of 'x' that would be required.
Given: I.E. of H = 13.6 eV/atom, Bond energy of H_2 = 4.526 eV/molecule.

33. 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.

34. In a sample of hydrogen atom in ground state electrons make transition from ground state to a particular excited state where path length is five times de-broglie wavelength, electrons make back transition to the ground state producing all possible photons. If photon having 2nd highest energy of this sample can be used to excite the electron in a particular excited state of Li^{2+} atom then find the final excited state of Li^{2+} atom.

35. 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 in grams is : ($h = 6.625 \times 10^{-34}$Js). Represent answer by dividing with 10.

36. If each orbital can hold a maximum of 3 electrons, the number of elements in 4th periodic table (long form) is.

37. In all how many nodal planes are there in the atomic orbitals for the principal quantum number n = 3

38. $^{234}_{90}Th$ disintegrates to give $^{206}_{82}Pb$ as the final product. How many alpha and beta particles are emitted during this process ? Express answer as number of α-particle + number of β-particle emitted.

ONE OR MORE THAN ONE OPTIONS CORRECT TYPE

39. 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

40. 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

41. 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 30 watt 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

42. 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

43. 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.

44. d_{z^2} – orbital has :
(A) Two lobes along z-axis (B) Ring along yz-plane
(C) Ring along xy-plane (D) Ring along x axis

45. If m_p is the mass of proton. m_n that of a neutron, M_1 that of $_{10}Ne^{20}$ nucleus and M_2 that of $_{20}Ca^{40}$ nucleus, then which of the following relations is/are not true ?
(A) $M_2 > 2M_1$ (B) $M_2 < 20\ (m_p + m_n)$ (C) $M_2 = 2M_1$ (D) $M_2 < 2M_1$

PART - IV : PRACTICE TEST-2 (IIT-JEE (ADVANCED Pattern))

Max. Time : 1 Hr. **Max. Marks : 66**

Important Instructions

A. General :

1. The test is of 1 hour duration.
2. The Test Booklet consists of 22 questions. The maximum marks are 66.

B. Question Paper Format

3. Each part consists of five sections.
4. Section 1 contains 7 multiple choice questions. Each question has four choices (A), (B), (C) and (D) out of which ONE is correct.
5. Section 2 contains 5 multiple choice questions. Each question has four choices (A), (B), (C) and (D) out of which ONE OR MORE THAN ONE are correct.
6. Section 3 contains 6 questions. The answer to each of the questions is a single-digit integer, ranging from 0 to 9 (both inclusive).
7. Section 4 contains 1 paragraphs each describing theory, experiment and data etc. 3 questions relate to paragraph. Each question pertaining to a partcular passage should have only one correct answer among the four given choices (A), (B), (C) and (D).
8. Section 5 contains 1 multiple choice questions. Question has two lists (list-1 : P, Q, R and S; List-2 : 1, 2, 3 and 4). The options for the correct match are provided as (A), (B), (C) and (D) out of which ONLY ONE is correct.

C. Marking Scheme :

9. For each question in Section 1, 4 and 5 you will be awarded 3 marks if you darken the bubble corresponding to the correct answer and zero mark if no bubble is darkened. In all other cases, minus one (– 1) mark will be awarded.
10. For each question in Section 2, you will be awarded 3 marks. If you darken all the bubble(s) corresponding to the correct answer(s) and zero mark. If no bubbles are darkened. No negative marks will be answered for incorrect answer in this section.
11. For each question in Section 3, you will be awarded 3 marks if you darken only the bubble corresponding to the correct answer and zero mark if no bubble is darkened. No negative marks will be awarded for incorrect answer in this section.

SECTION-1 : (Only One option correct Type)

This section contains 7 multiple choice questions. Each questions has four choices (A), (B), (C) and (D) out of which Only ONE option is correct.

1. Find the quantum number of the excited state of electrons in He^+ ion which on transition to first excited state emit photons of wavelengths 108.5 nm. ($R_H = 1.09678 \times 10^7\ m^{-1}$)
(A) 6 (B) 5 (C) 4 (D) 2

2.✍ For a 3s orbital $\Psi\ (3s) = \frac{1}{9\sqrt{3}}\left(\frac{1}{a_0}\right)^{1/2}(6 - 6\sigma + \sigma^2)\ \Psi^{-\sigma/2}$

Where $\sigma = \frac{2Zr}{3a_0}$. What is the maximum radial distance of node from nucleus ?

(A) $\frac{2}{3}\frac{(3+\sqrt{3})a_0}{Z}$ (B) $\frac{3}{2}\frac{(3+\sqrt{3})a_0}{Z}$ (C) $\frac{3}{2}\frac{(3-3\sqrt{3})a_0}{Z}$ (D) $\frac{3}{2}\frac{(3-\sqrt{3})a_0}{Z}$

3. A glow–worm of mass 5.0 g emits red light (650 nm) with a power of 0.10 w. entirely in the backward direction. To what speed will it have accelerated after 10 year if released into free space and assumed to live?
(A) 21 ms^{-1} (B) 29 ms^{-1} (C) 31.8 ms^{-1} (D) 0.08 ms^{-1}

4.✍ Calculate the energy required to excited one litre of hydrogen gas at 1 atm and 298 K to the first excited state of atomic hydrogen. The energy for the disociation of H–H bond is 436 kJ mol^{-1}. Also calculate the minimum frequency of photon to break this bond.
(A) 98.19 Hz (B) 10.93 × 10^{14} Hz (C) 10^{15} Hz (D) 6.22 × 10^{14} Hz

5. O_2 undergoes photochemical dissociation into 1 normal oxygen atom (O) and more energetic oxygen atom O*. If (O) has 1.967 eV more energy than (O) and normal dissociation energy of O_2 is 498 kJ mol^{-1}, what is the maximum wavelength effective for the photo chemical dissociation of O_2?
(A) 1.01 nm (B) 1.64 nm (C) 1.74 nm (D) 2.74 nm

6. If the subsidiary quantum number of a subenergy level is 4, the maximum and minimum values of the spin multiplicities are :
(A) 9, 1 (B) 10, 1 (C) 10, 2 (D) 4, –4

7. 1 mol of He^+ ion is excited. Spectral analysis showed existence of 50% ions in 3rd level, 25% in 2nd level and remaining 25% in ground state. Ionization energy of He^+ is 54.4 eV; calculate total energy evolved when all the ions return ground state.
(A) 331.13×10^4 J (B) 400.14×10^4 J (C) 10^4 J (D) 6.66×10^4 J

Section-2 : (One or More than one options correct Type)
This section contains 5 multipole choice questions. Each questions has four choices (A), (B), (C) and (D) out of which ONE or MORE THAN ONE are correct.

8. Consider the following six electronic configurations (remaining inner orbitals are completely filled) and mark the correct option.

(I) 3s [↑] 3p [↑][↑][↑]	(II) 3s [↑↓] 3p [↑][↑][ ]	(III) 3s [↑↓] 3d [↑][↑][↑][↑][ ]
(IV) 4s [↑] 3d [↑][↑][↑][↑][↑]	(V) 4s [↑] 4p [↑][↑][↑↑]	(VI) 4s [↑↓] 3d [↑][↑][ ][ ][ ]

(A) Stability order : II > I > IV > III
(B) Order of spin multiplicity : IV > III = I > II
(C) V does not violate all the three rules of electronic configuration
(D) If VI represents A and A^+ when kept near a magnet, acts as diamagnetic substance.

9. Choose the correct statement(s) :
(A) The shape of an atomic orbital depends upon azimuthal quantum number
(B) The orientation of an atomic orbital depends upon the magnetic quantum number
(C) The energy of an electron in an atomic orbital of multi-electron atom depends upon principal quantum number only
(D) The number of degenerate atomic orbitals of one type depends upon the value of azimuthal quantum number

10. The radial distribution functions [P(r)] is used to determine the most probable radius, which is used to find the electron in a given orbital $\frac{dP(r)}{dr}$ for 1s-orbital of hydrogen like atom having atomic number Z, is

$$\frac{dP}{dr} = \frac{4Z^3}{a_0^3}\left(2r - \frac{2Zr^2}{a_0}\right) e^{-2Zr/a_0} :$$

(A) At the point of maximum value of radial distribution function $\frac{dP(r)}{dr} = 0$; one antinode is present
(B) Most probable radius of Li^{2+} is $\frac{a_0}{3}$ pm
(C) Most probable radius of He^+ is $\frac{a_0}{2}$ pm
(D) Most probable radius of hydrogen atom is a_0 pm

11. For radial probability curves, which of the following is/are correct ?
(A) The number of maxima in 2s orbital are two
(B) The number of spherical or radial nodes is equal to $n - \ell - 1$
(C) The number of angular nodes are 'ℓ'
(D) $3d_{z^2}$ has 3 angular nodes

12. d_{xy} orbital has four lobes between x- and y-axes. The wave functions of two lobes are positive and those of other two are negative. The positive wave function signifies that :
(A) both x and y are positive (B) both x and y are negative
(C) either x or y is negative (D) none of these

Section-3 : (One Integer Value Correct Type)
This section contains 6 questions. Each question, when worked out will result in one integer from 0 to 9 (both inclusive)

13. The dissociation energy of H_2 is 430.53 kJ mol^{-1}. If H_2 is exposed to radiant energy of wavelength 253.7 nm. What % of radiant energy will be converted into kinetic energy? (Report your answer as nearest integer)

14. The IE_1 of H is 13.6 eV. It is exposed to electromagnetic waves of 1028Å and gives out induced radiation. Find out orbit of these induced radiation.

15. 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). Give answer = n + Z.

16. A moving particle is associated with wavelength 5×10^{-8}m. If its momentum is reduced to half of its value, compute the new wavelength. If answer is 10^{-x} then find 'x'.

17. According to Bohr theory, the electronic energy of a hydrogen atom in the n^{th} Bohr atom is given by $E_n = -\frac{21.76 \times 10^{-19}}{n^2}$ J. Calculate the longest wavelength of light that will be needed to remove an electron from the third Bohr orbit of the He^+ ion (If the wavelength is $x \times 10^{-7}$ (in meter) and x is an integer. Report 'x')

18. ${}_{4}^{7}Be$ captures a K-electron into its nucleus. What will be the sum of mass number and atomic number of the nuclide formed?

SECTION-4 : Comprehension Type (Only One options correct)
This section contains 1 paragraphs, each describing theory, experiments, data etc. 3 questions relate to the paragraph. Each question has only one correct answer among the four given options (A), (B), (C) and (D)

Paragraph for Questions 19 to 21

Werner Heisenberg considered the limits of how precisely we can measure the properties of an electron or other microscopic particle. He determined that there is a fundamental limit to how closely we can measure both position and momentum. The more accurately we measure the momentum of a particle, the less accurately we can determine its position. The converse is also true. This is summed up in what we now call the Heisenberg uncertainty principle.

The equation is $\Delta x.\Delta(mv) \geq \frac{h}{4\pi}$

The uncertainty in the position or in the momentum of a macroscopic object like a baseball is too small to observe. However, the mass of microscopic object such as an electron is small enough for the uncertainty to be relatively large and significant.

19. If the uncertainties in position and momentum are equal, the uncertainty in the velocity is :
(A) $\sqrt{\frac{h}{\pi}}$ (B) $\sqrt{\frac{h}{2\pi}}$ (C) $\frac{1}{2m}\sqrt{\frac{h}{\pi}}$ (D) none of these

20. If the uncertainty in velocity and position is same, then the uncertainty in momentum will be :

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

21. What would be the minimum uncertainty in de-Broglie wavelength of a moving electron accelerated by potential difference of 6 volt and whose uncertainty in position is $\frac{7}{22}$ nm ?

(A) 6.25 Å (B) 6 Å (C) 0.625 Å (D) 0.1325 Å

SECTION-5 : Matching List Type (Only One options correct)

This section contains 1 questions, each having two matching lists. Choices for the correct combination of elements from List-I and List-II are given as options (A), (B), (C) and (D) out of which one is correct.

22. Match each List-I with an appropriate pair of characteristics from List-II and select the correct answer using the code given below the lists.

	List-I		**List-II**
P	Lyman series	1	maximum number of spectral line observed = 6
Q	Balmer series	2	maximum number of spectral line observed = 2
R	In a sample of H-atom for 5 upto 2 transition.	3	2^{nd} line has wave number $\frac{8R}{9}$
S	In a single isolated H-atom for 3 upto1 transition.	4	2^{nd} line has wave number $\frac{3R}{16}$

Code :

	P	Q	R	S
(A)	3	4	1	2
(B)	1	2	4	3
(C)	3	1	2	4
(D)	2	3	1	4

Practice Test-2 (IIT-JEE (ADVANCED Pattern))

OBJECTIVE RESPONSE SHEET (ORS)

Que.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Ans.										
Que.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Ans.										
Que.	**21**	**22**								
Ans.										

APSP Answers

PART - I

1.	(4)	**2.**	(3)	**3.**	(2)	**4.**	(4)	**5.**	(4)
6.	(2)	**7.**	(1)	**8.**	(1)	**9.**	(2)	**10.**	(1)
11.	(4)	**12.**	(1)	**13.**	(3)	**14.**	(4)	**15.**	(4)
16.	(2)	**17.**	(3)	**18.**	(3)	**19.**	(1)	**20.**	(4)
21.	(3)	**22.**	(1)	**23.**	(1)	**24.**	(2)	**25.**	(1)
26.	(4)	**27.**	(1)	**28.**	(4)	**29.**	(1)	**30.**	(4)

PART - II

1.	(A)	**2.**	(D)	**3.**	(A)	**4.**	(B)	**5.**	(D)
6.	(A)	**7.**	(A)	**8.**	(B)	**9.**	(A)	**10.**	(B)
11.	(C)	**12.**	(B)	**13.**	(A)	**14.**	(D)	**15.**	(B)
16.	(A)	**17.**	(C)	**18.**	(C)	**19.**	(C)	**20.**	(D)
21.	(B)	**22.**	(C)	**23.**	(A)	**24.**	(A)	**25.**	(A)
26.	(B)	**27.**	(C)	**28.**	(A)	**29.**	(D)	**30.**	(B)
31.	(C)	**32.**	(A)	**33.**	(A)	**34.**	(B)	**35.**	(C)
36.	(D)	**37.**	(A)	**38.**	(A)	**39.**	(D)	**40.**	(B)
41.	(B)	**42.**	(A)	**43.**	(C)	**44.**	(C)	**45.**	(A)
46.	(D)	**47.**	(B)	**48.**	(C)	**49.**	(A)	**50.**	(C)
51.	(C)	**52.**	(B)	**53.**	(A)	**54.**	(A)	**55.**	(A)
56.	(A)	**57.**	(C)	**58.**	(A)	**59.**	(A)	**60.**	(A)
61.	(C)	**62.**	(C)	**63.**	(B)	**64.**	(D)	**65.**	(D)

PART - III

1. At atmospheric pressure in the cathode tube the generated cathode rays shall face numerous collisions. Hence the distance traveled by the rays will be infinitisimally small.

2. No **3.** (a) 4000 Å (b) 1.033 ev

4. 4.36×10^6 m/s, 0.0145, 3.8×10^{-17} sec, 2.63×10^{16} revolution

5. n = 3 **6.** (a) 15.6 V , (b) 233.9 nm, (c) $1.009 \times 10^7\ m^{-1}$

7. 182.5 kJ **8.** $\geq 1 \times 10^{-9}$ m **9.** 98.17 kJ **10.** $r_0 = 7.1a_0$ and $r_0 = 1.95\ a_0$

11.	(B)	**12.**	(C)	**13.**	(A)	**14.**	(D)	**15.**	(D)
16.	(C)	**17.**	(C)	**18.**	(D)	**19.**	(A)	**20.**	(D)
21.	(D)	**22.**	(B)	**23.**	(D)	**24.**	(A)	**25.**	(A)

26. (A) - (p) ; (B) - (p,q,s) ; (C) - (q,s) ; (D) - (q,s) **27.** 5 (i, ii, v, vi, vii)

28.	4	**29.**	1	**30.**	4	**31.**	12	**32.**	6
33.	4	**34.**	12	**35.**	10	**36.**	48	**37.**	11
38.	13	**39.**	(ABCD)	**40.**	(ABC)	**41.**	(ABC)		
42.	(ABC)	**43.**	(BD)	**44.**	(A)	**45.**	(AC)		

PART - IV

1.	(B)	**2.**	(B)	**3.**	(A)	**4.**	(B)	**5.**	(C)
6.	(C)	**7.**	(A)	**8.**	(ABC)	**9.**	(ABD		
10.	(ABCD	**11.**	(ABC)	**12.**	(AB)	**13.**	9 (8.68%)	**14.**	3
15.	9	**16.**	7	**17.**	2	**18.**	10 (7 + 3 = 10)	**19.**	(C)
20.	(A)	**21.**	(C)	**22.**	(A)				

APSP Solutions

PART - I

1. Total number of nodes = n – 1 = 5 – 1 = 4
Angular node = ℓ = 4.
Zero radial node and 4 angular nodes.

2. The threshold frequency (ν_0) corresponding to the wavelength 6500 Å is c/λ_0.
Therefore, the threshold energy = $h\nu_0 = hc/\lambda_0$.
Substituting for h, c and λ_0 we get, threshold energy = 3.056×10^{-12} ergs.
The energy of the incident photons is given by E = hc/λ_0, since incident wavelength λ = 360 Å. Therefore, incident energy = 55.175×10^{-12} ergs.
The kinetic energy of the photoelectrons will be the difference of incident energy and threshold energy,
$\therefore$ KE = $h\nu - h\nu_0 = (55.175 \times 10^{-12}) - (3.056 \times 10^{-12})$ ergs. = 52.119×10^{-12} ergs

3. For an electron $mu^2 = eV$ and $\lambda = \dfrac{h}{mu}$

Thus, $\dfrac{1}{2} m \times \dfrac{h^2}{m^2\lambda^2} = eV$

or $V = \dfrac{1}{2}\dfrac{h^2}{m\lambda^2 e} = \dfrac{1\times(6.62\times10^{-34})^2}{2\times9.108\times10^{-31}(1.54\times10^{-10})^2\times1.602\times10^{-19}}$ = 63.3 volt.

4. $E_n = \dfrac{13.6}{n^2}$ – eV; $E_2 = \dfrac{13.6}{2^2}$

$E_4 = -\dfrac{13.6}{4^2}$ eV/atom

$\Delta E = E_4 - E_2 = 2.55$ eV
Absorbed energy = work function of metal + K.E. 2.55 = 2.5 + K.E. ; K.E. = 0.05 eV

5. The number of photon is $N = \dfrac{E}{h\nu} = \dfrac{P\Delta t}{h(c/\lambda)} = \dfrac{\lambda P\Delta t}{hc}$

Substitution of the data gives

$$N = \frac{(5.60\times10^{-7}\text{m})\times(100\text{Js}^{-1})\times(1.0\text{s})}{(6.626\times10^{-34}\text{s})\times(3\times10^{8}\text{ms}^{-1})} = 2.8 \times 10^{20}$$

7. ${}_{X}A^{Z} \rightarrow {}_{X-2}B^{Z-4} + {}_{2}He^{4}$
${}_{X-2}B^{Z-4} \rightarrow {}_{X-1}C^{Z-4} + {}_{-1}e^{0}$
${}_{X-1}C^{Z-4} \rightarrow {}_{X}D^{Z-4} + {}_{-1}e^{0}$

8. E_n = – 78.4 kcal/mole = – 78.4 × 4.2 = – 329.28 kJ/mole
$= -\dfrac{329.28}{96.5}$ eV = – 3.4 eV. (energy of II orbit of H atom).

9. Wave numbers are the reciprocals of wavelengths and are given by the expression $= \bar{\nu}\ \dfrac{1}{\lambda}$.

$\dfrac{1}{\bar{\nu}} = 1.1 \times 10^5 \left[\dfrac{1}{n_1} - \dfrac{1}{n_2}\right]$

11. Charge/mass for n = 0, for $\alpha = \frac{2}{4}$,

for p = $\frac{1}{1}$, for e^- = $\frac{1}{1/1837}$

12. Change in P.E. = $-\frac{2x}{4} + (2x) \Rightarrow \frac{3}{2}x$

13. $r_1 = 0.529$ Å; $r_{4(X)} = r_1 \times \frac{n^2}{Z}$;

$r_{4(X)} \Rightarrow \frac{0.529 \times (4)^2}{Z}$; Z = 16

16. The ionization potential of an atom of nucleus of proton and the new sub-atomic particle system is determined by replacing the mass of electron by reduced mass m, while

$$m = \frac{m_p m'}{m_p + m'} = \frac{1836m_e \times 207m_e}{1836m_e + 207m_e}$$

$m = 1836\ m_e$

I.E. $\propto$ m, So, I.E. increases

17. Maximum number of electrons with same spin is equal to maximum number of orbitals, i.e., $(2\ell + 1)$.

18. It is fact.

19. It is fact.

20. Total nodes = n – 1.

21. Cl_{17} : [Ne] $3s^2\ 3p^5$.

Unpaired electron is in 3p orbital. $\therefore$ n = 3, ℓ = 1, m = 1, 0, – 1.

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

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

By equations (i) and (ii),

Angular velocity $(\omega) = \frac{u}{r} = \frac{8\pi^3Z^2me^4}{n^3h^3}$ ....(iii)

$$= \frac{8 \times (22/7)^3 \times (2)^2 \times (9.108 \times 10^{-28}) \times (4.803 \times 10^{-10})^4}{(2)^3 \times (6.626 \times 10^{-26})^3} = \mathbf{2.067 \times 10^{16}\ sec^{-1}}.$$

24. $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$; $n_1 = 1$, n_2 = ?;

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

$\Rightarrow n_2 = \sqrt{\frac{\lambda R}{\lambda R - 1}}$

25. Number of emitted electron $\propto$ Intensity of incident light.

26. $\dfrac{R_{Os}}{R_{Li}} = \left(\dfrac{189}{7}\right)^{1/3} = 3$

27. It would be same in x and y axis for $d_{x^2-y^2}$.

28. For II to I transition, $\Delta E = \dfrac{4E}{3} - E = \dfrac{hc}{\lambda_{II\to I}}$; $\dfrac{E}{3} = \dfrac{hc}{\lambda_{II-I}}$

For III to I transition, $\Delta E = 2E - E = \dfrac{hc}{\lambda}$ or $E = \dfrac{hc}{\lambda}$

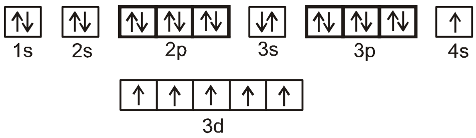
$\therefore$ $\dfrac{hc}{3\times\lambda} = \dfrac{hc}{\lambda_{II-I}}$ $\lambda_{II-I} = 3\lambda$

29. Number of unpaired elecron are given by Magnetic moment = $\sqrt{[n(n+2)]}$ where n is number of unpaired electrons or 1.73 = $\sqrt{[n(n+2)]}$ or $1.73 \times 1.73 = n^2 + 2n$

$\therefore$ n = 1.

Now vanadium atom must have one unpaired electron and thus its confiuration is :

$_{23}V^{4+}$: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^1$

30. 

Out of 6 electrons in 2p and 3p must have on electron with m = + 1 and s = $\dfrac{1}{2}$ but in 3d-subshell an orbital having m = + 1 may have spin quantum no. $-\dfrac{1}{2}$ or + $\dfrac{1}{2}$. Therefore, minimum and maximum possible values are 2 and 3 respectively.

PART - III

2. Work function $W = h\nu_0 = 6.626 \times 10^{-34} \times 5.3 \times 10^{14} = 3.5 \times 10^{-19}$ J

As W > Energy of photon, photoelectric effect will not be exhibited.

3. (a) $\lambda_0 = \dfrac{hc}{w} = \dfrac{12400}{3.1} = 4000$ Å

(b) $KE_{max} = \dfrac{hc}{\lambda} - w = \dfrac{12400}{3000} - 3.1 = 4.133 - 3.1 = 1.033$ eV.

4. $v = 2.18 \times 10^6 \times \dfrac{Z}{n} = 2.18 \times 10^6 \times \dfrac{2}{1} = 4.36 \times 10^6$ m/s

Fraction = $\dfrac{v}{c} = \dfrac{4.36\times10^6}{3\times10^8} = 0.0145$

Time taken for one revolution = $\dfrac{2\pi r}{v} = \left(\dfrac{2\times\dfrac{22}{7}\times0.529\times\dfrac{1^2}{2}\times10^{-10}}{4.36\times10^6}\right) = 3.8 \times 10^{-17}$ sec,

Frequency = $\dfrac{v}{2\pi r} = \dfrac{1}{3.8\times10^{-17}} = 2.63 \times 10^{16}$ revolutions

5. For He^+ ion,

$E_{n+2} - E_n = 6.172 \times 10^{-19}$

$\therefore \quad 13.6\,(2)^2 \left[\dfrac{1}{n^2} - \dfrac{1}{(n+2)^2}\right] = \dfrac{6.172 \times 10^{-19}}{1.602 \times 10^{-19}}$

$\therefore \quad 13.6\left[\dfrac{1}{n^2} - \dfrac{1}{(n+2)^2}\right] = \dfrac{6.127 \times 10^{-19}}{4 \times 1.602 \times 10^{-19}} = 0.966$

Left side of above equation represents difference in energy of (n + 2) state and n state for Hydrogen atom and Right side of above equation represents difference in energy of 5^{th} state and 3^{rd} state for H atom.

$\therefore \quad n = 3.$

6. Ionisation energy = $E_\infty - E_1 = 0 - (-15.6) = 15.6$ eV

$\therefore$ Ionisation Potential = 15.6 V.

Series terminating at n = 2 $\Rightarrow$ Balmer series.

Shortest wavelength of Balmer series corresponds to the transition $\infty \to 2$.

$E_{\infty\to 2} = E_\infty - E_2 = 0 - (-5.3) = 5.3$ eV.

$\therefore \quad \lambda_{\infty\to 2} = \dfrac{12400}{5.3} = 2339$ Å = 233.9 nm.

$E_{3\to 1} = E_3 - E_1 = (-3.08) - (-15.6) = 12.52$ eV

$\therefore \quad hc\,\bar{\nu}_{3\to 1} = 12.52 \times 1.6 \times 10^{-19}$

$\therefore \quad \bar{\nu}_{3\to 1} = \dfrac{12.52 \times 1.6 \times 10^{-19}}{6.626 \times 10^{-34} \times 3 \times 10^{8}} = 1.009 \times 10^7\ m^{-1}$.

7. $E = 13.6\left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$ ev/ atom $\qquad E = 13.6\left[\dfrac{9-4}{36}\right]$ ev/atom

$E = 13.6\left[\dfrac{9-4}{36}\right] \times 6.023 \times 10^{23} \times 1.6 \times 10^{-19} \qquad \Rightarrow$ 182.5 kJ.

8. Finding the uncertainty in speed Δu ; $\Delta u = (6 \times 10^6$ m/s) (0.01) = 6×10^4 m/s

Calculating the uncertainty in position, $\Delta x \geq \dfrac{h}{4\pi m \Delta u} \geq \dfrac{6.626 \times 10^{-34}\ kg.m^2/s}{4\pi(9.11 \times 10^{-31}\ kg)(6 \times 10^4\ m/s)} \geq 1 \times 10^{-9}$ m

9. Determination of number of moles of hydrogen gas, $n = \dfrac{PV}{RT} = \dfrac{1 \times 1}{0.082 \times 298} = 0.0409$

The concerned reaction is $H_2 \longrightarrow 2H$; ΔH = kJ mol^{-1}

Energy required to bring 0.0409 moles of hydrogen gas to atomic state = 436 × 0.0409 = 17.83 kJ

1 mole of H_2 gas has 6.02×10^{23} molecules

0.0409 mole of H_2 gas = $\dfrac{6.02 \times 10^{23}}{1} \times 0.0409$

Since 1 molecule of H_2 gas has 2 hydrogen atoms

$6.02 \times 10^{23} \times 0.0409$ molecules of H_2 gas = $2 \times 6.02 \times 10^{23} \times 0.0409 = 4.92 \times 10^{22}$ atoms

Energy required to excite an electron from the ground state to the next excited state

$= 13.6\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$ eV $= 13.6 \times \left(\dfrac{1}{1} - \dfrac{1}{4}\right) = 13.6 \times \dfrac{3}{4} = 10.2$eV $= 1.632 \times 10^{-21}$ kJ

Therefore energy required to excite 4.92×10^{22} electrons = $1.632 \times 10^{-21} \times 4.92 \times 10^{22}$ kJ

= 8.03 × 10 = 80.3 kJ

Therefore total energy required = 17.83 + 80.3 = **98.17 kJ**

10. Nodal point

$|\Psi|^2 = 0$

$$\left[27 - 18\left(\frac{r}{a_0}\right) + 2\left(\frac{r}{a_0}\right)^2\right] = 0$$

$$\frac{r_0}{a_0} = \frac{18 \pm \sqrt{18^2 - 4 \times 27 \times 2}}{4} = \frac{18 \pm 10.4}{4}$$

11. $\lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{8 \times 10^{15}} = 3.75 \times 10^{-8}$ m

12. **S_1 :** Be^{2+} ion has 2 electron so Bohr model is not applicable.

S_2, S_3 and S_4 are correct statement.

13. By Heisenburgs uncertainty principle $\Delta x.\Delta p \geq \frac{h}{4\pi}$

Given $\Delta x = \Delta p$,

Hence $\Delta x = \Delta p = \sqrt{\frac{h}{4\pi}} = 0.726 \times 10^{-17}$

Also, $\Delta x.\Delta \nu \geq \frac{h}{4\pi m}$ thus $\Delta \nu = \frac{h}{4\pi m}/\Delta x$ in a limiting case

$= \frac{h}{4\pi m} / \sqrt{\frac{h}{4\pi}} = \sqrt{\frac{h}{4\pi}} \times \frac{1}{m} = \frac{0.72 \times 10^{-17}}{9.1 \times 10^{-31}} = 7.98 \times 10^{12}$ ms^{-1}.

14. $\frac{1}{2}mv^2 = h(\nu - \nu_0) = h\Delta\nu$

$\lambda = \frac{h}{P} = \frac{h}{mv} \Rightarrow v = \frac{h}{m\lambda} \Rightarrow \frac{1}{2} m \times \frac{h^2}{m^2\lambda^2} = h\Delta\nu$

$\Delta\nu = \frac{h}{2m\lambda^2} \Rightarrow \lambda = \sqrt{\frac{h}{2m\Delta\nu}}$

15. ψ represent the atomic orbital, ψ^2 is probablity distribution.

16. The $d_{x^2-y^2}$, d_{xy} orbital lies in the xy plane.

17. X-ray are uncharged so no deflection.

18. Charge/mass for n = 0, for $\alpha = \frac{2}{4}$,

For p = $\frac{1}{1}$, for $e^- = \frac{1}{1/1837}$

19. $hv = hv_0 + eV_0$; $eV_0 = hv - hv_0$ or $V_0 = \frac{h}{e}v - \frac{h}{e}v_0$; slope$_1 = \frac{h}{e}$

Similarly, $hv = hv_0 + K_{max}$ or $K_{max} = hv - hv_0$;

slope$_2$ = h, $\frac{slope_2}{slope_1} = \frac{h}{h/e} = e$

20. Factual.

21. $I_n = \dfrac{eV_n}{2\pi r_n} = \dfrac{e \times \left(\dfrac{2\pi Ke^2}{nh}\right)}{2\pi \times \left(\dfrac{n^2h^2}{4\pi^2me^2K}\right)} = \dfrac{4\pi^2mk^2e^5}{n^3h^3}$.

22. $\lambda \propto \dfrac{1}{\sqrt{K.E.}}$

$\sqrt{\dfrac{KE_1}{KE_2}} = \dfrac{\lambda_2}{\lambda_1} = \dfrac{0.99 \quad \lambda_1}{\lambda_1}$

$\dfrac{KE_1}{KE_2} = (0.99)^2$

$KE_2 = 1.02\ KE_1$

% change in KE $= \dfrac{KE_2 - KE_1}{KE_1} \times 100 = 2\%$

23. $\dfrac{hc}{\lambda} = E_1 - E_2 = KE_2 - KE_1$

$\therefore \quad \lambda = \dfrac{h}{mV} \qquad (mV)^2 = \left(\dfrac{h}{\lambda}\right)^2; \qquad \dfrac{1}{2}\ mV^2 = \dfrac{1}{2m}\dfrac{h^2}{\lambda^2}$

$\therefore \quad \dfrac{hc}{\lambda} = \dfrac{h^2}{2m \quad \lambda_2^2} - \dfrac{h^2}{2m \quad \lambda_1^2}. \qquad \therefore \quad \lambda = \dfrac{2mc}{h}\left\{\dfrac{\lambda_1^2 \quad \lambda_2^2}{\lambda_1^2 - \lambda_2^2}\right\}.$

25. I : For n = 5, $l_{min} = 0$. $\therefore$ Orbital angular momentum $= \sqrt{\ell \quad (\ell + 1)} \quad \hbar = 0$.(False)

II : Outermost electronic configuration = $3s^1$ or $3s^2$. $\therefore$ possible atomic number = 11 or 12 (False).

III : Mn_{25} = [Ar] $3d^5\ 4s^2$. $\therefore$ 5 unpaired electrons. $\therefore$ Total spin = $\pm\ \dfrac{5}{2}$ (False).

IV : Inert gases have no unpaired electrons. $\therefore$ spin magnetic moment = 0 (True).

26. (A) s-orbital $\because$ r = 0, $\psi \neq 0$ and 3 radial nodes $\Rightarrow$ 4s

(B) 3 radial nodes (s, p, d) $\Rightarrow$ 4s, $5p_x$ $6d_{xy}$

(C) Angular probability is dependent of θ and ϕ for $5p_y$, $6d_{xy}$

(D) Atleast one angular node $\Rightarrow$ $5P_x$ (1); $6d_{xy}$ (2)

28. By photoelectric effect. $h\nu = h\nu_0 + KE$

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

$KE_2 = h(\nu_2 - \nu_0) = KE_1/2$ ......(2)

Dividing equation (2) by (1) we have $\dfrac{\nu^2 - \nu_0}{\nu_1 - \nu_0} = \dfrac{1}{2}$

$\dfrac{1.0 \times 10^{16}}{1.6 \times 10^{16} - \nu_0} = \dfrac{1}{2} \qquad 2.0 \times 10^{16} - 2\nu_0 = 1.6 \times 10^{16} - \nu_0$

$\nu_0 = 4 \times 10^{15}$ Hz

29. $C = \dfrac{d}{t}$, $t = \dfrac{d}{C} = \dfrac{300 \times 1000}{3 \times 10^8} = \dfrac{3 \times 10^5}{3 \times 10^8} = 1 \times 10^{-3}$ sec = 1

30. IE = $\frac{Z^2}{n^2}$ = 21.69 × 10^{-19} J

$\frac{20902.2\times10^3}{6.023\times10^{23}} = \frac{Z^2}{1}$ × 21.69 × 10^{-19}

Z = 4.

31. In H–atom, 4 lines are observed in Balmer series. So, electron is in n = 6(6 → 2, 5 → 2,4 → 2,3 → 2).
In He^+ ion, one line is observed in Paschen series. So electron is in n = 4 (4 → 3).
$(H)_{6\rightarrow2} = (He^+)_{12\rightarrow4}$
∴ electron in He^+ will jump from n = 4 to n = 12.

32. $x + e^- \rightarrow x^-$
energy released = $E.A_1 + E.A_2$ = 30.87 eV/atom
Let no. of moles of X be a
∴ a × N_a × 30.87 = 6 × N_a × 4.526 + 6 × N_a ×13.6 + 6 × N_a × 12.75 ⇒ a = 6 moles

33. $KE_1 = E_{photon} - BE_{n=1}$
$KE_2 = E_{photon} - BE_{n=n}$
$KE_2 - KE_1 = BE_{n=1} - BE_{n=n} = 13.6\, Z^2 \left[\frac{1}{1^2}-\frac{1}{n^2}\right]$ = 12.75 (given).
∴ $n^2 = 16$ or n = 4.
BE : Binding energy.

34. In the particular excited state of H-atom, path length is five times the de-Broglie wavelength.
∴ $2\pi r = 5\lambda$ .... (1)
However, path length in a state n is n times the de-Broglie wavelength.
∴ $2\pi r = n\lambda$ .... (2)
From (1) & (2), principal quantum number (n) of the excited state = 5. Photon having 2nd highest energy corresponds to back transition of electron from n = 4 to n = 1
This photon will cause an already excited Li^{2+} electron to go to some higher state. Let the initial excited state of Li^{2+} ion be n_1 and final excited state of Li^{2+} ion be n_2

$$\therefore \underbrace{13.6\ (1)^2\left[\frac{1}{1^2}-\frac{1}{4^2}\right]}_{\text{Photon having 2nd highest energy corresponding to transition n=4 to n=1 in H–atom}} = \underbrace{13.6\ (3)^2\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]}_{\text{Energy absorbed by Li}^{+}\text{ ion to make a transition from }n_1\text{ to }n_2}$$

$$\therefore 13.6\left[\frac{1}{1^2}-\frac{1}{4^2}\right] = 13.6\left[\frac{3^2}{n_1^2}-\frac{3^2}{n_2^2}\right] \quad \text{or} \quad 13.6\left[\frac{1}{1^2}-\frac{1}{4^2}\right] = 13.6\left[\frac{1}{(n_1/3)^2}-\frac{1}{(n_2/3)^2}\right]$$

On comparing both sides,
$\frac{n_1}{3} = 1$ & $\frac{n_2}{3} = 4$ ⇒ $n_1 = 3$ & $n_2 = 12$
Thus, the final excited state of Li^{2+} ion electron is n = 12 Ans.

35. $\Delta x = 0.1 \times 10^{-9}$ m.
$\Delta V = 5.27 \times 10^{-27}\ ms^{-1}$.
∴ $\Delta x \times m\Delta V = \frac{h}{4\pi}$
∴ $0.1 \times 10^{-9} \times m \times 5.27 \times 10^{-27} = 0.527 \times 10^{-34}$.
∴ m = 0.1 kg. = 100 gm.

36. n = 4
ℓ = 0, 1, 2, 3
s, p, d, f
So, number of orbitals = s = 1, p = 3, d = 5, f = 7.
Number of elements = 1 × 3 + 3 × 3 + 5 × 3+ 7 × 3 = 48.

37. In n = 3 shell
1s (3s)
3p (P_x, p_y, p_z)
5d (d_{xy}, d_{yz}, d_{xz}, $d_{x^2-y^2}$, d_{z^2})

* S has no nodal plane.
* Each of P_x, p_y, p_z has one nodal plane, which means a total of three nodal planes.
* d_{z^2} has no nodal plane and each of d_{xy}, d_{xz}, d_{yz}, $d_{x^2-y^2}$ has two nodal planes which means a total of eight nodal planes.
Hence n = 3, a total of 11 nodal planes are there.

38. Since the change in mass number is only due to the emission of α-particle, we have
Number of α-particle emitted = $\frac{234-206}{4}$ = 7
Now the associated decrease in atomic number would be 14 (= 2 × 7) and thus the atomic number of the daughter atom would be 76 (= 90– 14). But the actual atomic number of lead is 82 e. the atomic number is six more than expected. This is because of the emission β-particle. Since there is an increase of one in atomic number due to the emission of one β-particle, we have
Number of β-particles emitted = $\frac{82-76}{1}$ = 6
Hence, number of α-particles emitted = 7
Number of β-particles emitted = 6.
Answer is 6 + 7 = 13.

39. $m_e = 9.1 \times 10^{-31}$ kg = 9.1×10^{-28} g.
$m = \frac{m_0}{\sqrt{1-\frac{v^2}{c^2}}}$ (m_0 : rest mass ; m : dynamic mass).
As v $\uparrow$, $\left(1-\frac{v^2}{c^2}\right)\downarrow$ $\therefore$ m $\uparrow$
Molar mass of e = $9.1 \times 10^{-28} \times 6.023 \times 10^{23} = 5.48 \times 10^{-4}$ g/mole.
For electron, $\frac{e}{m} = \frac{1.6\times10^{-19}}{9.1\times10^{-28}} = 1.7 \times 10^{8}$ c/g.

40. Non integral atomic masses of elements are due to existence of isotopes of that element which have different masses.

41. (A) Since the number of photons is not specified (it may or may not be equal to 4 N_A). So, this statement is not always true.
(B) No.of photon emitted per day × Energy of one photon = Energy emitted per day.
For bulb A, $n_{e_A} \times \frac{12400}{2000} \times 1.6 \times 10^{-19} = 40 \times 24 \times 3600$.
For bulb B, $n_{e_B} \times \frac{12400}{3000} \times 1.6 \times 10^{-19} = 30 \times 24 \times 3600$.
$\therefore$ $n_{e_A} : n_{e_B} = 8 : 9$.
(C) When an electron make transition from lower to higher orbit, a photon is absorbed.

42. If photon A has more energy than photon B, then λ of photon A must be less than λ of photon B. If $\lambda$of photon B is in IR region, λ of photon A can be in Infrared region or visible region or ultra violet region.

43. (A) λ can be calculated as : $\lambda = \frac{h}{mv} = \frac{6.626\times10^{-34}}{1\times100} = 6.626 \times 10^{-36}$ m. (very small).

(B) de-Broglie wavelength associated with macroscopic particles is extremely small and so, difficult to observe.

(C) de-Broglie wavelength associated with electron can be calculated by using $\lambda = \frac{h}{mv}$.

(D) $KE_f = 5 + 20 = 25$ eV. $\therefore$ $\lambda = \sqrt{\frac{150}{KE_f}} = \sqrt{\frac{150}{25}} = \sqrt{6}$ Å.

44. d_{z^2} orbital has two lobes along Z axis and a ring along XY plane.

45. More the nucleons, more the more the binding energy & more reduced is the mass.
So, $M_2 < 20\ (m_p + m_n)$ (Because some mass got reduced on release of binding energy)
$M_2 < 2M_1$ (Because more mass is reduced for binding more nucleons)

PART - IV

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

$\frac{1}{108.5\times10^{-9}} = 1.09678 \times 10^7 \times 4 \left[\frac{1}{2^2} - \frac{1}{n_2^2}\right]$

This gives $n_2 = 5$.

2. Radial node occurs where probability of finding of e^- is zero.

$\therefore$ $\Psi^2 = 0$ or $\Psi = 0$

$\therefore$ $6 - 6\sigma + \sigma^2 = 0$ $\sigma = 3 \pm \sqrt{3}$

For maximum distance $r = \frac{3}{2}\frac{(3+\sqrt{3})a_0}{Z}$

3. The total energy emitted in a period τ is $p\tau$. The energy of a photon of 650 nm light is $E = \frac{hc}{\lambda}$ with $\lambda = 650$ nm. The total number of photons emitted in a interval τ is then the total energy divided by the energy per photon.

$N = \frac{P\tau}{E} = \frac{P\tau\lambda}{hc}$

DeBroglie's relation applies to each photon and thus the total momentum imparted to the glow–worm is

$p = \frac{Nh}{\lambda} = \frac{P\tau\lambda}{hc} \times \frac{h}{\lambda} = \frac{P\tau}{c}$

$P = 0.10$ w $= 0.10$ J s^{-1}, $\tau = 10y$, $p = mv$

Hence the final speed is :

$$v = \frac{P\tau}{cm} = \frac{(0.10 Js^{-1})\times(3.16\times10^8)}{(2.998\times10^8 ms^{-1})\times(5.0\times10^{-3}\ kg)} = 21\ ms^{-1}$$

4. Mole of H_2 present in one litre = $\frac{PV}{RT} = \frac{1\times1}{0.0821\times298} = 0.0409$

Thus, energy needed to break H–H bonds in 0.0409 mole of H_2 = 0.0409 × 436 = 17.83 kJ.
Also energy needed to excite one H atom from 1st to 2nd energy level

$= 13.6\left(1-\frac{1}{4}\right)$ eV = 10.2 eV = 10.2 × 1.6 × 10^{-19} J

∴ Energy needed to excite 0.0409 × 2 × 6.02 × 10^{23} atoms of H
= 10.2 × 1.6 × 10^{-19} × 0.0409 × 2 × 6.02 × 10^{23} J = 80.36 kJ
Thus, total energy needed = 17.83 + 80.36 = 98.19 kJ

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

E = hν ∴ $\frac{436\times10^3}{6.023\times10^{23}} = 6.625\times10^{-34}\,\nu$

ν = 10.93 × 10^{14} sec^{-1} or Hz.

5. $O_2 \rightarrow O + O^*$; Dissociation energy = 468 kJ mol^{-1} = $\frac{498\times10^3}{6.02\times10^{23}}$ J mol^{-1} = 8.27 × 10^{-19} J.$molecules^{-1}$

Extra energy of the excited atom = 1.967 eV = 1.967 × 1.6 × 10^{-19} J = 3.15 × 10^{-19} J $atom^{-1}$

$\lambda = \frac{hc}{E} = \frac{6.626\times10^{-24}\times3\times10^8}{11.42\times10^{-19}} = 174\times10^{-9}$ m

Thus, λ = 174 nm.

6. l = 4;
number of degenerate orbitals = 2l + 1 = 9;

maximum total spins = 9 × $\frac{1}{2}$

maximum multiplicity = 2S + 1 = 2 × $\frac{9}{2}$ + 1 = 10

minimum multiplicity = $\frac{1}{2}$

minimum multiplicity = 2 × $\frac{1}{2}$ + 1 = 2

7. 25% of He^+ ions are already in ground state, hence energy emitted will be from the ions present in 3rd level and 2nd level.

$\Delta E = (IP)_Z\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$ per ion or atom

$(\Delta E)_{3\rightarrow1} = (54.4)\,\frac{N_0}{2}\left[\frac{1}{1^2}-\frac{1}{3^2}\right]$

for $\frac{N_0}{2}$ ions falling to ground state = 54.4 × $\frac{4\times N_0}{9}$ eV

and $(\Delta E)_{2\rightarrow1} = (54.4)\,\frac{N_0}{2}\left[\frac{1}{1^2}-\frac{1}{2^2}\right]$

for $\frac{N_0}{4}$ ions falling to ground state = 54.4 × $\frac{3\times N_0}{16}$ eV

Hence total energy = 54.4 × N_0 $\left[\frac{4}{9}+\frac{3}{16}\right]$ = 54.4 × 602 × 10^{23} × $\frac{91}{144}$ eV

= 54.4 × 6.02 × 10^{23} × $\frac{91}{144}$ × 1.6 × 10^{-19} J = 331.13 × 10^4 J.

8. A : excitation possible only in d-orbitals
B : Spin multiplicity = 2 |S| + 1; |S| = total spin
C : V violated Hund`s rule
D : A^+ is paramagnrtic due to unpaired e^-
$\therefore$ A, B, C are correct.

10. At the point of maximum value of RDF

$$\frac{dP}{dr} = 0$$

$$\left(2r - \frac{2Zr^2}{a_0}\right) = 0; \ r = \frac{a_0}{Z}$$

where $Z = 3$ for Li^{2+} and $Z = 2$ for the He^+ ;
$Z = 1$ for hydrogen.

13. E_{H-H} bond dissocation = $\frac{430.53 \times 10^3}{6.023 \times 10^{23}}$ J per molecule = 7.15×10^{-19} J per molecule

$E_{Photon} = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3.0 \times 10^8}{253.7 \times 10^{-9}} = 7.83 \times 10^{-19}$ J.

Energy converted into kinetic energy = Energy left after dissociation of bond.
$\therefore$ Energy converted into KE = $(7.83 - 7.15) \times 10^{19}$ J = 0.68×10^{-19} J

$\therefore$ % of energy converted into KE = $\frac{0.68 \times 10^{-19}}{7.83 \times 10^{-19}} \times 100 = 8.68\%$.

14. E_1 for H-atom = – 13.6

$\because$ $E = \frac{12375}{\lambda}$; when λ is in Å

$\therefore$ Energy given to H-atom = $\frac{12375}{1028}$ eV = 12.07 eV

$\therefore$ Energy of H-atom after excitation = – 13.6 + 12.07 = – 1.53 eV

$\because$ $E_n = \frac{E_1}{n^2}$

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

15. Total energy liberated during tranition of electron from nth shell to first excited state, (i.e., 2nd shell)
= 10.20 + 17.0 = 27.20 eV
= $27.20 \times 1.602 \times 10^{-12}$ erg

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

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

Similarly, total energy liberated during transition of electron from nth shell to second excited state, (i.e., 3rd shell)
= 4.25 + 5.95 = 10.20 eV
= $10.20 \times 1.602 \times 10^{-12}$ erg

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

Dividing Equations (i) by (ii) n = 6
On substituting the value of n in Equations (i) Z = 3
So, n +Z = 6 + 3 = 9.

16. Given $\lambda = 5 \times 10^{-8}$ m

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

$$\therefore \quad \frac{\lambda_1}{\lambda_2} = \frac{(\text{momentum})_2}{(\text{momentum})_1}$$

Since, $(\text{momentum})_2 = \frac{1}{2}\,(\text{momentum})_1$

Or $\quad \lambda_2 = \frac{(\text{momentum})_1 \times \lambda_1}{(\text{momentum})_2} = 2 \times 5 \times 10^{-8} = 10^{-7}$ m.

17. Let us first calculate the energy required to remove an electron from the third orbit of the He^+ ion. This energy will be equal to the energy released (ΔE) when an electron will drop from ∞ orbit to third orbit. For He^+, Z = 2 and for H^+, Z = 1, Thus for He^+

$$\Delta E = -\frac{21.76 \times 10^{-19}}{\infty^2} \times 2^2 - \left(\frac{21.76 \times 10^{-19}}{3^2} \times 2^2\right) = 0 + 9.67 \times 10^{-19} \text{ J.}$$

Now, $\quad \Delta E = h\nu = \frac{hc}{\lambda}$

$$\therefore \quad \lambda = \frac{hc}{\Delta E} = \frac{(6.626 \times 10^{-34})(3 \times 10^8)}{9.67 \times 10^{-19}} = 2.055 \times 10^{-7} \text{ metres.}$$

18. When a nucleus captures a K-electron, a proton is converted to a neutron. So the mass number does not change but the atomic number reduces by 1 unit. Thus the mass number and atomic number of the resulting nuclide will be 7 and 3 respectively.

19. $\Delta x\, \Delta p = \frac{h}{4\pi} \Rightarrow \Delta p^2 = \frac{h}{4\pi} \qquad \Rightarrow m^2\, \Delta v^2 = \frac{h}{4\pi} \Rightarrow \Delta v = \frac{1}{2m}\sqrt{\frac{h}{\pi}}$

20. $\Delta x = \sqrt{\frac{h}{4\pi m}}$; $\Delta x\, \Delta p = \frac{h}{4\pi}$

$\sqrt{\frac{h}{4\pi m}}$; $\Delta p = \frac{h}{4\pi}$; $\Delta p = \sqrt{\frac{mh}{4\pi}}$

21. $\lambda_{D.B.} = \sqrt{\frac{150}{6}}$ Å = 5 Å

and $\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$; $p = \frac{h}{\lambda}$ or $\Delta p = \frac{h}{\lambda^2}\Delta\lambda \;\Rightarrow \Delta x \cdot \frac{h}{\lambda^2} \times \Delta\lambda \geq \frac{h}{4\pi}$

$\Rightarrow \frac{1}{\pi} \times \frac{10^{-9}}{\lambda^2} \times \Delta\lambda \geq \frac{1}{4\pi} \;\Rightarrow \Delta\lambda \geq \frac{2.5}{4} \times 10^{-10}$

$\Delta\lambda \geq 0.625$ Å

22. P : For Lyman series, $\bar{\nu}$ for second line ($3 \to 1$) = $R(1)^2\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = \frac{8R}{9}$ (3).

Q : For Balmer series, $\bar{\nu}$ for second line ($4 \to 2$) = $R(1)^2\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = \frac{3R}{16}$ (4).

R : In a sample of H-atom for $5 \to 2$ transition, maximum number of spectral lines observed

$= \frac{(5-2)(5-2+1)}{2} = 6$ (1).

S : In a single isolated H-atom for $3 \to 1$ transition, maximum number of spectral lines observed

$= 2\ (3 \to 2,\ 2 \to 1)$ (2).