ATOMIC STRUCTURE

UNIT : 1

1 Characteristics of electron, proton and neutron
2 Rutherfords Model of an atom
3. Nature of Electromagnetic Radiation
4. Planck's Quantum Theory
5. Explanation of Photo electric Effect

VERY SHORT ANSWERS :

1. Write the charge, mass and charge to mass ratio of an electron. ?

A. Charge on the electron = 1.602×10^{-19}

coulomb= $-4.802\times10^{-10}e.s.u.$

Absolute mass of the electron = $9.11\times10^{-28}gram=9.11\times10^{-31}kg$

= 0.0005486 amu

Charge to mass of electron = $1.75882\times10^{11}C\,kg^{-1}$

2 . What is electromagnetic spectrum ?

A. The systematic arrangement of several electromagnetic radiations in ascending order of their wavelengths or descending order of frequencies is called electromagnetic spectrum.

Wavelength order of various electromagnetic radiation is

Gamma rays < X – rays < U.V < Visible < Infrared < Micro wave < TV < Radio

3. What is a black body ?

A. The body which perfectly absorbs all types of radiations and perfectly emits the radiations is called black body

4. 2×10^{-8} atoms of carbon are arranged side by side. Calculate the radius of carbon atom if the length of this arrangement is 2.4cm

A. Length of the arrangement = 2.4 cm

Number of atoms arranged side by side = 2×10^{-8}

$\therefore$ Diameter of each 'c' atom = $\dfrac{2.4}{2\times10^{8}}=1.2\times10^{-8}cm$

$\therefore$ radius = $0.6\times10^{-8}cm=6\times10^{-9}cm$

5. A certain particle carries $-2.5\times10^{-16}C$ of static charge. Calculate the number of electrons present in it.

A. Charge of each electron = $1.602\times10^{-19}C$

Number of electrons in -2.5×10^{-16} are $\dfrac{2.5\times10^{-16}}{1.602\times10^{-19}}=1.56\times10^{3}e$

6. What is the wave number of radiations of wavelength 400nm ?

A. Wave number = $1/400\times10^{-9}m = 2.5\times10^{6}m^{-1}$.

7. What are the units of wavelength, wavenumber and frequency ?

A. Wavelength units : A° or nm or m or cm

Wavenumber units : Cm^{-1} or m

Frequency units : Hertz (Hz) or cycles/second

8. What is the wave number of radiations of wavelength 400nm ?

A. Wave number = $1/400\times10^{-9}m = 2.5\times10^{6}m^{-1}$

9. Calculate the frequency and wave number of the yellow light of wavelength 580nm emitted from sodium lamp.

A. $\upsilon = \frac{c}{\lambda} = 310^{8}m - s^{-1}/580\times10^{-9}m = 5.1\times10^{14}s^{-1}$

$\overline{\upsilon} = \frac{1}{\lambda} = 1/580\times10^{-9}m = 1.72\times10^{6}m^{-1}$

SHORT ANSWERS :

1. Find energy of photon which corresponds to light of frequency.

$3\times10^{12}Hz\left(h = 6.626\times10^{-34}Js\right)$

A. Energy of a photon is given by $E = h\upsilon$

$E = 6.626\times10^{-34}Js \times 3\times10^{12}S^{-1}$

$= 1.9878\times10^{-21}J$ (for one photon)

2 Calculate the wavenumbers corresponding to the following wavelengths.

a) $2000^\circ A$ b) 800 nm

A. (a) $2000^\circ A$

$\overline{\upsilon} = \frac{1}{\lambda}$

$\lambda = 2000^\circ A = 2000\times10^{-8}cm$

$\overline{\upsilon} = \frac{1}{2000\times10^{-8}cm} = 5\times10^{4}cm^{-1}$

(b) 800 nm

$\lambda = 800\,nm$

$= 800\times10^{-9}m$

$$\bar{\upsilon} = \frac{1}{800 \times 10^{-9} m} = 1.25 \times 10^{5} m^{-1}$$

LONG ANSWERS :

1. Explain Rutherfords planetory model of an atom. Discuss its drawbacks.

A. Rutherford proposed the model of the atom to explain the result of α ray scattering experiment. It is called planetory model or Nuclear model of atom. The main features of the model are given below.

1) Atom is spherical and most part of the atom is empty.

2) The positive charge and the mass of the atom is concentrated in a small region at the centre of the atom. The region, is called nucleus.

3) The electrons and protons present in the nucleus are equal in number .

4) Just as the planets revolve around the sun, the electrons revolve around the nucleus.

5) The revolving electron is under the influence of two forces

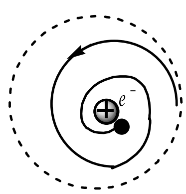
i. The centripetal force of attraction towards nucleus and

ii. These two forces being equal and opposite, balance each other and the electron continues to move in its orbit.

Drawbacks of Ruther's Model

i. According to electrodynamics, any charged article moving under the influence of opposite charge should lose energy continuously, come closer and closer the nucleus as shown in figure. Then the atom shall collapse due to the merging of electrons with the nucleus.

ii. If the electrons lose energy continuously, the atomic spectrum should have a continuous band. But the atomic spectrum of the elements are found to contain discrete lines.



spiral path of electron

2. Define electromagnetic radiation and explain the characteristics of electromagnetic radiations.

A. According to Maxwell, electromagnetic radiation is made up of electromagnetic wave propagating through space is a combination of two components, one is varying electric and the other is the varying magnetic field. These two fields are perpendicular to each other and are perpendicular to the direction of propagation of wave.

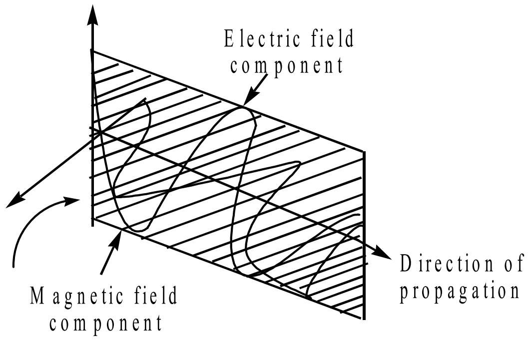
Characeristics of electromagnetic radiations

1. these are reduced b oscillating charged particles in a bond

2. the radiations can pass through vaccum also. So medium for transmission is not required.

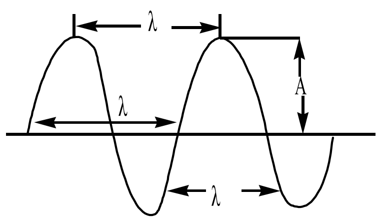
3. the wavelengths (λ) is the distance between two neighbouring crest or troughs of the wave.

Unit for λ is cm, m, nm, A^o $\boxed{\lambda = \frac{C}{\upsilon}}$



4. **Frequency of the wave (υ) is the number of waves which cross particular point on one second.**

$$\upsilon = \frac{velocity}{wavelengh} = \frac{c}{\lambda}$$



Propagation of electromagnetic wave

Unit of frequency is cycles per sec (cs or herz (Hz = 1 cs

He frequency is inversely proprional to its wavelength

5 Velocity (C) of a wave is the distance travelled by the wave in one second

Velocity = wavelength $\times$ frequency

$c = \lambda \times \upsilon$

Velocity of all electromagnetic radiations in vaccum is the same and is equal o $3 \times 10^{m}\ cm/\sec$

6. Wave number $(\overline{\upsilon})$ is the number of waves that are present in unit length. It is reciprocal of wavelength (λ). Unit of (υ) is cm^{-1} or m^{-1}

7. Amplitude is the height of the crest or depth of trough of a wave. It determines he inensity or brightness of the light,

8. Electromagnetic spectrum is the spectrum which shows the wavelengths or frequencies of wave numbers of various regions of electromagnetic radiations.

3. Explain Planck's quantum theory.

A. The postulates of Plank's quantum theory are

a) The emission of radiation is due to vibrations of charged particles (electrons) in the body

b) The emission is not continuous but in discrete packets of energy called "quanta". This emitted radiation propagates in the form of waves

c) The energy (E) association with each quantum for a particular radiation of frequency 'υ' is given by $E = h\upsilon$. Here 'h' is Plank's constant

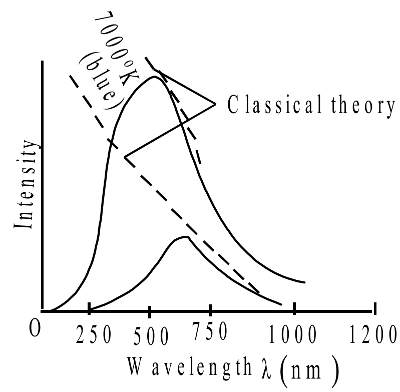
d) A body can emit or absorb either one quantum $(h\upsilon)$ of energy or some whole number multiple of it. Thus energy can be emitted or absorbed as $h\upsilon, 2h\upsilon, 3h\upsilon$ etc but not fractional values. This is called quantization of energy

e) The emitted radiant energy is propagated in the form of waves

f) Values of Planck's constant in various units :

$$h = 6.6256\times10^{-27}\,\text{erg.sec (or) } g\,cm^2s^{-1}$$

$$= 6.6256\times10^{-34}\,J.s \text{ (or) } kg\,m^2s^{-1} = 1.58\times10^{-34}\,cal.s.$$



Radiations emitted by a black body at different temperatures

ATOMIC STRUCTURE

UNIT: 2

1 Features of atomic spectra
2 Characteristics of Hydrogen spectrum
3 Bohr's Theory of the Structure of Atom
4 Bohr's explanation of spectral lines
5 Failure of Bohr's theory

VERY SHORT ANSWERS:

1. What is Balmer series? To which part of the electromagnetic spectrum dos it belong to?

A. It is a series of spectral lines formed when electron in the hydrogen atom jumps from any higher energy level to n = 2. It belongs to visible region of electromagnetic spectrum.

2. In which region the spectral line is obtained when an electron is transferred from n = 4 to n = 2 orbit?

A. When an electron is transferred from $n_1 = 4$ to $n_2 = 5$, the spectral lines formed are belong to Brackete series in the middle infrared region.

3. Electrons are emitted with zero velocity from a metal surface when it is exposed of radiation of wavelength $6800 A^\circ$. Give relation between energy of radiation and work function of the metal.

A. $h\upsilon = h\upsilon_o + 1/2\, mv^2$

As velocity of ejected electrons is zero

$h\upsilon = h\upsilon_o$

4. What is the wavelength of light emitted when the electron in a hydrogen atom undergoes transition from an energy level with n = 4 to an energy level with n = 2?

A. Rydberg's equation is $\overline{\upsilon} = \frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

$= 109677\left[\frac{1}{4} - \frac{1}{16}\right]$

$= 109677 \times \frac{12}{564} = 205764.4\, cm$

$$\lambda = \frac{1}{\overline{\upsilon}} = \frac{1}{20564.4\,cm} = 4.86\times10^{-5}\,cm = 4862\,A^{\circ}$$

SHORT ANSWERS:

1. Explain the differences between emission and absorption spectra.

Emission spectra	Absorption spectra
1. The spectra is formed when electron jumps from higher orbits to lower orbits	1. The spectra is found when electron jumps from lower orbits to higher orbits
2. It is formed due to emission of energy in quanta	2. It is formed due to absorption of energy in quanta
3. It contains bright lines on dark background	3. It contains dark lines on bright background

2. Explain the influence of Planck's quantum theory of Bohr's model of structure of an atom.

A. 1) According to 'Planck', energy is released in a discontinuous manner. Based on this 'Bohr' proposed the presence of shells or energy levels for electrons in an atom.

2) Bohr proposed that energy is emitted when electron moves from higher level to lower level, (i.e) $E_2 - E_1 = h\upsilon = \Delta E$. This is in accordance with Planck's quantum theory.

3. What is 'line spectrum' and 'band spectrum'?

Line spectra	Band spectra
1. Line spectra is characteristic property gaseous atoms	1. Band spectra is the characteristic property of the gaseous molecules
2. It contains sharp and distinct lines	2. It contains closely spaced lines known as bands
3. Ex : Na vapours produce two lines In visible region with wavelengths 5894and 5896	3. Ex : Molecules like O_2, H_2 give band spectra

4. Explain photoelectric effect based on Einstein's theory.

A. The ejection of electrons from a metal surface, when the radiation of suitable frequency strikes the metal surface is called photoelectric effect.

Explanation using Einstein's quantum theory:

1) To explain photoelectric effect, Einstein utilized Quantum theory

2) When a photon strikes metal surface, it uses some part of its energy to eject the electron from the metal atom. The remaining part of the total energy is given to the ejected electrons in the form of kinetic energy.

Hence we can write $\boxed{h\upsilon = W + KE} \Rightarrow h\upsilon = h\upsilon_o + \frac{1}{2}m_eV^2$

Where $h\upsilon$ = energy of photon, υ_o = Threshold frequency, m_e = mass of electron

W = energy required to overcome the attractive forces on the electron in the metal (work function)

KE = Kinetic energy of ejected electron, V = Velocity of ejected electron

3) If a photon of sufficient energy struck the metal surface and could eject the electron. But if a photon has insufficient energy, it cannot eject the electron from the metal.

Eg : A photon of violet light (high frequency) can eject the electrons from the surface of potassium but a photon of red light (low frequency) cannot eject the electrons.

LONG ANSWER QUESTIONS:

1. State the postulates of Bohr are a body atomic model. Explain the different lines in various series of hydrogen spectrum.

A. Postulates of Bohrs theory:

1) Electrons revolve around the nucleus in certain, definite circular paths called orbits. They are also known as energy levels or shells.

2 Each orbit is associated with a definite amount of energy. Hence these orbits are called energy orbits or energy levels or energy shells.

3 The circular orbits are numbered 1, 2, 3, ……… according to number method and according to letter method they are represented as K, L, M, N, ……..

4 The circular orbits are represented by the letter n, which represents principal Quantum number.

5. As the value of n increases, the size and energy of the orbit increases.

6. More than one stationary orbit is possible for any electron and the angular momentum of the revolving electron is quantize. That is, the electrons revolve in those circular orbits in which the angular momentum of the revolving electron is an integral multiple of $h/2\pi$

This can be expressed as $mvr = n \times \frac{h}{2\pi}$

Where m = mass of the electron, h = plancks constant, n = principal quantum number

7 The energy of electron changes when the electron jumps from one orbit to another orbit. When the electron jumps from a lower orbit to a higher orbit, energy is absorbed. Similar when the electron jumps from a higher orbit to a lower orbit, energy is emitted.

The energy emitted or absorbed is given by the equations, $E = E_2 - E_1 = h$

ΔE = difference in energy

E_2 = energy of higher orbit, E_1 = energy of lower orbit

Explanation of formation of different lines in various series of Hydrogen atomic spectrum

1) Hydrogen atom has only one electron and it revolves around the nucleus in the first orbit
2) When certain hydrogen gas containing a large number of electrons is heated or exposed to light energy or is subject to electric discharge, the different electrons absorb different amounts energy and get excited to different higher orbits.
3) But, they do not stay there for longer period. Hence, they try to come back to lower orbits (deexcitation). This de-excitation need not necessarily be the same for all the atoms.
4) Some excited electrons may come back from any of the high energy levels to lower energy level n = 1. Then Lyman series is formed in the u.v region.
5) Some excited electrons may come back from any of the higher energy levels to lower energy level n = 2.

   Then Balmer series is formed in the visible region. Similarly when the excited electron come back, from any of the higher energy level to lower levels 3, 4 and 5 we set paschen, Brackett and Pfund series respectively in the I.R region

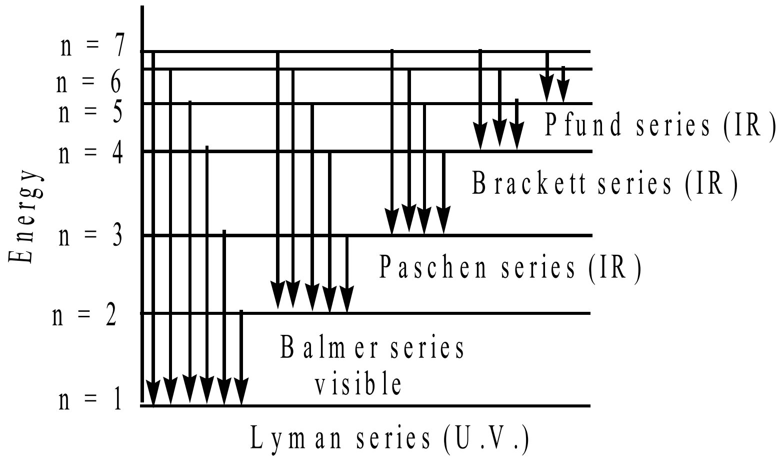
   The de-excitation process from higher energy level to lower energy level also may take place in a single step or in different steps. For example the de-excitation process of an electron from 4^{th} energy level to 1^{st} energy level can be shown below.

   Direct step, From 4^{th} level to 1^{st} (i.e.,) $4 \rightarrow 1$

   Different steps: $4 \rightarrow 3 \rightarrow 2 \rightarrow 1$

   $4 \rightarrow 3 \rightarrow 1, 4 \rightarrow 2 \rightarrow 1$

   For each electronic transition, one line is formed in the spectrum. Thus we get a large number of lines in a given below.



Energy releases due to inward eelctron jumps

2. Discuss the defects in Bohr's atomic model.

A. **Limitations:**

1) **Spectra of multielectron atoms:** Bohr's theory could explain the spectra of Hydrogen and single electron species like He^{+}, Li^{2+}, Be^{3+}, but if fails to explain the spectra of multielectron atoms.

2) **Fine structure:** It fails to explain the fine structure of hydrogen atom

3) **Splitting up of spectral lines:** The theory fails to explain Zeeman effect and Stark effect. The splitting of spectral lines when an atom is subjected to strong magnetic field is called Zeeman Effect. The splitting up of spectral lines when an atom is subjected to strong electric field is called Stark effect.

4) **Flat model:** Bohr's theory gives a flat model of the orbits. Bohr's theory predicts definite orbits for electrons considering them as particles. However, according to de Broglie electron has both wave nature and particle nature. Bohr's theory cannot explain this dual role.

5) It fails to support the uncertainty principle proposed by Heisenberg

6) It could not explain the ability of atoms to form molecules by chemical bonds

ATOMIC STRUCTURE

UNIT: 3

1 Wave – particle nature of electrons
2 de Broglie's hypothesis, Heisenberg's uncertainty principle
3 Important features of the Quantum Mechanical Model of an atom
4 Quantum numbers, Concept of orbitals , define an atomic orbital in terms of quantum numbers- shapes of s, p and d orbitals, State Aufbau principle, Pauli's exclusion principle and Hundi's rule of maximum multiplicity
5 Electronic configurations of Atoms

VERY SHORT ANSWERS:

1.. **What is an atomic orbital ?**

A. An atomic model is the three dimensional space around the nucleus in an atom where the probability of finding the electron is maximum (95%)

2. **Draw the shapes of p – orbital**.

3. **How many p electons are present in sulphur?**

A. Electronic configuration = $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4$

Hence there are '10' 'p' electrons in sulphur.

4 **What is Zeeman Effect?**

A. When hydrogen spectrum is recorded subjecting the hydrogen gas to the influence of an external magnetic field, it is observed that each line in the spectrum is split into finer lines. This splitting is called zeeman effect.

5. **What is Stark effect?**

A. When hydrogen spectrum is recorded subjecting the hydrogen gas to the influence of an external magnetic field, it is observed that each line in the spectrum is split into finer lines. This splitting is called stark effect.

6. **Write the values for 'n' and 'l' for 3d electron.**

A. For 3d electron 'n' value is 3 and 'l' value is 2

7. **Write the electronic configuration of Magnesium**.

A. $1s^2\ 2s^2\ 2p^6\ 3s^2$

8. **To which element does the following electronic configuration corresponds to**

i) $1s^2\ 2s^2\ 2p^2$ ii) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$ iii) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$

v) $1s^2\ 2s^2\ 2p^5$ vi) $1s^2\ 2s^1$

A. As total number of electrons in the given electronic configurations i, ii, iii, iv and v are respectively 6, 13, 18, 9 and 3 hence elements are Carbon, Aluminium, Argon, Fluorine and Lithium respectively.

9. Explain the significance of ψ^2

A. ψ^2 is probability function which signifies the probability of finding an electron in the space around the nucleus or electron density around the nucleus.

10. What is Pauli's exclusion principle?

A. No two electrons in an atom can have same set of four quantum numbers. They differ at least in their spin quantum numbers.

11. What is aufbau principle?

A. In the building up of atoms, the electrons enter the various orbitals, in the increasing order of their energies.

The orbital with a lower energy is filled up followed by the orbitals of higher energy.

12. What is Hund 's rule ?

A. Pairing of electrons takes place in an orbital only after all the orbitals of the sub energy level are filled with one electron each.

13. Which of the orbitals are possible and why? 1p, 2s, 2p, 3f

A. Among the given, 2s and 2p orbitals are only possible because when n = 2, 'l' can have 0 and 1 values which represent s and p orbitals.

1p is not possible because when n = 1, l an have only one value i.e 0 which represents s not 'p' 3f is not possible because when n = 3, l can have 3 values the are 0, 1, and 2 which represent 's' 'p' and 'd' respectively

14. The mass of an electron is $9.1\times10^{-31}kg$. If its kinetic energy is $3.0\times10^{-25}J$. Calculate its wavelength

A. $$\lambda = \frac{h}{\sqrt{2mK.E}}$$

$$\lambda = \frac{6.625\times10^{-34}}{\sqrt{2\times9.1\times3\times10^{-25}}}$$

$$\lambda = \frac{6.625\times10^{-34}}{7.38\times10^{-28}} = 8.9\times10^{-7}m = 8900A^{\circ}$$

15. Calculate the wavelength of an electron moving with a velocity of $2.05\times10^{7}ms^{-1}$

A. $$\lambda = \frac{h}{mv} = \frac{6.625\times10^{-34}}{9.11\times10^{-31}\times2.05\times10^{7}} = 3.5\times10^{-11}m$$

16. Explain giving reasons, which of the following sets of quantum numbers are not possible.

A. a) $n = 0 \quad l = 0 \quad m_l = 0 \quad m = \frac{+1}{2}$

b) $n = 1 \quad l = 0 \quad m_l = 0 \quad m_s = \frac{-1}{2}$

c) $n = 1 \quad l = 1 \quad m_l = 0 \quad m_s = \frac{+1}{2}$

d) $n = 2 \quad l = 1 \quad m_l = 0 \quad m_s = \frac{-1}{2}$

e) $n = 3 \quad l = 3 \quad m_l = -3 \quad m_s = \frac{+1}{2}$

f) $n = 3 \quad l = 1 \quad m_l = 0 \quad m_s = \frac{+1}{2}$

a) is not possible because zero is no permissible for n

b) is not possible since for n = 1, possible values of l is zero only

c) is not possible since for n = 3 permissible values of l are 0, 1, 2 only

17. How many electrons in an atom may have the following quantum numbers?

a) $n = 3,\ m_s = \frac{-1}{2}$ b) $n = 4,\ l = 0$

A. a) total number of electron possible in a particular orbit are = $2n^2 = 2 \times 3^2 = 18$ and all 18 electrons are paired.

$\therefore$ out of $18e^-$, $9e^-$ will have $\frac{-1}{2}$ spin

b) n = 4, l = 0 is 4s orbital

$\therefore$ 4s orbitals can have only $2e^-$

18.. Explain, giving reasons, which of the following sets of quantum numbers are not possible.

A. 1) $n = 4 \quad l = 2 \quad m_l = -2 \quad m_s = \frac{-1}{2}$

2) $n = 2 \quad l = 2 \quad m_l = 1 \quad m_s = \frac{+1}{2}$

3) $n = 4 \quad l = 1 \quad m_l = 0 \quad m_s = \frac{+1}{2}$

4) $n = 3 \quad l = 2 \quad m_l = -2 \quad m_s = \frac{-1}{2}$

5) $n = 3 \quad l = 1 \quad m_l = -1 \quad m_s = \frac{+1}{2}$

6) $n = 4 \quad l = 1 \quad m_l = 0 \quad m_s = \frac{+1}{2}$

Energies of various electrons are calculated by using n + 1 rule

$n + l$	value
1e =	4 + 2 = 6
2e =	3 + 2 = 5
3e =	4 + 1 = 5
4e =	3 + 2 = 5
5e =	3 + 1 = 4
6e =	4 + 1 = 5

Among the electrons, which have same n + 1 value, he electron with lower 'n' value will have lower energy

$\therefore$ order = 53 < 2e < 3e = 6e < 1e

19. How many sub – shells are associated with n = 4? How many electrons will be present in the sub – shell having m_s value of $\frac{-1}{2}$ for n = 4?

A. For n = 4, four sub shells are possible

Total number of electron possible in a particular orbit is = $2n^2 = 2 \times 4^2 = 32$

$\therefore$ out of $32e^-$ half of the electrons i.e, $16e^-$ will have $\frac{-1}{2}$ spin

20. Among the following pairs of orbitals which orbital will experience the larger effective nuclear charge?

A. The orbital closer to the nucleus will experience larger effective nuclear charge. Hence 2s more than 3s, 4d more than 4f and 3p more than 3d will experience more effective nuclear charge.

. The bromine atom possesses 35 electrons. It contains 6 electrons in 2p orbital, 6 electrons in 3p orbital and 5 electrons in 4p orbital.

21. Which of these electrons experience the lowest effective nuclear charge?

A. Among the given electrons as 4p are away from the nuclear they will experience lowest effective nuclear charge.

SHORT ANSWERS:

1. What is Principal quantum number and explain its significance?

A. **Principal quantum number (n):**

1) It is proposed by 'Bohr' and indicated by the letter 'n'

2) 'n' is positive integer with value of n = 1, 2, 3, …. (or) K, L, M….

3) This quantum number determines the size and energy of the orbital

4) Size of an orbital increases with increase in ‘n’. The energy of the orbital will increase with increase in ‘n’

5) It tells about the electron belongs to which main energy level.

2. What is Azimuthal quantum number and explain its significance?

A. 1) Azimuthal quantum number was proposed by Sommerfeld.

2) This quantum number determines the magnitude of the orbital angular momentum. So it is also called, ‘orbital angular momentum quantum number’

3) This quantum number explains reasons for the closely spaced spectral lines in the fine spectrum of hydrogen. It is represented by ‘l’

4) ‘l’ represents the sub – shells present in a principal shell

5) ‘l’ can take up values from 0 to (n – 1) i.e, = 0, 1, 2, 3, …. (n – 1), for a given value of n

6) Each value of l represents a particular sub – shell within a principal shell. Thus,

$l = 0$ represents s sub – shell

$l = 1$ represents p sub – shell

$l = 2$ represents d sub – shell

$l = 3$ represents f sub – shell

7) The number of sub – shell in a principal shell :

n (Principal shell)	l (Sub – shell)	Symbol of sub – shell
n = 1	$l = 0$	s
n = 2	$l = 0$	s
	$l = 1$	p
n = 3	$l = 0$	s
	$l = 1$	p
	$l = 2$	d
n = 3	$l = 0$	s
	$l = 1$	p
	$l = 2$	d
	$l = 3$	f

8) Maximum number of electrons in a given sub – shell is given by $2(2l+1)$. Thus

Sub – shell	Value of l	Maximum number of electrons
s	0	$2(2\times0+1)=2$
p	1	$2(2\times1+1)=6$
d	2	$2(2\times2+1)=10$
f	3	$2(2\times3+1)=16$

3. State and explain Heisenberg's uncertainty principle.

A. Heisenberg's uncertainty principle: "Simultaneous and exact determination of the position and momentum of a sub- atomic particle, like electron moving with high speed is impossible".

If Δx and Δp represents the uncertainties in the position and momentum respectively. Then according to Heisenberg

$$\Delta x.\Delta p \geq \frac{h}{4\pi} \text{ ---------- (1)}$$

The product of uncertainties in position (Δx) and momentum (Δp) of an electron cannot be less than $\frac{h}{4\pi}$. It can be equal or greater than $\frac{h}{4\pi}$

Since momentum = mass $\times$ velocity, the equation (1) can be written as

$$\Delta x \times m(\Delta v) \geq \frac{h}{4\pi} = \Delta x \times \Delta v \geq \frac{h}{4\pi m}$$

If the position is determined accurately $\Delta x = 0$ and $\Delta v = \alpha$. That means the inaccuracy in measuring the velocity is α. If velocity is determined accurately $\Delta v = 0$ and $\Delta x = \alpha$

Significance of uncertainty principle:

1) This principle rules out the existence of definite paths or trajectories of electrons and other similar particles

2) This principle is significant only for motion of microscopic objects, and is negligible for that of macroscopic objects

3) In dealing with milligram size of heavier objects, the associated uncertainties are hardly of any real consequence.

4. Write the Schrodinger wave equation and explain each term in it.

A. A satisfactory description of an electron in an atom is provided by Schrodinger wave equation. This equation formed the basis for the modern quantum mechanical model of the atom. The wave equation in the three dimensional space is written in Cartesian coordinates as

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

Where m = mass of the electron

E = total energy of electron

V = P.E. of the electron

H = Planck's constant = $6.626\times10^{-27}\, ergs$

ψ = wave function

x, y and z are Cartesian coordinates

Meaning of ψ :

1) ψ is a wave function

2) It gives amplitude of an electron – wave

3) ψ takes up a positive value above the axis and a negative value below the axis and becomes '0', while crossing the axis

Significance of ψ^2 :

1) It is a probability function

2) ψ may be positive or negative. But ψ^2 is always positive

3) The region of space around the nucleus, where there is high probability of finding the electron (ψ^2 value is more than 95%) is called an atomic model

5. **What is Aufbau principle? Give the sequence in which various orbitals are filled with electrons**.

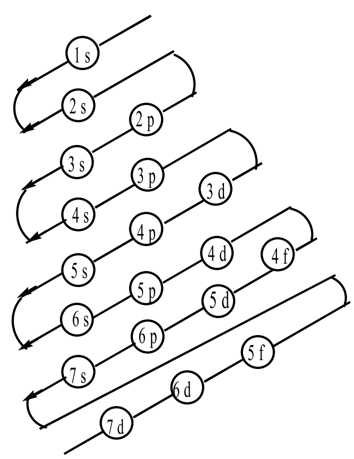
A. Aufbau principle:

In Germal, Aufbau means 'build up'. The principle states that "The orbitals are filled up with electrons in the increasing order of their energy"

The relative order of energy of various orbitals in an atom is:

1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d < 7p < 8s….

The sequence given above can be represented by Moellar diagram.



Order of filling of orbitals

Case: If two orbitals have the same relative energy, then the orbital with lower 'n' value is filled first

Ex : (n + 1) value of 2p = 2 + 1 = 3

(n + 1) value of 3s = 3 + 0 = 3

While filling up these orbitals, the 2p orbital (n = 2) is filled first and then the 3s (n = 3) orbital

6. **State and explain Pauli's exclusion principle.**

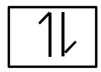
A. **Pauli's exclusion principle**:

According to this principle

"No two electrons in an atom can have the same set of four quantum numbers". This can also be stated as "only two electrons may exist in the same orbital and these electrons must have opposite spins".

This means that the two electrons can have the same value of three quantum numbers n, l and m_l but have the opposite spin quantum number.

Ex : Consider 'K' shell of the atom having two electrons



	n	l	m	s
1^{st} electron	1	0	0	$+\frac{1}{2}$
2^{nd} electron	1	0	0	$-\frac{1}{2}$

7. State and explain Hund's rule of maximum multiplicity.

A. **Hund's Rule:** "Pairing up of electrons takes place only when all the available degenerate orbital in a given sub – shell are filled with one electron each".

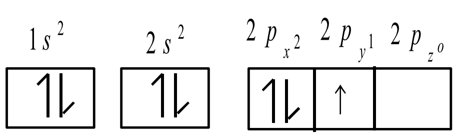
Explanation: Degenerate orbitals means, orbitals with equal energy

Ex : p_x, p_y, p_z

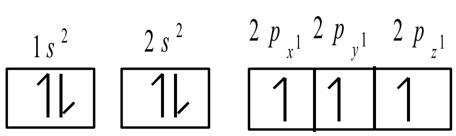
Example 1 : Nitrogen, $Z = 7\ 1s^2 2s^2 2p^3$

Nitrogen can be given the following two types of configurations:

A)



B)

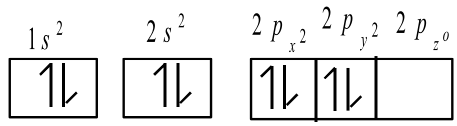


According to Aufbau principle, configuration B is correct, since each degenerate p orbital is having an electron.

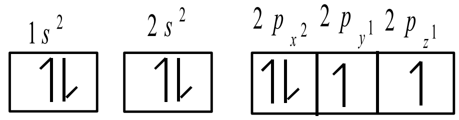
Example 2: Oxygen, $Z = 8\ 1s^2 2s^2 2p^4$

Oxygen can be given the following two types of configurations

A)



B)



According to Aufbau principle, configuration B is correct, since each degenerate p orbital has at least one electron.

8. Write the four quantum numbers for $3d^1$ electron.

A. $n = 3, l = 2, m = -2, s = \pm\frac{1}{2}$

9. What is electronic configuration? Write the electronic configuration of sodium.

A. The distribution of electrons in various shells, sub – shells and orbitals in an atom of an element is called its 'electronic configuration'. The electronic configuration of an atom is written in terms of nl^x notation.

Sodium, Na Z = 11 ; $1s^2\, 2s^2\, sp^6\, 3s^1$

10. Why does the electronic configuration of chromium and copper have special features?

A. The expected configuration for Cr and Cu are

Cr (Z = 24) $1s^2\, 2s^2\, sp^6\, 3s^2\, 3p^6\, 4s^2\, 3d^4$ and Cu (Z = 29) $1s^2\, 2s^2\, sp^6\, 3s^2\, 3p^6\, 4s^2\, 3d^9$

The two sub – shells 4s and 3d differ slightly in their energies. Then the electron shifts from a sub – shell of lower energy (4s) to a sub – shell of higher energy (here, 3d) getting either completely filled or half – filled. So the electronic configuration of Cr and Cu are

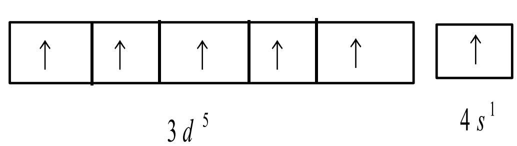
Cr Z = 24 $1s^2\, 2s^2\, sp^6\, 3s^2\, 3p^6\, 4s^1\, 3d^5$

Cu Z = 29 $1s^2\, 2s^2\, sp^6\, 3s^2\, 3p^6\, 4s^1\, 3d^{10}$

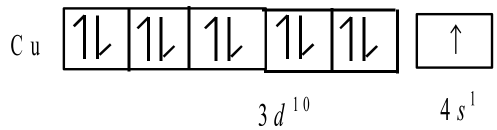
These configurations are more stable

The completely filled and half filled sub – shells are more stable for the following reasons :

1) There is symmetrical distribution of electrons in the sub – shells So they are more stable.



Each orbitals has 1 electron. They are half - filled. The 3d orbitals are completely filled.



2) When two or more electrons with the same spin are present in the degenerate orbitals, these electrons exchange their positions, then some energy is released called 'exchange energy'. Then the energy of the atom decreases and it becomes more stable. The more the number of 'exchange pair' of electrons, the greater would be the decrease of energy and hence the greater is the stability of the atom. In the above configuration of Cr and Cu, there are more 'exchange pairs' than in their previous configurations.

11. Discuss he significance of de – Broglie's hypothesis.

A. **Significance of de Broglie hypothesis**: Based on the ideas of the dual nature of light, de Broglie proposed that all micro particles including the electron moving wit high velocity are also associated with wave nature.

Bohr's theory and de – Broglie concept: Bohr assumed electron as a particle and postulated that an electron can revolve only in an orbit in which its angular momentum (mvr) is equal to $\frac{nh}{2\pi}$

According to de Broglie an electron moving round the nucleus in a circular orbit, behaves as a standing or stationary wave. To behave in such away the circumference of the Bohr's orbit ($=2\pi r$) should be equal to the whole number multiple of the wavelength (λ) of the electron wave.

$$2\pi r = n\lambda$$

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

n = whole number

According to de Broglie

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

$$\therefore \frac{2\pi r}{n} = \frac{h}{mv} \text{ or } mvr = \frac{nh}{2\pi}$$

Hence de Broglie's theory and Bohr's theory are in agreement with each other

12. What is nodal plane? How many nodal planes are possible for 'p' and'd' orbitals?

A. The probability to find the electron at the nucleus in an atom is negligible. This point is called nodal point. The plane passing through this point is called 'nodal plane' (or 'angular node'). So, nodal plane is the plane of zero electron density.

The number of nodal planes for an orbital is equal to its Azimuthal quantum number ℓ value. Thus,

Number of nodal planes for s – orbital $(l = 0)$ is zero

Number of nodal planes for p – orbital $(l = 1)$ is 1

Number of nodal planes for d – orbital $(l = 2)$ is 2

Number of nodal planes for f – orbital $(l = 3)$ is 3

13. What is the significance of spin quantum number in electronic structure of an atom?

A. Spin quantum momentum of the electron can have two orientations relative to the chosen axis. These two orientations are distinguished by the spin quantum numbers (m_s) which can take the values of $+\frac{1}{2}$ or $-\frac{1}{2}$. These are called **two spin states of the electron**. Two electrons that have different m_s values $\left(+\frac{1}{2} \text{ and } -\frac{1}{2}\right)$ are said to have opposite spins. **An orbital cannot hold more than two electrons and these two electrons should have opposite spins.**

14. A line in the Lyman spectrum of hydrogen has a wavelength of $1.03 \times 10^{-7} m$. Find the original energy level of the electron.

A. $\bar{\upsilon} = \frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ Given $n_1 = 1,\ n_2 = ?$

$$\frac{1}{1.03 \times 10^{-7} m} = 1.09678 \times 107 m^{-1}\left(\frac{1}{1^2} - \frac{1}{n_2^2}\right)$$

On simplification, we can write $\frac{1}{1 \times 10^{-7} m} = 1.1 \times 10^7\left(\frac{1}{1^2} - \frac{1}{n_2^2}\right)$

or $1 = 1 \times 10^{-7} m \times 1.1 \times 10^7\left(\frac{1}{1^2} - \frac{1}{n_2^2}\right)$

$\therefore\ 1 = 1.1\left(\frac{1}{1^2} - \frac{1}{n_2^2}\right)$

or $\therefore\ 1 - \frac{1}{n_2^2} = \frac{1}{1.1} = 0.9(\text{approximately})$

Now, substituting $n_2 = 2$, we get, $1 - \frac{1}{2^2} = \frac{3}{4} = 0.75$

Substituting $n_2 = 3$, we get, $1 - \frac{1}{9} = \frac{8}{0} = 0.9$ (approximately)

Hence by trial and error method, we found, $n_2 = 3$

So the electron belongs to 3rd energy level (M = 3) originally.

15. The Lyman series occurs between 19.2 mm and 121.6 nm. the Balmer series occurs between 364.7 and 656.7 nm and the Paschen series occurs between 820.6 nm1876 nm. Identify the spectral regions to which these wavelengths correspond.

A.

Name of series	Spectral region
1) Lyman	Ultra violet
2) Balmer	Visible
3) Paschen	Near infrared

LONG ANSWERS:

1. State de-Broglie's hypothesis. Discuss its significance to microscopic particles like electrons.

A. **De-Broglie's hypothesis** : The light is found to exhibit wave nature as well as particle nature (dual nature). Based on this idea of 'dual nature of light', de Broglie in 1924 proposed that 'all microparticles including the electron moving with high velocity are associated with wave nature"

Explanation: According to de-Broglie, every moving object has a wave character. The wavelength of the ordinary moving object is so short (because of large mass) that its wave particles cannot be detected.

According to de-broglie, an electron moving with a high speed describes a wave.

Expression for de-Broglie wavelengths:

According to Planck's quantum theory, energy of a photon, $E = h\upsilon$, But $\upsilon = \frac{c}{\lambda}$

$\therefore\ E = h.\frac{c}{\lambda}$ .... (1)

Einstein's mass energy equivalence equations is

$E = mc^2$ .... (2)

Combining equations (1) and (2), $\frac{hc}{\lambda} = mc^2$ (or) $\lambda = \frac{h}{mc} = \frac{h}{p}$ (p = mc = momentum)

This equation is applicable to photons as well as to all micro particles, moving with high speed.

$\therefore$ We can write in general, $\lambda = \frac{h}{p} = \frac{h}{mv}$ where m = mass of the micro particle and v – its velocity

'λ' is called, de-Broglie wavelength or material wavelength.

Significance of de-Broglie's concept :

According to Bohr's theory, electron revolves in an orbit in which its angular momentum (mvr is an integral multiple of $\frac{h}{2\pi}$. Bohr assumed electron as a particle. Hence his equation can be taken as

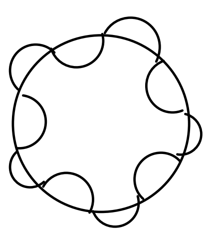
$$mvr = n\left(\frac{h}{2\pi}\right)$$ where n = a whole number

1. According to deBroglie, electron behaves as a standing (or stationary wave which extends around the nucleus in a circular orbit
2. If the ends of the electron wave meet to give a regular series of crests and troughs, the electron wave is said to be in phase.
3. It means, there is constructive interference of electron waves and the electron motion has a character of standing wave or non energy radiating motion, always it is necessary condition to get an electron – wave in phase such that the circumference of the Bohrs orbit $(= 2\pi r)$ is equal to the whole number of multiples the wavelength (λ) of the electron – wave.

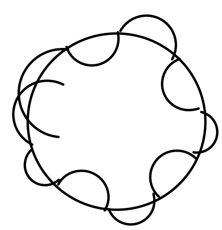
$$n\lambda = 2\pi r$$

$$\lambda = \frac{2\pi r}{n} \text{ but } \lambda = \frac{h}{mv}$$

$$\frac{2\pi r}{n} = \frac{h}{mv} \text{ or } mvr = \frac{nh}{2\pi}$$



(a) wave in - phase



(b) wave out - of - phase

2. Explain the salient features of quantum mechanical method of an atom.

A. Classical mechanics deals with the motion of microscopic objects, while quantum mechanics deals with the motion of microscopic objects. The microscopic bodies exhibit dual nature i.e, they possess particle as well as wave nature.

Schrondinger wave equation applies to electron in an atom, which describes a stationary wave. It is

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

In this equation, ψ = wave function,

m = mass of the electron

E = Total energy (K.E + p.E of the electron)

V = P.E of the electron

E – V = K.E of the electron

H = Planck's constant

x, y and z are Cartesian coordinates in the three dimensional space.

Significance of ψ :

1) ψ is an orbital wave function

2) It gives amplitude of an electron wave

3) ψ takes positive value above the axis and a negative value of below the axis and becomes zero while crossing the axis

Significance of ψ^2 :

1. It is a probability function
2. Value of ψ^2 is always positive
3. ψ^2 describe the probability of finding an electron around the nucleus and where the value is maximum is called an orbital

Salient features of the quantum mechanical model of atom :

1. The energy of an electron in an atom is quantized. It means, the electrons can have only certain values of energy.
2. The energy levels in an atom are quantize, which are the allowed solutions of schrodinger wave equation, applied for electron wave.
3. All the information about the orbiting electron in atom is contained in the orbital wave function
4. The exact path of an electron cannot be determined accurately. We can only find the probability of the electron at different in an atom
5. ψ^2 is the probability density, which is always positive. From the value of ψ^2 at different points within the atom, it is possible to find the orbital of electron.

Orbital is the three – dimensional space around the nucleus of an atom, where there is high probability of finding the electron.

3. State Heisenbergs uncertainty principle and discuss the significance of uncertainty principle.

A. **Heisenbergs uncertainty principle**: "It is impossible to determine simultaneously the exact position and exact momentum of an electron.

Heisenbergs equations is $\Delta x \times \Delta p \geq \frac{h}{n\pi}$ (where n = 1, 2, 3, 4, ….

Δx = uncertainity in the determination of the position of electron

Δp = uncertainity in the determination of the position of the electron

h= Planck's constant

If the position of the electron is determined accurately, then $\Delta x = 0$. Therefore,

$$\Delta p = \frac{h}{4\pi \times \Delta x} \text{ or } \Delta p = \frac{h}{4\pi \times 0} = \frac{h}{0} \text{ or } \Delta p = \propto$$

Uncertainity in determination of the momentum of the electron is infinity.

Significance of uncertainty principle:

1. This principle applies for motion of microscopic objects and not so of macroscopic objects.
2. For massive bodies, the uncertainties have no practical importance.
3. Microscopic bodies like electrons cannot have fixed paths of motion, according to this principle.

4. What are quantum numbers? Explain the significance of various types of quantum numbers.

A. To describe an electron completely in an atom four Quantum numbers were given. They are

a. Principal quantum number b. Azimuthal quantum number

c. Magnetic quantum number d. Spin quantum number

a) Principal quantum number:

1. This was proposed by Neils Bohr
2. It is denoted by the letter n
3. It represents the circular orbits around the nucleus
4. As the value of n increases the size and energy of the orbit also increases
5. According to number method, the values of 'n' are 1, 2, 3, …. According to letter method 'n' can be represented by the letters K, L, M, …..
6. In any orbit, the maximum number of sub orbits = n, number of orbitals = n^2, number of electrons = $2n^2$
7. This quantum number describes the size and energy of the orbit

b) Azimuthal quantum number:

1. This was proposed by Sommerfeld
2. It is also known as Angular momentum quantum number
3. It is denoted by the letter *l*
4. This quantum number represents the sub- levels present in the main levels
5. The sub levels are s, p, d and f
6. The *l* values of s, p, d and f sub – levels are 0, 1, 2 and 3 respectively

7. The first main level contain only one sub – level and it is ‘s’. The second main level contain ‘s, p’ sub – levels. The third main level contains s, p, d sub – levels. The fourth main level contains s, p, d and f sub – levels

8. The quantum number describes the shape of the orbital

c) Magnetic quantum number:

1. This was proposed by Lande
2. It is denoted by the letter ‘m’
3. This quantum number describes the sub – sub levels orbitals present in a given sub – level
4. ‘m’ has values from $-\ell$ to $+\ell$ through ‘0’
5. The total number of ‘m’ values for a given value of ‘ℓ’ is $(2\ell+1)$
6. All the orbitals present in a given sub – level possess the same energy values, because they possess the same ‘n’ and ‘ℓ’ values
7. This quantum number describes the orientation of the orbitals in space

d) Spin quantum number:

1. This was proposed by Unlenbeck and Goudsmidt
2. It is denoted by the letter ‘s’
3. This quantum number describes the spin of the revolving electron
4. The spin quantum number value of an electron revolving in clockwise direction is $+1/2$ and that of an electron revolving in anti – clockwise direction is $-1/2$
5. The clock – wise revolving electron is represented by upward arrow mark $(\uparrow)$
6. The anti – clockwise revolving electron is represented by downward arrow mark $(\downarrow)$
7. This quantum number describes the direction of spin of the revolving electron

5. Define atomic model. Explain the shapes of s, p and d orbitals with the help of diagrams.

A. **Atomic orbital:** The three – dimensional space around the nucleus in an atom where the probability of finding an electron is maximum is called an atomic orbital.

Shapes of s, p and orbitals:

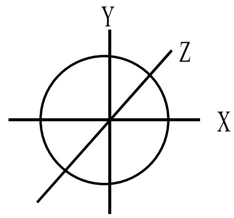
The shapes of the orbitals are the ‘angular distribution curves’, obtained as one of the solutions of Schrodinger wave equation

1) Shape of s – orbital

i) s orbital is spherical in shape

ii) As the value of principal quantum number ‘n’ increases, size of ‘s’ orbital increases. Thus, sizes are : 1s < 2s < 3s ….

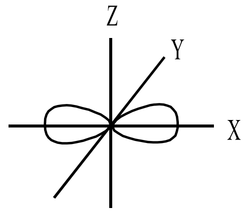
iii) An ‘s’ orbital has no directional property



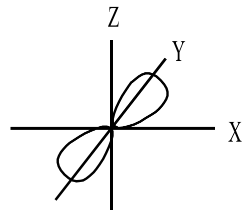
s - orbital

2) Shape of p – orbital:

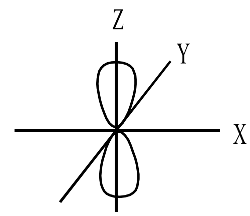
Shape of p – orbital is dumbbell. There are three p – orbitals. They are P_x, P_y and P_z orbitals. Each orbital has two lobes. These lobes are oriented along their respective axes. Each p – orbital has one nodal plane



P_x orbital



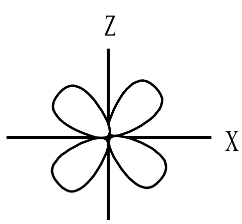
P_y orbital



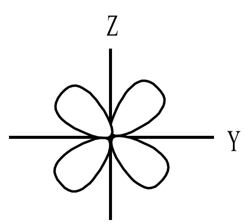
P_z orbital

3) Shape of d – orbitals:

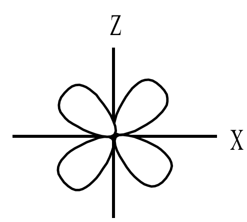
d – orbital has double dumb – bell shape. There are five d – orbitals. They are d_{xy}, d_{yz}, d_{xz} $d_{x^2-y^2}$ and d_{z^2}. Each d – orbital has 4 lobes. In d_{xy} orbital, the lobes are placed in between x and y axes, similar in the case with other orbitals, d_{yz} and d_{xz}. In d_{z^2} orbital, two lobes lie on Z – axis and there is a ring of electron – cloud around the centre. In $d_{x^2-y^2}$ orbital, the lobes lie on X and Y – axes. Each 'd' orbital has two nodal planes.



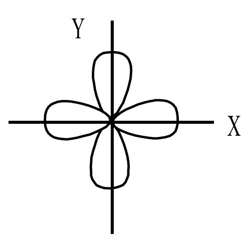
d_{xy}



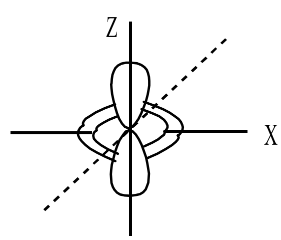
d_{yz}



d_{zx}



$d_{x^2-y^2}$



d_{z^2}

6. What are the facts in support of the belief that electrons are an essential constituent of atoms?

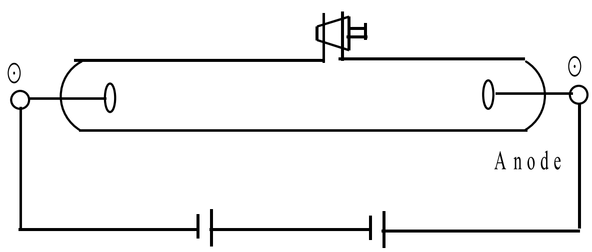
A. Following facts support the electrons are an essential constituents of all atoms:

1) Michael Faraday showed that particulate nature of electricity

2) Cathode ray discharge tube experiment:

A cathode ray tube is made of glass containing two thin pieces of metal, called electrodes, sealed in it. The electrical discharge through the gases observed only at very low pressure and at very high voltage. The pressure of different gases could be adjusted by eva-cuation. When sufficient high voltage is applied across the electrodes, current starts flowing through a stream of particles moving in the tube from the negative electrode (cathode) to the positive electrode (anode).

These were called cathode rays (or) cathode ray particles. (Because these emanated from negative electrode.



Discharge tube

A number of additional facts suggested that:

1) Cathode rays themselves are not visible but their behaviour can be observed with the help of certain kind of materials (fluorescent (or) phosphorescent) which glow when hit by them.

1. **Example:** Television picture tube

2) Cathode rays starts from cathode and move towards anode

3) These rays travel in straight lines in the absence of electric and magnetic field

4) In the presence of electric and magnetic field they are deflected in a manner expected for negatively charged particles, suggesting that cathode rays consists of negatively charged particles called “Electrons”

5) These rays were found to be independent of the nature of the cathode materials and nature of the gas present in the cathode ray tube.

2. Hence, it was concluded that electrons are basic constituents of all the atoms.