Chapter- 2 Structure of Atom

1. Which are the major problem before scientist after discovery of subatomic particles?
2. Explain discovery of electron? (2 marks)

- In 1830, Michael Faraday showed that if electricity is passed through a solution of an electrolyte, chemical reactions occurred at the electrodes, which resulted in the liberation and deposition of matter at the electrodes. . These results suggested the particulate nature of electricity.
- Behaviour of charged particles : "Like charges repel each other and unlike charges attract each other".
- In mid 1850s many scientists mainly Faraday discover cathode ray tube pass the electricity from cathode to anode in evacuated tube at high pressure these were called negatively charge 'electrons'

3. What is cathode ray discharge tube ? write it's uses. (2 marks)

cathode ray discharge tube - partially evacuated tubes, known as cathode ray discharge tubes.

Uses -

a) A cathode-ray tube is used in television. It converts electrical signals into visual signals.
b) A cathode-ray tube is also used to study the behavior of cathode rays.

4. What is the characteristics of Cathode ray tube? (2 0r 3 marks)

- The cathode rays consist of negatively charged particles known as electrons.
- The cathode rays always travel in a straight line
- A green glow fluorescence is produced when the cathode rays strike against a glass surface or screen coated with zinc sulphide.
- The cathode rays produce heat when they strike a material surface.
- The cathode rays are deflected from their path by electric and magnetic fields.
- The cathode rays are negatively charged particles

5. Write down the result of cathode ray discharged tube .(3 marks)

(i)The cathode rays start from cathode and move towards the anode.

(ii)These 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. Television picture tubes are cathode ray tubes and television pictures result due to fluorescence on the television screen coated with certain fluorescent or phosphorescent materials.

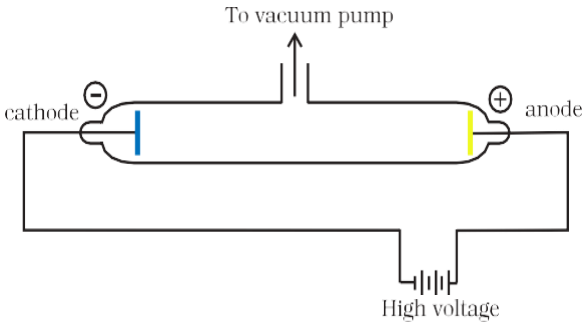
(iii)In the absence of electrical or magnetic field, these rays travel in straight lines

(iv)In the presence of electrical or magnetic field, the behaviour of cathode rays are similar to that expected from negatively charged particles, suggesting that the cathode rays consist of negatively charged particles, called electrons.

(v)The characteristics of cathode rays (electrons) do not depend upon the material of electrodes and the nature

of the gas present in the cathode ray tube.

6. Draw a well labelled diagram of Cathod ray discharged tube. (2 marks)



7. Who discover the ratio of chrge to mass of electron and how explain with diagram? (5 marks)

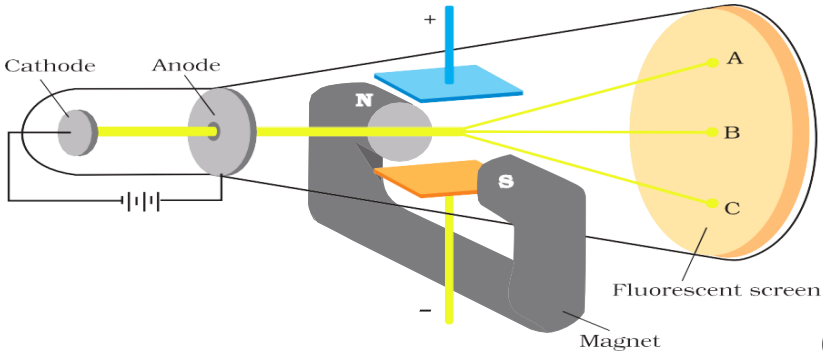
In 1897, British physicist **J.J. Thomson** measured the ratio of electrical charge (e) to the mass of electron (m_e). (1 marks)

$e / m_e = 1.758820 \times 1011$ C kg–1 (0.5 mark)

Where m_e -is the mass of the electron in kg

e - is the magnitude of the charge on the electron in coulomb (C).

Experimental determination of e / m_e raio – to determine e/m_e ratioThomson used cathode ray tube and applying electrical and magnetic field perpendicular to each other as well as to the path of electrons .



(1.5 marks)

Observation- (1 marks)

a) When only electric field is applied, the electrons deviate from their path and hit the cathode ray tube at point A Similarly when only magnetic field is applied, electron strikes the cathode ray tube at point C. By carefully balancing the electrical and magnetic field strength, it is possible to bring back the electron to the path which is followed in the absence of electric or magnetic field and they hit the screen at point B.

b) By carrying out accurate measurements on the amount of deflections observed by the electrons on the electric field strength or magnetic field strength, Thomson was able to determine the value of e/me as:

Factor on which direction of cathode particle depends in electric discharge tube.(1 marks)

- The magnitude of the negative charge on the particle, greater the magnitude of the charge on the particle, greater is the interaction with the electric or magnetic field and thus grater the deflection.
- Lighter the particle, greater the deflection.
- The strength of the electrical or magnetic field — the deflection of electrons from its original path increases with the increase in the voltage across the electrodes, or the strength of the magnetic field.

8. Who discovered charge of electron ? State chrge mass of electron .
   - R.A. Millikan (1868-1953) discovered charge of electron .
   - According to Millikan the charge on the electron to be -1.6×10^{-19} C.
   - The present accepted value of electrical charge is $-1.602176 \times 10^{-19}$ C.

$$\frac{e}{me} = \frac{1.6022 \times 10^{-19}\ C}{1.758820 \times 10^{11}\ C\ Kg^{-1}}$$

9.Explain discovery of Proton .

Electrical discharge carried out in the modified cathode ray tube led to the discovery of canal rays carrying positively charged particles.

Characteristics of Canal rays –

(i) Mass of positively charged particles depends upon the nature of gas present in the cathode ray tube. These are simply the positively charged gaseous ions.

(ii)The charge to mass ratio of the particles depends on the gas from which these originate.

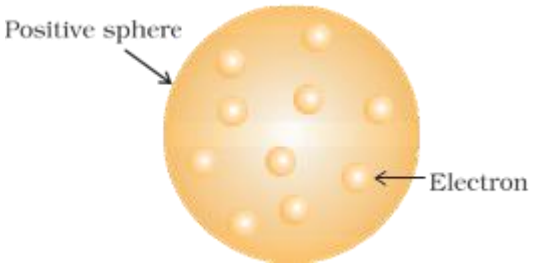
(iii) Some of the positively charged particles carry a multiple of the fundamental unit of electrical charge.

(iv) The behaviour of these particles in the magnetic or electrical field is opposite to that observed for electron or cathode rays.

(v)The smallest and lightest positive ion was obtained from hydrogen and was called proton.

10. Write about J.J Thomson model .

a) J. J. Thomson, in 1898, proposed that an atom possesses a spherical shape (radius approximately 10^{-10} m) in which the positive charge is uniformly distributed.



b) The electrons are embedded into it in such a manner as to give the most stable electrostatic arrangement.
c) According to Thomson positive chrge concentrated in small volume.
d) Many different names are given to this model, for example, plum pudding, raisin pudding or watermelon.
e) The mass of the atom is assumed to be uniformly distributed over the atom.
f) This model was able to explain the overall neutrality of the atom

11. Ruther ford 's Nuclear Model of atom . (5 marks)

- Rutherford and his students (Hans Geiger and Ernest Marsden) gives alpha –particle scattering experiment .
- A stream of high energy α–particles from a radioactive source was directed at a thin foil (thickness ~ 100 nm) of gold metal.
- fluorescent zincsulphide screen was kept around thin gold foil
- Whenever α–particles struck the screen, a tiny flash of light was produced at that point.
- α–particles had enough energy to pass directly through such a uniform distribution of mass. It was expected that the particles would slow down and change directions only by a small angles as they passed through the foil.

Observation –(i) most of the α–particles passed through the gold foil undeflected.

(ii) a small fraction of the α–particles was deflected by small angles.

(iii) a very few α–particles (~1 in 20,000) bounced back, that is, were deflected by nearly 180

Rutherford drew the following conclusions regarding the structure of atom:

(i) Most of the space in the atom is empty as most of the □–particles passed through the foil undeflected.

(ii) A few positively charged □–particles were deflected. The deflection must be due to enormous repulsive force showing that the positive charge of the atom is not spread throughout the atom as Thomson had presumed. The positive charge has to be concentrated in a very small volume that repelled and deflected the positively charged □–particles.

(iii) Calculations by Rutherford showed that the volume occupied by the nucleus is negligibly small as compared to the total volume of the atom. The radius of the atom is about 10–10 m, while that of nucleus is 10^{-15} m. One can appreciate this difference in size by realising that if a cricket ball represents a nucleus, then the radius of atom would be about 5 km.

On the basis of above observations and conclusions, Rutherford proposed the nuclear model of atom. According to this model:

(i) The positive charge and most of the mass of the atom was densely concentrated in extremely

small region. This very small portion of the atom was called nucleus by Rutherford.

(ii) The nucleus is surrounded by electrons that move around the nucleus with a very high speed in circular paths called orbits. Thus, Rutherford's model of atom resembles the solar system in which the electrons that of revolving planets.

(iii) Electrons and the nucleus are held together by electrostatic forces of attraction.

12. What is atomic number , mass number and nucleons ? (3 marks)

Atomic number - The number of protons present in the nucleus is equal to atomic number (Z).

Atomic number (Z) = number of protons in the nucleus of an atom = number of electrons in a nuetral atom .

Nucleons - protons and neutrons present in the nucleus are collectively known as nucleons.

Mass number- The total number of nucleons is termed as mass number (A) of the atom.

Mass number (A) = number of protons (Z) + number of neutrons (n)

13. Give definition and examples of isobars and isotopes .(2 marks)

Isobars -

Isobars are the atoms with same mass number but different atomic number

Example - ^{14}C and ^{14}N.

Isotopes –

Atoms with identical atomic number but different atomic mass number are known as Isotopes.

Example - Hydrogen has three isotopes

Protium (11H) , Deuterium (21D), Tritium (31T).

14. Which are the drawbacks of Rutherford's atomic model ? (2 marks)

Drawbacks of Rutherford's Atomic Model:

1. This model could not explain the motion of electrons in circular orbitals.
2. A charged particle would release energy during acceleration and eventually, it will fall into the nucleus.

15. Which development played a role in formation of Bohr's model of atom ? (2 marks)

Two developments played a major role in the formulation of Bohr.s model of atom Results observed from the studies of interactions of radiations with matter have provided immense information regarding the structure of atoms and molecules . Neils Bohr utllised these reuslts to give atomic model

(i) Dual character of the electromagnetic radiation which means that radiations possess both wave like and particle like properties.

(ii) Experimental results regarding atomic spectra which can be explained only by assuming quantized electronic energy levels in atoms.

16. What is electromagnetic radiation? (2 marks)

When electrically charged particle moves under accelaration, alternating electrical and magnetic fields are

produced and transmitted. These fields are transmitted in the forms of waves called electromagnetic waves or electromagnetic radiation.hat is electromagnetic radiation .

17. Explain properties of Electromagnetic wave? (3 marks)

(i) The oscillating electric and magnetic fields produced by oscillating charged particles are perpendicular to each other and both are perpendicular to the direction of propagation of the wave.

(ii) Unlike sound waves or waves produced in water, electromagnetic waves do not require medium and can move in vacuum.

(iii) that there are many types of electromagnetic radiations, which differ from one another in wavelength (or frequency). These constitute what is called electromagnetic spectrum

(iv) Radio frequency 10 Hz, used for broadcasting;

Microwave region around 10 Hz used for radar

Infrared region around 10^{13} Hz used for heating

Ultraviolet region around 10^{16}Hz

Visible light 10^{15} Hz

(v) Different kinds of units are used to represent electromagnetic radiation.

18. Give the characteristics of electromagnetic radiation.(3 marks)

Wavelength: It may be defined as the distance between two neighbouring crests or troughs of wave as shown. It is denoted by λ.

Frequency (v): It may be defined as the number of waves which pass through a particular point in one second.

Velocity (v): It is defined as the distance travelled by a wave in one second. In vacuum all types of electromagnetic radiations travel with the same velocity. Its value is 3×10^8 m $sec^{-1.}$ It is denoted by v

Wave number: Wave number (bar v) is defined as the number of wavelengths per unit length.

Velocity = frequency x wavelength

$c = \nu\lambda$

19. Which observation arenot explained by electromagnetic theory of physics? (2 Marks)

(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 as a function of temperature

(iv) Line spectra of atoms with special reference to hydrogen.

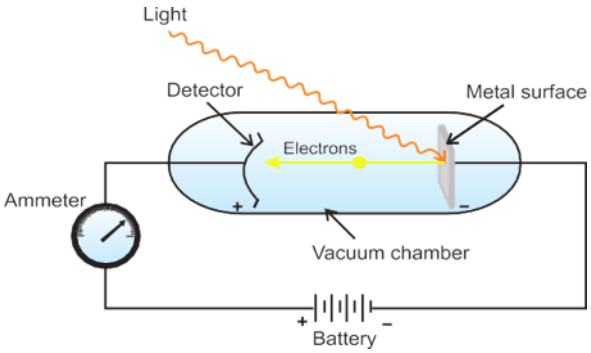
20. Define black body radiation

An ideal body, which emits and absorbs radiations of all frequencies uniformly, is called a black body and the radiation emitted by such a body is called black body radiation.

21. Explain Photo electric effect.(5 marks)

Electrons (or electric current) were ejected when certain metals (for example potassium, rubidium, caesium etc.)

were exposed to a beam of light.The phenomenon is called Photoelectric effect.



Experimental result and observation of Photoelectric effect.

(i) The electrons are ejected from the metal surface as soon as the beam of light strikes the surface.

Assumption - 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.

Assumption - number of electrons intensity of light

(iii) For each metal, there is a characteristic minimum frequency known as threshold frequency.

Assumption - Below threshold frequency photoelectric effect is not observed. At a frequency 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.

22. Write down the dual behaviour of electromagnetic radiation.(2 marks)

- The particle nature of light could explain the black body radiation and photoelectric effect satisfactorily
- Light possesses both particle and wave-like properties, i.e., light has dual behaviour haviour of light which could account for the phenomena of interference and diffraction.
- Light behaves either as a wave or as a stream of particles
- Some microscopic particles like electrons also exhibit this wave- particle duality.

23. Explain absorption and Emission spectra .(3 marks)

Absorption spectrum is the spectrum with dark band of lines when electromagnetic radiation is passed through a material which absorbs it. The bands corresponding to the energy absorbed by the material appears dark in the spectrum.

Emission spectrum: It is the spectrum observed when the energy absorbed by a material is emitted. When energy is absorbed by a material, the electrons are excited to a higher energy state. When the excited electrons return to their ground state they emit radiation. So, the energy corresponding to the emitted radiation forms the emission spectrum.

24. What is hydrogen spectrum and it's characteristics ?(2 marks)

When an electric discharge is passed through gaseous hydrogen, the H molecules dissociate and the energetically excited hydrogen atoms produced emit electromagnetic radiation known as hydrogen spectrum.

Characteristics –

- Hydrogen spectrum is line spectrum ,emission spectrum and discontinuous spectrum .
- The spectrum consists of large number of line appearing in different region of wavelength .Each being name after the name of it's discovered.

25. Write postulates of Bohr's model of hydrogen atom.(3 marks)

- In an atom, electrons (negatively charged) revolve around the positively charged nucleus in a definite circular path called orbits or shells.
- Each orbit or shell has a fixed energy and these circular orbits are known as orbital shells.
- The energy levels are represented by an integer (n=1, 2, 3…) known as the quantum number. This range of quantum number starts from nucleus side with n=1 having the lowest energy level. The orbits n=1, 2, 3, 4… are assigned as K, L, M, N…. shells and when an electron attains the lowest energy level, it is said to be in the ground state.
- The electrons in an atom move from a lower energy level to a higher energy level by gaining the required energy and an electron moves from a higher energy level to lower energy level by losing energy.

26. Explain according to bohr's model of hydrogen atom .(5 marks)

(i) Principle quntum number

(iii)Stationary orbit radii

(iii) Radius of stationary orbit

(iv) Energy of stationary state

(v) Isoelectronic ion of hydrogen

(vi) Velocity of electron

Principle quntum number - The stationary states for electron are numbered n = 1,2,3. These integral numbers are known as Principal quantum numbers.

Stationary orbit radii - The radii of the stationary states are expressed as: $r_n = n^2 a_0$

The radius of the first stationary state is called Bohrorbit is 52.9pm

Normally the electron in the hydrogen atom is found in this orbit (that is n=1). As n increases the value of r will increase. In other words the electron will be present away from the nucleus.

Energy of stationary state –

27. Write down limitation of bohr's model of atom .(3 marks)

a) The Bohr atomic model theory made correct predictions for smaller sized atoms like hydrogen, but poor spectral predictions are obtained when larger atoms are considered.

b) It failed to explain the Zeeman effect when the spectral line is split into several components in the presence of a magnetic field.

c) It failed to explain the Stark effect when the spectral line gets split up into fine lines in the presence of an electric field.

d) It fails to account for the finer details (doublet, that is two closely spaced lines) of the hydrogen atom spectrum observed by using sophisticated spectroscopic techniques.

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

28. Which two development remove drawbacks of Bohr's model ?(2 marks)

Dual behaviour of matter (de – Broglie theory)

Heisenberg's uncertainty principle theory.

29. Write about dual behavior of matter.(3 marks)

De-brogli principle -De Broglie proposed that as light exhibits both wave-like and particle-like properties, matter exhibits wave-like and particle-like properties. This nature was described as dual behaviour of matter. On the basis of his observations, de Broglie derived a relationship between wavelength and momentum of matter. This relationship is known as the de Broglie relationship.

Considering the particle nature, Einstein's equation is given as,

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Considering the particle nature, Einstein's equation is given as,

$E= mc^2$ —- (1)

Where,

E= energy

m= mass

c = speed of light

Considering the wave nature, the Plank's equation is given as,

$E = h\nu$ ——— (2)

Where,

E= energy

h = Plank's constant

ν = frequency

From (1) and (2),

$mc^2 = h\nu$ ——— (3)

Frequency, ν can be expressed in terms of wavelength, λ as,

For a general particle, c can be replaced with the velocity of object, v. Hence, equation (3) can be given as,

The above equation is known as de Broglie relationship and the wavelength, λ is known as de Broglie wavelength. Diffraction of electron beams explains the de Broglie relationship as diffraction is the property of waves. An electron microscope is a common instrument illustrating this fact. Thus, every object in motion has a wavelike character. Due to a large mass, the wavelengths associated with ordinary objects are so short that their wave properties cannot be detected. On the other hand, the wavelengths associated with electrons and other subatomic particles can be detected experimentally.

30. Write down Heisenberg's Uncertainty Principle. (5 marks)

    Heisenberg's uncertainty principle states that it is impossible to measure or calculate exactly both the position and the momentum of an object.

$$\Delta x \times \Delta p_x \geq \frac{h}{4\pi}$$

$$\Delta x \times \Delta v_x \geq \frac{h}{4\pi m}$$

    where x is the uncertainty in position and

    px (or vx) is the uncertainty in momentum (or velocity) of the particle. If the position of the electron is known with high degree of accuracy (x is small), then the velocity of the electron will be uncertain [(vx) is large]. On the other hand, if the velocity of the electron is known precisely ((vx) is small), then the position of the electron will be uncertain (x will be large). Thus, if we carry out some physical measurements on the electron's position or velocity, the outcome will always depict a fuzzy or blur picture. in order to determine the position of an electron, we must use a meterstick calibrated in units of smaller than the dimensions of electron . To observe an electron, we can illuminate it with "light" or electromagnetic radiation. The "light" used must have a wavelength smaller than the dimensions of an electron.

    The high would change the energy of electrons by collisions. In this process we, no doubt, would be able to calculate the position of the electron, but we would know very little about the velocity of the electron after the collision.

31. Which are the significance and limitation of Heisenberg's Uncertainty Principle.
32. Give Reasons for the Failure of the Bohr Model.(2 marks)

- In bohr model and electron regarded as a charged particle but the wave character of the electron is not considered.
- In bohr.s model moving in well defined circular orbits it completely be defined only if both the known exactly at the same time. This is not possible according to the Heisenberg uncertainty principle
- Bohr model of the hydrogen atom therefore not only ignores dual behaviour of matter but also contradicts Heisenberg uncertainty principle Therefore there was no point in extending Bohr model to other atoms.

33. What is quntum mechanics?(2 marks)

Quantum mechanics is the branch of physics that deals with the behavior of matter and light on a subatomic and atomic level. It attempts to explain the properties of atoms and molecules and their fundamental particles like protons, neutrons, electrons.

34. Write down Schrödinger Equation of hydrogen atom.(2 marks)

- The solution gives the possible energy levels the electron can occupy and the corresponding wave function.
- Quantized energy states and corresponding wave functions which are characterized by a set of three quantum numbers (principal quantum number n, azimuthal quantum number l and magnetic quantum number ml)nction(s) ( ) of the electron associated with each energy level.
- When an electron is in any energy state, the wave function corresponding to that energy state contains all information about the electron.

35. Write down Principle quntum number. (2 marks)

The Principal Quantum Number represents the principal energy level or shell in which an electron revolves around the nucleus. It is denoted by the letter n and can have any integral value except the 0 i.e. n = 1, 2, 3, 4 … ….etc. The energies of the various principal shells will follow the sequence as :

K < L < M < N < O…..

1 < 2 < 3 < 4 < 5…….

36. Write down about Azimuthal Quantum Number .(3 marks)

Azimuthal quantum number, also known as orbital quantum number determines the subshell to which an electron belongs. As a matter of result, the number of electronic jump increases and the number of lines at the same time.

For a given value of n, it can have any integral value ranging from 0 to n – 1.

For the 1st Shell, say K, n =1, you can have only one value i.e. l = 0

For the 2nd Shell, say L, n = 2, you can have two values i.e. l = 0 and 1

For the 3rd Shell, say M, n = 3, you can have three values i.e. l = 0, 1 and 2

For the 4th shells, say N, n = 4, you can have 4 values i.e. l = 0, 1, 2 and 3

37. Write about Magnetic Quantum Number .(3 marks)

Magnetic Quantum Number denoted by the symbol m is what represents the orientation of atomic orbital in space. The value of the Magnetic Quantum Number, m, depends on the value of l. Magnetic Quantum Number can have a total number of (2l + 1).

Sublevel	l	ml
s	0	0
p	1	-1, 0, +1
d	2	-2, -1, 0, +1, +2
f	3	-3, -2, -1, 0, +1, +2, +3

38. Write about Spin Quantum Number.(2 marks)

Spin Quantum Number represents the direction of the spin of the electrons. This can either be in the direction of clockwise or even anti-clockwise. Spin Quantum Number is denoted by the symbol s. It can have about only two values i.e. +1/2 or -1/2.

39. Write about energy of orbital on hydrogen. (2 marks)

The energy of an electron in a hydrogen atom is calculated solely by the principal quantum, m (n). Therefore, the energy of the orbitals in hydrogen atom increases as follows : 1s < 2s = 2p < 3s = 3p = 3d <4s = 4p = 4d = 4f <..

40. Give the order of energy of orbitals in multi electron atom. (2 marks)

The energy order of orbitals of multi electron atom in ground state is shown by following diagram .In it subsidiary quntum number (l) is change than energy of orbital also change.

1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p...

41. Explain (n + l) rules for energy of orbital by example. (3 marks)

Energy of electron in orbital is based on value of n and l

Rule- 1 The orbital which has low value of (n + l) has less energy

Energy of 2P is more than 2S

2S : n= 2 and l =0 (n+l) = (2 + 0) = 2

2P : n = 2 and l = 1 (n + l) = (2 + 1)= 3

2S < 2P

Rule – 2 If two orbitals have same (n + l) than the orbital which has less value of n has less energy

Energy of 3P orbital which has less value of n has less energy.

Energy of 3P orbital is less than 4P

For 4S :n= 4 l= 0 (n + l) = (4 +0)=4

3P : n = 3 l =0 (n+l) = (3+1) = 4

Energy of 4S > 3P

44.On the basis of which rule arrangement of electron takes place in atom ? (2 marks)

(i) Aufbau Principle

(ii)Paulie exclusion Principle

(iii)Hund's rule

45.Explain Aufbau Principle with example .(5 marks)

Aufbau Principle states that in ground state of an ion, electrons fill atomic orbitals of lowest available energy levels before occupying higher levels.This means that the orbital with lower energy will be filled first followed by the orbital of higher energy.

The order in which the energy of orbitals increases can be determined by the (n+l) rule:

Increasing order of energy of an orbital: The energy of an orbital increase with the sum of the Principal quantum number (n) and azimuthal Quantum Number (l).If the sum value of two orbitals are the same i.e. (n + l), then, among them one with the lowest 'n', the value will have the lower energy

Example:Let us consider different values for n and l.

(i)For 4p, n = 4, l = 1,

(ii)For 4s,n = 4, l = 0,

(iii)For 3d,n = 3, l = 2, and

(iv) For 3p, n = 3, l = 1

The energy of the orbitals will then be:

Principal Quntum Number	Azimuthal Quntum Number	(n + l)
4	1	5
4	0	4
3	2	5
3	1	4

Orbitals (ii) and (iv) has lowest (n + l) of 4. So, they are of lower energy than (i) and (iii).

Among (ii) and (iv), the latter has a minimum 'n'. So, (iv) has the lowest energy followed by (ii).

Among higher energy (i) and (iii) having the same (n + l) value of 5, (iii) has a low ‘n’ value and has lower energy than (i).

Arranging them in order of their energy, we have (iv) < (ii) < (iii) < (i)

Thus, lower energy orbitals are filled first.

46. Explain Pauli exclusion principle by example .(3 marks)

Pauli's Exclusion principle:

Pauli exclusion principle states that no two electrons will have an identical set or the same quantum numbers (n, l, m, and s).

For example, in a helium atom, the atom has 2 bound electrons and they occupy the outermost shell with opposite spins. Here, we will find that the two electrons are in the 1s subshell where n = 1, l = 0, and m= 0. Their spin moments will also be different. One will be s = -1/2 and the other will be +1/2.

There are two salient rules that the Pauli exclusion principle follows:

Only two electrons can occupy the same orbital.

The two electrons that are present in the same orbital must have opposite spins, or they should be antiparallel.

It is called the exclusion principle because, according to this principle, if one electron in an atom has the same particular values for the four quantum numbers, then all the other electrons in that atom are excluded from having the same set of values.

47.Explain Hund ‘s ruole of maximum multiplicity.(5 marks)

It states that electron pairing in orbitals belonging to the same subshell (p, d, or f) does not occur until each orbital of that subshell has one electron, i.e. it is singly occupied. The filling of electrons into orbitals belonging to the same subshell is dealt with by this rule (that is, orbitals of equal energy, called degenerate orbitals). Because an electron has the ability to fill all of its orbitals with similar energy, it will not pair with another electron in a half-filled orbital. Atoms in the ground state have a large number of unpaired electrons. When two electrons come into touch, they behave similarly to two magnets. Before they have to pair up, the electrons want to go as far apart from each other as possible.

As there are three p, five d, and seven f orbitals, electron pairing begins with the entry of the fourth, sixth, and eighth electrons, respectively, in the p, d, and f orbitals. The symmetry of half-filled and fully-filled degenerate orbitals has been demonstrated to provide additional stability.

Explanation of Hund’s Rule

Before pairing up, the electrons enter an empty orbital. Electrons repel each other because they are negatively charged. To decrease repulsion, the electrons do not share orbitals.

The spin of unpaired electrons in singly occupied orbitals is the same when the second rule is applied. The spin of the first electrons in the sub-level determines the spin of the other electrons. The electron

configuration of a carbon atom, for example, is $1S^2 2S^2 2P^2$. According to Hund's rule, the two 2s electrons will occupy the same orbital, but the two 2P electrons will occupy distinct orbitals.