

ATOMIC STRUCTURE

- ◆ Rutherford's model of atom and its draw backs
 - ◆ Bohr's model of atom and its draw backs
 - ◆ Sommerfelds elliptical model
 - ◆ Sub Energy levels - Quantum Numbers
 - ◆ Atomic orbitals
 - ◆ Relative energies of the atomic orbitals
 - ◆ Electronic configuration of elements
 - ◆ Some Physical Quantities of Atoms
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- ◆ 1) Ionization potential
 - 2) Atomic radius
 - 3) Electron affinity
 - ◆ Some principles to write electronic configuration
 - Aufbau principle
 - Hund's rule of
 - Pauli's exclusion principle
 - Maximum multiplicity

UNIT - 1

Important Points:

1. Electrons, protons and neutrons are called sub-atomic particles.
2. J.J. Thomson's atomic model could not explain the atomic spectra.
3. Rutherford proposed "Planetary atomic model" based on α -ray scattering experiments.
4. According to this model, electrons are subjected to two types of forces that is
 - 1) The force of attraction between electrons and the nucleus
 - 2) The centrifugal forceThese two forces are equal and opposite.
5. Max Planck proposed the Quantum theory of radiation.
6. $E = hv$ Planck's constant $h = 6.625 \times 10^{-27}$ erg.sec. (or) 6.625×10^{-34} J.sec.
7. Bohr proposed his atomic model based on Planck's Quantum theory.
8. Bohr model explains stationary orbits, angular momentum and radiation of energy.
9. Bohr model could not explain the atomic spectra of higher elements, Zeeman effect, quantization of angular momentum.
10. Sommerfeld proposed the elliptical orbits and sub-stationary states.
11. Orbits are indicated by "Principal Quantum number" ie '**n**', sub-stationary states are indicated by "Azimuthal Quantum number i.e '**l**', orientation of orbitals is indicated by "magnetic Quantum number" i.e, '**m**' and spinning of electrons of "Spin Quantum number" '**s**'.
12. l value = $(n - 1)$, the number of '**m**' values is equal to $(2l + 1)$ and ranges from $-l \dots 0 \dots +l$. s is $+1/2$ or $-1/2$.
13. "The region in space where there is finite probability of finding electron" is called "atomic orbital".
14. s, p, d and f orbitals are present in the orbits. 1, 2, 3 and 4 onwards (or) K, L, M and

- N onwards successively.
15. Orbitals having same energy are called degenerate orbitals.
 16. "Electron occupies the orbital whose $(n + l)$ value is minimum. If $(n + l)$ value is same, it occupies the orbital having less 'n' value" _____ **Aufbau Principle.**
 17. "No two electrons will have all the four Quantum numbers same" _____ **Pauli exclusion principle.**
 18. "Pairing of electrons takes place when all the degenerate orbitals are occupied by one electron each" _____ **Hund's rule.**
 19. Atomic radius is the distance between the nucleus and outermost orbital.
Units: \AA ; $1\text{\AA} = 10^{-8} \text{ cm}$ or 10^{-10}m .
 20. Ionization potential is "the minimum energy required to remove an electron from outermost orbital in the gaseous state".
Units: eV (or) K.J. mol^{-1} (or) K.Cal.mol^{-1} .
 21. Electron affinity is "the energy released when an electron is added to a neutral gaseous atom in the ground state".
Units: eV (or) K.J. mol^{-1} (or) K.Cal.mol^{-1} .

PART - A SECTION - I

Short Answer Questions (2 Marks Each)

1. Explain why electrons enter into '4s' orbital but not '3d' after filling '3p' orbital?
2. Write the electronic configuration of (a) Nitrogen (b) Chromium (c) Copper?
3. Distinguish between orbit and orbital?
4. Write a short notes on Quantum theory of radiation?
5. Distinguish between Principal Quantum number and sub-level Quantum number.

SECTION - II

Very Short Answer Questions (1 Mark Each)

1. What is Planck's Quantum equation? and what is the value of Planck's constant?
2. What is a stationary orbit?
3. What are degenerate orbitals?
4. Who proposed the principal Quantum number?
5. What are the limits of azimuthal Quantum number for a given 'n'?
6. What are upper and lower limits of m for $l = 4$?
7. How many 'm' values are possible for $l = 3$?
8. What is the shape of '1s' orbital?
9. What is nodal plane?
10. Write the designations of any two d-orbitals?
11. How are the three p-orbitals designated?
12. What is the unit of electron affinity?

SECTION - III
Long Answer Questions (4 Marks Each)

1. State The Postulates of Bohr's model. What are the defects of Bohr's model?
2. Explain the important features of Rutherford's model of atom. Discuss its draw-backs?
3. State and explain with one example The Hund's rule of maximum multiplicity?
4. Define the ionization energy and mention the factors that influence it.
5. Explain the four Quantum numbers briefly.
6. State and explain Pauli's exclusion principle with example.
7. Discuss the features of modern atomic structure.

SECTION - IV
DIAGRAMS (5 Marks Each)

1. Draw the shapes of s and p orbitals?
2. Draw the shapes of five 'd' orbitals?
3. Draw the diagram showing the sequence of filling of various atomic orbitals?

PART - A
(Answers)
SECTION - I
Short Answers

- 1.A** The $(n + l)$ value of 4s energy level is $4 + 0 = 4$
The $(n + l)$ value of 3d energy level is $3 + 2 = 5$
According to Aufbau principle, the electron enter into the orbital having least $(n + l)$ value. The $(n + l)$ value of 4s is less than 3d. Hence the electrons enter into 4s orbital but not 3d after filling 3p orbital.
- 2.A** (a) electronic configuration of Nitrogen is
 $N = Z = 7 = 1s^2 2s^2 2p^3$
- (b) electronic configuration of Chromium is
 $Cr = Z = 24 = [Ar] 4s^1 3d^5$
- (c) electronic configuration of Copper is
 $Cu = Z = 29 = [Ar] 4s^1 3d^{10}$

3.A

Sl.No.	ORBIT	ORBITAL
1.	The path of electron around the nucleus is called "orbit".	The region in space where there is finite probability of finding electron is called "orbital".
2.	It is two dimensional.	It is three dimensional.
3.	its shape is circular.	It has spherical or dumb-bell or double dumb-bell shapes.
4.	The maximum number of electrons is $2n^2$.	The maximum number of electrons is 2.

- 4.A**
- (1) Max Planck proposed "Quantum theory of radiation", to explain the absorption (or) emission of electromagnetic radiation.
 - (2) The energy is emitted (or) absorbed in the form of small packets called 'Quanta'.
 - (3) Energy of radiation is directly proportional to its frequency. $E \propto \nu$.
 - (4) The Planck's equation is $E = h\nu$
 Where, E = energy of radiation
 h = Planck's constant
 ν = frequency of radiation

5.A

Sl.No.	Principal Quantum Number	Sub-level Quantum Number
1.	Proposed by Neils Bohr.	Proposed by Sommerfeld.
2.	Denoted by 'n'.	Denoted by 'l'.
3.	It indicates size and energy of a stationary orbit.	It indicates the shape of the sub-shell.
4.	Its values are 1, 2, 3, 4..... (or) K, L, M, N.....	Its values are 0, 1, 2, 3..... and designated by s, p, d, f.....
5.	It gives the number of the orbit (or) shell.	It depends on 'n' value $l = 0$ to $(n - 1)$.

SECTION - II

Very Short Answers

- 1.A** Planck's Quantum equation is $E = h\nu$
Where E is Energy of radiation.
 ν is the frequency of radiation.
 h is the Planck's constant.
The value of Planck's constant is $h = 6.625 \times 10^{-27}$ erg.sec.
(or) $h = 6.625 \times 10^{-34}$ J.sec.
- 2.A** **Stationary orbit:** Electrons are moving with high velocity around the nucleus in specified paths called "orbits" (or) "shells". The energy of the electron in a particular orbit is constant. Hence these orbits are called "stationary orbits".
- 3.A** **Degenerate orbitals:** Orbitals having the same energy are called "degenerate orbitals".
- 4.A** Neils Bohr proposed the principal Quantum number.
- 5.A** The limits of Azimuthal Quantum number for given n are 0 and $(n - 1)$.
- 6.A.** For $l = 4$, the upper limit is +4 and,
the lower limit is -4.
- 7.A** The magnetic Quantum number m has $(2l + 1)$ values.
If $l = 3$; m has $(2 \times 3 + 1) = 7$ values.
seven values are possible for $l = 3$
They are -3, -2, -1, 0, +1, +2, +3
- 8.A** Shape of '1s' orbital is symmetrically spherical.
- 9.A** **Nodal Plane:** The region or space around the nucleus where the probability of finding the electron is zero is called "nodal plane" or "nodal region".
- 10.A** d-orbital has five degenerate orbitals. They are designated as $d_{xy}, d_{yz}, d_{zx}, d_{x^2 - y^2}, d_{z^2}$
- 11.A** The three p-orbitals are designated as p_x, p_y, p_z .
- 12.A** The units of electron affinity are electron volts.

SECTION - III

Long Answers

1.A Postulates of Bohr's Atomic Model are:

Bohr proposed the model of the atom based on Planck's Quantum theory.

1. Electrons are moving around the nucleus in specified paths called "orbits". As the energy of the electron remains constant in a particular orbit, these are called as "stationary orbits".
2. The stationary orbits are designated by K, L, M, N.....
The orbit close to the nucleus has less energy.
3. When an electron jumps from a higher energy orbit to a lower energy orbit. The difference in the energy is emitted as radiation".

$$E_2 - E_1 = h\nu$$

E_2 and E_1 are energies of higher and lower orbits.

ν is the frequency orbits of radiation.

h is the Planck's constant.

4. The angular momentum of the electron revolving in a stationary orbit is equal to integral multiples of $h/2\pi$ ie.

$$\text{Angular momentum, } mvr = n \frac{h}{2\pi}$$

Where, m = mass of an electron.
 v = velocity of an electron.
 r = radius of stationary orbit.
 n = an integer $n = 1, 2, 3$.
 h = Planck's constant.

Defects of Bohr's Model:

Bohr's atomic model could not explain.

- (1) The atomic spectra of higher elements like He, Li, Be, B, C which have more than an electron.
- (2) The spectral lines in presence of magnetic and electric field.
- (3) The Quantization of angular momentum.
- (4) The formation of chemical bonds.

2.A Rutherford's Planetary Atomic Model:

1. Rutherford proposed an atomic model in 1911, based on α -ray scattering experiments. This is called "Planetary model" (or) "Nuclear model".
2. Atoms are spherical in shape and mostly hollow.
3. The mass of the atom is due to its nucleus. The nucleus is made up of protons and neutrons.
4. Electrons revolve round the nucleus, just like planets revolve around the sun.
5. Two types of forces are present in the atom.
(a) The force of attraction between electrons and nucleus. It pulls the electrons towards the nucleus.
(b) The revolving electrons experience a centrifugal force directed away from the moving path of electrons.

It pulls the electrons away from the nucleus.

6. These two forces are equal and opposite. So atom is stable.

Defects of Rutherford's Model:

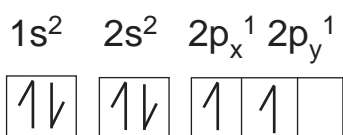
1. According to classical laws of physics, a moving particle should lose energy and come closer to the nucleus.
2. If it loses energy, it eventually should fall into the nucleus and the atom should collapse. But atoms are stable.
3. If the electron loses energy continuously, the atomic spectra should consist of continuous bands. But atomic spectra are made up of discrete spectral lines.

3.A. Hund's Rule:

1. It states that "electron pairing takes place only after all the available degenerate orbitals are occupied by one electron each".

Eg: Consider carbon atom = $Z = 6 = (1s^2 2s^2 2p^2)$. It has six electrons. The first electron enters into '1s' orbital of K-shell. The second electron will be paired up with the first in the same '1s' orbital. The third and fourth electrons occupy the '2s' orbital of L-shell.

The fifth electron goes into one of the three 2p orbitals of the L-shell. Let it be $2p_x$. Since the three p orbitals (p_x, p_y, p_z) are degenerate, sixth electron goes into $2p_y$ (or) $2p_z$ but not $2p_x$. Thus the electronic configuration of carbon is



4.A Ionization Energy:

"The minimum energy required to remove an electron from the outermost orbital of an atom in gaseous state".

It depends on

- i) nuclear charge
- ii) size of the atom
- iii) charge on the ion
- iv) electronic configuration

i) Nuclear Charge: As the nuclear charge increases the ionization energy increases. This is due to increase in the attraction of the nucleus over the valence electrons.

ii) Size of the atom: As the size of the atom increases the ionization energy decreases. This is due to decrease in the attraction power of nucleus over the valence electrons.

iii) Charge on the ion: As the charge decreases as the energy required to remove an electron from a cation is more than the energy required to remove from a neutral atom.

iv) **Electronic Configuration:** Atoms with stable electronic configuration possess high ionization potential values.

5.A 1. Principal Quantum Numbers:

1. It was proposed by Neil's Bohr
2. It is denoted by the letter 'n'
3. It indicates the size and energy of a stationary orbit
4. Its values are 1, 2, 3, 4..... and these are designated as K, L, M, N.....

2. Azimuthal Quantum Number:

1. It was proposed by Sommerfeld.
2. It is denoted by the letter 'l'.
3. It indicates the shape of the sub-shell.
4. Its values are 0, 1, 2, 3, 4..... and these are designated as s, p, d, f, g etc.,

3. Magnetic Quantum Number:

1. It was proposed by Lande.
2. It is denoted by the letter 'm'.
3. It indicates the orientation of the orbitals in the presence of magnetic field.
4. Its values depends on the value of 'l'.
5. For a given 'l', m can have $(2l + 1)$ values.

4. Spin Quantum Number:

1. It was proposed by Uhlenbeck and Goldsmith.
2. It is denoted by the letter 's'.
3. It indicates the direction of spin of electrons.
4. Its values are $+\frac{1}{2}$ and $-\frac{1}{2}$

6.A Pauli's Exclusion Principle:

1. "No two electrons will have all the four Quantum numbers the same".
2. **Eg:** Atomic number of Helium (He) is = $Z = 2$. So the electronic configuration $1s^2$.
3. The Quantum numbers of the two electrons in Helium are:

	n	l	m	s
1 st electron	1	0	0	+1/2
2 nd electron	1	0	0	-1/2

4. For the two electrons though the first three Quantum numbers are the same, but the fourth Quantum number differs.

7.A The modern concepts of atomic structure are as follows:

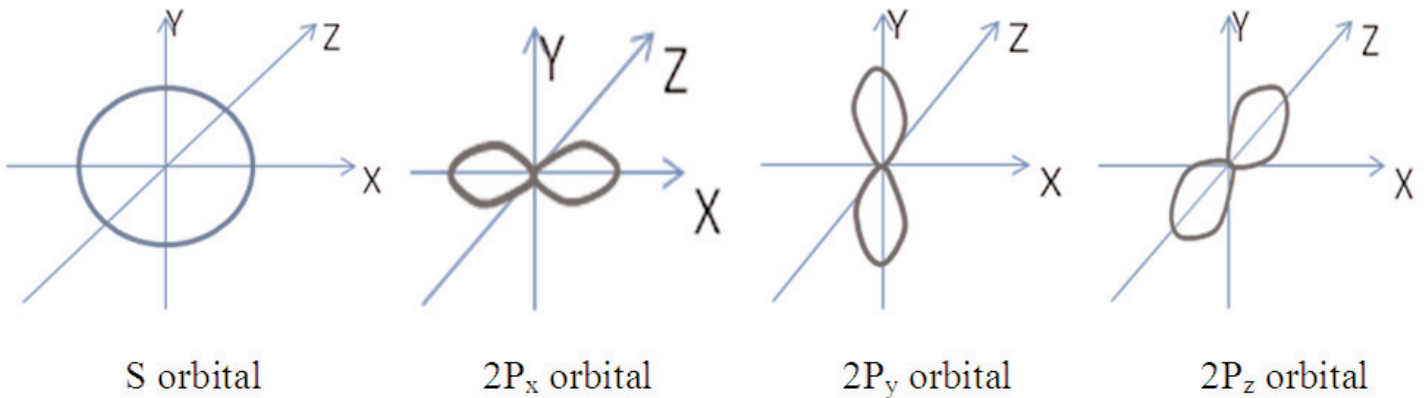
1. Atom consists of several stationary states or stationary orbits. These states are designated by 'n' values.
2. Each stationary state is divided into sub-states. These sub-states are called sub-

energy levels and are designated by 'l' values.

3. The first stationary state $n = 1$ has only one sub-state, the second has two and third has three etc. These sub-states are designated as s, p, d, f, g etc. Corresponding to $l = 0, 1, 2, 3, 4$ etc.,
4. Under the influence of magnetic field, these sub-states are further split into groups of states.
5. The electrons are placed in the sub-levels. They revolve around the nucleus and in addition rotate on their own axes clock-wise or anti-clock wise.

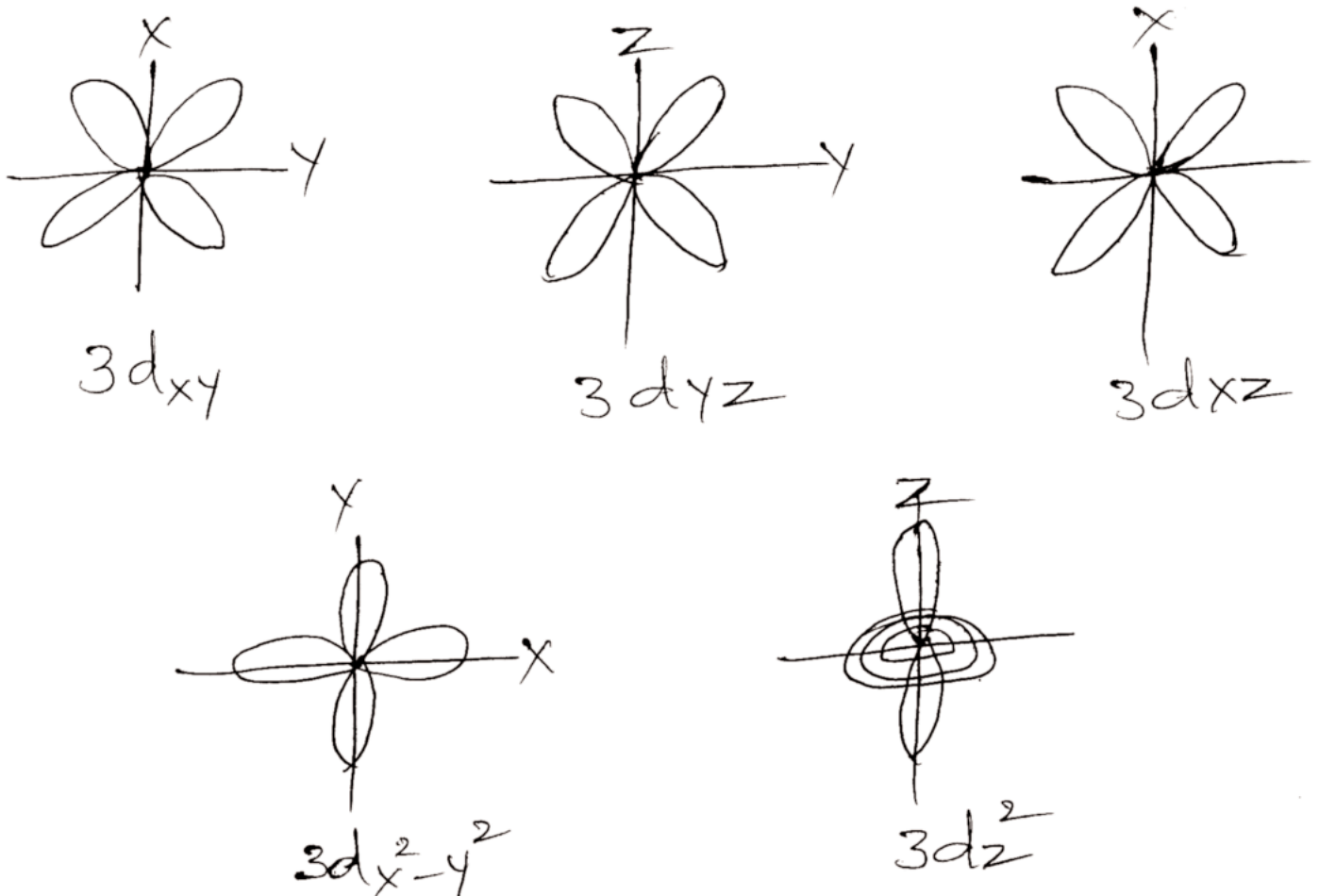
SECTION - IV DIAGRAMS

1.A

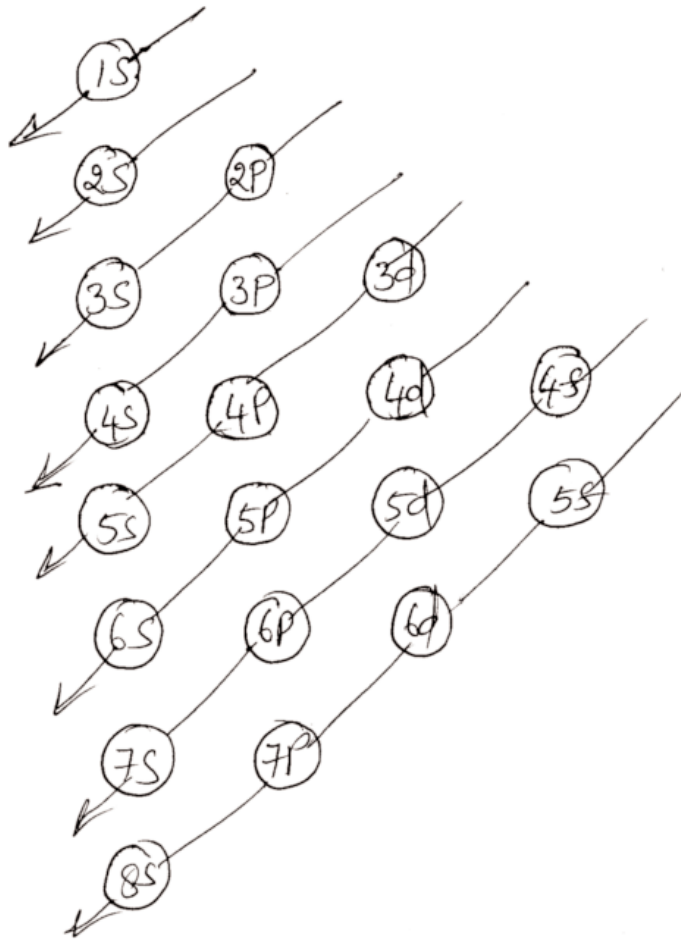


2.A

Shapes of five d-orbitals



3.A Moeller's diagram



Increasing order of energy orbitals

$1s < 2s < 2p < 3s < 3p < 4s$

$< 3d < 4p < 5s < 4d$

$< 5p < 6s < 4f < 5d < 6p$

$< 7s < 5f < 6d < 7p < 8s$

UNIT - 1
PART - B
(1/2 Mark Each)

I. Pick up the Correct Answer:

1. Electron was discovered by
A) Rutherford
B) Sommerfeld
C) J.J. Thomson
D) Planck
2. The sub-shells present in N-shell are
A) s and d
B) s and p
C) s, p, d
D) s, p, d, f

3. The number of d-orbitals present in $n = 3$ is
 - A) 1
 - B) 3
 - C) 5
 - D) 7

4. The shape of p-orbitals is
 - A) spherical
 - B) dumb-bell
 - C) double dumb-bell
 - D) Cylindrical

5. Magnetic Quantum number is related to
 - A) size
 - B) shape
 - C) orientation
 - D) spin

6. Number of electrons that can be accommodated in f sub-shell is
 - A) 2
 - B) 8
 - C) 32
 - D) 14

7. An electron spinning in clock-wise direction is represented as
 - A) \rightarrow
 - B) \leftarrow
 - C) \downarrow
 - D) \uparrow

8. The scientist who invented elliptical orbits is
 - A) Bohr
 - B) Rutherford
 - C) Sommerfeld
 - D) Zeeman

9. Among 3p, 4s, 3d and 4p. The orbital having least energy is
 - A) 4s
 - B) 3p
 - C) 3d
 - D) 4p

10.

11. The phenomenon of black body radiation was successfully explained by
 - A) Rutherford
 - B) Thomson
 - C) Max Planck
 - D) Schrodinger

12. The electronic configuration of copper is
 - A) [Ar] 4s¹ 3d¹⁰
 - B) [Ar] 4s² 3d¹⁰
 - C) [Ar] 4s¹ 3d⁵
 - D) [Ar] 4s² 3d⁸

13. Orbital without any directional character is
 - A) s
 - B) p
 - C) d
 - D) f

14. Splitting of spectral lines in presence of magnetic field is called
 - A) Stark Effect
 - B) Zeeman Effect
 - C) Bohr's Model
 - D) Nucleons

15. Orbitals will have
 - A) Crests
 - B) Troughs
 - C) Anti-nodal regions
 - D) Nodal regions

II. Fill in the Blanks:
(1/2 Mark Each)

16. Quantum theory of radiation is proposed by _____
17. Rutherford proposed planetary model based on his _____ experiment.
18. $E_2 - E_1 = h\nu$ where ν is _____
19. The electronic configuration of zinc is _____
20. In stationary orbits, the energy of the electron is _____
21. 3d¹⁰ 4s¹ is the electronic configuration of _____
22. The 's' orbital of L-shell is called _____
23. After filling the 3d orbital, the electron enters into _____ orbital.
24. The sub-states are also called _____
25. _____ proposed spin Quantum number.
26. The element with high electron affinity is _____
27. The _____ orbitals correspond to $l = 2$.
28. 1s² 2s² 2p⁶ 3s¹ is the electronic configuration of the element _____

29. Two electrons in an orbital will have _____ spins.
30. The value of Planck's constant is _____ erg.sec.
31. The electrons revolve round the nucleus and _____ on their own areas.
32. As the n value increases, the size and energy of the orbit also _____
33. Quantum means _____ of energy.
34. $(n + l)$ value of 4s is _____ that of 3p.
35. The electronic configuration of Argon is _____

**III. Match the Following:
(1/2 Mark Each)**

I. Group - A		Group - B (no. of electrons)
36. K-shell	[]	A) 8
37. L-shell	[]	B) 18
38. M-shell	[]	C) 32
39. N-shell	[]	D) 2
40. P-orbitals	[]	E) 6

II. Group - A		Group - B
41. Nitrogen	[]	A) [Ne] 3s ¹
42. Sodium	[]	B) [He] 2s ² 2p ³
43. Copper	[]	C) [Ar] 4s ² 3d ¹⁰
44. Zinc	[]	D) [Ar] 4s ¹ 3d ⁵
45. Chromium	[]	E) [Ar] 4s ¹ 3d ¹⁰

III. Group - A		Group - B
46. Stationary orbits	[]	A) Schrodinger
47. Elliptical orbits	[]	B) Louis De Broglie
48. Dual nature of electron	[]	C) Max Planck
49. Wave equation	[]	D) Neils Bohr
50. Quantum theory	[]	E) Sommerfeld

**PART - B
(ANSWERS)**

1. C
2. D
3. C
4. B
5. C
6. D
7. D
8. C
9. B
10. A

11. C
12. A
13. A
14. B
15. D

II.

16. Max Planck
17. α -ray scattering
18. frequency of radiation
19. [Ar] 4s²3d¹⁰
20. constant
21. copper
22. 2s
23. 4p
24. sub-shells
25. Uhlenbeck and Goldsmith
26. chlorine
27. d-orbitals
28. sodium
29. opposite
30. 6.625×10^{-27} erg.sec
31. spin
32. increases
33. a packet
34. equal
35. [Ne]3s²3p⁶

III.I.

36. D
37. A
38. B
39. C
40. E

II.

41. B
42. A
43. E
44. C
45. D

III.

46. D
47. E
48. B
49. A
50. C