UNIT – II – QUANTUM MECHANICAL MODEL OF ATOM

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

UNIT – 2 – QUANTUM MECHANICAL MODEL OF ATOM

II. WRITE BRIEF ANSWER TO THE FOLLOWING QUESTIONS.

26. Which quantum number reveal information about the shape, energy, orientation and size of orbitals?

Magnetic quantum number reveal information about the shape, energy orientation and size orbitals.

27. How many orbitals are possible for n = 4? [MAY-22]

If n = 4, the possible number of orbitals are calculated as follows.

n	*l*	*m*
If n = 4	0	4s orbital = 1 orbital
	1	-1, 0, 1 = 3 orbitals
	2	-2, -1, 0, 1, 2 = 5 orbitals
	3	-3, -2, -1, 0, 1, 2, 3 = 7 orbitals

∴ Total number of orbitals = 16 orbitals.

***28.* How many radial nodes for 2s, 4p, 5d and 4f orbitals exhibit? How many angular nodes? [QY-22]**

Orbital	*n*	*l*	*Radial node (n-l-1)*	*Angular node l*
2s	2	0	1	0
4p	4	1	2	1
5d	5	2	2	2
4f	3	3	0	3

***29.* The stabilisation of a half filled d-orbital is more pronounced than that of the p-orbital why?**

Symmetry: The half-filled orbitals are more symmetrical than partially filled orbital and this symmetry leads to greater stability.

Exchange energy: The electrons with same spin in the different orbitals of the same subshell can exchange their position.

Each such exchange releases energy and this is known as exchange energy. Greater the number of exchanges, greater the exchange energy and greater the stability.

In d-orbital 10 exchanges are possible but in p-orbital 6 exchanges are possible.

***30.* Consider the following electronic arrangements for the d^5 configuration.**

(a)

↑↓	↑↓	↑		

(b)

↑	↑	↑	↑↓	

(c)

↑	↑	↑	↑	↑

(i) Which of these represents the ground state

(ii) Which configuration has the maximum exchange energy.

↑	↑	↑	↑↓	

(i) Ground state

↑	↑	↑	↑	↑

(ii) Maximum exchange energy

***31. State and explain pauli's exclusion principle.* [FMT,HY-18, MAR-19]**

- Pauli's exclusion principle states that "No two electrons in an atom can have the same set of values of all four quantum numbers." $H_{(Z=1)}$ $1s^1$
- For the lone electron present in hydrogen atom, the four quantum numbers are: *n* = 1; *l* = 0; *m* = 0 and *s* = +½.

- For the two electrons present in helium, one electron has the quantum numbers same as the electron of hydrogen atom, *n* = 1, *l* = 0, *m* = 0 and *s* = +½. For other electron, the fourth quantum number is different i.e., *n* = 1, *l* = 0, m = 0 and *s* = –½

32. Define orbital? What are the n and l values for $3p^x$ and $4d_{x^2-y^2}$ electron? [FMT,QY-18, JUN-19, MAR-24]

- Orbital is a three dimensional space where the probability of finding the electron is maximum.
- For $3p^x$ electron *n* value = 3, *l* value = 1
- For $4d_{x^2-y^2}$ electron *n* value = 4, *l* value = 2

33. Explain briefly the time independent schrodinger wave equation? [QY-19]

Erwin Schrödinger expressed the wave nature of electron in terms of a differential equation. This equation determines the change of wave function in space depending on the field of force in which the electron moves. The time independent Schrödinger equation can be expressed as,

$$\hat{H}\Psi = E\Psi$$

Where $\hat{H}$ is called Hamiltonian operator, Ψ is the wave function and is a function of position co-ordinates of the particle and is denoted as Ψ(x, y, z) E is the energy of the system

$$\hat{H} = \left[\frac{-h^2}{8\pi^2 m}\left(\frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2} + \frac{\partial^2}{\partial z^2}\right) + V\right]$$

can be written as

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

Multiply by $-\frac{8\pi^2 m}{h^2}$ and rearranging

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

The above schrÖdinger wave equation does not contain time as a variable and is referred to as time independent Schrödinger wave equation.

34. Calculate the uncertainty in position of an electron, if Δv = 0.1% and v = 2.2 x 10^6 ms^{-1}.

$\Delta x.\Delta p \geq h/4\pi$

$\Delta x.\Delta p \geq 5.28 \times 10^{-35}\ Kgm^2s^{-1}$

Let, $\Delta x.(m\Delta v) \geq 5.28 \times 10^{-35}\ Kgm^2s^{-1}$

$\Delta x \geq \frac{(5.28 \times 10^{-35}\ Kgm^2s^{-1})}{(m\Delta v)}$

Given, Δv = 0.1%; v = 2.2 x 10^6 ms^{-1}; m = 9.1 x 10^{-31} Kg

$\Delta v = \frac{0.1}{100} \times 2.2 \times 10^6\ ms^{-1} = 2.2 \times 10^3\ ms^{-1}$

$\Delta x \geq \frac{(5.28 \times 10^{-35}\ Kgm^2s^{-1})}{9.1 \times 10^{-31}\ Kg \times 2.2 \times 10^3\ ms^{-1}}$

$\Delta x \geq$ **2.64×10^{-8} m**

35. Determine the values of all the four quantum numbers of the 8^{th} electron in O atom and 15^{th} electron in Cl atom.

Electronic configuration of Oxygen, $1s^2\ 2s^2\ 2p^4$

1s²	2s²	2p⁴		
↑↓	↑↓	↑↓	↑	↑

∴ 8^{th} electron present in $2p_x$ orbital and the quantum numbers are,

n = 2, *l* = 1, m_1 = either +1 or -1 and *s* = –½

UNIT – II – QUANTUM MECHANICAL MODEL OF ATOM

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

Electronic configuration of Chlorine, $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

↑↓	↑↓	↑↓ ↑↓ ↑↓	↑↓	↑↓ ↑↓ ↑
$1s^2$	$2s^2$	$2p^6$	$3s^2$	$4p^5$

∴ 15^{th} electron present in $3p_z$ orbital and the quantum numbers are,
$n = 3$, $l = 1$, m_1 = either +1 or -1 and $s = +½$

36. The quantum mechanical treatment of hydrogen atom gives the energy value: $E_a = \frac{-13.6}{n^2}$ ev atom^{-1}; (i) use this expression to find ΔE between n = 3 and n = 4; (ii) Calculate the wavelength corresponding to the above transition.

i) When $n = 3$ $\quad E_3 = \frac{-13.6}{3^2} = \frac{-13.6}{9} = -1.511$ eV atom^{-1}

When $n = 4$ $\quad E_4 = \frac{-13.6}{4^2} = \frac{-13.6}{16} = -0.85$ eV atom^{-1}

$\Delta E = E_4 - E_3 = -0.85 - (-1.511) =$ **+ 0.661 eV atom^{-1}**

$\Delta E = E_3 - E_4 = -1.511 - (-0.85) =$ **– 0.661 eV atom^{-1}**

ii) Wave length = λ; $\quad \Delta E = \frac{hc}{\lambda}$ $\quad ∴ \lambda = \frac{hc}{\Delta E}$

h = Planck's constant = 6.626×10^{-34} Js^{-1}; c = 3×10^8 m/s;

$\lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{0.661 \times 1.6 \times 10^{-19} J} = 1.875 \times 10^{-6}$ m

λ = 1.875×10^{-6} m

37. How fast must a 54g tennis ball travel in order to have a de Broglie wavelength that is equal to that of a photon of green light 5400 Å? [FMT-18]

de Broglie wavelength of the tennis ball equal to 5400 Å. m = 54 g; v = ?

$\lambda = \frac{h}{mV}$ $\quad$ Let, $V = \frac{h}{m\lambda}$

$V = \frac{6.626 \times 10^{-34}\ JS}{54 \times 10^{-3}\ Kg \times 5400 \times 10^{-10}\ m}$ = **2.27×10^{-26} ms^{-1}**

38. For each of the following, give the sub level designation, the allowable m values and the number of orbitals. (i) n = 4, l = 2, (ii) n = 5, l = 3, (iii) n = 7, l = 0

(i) $n = 4$, $l = 2$
If $l = 2$, 'm' values are -2, -1, 0, 1, 2
So, 5 orbitals such as d_{xy}, d_{yz}, $d_{x^2-y^2}$ and d_{z^2}
(ii) $n = 5$, $l = 3$
If $l = 3$, 'm' values are -3, -2, -1, 0, 1, 2, 3
So, 7 orbitals such as f_{x^3}, f_{xz^2}, f_{yz^2}, f_{xyz}, $f_z(x^2-y^2)$, $f_x(x^2-3y^2)$ and $f_y(3x^2-y^2)$
(iii) $n = 7$, $l = 0$
If $l = 0$, 'm' values are 0. Only one value. So, 1 orbitals such as 7s orbital.

39. Give the electronic configuration of Mn^{2+} and Cr^{3+}. [QY-18, QY-19, AUG-22]

Mn (Z=25-2 = **23**) $\quad Mn \rightarrow Mn^{2+} + 2e^-$
Mn^{2+} Electronic configuration is $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^0, 3d^5$
Cr (Z=24-3 = **21**) $\quad Cr \rightarrow Cr^{3+} + 3e^-$
So, Cr^{3+} Electronic configuration is $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^0, 3d^3$

40. Describe the Aufbau principle. [GMQ-18]

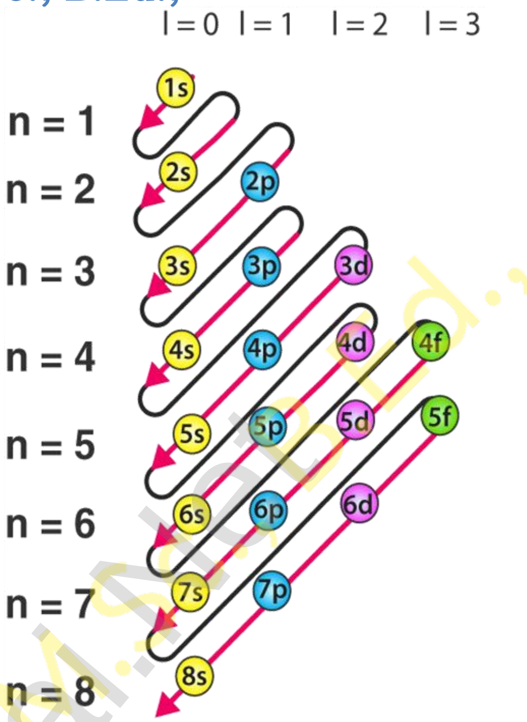
The word Aufbau in German means 'building up'. In the ground state of the atoms, the orbitals are filled in the order of their increasing energies. That is the electrons first occupy the lowest energy orbital available to them.

UNIT – II – QUANTUM MECHANICAL MODEL OF ATOM

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

Once the lower energy orbitals are completely filled, then the electrons enter the next higher energy orbitals. The order of filling of various orbitals as per the Aufbau principle which is in accordance with (*n*+*l*) rule.

The lower the value of (*n*+*l*) for an orbital, the lower is its energy. If two orbitals have the same value of (*n*+*l*), the orbital with lower value of n will have the lower energy.



41. An atom of an element contains 35 electrons and 45 neutrons. Deduce, (i) the number of protons, (ii) the electronic configuration for the element, (iii) All the four quantum numbers for the last electron. [FMT-18]

No. of electrons: 35 (given)

(i) No. of protons : 35

(ii) Electronic configuration

$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^5$

(iii) All the four quantum numbers for the last electron

↑↓	↑↓	↑
$4p_x$	$4p_y$	$4p_z$

last electron present in 4py orbital. $n = 4$, $l = 1$, m_l = either + 1 or -1 and $s = -½$

42. Show that the circumference of the Bohr orbit for the hydrogen atom is an integral multiple of the de Broglie wave length associated with the electron revolving around the nucleus. [GMQ-18]

In order for the electron wave to exist in phase, the circumference of the orbit should be an integral multiple of the wavelength of the electron wave. Otherwise, the electron wave is out of phase.

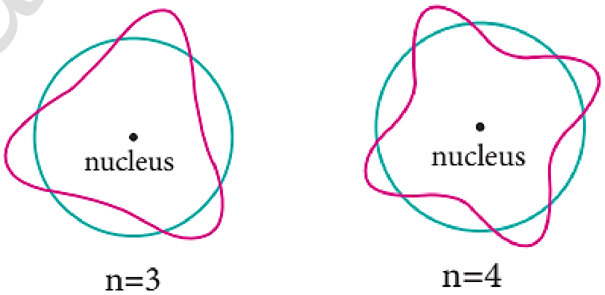
$mvr = \frac{nh}{2\pi}$

where mvr = angular momentum

where 2π = circumference of the orbit

circumference of the orbit = $n\lambda$

$2\pi = n\lambda$ Let, $n = 3$, $n = 4$



43. Calculate the energy required for the process. $He^+_{(g)} \rightarrow He^{2+}_{(g)} + e^-$. The ionisation energy for the H atom in its ground state is -13.6 eV atom^{-1}.

The ionisation energy for the H atom in its ground state = -13.6 eV atom^{-1}

Ionisation energy = $\frac{-13.6}{n^2}Z^2$ eV Z = atomic number; n = Principle quantum number

For He, n = 1, Z = 2 $E_1 = \frac{-13.6\,(2)^2}{(1)^2} = -54.4$ $E_\infty = \frac{-13.6\,(2)^2}{(\infty)^2} = 0$

∴ Required Energy for the given process = $E_\infty - E_1 = 0 - (-54.4) =$ **54.4 eV**

44. An ion with mass number 37 possesses unit negative charge. If the ion contains 11.1% more neutrons than electrons. Find the symbol of the ion.

	Atom	Uni-negative ion
Number of electrons	x – 1	x
Number of protons	x – 1	x – 1
Number of neutrons	y	y

UNIT – II – QUANTUM MECHANICAL MODEL OF ATOM

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

Given that, y = x + 11.1% of x = $\left(x + \frac{11.1}{100}\,x\right)$ = x + 0.111x = **1.111x**

Mass number = number of protons + number of neutrons = 37 = (x – 1) + 1.111x = 37

x + 1.111x = 38 2.111x = 38 x = $\frac{38}{2.111}$ = 18.009 **x = 18** (whole number)

∴ Atomic number = x – 1 = 18 – 1 = 17

Mass number = 37 **Symbol of the ion** $^{37}_{17}Cl^{-}$

45. The Li^{2+} ion is a hydrogen like ion that can be described by the Bohr model. Calculate the Bohr radius of the third orbit and calculate the energy of an electron in 4th orbit.

$r_n = \frac{(0.529)n^2}{Z}$ Å $E_n = \frac{-13.6(Z^2)}{n^2}$ eV $atom^{-1}$

for Li^{2+} z = 3, Bohr radius for the third orbit, $(r_3) = \frac{(0.529)(3)^2}{3}$ = 0.529 x 3 = **1.587 Å**

Energy of an electron in the 4th orbit, $(E_4) = \frac{-13.6(3)^2}{(4)^2}$ = **-7.65 eV $atom^{-1}$**

46. Protons can be accelerated in particle accelerators. Calculate the wavelength (in Å) of such accelerated proton moving at 2.85×10^8 ms^{-1} (the mass of proton is 1.673×10^{-27} Kg)

v = 2.85×10^8 ms^{-1}; $m_p = 1.673 \times 10^{-27}$ Kg

$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-27}\ kgm^2s^{-1}}{1.673 \times 10^{-27}\ kg \times 2.85 \times 10^8\ ms^{-1}}$ = 1.389×10^{-15} = **1.389×10^{-5} Å** [∵Å = 10^{-10}]

47. What is the de Broglie wavelength (in cm) of a 160g cricket ball travelling at 140Km hr^{-1}

m = mass of the cricket ball = 160g = 0.16kg; *h* = Plank's constant = 6.626×10^{-34} Kgm^2s^{-1};

v = velocity of the cricket ball = 140km hr^{-1} = $\frac{140 \times 10^3}{60 \times 60}$ ms^{-1} = 38.88 ms^{-1}

de Broglie equation, $\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34} \times Kg\ m^2\ s^{-1}}{0.16\ Kg \times 38.88\ ms^{-1}} = \frac{6.626 \times 10^{-34}}{6.2208}$ = 1.065×10^{-34} m

Wavelength in cm = $1.065 \times 10^{-34} \times 100$ = **1.065×10^{-32} cm** (or) **1.065×10^{-34} m**

48. Suppose that the uncertainty in determining the position of an electron in an orbit is 0.6Å. What is the uncertainty in its momentum?

Δx = uncertainty in position of an electron = 0.6 Å = 0.6×10^{-10} m

Δp = uncertainty in momentum = ?

Heisenberg's uncertainty principle states that $\Delta x.\Delta p \geq \frac{h}{4\pi}$ $\Delta p \geq \frac{h}{4\pi.\Delta x}$

h ≥ Planck's constant ≥ 6.626×10^{-34} Kg m^2 s^{-1}

$\Delta p \geq \frac{6.626 \times 10^{-34} \times Kg\ m^2\ s^{-1}}{4 \times 3.14 \times 0.6 \times 10^{-10}\ m} = \frac{6.626 \times 10^{-34} \times 10^{10}}{7.536}$ = 0.8792×10^{-24} Kg ms^{-1}

Δp ≥ 8.792×10^{-25} Kg ms^{-1} (or) 8.8×10^{-25} Kg ms^{-1}

49. Show that if the measurement of the uncertainty in the location of the particle is equal to its de Broglie wavelength, the minimum uncertainty in its velocity (ΔV) is equal to 1/4π of its velocity (V). [FMT-18]

The uncertainty in the location of the particle, **Δx** = de Broglie wavelength, **λ**

Heisenberg's uncertainty principle states that $\Delta x.\Delta p \geq \frac{h}{4\pi}$ [∵Δp = mΔv]

$\lambda.m\Delta v \geq \frac{h}{4\pi}$ rearrange to get $\Delta v \geq \frac{h}{4\pi.m.\lambda}$ [∵$\lambda = \frac{h}{mv}$]

$\Delta v \geq \frac{h}{4\pi.m.\frac{h}{mv}} = \frac{v}{4\pi}$ ∴ minimum uncertainty in velocity = $\frac{v}{4\pi}$

50. What is the de Broglie wave length of an electron, which is accelerated from the rest, through a potential difference of 100 V? [GMQ-18]

Potential difference = V = 100 V; Potential energy = eV = 1.609 x 10^{-19}c x 100V

$\frac{v}{4\pi}$ m v^2 = 1.609 x 10^{-19} x 100 = 1.609 x 10^{-19} J

$v^2 = \frac{2\times1.609\times10^{-17}}{m}$

m = mass of electron = 9.1 x 10^{-31} Kg

$\therefore v^2 = \frac{2\times1.609\times10^{-17}}{9.1\times10^{-31}}$

$\therefore v = \sqrt{\frac{2\times1.609\times10^{-17}}{9.1\times10^{-31}}} = \sqrt{\frac{2\times1.609\times10^{-17}\times10^{31}}{9.1}} = \sqrt{\frac{3.218\times10^{14}}{9.1}}$

v = 5.93 x 10^{6} m/s; where h = 6.62 x 10^{-34} JS

$\lambda = \frac{h}{mv} = \frac{6.62\times10^{-34}}{9.1\times10^{-31}\times5.93\times10^{6}}$ = 1.2 x 10^{-10}m = **1.2 Å**.

51. Identify the missing quantum numbers and the sub energy level.

n	l	m	Sub energy level
?	?	0	4d
3	1	0	?
?	?	?	5p
?	?	-2	3d

n	l	m	Sub energy level
4	**2**	0	4d
3	1	0	**3p**
5	**1**	**Any one value -1, 0, +1**	5p
3	**2**	-2	3d

EVALUATE YOURSELF

1. Calculate the de-Broglie wavelength of an electron that has been accelerated from rest through a potential difference of 1 keV.

Accelerated potential difference = 1 keV

The kinetic energy of the electron = the energy due to accelerating potential

$\frac{1}{2}mv^2 = eV$ rearrange to get, $\mathbf{mv^2 = 2eV}$

multiple with **m** $m^2v^2 = 2meV$

$mv = \sqrt{2meV}$

de Broglie wavelength, $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2meV}}$

m = mass of the electron = 9.1 x 10^{-31} kg; h = Planck constant = 6.626 x 10^{-34} Js

[∴1 eV = 1.6 x 10^{-19}J, 1 keV = 10^{3} x 1.6 x 10^{-9}J]

[∴$\frac{Js}{\sqrt{J\,kg}} = J^{1/2}\,kg^{1/2}\,s = (kg\,m^2\,s^{-2})^{1/2}.\,kg^{1/2}\,s]$ = m]

$\lambda = \frac{6.626\times10^{-34}\,Js}{\sqrt{2\times9.1\times10^{-31}\times1\times10^{3}\times1.6\times10^{-19}\,kg}} = \frac{6.626\times10^{-34}}{\sqrt{29120\times10^{-50}}}m = \frac{6.626\times10^{-34}}{170.645\times10^{-25}}m$

λ = 0.0388 x 10^{-9}m = **3.88 x 10^{-11}m**

UNIT – II – QUANTUM MECHANICAL MODEL OF ATOM

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

2. Calculate the uncertainty in the position of an electron, if the uncertainty in its velocity is $5.7 \times 10^5\ ms^{-1}$. [JUN-19]

$\Delta v = 5.7 \times 10^5\ ms^{-1}$; Δx = ?

According to Heisenberg's uncertainty principle, $\Delta x.\Delta p \geq \frac{h}{4\pi} = \frac{6.626 \times 10^{-34}}{4 \times 3.14}\ kgm^2s^{-1}$

$\frac{h}{4\pi} = 5.28 \times 10^{-35}\ kgm^2s^{-1}$

$\Delta x.\Delta p = \Delta x.m\Delta v \geq 5.28 \times 10^{-35}\ kgm^2s^{-1}$

$\Delta x \geq \frac{5.28 \times 10^{-35}\ kg\, m^2\, s^{-1}}{9.1 \times 10^{-31}\ kg \times 5.7 \times 10^5\ ms^{-1}}$ = $\mathbf{1.017 \times 10^{-10}\ m}$

3. How many orbitals are possible in the 4th energy level? (n = 4)

If n = 4, the possible number of orbitals are calculated as follows.

n	*l*	*m*
If n = 4	0	4s orbital = 1 orbital
	1	-1, 0, 1 = 3 orbitals
	2	-2, -1, 0, 1, 2 = 5 orbitals
	3	-3, -2, -1, 0, 1, 2, 3 = 7 orbitals

∴ Total number of orbitals = 16 orbitals.

4. Calculate the total number of angular nodes and radial nodes present in 3d and 4f orbitals. [QY-18, SEP-20]

Orbital	*n*	*l*	Radial node *n*-*l*-1	Angular node *l*	Total node *n*-1
3d	3	2	0	2	2
4f	4	3	0	3	3

5. Energy of an electron in hydrogen atom in ground state is -13.6 eV. What is the energy of the electron in the second excited state? [HY-19]

$E_n = \frac{-13.6}{n^2}$ eV Second excited state, **n = 3**

∴ $E_3 = \frac{-13.6}{(3)^2}$ eV = $\frac{-13.6}{9}$ eV = **-1.51 eV**

6. How many unpaired electrons are present in the ground state of Fe^{3+} (z=26), Mn^{2+} (z=25) and argon (z=18)? [QY-22]

Electronic configuration Fe^{3+} is $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^0, 3d^5$

↑	↑	↑	↑	↑

$3d^5$ five unpaired electrons

Electronic configuration Mn^{2+} is $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^0, 3d^5$

↑	↑	↑	↑	↑

$3d^5$ five unpaired electrons

Electronic configuration Ar is $1s^2, 2s^2, 2p^6, 3s^2, 3p^6$

↑↓	↑↓	↑↓

$3p^6$ no unpaired electrons

7. Explain the meaning of the symbol $4f^2$. Write all the four quantum numbers for these electrons.

$4f^2$: It means that the element has 2 electrons in outermost 4f shell.

Quantum number values are,

1	1					

n = principal quantum number = 4 *l* = azimuthal quantum number = 3

m_l = magnetic quantum number = – 3, -2 s = spin quantum number = +½, +½.

8. Which ion has the stable electronic configuration? Ni^{2+} or Fe^{3+}

Electronic configuration Ni^{2+} is $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^0, 3d^8$ **(or)** $[Ar]\ 3d^8$

Electronic configuration Fe^{3+} is $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^0, 3d^5$ **(or)** $[Ar]\ 3d^5$

Half-filled and completely filled orbitals are more stable compare to partially filled orbitals. Therefore Fe^{3+} is more stable compared to Ni^{2+}.

GOVERNMENT QUESTIONS AND ANSWERS

1. Consider the following electronic arrangement for p^3 configuration. [GMQ-18]

(a) | ↑ | ↑ | ↑ | **(b)** | ↑↓ | ↑ | | **(c)** | ↑ | ↑↓ | | **(d)** | ↑ | | ↑↓ |

Which of these represents the ground state? Substantiate your answer with a proper reason.

(a) | ↑ | ↑ | ↑ | (b) | ↑↓ | ↑ | | (c) | ↑ | ↑↓ | | (d) | ↑ | | ↑↓ |

(i) Among these the electronic configuration **(a)** represents the ground state.

(ii) It is considered to be the most **stable state.**

2. Calculate the de Broglie wavelength of a particle whose momentum is 66.26 x 10^{-28} kg m s^{-1}. [GMQ-18]

$\lambda = \frac{h}{p} = \frac{6.626 \times 10^{-34}}{66.26 \times 10^{-28}} = \mathbf{1 \times 10^{-7}\ m}$

3. State Heisenberg's uncertainty principle and give its mathematical expression. [FMT-18, SEP-20, CRT, AUG-22]

- Heienberg's uncertainty principle states that 'It is impossible to **accurately** determine both the position and the momentum of a microscopic particle **simultaneously**'.
- The product of uncertainty (error) in the measurement is expressed as follows.

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

where, Δx and Δp are uncertainties in determining the position and momentum, respectively.

4. Write the descending order of electrons releasing tendencies of the Zn, Cu and Ag metals. Arrange the metals Zn, Cu and Ag in the descending order of their effective nuclear charge. [QY-18]

Zinc, copper and silver the electro releasing tendency is the following order.

5. State Aufbau principle. [HY-19, SEP-21]

In the ground state of the atoms, the orbitals are filled in the order of their increasing energies.

6. In degenerate orbitals, why do the completely filled and half-filled configurations are more stable than the partially filled configuration? [SEP-20, 21]

The exactly half filled and completely filled orbitals have greater stability than other partially filled configurations in degenerate orbitals. This can be explained on the basis of symmetry and exchange energy.

Symmetry leads to stability. The half-filled and fully filled configurations have symmetrical distribution of electrons and hence they are more stable than the unsymmetrical configurations.

Exchange energy:

If two or more electrons with the same spin are present in degenerate orbitals, there is a possibility for exchanging their positions. During exchange process the energy is released and the released energy is called exchange energy. If more number of exchanges are possible, more exchange energy is released. More number of exchanges are possible only in case of half-filled and fully filled configurations.

7. Calculate the maximum number of electrons that can be accommodated in L-shell. [MAY-22]

'L' shell refers to the principle quantum number, n = 2. There are 4 orbital associated with n = 2 ⇒ $2p_y$, $2p_z$, and $2p_x$ = $2(2)^2$ = **8**

8. State Hund's rule. [CRT-22]

Hund's rule states that electron pairing in the degenerate orbitals does not take place until all the available orbitals contains one electron each.

9. Enlist the postulates of Bohr's atom model. [FMT,HY-18, HY-19, CRT-22]

Bohr's atom model is based on the following assumptions:

- The energies of electrons in an atom are quantised.
- The electron is revolving around the nucleus in a certain circular path of fixed energy called stationary orbit.
- Electron can revolve only in those orbits in which the angular momentum (mvr) of the electron must be equal to an integral multiple of h/2π.

i.e. $mvr = nh/2\pi$ where n = 1,2,3,...etc.,

- As long as an electron revolves in the fixed stationary orbit, it doesn't lose its energy. However, when an electron jumps from higher energy state (E_2) to a lower energy state (E_1), the excess energy is emitted as radiation. The frequency of the emitted radiation is

$E_2 - E_1 = h\nu$ and $\nu = \frac{(E_2 - E_1)}{h}$

- Conversely, when suitable energy is supplied to an electron, it will jump from lower energy orbit to a higher energy orbit.

10. Derive de Broglie's equation. [FMT,QY-18, QY-19, MAR-19]

- de-Broglie combined the following two equations of energy of which one represents wave character (hυ) and the other represents the particle nature (mc^2).

(i) Planck's quantum hypothesis: $E = h\nu$

(ii) Einstein's mass-energy relationship: $E = mc^2$

From eq. (i) and (ii) $h\nu = mc^2$

$hc/\lambda = mc^2$ $\therefore \boldsymbol{\lambda = h / mc}$

- The equation represents the wavelength of photons whose momentum is given by mc (Photons have zero rest mass)
- For a particle of matter with mass m and moving with a velocity v, the equation can be written as $\therefore \boldsymbol{\lambda = h / mv}$
- This is valid only when the particle travels at speeds much less than the speed of Light.

11. Explain azimuthal quantum number. (or) Explain Angular quantum number? [QY,CRT-22]

- It is represented by the letter 'l', and can take integral values from zero to n-1, where n is the principal quantum number
- Each l value represents a subshell (orbital). l = 0, 1, 2, 3 and 4 represents the s, p, d, f and g orbitals respectively.
- The maximum number of electrons that can be accommodated in a given subshell (orbital) is $2(2l+1)$.
- It is used to calculate the orbital angular momentum using the expression

Angular momentum = $\sqrt{l(l+1)}\,\frac{h}{2\pi}$

UNIT – II – QUANTUM MECHANICAL MODEL OF ATOM

| Mr. S.JOHNSON., M.Sc., M.Sc., B.Ed.,

12.Describe about magnetic quantum number. [AUG-22]

- It is denoted by the letter 'm_l'. It takes integral values ranging from -*l* to +*l* through 0. i.e. if *l*=1; *m* = -1, 0 and +1
- Different values of *m* for a given *l* value, represent different orientation of orbitals in space.
- The Zeeman Effect (the splitting of spectral lines in a magnetic field) provides the experimental justification for this quantum number.
- The magnitude of the angular momentum is determined by the quantum number *l* while its direction is given by magnetic quantum number.

13.Calculate the total number of radial nodes and angular nodes present in 4d and 5f orbitals. [QY-19]

Orbital	*n*	*l*	Radial node *n*-*l*-1	Angular node *l*	Total node *n*-1
4d	4	2	1	2	3
5f	5	3	1	3	4

14.Calculate the orbital angular momentum for d and f orbital. [JUN-19]

The formula of the orbital angular momentum is, L = $\sqrt{l(l+1)}\,\frac{h}{2\pi}$

The value of '*l*' for d-orbital = 2	The value of '*l*' for f-sub orbital = 3
L = $\sqrt{2(2+1)}\,\frac{h}{2\pi} = \frac{h\sqrt{6}}{2\pi}$ Therefore, the angular momentum of electron in d orbital is equal to $\boldsymbol{\frac{h\sqrt{6}}{2\pi}}$	L = $\sqrt{3(3+1)}\,\frac{h}{2\pi} = \frac{h\sqrt{3}}{\pi}$ Therefore, the angular momentum of electron in f sub orbital is equal to $\boldsymbol{\frac{h\sqrt{3}}{\pi}}$

15.Write a note on principle quantum number. [SEP-21]

This quantum number represents the energy level in which electron revolves around the nucleus and is denoted by the symbol '*n*'.

- The '*n*' can have the values 1, 2, 3,… *n*=1 represents K shell; *n*=2 represents L shell and *n* = 3, 4, 5 represent the M, N, O shells, respectively.
- The maximum number of electrons that can be accommodated in a given shell is $2n^2$.
- '*n*' gives the energy of the electron, $E_n = \frac{-1312.8(Z^2)}{n^2}$ kJ mol^{-1} and the distance of the electron from the nucleus is given by $r_n = \frac{(0.529)n^2}{Z}$ Å

16.Distinguish Orbit and Orbital [QY-22]

	ORBIT	ORBITAL
1	It is a well defined circular path around the nucleus in which the electron revolve.	It's the three dimensional space around the nucleus within which the probability of finding an electron is maximum
2	The concept of an orbit does not consider the wave character of electrons and uncertainty principle	The concept of an orbital is in accordance with the wave character of electrons and uncertainty principle
3	They do not have any directional characteristics	Except s-orbitals, all orbitals have directions characteristics
4	The maximum number of electrons that an orbit can have is given by $2n^2$ where n is the number of the orbit	The maximum number of electrons that can be occupied by an orbital is always two.

17.Write short notes on spin quantum number. [MAR-24]

- The spin quantum number represents the spin of the electron and is denoted by the letter 'm_s'
- The electron in an atom revolves not only around the nucleus but also spins. It is usual to write this as electron spins about its own axis either in a clockwise direction or in anti-clockwise direction. The visualisation is not true. However spin is to be understood as representing a property that revealed itself in magnetic fields.
- Corresponding to the clockwise and anti-clockwise spinning of the electron, maximum two values are possible for this quantum number.
- The values of 'm_s' is equal to -½ and + ½