ATOMIC STRUCTURE

SYNOPSIS

❖ **Photoelectric effect:**

When radiations of a certain minimum frequency (v_0), called threshold frequency, strike the surface of a metal, electrons called photoelectrons are ejected from the surface. The minimum energy required to eject the electrons from the metal surface is called threshold energy or work function.

Absorbed energy = Threshold energy + Kinetic energy of photoelectrons

$$E = E_0 + KE$$

$$hv = hv_0 + \frac{1}{2}mv^2$$

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_0} + \frac{1}{2}mv^2$$

v_0 and λ_0 are called threshold frequency and threshold wavelength respectively.

❖ **Hydrogen spectrum:**

Hydrogen spectrum is a line spectrum. The lines lie in visible, ultraviolet and infrared regions. All the lines can be classified into five series. To find the wavelengths of various lines -

$$\frac{1}{\lambda} = \bar{v} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Where, R is Rydberg constant $\left(R = 109678\,cm^{-1}\right)$.

		n_1	n_2
Lyman series	(UV region)	1	2, 3, 4, 5,…
Balmer series	(Visible region)	2	3, 4, 5, 6,…
Paschen series	(IR region)	3	4, 5, 6, 7,…
Bracket series		4	5, 6, 7, 8,…
Pfund series		5	6, 7, 8, 9,…

Balmer series consists of four prominent lines $H_\alpha, H_\beta, H_\gamma$ and H_δ having wavelength $6563A^o$, $4861A^o$, $4340A^o$ and $4102A^o$ respectively.

Balmer equation is,

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

Where, $n = 3,4,5,6,...$

$$\text{Number of lines} = \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

❖ **Bohr's atomic model:**

Angular momentum of electrons are quantized, i.e.

$$m\upsilon r = n\left(\frac{h}{2\pi}\right)$$

The energy as well as angular momentum both are quantized for electrons. It means they can have only certain values of energy and angular momenta.

❖ **Important formulations obtained from Bohr's atomic model which are valid for single electron species like** $H, He^{+}, Li^{2+}, Be^{3+}$, etc.:

(i) $E_1 < E_2 < E_3 < E_4$

(ii) $(E_2 - E_1) > (E_3 - E_2) > (E_4 - E_3)...$

Where, $E_1, E_2, E_3...$ are energies of corresponding shells.

(iii) $$r_n = \frac{n^2h^2}{4\pi^2Ke^2mZ}$$

$$K = \frac{1}{4\pi\varepsilon_0} = 9\times10^9\,Nm^2/C^2$$

$r = \frac{n^2}{Z}\times 0.529\,\text{A}^{\circ}$ (where, r is the radius of Bohr orbit of electrons).

(iv) Energy of electrons in a particular shell can be calculated as

$$E = -\frac{Z^2}{n^2}\frac{2\pi^2mK^2e^4}{h^2}$$

$$E = -\frac{Z^2}{n^2}\times 2.18\times10^{-18}\,J/atom$$

$$= -\frac{Z^2}{n^2}\times 13.6\,eV \quad = -\frac{Z^2}{n^2}\times 1312\,kJ/mol$$

$$E_n = \frac{Z^2R_E}{n^2}$$

$R_E = -13.6\,eV$ (Rydberg energy)

(v) $E_n = E_1/n^2; E_n = E_1\times\frac{Z^2}{n^2}$ for hydrogen like species.

(vi) Velocity of electrons in a particular shell or orbit can be calculated as :

$$v_n = \frac{2\pi e^2Zk}{nh}$$

Where, $K = \frac{1}{4\pi\varepsilon_0} = 9\times10^9\,Nm^2/C^2$

$$v = \frac{Z}{n} \times 2.188 \times 10^8 \ cm/\sec$$

(vii) Potential energy of electrons in a particular shell:

$$PE = \frac{-KZe^2}{r} = -\frac{27.2}{n^2} \times Z^2 \ eV$$

(viii) Kinetic energy of electrons in a particular shell:

$$KE = \frac{1}{2}\frac{KZe^2}{r} = +\frac{13.6}{n^2} Z^2 \ eV$$

Total Energy, $TE = -\frac{1}{2}\frac{KZe^2}{r}$

$$TE = \frac{1}{2} PE$$

$$TE = -KE$$

(ix) Number of revolutions per second by an electron in a shell:

$$= \frac{\text{Velocity}}{\text{Circumference}} = \frac{v}{2\pi r} = -\frac{E_1}{h} \times \frac{2}{n^3} = \frac{6.62 \times 10^{15} Z^2}{n^3} \ \sec^{-1}$$

(x) Period of revolution of electrons in nth orbit (T_n):

$$T_n = \frac{2\pi r}{v_n} = \frac{1.5 \times 10^{-16} n^3}{Z^2} \sec$$

$$T \propto \frac{n^3}{Z^2}$$

(xi) Ionization energy $= E_\infty - E_1 = 0 - \left(-13.6 \times Z^2\right) = 13.6 \times Z^2 \text{eV/atom}$

(xii) $\frac{I_1}{I_2} = \frac{Z_1^2}{Z_2^2} \times \frac{n_2^2}{n_1^2}$

I_1 and I_2 are ionization energies of two elements 1 and 2.

(xiii) ΔE (Energy of transition)

$$= R_E \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

$R_E = -13.6$ eV

R_H = Rydberg constant$= \frac{R_E}{hc} = 109677 \text{ cm}^{-1}$

❖ De-Broglie wavelength:

$\rightarrow \lambda = \frac{h}{mV}$

$\rightarrow \lambda = \frac{h}{\sqrt{2Em}}$; where, $E =$ kinetic energy of the particle.

For neutron:

$$\lambda = \frac{0.286}{\sqrt{E(eV)}} A^o$$

$\rightarrow \lambda = \frac{h}{\sqrt{2qVm}}$; where, $q =$ charge of the particle accelerated by the potential of V volt.

For electron:

$$\lambda = \frac{12.27}{\sqrt{V}} A^o$$

For proton:

$$\lambda = \frac{0.286}{\sqrt{V}} A^o$$

For α-particle:

$$\lambda = \frac{0.101}{\sqrt{V}} A^o$$

$\rightarrow$ de-Broglie wavelength of electron in nth orbit:

$$\lambda_n = \frac{nh^2}{2\pi e^2 mzk} = 3.33 \times \frac{n}{z} A^o$$

- ❖ **Heisenberg uncertainty principle:**

It is impossible to measure simultaneously both the position and momentum of any microscopic particle with accuracy. Mathematically, $\Delta x \Delta p = \frac{h}{4\pi}$; where, $\Delta x =$ uncertainty of position and $\Delta p =$ uncertainty of momentum.

- ❖ **Correct set of quantum numbers condition:**

$$n > l \geq m \text{ and } s = \pm\frac{1}{2}$$

- ❖ **Spin multiplicity =** $(2|S|+1)$

S = Total spin of electrons

- ❖ **Energies of electrons:**

Energy of electron in a single electron species $(E) \propto n$

$\therefore$ Energy of $1s < 2s = 2p < 3s = 3p = 3d < 4s = 4p = 4d = 4f$

Energy of electron in a multi electron species $(E) \propto n + l$

$\therefore$ Energy of $1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < \ldots$

Note: When $n + l$ is same then the energy depends only on n.

- ❖ **Orbital angular momentum of electron**

$$\mu_l = \sqrt{l(l+1)}\frac{h}{2\pi} = \sqrt{l(l+1)}\hbar$$

- ❖ **Spin angular momentum:**

$$\mu_s = \sqrt{S(S+1)}\frac{h}{2\pi}$$

Total spin of an atom or an ion $=\frac{n}{2}$;

where, 'n' is the number of unpaired electrons.

Spin multiplicity of an atom $=(2\Sigma S+1)$

❖ **Z-component of the angular momentum:**

$$L_Z = m\left(\frac{h}{2\pi}\right)$$

where m is magnetic quantum number.

❖ **Shells – Subshells – Orbitals:**

(i) Number of subshells in a shell $=n$

(ii) Maximum number of orbitals in a shell $=n^2$

(iii) Maximum number of orbitals in a subshell $=2l+1$

(iv) Maximum number of electrons in a shell = $=2n^2$

(v) Maximum number of electrons in a subshell $=2(2l+1)$

❖ **Radial and angular nodes:**

Number of radial (or) spherical nodes of any orbital $=(n-l-1)$

Number of angular nodes (or) nodal planes $=l$

Total number of nodes $=n-1$

❖ **Wave mechanical model of atom:**

Schrodinger developed wave mechanical model of atom by incorporating the conclusions of de Broglie and Heisenberg uncertainty principles.

Schrodinger equation:

$$\frac{d^2\psi}{dx^2}+\frac{d^2\psi}{dy^2}+\frac{d^2\psi}{dz^2}+\frac{8\pi^2 m}{h^2}(E-V)\psi=0$$

ψ is orbital wave function which is a measure of the amplitude of the electron wave.

ψ^2 is probability density of electron.

Schrodinger wave equation does not give spin quantum number

Operator form Schrodinger wave equation:

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

$$\hat{H}\,(\text{Hamiltonian operator}) = \left[-\frac{h^2}{8\pi^2 m}\nabla^2+\hat{V}\right]$$

$$=\hat{T}+\hat{V}$$

$\hat{T}$ = Kinetic energy operator

$\hat{V}$ = Potential energy operator

$$\nabla^2\,(\text{del squared}) = \left[\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2}\right]$$

❖ Orbital wave function:

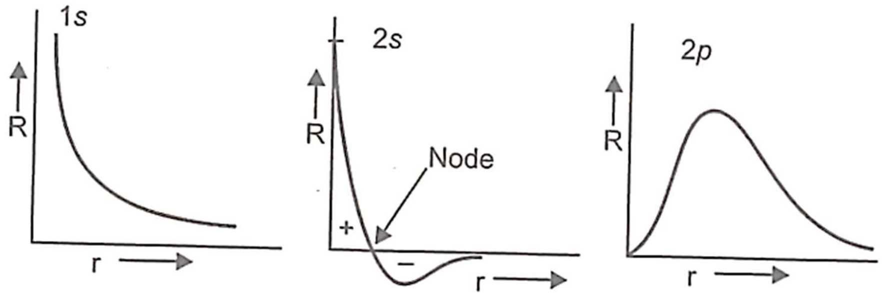
$$\psi(r,\theta,\phi) = \underbrace{R(r)}_{\text{Radial part}}\ \underbrace{\Theta(\theta)\Phi(\phi)}_{\text{Angular part}}$$

Dependence of the wave function on quantum numbers can be given as:

$$\psi_{nlm}(r,\theta,\phi) = R_{n,l}(r)\Theta_{lm}(\theta)\Phi_m(\phi)$$

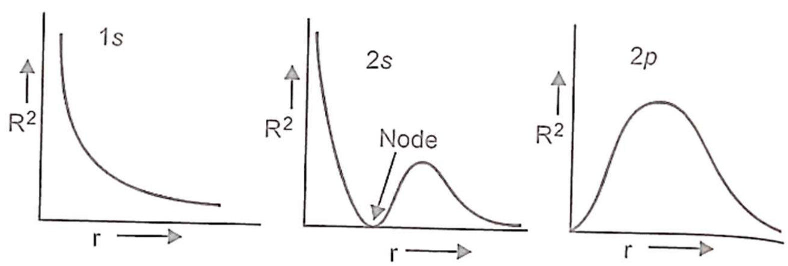
❖ Plots of radial wave function (R) Vs Radius (*r*):

At node, the value of 'R' changes from positive to negative.

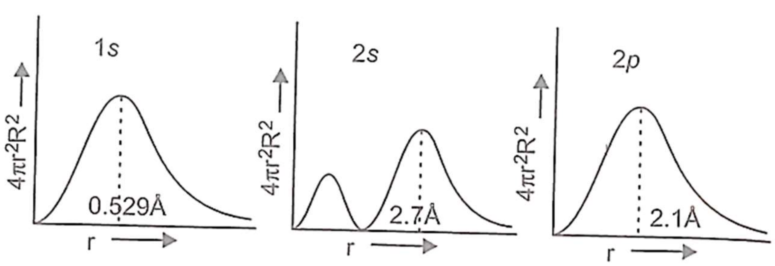


Number of radial nodes $= (n - l - 1)$

❖ Plot of radial probability density (R^2) Vs radius (*r*):



❖ Plot of radial probability function $\left(4\pi r^2 R^2\right)$ Vs radius (*r*):



In the plot of radial probability against '*r*', number peaks $= n - 1$.

❖ Spin only magnetic moment (μ_s):

$$\mu_s = \sqrt{n(n+2)}BM$$

n = number of unpaired electrons

EXERCISE - 1

I. Subatomic Particles (Electron, Proton and Neutron):

1. Amongst the following which is not a postulate of Dalton's atomic theory

[JEE Mains 2020, Jan]

(a) Matter is formed of indivisible atoms

(b) Under identical conditions of pressure and temperature gases combines and give gaseous products in simple volume ratio.

(c) During Chemical reactions atoms remains conserved and only pass through rearrangement

(d) Some atoms have same properties including atomic mass

2. Electrons in a cathode ray tube have been emitted with a velocity of 1000 ms^{-1}. The number of following statements which is/are true about the emitted radiation is …….

Given: $h = 6\times10^{-34}\,Js, m_e = 9\times10^{-31}\,kg$ [JEE Mains 2023, 01 February - Shift 1]

(a) The de Broglie wavelength of the electron emitted is 666.67nm.

(b) The characteristic of electrons emitted depends upon the material of the electrodes of the cathode ray tube.

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

(d) The nature of the emitted electrons depends on the nature of the gas present in cathode ray tube.

3. Observe the following statements regarding isotones:

a) ^{39}K and ^{40}Ca are isotones.

b) Nucleides having different atomic number(Z) and mass numbers (a) but same number of neutrons (n) are called isotones.

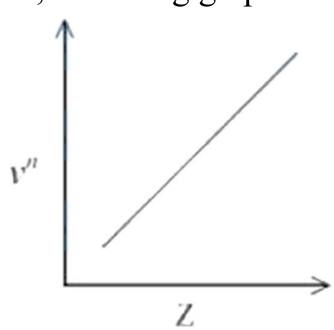
c) ^{19}F and ^{23}Na are isotones.

The correct answer is

(a) a, b and c are correct (b) Only a and b are correct

(c) Only a and c are correct (d) Only b and c are correct

4. It is observed that characteristic X-ray spectra of elements show regularity. When frequency to the power 'n' i.e. v^n of X-rays emitted is plotted against atomic number 'Z', following graph is obtained. [JEE Mains 2023, 24 January – Shift 1]



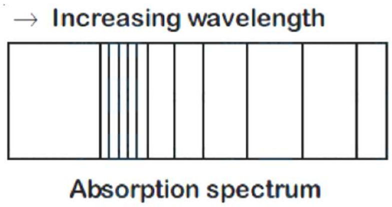
The value of 'n' is

(a) 1 (b) 2 (c) 1/2 (d) 3

II. Black Body Radiation, Planck's Quantum Theory, Photoelectric Effect:

5. The figure that is not direct manifestation of the quantum nature of atoms is

[JEE Mains 2020 – 2 September, Morning]

(a)


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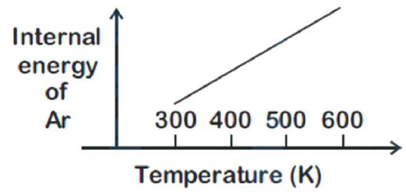
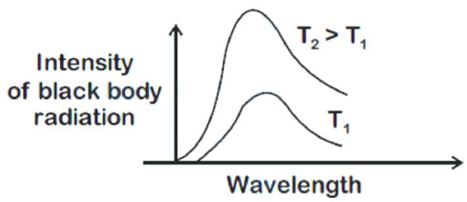
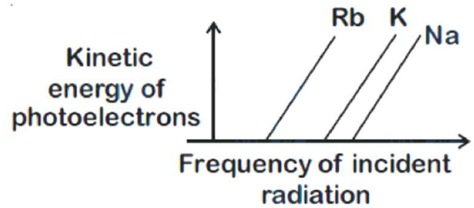
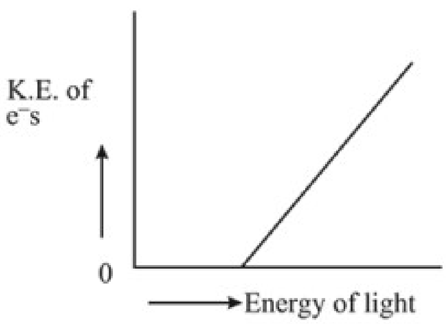


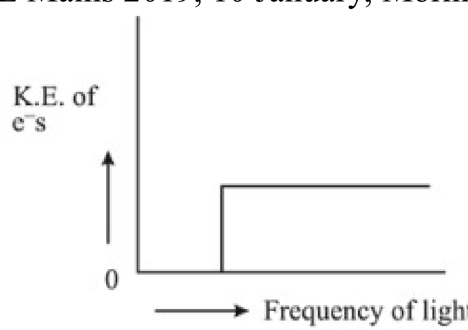
(c)


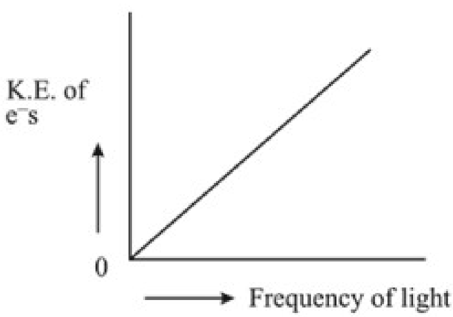
(d)


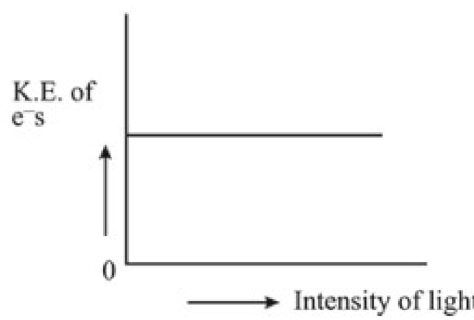
6. Which of the graphs shown below does not represent the relationship between incident light and the electron ejected from metal surface?

[JEE Mains 2019, 10 January, Morning]

(a)


(b)


(c)


(d)


III. Classical Atomic Models (Thomson's Atomic Model, Rutherford's Model of Atom and Bohr's Model)

7. Rutherford's experiment, which established the nuclear model of the atom, used a beam of [2002S]

(a) $\beta-$ particles, which impinged on a metal foil and got absorbed

(b) $\gamma-rays$, which impinged on a metal foil and ejected electrons.

(c) Helium atoms, which impinged on a metal foil and got scattered

(d) helium nuclei, which impinged on a metal foil and got scattered.

8. If the Thompson model of the atom was correct, then the result of Rutherford's gold foil experiment would have been: [JEE Mains (27 July 2021 Shift 2)]

(a) All of the α -particles pass through the gold foil without decrease in speed.

(b) α -Particles are deflected over a wide range of angles.

(c) All α -particles get bounced back by 1800

(d) α -Particles pass through the gold foil deflected by small angles and with reduced speed.

9. According to Bohr's atomic theory : [JEE Mains 2021, 24 Feb (Shift 2)]

(A) Kinetic energy of electron is $\propto \frac{Z^2}{n^2}$

(B) The product of velocity (v) of electron and principal quantum number (n). 'vn' $\propto Z^2$

(C) Frequency of revolution of electron in an orbit is $\propto \frac{Z^3}{n^3}$

(D) Coulombic force of attraction on the electron is $\propto \frac{Z^3}{n^4}$. Choose the most appropriate answer from the options given below:

(a) (C) only (b) (A) &(D) only (c) (A) only (d) (A), (C) and (D) only

10. According to Bohr's atomic theory, which of the following is correct ?

(a) Potential energy of electron $\propto \frac{Z^2}{n^2}$

(b) The product of velocity of electron and principle quantum number (n) $\propto Z^2$

(c) Frequency of revolution of electron in an orbit $\propto \frac{Z^2}{n^3}$

(d) Coulombic force of attraction on the electron $\propto \frac{Z^2}{n^2}$

IV. Hydrogen Spectrum and Spectra of Single Electron Species:

11. Which electronic level would allow the hydrogen atom to absorb a photon but not to emit a photon

(a) 3s (b) 2p (c) 2s (d) 1s

12. The region in the electromagnetic spectrum where the Balmar series lines appear is [JEE Mains 2020, 4 September, Morning]

(a) Microwave (b) Ultraviolet (c) Visible (d) Infrared

13. For the Balmer series in the spectrum of for $H-atom\ \bar{v}=R_H\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

Select the correct options regarding this formula for Balmer series.

[JEE Mains 2020, 8 January, Morning]

(A) The integer n_1 is equal to = 2

(B) Ionization energy of H atom can be calculated from wave number of these lines.

(C) The lines of longest wavelength corresponds to $n_2 = 3$

(D) If λ decreases then spectrum lines will converge.

(a) A, B (b) C, D (c) A & C & B (d) A, B, C & D

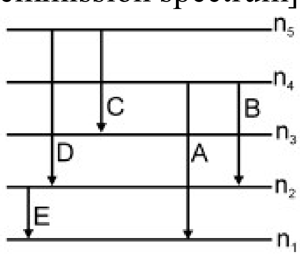
14. Suppose a hypothetical H-like atom produces a blue, yellow, red and violet line in emission spectrum. Match the above lines with their corresponding possible electronic transition :

Colour of spectral lines	Possible corresponding transitions
(1) Blue	(p) $6 \rightarrow 3$
(2) Yellow	(q) $2 \rightarrow 1$
(3) Red	(r) $5 \rightarrow 2$
(4) Violet	(s) $4 \rightarrow 3$

Code :

	(1)	(2)	(3)	(4)		(1)	(2)	(3)	(4)
(a)	r	p	s	q	(b)	r	s	q	p
(c)	p	r	s	q	(d)	p	r	q	s

15. For a hypothetical H like atom which follows Bohr"s model, some spectral lines were observed as shown. If it is known that line 'E' belongs to the visible region, then the lines possibly belonging to ultra violet region will be (n_1 is not necessarily ground state) [Assume for this atom, no spectral series shows overlap with other series in the emmission spectrum]



(a) B and D (b) D only (c) C only (d) A only

16. The ionization energy of hydrogen atom in terms of Rydberg constant (R_H) is given by the expression

(a) $R_H hc$ (b) $R_H c$ (c) $2R_H hc$ (d) $R_H N_A hc$

17. For emission line of atomic hydrogen from $n_i = 8$ to $n_f = n$ the plot of wave number $(\bar{v})$ against $\left(\frac{1}{n^2}\right)$ will be (the Rydberg constant, R_H is in wave number unit)

[JEE Mains 2019, 9 January, Morning]

(a) Linear with intercept - R_H
(b) Non linear
(c) Linear with slope R_H
(d) Linear with slope - R_H

IV. de-Broglie's Concept:

18. A particle initially at rest having charge q coulomb. & mass m kg is accelerated by a potential difference of V volts. What would be its K.E & de Broglie wavelength respectively after acceleration

(a) $qV, \frac{h}{\sqrt{2qVm}}$ (b) $\frac{h}{\sqrt{2qVm}}, qV$ (c) $qV, \frac{h}{mV}$ (d) $\frac{h}{mV}, qV$

19. The correct order of wavelength of Hydrogen $\left({}_1H^1\right)$, Deuterium $\left({}_1H^2\right)$ and Tritium $\left({}_1H^3\right)$ moving with same kinetic energy is

(a) $\lambda_H > \lambda_D > \lambda_T$ (b) $\lambda_H = \lambda_D = \lambda_T$ (c) $\lambda_H < \lambda_D < \lambda_T$ (d) $\lambda_H < \lambda_D > \lambda_T$

20. The de Broglie wavelength (λ) associated with a photo electron varies with the frequency (v) of the incident radiation as, [v_0 is threshold frequency]:

[JEE Mains, 11 January Evening]

(a) $\lambda \propto \frac{1}{(v - v_0)}$ (b) $\lambda \propto \frac{1}{(v - v_0)^{\frac{1}{4}}}$ (c) $\lambda \propto \frac{1}{(v - v_0)^{\frac{3}{2}}}$ (d) $\lambda \propto \frac{1}{(v - v_0)^{\frac{1}{2}}}$

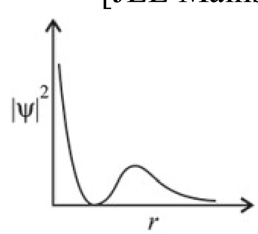
VI. Quantum Mechanical Model of Atom (Schrodinger's Wave Equation, Wave Function, Probability Density, Radial Probability):

21. The correct statement about probability density (except at infinite distance from nucleus) is [JEE Mains 2020, 5 September, Evening]

(a) It can never be zero for 2s orbital
(b) It can be zero for 3p orbital
(c) It can be zero for 1s orbital
(d) It can be negative for 2p orbital

22. The graph between $|\Psi|^2$ and r (radial distance) is shown below. This represents:

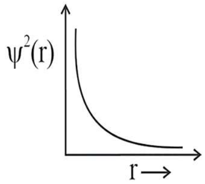
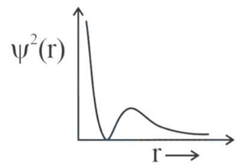
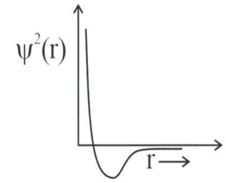
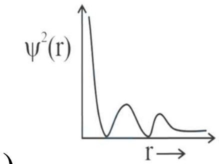
[JEE Mains 2019, 10 April Morning]



(a) 3s orbital (b) 2s orbital (c) 1s orbital (d) 2p orbital

23. Which of the following is the correct plot for the probability density $\Psi^2(r)$ as a function of distance 'r' of the electron form the nucleus for 2s orbital?

[JEE Mains 2022, 29 June - Shift 2]

(a) 
(b) 
(c) 
(d) 

24. Identify the incorrect statement from the following. [JEE Mains 2022, 28 July - Shift 1]

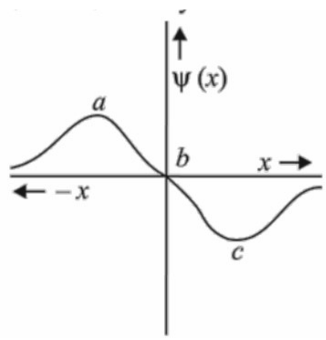
(a) A circular path around the nucleus in which an electron moves is proposed as Bohr's orbit.

(b) An orbital is the one electron wave function (Ψ) in an atom.

(c) The existence of Bohr's orbits is supported by hydrogen spectrum.

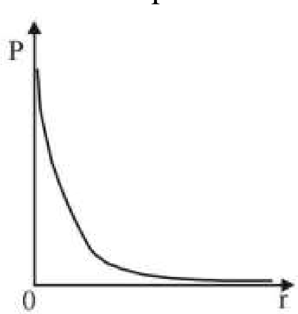
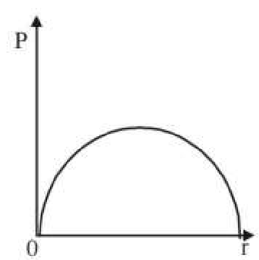
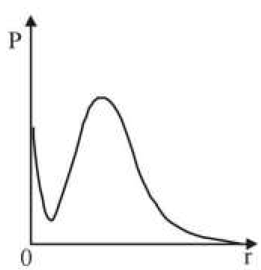
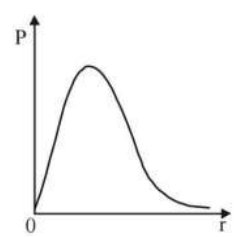
(d) Atomic orbital is characterised by the quantum numbers n and 1 only

25. The electrons are more likely to be found:



(a) in the region a and c
(b) in the region a and b
(c) only in the region a
(d) only in the region e

26. P is the probability of finding the $1s$ electron of hydrogen atom in a spherical shell of infinitesimal thickness, dr, at a distance r from the nucleus. The volume of this shell is $4\pi r^2 dr$. The qualitative sketch of the dependence of P on r is [JEE Adv. 2016]

(a) 
(b) 
(c)
(c) 
(d) 

27. Which of the following combination of statements is true regarding the interpretation of the atomic orbitals? [JEE Mains 2019, 9 January, Evening]

(A) An electron in an orbital of high angular momentum stays away from the nucleus than an electron in the orbital of lower angular momentum.

(B) For a given value of the principal quantum number, the size of the orbit is inversely proportional to the azimuthal quantum number.

(C) According to wave mechanics, the ground state angular momentum is equal to $\frac{4}{2\pi}$

(D) The plot of Ψ vs r for various azimuthal quantum numbers, shows peak shifting towards higher r value.

(a) (A), (D) (b) (A), (B) (c) (A), (C) (d) (B), (C)

28. Which one of the following about an electron occupying the $1s$ orbital in a hydrogen atom is incorrect? (The Bohr radius is represented by a_0). [JEE Mains 2019, 9 April, Evening]

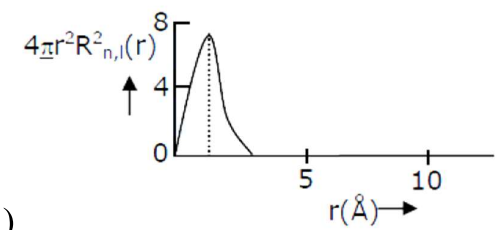
(a) The probability density of finding the electron is maximum at the nucleus.

(b) The electron can be found at a distance $2a_0$ from the nucleus.

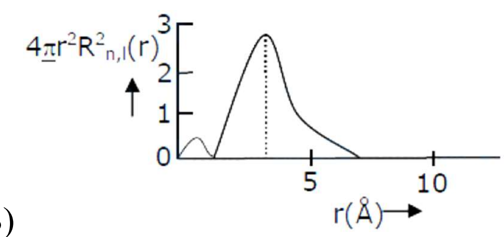
(c) The magnitude of the potential energy is double that of its kinetic energy on an average.

(d) The total energy of the electron is maximum when it is at a distance a_0 from the nucleus.

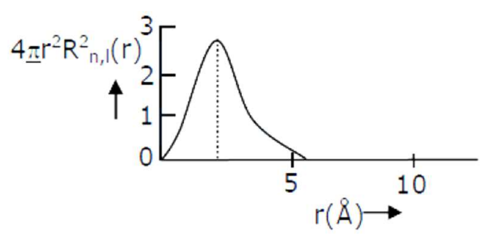
29. The plots of radial distribution functions for various orbitals of hydrogen atom against 'r' are given below: [JEE Mains 2021, 25 Feb (Shift 1)]



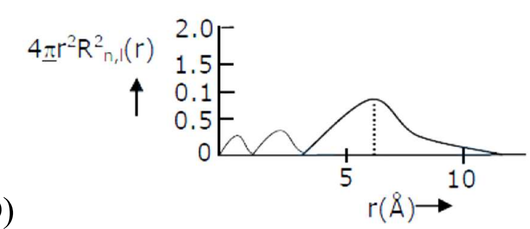
(A)



(B)



(C)



(D)

The correct plot for 3 s orbital is:

(a) D (b) B (c) A (d) C

VII. Radial and Angular Nodes:

30. The number of nodal planes in a p_x orbital is [2000S]

(a) one (b) two (c) three (d) zero

31. The orbital having two radial as well as two angular nodes is [JEE Mains 2021, 26 Feb (Shift 1)]

(a) 5 d (b) 4f (c) 3p (d) 4 d

32. A certain orbital has no angular nodes and two radial nodes. The orbital is:
[JEE Mains 2021, 18 March (Shift 1)]
(a) 2 s (b) 3 s (c) 3p (d) 2p

33. The number of radial nodes of $3s$ and $2p$ orbitals are respectively [2005S]
(a) 2, 0 (b) 0, 2 (c) 1, 2 (d) 2, 1

34. The number of radial and angular nodes in 4d orbital are. Respectively
[JEE Mains 2022, 26 June - Shift 1]
(a) 1 and 2 (b) 3 and 2 (c) 1 and 0 (d) 2 and 1

VIII. Quantum Numbers and Electronic Configurations of Elements:

35. The electrons, identified by quantum numbers n and l, $(i) n = 4, l = 1$, $(ii) n = 4, l = 0$, $(iii) n = 3, l = 2$, and $(iv) n = 3, l = 1$ can be placed in order of increasing energy, from the lowest to highest, as [1999 – 2 Marks]
(a) (iv) < (ii) < (iii) < (i) (b) (ii) < (iv) < (i) < (iii)
(c) (i) < (iii) < (ii) < (iv) (d) (iii) < (i) < (iv) < (ii)

36. The quantum numbers $+\frac{1}{2}$ and $-\frac{1}{2}$ for the electron spin represent [2001S]
(a) Rotation of the electron in clockwise and anticlockwise direction respectively.
(b) Rotation of the electron in anticlockwise and clockwise direction respectively
(c) Magnetic moment of the electron pointing up and own respectively
(d) Two quantum mechanical spin states which have no classical analogue

37. Consider the hypothetical situation where the azimuthal quantum number, ℓ, takes value 0, 1, 2, … n + 1, where n is principal quantum number. Then, the element with atomic number [JEE Mains 2020, 3 September, Evening]
(a) 9 is the first alkali metal (b) 6 has a 2p-valence subshell
(c) 8 is the first noble gas (d) 13 has a half filled valence subshell

38. The quantum number of four electrons are given below:
[JEE Mains 2019, 8 April Morning]
$I.\ n = 4, l = 2, m_l = -2, m_s = -1/2$
$II.\ n = 3, l = 2, m_l = 1, m_s = +1/2$
$III.\ n = 4, l = 1, m_l = 0, m_s = +1/2$
$IV.\ n = 3, l = 1, m_l = 1, m_s = -1/2$
The correct order of their increasing energies will be:
(a) IV < III < II < I (b) I < II < III < IV
(c) IV < II < III < I (d) I < III < II < IV

39. Given below are the quantum numbers for 4 electrons.

A. $n=3, l=2, m_1=1, m_s=+1/2$

B. $n=4, l=1, m_1=0, m_s=+1/2$

C. $n=4, l=2, m_1=-2, m_s=-1/2$

D. $n=3, l=1, m_1=-1, m_s=+1/2$

The correct order of increasing energy is:

(a) D < B < A < C (b) D < A < B < C

(c) B < D < A < C (d) B < D < C < A

40. The number of orbitals with $n=5, m_l=+2$ is …. (Round off to the Nearest Integer).

[JEE Main s2021, 16 March (Shift 2)]

a) 4 b) 5 c) 3 d) 2

41. The value of magnetic quantum number of the outermost electron of Zn^+ ion is…..

[JEE Mains 2021 (31 Aug Shift 1)]

(a) 2 (b) 0 (c) 3 (d) 1

42. Consider the following pairs of electrons

[JEE Mains 2022, 24 June – Shift 1]

(A) (i) $n=3, 1=1, m_1=1, m_s=+\frac{1}{2}$

(ii) $n=3, 1=2, m_1=1, m_s=+\frac{1}{2}$

(B) (i) $n=3, 1=2, m_1=-2, m_s=-\frac{1}{2}$

(ii) $n=3, 1=2, m_1=-1, m_s=-\frac{1}{2}$

(C) (i) $n=4, 1=2, m_1=2, m_s=+\frac{1}{2}$

(ii) $n=3, 1=2, m_1=2, m_s=+\frac{1}{2}$

The pairs of electron present in degenerate orbitals is/are:

(a) Only A (b) Only B (c) Only C (d) (B) and (C)

43. Consider the following set of quantum numbers [JEE Mains 2022, 27 June - Shift 2]

The correct set of quantum numbers is

	n	1	m_1
a.	3	3	-3
b.	3	2	-2
c.	2	0	+1
d.	2	2	+2

44. Consider the following statements : [JEE Mains 2022, 28 June - Shift 2]

(A) The principal quantum number 'n' is a positive integer with values of 'n' = 1, 2, 3

(B) The azimuthal quantum number 'l' for a given 'n' (principal quantum number) can have values as 'l' = 0, 1, 2

(C) Magnetic orbital quantum number 'm_l' for a particular 'l' (azimuthal quantum number) has $(2l+1)$ values.

(D) ±1/2 are the two possible orientations of electron spin.

(E) For $l=5$, there will be a total of 9 orbital.

Which of the above statements are correct'?

(a) (A), (B) and (C) (b) (A), (C), (D) and (E)

(c) (A), (C) and (D) (d) (A), (B), (C) and (D)

45. Which of the following statements are correct?

[JEE Mains 2022, 29 June - Shift I]

(A) The electronic configuration of Cr is $[Ar]3d^5 4s^1$

(B) The magnetic quantum number may have a negative value.

(C) In the ground state of an atom, the orbitals are filled in order of their increasing energies.

(D) The total number of nodes are given by $n-2$.

Choose the most appropriate answer from the options given below:

(a) (A), (C) and (D) only (b) (A) and (B) only

(c) (A) and (C) only (d) (A), (B) and (C) only

46. Which of the following sets of quantum numbers is not allowed?

[JEE Mains 2022, 25 July Shift 1]

(a) $n=3, 1=2, m_1=0, s=+\frac{1}{2}$ (b) $n=3, 1=2, m_1=-2, s=+\frac{1}{2}$

(c) $n=3, 1=3, m_1=-3, s=-\frac{1}{2}$ (d) $n=3, 1=0, m_1=0, s=-\frac{1}{2}$

47. The correct decreasing order of energy for the orbitals having, following set of quantum numbers: [JEE Mains 2022, 27 July - Shift 2]

(A) n = 3, l = 0, m = 0

(B) n = 4, l = 0, m = 0

(C) n = 3, l = l, m = 0

(D) n = 3, 1 =2, m = 1

(a) (D) > (B) > (C) > (A) (b) (B) > (D) > (C)> (A)

(c) (C) > (B) > (D) > (A) (d) (B)> (C) > (D) > (A)

48. If the nitrogen atom has electronic configuration $1s^7$, it would have energy lower than that of the normal ground state configuration $1s^2 2s^2 2p^3$, because the electrons would be closer to the nucleus. Yet $1s^7$ is not observed because it violates. [2002S]

(a) Heisenberg uncertainty principle (b) Hund's rule
(c) Pauli exclusion principle (d) Bohr postulate of stationary orbits.

49. The electronic configuration of an element is $1s^2, 2s^2, 2p^6, 3s^2, 3s^6, 3d^5, 4s^1$. This represents its [2000S]

(a) excited state (b) ground state (c) cationic form (d) anionic form

50. In the sixth period, the orbitals that are filled are [JEE mains 2020, 5 September, Morning]

(a) 6s, 4f, 5d, 6p (b) 6s, 5d, 5f, 6p (c) 6s, 6p, 6d, 6f (d) 6s, 5f, 6d, 6f

51. The electronic configuration of Pt (atomic number 78) is: [JEE Mains 2022, 29 June - Shift 1]

(a) $[Xe]4f^{14}5d^9 6s^1$ (b) $[Kr]4f^{14}5d^{10}$
(c) $[Xe]4f^{14}5d^{10}$ (d) $[Xe]4f^{14}5d^8 6s^2$

52. Which one of the following sets of ions represents a collection of isoelectronic species? (Given: Atomic Number : F : 9 , Cl : 17, Na = 11, Mg = 12, A1 = 13, K = 19, Ca = 20, Sc = 21) [JEE Mains 2023, 01 February - Shift 2]

(a) $Li^+, Na^+, Mg^{2+}, Ca^{2+}$ (b) $Ba^{2+}, Sr^{2+}, K^+, Ca^{2+}$
(c) $N^{3-}, O^{2-}, F^-, S^{2-}$ (d) $K^+, Cl^-, Ca^{2+}, Sc^{3+}$

IV. Magnetic Moment:

53. Arrange the following metal complex/ compounds in the increasing order of spin only magnetic moment. Presume all the three, high spin system. (Atomic numbers Ce = 58, Gd = 64 and Eu = 63.) [JEE Mains 2021, 16 March (Shift 2)]

(A) $(NH_4)_2[Ce(NO_3)_6]$ (B) $Gd(NO_3)_3$ and (C) $Eu(NO_3)_3$

Answer is:

(a) (B) < (A) < (C) (b) (C) < (A) < (B)
(c) (A) < (B) < (C) (d) (A) < (C) < (B)

EXERCISE - 1KEY

1.	(b)	**2.**	(b)	**3.**	(b)	**4.**	(c)	**5.**	(b)
6.	(c)	**7.**	(d)	**8.**	(d)	**9.**	(b)	**10.**	(c)
11.	(d)	**12.**	(c)	**13.**	(c)	**14.**	(a)	**15.**	(d)
16.	(a)	**17.**	(d)	**18.**	(a)	**19.**	(a)	**20.**	(d)
21.	(b)	**22.**	(b)	**23.**	(b)	**24.**	(d)	**25.**	(a)
26.	(d)	**27.**	(a)	**28.**	(d)	**29.**	(a)	**30.**	(a)
31.	(a)	**32.**	(b)	**33.**	(a)	**34.**	(a)	**35.**	(a)
36.	(d)	**37.**	(d)	**38.**	(c)	**39.**	(b)	**40.**	(c)
41.	(b)	**42.**	(b)	**43.**	(b)	**44.**	(c)	**45.**	(d)
46.	(c)	**47.**	(a)	**48.**	(c)	**49.**	(b)	**50.**	(a)
51.	(a)	**52.**	(d)	**53.**	(d)				

SOLUTIONS

1. Statement b is Gaylussac's Law
2. (A) $V_e = 1000m/s; h = 6\times10^{-34} Js;$

   $m_e = 9\times10^{-31} kg$

   $$\lambda = \frac{h}{mv} = \frac{6\times10^{-34}}{9\times10^{-31}\times1000} = 666.67\times10^{-9} m$$

   = 666.67 nm

   (B) The characteristic of electrons emitted is independent of the material of the electrodes of the cathode ray tube.

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

   (D) The nature of the emitted electrons is independent on the nature of the gas present in cathode ray tube.
3. Conceptual
4. According to Henry Moseley $1\sqrt{v} = a(z-b)$

   So $n = \frac{1}{2}$
5. Explanation of variation of internal energy of Ar with temperature (Straight line and $U \propto T$) is not a direct manifestation of the quantum nature of atoms. While explanation of absorption spectrum, nature of emission of radiation from hot bodies (black body radiation) and photoelectric effect are direct manifestation of the quantum nature of atoms.
6. $K.E. = hv - hv_0$

   where, v = Frequency of incident radiation

   v_0 = Threshold frequency

   KE is independent of intensity, it depends on frequency of light. Intensity is directly proportional to the no. of electrons emitted.
7. Rutherford's experiment was actually $\alpha - particle$ scattering experiment. $\alpha - particle$ is doubly positively charged helium ion i.e., $He-$ nucleus.
8. As in Thomson model, protons are diffused (charge is not centred) α - particles deviate by small angles and due to repulsion from protons, their speed decreases.
9. (A) $Ke = -TE = 13.6\times\frac{z^2}{n^2} eV \quad KE \propto \frac{Z^2}{n^2}$

   (B) $V = 2.188\times10^6\times\frac{z}{n} m/\sec \quad So, Vn \propto Z$

   (C) Frequency $= \frac{v}{2\pi r}$

So, $F \propto \frac{Z^2}{n^3}$

$\left[\therefore r \propto \frac{n^2}{z} \text{ and } V \propto \frac{z}{n}\right]$

(D) Force $\propto \frac{z}{r^2}$

So, $F \propto \frac{z^3}{n^4}$

So, only statement (A) is correct

10. $v \propto \frac{Z}{n}; r \propto \frac{n^2}{Z};$

Frequency of revolution $= \frac{V_n}{2\pi r_n}$; Coulombic force of attraction $= \frac{Ze^2}{(4\pi\varepsilon_0)r^2}$

11. 1s orbital has least energy.
12. In the hydrogen spectrum, Balmer series lies in visible region.
13. For Balmer series $n_1 = 2$

Longest wave length $3 \to 2$

$\lambda \propto \frac{1}{E}$

14. Order of energy $\to$ Violet > Blue > Yellow > Red

Order of energy $\to E_{2\to 1} > E_{5\to 2} > E_{6\to 3} > E_{4\to 3}$

Violet $(2 \to 1)$, Blue $(5 \to 2)$, yellow $(6 \to 3)$, Red $(4 \to 3)$

15. In the given figure if line 'E' is in visible region then line belonging to ultraviolet region will have more energy than 'E' i.e. line A
16. $\frac{1}{\lambda} = R_H z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

For ionization energy, $n_1 = 1$ and $n_2 = \infty$

$\frac{1}{\lambda} = R_H$

$IE_1 = E_\infty - E_1 = \frac{hc}{\lambda} = R_H hc$

17. As we know

$\bar{v} = -R_H \left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) z^2$ (where, Z = 1)

After putting the values, we get

$\bar{v} = -R_H \left(\frac{1}{n^2} - \frac{1}{8^2}\right)$

$$\Rightarrow \bar{v} = \frac{R_H}{64} - \frac{R_H}{n^2}$$

Comparing to $y = mx + c$, we get

$x = \frac{1}{n^2}$ and $m = -R_H$ (slope)

18. $KE = \frac{1}{2}mv^2 = qV$

$$\lambda = \frac{h}{\sqrt{2qVm}}$$

19. $\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2mKE}}$

20. According to de-Broglie wavelength equation,

$$\lambda = \frac{h}{mv} \Rightarrow \lambda \propto \frac{1}{v}$$

According to photoelectric effect,

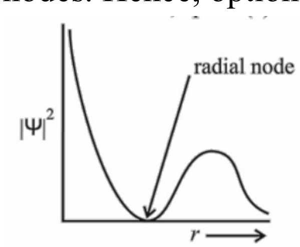
$$hv - hv_0 = \frac{1}{2}mv^2; v - v_0 = \frac{1}{2}\frac{mv^2}{h}$$

$$v - v_0 \propto v^2$$

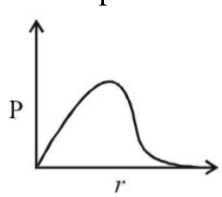
$$v \propto (v - v_0)^{1/2}$$

21. ϕ^2 (probability density) can be zero for 3p orbital other than infinite distance. It has one radial node.

22. The given probability density curve is for 2s orbital due to the presence of only one radial node. 1s and 2p orbital do not have any radial node and 3s orbital has two radial nodes. Hence, option (2) is correct.



23. For 2s, number of radial nodes = 2 - 0 - 1 = 1 and value of Ψ^2 is always positive.
24. Atomic orbital is characterised by n, *l*, m.
25. Probability of finding an electron will have maximum value at both ‘a’ and ‘c’. There is zero probability of finding an electron at ‘b’.
26. Radial probability function curve for $1s$ is (D). Here P is $4\pi r^2 R^2$.



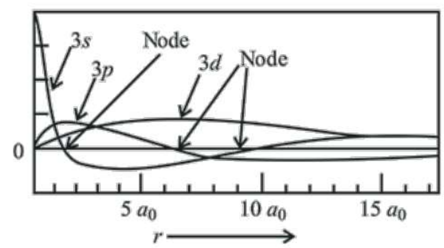
27. (a) Angular moment $(L) = \frac{nh}{2\pi}$

Therefore, the n increases, L also increases.

(b) $r \propto \frac{n^2}{z}$

(c) For $n = 1, L = \frac{h}{2\pi}$

(d) As l increases, the peak of Ψ vs r shifts towards higher 'r' value.



28. The total energy of the electron is minimum at a distance of a_0 from the nucleus for $1s$ orbital.

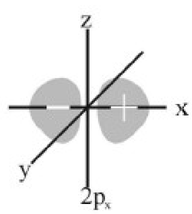
29. 3s orbital

Number of radial nodes $= n - \ell - 1$

For 3 s orbital $n = 3 \quad \ell = 0$

Number of radial nodes $= 3 - 0 - 1 = 2$. It is correctly represented in graph of option D

30. p_x orbital being dumbbell shaped, have number of nodal planes = 1, in *yz* plane.



31. A · N · = ℓ

R · N = n − ℓ − 1

Orbital	AngularNode	RadialNode
5 d	2	2
4f	3	0
3p	1	1
4 d	0	1

32. 1 = 0 ⇒ 's' orbital

n − 1 − 1 = 2

n − 1 = 2

n = 3

33. Number of radial nodes $= (n - l - 1)$

For $3s$: $n = 3, l = 0$ (number of radial node = 2)

For $2p: n = 2, l = 1$ (number of radial nod e= 0)

34. Radial node $= n - 1 - 1$
$= 4 - 2 - 1$
$= 1$
Angular node $(l) = 2$

35. The two guiding rules to arrange the various orbitals in the increasing energy are:
(i) Energy of an orbital increases with increase in the value of $n+l$.
(ii) Of orbitals having the same value of $n+l$, the orbital with lower value of n has lower energy.
Thus for the given orbitals, we have
$(i) n + l = 4 + 1 = 5 \quad (ii) n + l = 4 + 0 = 4 \quad (iii) n + l = 3 + 2 = 5 \quad (iv) n + l = 3 + 1 = 4$

36. The term spin implies that this magnetic moment is produced by the electron charge as the electron rotates about its own axis. Although this conveys a vivid mental picture of the source of the magnetism, the electron is not an extended body and its rotation is meaningless. Electron spin has no classical counterpart; the magnetic moment is a consequence of relativistic shifts in the local space and time due to the high effective velocity of the electron in the atom.

37. Under hypothetical situation, the value of I is greater than n which varies from 0 to $n+1$
n for n = 1, 1 = 0, 1, 2
n = 2, ℓ = 0, 1, 2, 3
Elements follow the following electronic configuration
1s1p1d2s2p2d2f
Atomic number (Z) = 9
$1s^2 1p^6 1d^1$
Atomic number 6
$1s^2 1p^4$
Atomic number 8
$1s^2 1p^6$
Atomic number 13
$1s^2 1p^6 1d^5$
Here atomic number of first noble gas will be 18

38. $n + \ell$
(I) $n = 4 \quad \ell = 2 \quad 4d \qquad 6$
(II) $n = 3 \quad \ell = 2 \quad 3d \qquad 5$
(III) $n = 4 \quad \ell = 1 \quad 4p \qquad 5$
(IV) $n = 3 \quad \ell = 1 \quad 3p \qquad 4$
The energy of an atomic orbital increases with increasing n + $n + \ell$. For identical values of $n + \ell$, energy increases with increasing n. Therefore, the correct order of energy is:
$3p < 3d < 4p < 4d$
IV II III I

39. Energy order of subshell decided by $(n+\lambda)$ rule.

$A \Rightarrow 3d \Rightarrow n+1=5$

$B \Rightarrow 4d \Rightarrow n+\lambda=5$

$C \Rightarrow 4d \Rightarrow n+\ell \Rightarrow 6$

$D \Rightarrow 3s \Rightarrow (n+\ell)=4$

D < A < B < C

40. for n = 5

$\ell = (0, 1, 2, 3, 4)$

If $\ell = 0$, m = 0

$\ell = 1$, m = {−1, 0, +1}

$\ell = 2$, m = {−2, −1, 0, +1, +2}

$\ell = 3$, m = {−3, −2, −1, 0, +1, +2, +3}

$\ell = 4$, m = {−4, −3, −2, −1, 0, +1, +2, +3, +4}

5 d, 5f and 5g subshell contain one-one orbital having $m_c = +2$

41. $Zn^+ = 1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} \underline{4s^1}$

For $4s$ electron m = 0

42. Based on "n + 1" rule only (B) has pair of electron in degenerate orbitals

43. Correct set $n > \ell \geq lm$

44. (A) Number of values of n = 1, 2, 3 ... ∞

(B) Number of values of $\ell = 0$ to (n - 1)

(C) Number of values of $m = -\ell$ to $+\ell$

Total values $= 2\ell + 1$

(D) Values of spin $= \pm\frac{1}{2}$

(E) For $\ell = 5$ number of orbitals $= 2\ell + 1 = 11$

45. (A) $Cr = [Ar]3d^5 4s^1$

(B) $m = -\ell$ to $+\ell$

(C) According to Aufbau principle, orbitals are filled in order of their increasing energies.

(D) Total nodes = n -1

46. $1 = 0, 1, 2 .... (n-1)$

$\therefore$ for $n = 3$

$1 = 0, 1, 2$

$\Rightarrow 1 = 3$

Not possible for $n = 3$

47. $(A) n + \ell = 3 + 0 = 3$

$(B) n + \ell = 4 + 0 = 4$

$(C) n + \ell = 3 + 1 = 4$

$(D) n + \ell = 3 + 2 = 5$

Higher $n+\ell$ value, higher the energy & if same $n+\ell$ value, then higher n value, higher the energy.

Thus D > B > C > A

48. As per Pauli Exclusion Principle "no two electrons in the same atom can have all the four quantum numbers equal or an orbital cannot contain more than two electrons and it can accommodate two electrons only when their directions of spins are opposite".

49. $3d^5 4s^2$ system is more stable than $3d^4 4s^2$, hence former is the ground state configuration.

50. Filling of electrons in orbitals in any period takes place as:

$ns, (n-2)\text{f}$

$(n-1)\text{d}$

if possible

$\therefore$ for sixth period n = 6

orbitals that are filled are 6s, 4f, 5d and 6p

51. ${}_{78}Pt = [Xe]4f^{14}5d^9 6s^1$ (exceptional electronic configuration)

52.

K^+	Cl^1	Ca^{2+}	Sc^{3+}
18	18	18	18

53. (a) $Ce \rightarrow [Xe]4f^2 5d^0 6s^2$

In complex $Ce^{4+} \rightarrow [Xe]4f^0 5d^0 6s^0$

There is no unpaired electron so $\mu_m = 0$

(b) ${}_{64}Gd^{3+} \rightarrow [Xe]4f^7 5d^0 6s^0$

Contain seven unpaired electrons so $\mu_m = \sqrt{7(7+2)} = \sqrt{63} B.M.$

(c) ${}_{63}Eu^{3+} \rightarrow [{}_{54}Xe]4f^6 5d^0 6s^0$

Contain six unpaired electron

So, $\mu_m = \sqrt{6(6+2)} = \sqrt{48} B.M.$

Hence, order of spin only magnetic movement

(A) < (C) < (B)

EXERCISE - 2

I. Subatomic Particles (Electron, Proton and Neutron):

1. Consider an imaginary ion $^{48}_{22}X^{3-}$. The nucleus contains 'a'% more neutrons than the number of electrons in the ion. The value of 'a' is … (nearest integer)
[JEE Mains 2022, 26 July Shift 2]

2. Given that the abundances of isotopes $^{54}Fe, ^{56}Fe$ and ^{57}Fe are 5%, 90% and 5% respectively, the atomic mass of Fe is [2009S]
(a) 55.85 (b) 55.95 (c) 55.75 (d) 56.05

II. Black Body Radiation, Planck's Quantum Theory, Photoelectric Effect:

3. A 50watt bult emits monochromatic red light of wavelength of 795 nm. The number of photons emitted per second by the bulb is $x \times 10^{20}$. The value of x is …..
[Given: $h = 6.63 \times 10^{-34} Js$ and $c = 3.0 \times 10^{8} ms^{-1}$]
[Jee Mains 2021 (01 Sep Shift 2)]

4. The number of photons emitted by a monochromatic (single frequency) infrared range finder of power 1 mW and wavelength of 1000 nm, in 0.1 second is $x \times 10^{13}$. The value of x is ….(Nearest integer)
$\left(h = 6.63 \times 10^{-34} Js, C = 3.00 \times 10^{8} ms^{-1}\right)$ [JEE Mains 2021 (27 Aug Shift 2)]

5. Photon having wavelength 310 nm is used to break the bond of A_2 molecule having bond energy $288\, kg\, mol^{-1}$ then % of energy of photon converted to the K.E. is [hc = 12400 evÅ , 1 ev = 96 kJ/mol]
(a) 25 (b) 50 (c) 75 (d) 80

6. The work function (ϕ) of some metals is listed below. The number of metals which will show photoelectric effect when light of 300 nm wavelength falls on the metal is [2011]

Metal	Li	Na	K	Mg	Cu	Ag	Fe	Pt	W
$\phi(eV)$	2.4	2.3	2.2	3.7	4.8	4.3	4.7	6.3	4.75

7. The work function of sodium metal is $4.41 \times 10^{-19} J$. If photons of wavelength 300 nm are incident on the metal, the kinetic energy of the ejected electrons will be $(h = 6.63 \times 10^{-34} Js; c = 3 \times 10^{8} m/s)$_______$\times 10^{-21} J$
[JEE Mains 2020, 2 September, Evening]

8. What is the work function of the metal if the light of wavelength $4000 A^o$ generates photoelectrons of velocity $6\times10^5 ms^{-1}$ from it?

[JEE Mains 2019, 12 January, Morning]

(Mass of electron $=9\times10^{-31}kg$

Velocity of electron $=3\times10^8 ms^{-1}$

Planck's constant = $=6.626\times10^{-34} Js$

Charge of electron $=1.6\times10^{-19} JeV^{-1}$)

(a) 0.9 eV (b) 3.1 eV (c) 2.1 eV (d) 4.0 eV

9. If p is the momentum of the fastest electron ejected from a metal surface after the irradiation of light having wavelength λ , then for $1.5p$ momentum of the photoelectron, the wavelength of the light should be:
(Assume kinetic energy of ejected photoelectron to be very high in comparison to work function): [JEE Mains 2019, 8 April Evening]

(a) $\frac{3}{4}\lambda$ (b) $\frac{1}{2}\lambda$ (c) $\frac{2}{3}\lambda$ (d) $\frac{4}{9}\lambda$

10. Electromagnetic radiation of wavelength 663 nm is just sufficient to ionize the atom of metal A. The ionization energy of metal A in $kJ mol^{-1}$ is …. (Rounded off to the nearest integer) [JEE Mains 2021, 25 Feb (Shift 2)]

$\left[h = 6.63\times10^{-34} Js, C = 3.00\times10^8 ms^{-1}, N_A = 6.02\times10^{23} mol^{-1}\right]$

11. When light of wavelength 248 nm falls on a metal of threshold energy 3.0eV, the de-Broglie wavelength of emitted electrons is … $\backslash A^o$. (Round off to the Nearest Integer).

[Use: $\sqrt{3}=1.73, h = 6.63\times10^{-34} Js$

$m_e = 9.1\times10^{-31} kg; c = 3.0\times10^8 ms^{-1}$

$leV = 1.6\times10^{-19} J$] [JEE Mains 2021, 16 March (Shift 1)]

12. A metal surface is exposed to 500 nm radiation. The threshold frequency of the metal for photoelectric current is $4.3\times10^{14} Hz$. The velocity of ejected electron is ____ $\times10^5 ms^{-1}$ (Nearest integer) [Use : $h = 6.63\times10^{-34} Js, m_e = 9.0\times10^{-31} kg$]

[JEE Mains 2021 (26 Aug Shift 2)]

13. A source of monochromatic radiation of wavelength 400 nm provides 1000 J of energy in 10 seconds. When this radiation falls on the surface of sodium, $x\times10^{20}$ electrons are ejected per second. Assume that wavelength 400 nm is sufficient for ejection of electron from the surface of sodium metal. The value of x is ….. (nearest integer)

$\left(h = 6.626\times10^{-34} Js\right)$ [JEE Mains (25 July 2021 Shift 1)]

14. The energy of one mole of photons of radiation of wavelength 300 nm is

(Given : $h = 6.63 \times 10^{-34} Js,\ N_A = 6.02 \times 10^{23} mol^{-1},\ c = 3 \times 10^8 ms^{-1}$)

[JEE Mains 2022 24 June - Shift 2]

(a) $225 kJ\,mol^{-1}$ (b) $325\,kJ\,mol^{-1}$ (c) $399\,kJ\,mol^{-1}$ (d) $435\,kJ\,mol^{-1}$

15. The minimum energy that must be possessed by photons in order to produce the photoelectric effect with platinum metal is:

[Given: The threshold frequency of platinum is $.3 \times 10^{15} s^{-1}$ and $h = 6.6 \times 10^{-34} Js$]

(a) $3.21 \times 10^{-14} J$ (b) $6.24 \times 10^{-16} J$ (c) $8.58 \times 10^{-19} J$ (d) $9.76 \times 10^{-20} J$

16. If the work function of a metal is $6.63 \times 10^{-19} J$, the maximum wavelength of the photon required to remove a photoelectron from the metal is ________ nm. (Nearest integer)

[Given : $h = 6.63 \times 10^{-34} Js,$ and $c = 3 \times 10^8 ms^{-1}$]

[JEE Mains 2022, - 28 June - Shift 1]

17. The energy of one mole of photons of radiation of frequency $2 \times 10^{12} Hz$ in $J\,mol^{-1}$ is ________ (Nearest integer) [JEE Mains 2023, 30 January - Shift I]

(Given: $h = 6.626 \times 10^{-34} Js; N_A = 6.022 \times 10^{23} mol^{-1}$)

18. The work function (Φ) of some metals is listed below. The number of metals which will show photoelectric effect when light of 300nm wavelength fails on the metal is [2011]

Metal	$\Phi(eV)$
Li	2.4
Na	2.3
K	2.2
Mg	3.7
Cu	4.8
Ag	4.3
Fe	4.7
Pt	6.3
W	4.75

19. Photons of minimum energy $496 k.J.mol^{-1}$ are needed to ionize sodium atoms. Calculate the lowest frequency of light that will ionize a sodium atom.

(a) $1.24 \times 10^{14} s^{-1}$ (b) $1.24 \times 10^{15} s^{-1}$ (c) $2.48 \times 10^{15} s^{-1}$ (d) $2.48 \times 10^{14} s^{-1}$

20. If the wavelength for an electron emitted from H-atom is $3.3 \times 10^{-10} m$, then energy absorbed by the electron in its ground state compared to minimum energy required for its escape from the atom, is ______ times. (Nearest integer).

(Given: $h = 6.626 \times 10^{-34} Js$; Mass of electron $= 9.1 \times 10^{-31}$)

[JEE Mains 2022, 28 July - Shift 2]

III. Classical Atomic Models (Thomson's Atomic Model, Rutherford's Model of Atom and Bohr's Model):

21. The radius of the second Bohr orbit, in terms of the Bohr radius, a_0, in Li^{2+} is [JEE Mains 2020, 8 January, Evening]

(a) $\frac{3a_0}{4}$ (b) $\frac{4a_0}{3}$ (c) $\frac{a_0}{3}$ (d) $\frac{16a_0}{9}$

22. The radius of which of the following orbit is same as that of the first Bohr's orbit of hydrogen atom? [2004S]

(a) $He^{+}(n=2)$ (b) $Li^{2+}(n=2)$ (c) $Li^{2+}(n=3)$ (d) $Be^{3+}(n=2)$

23. According to Bohr's theory, the ratio of electrostatic force of attraction acting on electron in 3rd orbit of He^{+} ion and 2nd orbit of Li^{2+} ion is $\left(\frac{3}{2}\right)^x$. The, the value of x is :

(a) 7 (b) -6 (c) 6 (d) -7

24. If the radius of the 3rd Bohr's orbit of hydrogen atom is r_3 and the radius of 4th Bohr's orbit is r_4. Then: [JEE Mains 2022, 25 June - Shift 2]

(a) $r_4=\frac{9}{16}r_3$ (b) $r_4=\frac{16}{9}r_3$ (c) $r_4=\frac{3}{4}r_3$ (d) $r_4=\frac{4}{3}r_3$

25. The radius of the 2nd orbit of Li^{2+} is x. The expected radius of the 3rd orbit of Be^{3+} is [JEE Mains 2023, 25 January – Shift 1]

(a) $\frac{9}{4}x$ (b) $\frac{4}{9}x$ (c) $\frac{27}{16}x$ (d) $\frac{16}{27}x$

26. The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is equal to $\frac{h^2}{xma_0^2}$. The value of 10x is … (a_0 is radius of Bohr's orbit) (Nearest integer) [Given : π = 3.14] [JEE Mains2021 (27 Aug Shift 1)]

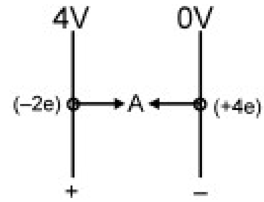
27. The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is [a_0 is Bohr radius] [2012]

(a) $\frac{h^2}{4\pi^2 ma_0^2}$ (b) $\frac{h^2}{16\pi^2 ma_0^2}$ (c) $\frac{h^2}{32\pi^2 ma_0^2}$ (d) $\frac{h^2}{64\pi^2 ma_0^2}$

28. What is the potential energy of an electron present in N-shell of the Be^{3+} ion?

(a) –3.4 eV (b) –27.2 eV (c) –13.6 eV (d) –6.8 eV

29. In the assembly as shown below, the potential difference across the plates is 4 volts. A positive particle of charge +4e is projected from the negative plate with an initial kinetic energy of 4eV and the negative particle of charge (–2e) is projected from the positive plate. Both the particles reach point 'A' with zero kinetic energy. The initial kinetic energy of the negative particle in eV.



30. What is the frequency of revolution of electron present in 2nd Bohr's orbit of H-atom ?
(a) $1.016\times10^{16}s^{-1}$ (b) $4.065\times10^{16}s^{-1}$ (c) $1.626\times10^{16}s^{-1}$ (d) $8.13\times10^{16}s^{-1}$

31. 1^{st} excitation Potential of a hydrogen like sample is 15 volt. If all the atoms of the sample are in 2^{nd} excited state then find the K.E. in eV of the electron ejected if a photon of energy $\frac{65}{9}eV$ is supplied to this sample.
(a) 5 (b) 2 (c) 6 (d) 4

32. If in Bohr's model, for unielectronic atom, time period of revolution is represented as $T_{n,z}$ where n represents shell no. and Z represents atomic number then the value of $T_{1,2} : T_{2,1}$ will be :
(a) 8 : 1 (b) 1 : 8 (c) 1 : 1 (d) 1 : 32

IV. Hydrogen Spectrum and Spectra of Single Electron Species:

33. For any given series of spectral lines of atomic hydrogen, let $\bar{v} = \bar{v}_{max}$ fl $\bar{v}_{min}$ be the difference in maximum and minimum frequencies in cm^{-1}. The ratio $\Delta\bar{v}_{Lyman} / \Delta\bar{v}_{Balmer}$ is: [JEE Mains 2019, 9 April, Morning]
(a) 4 : 1 (b) 9 : 4 (c) 5 : 4 (d) 27 : 5

34. The ratio of the wave number corresponding to the 1^{st} line of Lyman series of H-atom and 3^{rd} line of Paschen series of a hydrogen like sample is 9 : 16. Then find the third excitation potential in terms of volt for this H-like samples.
(a) 210 (b) 204 (c) 100 (d) 300

35. Wavelength of high energy transition of H-atoms is 91.2 nm. The corresponding wavelength of He atoms (in nm)

36. The shortest wavelength of H atom in the Lyman series is λ_1. The longest wavelength in Bamar series of He^+ is [JEE Mains 2020, 4 September, Evening]
(a) $\frac{5\lambda_1}{9}$ (b) $\frac{36\lambda_1}{5}$ (c) $\frac{27\lambda_1}{5}$ (d) $\frac{9\lambda_1}{5}$

37. A hydrogen like atom (atomic number Z) is in a higher excited state of quantum number n. This excited atom can make a transition to the first excited state by successively emitting two photons of energies 10.20 eV and 17.00 eV respectively. Alternatively, the atom from the same excited state can make a transition to the second excited state by successively emitting two photons of energy 4.25 eV and 5.95 eV respectively. Determine the values of n and Z (ionisation energy of hydrogen atom = 13.6 eV). Give your answer as (Z + n)

38. In a sample of hydrogen atom in ground state electrons make transition from ground state to a particular excited state where path length is five times de-Broglie wavelength, electrons make back transition to the ground state producing all possible photons. If photon having 2nd highest energy of this sample used to excite the electron in a particular excited state of Li^{2+} ion then find the final excited state of Li^{2+} ion.

39. Electrons in a sample of H–atoms make transitions from state n = x to some lower excited state. The emission spectrum from the sample is found to contain only the lines belonging to a particular series. If one of the photons had an energy of 0.6375 eV. Then find the value of x. $\left[Take\,0.6375\,eV = \frac{3}{4} \times 0.85\,eV\right]$

40. Electrons in a sample of H–atoms make transitions from state n = x to some lower excited state. The emission spectrum from the sample is found to contain only the lines belonging to a particular series. If one of the photons had an energy of 0.6375 eV. Then find the value of x. $\left[\text{Take } 0.6375\,\text{eV} = \frac{3}{4} \times 085\text{ eV}\right]$

(a) 16 (b) 24 (c) 8 (d) 20

41. Heat treatment of muscular pain involves radiation of wavelength of about 900 nm. Which spectral line of H-atom is suitable for this purpose?

[JEE mains 2019, 11 January, Morning]

$\left[R_H = 1\times10^5 cm^{-1}. h = 6.6\times10^{-34} Js, c = 3\times10^8 ms^{-1}\right]$

(a) Paschen, $\infty \to 3$ (b) Paschen, $5 \to 3$
(c) Balmer, $\infty \to 2$ (d) Lyman, $\infty \to 1$

42. The ratio of the shortest wavelength of two spectral series of hydrogen spectrum is found to be about 9. The spectral series are [JEE Mains 2019, 10 April, Evening]

(a) Lyman and Paschen (b) Balmer and Brackett
(c) Brackett and Pfund (d) Paschen and Pfund

43. If wavelength of the fist line of the Paschen series of hydrogen atom is 720 nm, then the wavelength of the second line of this series is ….. nm. (Nearest integer)

[JEE Mains 2023, 24 January – Shift 1]

44. The shortest wavelength of hydrogen atom in Lyman series is λ. The longest wavelength in Balmer series of He^+ is [JEE Mains 2023 29 January - Shift 1]

(a) $\frac{5}{9\lambda}$ (b) $\frac{9\lambda}{5}$ (c) $\frac{36\lambda}{5}$ (d) $\frac{5\lambda}{9}$

45. Which transition in the hydrogen spectrum would have the same wavelength as the Balmer type transition from n=4 to n = 2 of He spectrum

[JEE Mains 2023, 31 January - Shift 1]

(a) n = 2 to n = 1 (b) n = 1 to n = 3 (c) n = 1 to n = 2 (d) n = 3 to n = 4

46. For He^+, a transition takes place from the orbit of radius 105.8 pm to the orbit of radius 26.45 pm. The wavelength (in nm) of the emitted photon during the transition is…..

$\left(\frac{1}{R_H} = 912A^o\right)$

47. If n n_1 and n_2 are the boundary value principal quantum numbers of a portion of spectrum of emission spectrum of H atom, determine the wavelength (in metre) corresponding to last line (longest λ). Given :
$n_1 + n_2 = 7, n_2 - n_1 = 3$ and $R_H = 1.097 \times 10^7 m^{-1}$. (Give you answer in multiple of 10^{-6})
(a) 8 (b) 4 (c) 10 (d) 15

48. In the emission spectrum of H-atom from energy level 'n' to ground state in one or more step, no line belonging to the Brackett series is observed. The wave number of lines belonging to Balmer series may be
(a) $\frac{8R}{9}, \frac{5R}{36}$ (b) $\frac{3R}{16}, \frac{8R}{9}$ (c) $\frac{5R}{36}, \frac{3R}{16}$ (d) $\frac{3R}{4}, \frac{3R}{16}$

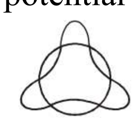
49. The ground state energy of hydrogen atom is -13.6 eV. The energy of second excited state of He^+ ion in eV is : [JEE Mains 2019, 10 January, Evening[
(a) -54.4 (b) -3.4 (c) -6.04 (d) -27.2

50. Calculate the energy required to excite one litre of hydrogen gas at 1 atm and 298 K to the first excited state of atomic hydrogen. The energy for the dissociation of H-H bond is $436 kJ\, mol^{-1}$ …. (kJ) [2000 – 4 Marks]

V. de-Broglie's Concept:

51. The wavelength of an electron and a neutron will become equal when the velocity of the electron is x times the velocity of neutron. The value of x is …. (nearest integer) [JEE Mains 2022, 26 July Shift 1]

52. The wave motion of electron in a Bohr's orbit of hydrogen is as shown in diagram. The potential energy of electron in the given orbit of hydrogen atom is :



(a) –3.4 eV (b) + 3.4 eV (c) –3.02 eV (d) –1.51 eV

53. The wavelength associated with a golf ball weighing 200g and moving at a speed of 5 m/h is of the order
(a) $10^{-10} m$ (b) $10^{-20} m$ (c) $10^{-30} m$ (d) $10^{-40} m$

54. A ball of mass 100 g is moving with $100\, ms^{-1}$. Its de Broglie's wavelength is $x \times 10^{-25}$ A^0 then x is ______ (given h = 6×10^{-34})

55. The orbital angular momentum of $2p$ orbital of hydrogen atom is $\sqrt{n} \times \frac{h}{2\pi}$ then 'n' is ______

56. The atomic masses of 'He' and 'Ne' are 4 and 20 a.m.u., respectively. The value of the de Broglie wavelength of 'He' ga at -73°C is 'M' times that of the de Broglie wavelength of 'Ne' at 727°C 'M is…. [JEE Adv.2013]

57. Determine wavelength of electron in 4th Bohr's orbit? [JEE Mains 2020, Jan]

(a) $4\pi a_0$ (b) $2\pi a_0$ (c) $8\pi a_0$ (d) $6\pi a_0$

58. A proton and a Li^{3+} nucleus are accelerated by the same potential. If λ_{Li} and λ_p denote the de Broglie wavelengths of Li^{3+} and proton respectively, then the value of $\frac{\lambda_{Li}}{\lambda_p}$ is $x \times 10^{-1}$. The value of x is ….

[Rounded off to the nearest integer] [Mass of $Li^{3+} = 8.3$ mass of proton]

[JEE Mains 2021, 24 Feb (Shift 1)]

59. The wavelength of electrons accelerated from rest through a potential difference of 40 kV is $x \times 10^{-12} m$. The Value of x is .. .(Nearest integer)

[JEE mains (20 July 2021 Shift 2)]

Given: Mass of electron $= 9.1 \times 10^{-31} kg$

Charge on an electron $= 1.6 \times 10^{-19} C$

Plank's constant $= 6.63 \times 10^{-34} Js$

60. If the de Broglie wavelength of the electron in nth Bohr orbit in a hydrogenic atom is equal to $1.5\pi a_0$ (a_0 is Bohr radius), then the value of n/z is :

(a) 0.40 (b) 1.50 (c) 1.0 (d) 0.75

VI. Heisenberg's Uncertainty Principle:

61. A ball weighing 10 g is moving with a velocity of $90 ms^{-1}$. If the uncertainty in its velocity of 5%, then the uncertainty in its position is …… $\times 10^{-33} m$. (Rounded off to the nearest integer) [Given : $h = 6.63 \times 10^{-34} Js$] [JEE Mains 2021, 26 Feb (Shift 2)]

62. An accelerated electron has a speed of $5 \times 10^6 ms^{-1}$ with an uncertainty of 0.02%. The uncertainty in finding its location while in motion is x x i0 m. The value of x is. (Nearest integer) [Use mass of electron $= 9.1 \times 10^{-31} kg$, $h = 6.63 \times 10^{-34} Js, \pi = 3.14$]

[JEE Mains (25 July 2021 Shift 2)]

63. If the uncertainty in velocity and position of a minute particle in space are, $2.4 \times 10^{-26} \left(ms^{-1}\right)$ and $10^{-7} (m)$) respectively. The mass of the particle of g is ___________ (Nearest integer) (Given : $h = 6.626 \times 10^{-34} Js$)

[JEE Mains 2022, 27 June - Shift I]

64. The minimum uncertainty in the speed of an electron in an one dimensional region of length $2a_0$ (Where a_0 = Bohr radius 52.9 pm) is _____ $km\, s^{-1}$ (Given: Mass of electron $= 9.1 \times 10^{-31} kg$, Planck's constant $h = 6.63 \times 10^{-34} Js$) [JEE Mains 2022, 29 July,Shift 1]

VII. Quantum Mechanical Model of Atom (Schrodinger's Wave Equation, Wave Function, Probability Density, Radial Probability):

65. The wave function (Ψ) of 2s is given by $\Psi_{2x} = \frac{1}{2\sqrt{2\pi}}\left(\frac{1}{a_0}\right)^{1/2}\left(2-\frac{r}{a_0}\right)e^{-r/2a_0}$

At $r = r_0$, radial node is formed. Thus, r_0 in terms of a_0

[JEE Mains 2023, 30 January - Shift 2]

(a) $r_0 = a_0$ (b) $r_0 = 4a_0$ (c) $r_0 = \frac{a_0}{2}$ (d) $r_0 = 2a_0$

VIII. Radial and Angular Nodes:

66. A certain orbital has $n=4$ and $m_L = -3$. The number of radial nodes in this orbital is ____ (Round off to the Nearest Integer) [JEE Mains 2021, 17 March (Shift 1)]

67. The maximum number of electrons that can have principal quantum number, $n=3$, and spin quantum $m_s = -\frac{1}{2}$, is [2011]

68. In an atom, the total number of electrons having quantum numbers $n=4, |m_1| = 1$ and $m_s = -\frac{1}{2}$ is [JEE Adv.2014]

69. $n=5, m_s = +\frac{1}{2}$. How many orbitals are possible? [JEE Mains 2020, Jan]

(a) 25 (b) 30 (c) 50 (d) 35

70. The number of subshells associated with $n=4$ and $m = -2$ quantum numbers is

[JEE Mains 2020 – 2 September, Evening]

(a) 2 (b) 8 (c) 4 (d) 16

71. The number of orbitals associated with quantum number $n=5, m_s = +\frac{1}{2}$

[JEE Mains 2020, 7 January, Morning]

(a) 25 (b) 30 (c) 50 (d) 35

IX. Quantum Numbers and Electronic Configurations of Elements:

72. $Ge(Z=32)$ in its ground state electronic configuration has x completely filled orbitals with $m_l = 0$. The value of x is ____. [JEE Mains 2021 (31 Aug Shift 1)

73. The Azimuthal quantum number for the valence electrons of Ga^+ ion is ___(Atomic number of Ga = 31) [JEE Mains (20 July 2021 Shift 1)]

74. The maximum number of electrons that can have principal quantum number, n = 3, and spin quantum number, $m_s = -\frac{1}{2}$ is [2011]

75. In an atom, the total number of electrons having quantum numbers $n=4, |m_1| = 1$ and $m_s = -1/2$ is [2014]

76. Not considering the electronic spin, the degeneracy of the second excited state (n = 3) of H atom is 9, while the degeneracy of the second excited state of H^{-} is

[JEE Adv.2015]

77. The number of s-electrons present in an ion with 55 protons in its unipositive state is

[JEE Mains 2023, 24 January – Shift 2]

(a) 8 (b) 9 (c) 12 (d) 10

78. Maximum number of electrons that can be accommodated in shell with n = 4 are:

[JEE Mains 2023, 30 January - Shift 2]

(a) 16 (b)32 (c)50 (d)72

X. Magnetic Moment:

79. What is the spin-only magnetic moment value (BM) of a divalent metal ion with atomic number 25 in it's aqueous solution? [JEE Mains 2021, 17 March (Shift 1)]

(a) 5.92 (b) 5 (c) Zero (d) 5.26

80. In the ground state of atomic $Fe(Z=26)$, the spin-only magnetic moment is ____$\times 10^{-1} BM$. (Round off to the Nearest Integer).

$\left[\text{Given}: \sqrt{3}=1.75, \sqrt{2}=1.41\right]$ [JEE Mains 2021, 17 March (Shift 2)]

81. The spin only magnetic moments (in BM) for free Ti^{3+}, V^{2+} and Sc^{3+} ions respectively are (At.No.Sc:21,Ti:22, V:23) [JEE Mains (25 July 2021 Shift 2)]

(a) 3.87, 1.73,0 (b) 1.73, 3.87,0 (c) 1.73, 0, 3.87 (d) 0,3.87, 1.73

82. Spin only magnetic moment of ${}_{25}Mn^{x+}$ ion is $\sqrt{15}$ B.M. Then, the value of x is :

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

EXERCISE – 2 KEY

1.	4	**2.**	(b)	**3.**	2	**4.**	50	**5.**	(a)
6.	4	**7.**	222	**8.**	(c)	**9.**	(d)	**10.**	180
11.	9	**12.**	5	**13.**	2	**14.**	(c)	**15.**	(c)
16.	300	**17.**	798	**18.**	4	**19.**	(b)	**20.**	2
21.	(b)	**22.**	(d)	**23.**	(d)	**24.**	(b)	**25.**	(c)
26.	3155	**27.**	(c)	**28.**	(b)	**29.**	6	**30.**	(d)
31.	(a)	**32.**	(d)	**33.**	(b)	**34.**	(b)	**35.**	22.8
36.	(d)	**37.**	9	**38.**	12	**39.**	8	**40.**	(c)
41.	(a)	**42.**	(a)	**43.**	492	**44.**	(b)	**45.**	(a)
46.	243.2	**47.**	(b)	**48.**	(c)	**49.**	(c)	**50.**	98.17
51.	1758	**52.**	(c)	**53.**	(a)	**54.**	6	**55.**	2
56.	5	**57.**	(c)	**58.**	2	**59.**	6	**60.**	(d)
61.	1	**62.**	58	**63.**	22	**64.**	548	**65.**	(d)
66.	0	**67.**	9	**68.**	6	**69.**	(a)	**70.**	(b)
71.	(a)	**72.**	7	**73.**	0	**74.**	9	**75.**	6
76.	3	**77.**	(d)	**78.**	(b)	**79.**	(a)	**80.**	49
81.	(b)	**82.**	(d)						

EXERCISE – 2 SOLUTIONS

1. $^{48}_{22}X^{3-}$

No. of neutrons =26

No. of electrons = 25

% of extra neutrons than electrons $=\frac{26-25}{25}\times 100=4$

2. Average atomic mass of $Fe=\frac{(54\times 5)+(56\times 90)+(57\times 5)}{100}=55.95$

3. $E=nhv=\frac{nhc}{\lambda}$

$\Rightarrow n=\frac{E\lambda}{hc}=\frac{50\times 79s\times 10^{-9}}{6.63\times 10^{34}\times 3\times 10^{8}}=2\times 10^{20}$

4. $E=\frac{nhc}{\lambda}$

$\Rightarrow n=\frac{E\lambda}{hc}=\frac{(10^{-6}\times 0.1)(1000\times 10^{-9})}{6.63\times 10^{-34}\times 3\times 10^{8}}$

$=50kt10^{13}$

5. Energy of one photon $=\frac{12400}{3100}=4eV=4\times 96=384\,kJ\,mol^{-1}$

% of energy converted to K.E. $=\frac{384-288}{384}=\frac{96}{384}\times 100=25\%$

6. Energy associated with incident photon $=\frac{hc}{\lambda}$

$E=\frac{6.6\times 10^{-34}\times 3\times 10^{8}}{300\times 10^{-9}}J$

$=\frac{6.6\times 10^{-34}\times 3\times 10^{8}}{300\times 10^{-9}\times 1.6\times 10^{-19}}eV=4.16eV$

Photoelectric effect can take place only when $E_{photon}>\phi$.

Thus, number of metals showing photoelectric effect will be 4 (ie. Li, Na, K and Mg)

7. w = work function of sodium metal

$=4.41\times 10^{-19}J$

λ , wavelength of incident light = 300 nm

$=3\times 10^{-7}m$

According to photoelectric effect

$\frac{hc}{\lambda}=w+KE$

$$\frac{6.63\times10^{34}\times3\times10^{8}}{3\times10^{-7}}=4.41\times10^{-19}+KE$$

$$6.63\times10^{-19}=4.41\times10^{-19}+KE$$

$$KE=2.22\times10^{-19}J=222\times10^{-21}J$$

8. $E=h\nu=\frac{hc}{\lambda}$

$$E=\frac{6.626\times10^{-34}\times3\times10^{8}}{4000\times10^{-10}\times1.6\times10^{-19}}=3.1\,eV$$

$$KE=\frac{1}{2}mv^{2}=\frac{1}{2}\times9\times10^{-31}\times36\times10^{10}J$$

$$=1.62\times10^{-19}J$$

$$=1\,eV$$

According to photoelectric effect,

$$K.E.=h\nu-h\nu_{0}$$

$$h\nu_{0}=h\nu-K.E.$$

Work function $(W_{0})=E-K.E.$

$$=3.1-1=2.1\,eV$$

9. In photoelectric effect,

$\frac{hc}{\lambda}=w+KE$ of electron

Given that KE of ejected photoelectron is very high in comparison to work function w.

$$\frac{hc}{\lambda}=KE\Rightarrow\frac{hc}{\lambda}=\frac{p^{2}}{2m}$$

New wavelength

$$\frac{hc}{\lambda_{1}}=\frac{(1.5P)^{2}}{2m}\Rightarrow\lambda_{1}=\frac{4}{9}\lambda$$

10. Energy req. to ionize an atom of metal $'A'=\frac{hc}{\lambda}=\frac{hc}{663nm}$ for 1 mole atoms of ‘A’ Total energy required = $N_{A}\times\frac{hc}{\lambda}$

$$=\frac{6.023\times10^{23}\times6.63\times10^{-34}\times3\times10^{8}}{663\times10^{-9}}$$

$$=6.023\times3\times10^{23-34+8+7}$$

$$=180.4KJ/mol$$

Nearest Integer = 180 KJ / mol

11. Energy $= \frac{hc}{\lambda}$

$$\frac{6.63\times10^{-34}\times3.0\times10^{8}}{248\times10^{-9}\times1.6\times10^{-19}}eV$$

$$\frac{6.63\times3\times100}{248\times1.6}$$

$$=0.05eV\times100=5eV$$

Now, using $E=\phi+K.E.$

$$K.E.=2eV=3.2\times10^{-19}J$$

for De Broglie wavelength $\lambda=\frac{h}{mv}$

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

$$so\, v=\sqrt{\frac{2KE}{m}}$$

$$\text{hence } \lambda=\frac{j}{\sqrt{2KE\times m}}$$

$$=\frac{6.63\times10^{-34}}{\sqrt{2\times3.2\times10^{-19}\times9.1\times10^{-31}}}$$

$$=\frac{6.63}{7.6}\times\frac{10^{-34}}{10^{-25}}=\frac{66.3\times10^{-10}m}{7.6}$$

$$=8.72\times10^{-10}m$$

$$\approx9\times10^{-10}m$$

$$=9\setminus A^{o}$$

12. $\frac{hc}{\lambda}=hv_0+\frac{1}{2}mv^2$

$$\Rightarrow v=\sqrt{\frac{2}{m}\left(\frac{hc}{\lambda}-hv_0\right)}$$

13. Total energy provided by Source per second $=\frac{1000}{10}=100J$

Energy required to eject electron $=\frac{hc}{\lambda}$

$$=\frac{6.626\times10^{-34}}{400\times10^{-9}\times3\times10^{8}}$$

Number of electrons ejected

$$= \frac{400 \times 10^{-7} \times 10^{26}}{6.626 \times 3}$$

$$= \frac{40 \times 10^{-20}}{6.626 \times 3}$$

$$= 2.01 \times 10^{20}$$

14. Energy of one mole of photons $= \frac{hc}{\lambda} \times N_A$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{300 \times 10^{-9}} \times 6.02 \times 10^{23}$$

$= 399.13 \times 10^{3}$ Joule/mole

=339kJ/mole

15. $W = hv$

$$= 6.6t \times 10^{-34} \times 1.3 \times 10^{15}$$

$$= 8.58 \times 10^{-19} J$$

16. $\phi = 6.63 \times 10^{-19} J = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{\lambda}$

$$\Rightarrow \lambda = 3 \times 10^{-7} m = 300 nm$$

17. For one photon E hv

For one mole photon,

$$E = 6.026 \times 10^{23} \times 6.626 \times 10^{-34} \times 2 \times 10^{12}$$

$$= 798.16 J$$

$$\approx 798 J$$

18. Energy of photon $= \frac{hc}{\lambda} J = \frac{hc}{e\lambda} eV$

$$= \frac{6.625 \times 10^{-34} \times 3 \times 10^{8}}{300 \times 10^{-9} \times 1.602 \times 10^{-19}} = 4.14 eV$$

For photoelectric effect to occur, energy of incident photons must be greater than work function of metal. Hence only Li, Na, K and Mg have work functions less than 4.14V.

19. $Na(g) + 496\, kJ\, mol^{-1} \rightarrow Na^{+}(g)$

For one photon: $E = \frac{496\, kJ\, mol^{-1}}{N_A\, mol^{-1}} = hv$

$$v = \frac{\left(496\, kJ\, mol^{-1}\right)\left(\frac{10^{3} J}{1 kJ}\right)}{\left(6.63 \times 10^{-34}\, Js\right)\left(6.022 \times 10^{23}\, mol^{-1}\right)} = 1.24 \times 10^{15} s^{-1} (Hz)$$

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

$$K=\frac{h^2}{2m\lambda^2}$$

$$K=\frac{h_2}{2m\lambda^2}=\frac{43.9\times10^{-68}}{2\times9.1\times10^{-31}\times10.89\times10^{-20}}$$

$$K=2.215\times10^{-18}$$

$$E_{abs}=E_{req+}K$$

$$\frac{E_{abs}}{E_{req}}=1+\frac{K}{E_{req}}=1+\frac{2.215\times10^{-18}}{13.6\times1.602\times10^{-19}}=2.0166$$

21. $r=\frac{a_0n^2}{2}$

For Li^{2+} $r=\frac{a_0(2)^2}{3}=\frac{4a_0}{3}$

22. $r_n=0.529\frac{n^2}{Z}\overset{\circ}{\mathrm{A}}$

For hydrogen, $n=1$ and $Z=1$; $\therefore r_H = 0.529$

For Be^{3+}, $n=2$ and $Z=4$;

$$\therefore r_{Be^{3+}}=\frac{0.529\times2^2}{4}=0.529$$

23. Electrostatic force of attraction $F\propto\frac{Z^3}{n^4}$

$$\therefore\frac{(F_{n=3})_{He^+}}{(F_{n=2})_{Li^{2+}}}=\frac{2^3/3^4}{3^3/2^4}=\left(\frac{2}{3}\right)^7=\left(\frac{3}{2}\right)^{-7}$$

$\therefore x=-7$ $\qquad F=\frac{KZe^2}{R^2}$

24. $r=0.529\times\frac{n^2}{z}\overset{\circ}{\mathrm{A}}$

$$r_3=0.529\times\frac{3^2}{1}$$

$$r4=0.529\times\frac{4^2}{1}$$

$$\frac{r4}{r_3}=\frac{4^2}{3^2}=\frac{16}{9}$$

$$r_4=\frac{16r_3}{9}$$

25.

Li^{2+}	Be^{3+}
$r_2 = x = k \times \frac{2^2}{3} = \frac{4k}{2}$	$r_3 = y = k \times \frac{3^2}{4}$

$$\frac{y}{x} = \frac{9}{4} \times \frac{3}{4} = \frac{27}{16}$$

$$y = \frac{27}{16}x$$

26. $KE = \dfrac{h^2}{2\pi^2 m a_0^2}$

$\Rightarrow x = 32\pi^2$

27. As per Bohr's postulate,

$$mvr = \frac{nh}{2\pi} \qquad So, \upsilon = \frac{nh}{2\pi mr}$$

$$\text{KE} = \frac{1}{2}mv^2 \quad \text{So, KE} = \frac{1}{2}m\left(\frac{nh}{2\pi mr}\right)^2$$

Since, $r = \dfrac{a_0 \times n^2}{z}$

So, for 2nd Bohr orbit

$$r = \frac{a_0 \times 2^2}{1} = 4a_0$$

$$\text{KE} = \frac{1}{2}m\left(\frac{2^2 h^2}{4\pi^2 m^2 \times (4a_0)^2}\right) = \frac{h^2}{32\pi^2 m a_0^2}$$

28. Energy of N-shell $= \dfrac{-13.6 \times (4)^2}{(4)^2} = -13.6eV$

$\therefore P.E. = 2 \times E \Rightarrow 2 \times -13.6 = -27.2eV$

29. For the positive particle, applying energy conservation initially and at a point A.

$K.E._i + P.E._i = K.E._f + P.E._f$

$\Rightarrow$ 4eV + (+4e) (0V) = 0 + (+4e) (x volt) {x = potential at point A}

$\Rightarrow$ x = 1 volt

Now applying energy conservation for the negative particle at point „A" and initially

$\Rightarrow K.E._i + (-2e)(4V) = 0 + (-2e)(1 volt)$

$\Rightarrow K.E._i - 8eV = -2eV \Rightarrow K.E._i = 6eV$

30. Frequency of revolution = $\dfrac{\text{velocity of second orbit } (V_2)}{2\pi r_2}$

$$= \frac{1.082 \times 10^6 ms^{-1}}{2 \times \pi \times (2.12 \times 10^{-10})m} = 8.13 \times 10^{16} s^{-1}$$

31. $15eV = 13.6Z^2 \times \frac{3}{4} \Rightarrow 13.6Z^2 = 20eV$

Energy of 2nd excited state $= -\frac{13.6Z^2}{3^2} = \frac{-20}{9}eV$

$\therefore K.E.$ of electron $= \frac{65}{9} - \frac{20}{9} = \frac{45}{9} = 5eV$

32. $T \propto \frac{n^3}{Z^2}; \frac{T_{1,2}}{T_{2,1}} = \frac{1}{4} \times \frac{1}{8} = \frac{1}{32}$

33. $\bar{v} \propto \Delta E$

For H-atom

$$\bar{v} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

For Lyman series,

$$\bar{v}(\max) = 13.6\left(1 - \frac{1}{\infty}\right)$$

$$\bar{v}(\min) = 13.6\left(1 - \frac{1}{4}\right)$$

$$\therefore \bar{v}_{\max} - \bar{v}_{\min} = 13.6\left(\frac{1}{4}\right)$$

For Balmer series

$$\bar{v}(\max) = 13.6\left(\frac{1}{4} - \frac{1}{\infty}\right)$$

$$\bar{v}(\min) = 13.6\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\therefore \bar{v}_{\max} - \bar{v}_{\min} = 13.6\left(\frac{1}{9}\right)$$

$$\frac{\Delta\bar{v}_{Lyman}}{\Delta\bar{v}_{Balmer}} = \frac{9}{4}$$

34. Wave number

$$N = \frac{1}{\lambda} = Rz^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$\frac{N_1}{N_2} = \frac{z_1^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)}{z_2^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)} = \frac{(1-1/4)}{z^2\left(\frac{1}{9} - \frac{1}{36}\right)} \Rightarrow \frac{N_1}{N_2} = \frac{9}{z^2} = \frac{9}{16} \Rightarrow z = 4$$

Hence third excitation potential $= 12.75 \times 16 = 204V$.

35. For maximum energy $n_1 = 1$ and $n_2 = \infty$

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

Since R_H is constant and transition remains the same $\frac{1}{\lambda} \propto Z^2$; $\frac{\lambda_{He}}{\lambda_H} = \frac{Z_H^2}{Z_{He}^2} = \frac{1}{4}$

Hence, $\lambda_{He} = \frac{1}{4} \times 91.2 = 22.8\,nm$

36. Shortest wavelength $\rightarrow$ Max energy $(\infty \rightarrow 1)$ (Lyman series)

$$\frac{1}{\lambda_1} = R_H (1)^2 \left[\frac{1}{1} - 0 \right]$$

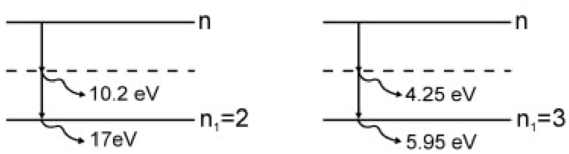
$$\frac{1}{\lambda_1} = R_H \Rightarrow R_H = \frac{1}{\lambda_1}$$

For Balmer series,

$$\frac{1}{\lambda_1} = R_H (2)^2 \left[\frac{1}{2^2} - \frac{1}{3^2} \right] \Rightarrow \frac{1}{\lambda} = R_H (4) \left(\frac{9-4}{36} \right)$$

$$\frac{1}{\lambda} = \frac{5R_H}{9} \Rightarrow \lambda = \frac{9}{5R_H} = \frac{9\lambda_1}{5}$$

37.



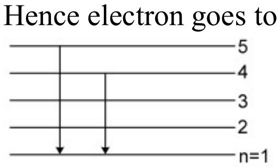
$$10.0 + 17 = 13.6 Z^2 \left(\frac{\ }{2^2} - \frac{1}{n^2} \right) \text{ and } 4.25 + 5.95 = 13.6 Z^2 \left(\frac{1}{3^2} - \frac{1}{n^2} \right)$$

solving the above two equation we get, Z = 3, n = 6

38. Since electron goes the state where the path length is 5 times de-Broglie wavelength.

$\Rightarrow 2\pi r = 5\lambda$ also $\frac{2\pi r}{n} = \lambda$ $\Rightarrow$ n = 5

Hence electron goes to the 5th state.



2nd highest energy line will be $4 \rightarrow 1$

If this photon is used for Li^{+2} then, $13.6\left(1 - \frac{1}{4^2}\right) = 13.6 \times Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$

$n_1\ n_2 \Rightarrow 3 \rightarrow 12$

Hence final excited state = 12.

39. We have, $\Delta E = \frac{3}{4} \times 0.85\,eV$

as energy = 0.6375 the photon will belong to brackett series (as for brackett $0.31 \le E \le 0.85$)

$$0.85 \times \left(1 - \frac{1}{4}\right) = 13.6\left(\frac{1}{4^2} - \frac{1}{n^2}\right)$$

$$0.85\left(1 - \frac{1}{4}\right) = \frac{13.6}{16} \Rightarrow \left[1 - \left(\frac{4}{n}\right)^2\right]$$

$\therefore \frac{4}{n} = \frac{1}{2} \Rightarrow n = 8$. Hence x = 8

40. We have, $\Delta E = \frac{3}{4} \times 0.85\,eV$

as energy = 0.6375 the photon will belong to brackett series (as for brackett $0.31 \le E \le 0.85$)

41. $\frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$n_1 = 3, n_2 = \infty$

$$\frac{1}{\lambda} = R\left(\frac{1}{9}\right) \Rightarrow \lambda = \frac{9}{R} = \frac{9}{10^5} = 9 \times 10^{-5}\,cm = 900\,nm$$

42. For determined shortest wavelength, $n_2 = \infty$

Lyman series $\bar{v}_L = \frac{1}{\lambda_L} = R\left[\frac{1}{(1)^2} - \frac{1}{\infty^2}\right]$

Paschen series $\bar{v}_P = \frac{1}{\lambda_P} = R\left[\frac{1}{(3)^2} - \frac{1}{\infty^2}\right]$

$$\frac{\bar{v}_L}{\bar{v}_P} = \frac{\lambda_P}{\lambda_L} = 9$$

43. $\frac{1}{(\lambda_1)_P} = R_H Z^2\left(\frac{1}{9} - \frac{1}{16}\right)$

$$\frac{1}{(\lambda_2)_P} = R_H Z^2\left(\frac{1}{9} - \frac{1}{25}\right)$$

$$\frac{(\lambda_2)_P}{(\lambda_1)_P} = \frac{\frac{7}{16 \times 9}}{\frac{16}{25 \times 9}} = \frac{25 \times 7}{16 \times 16}$$

$$(\lambda_2)_P = \frac{25 \times 7}{16 \times 16} \times 720$$

44. For H: $\frac{1}{\lambda} = R_H \times 1^2\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right)...(1)$

$$\frac{1}{\lambda_{He^+}} = R_H \times 2^2 \times \left(\frac{1}{4} - \frac{1}{9}\right)...(2)$$

From (1) & (2) $\frac{\lambda_{He^+}}{\lambda} = \frac{9}{5}$

$$\lambda_{He^+} = \lambda \times \frac{9}{5}$$

$$\lambda_{He^+} = \frac{9\lambda}{5}$$

45. He^+ ion:

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

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

Given $\lambda(H) = \lambda\left(He^+\right)$

$$R(1)^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R(4)\left[\frac{1}{2^2} - \frac{1}{4^2}\right]$$

$$\frac{1}{n_1^2} - \frac{1}{n_2^2} = \frac{1}{1^2} - \frac{1}{2^2}$$

On Comparing $n_1 = 1 \& n_2 = 2$

46. $r_n = 0.529 \times \frac{n^2}{z} A^o$

$n_2 = 4 \qquad n_1 = 1$

$$\frac{1}{\lambda} = 2.2 \times 10^{-18}\left(\frac{1}{1^2} = \frac{1}{4^2}\right)$$

$$= 2.0625 \times 10^{-18}$$

47. Here $n_2 = 5 \& n_1 = 2$

So longest wavelength means least energy difference transition i.e. $n_2 = 5$ to $n_1 = 4$

$$\frac{1}{\lambda} = R_H (1)^2\left(\frac{1}{(4)^2} - \frac{1}{(5)^2}\right)$$

So $\lambda = 4 \times 10^{-6} m$

48. Possible transition are

$3 \longrightarrow 2 \quad \& \quad 4 \longrightarrow 2$

$$\overline{v} = Rz^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$\overline{v}_{3\to 2} = R \times 1\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36} \text{ and } \overline{v}_{4\to 2} = R \times 1\left[\frac{1}{4} - \frac{1}{16}\right] = \frac{3R}{16}$$

49. According to Bohr's model energy in n^{th} state

$$= -13.6 \times \frac{Z^2}{n^2} eV$$

For second excited state, of $He^+, n = 3$

$$\therefore E_3\left(He^+\right) = -13.6 \times \frac{2^2}{3^2} eV = -6.04 eV$$

50. Determination of number of moles of hydrogen gas,

$$n = \frac{PV}{RT} = \frac{1 \times 1}{0.082 \times 298} = 0.0409$$

The concerned reaction is $H_2 \longrightarrow 2H; \Delta H = 436\, kJ\, mol^{-1}$

Energy required to bring 0.0409 moles of hydrogen gas to atomic state

$= 436 \times 0.0409 = 17.83 kJ$

Calculation of total number of hydrogen atoms is 0.0409 mole of H_2 gas.

1 mole of H_2 gas has 6.02×10^{23} molecules

0.0409 mole of H_2 gas $= \frac{6.02 \times 10^{23}}{1} \times 0.0409$ molecules.

Since 1 molecule of H_2 gas ahs 2 hydrogen atoms $6.02 \times 10^{23} \times 0.0409$ molecules of H_2 gas $= 2 \times 6.02 \times 10^{23} \times 0.0409 = 4.92 \times 10^{22}$ atoms of hydrogen

Since energy required to excited and electron from the ground state to the next excited state is given by

$$E = 13.6\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) eV = 13.6 \times \left(\frac{1}{1} - \frac{1}{4}\right) = 13.6 \times \frac{3}{4} = 10.2 eV = 1.632 \times 10^{-21} kJ$$

Therefore total energy required $= 17.83 + 80.3 = 98.17\, kJ$

51. $v_e = X V_N$

$\lambda_e = \lambda_N$

$$\Rightarrow \frac{4}{m_e v_e} = \frac{h}{m_N v_N}$$

$v_e = \frac{m_N}{m_e}.v_N$

$= \frac{1.6\times10^{-27}}{9.1\times10^{-31}}v_N$

$v_e = 1758.24\times v_N$

$\therefore x = 1758.24$

52. $n = 3$

$Pe = -27.2\times\frac{Z^2}{n^2}eV \Rightarrow PE = -27.2\times\frac{1^2}{3^2} = -3.02eV$

53. According to de-Broglie's equation

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

Given, $h = 6.6\times10^{-34}Js, m = 200\times10^{-3}kg$

$v = \frac{5}{60\times60}m/s$

$\lambda = \frac{6.6\times10^{-34}}{200\times10^{-3}\times5/(60\times60)} = 2.38\times10^{-10}m$

54. $\lambda = \frac{h}{mu} = \frac{6.627\times10^{-34}}{0.1\times100}$

or λ=$6.627\times10^{-35}m = 6.627\times10^{-25}\overset{\text{o}}{\text{A}}$

55. For $2p, l = 1$

$\therefore$ Orbital angular momentum $= \sqrt{l(l+1)}\frac{h}{2\pi} = \sqrt{2}\frac{h}{2\pi}$

56. Since,

$\lambda = \frac{h}{mV} = \frac{h}{\sqrt{2\text{M K.E}}}(\text{since K.E.} \propto \text{T})$

$\rightarrow \lambda \propto \frac{1}{\sqrt{MT}}$

For two gases,

$\frac{\lambda_{He}}{\lambda_{Ne}} = \sqrt{\frac{M_{Ne}T_{Ne}}{M_{He}T_{He}}} = \sqrt{\frac{20}{4}\times\frac{1000}{200}} = 5$

57. $2\pi r = n\lambda$

$2\pi\times\frac{n^2}{z}a_0 = n\lambda$

$2\pi\times\frac{4^2}{1}a_0 = n\lambda$

$\lambda = 8\pi a_0$

58. De Broglie wavelength $\lambda = \frac{h}{\sqrt{2mk.E}}$

$$\frac{\lambda_{Li^{+3}}}{\lambda_p} = \sqrt{\frac{m_p \times (e-v)_p}{m_{L^{+3}} \times 3e_p V}}$$

$$m_{L^{+3}} = 8.3mp$$

$$\frac{\lambda_{Li^{+3}}}{\lambda_p} = \sqrt{\frac{m_p}{3 \times 8.3 m_p}} = \sqrt{\frac{1}{25}}$$

$$= \frac{1}{5} = 0.2 = 2 \times 10^{-1}$$

$x = 2$

59. de-Broglie-wave length of electron:

$$\lambda_e = \frac{h}{\sqrt{2m(KE)}} \begin{cases} \because e^- \text{ is accelerated from rest} \\ \Rightarrow \text{KE} = \text{q} \times \text{V} \end{cases}$$

$$\lambda = \frac{h}{\sqrt{2mqv}}$$

$$= \frac{6.63 \times 10^{-34}}{\sqrt{2 \times 1.6 \times 10^{-19} \times 9.1 \times 10^{-31}} \times 40 \times 10^3}$$

$$= 6.614 \times 10^{-11} m$$

$$= 6.14 \times 10^{-12} m$$

Nearest integer 6

OR

$$\lambda = \frac{12.3}{\sqrt{V}} \bar{A}...$$

$$= \frac{12.3}{200} = 6.15 \times 10^{-12} m$$

Ans is 6

60. Given $\lambda = 1.5\pi a_0$

$$n\lambda = 2\pi r \qquad \ldots(i)$$

Radii of stationary states (r) is expressed as:

$$r = a_0 \frac{n^2}{z} \qquad \ldots(ii)$$

From eqn (i) and (ii)

$$n\lambda = \frac{2\pi a_0 n^2}{z}, \lambda = \frac{2\pi a_0 n}{z}$$

$$1.5\pi a_0 = 2\pi a_0 \frac{n}{z}$$

$$\frac{n}{z} = \frac{3}{4} = 0.75$$

61. $m = 10g = 10^{-2} Kg$

$v = 90\,m\,/\sec$

$$\Delta v = v \times 5\% = 90 \times \frac{5}{100} = 4.5m/\sec$$

$$m \cdot \Delta v \cdot \Delta x \geq \frac{h}{4\pi}$$

$$10^{-2} \times 4.5\Delta x \geq \frac{6.63 \times 3 \times 10^{-34}}{4 \times \frac{22}{7}}$$

$$\Delta x \geq \frac{6.63 \times 7 \times 2 \times 10^{-24}}{9 \times 4 \times 22 \times 10^{-2}}$$

$\Delta x \geq 1.17 \times 10^{-33} = x \times 10^{-33}$

$x = 1.17 \approx 1$

62. $\Delta v = \frac{0.02}{100} \times 5 \times 10^{6} = 10^{3}\,m/s$

$$\Delta x.\Delta v = \frac{h}{4\pi m}$$

$$x \times 10^{-9} \times 10^{3} = \frac{6.63 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31}}$$

$x \times 10^{-9} \times 10^{3} = 0.058 \times 10^{-3}$

$$x = \frac{0.058 \times 10^{-6}}{10^{-9}} = 58$$

63. $\Delta V = 2.4 \times 10^{-26} ms^{-1}$

$\Delta x = 10^{-7} m$

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

$$\therefore m\Delta V.\Delta x = \frac{h}{4\pi}$$

$$\Rightarrow m \times 2.4 \times 10^{-26} \times 10^{-7} = \frac{6.626 \times 10^{-34}}{4 \times \pi}$$

$$m = \frac{6.626}{9.6 \times \pi} \times 10^{-1}$$

m = 0.02198 kg m=21.98gm

nearest integer = 22

64. Heisenberg's uncertainty principle

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

$\Rightarrow 2a_0 \times m\Delta v_x = \frac{h}{4\pi}(\text{minimum})$

$\Rightarrow \Delta v_x = \frac{h}{4\pi} \times \frac{1}{2a_0} \times \frac{1}{m}$

$= \frac{6.63\times10^{-34}}{4\times3.14\times2\times52.9\times10^{-12}\times9.1\times10^{-31}}$

$= 548273 ms^{-1}$

$= 548.273\, km\, s^{-1}$

$= 548\, km\, s^{-1}$

65. At node $\Psi_{2s} = 0$

$\therefore 2 - \frac{r_0}{a_0} = 0$

$\therefore r_0 = 2a_0$

66. n = 4 and $m_\ell = -3$

Hence, ℓ value must be 3. Now, number of radial nodes $= n - \ell - 1$

= 4 – 3 – 1 = 0

67. Maximum number of electrons (n^2) when $n = 3 = 3^2 = 9$

$\therefore$ Number of orbitals = 9

$\therefore$ Number of electrons with $m_s = -\frac{1}{2}$ will be 9.

68. $|m_l| = 1$ means m_l can +1 and -1.

So, for $n = 4$, six orbitals are possible and each has 1 electron with $s = -\frac{1}{2}$. So total number of electrons = 6

69. Maximum number of electrons with $+\frac{1}{2}$ spin $= n^2$

70. 2 subshells are associate with $n = 4$ and $m = -2$

71. Maximum number of orbitals with $+\frac{1}{2}$ spin $= n^2$

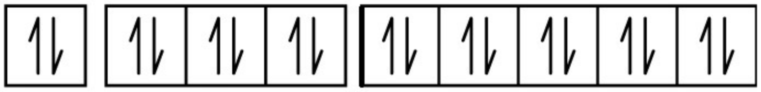
72. $Ge(Z = 32) = 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^{10} 4p^2$

$m_l = 0$ for $1s, 2s, 2p_z, 3s, 3p_z, 4s, 3d_{z^2}$

73. $Is^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2$

The azimuthal quantum number for the valence electrons (4s-subshell) of Ga+ ion is zero (0).

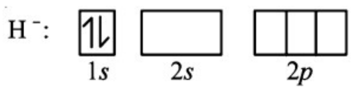
74. When n = 3, l = 0, 1, 2, i.e. there are 3s, 3p and 3d orbitals, If all these orbitals are completely occupied as



Total 18 electrons, 9 electrons with $s = +\frac{1}{2}$ and 9 with $s = -\frac{1}{2}$

75. 4p, 4d, 4f

76. Ground state configuration :



In second excited state, electron will jump from $1s$ to $2p$, so degeneracy of second excited state of H^{-} is 3.

77. $Z = 55[Cs] \Rightarrow [Xe]6s^1$

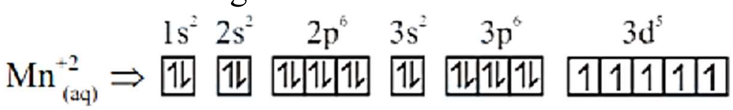
$\left[Cs^+\right] \Rightarrow [Xe]$ i.e. upto 5s count e^- of s-subshell

i.e. is, 2s, 3s, 4s, 5s $\Rightarrow$10 electrons

78. The number of electrons in the orbitals of sub-shell of n = 4 are

4s	2
4p	6
4d	10
4f	14
(Total)	**32**

79. Electronic configuration of divalent metal ion having atomic number 25 is

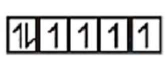


Total number of unpaired electrons = 5

μ (Magnetic moment) $= \sqrt{n(n+2)}BM$

Where n = number of unpaired e^-

$\therefore \mu - \sqrt{5(5+2)} = \sqrt{35}BM = 5.92BM$

80. Fe $\rightarrow$ [Ar] $4s^2 3d^6$ 

Number of unpaired $e^- = 4$

$$\mu = \sqrt{4(4+2)}B \cdot M$$

$$\mu = \sqrt{24}B \cdot M$$

$$\mu = 4.89B \cdot M$$

$$\mu = 48.9 \times 10^{-1} B \cdot M$$

Nearest integer value will be 49 .

81.

$$\mu = \sqrt{n(n+2)}BM$$

$Ti^{+3} = [Ar]3d^1$ $\quad n=1 \quad \mu = 1.73BM$

$V^{+2} = [Ar]3d^3 \quad n = 3 \quad \mu = 3.87BM$

$Sc^{+3} = [Ar]3d^0 4s^0 \quad n = 0 \quad \mu = 0$

82. $25^{Mn} - [Ar]3d^5 4s^2$

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

Given $\sqrt{n(n+2)} = \sqrt{15} \Rightarrow n = 3$

Hence to have '3' unpaired electrons MN must be in '+4' state.

EXERCISE - 3

I. Black Body Radiation, Planck's Quantum Theory, Photoelectric Effect:

1. Which of the following statements is/are INCORRECT?

(a) All spectral lines belonging to Balmer series in hydrogen spectrum lie in visible region.

(b) If a light of frequency v falls on a metal surface having work function hv, photoelectric effect will take place only if $v \le v_0$.

(c) The number of photoelectrons ejected from a metal surface in photoelectric effect depends upon the intensity of incident radiations.

(d) The series limit wavelength of Balmer series for H-atom is $\frac{4}{R}$, where R is Rydberg's constant.

2. Hydrogen atoms in a particular excited state 'n', when all returned to ground state, 6 different photons are emitted. Which of the following is/are incorrect.

(a) out of 6 different photons only 2 photons have speed equal to that of visible light.

(b) If highest energy photon emitted from the above sample is incident on the metal plate having work function 8 eV, KE of liberated photo-electron may be equal to or less than 4.75 eV.

(c) Total number of radial nodes in all the orbitals of n^{th} shell is 14.

(d) Total number of angular nodes in all the orbitals in $(n–1)^{th}$ shell is 13.

II. Hydrogen Spectrum and Spectra of Single Electron Species:

3. If the wave number of 1^{st} line of Balmer series of H-atom is ‘x’ then :

(a) Wave number of 1^{st} line of lyman series of the He^+ ion will be $\frac{108x}{5}$

(b) Wave number of 1^{st} line of lyman series of the He^+ ion will be $\frac{36x}{5}$

(c) The wave length of 2^{nd} line of lyman series of H-atom is $\frac{5}{32x}$

(d) The wave length of 2^{nd} line of lyman series of H-atom is $\frac{32x}{5}$

III. Quantum Mechanical Model of Atom (Schrodinger’s Wave Equation, Wave Function, Probability Density, Radial Probability):

4. Select the correct statement (s) :

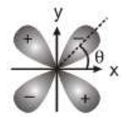
(a) Radial function [R(r)] a part of wave function is dependent on quantum number n only

(b) Angular function depends only on the direction and is independent to the distance from the nucleus

(c) $\psi^2(r,\theta,\phi)$ is the probability density of finding the electron at a particular point in space

(d) Radial distribution function $\left(4\pi r^2 R^2\right)$ gives the probability of the electron being present at a distance r from the nucleus

5. Which of the following statement is correct for $3d_{xy}$ orbitals?



(a) The orbitals drawn has two nodal planes, xz and yz.
(b) The minimum probability point lie along $\theta = 45°$
(c) + ve and – ve signs represent sign of amplitude of electron wave.
(d) It is a non-axial orbital.

IV. Radial and Angular Nodes:

6. The ground state energy of hydrogen atom is -13.6 eV. Consider an electronic state Ψ of He^+, whose energy, azimuthal quantum number and magnetic quantum number are -3.4 eV, 2 and 0, respectively. Which of the following statement(s) is (are) true from the state? [2019]

(a) It is a 4d state
(b) It has 3 radial nodes
(c) It has 2 angular nodes
(d) The nuclear charge experienced by the electron in this state is less than 2e, where e is the magnitude of electronic charge.

EXERCISE – 3 KEY

1.	a, b	**2.**	a, c, d	**3.**	a, c	**4.**	a, b, c	**5.**	a, b, c
6.	a, c								

EXERCISE – 3 SOLUTIONS

1. (A) Only first four spectral lines belonging to Balmer series in hydrogen spectrum lie in visible region.

   (B) If a light of frequency v falls on a metal surface having work functional hv, photoelectric effect will take place only if $v \geq v_0$, since v_0 is the minimum frequency required for photoelectric effect.

2. Number of photons emitted = 6

   So, $\frac{n(n-1)}{2} = 6; n = 4$

   excited state is 3rd or n = 4

   photon having highest energy will ge $4 \to 1$

   So, its energy will be $= 13.6\left(\frac{1}{1^2} - \frac{1}{4^2}\right) = 13.6 \times \frac{15}{16} = 12.75$

   when it is incident on plate having work function 8 eV, then KE = 12.75 – 8 = 4.75 KE will be equal to this value or may be less if electron is inner electron. So option (B) is correct.

   Option (A) is incorrect because all photon have equal velocity which is $3 \times 10^8 m/s$ (C), (D) also incorrect because number of nodes in nth & (n–1)th shall are 6 (Radial node) & 3 (Angular node) respectively.

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

   $X = R\left(\frac{1}{2^2} - \frac{1}{3h2}\right) = \frac{5R}{36}$

   $\bar{v}_1 = R \times 2^2\left(1 - \frac{1}{2^2}\right) = 3R = \frac{36}{5} X \times 3 = \frac{108x}{5}$

   Wave length of 2nd line of lyman series of H-atom

   $\frac{1}{\lambda} = R \times 1^2\left(\frac{1}{1^2} - \frac{1}{3^2}\right) \Rightarrow \frac{1}{\lambda} = R \times \frac{8}{9} \Rightarrow \frac{1}{\lambda} = \frac{36x}{5} \times \frac{8}{9} \Rightarrow \lambda = \frac{5}{32} x$

4. Conceptual
5. These are the facts.
6. $E = -13.6 \times \frac{2^2}{n^2} = -3.4$

$13.6 \times \frac{2^2}{n^2} = 3.4;$

$n^2 = 4^2 \Rightarrow n = 4$

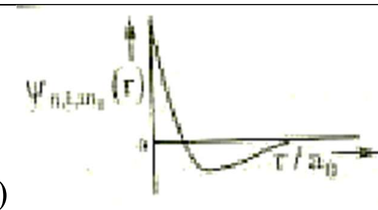
Wave function corresponds to $\Psi_{4,2,0}$ represents $4d_{z^2}$ – orbital which has only one radial nodes and two angular nodes. It experiences nuclear change of 2e units.

EXERCISE - 4

Comprehension # 1:

Answer 1, 2, 3 by appropriately matching the information given in the three columns of the following table.

The wave function Ψ_{n,l,m_l} is a mathematical function whose value depends upon spherical polar coordinates (r,θ,ϕ) of the electron and characterized by the quantum numbers, n, l and m_l. Here r is distance from nucleus, θ is colatitude and ϕ azimuth. In the mathematical functions given in the Table, Z is atomic number and a_0 is Bohr radius [2017]

Column 1	Column 2	Column 3
I) 1s orbital	i) $\Psi_{n,l,m_l} \alpha \left(\frac{Z}{a_0}\right)^{\frac{3}{2}} e^{-\left(\frac{Zr}{n_0}\right)}$	P) 
II) 2s orbital	ii) One radial node	Q) Probability density at nucleus $\alpha \frac{1}{a_0{}^3}$
III) $2P_z$ orbital	iii) $\Psi_{n,l,m_l} \alpha \left(\frac{Z}{a_0}\right)^{\frac{5}{2}} e^{-\left(\frac{Zr}{2n_0}\right)} \cos\theta$	R) Probability density is maximum at nucleus
IV) $3d_z^2$ orbital	iv) xy-plane is a nodal plane	S) Energy needed to excite electron from n = 2, state to n = 4 state is 27/32 times the energy needed to excite electron from n = 2 state to n = 6 state.

1. For He^+ ion, the only INCORRECT combination is [2017]
   (a) I – i - R (b) II – ii - Q (c) I – i - S (d) I – iii - R
2. For the given orbital in Column I, the only Correct combination for any hydrogen like species is
   (a) I – ii - S (b) IV – iv - R (c) III – iii - P (d) II – ii - P
3. For hydrogen atom, the only CORRECT combination is
   (a) II – i - Q (b) I – iv - R (c) I – i - P (d) I – i - S

Comprehension # 2: (Qns.4 to 6)

The hydrogen-like species Li^{2+} is in a spherically symmetric state S_1 with one radial node. Upon absorbing light the ion undergoes transition to a state S_2. The state S_2 has one radial node and its energy is equal to the ground state energy of the hydrogen atom. [2010]

4. The state S_1 is :
   (a) 1s (b) 2s (c) 2p (d) 3s

5. Energy of the state s_1 in units of the hydrogen atom ground state energy is :
(a) 0.75 (b) 1.50 (c) 2.25 (d) 4.50
6. The orbital angular momentum quantum number of the state s_2 is
(a) 0 (b) 1 (c) 2 (d) 3

Comprehension # 3: (Qns. 7 to 9)

Definition valid for single electron system:

Ground state: Lowest energy state of any atom or ion is called ground state of the atom. It is n = 1.

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

Ionisation energy (IE): Minimum energy required to move an electron from ground state to $n=\infty$ is called ionisation energy of the atom or ion.

Ionisation Potential (I.P.) : Potential difference through which a free electron must be accelerated from rest, such that its kinetic energy becomes equal to ionisation energy of the atom is called ionisation potential of the atom.

Excitation Energy: Energy required to move an electron from ground state of the atom to any other state of the atom is called excitation energy of that state.

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

Binding Energy 'or' Separation Energy: Energy required to move an electron from any state to $n=\infty$ is called binding energy of that state.

The wavelength of the photon emitted upon an electronic transition from n_2 to n_1 orbit in a H-like species is given by the formula :

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

Now answer the following questions:

7. If the binding energy of II excited state of a H-like species is 13.6 eV, then : (AS)
(a) The atomic number Z of given H-like species is 2.
(b) A photon of energy 30 eV can ionise an electron from I excited state of given H-like species.
(c) Upon de-excitation from n = 4 to n = 2 in given H-like species, the emitted photon has wavenumber $\overline{v}=\frac{3R}{16}$ (R = Rydberg's constant)
(d) Ionisation potential of given H-like species is 122.4 V.
8. If the wavelength of photon emitted from an electron jump n = 4 to n = 2 in a H-like species is 1216 Å, then the species is :
(a) H-atom (b) He^{+} ion (c) Li^{2+} ion (d) Be^{3+} ion

9. If the I excitation potential of a hypothetical H-like atom is 162 V, then the value of II excitation energy is about :

(a) 192 eV (b) 30 eV (c) 216 eV (d) 40.5 eV

Comprehension # 4 (Qns. 10 to 12)

The French physicist Louis de Broglie in 1924 postulated that matter, like radiation, should exhibit a dual behaviour. He proposed the following relationship between the wavelength p of a material particle, its linear momentum p and planck constant h.

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

The de Broglie relation implies that the wavelength of a particle should decrease as its velocity increases. It also implies that for a given velocity heavier particles should have shorter wavelength than lighter particles.

The waves associated with particles in motion are called matter waves or de Broglie waves. These waves differ from the electromagnetic waves as they

(i) have lower velocities

(ii) have no electrical and magnetic fields and

(iii) are not emitted by the particle under consideration.

The experimental confirmation of the de Broglies relation was obtained when Davisson and Germer, in 1927, observed that a beam of electrons is diffracted by a nickel crystal. As diffraction is a characteristic property of waves, hence the beam of electron behaves as a wave, as proposed by de Broglie.

Now, answer the following questions:

10. If proton, electron and α-particle are moving with same kinetic energy then the order of their de-Broglie's wavelength.

(a) $\lambda_p > \lambda_e > \lambda_\alpha$ (b) $\lambda_\alpha > \lambda_p > \lambda_e$ (c) $\lambda_\alpha < \lambda_p < \lambda_e$ (d) $\lambda_e = \lambda_p < \lambda_\alpha$

11. Using Bohr's theory, the transition, so that the electrons de-Broglie wavelength becomes 3 times of its original value in He + ion will be

(a) $2 \longrightarrow 6$ (b) $2 \longrightarrow 4$ (c) $1 \longrightarrow 4$ (d) $1 \longrightarrow 6$

12. De-Broglie wavelength of an electron travelling with speed equal to 1% of the speed of light

(a) 400 pm (b) 120 pm (c) 242 pm (d) 375 pm

Comprehension # 05: (Qns. 13 to 15)

Answer next 3 questions by appropriately matching the information given in the three columns of the following table. If the electron comes back form energy level having energy E_2 to energy level having E_1 then the difference may be expressed

$$E_2 - E_1 = \Delta E \qquad \lambda = \frac{hc}{\Delta E}$$

Each transition from one energy level to another will produce a light of definite wavelength

Wave number $\bar{v} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$ where R is Rydberg constant

Column – 1		Column – 2		Column - 3	
(I)	First line of Balmer series for H	(i)	wave number $\bar{v} = 9R$	(P)	Change in angular Momentum is $\frac{3h}{2\pi}$
(II)	Third line of paschen series of He^+ ion	(ii)	Wavelength $\lambda = \frac{9}{32R}$	(Q)	Difference of energy corresponding transition is 48.4 eV
(III)	Lyman series limit for Li^{+2} ion	(iii)	Difference of potential energy of corresponding transition is 3.78 eV	(R)	wave length $\lambda = \frac{36}{5R}$
(IV)	2nd line of Lyman series for He^+ ion	(iv)	Difference of energy corresponding transition is 4.54 eV	(S)	Difference of energy corresponding transition is 122.4 eV

13. The only correct combination is
    (a) (I) (ii) (P) (b) (IV) (iii) (Q) (c) (II) (iv) (R) (d) (III) (i) (S)
14. Only correct combination is
    (a) (I) (iii) (R) (b) (II) (i) (S) (c) (III) (ii) (P) (d) (IV) (iv) (Q)
15. Only correct combination is
    (a) (II) (iv) (P) (b) (I) (ii) (Q) (c) (III) (ii) (R) (d) (IV) (iii) (S)
16. According to Bohr's theory,
    E_n = Total energy; K_n = Kinetic Energy, V_n = Potential energy, r_n = Radius of n^{th} orbit.
    Match the following:

Column – I		Column – II	
(A)	$V_n / K_n = ?$	(p)	0
(B)	If radius of n^{th} orbit $\propto E_n^x, x = ?$	(q)	-1
(C)	Angular momentum in lowest orbital	(r)	-2
(D)	$\frac{1}{r^n} \propto Z^y, y = ?$	(s)	1

17. Match the entries in Column I with the correctly related quantum number(s) in Column II. Indicate your answer by darkening the appropriate bubbles of the 4×4 matrix given in the ORS

Column – I		**Column – II**	
(A)	Orbital angular momentum of the electron in a hydrogen-like atomic orbital	(p)	Principal quantum number
(B)	A hydrogen-like one-electron wave function obeying Pauli principle	(q)	Azimuthal quantum number
(C)	Shape, size and orientation of hydrogen-like atomic orbitals	(r)	Magnetic quantum number
(D)	Probability density of electron at the nucleus in hydrogen like atom	(s)	Electron spin quantum number

18. If in Bohr's model, for unielectronic species following symbols are used

$r_{n,z} \rightarrow$ Radius of n*th* orbit with atomic number Z;

$U_{n,z} \rightarrow$ Potential energy of e^-; $K_{n,z} \rightarrow$ Kinetic energy of e^-;

$V_{n,z} \rightarrow$ Velocity of e^-; $T_{n,z} \rightarrow$ Time period of revolution

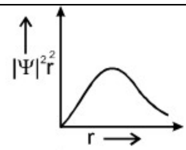
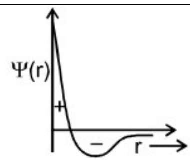
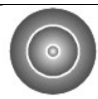
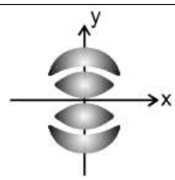
Match the List I with the appropriate List II and select the correct answer using the code given below the lists :

List I		**List II**	
(P)	$U_{1,2} : K_{1,1}$	(1)	1 : 8
(Q)	$r_{1,2} : K_{1,2}$	(2)	–8 : 1
(R)	$V_{1,3} : V_{3,1}$	(3)	9 : 1
(S)	$T_{1,2} : T_{2,2}$	(4)	8 : 1

Codes :

	(P)	(Q)	(R)	(S)
(A)	1	2	3	4
(B)	4	3	2	1
(C)	3	2	1	4
(D)	2	4	3	1

19. Match the graph/diagram in List-I with information in List-II.

List I		List II	
(P)		(1)	$3p_y$
(Q)		(2)	2s
(R)	 A spherical orbital with radial nodes	(3)	3s
(S)	 A dumb-bell orbital with radial nodes	(4)	8 : 1 2p-orbital probability distribution with distance

Codes:

	(P)	(Q)	(R)	(S)		(P)	(Q)	(R)	(S)
(A)	4	2	3	1	(B)	1	3	2	4
(C)	4	3	2	1	(D)	1	2	3	4

EXERCISE – 4 KEY

1.	(d)	**2.**	(d)	**3.**	(d)	**4.**	(b)	**5.**	(c)
6.	(b)	**7.**	(d)	**8.**	(b)	**9.**	(a)	**10.**	(c)
11.	(a)	**12.**	(c)	**13.**	(d)	**14.**	(a)	**15.**	(a)
16.	(A) – (r); (B) – (q); (C) – (p); (D) – (s)								
17.	(A)-q, r; (B)- p, q, r, s; (C)- p, q, r; (D)- p, q								
18.	(d)	**19.**	(a)						

EXERCISE – 4 SOLUTIONS

1. $1s \rightarrow 0$ radial nodes, no angular component $(\Rightarrow \text{ no } \cos\theta)$

$2s \rightarrow 1$ radial nodes, no angular component $(\Rightarrow \text{ no } \cos\theta)$

$2p_z \rightarrow 0$ radial node, no angular component $(\Rightarrow \cos\theta)$

$2p_z \rightarrow 0$ radial node, no angular component is present $(\Rightarrow \cos\theta)$

$3d_z^2 \rightarrow 0$ radial node, no angular component is present $(\Rightarrow \cos\theta)$

(A) $1s \rightarrow (i) \rightarrow 'R' \rightarrow 1s$ orbital $\rightarrow$ '0' radial node probaility max $\rightarrow$ nucleas $\Rightarrow$ Correct

(B) $2s \rightarrow 1$ radial node of $\theta \rightarrow$ correct

(C) $1s \rightarrow (i) \rightarrow 's' \rightarrow$ correct

2. (A) $1s \rightarrow 0$ radial node $\Rightarrow$ wrong as (ii), (i) 1 radial node

(B) $3d_x^2 \Rightarrow dz^2$ 'R' is wrong point

(C) for $2p_z$, graph 'p' is wrong,

(D) Correct

3. (A) $2s \rightarrow 1$ radial node / column (2) (i) no radial node $\Rightarrow$ wrong

(B) $1s \rightarrow$ no node plane $\Rightarrow$ wrong

(C) $1s \rightarrow$ no radial node $\Rightarrow$ column (3) 'p' $\rightarrow 1$ radial node $\Rightarrow$ wrong

(D) Correct

4-6. The spherically symmetric state s_1 of Li^{2+} with one radial node is $2s$. Upon absorbing light, the ion gets excited to state s_2, which also has one radial node. The energy of electron in s_2 is same as that of H-atom in its ground state.

$\therefore E_n = \dfrac{Z^2}{n^2} E_1$ where E_1 is the energy of H-atom in the ground state $= \dfrac{(3)^3 E_1}{n^2}$ for Li^{2+}

$E_n = E_1 \Rightarrow n = 3$

$\therefore$ State s_2 of Li^{2+} having one radial node is $3p$. Orbital angular momentum quantum number of $3p$ is 1.

Energy of state $S_1 = \dfrac{(3)^2}{(2)^2} E_1 = 2.25E_1$

7. Binding energy of II excited state $(n=3) = 13.6\left(\dfrac{Z^2}{3^2}\right) = 13.6\,eV \qquad \therefore Z = 3$

$\therefore$ Ionisation potential = $13.6\ Z^2 = 13.6 \times 3^2 = 122.4V$

8. Energy of photon $= \dfrac{12400}{1216} = 10.2\,eV = (H)_{2\to1} = \left(He^{+}\right)_{4\to2}$

So, species is He^{+} ion

9. I excitation potential $= 10.2Z^2 = 162V$

$\therefore$ II excitation energy $= 12.09\,Z^2 = 12.09 \times \dfrac{162}{10.2} = 192\,eV$

10. $\lambda = \dfrac{h}{\sqrt{2mKE}}$ if KE same $\lambda \propto \dfrac{1}{\sqrt{m}} \qquad m\uparrow \quad \lambda\downarrow$

11. $\lambda = \dfrac{h}{mv}\,\lambda \Rightarrow 3$ times $\quad V \Rightarrow \dfrac{1}{3}$ times $\quad V \propto \dfrac{z}{n}$ so, transition will be $2 \to 6$

12. $\lambda = \dfrac{h}{mv} = \dfrac{6.6\times10^{-34}}{9.1\times10^{-31}\times3\times10^{6}}\,242\,pm$

13-15. (I) First line of Balmer series

$n_1 = 2 \qquad n_2 = 3$

$\Delta P.E. = 27.2\times(Z)^2\left[\dfrac{1}{n_1^2}-\dfrac{1}{n_2^2}\right] = 27.2\times(1)^2\left[\dfrac{1}{4}-\dfrac{1}{9}\right] = 27.2\times\dfrac{5}{36} = 3.78\,eV$

$\Delta E. = 13.6\times(1)^2\left[\dfrac{1}{4}-\dfrac{1}{9}\right] = 1.88\,eV$

$\overline{v} = R\times\left(1^2\right)\left[\dfrac{1}{4}-\dfrac{1}{9}\right] = \dfrac{5R}{36}$

$\lambda = \dfrac{36}{5R}$

Angular momentum $= \dfrac{3h}{2\pi}-\dfrac{2h}{2\pi} = \dfrac{h}{2\pi}$

(II) Third line of paschen series of He^{+} ion

$n_1 = 3 \qquad n_2 = 6$

$\Delta P.E. = 27.2\times(2)^2\left[\dfrac{1}{9}-\dfrac{1}{36}\right] = 9.06eV; \Delta E = 13.6(2)^2\left[\dfrac{1}{9}-\dfrac{1}{36}\right] = 4.54eV$

$\overline{v} = R\times\left(2^2\right)\left[\dfrac{1}{9}-\dfrac{1}{36}\right] = \dfrac{R}{3}; \lambda = \dfrac{3}{R}$

Angular momentum $= \dfrac{6h}{2\pi}-\dfrac{3h}{2\pi} = \dfrac{3h}{2\pi}$

(III) Lyman series limit for Li^{+2} ion

$n_1 = 1 \qquad n_2 = \infty$

$$\Delta P.E. = 27.2 \times (3)^2 \left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = 27.2 \times 9 = 244.8\,eV$$

$$\Delta E. = 13.6 \times 9 \left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = 122.4\,eV$$

$$\bar{v} = R \times (3)^2 \left[\frac{1}{1^2} - \frac{1}{\infty^2}\right] = 9R$$

(IV) 2nd line of Lyman series for He^{+} ion

$n_1 = 1 \qquad n_2 = 3$

$$\Delta P.E. = 27.2 \times (2)^2 \left[\frac{1}{1} - \frac{1}{9}\right] = 96.71\,eV$$

$$\Delta E. = 13.6 \times (2)^2 \left[\frac{1}{1} - \frac{1}{9}\right] = 48.4\,eV$$

$$\bar{v} = R \times (2)^2 \left[\frac{1}{1} - \frac{1}{9}\right] = \frac{32R}{9}$$

$$\lambda = \frac{9}{32R}$$

Angular momentum $= \dfrac{3h}{2\pi} - \dfrac{h}{2\pi} = \dfrac{2h}{2\pi} = \dfrac{h}{\pi}$

16. (i) $\dfrac{V_n}{K_n} = \dfrac{-Kze^2 / r}{Kze^2 / 2r} = -2$; where $K = \dfrac{i}{4\pi\varepsilon_0}$ $\therefore (i) - (c)$

(ii) $r_n \propto (E_n)^{-1}$; $\therefore (ii) - (b)$

(iii) Angular momentum of electron in lowest $(1s)$ orbital

$$= \sqrt{\ell(\ell+1)}\frac{h}{2\pi} - \sqrt{0(0+1)}\frac{h}{2\pi} = 0; \therefore (iii) - (a)$$

(iv) $\dfrac{1}{r^n} \propto Z^1; \therefore (iv) - (d)$

17. Conceptual

18. Use TE = $-13.6\ Z^2 / n^2$

TE = $-13.6\ Z^2 / n^2$

PE = 2 TE

KE = $-$TE

$$T \propto \frac{n^3}{Z^2} \Rightarrow V \propto \frac{Z}{n} \Rightarrow r \propto \frac{n^2}{Z}$$

19. Conceptual

EXERCISE - 5

1. Statement-1: The plot of atomic number (y-axis) versus number of neutrons (x-axis) for stable nuclei shows a curvature towards x-axis from the line of 45° slope as the atomic number is increased.
   Statement-2: Proton-proton electrostatic repulsions begin to overcome attractive forces involving protons and neutrons in heavier nuclides. [2008]
   (a) Statement-1 is True, Statement-2 is True; Statement-2 is correct explanation for Statement-1
   (b) Statement-1 is True, Statement-2 is True; Statement-2 is not a correct explanation for Statement-1
   (c) Statement-1 is Ture, Statement-2 is False
   (d) Statement-1 is False, Statement-2 is True.
2. Given below are two statements: [JEE mains (27 July 2021 Shift 1)]
   Statement I : Rutherford's gold foil experiment cannot explain the line spectrum of hydrogen atom.
   Statement II: Bohr's model of hydrogen atom contradicts Heisenberg's uncertainty principle.
   In the light of the above statements, choose the most appropriate answer from the options given below:
   (a) Statement I is false but statement II is true.
   (b) Statement I is true but statement II is false.
   (c) Both statement I and statement II are false.
   (d) Both statement I and statement II are true.
3. Given below are two statements:
   Statement I : Bohr's theory accounts for the stability and line spectrum of Li^+ ion.
   Statement II : Bohr's theory was unable to explain the splitting of spectral lines in the presence of a magnetic field. In the light of the above statements, choose the most appropriate answer from the options given below:
   [JEE Mains 2021, 18 March (Shift 2)]
   (a) Both statement I and statement II are true.
   (b) Statement I is false but statement II is true.
   (c) Both statement I and statement II are false.
   (d) Statement I is true but statement II is false.

4. Given below are two statements. [JEE mains 2021 (26 Aug Shift 1)]

Statement I: According to Bohr's model of an atom, qualitatively the magnitude of velocity of electron increases with decrease in positive charges on the nucleus as there is no strong hold on the electron by the nucleus.

Statement II: According to Bohr's model of an atom, qualitatively the magnitude of velocity of electron increases with decrease in principal quantum number.

In the light of the above statements, choose the most appropriate answer from the options given below:

(a) Both Statement I and Statement II are false
(b) Both Statement I and Statement II are true
(c) Statement I is false but Statement II is true
(d) Statement I is true but Statement II is false

5. Given below are two statements : [JEE Mains 2021, 24 Feb (Shift 1)]

Statement-I: Two photons having equal linear momenta have equal wavelengths.

Statement-II: If the wavelength of photon is decreased, then the momentum and energy of a photon will also decrease.

In the light of the above statements, choose the correct answer from the options given below.

(a) Statement-I is false but Statement-II is true
(b) Both Statement-I and Statement-II are true
(c) Both Statement-I and Statement-II are false
(d) Statement-I is true but Statement-II is false

6. Given below are two statements. One is labelled as Assertion A and the other is labelled as Reason R. [JEE Mains 2022, 27 July - Shift 1]

Assertion A : Energy of 2s orbital of hydrogen atom is greater than that of 2s orbital of lithium.

Reason R : Energies of the orbitals in the same subshell decrease with increase in the atomic number.

In the light of the above statements, choose the correct answer from the options given below.

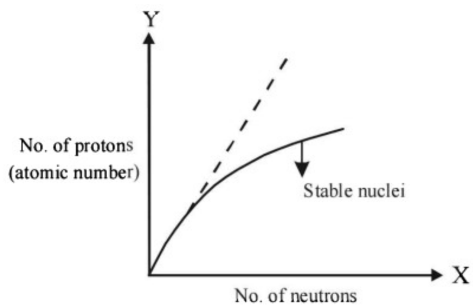
(a) Both A and R arc true and R is the correct explanation of A.
(b) Both A and R are true but R is NOT the correct explanation of A.
(c) A is true but R is false.
(d) A is false but R is true.

EXERCISE – 5 KEY

1.	(a)	**2.**	(d)	**3.**	(b)	**4.**	(c)	**5.**	(d)
6.	(a)								

EXERCISE - 5 SOLUTIONS

1.



A look at the above curve shows that for stable nuclei it shows a curvature towards x-axis from the line of 45° slope (dotted line) as the atomic number (i.e. number of protons) increases. So Statement-1 is true. The proton-proton repulsion would overcome the attractive force of proton and neutron. Thus Statement-2 in Ture. Also this Statement-2 is correct explanation for Statement-1. Therefore the correct answer is option (a).

2. Rutherford's gold foil experiment only proved that electrons are held towards nucleus by electrostatic forces of attraction and move in circular orbits with very high speeds. Bohr's model gave exact formula for simultaneous calculation of speed \& distance of electron from the nucleus, something which was deemed impossible according to Heisenberg.

3. Statement-I is false since Bohr's theory accounts for the stability and spectrum of single electronic species $\left(eg : He^{+}, Li^{2+}\text{etc}\right)$ Statement II is true.

4. $v_n = \dfrac{2\pi e^2 Zk}{nh}$

5. $\lambda = \dfrac{h}{m\theta} = \dfrac{h}{p}\left(p = \text{momentum}\right)$

6. Energy of orbitals decreases on increasing the atomic number.