

Energy of a photon : $E = h \cdot \nu = \frac{h \cdot c}{\lambda}$ where $h = 6.626 \times 10^{-34}$ joule second (planck's constant),
 $c = 3.0 \times 10^8 \text{ ms}^{-1}$ (velocity of light).

$$NE = N \cdot h \cdot \nu = \frac{N \cdot h \cdot c}{\lambda}, \text{ where } N = 6.022 \times 10^{23} \text{ (Avagadro Number)}$$

Isotopes : Atoms having same atomic number (Z) and different atomic mass number (A) are called isotopes.

Isobars : Atoms having same atomic mass number (A) and different atomic number (Z) are called Isobars.

Isotones : Atoms having different atomic number (Z), different atomic mass number (A) and same number of neutron (N) are called Isotones.

de-Broglie's principle : "Every moving particle possesses wave nature."

de-Broglie derived the equation relating wavelength and momentum of matter particle $\lambda = \frac{h}{mv}$ and it is known as de-broglie's equation (where, λ = wavelength of matterwave, h = planck's constant, m = mass of moving particle, v = velocity of moving particle)

If kinetic energy of moving particle is K, then the wavelength associated with it is $\lambda = \frac{h}{\sqrt{2mk}}$

de-broglie's principle is applicable to microscopic particles like electron, proton, hydrogen atom. Wavelength of a moving macroscopic particle is so small that it cannot be practically measured. Hence de-broglie's principle is of no importance to moving macroscopic particles.

● **Heisenberg's Uncertainty principle :**

"The position and momentum of moving microscopic particle cannot be determined simultaneously and precisely.

Mathematical form of Heisenberg's uncertainty principle : The product of experimentally measured uncertainty in position (Δx) and experimentally measured uncertainty in momentum (Δp) of a moving microscopic particle is at least $\frac{h}{4\pi}$.

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

-
- Which phenomena can not be explained by particle nature of light ?
 (A) Diffraction (B) Interference (C) Polarization (D) given all three
 - Which phenomena can be explained by particle nature of light ?
 (A) Diffraction (B) Interference (C) Photoelectric effect (D) given all three
 - Which phenomena can be explained by wave nature of light ?
 (A) Diffraction (B) Interference (C) Reflection (D) given all three
-

4. Which phenomena cannot be explained by wave nature of light ?
 (A) Diffraction (B) Interference (C) Photoelectric effect (D) given all three
5. Which phenomena can explain particle nature and wave nature of light ?
 (A) Diffraction (B) Interference (C) Refraction (D) given all three
6. Which phenomena can explain any one of the particles nature or wave nature of light ?
 (A) Reflection (B) Interference (C) Refraction (D) given all three
7. Based on which of the phenomena particle nature of light can be proven ?
 (A) Interference (B) Photoelectric effect (C) Diffraction (D) Dispersion
8. Isotopes have
 (A) same atomic mass number and different atomic numbers.
 (B) same atomic mass number but different number of electrons.
 (C) same atomic number but different atomic mass numbers.
 (D) same atomic number but different number of electrons.
9. Which of the following is the limitation of Bohr's model of an atom ?
 (A) cannot explain the doublet spectral lines obtained in Hydrogen spectrum.
 (B) cannot explain the atomic spectrum of atoms other than hydrogen atom.
 (C) cannot explain zeeman effect.
 (D) given all three
10. Isobars have
 (A) same atomic mass number but different atomic number.
 (B) same atomic mass number but different number of electrons.
 (C) same atomic number but different atomic mass number.
 (D) same atomic number but different number of electrons.
11. Isotones have ...
 (A) Different atomic mass number and atomic number but same number of neutrons.
 (B) Different atomic mass number and atomic number but same number of electrons.
 (C) Same atomic number, different atomic mass number and same number of neutrons.
 (D) Same atomic mass number and atomic number but different number of neutrons.
12. Which pair of atomic mass number (A) and atomic number (Z) is of isotones ?
 (A) (i) $A = 30, Z = 15$ (ii) $A = 31, Z = 14$ (B) (i) $A = 31, Z = 15$ (ii) $A = 30, Z = 14$
 (C) (i) $A = 32, Z = 15$ (ii) $A = 30, Z = 14$ (D) (i) $A = 31, Z = 16$ (ii) $A = 32, Z = 14$
13. Which pair of atomic number (Z) and number of neutron (n) is of isotopes ?
 (A) (i) $Z = 18, n = 21$ (ii) $Z = 20, n = 20$ (B) (i) $Z = 18, n = 22$ (ii) $Z = 20, n = 19$
 (C) (i) $Z = 18, n = 22$ (ii) $Z = 20, n = 21$ (D) (i) $Z = 18, n = 22$ (ii) $Z = 20, n = 20$

14. Which of the following species have electron, proton and neutron 24, 26 and 30 respectively ?
 (A) Fe^{3+} (B) Mn^{2+} (C) Zn^{2+} (D) Fe^{2+}
15. Which of the following species have electron, proton and neutron 10, 9 and 10 respectively ?
 (A) Na^+ (B) F^{2-} (C) F^- (D) F^+
16. Which molecule is isoelectronic to CN^- ?
 (A) O_2 (B) CH_4 (C) N_2 (D) NO
17. How many electrons are there in 36 gm of pure water (H_2O) ?
 (A) 2.44×10^{25} (B) 6.022×10^{24} (C) 1.2044×10^{21} (D) 1.2044×10^{25}
18. What is the thickness of goldsheet in scattering of α -particle experiment ?
 (A) 10^{-9} m (B) 10^{-2} m (C) 100 μm (D) 10^{-5} cm
19. In an atom if an electron in orbit emits radiation, then how much time will be required to attract the electron into the nucleus ?
 (A) 10^{-5} s (B) 10^{-8} s (C) 10^{-10} s (D) 10^{-7} s
20. Which of the following is directly proportional to energy of a photon ?
 (A) U (B) λ (C) $\sqrt{v}$ (D) $\frac{1}{v}$
21. Which of the following shows relation between wavelength (λ), its kinetic energy (E) and mass (m) of a moving particle ?
 (A) $\lambda = \frac{h}{\sqrt{2mE}}$ (B) $\lambda = \frac{hm}{\sqrt{2E}}$ (C) $\lambda = \frac{h}{\sqrt{mE}}$ (D) $\lambda = \frac{m}{\sqrt{2hE}}$
22. Which of the following is directly proportional to velocity of a photon ?
 (A) $\sqrt{\lambda}$ (B) v (C) $\frac{1}{C}$ (D) $\frac{1}{m}$
23. Which of the following is inversely proportional to energy of a photon ?
 (A) frequency (B) momentum (C) wavelength (D) motion
24. Construction of electron microscope is based on which of the following ?
 (A) wave nature of light (B) particle nature of light
 (C) particle nature of electron (D) wave nature of electron
25. Construction of a normal microscope is based on which of the following ?
 (A) wave nature of light (B) particle nature of light
 (C) particle nature of electron (D) wave nature of electron
26. How many times magnification can be done using electron microscope ?
 (A) 1.5×10^5 times (B) 1.5×10^6 times (C) 1.5×10^7 times (D) 1.5×10^4 times
27. Which of the following particle's wave nature is not measurable ?
 (A) H-atom (B) e^- (C) p^+ (D) particle having mass 1 mg

28. Calculate wavelength of an electron having kinetic energy 1.64×10^{-17} joule ?
(mass of electron 9.109×10^{-31} kg)
(A) 1.2 nm (B) 0.21 nm (C) 12.0 nm (D) $1.2 \text{ \AA}$
29. Calculate energy of a photon having wavelength 500 nm ?
(A) 3.97×10^{-19} joule (B) 3.97×10^{-12} joule (C) 3.97×10^{-17} joule (D) 3.97×10^{-10} joule
30. What will be the value of one einstein of photon having wavelength $400 \text{ \AA}$?
(A) $2.99263 \times 10^{12} \frac{\text{joule}}{\text{mole photon}}$ (B) $2.99263 \times 10^6 \frac{\text{joule}}{\text{mole photon}}$
(C) $2.99263 \times 10^5 \frac{\text{joule}}{\text{mole photon}}$ (D) $2.99263 \times 10^{14} \frac{\text{joule}}{\text{mole photon}}$
31. If value of one Einstein photon is 4.0×10^5 KJ mole^{-1} , then calculate the wavelength of its radiation ?
(A) 2.99×10^6 nm (B) 29.9 nm (C) 2.99×10^8 nm (D) 2.99×10^{-1} nm
32. Calculate the energy of a photon having frequency 6.67×10^{14} Hz ?
(A) 4.42×10^{-12} joule (B) 4.42×10^{-19} joule (C) 4.42×10^{-17} joule (D) None of these
33. Calculate value of one Einstein of photon having frequency 5.0×10^{14} Hz ?
(A) 199.5 joule mole^{-1} (B) 1.995×10^5 KJ mole^{-1}
(C) 199.5 KJ mole^{-1} (D) 199.5×10^5 J mole^{-1}
34. How many photons of wavelength 400 nm are required to produce 1 joule energy ?
(A) 2.01×10^{11} (B) 2.01×10^{16} (C) 2.01×10^9 (D) 2.01×10^{18}
35. Calculate wave frequency number of a photon having 1.5×10^{-16} joule energy ?
(A) 754 (B) 7546030 (C) 75460 (D) 7546
36. Which of the following option is true for two particles having identical wavelength ?
(A) both will have same velocity (B) both will have same mass
(C) both will have same momentum (D) None
37. Which of the following particle having identical velocity have maximum wavelength ?
(A) H atom (B) e^- (C) p^+ (D) n^0
38. Calculate wavelength of a ball, having 0.01 kg mass and 10 ms^{-1} velocity ?
(A) 6.626×10^{-26} m (B) 6.626×10^{-33} m (C) 6062×10^{-32} m (D) 60.626×10^{-25} m
39. The position of electron located at $1 \text{ \AA}$ with microscope. Calculate uncertainty in velocity of electron ?
(mass of electron = 9.11×10^{-31} kg.)
(A) $5.79 \times 10^7 \text{ ms}^{-1}$ (B) $5.79 \times 10^5 \text{ ms}^{-1}$ (C) $5.79 \times 10^4 \text{ ms}^{-1}$ (D) $5.79 \times 10^{12} \text{ ms}^{-1}$

40. If a moving microscope particle has mass m and have equal value of uncertainty in position and uncertainty in velocity, then calculate the total uncertainty value ?

(A) $\frac{h}{2\sqrt{\pi m}}$ (B) $\frac{h}{4\pi m}$ (C) $\frac{h}{2\sqrt{\pi m}}$ (D) $\frac{\sqrt{h}}{2\sqrt{\pi m}}$

41. If a moving microscopic particle has mass m and have equal value of uncertainty in position and uncertainty in momentum, then calculate the total uncertainty value.

(A) $\frac{\sqrt{h}}{2\sqrt{\pi m}}$ (B) $\frac{\sqrt{h}}{\sqrt{2\pi}}$ (C) $\frac{h}{2\sqrt{\pi m}}$ (D) $\frac{\sqrt{h}}{2\sqrt{\pi}}$

42. If a moving microscopic particle having mass m has value of uncertainty in velocity 16 times more than its uncertainty in position, then calculate its least possible uncertainty in momentum ?

(A) $\frac{\sqrt{hm}}{\sqrt{\pi}}$ (B) $\frac{\sqrt{mh}}{2\sqrt{\pi}}$ (C) $\frac{2\sqrt{mh}}{\sqrt{\pi}}$ (D) $\frac{h}{\sqrt{2\pi m}}$

43. If a moving microscopic particle having mass m has value of uncertainty in position $\frac{1}{4}$ times the uncertainty in velocity, then calculate its least possible uncertainty in momentum ?

(A) $\frac{\sqrt{hm}}{\sqrt{\pi}}$ (B) $\frac{\sqrt{mh}}{2\sqrt{\pi}}$ (C) $\frac{h}{4\pi m}$ (D) $\frac{mh}{4\pi m}$

Answers : 1. (D), 2. (C), 3. (D), 4. (C), 5. (C), 6. (B), 7. (B), 8. (C), 9. (D), 10. (A), 11. (A), 12. (B), 13. (D), 14. (D), 15. (C), 16. (C), 17. (D), 18. (D), 19. (B), 20. (A), 21. (A), 22. (B), 23. (C), 24. (D), 25. (A), 26. (C), 27. (D), 28. (D), 29. (A), 30. (B), 31. (D), 32. (B), 33. (C), 34. (D), 35. (B), 36. (C), 37. (B), 38. (B), 39. (B), 40. (D), 41. (D), 42. (C), 43. (A)

● According to Bohr's principle (for single electron system)

(1) **Bohr model's atomic radius :** $a_0 = \frac{h}{4\pi^2 m e^2} = 52.9 \times 10^{-10} \text{ cm} = 52.9 \text{ pm}$

Where, $h = 6.626 \times 10^{-27}$ erg seconds (Plancks constant), $m = 9.109 \times 10^{-28}$ g (mass of e^-)

charge of $e^- = 4.803 \times 10^{-10}$ esu (unit of charge in CGS)

- (2) **System containing single electron :** (H-atom or ions like He^+ , Li^{2+}) radius of any orbit,

$$r_n = a_0 \times \frac{n^2}{Z} = 52.9 \times \frac{n^2}{Z} \text{ pm},$$

where Z = atomic number, n = Orbit number (principal Quantum number)

$$\frac{r_{n_1}}{r_{n_2}} = \frac{n_1^2}{n_2^2} \times \frac{Z_2}{Z_1} \text{ (single electron containing system) (for atom or ion)}$$

If the electron moving in the n^{th} orbit has wavelength λ , then $n\lambda = 2\pi r$ (circumference of the orbit)

(3) **Angular momentum of an electron :** $mvr = \frac{nh}{2\pi}$

Speed of an electron : $V = \frac{nh}{2\pi mr} = \frac{Zh}{2\pi m a_0 n} = \frac{2.19 \times 10^6 \times Z}{n} \text{ ms}^{-1}$,

Where, n = orbit number (principal quantum number), $m = 9.109 \times 10^{-31} \text{ kg}$ (mass of electron),
 V = speed of electron, $h = 6.626 \times 10^{-34} \text{ J sec.}$ (Plancks constant)), Z = Atomic number

(4) Number of rotations made by electron around the nucleus = $\frac{V}{2\pi r}$

44. According to Bohr's postulates, which of the following is possible value of angular momentum of an accepted orbit of an electron ?

- (A) $\frac{h}{4\pi}$ (B) $\frac{5h}{4\pi}$ (C) $\frac{h}{\pi}$ (D) $\frac{3h}{4\pi}$

45. According to Bohr's postulates, which of the following is not a possible value of angular momentum of an accepted orbit of an electron ?

- (A) $\frac{2h}{\pi}$ (B) $\frac{5h}{4\pi}$ (C) $\frac{h}{\pi}$ (D) all three not possible

46. Which of the following is the limitation of Bohr's model of an atom ?

- (A) cannot explain Zeeman effect.
 (B) cannot explain Doublet in a spectrum.
 (C) cannot explain the ability of atoms to form molecule by chemical bond.
 (D) Mentioned all three

47. According to Bohr's postulates, if angular momentum of an electron in a H-atom is 4.22×10^{-34} joule second, then e^- will be present in which orbit ?

- (A) K (B) L (C) M (D) N

48. According to Bohr's postulates, calculate the angular momentum of an electron in the 4th orbit ?

- (A) $\frac{4h}{\pi}$ (B) $\frac{2h}{\pi}$ (C) $\frac{h}{4\pi}$ (D) $\frac{h}{\pi}$

49. In a Bohr's model of an atom, what will be the angular momentum of an electron in the 5th orbit?

- (A) $\frac{h}{4\pi}$ (B) $\frac{10h}{\pi}$ (C) $\frac{2.5h}{\pi}$ (D) $\frac{25h}{\pi}$

50. If radius of 1st orbit in a Bohr's model is x , then what will be the de-broglie wavelength of an electron rotating in its third orbit ?

- (A) $3\pi x$ (B) $2\pi x$ (C) $4\pi x$ (D) $6\pi x$

51. What will be the speed of electron rotating if it covers wavelength amount of distance in 1 second ?

- (A) $\sqrt{\frac{h}{m}}$ (B) $\sqrt{\frac{m}{h}}$ (C) $\sqrt{\frac{h}{p}}$ (D) $\sqrt{\frac{h}{2KE}}$

52. According to Bohr's postulates, what will be the angular momentum of an electron of H atom in its third orbit ?

- (A) $3.165 \times 10^{-34} \text{ kgm}^2 \text{ s}^{-1}$ (B) $6.33 \times 10^{-34} \text{ kgm}^2 \text{ s}^{-1}$
 (C) $1.055 \times 10^{-34} \text{ kgm}^2 \text{ s}^{-1}$ (D) $1.41 \times 10^{-34} \text{ kgm}^2 \text{ s}^{-1}$

53. According to Bohr's postulates, what will be the speed of e^- in P orbit of a H atom ?
- (A) $\frac{h}{2\pi mr}$ (B) $\frac{6h}{\pi mr}$ (C) $\frac{3h}{2\pi mr}$ (D) $\frac{3h}{\pi mr}$
54. According to Bohr's postulates, if radius of 2nd orbit in H atom is 2.12×10^{-10} m, then what is the speed of e^- in the second orbit ? (mass of $e^- = 9.11 \times 10^{-31}$ kg)
- (A) $2.1 \times 10^6 \text{ ms}^{-1}$ (B) $2.3 \times 10^4 \text{ ms}^{-1}$ (C) $1.1 \times 10^6 \text{ ms}^{-1}$ (D) $2.46 \times 10^5 \text{ ms}^{-1}$
55. Calculate the mass of a photon having $3.6 \text{ \AA}$ wavelength ?
- (A) $6.135 \times 10^{-26} \text{ kg}$ (B) $6.135 \times 10^{-33} \text{ kg}$ (C) $6.135 \times 10^{-33} \text{ gm}$ (D) $6.135 \times 10^{-26} \text{ gm}$

Answers : 44. (C), 45. (B), 46. (D), 47. (D), 48. (B), 49. (C), 50. (D), 51. (A), 52. (A),
53. (D), 54. (C), 55. (B)

● **Photoelectric effect :**

When light is bombarded on the surface of a metal, e^- s are emitted. Such effect of light is called photoelectric effect of light.

Kinetic energy of e^- emitted : When surface of a metal is bombarded with light of definite wavelength,

$$K = \frac{1}{2}mv^2 = \Delta E - \Delta E_0 = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = hc(\nu - \nu_0) \text{ where, } \Delta E = \text{Energy of photon emitted,}$$

λ = wavelength of emitted photon, ν = frequency of emitted photon, ΔE_0 = minimum amount of energy required for emission of e^- from the surface of a metal = Ionization energy of a metal (Threshold energy), λ_0 = Threshold wavelength, ν_0 = Threshold frequency, m = mass of e^- , v = Speed of e^- .

56. Ionization enthalpy of potassium atom is 416 KJmole^{-1} . Calculate the maximum wavelength of radiation required to remove e^- from gaseous potassium atom ?
- (A) 2877 nm (B) $287.7 \times 10^3 \text{ nm}$ (C) 0.02877 nm (D) 287.7 nm
57. Ionization enthalpy of Cesium (Cs) atom is 373 KJmole^{-1} . Radiation of which of the following wavelength is required to remove e^- from gaseous cesium (Cs) atom ?
- (A) 301 nm (B) 351 nm (C) 421 nm (D) 371 nm
58. Ionization enthalpy of lithium atom is 520 KJmole^{-1} . Calculate the radiation of minimum frequency required to remove e^- from gaseous lithium atom ?
- (A) $1.3 \times 10^{15} \text{ s}^{-1}$ (B) $1.3 \times 10^{12} \text{ s}^{-1}$ (C) $1.3 \times 10^8 \text{ s}^{-1}$ (D) $1.3 \times 10^{13} \text{ s}^{-1}$
59. Ionization enthalpy of magnesium (Mg) atom is 737 KJmole^{-1} . Radiation of which frequency is required to remove e^- from Mg atom ?
- (A) $1.847 \times 10^{14} \text{ Hz}$ (B) $1.847 \times 10^{19} \text{ Hz}$
(C) Both (A) and (B) (D) e^- will not be emitted by given frequency

60. A metal requires minimum $7.0 \times 10^{14} \text{s}^{-1}$ frequency of a photon to emit electron. What will be the kinetic energy of e^- having frequency of radiation $1.0 \times 10^{15} \text{s}^{-1}$.
- (A) 1.99×10^{-10} joule (B) 1.99×10^{-17} joule (C) 1.99×10^{-19} joule (D) 1.99×10^{-12} joule
61. Wavelength of 242 nm is required for ionization of sodium, calculate ionization enthalpy of sodium ?
- (A) 494 joule mole^{-1} (B) 494 KJ mole^{-1} (C) 49400 KJ mole^{-1} (D) 4940 J mol^{-1}
62. Which option is right for a metal which requires wavelength of x to remove electron. If λ is wavelength of radiation bombarded on surface to remove e^- ?
- (A) $\lambda > x$ (B) $\lambda < x$ (C) $\lambda = 2x$ (D) None
63. A metal requires wavelength of x to remove electron. If λ wavelength radiation is bombarded on its surface e^- is not removed then which of the following is right ?
- (A) $\lambda > x$ (B) $\lambda < x$ (C) $\lambda = \frac{x}{2}$ (D) all three
64. In order to remove electron from a metal atom, radiation of frequency x is required. If radiation of frequency ν is bombarded on its surface and e^- is removed, then which of the following is right ?
- (A) $\nu > x$ (B) $\nu < x$ (C) $\nu = \frac{x}{2}$ (D) all three
65. In order to remove electron from a metal atom, radiation of frequency x is required. If radiation of frequency ν is bombarded on its surface e^- is not removed then which of the following is right ?
- (A) $\nu > x$ (B) $\nu < x$ (C) $\nu = 2x$ (D) all three
66. If a metal is bombarded with radiation having wavelength λ , electrons are emitted. If radiation of same intensity but wavelength smaller than λ is bombarded on the metal, what will be the observation ?
- (A) Number of emitted electrons decreases (B) Kinetic energy of emitted electron decreases
(C) Number of emitted electrons increases (D) Kinetic energy of emitted electron increases
67. If a metal is bombarded with radiation having wavelength λ , electrons are emitted. If radiation of same intensity but wavelength larger than λ is bombarded on the metal. What will be the observation ?
- (A) Number of emitted electrons decreases (B) Kinetic energy of emitted electron decreases
(C) Number of emitted electrons increases (D) Kinetic energy of emitted electron increases
68. If a metal is bombarded with radiation having frequency ν , electrons are emitted. If radiation of same intensity but frequency larger than ν is bombarded on the metal, what will be the observation ?
- (A) Number of emitted electrons decreases (B) Kinetic energy of emitted electron decreases
(C) Number of emitted electrons increases (D) Kinetic energy of emitted electron increases

69. If a metal is bombarded with radiation having frequency ν , electrons are emitted. If radiation of same intensity but frequency lesser than ν is bombarded on the metal, what will be the observation ?
 (A) Number of emitted electrons decreases (B) Kinetic energy of emitted electron decreases
 (C) Number of emitted electrons increases (D) Kinetic energy of emitted electron increases
70. If a metal is bombarded with radiation having wavelength λ , electrons are emitted. What will be the effect if intensity of radiation increases ?
 (A) Number of emitted electrons decreases (B) Kinetic energy of emitted electron decreases
 (C) Number of emitted electrons increases (D) Kinetic energy of emitted electron increases
71. If a metal is bombarded with radiation having wavelength λ , electrons are emitted. What will be the effect if intensity of radiation decreases ?
 (A) Number of emitted electrons decreases (B) Kinetic energy of emitted electron decreases
 (C) Number of emitted electrons increases (D) Kinetic energy of emitted electron increases

Answers : 56. (D), 57. (A) 58. (A), 59. (B), 60. (C), 61. (B), 62. (D), 63. (A), 64. (A), 65. (B), 66. (D), 67. (B), 68. (D), 69. (B), 70. (C), 71. (A)

● **Energy of electron in Bohr's model of an atom or ion**

$$E_n = -R_H \times \frac{Z^2}{n^2} \text{ where, } R_H = \text{Rydberg's constant} = 2.18 \times 10^{-18} \text{ joule}$$

Z = atomic number, n = orbit number (principal quantum no.)

For interpretation of Hydrogen spectrum, according to the Bohr's postulate the energy difference due

to the transition of electron $n_2 \rightarrow n_1$ is $\Delta E = E_{n_1} - E_{n_2} = R_H \times Z^2 \times \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] \text{ joule electron}^{-1}$, where

$n_2 > n_1$, if $\Delta E < 0$ (-ve) means electron is transited from lower energy orbit to higher energy orbit and energy is released during this process.

If $n_2 < n_1$, $\Delta E > 0$ (+ve) means electron is transited from lower energy orbit to higher energy orbit and energy is absorbed during this process.

$$\Delta E = E_{n_f} - E_{n_i} = 1312.796 \times Z^2 \left[\frac{1}{n_i^2} - \frac{1}{n_f^2} \right] \text{ KJ mole}^{-1} \text{ electron}^{-1} \text{ to calculate ionization energy}$$

$$n_i = 1, n_f = \infty$$

$$\text{Ionization energy of } {}_1\text{H-atom, } \Delta E = E_{\infty} - E_1 = 1312.796 \times (1)^2 \left[\frac{1}{1^2} - \frac{1}{\infty^2} \right] = 1312.796 \text{ KJ/mole}$$

$$\text{Ionization energy of } {}_2\text{He}^+ \Delta E = E_{\infty} - E_1 = 1312.796 \times (2)^2 \left[\frac{1}{1^2} - \frac{1}{\infty^2} \right] = 5251.184 \text{ KJ/mole}$$

Ionisation energy of ${}_3\text{Li}^{+2}$ $\Delta E = E_\infty - E_1 = 1312.796 \times (3)^2 \left[\frac{1}{1^2} - \frac{1}{\infty^2} \right] = 11815.164 \text{ KJ/mole}$

With respect to Hydrogen spectrum, the total number of lines obtained due to transition of electron $n_2 \rightarrow n_1$ ($n_2 > n_1$) is

$$\frac{(n_2 - n_1 + 1)(n_2 - n_1)}{2}$$

● Series of lines obtained during Hydrogen emission spectrum

$R_H = 2.18 \times 10^{-18} \text{ joule}$, $R = 109737 \text{ cm}^{-1}$, $h = 6.626 \times 10^{-34} \text{ Jsec.}$, $c = 3.0 \times 10^8 \text{ ms}^{-1}$

No.	series	Region	Transition	emitted maximum wavelength $\lambda_{\max} = \frac{h \times c \times n_1^2 \times n_2^2}{R_H (n_2^2 - n_1^2)}$ or $\lambda_{\max} = \frac{n_1^2 \times n_2^2}{R (n_2^2 - n_1^2)}$	emitted minimum wavelength $\lambda_{\min} = \frac{h \times c \times n_1^2}{R_H}$ or $\lambda_{\min} = \frac{n_1^2}{R}$	emitted maximum frequency $\nu_{\max} = \frac{R_H}{h \times n_1^2}$	emitted minimum frequency $\nu_{\min} = \frac{R_H (n_2^2 - n_1^2)}{h \times n_1^2 \times n_2^2}$	$\frac{\lambda_{\max}}{\lambda_{\min}} = \frac{\nu_{\max}}{\nu_{\min}} = \frac{n_2^2}{(n_2^2 - n_1^2)}$
(1)	lyman	ultra violet	$n_1 = 1$ $n_2 = 2, 3, \dots$	$n_1 = 1, n_2 = 2$ $\lambda_{\max} = \frac{h \times c \times 4}{R_H \times 3}$ or $\lambda_{\max} = \frac{4}{3 \times R}$	$\lambda_{\min} = \frac{h \times c \times 1}{R_H}$ or $\lambda_{\min} = \frac{1}{R}$	$\nu_{\max} = \frac{R_H}{h \times 1}$	$\nu_{\min} = \frac{R_H \times 3}{h \times 4}$	$\frac{4}{3}$
(2)	Balmer	visible	$n_1 = 2$ $n_2 = 3, 4, \dots$	$n_1 = 2, n_2 = 3$ $\lambda_{\max} = \frac{h \times c \times 36}{R_H \times 5}$ or $\lambda_{\max} = \frac{36}{5 \times R}$	$\lambda_{\min} = \frac{h \times c \times 4}{R_H}$ or $\lambda_{\min} = \frac{4}{R}$	$\nu_{\max} = \frac{R_H}{h \times 4}$	$\nu_{\min} = \frac{R_H \times 5}{h \times 36}$	$\frac{9}{5}$

(3)	Paschen	Infrared	$n_1 = 3$ $n_2 = 4, 5, \dots$	$n_1 = 3, n_2 = 4$ $\lambda_{\max} = \frac{h \times c \times 144}{R_H \times 7}$ or $\lambda_{\min} = \frac{9}{R}$ $\lambda_{\max} = \frac{144}{7 \times R}$	$\lambda_{\min} = \frac{h \times c \times 9}{R_H}$ or $\lambda_{\min} = \frac{9}{R}$	$\nu_{\max} = \frac{R_H}{h \times 9}$	$\nu_{\min} = \frac{R_H \times 7}{h \times 144}$	$\frac{16}{7}$
(4)	Brackett	Infrared	$n_1 = 4$ $n_2 = 5, 6, \dots$	$n_1 = 4, n_2 = 5$ $\lambda_{\max} = \frac{h \times c \times 400}{R_H \times 9}$ or $\lambda_{\min} = \frac{16}{R}$ $\lambda_{\max} = \frac{400}{9 \times R}$	$\lambda_{\min} = \frac{h \times c \times 16}{R_H}$ or $\lambda_{\min} = \frac{16}{R}$	$\nu_{\max} = \frac{R_H}{h \times 16}$	$\nu_{\min} = \frac{R_H \times 9}{h \times 400}$	$\frac{25}{9}$
(5)	Pfund	Infrared	$n_1 = 5$ $n_2 = 6, 7, \dots$	$n_1 = 5, n_2 = 6$ $\lambda_{\max} =$ $\frac{h \times c \times 36 \times 25}{R_H \times 11}$ or $\lambda_{\max} = \frac{36 \times 25}{11 \times R}$	$\lambda_{\min} = \frac{h \times c \times 25}{R_H}$ or $\lambda_{\min} = \frac{25}{R}$	$\nu_{\max} = \frac{R_H}{h \times 25}$	$\nu_{\min} =$ $\frac{R_H \times 11}{h \times 36 \times 25}$	$\frac{36}{11}$
(6)	Humphrey	Infrared	$n_1 = 6$ $n_2 = 7, 8, \dots$	$n_1 = 6, n_2 = 7$ $\lambda_{\max} =$ $\frac{h \times c \times 49 \times 36}{R_H \times 13}$ or $\lambda_{\max} = \frac{49 \times 36}{13 \times R}$	$\lambda_{\min} = \frac{h \times c \times 36}{R_H}$ or $\lambda_{\min} = \frac{36}{R}$	$\nu_{\max} = \frac{R_H}{h \times 36}$	$\nu_{\min} =$ $\frac{R_H \times 13}{h \times 49 \times 36}$	$\frac{49}{13}$

72. Which of the following is the possible principal quantum number of valence e^- in its ground state in an atom ?
 (A) 1 (B) 2 (C) 3 (D) all three
73. Which of the following transition of an electron in a Hydrogen emission spectrum possess maximum frequency ?
 (A) $2 \rightarrow 1$ (B) $3 \rightarrow 2$ (C) $4 \rightarrow 3$ (D) $5 \rightarrow 4$
74. Which of the following transition of an electron in a Hydrogen emission spectrum possess maximum wavelength ?
 (A) $2 \rightarrow 1$ (B) $4 \rightarrow 2$ (C) $7 \rightarrow 5$ (D) $6 \rightarrow 4$
75. Which of the following transition of an electron in a Hydrogen emission spectrum possess maximum energy of photon ?
 (A) $2 \rightarrow 1$ (B) $3 \rightarrow 2$ (C) $4 \rightarrow 3$ (D) $5 \rightarrow 4$
76. Which of the following transition of an electron in a Hydrogen emission spectrum possess minimum energy of a photon ?
 (A) $2 \rightarrow 1$ (B) $3 \rightarrow 2$ (C) $4 \rightarrow 3$ (D) $5 \rightarrow 4$
77. Calculate energy of a photon emitted due to transition of e^- from $4 \rightarrow 1$ in a Hydrogen atom ?
 (A) 2.044×10^{18} joule (B) 2.044×10^{-18} joule (C) 2.044×10^{-18} erg (D) 8.0×10^{-17} joule
78. Calculate frequency of photon emitted due to transition of e^- from $5 \rightarrow 2$ in a Hydrogen atom ?
 (A) 6.14×10^7 Hz (B) 9.87×10^{14} Hz (C) 2.63×10^7 Hz (D) 6.91×10^{14} Hz
79. Calculate wavelength of a photon emitted due to transition of e^- from $6 \rightarrow 4$ in a Hydrogen atom ?
 (A) 2.63×10^3 nm (B) 1.09×10^{-6} m (C) 2.63×10^{-6} cm (D) 2.63×10^{-12} nm
80. If ionization energy of H atom and energy required to remove an electron from excited state of He^+ is same, then calculate the principal quantum of electron in He^+ .
 (A) 3 (B) 1 (C) 2 (D) 4
81. In Paschen series for a certain frequency energy of photon is $22.29 \text{ Kcal mol}^{-1}$ is possible for which of the following transition ? ($1 \text{ Kcal} = 4.184 \text{ joule}$)
 (A) $4 \rightarrow 3$ (B) $6 \rightarrow 3$ (C) $5 \rightarrow 3$ (D) None
82. What can be the maximum emitted wavelength in a Balmer series ?
 (A) 565.5 nm (B) 364.7 nm (C) 656.5 nm (D) 556 nm
83. What can be the minimum emitted wavelength in a Paschen series ?
 (A) 1875.8 nm (B) 820.6 nm (C) 1785 nm (D) 187.5 nm
84. What can be the minimum emitted frequency in a Lyman series ?
 (A) $3.29 \times 10^{15} \text{ s}^{-1}$ (B) $2.4675 \times 10^{15} \text{ s}^{-1}$ (C) $4.2675 \times 10^{15} \text{ s}^{-1}$ (D) $2.47 \times 10^{13} \text{ s}^{-1}$
85. What can be the minimum emitted frequency in a Brackett series ?
 (A) $2.056 \times 10^{14} \text{ s}^{-1}$ (B) $7.4 \times 10^{15} \text{ s}^{-1}$ (C) $2.56 \times 10^{15} \text{ s}^{-1}$ (D) $7.4025 \times 10^{13} \text{ s}^{-1}$

86. What can be the minimum emitted frequency in a Pfund series ?
 (A) $4.2 \times 10^{13} \text{s}^{-1}$ (B) $4.02 \times 10^{13} \text{s}^{-1}$ (C) $1.316 \times 10^{14} \text{s}^{-1}$ (D) $1.316 \times 10^{13} \text{s}^{-1}$
87. What can be the maximum emitted frequency in Lyman series ?
 (A) $3.29 \times 10^{15} \text{s}^{-1}$ (B) $2.4675 \times 10^{15} \text{s}^{-1}$ (C) $4.2675 \times 10^{15} \text{s}^{-1}$ (D) $2.47 \times 10^{13} \text{s}^{-1}$
88. Calculate the difference in energy (ΔE) for a transition of electron from $5 \rightarrow 2$ in a H-atom ?
 (A) -5.758×10^{-19} joule/electron (B) -4.578×10^{-19} joule/electron
 (C) -4.578×10^{-19} joule/electron (D) -4.857×10^{-7} joule/electron
89. Calculate the difference in energy (ΔE) for a transition of electron from $6 \rightarrow 3$ in a H-atom ?
 (A) -1.8167×10^{-18} joule/electron (B) -1.1867×10^{-18} joule/electron
 (C) -1.867×10^{19} joule/electron (D) -1.8167×10^{-19} joule/electron
90. Calculate the difference in energy (ΔE) for a transition of electron from $5 \rightarrow 1$ in a H-atom ?
 (A) -2.09×10^{-20} joule/electron (B) -2.09×10^{-18} joule/electron
 (C) -2.9×10^{-20} joule/electron (D) -2.9×10^{-17} joule/electron
91. When electron in Hydrogen atom jumps from 4th excited energy level to lower energy levels, then how many lines are seen in U.V.region, visible region, I.R.region and total number of lines respectively are ?
 (A) 3, 2, 1, 6 (B) 4, 2, 2, 8 (C) 3, 3, 4, 10 (D) 4, 3, 3, 10

Answers : 72. (D), 73. (A), 74. (C), 75. (A), 76. (D), 77. (B), 78. (D), 79. (A), 80. (C), 81. (C), 82. (C), 83. (B), 84. (B), 85. (D), 86. (B), 87. (A), 88. (B), 89. (D), 90. (B), 91. (D)

● Schrödinger's wave equation

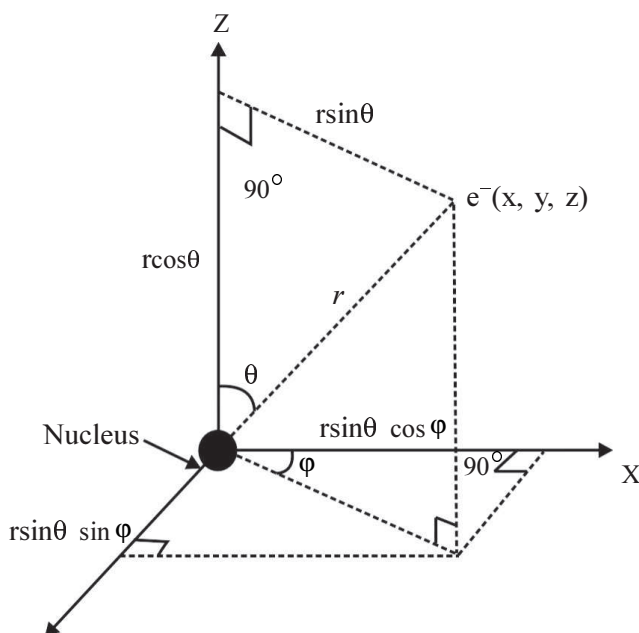
Schrödinger derived an equation for energy of an electron moving around the nucleus, which is known as 'Schrödinger's wave equation' and it is as follows :

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

where, x, y, z are cartesian coordinates describing position of electron in a H-atom. m = mass of electron, E = Energy of electron proton system, v = potential energy, Ψ = is known as wave function, which is similar to the amplitude of wavelength, $(E - V)$ = Kinetic energy, h = planck's constant, $\frac{d^2\Psi}{dx^2} =$

Mathematical operation performed on Ψ to find solution of the equation.

Position of an electron in a H-atom is described by cartesian co-ordinates (x, y, z) and spherical co-ordinates (r, θ and ϕ)



Relation between x, y, z and r, θ and ϕ are as follows :

$$x = r \cdot \sin \theta \cdot \cos \phi$$

$$y = r \cdot \sin \theta \cdot \sin \phi$$

$$z = r \cdot \cos \theta$$

$\therefore x^2 + y^2 + z^2 = r^2$, r = distance between electron and nucleus. Using the above mentioned relation, schrodinger wave equation containing cartesian co-ordinates is converted into spherical co-ordinate wave equation and thus the equation is separated into three parts such that every part will show only one variable r, θ or ϕ . In this three equation at constant θ variation in r and ϕ , at constant ϕ , variation in θ and r and at constant r, variation in ϕ and θ are done using these three variable, the total wave function Ψ_{total} of the system is as follows:

$$\Psi_{\text{total}} = R \cdot \Theta \cdot \Phi$$

or

$$\Psi_{\text{total}} = R_{n,l}(r) \cdot \Theta_{l,m}(\theta) \cdot \Phi_m(\phi)$$

92. Which of the following is the correct Schrödinger's equation ?

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

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

93. If electron is 3 unit away from the nucleus, then which of the following is the possible Cartesian co-ordinates of the electron ?

(A) (1, -1, 1) (B) (2, 1, -1) (C) (2, 0, 1) (D) (-1, 2, 2)

94. How many acceptable solution of Ψ are possible for $n = 4$, $l = 3$, $m = +2$?

(A) 16 (B) 7 (C) 1 (D) 32

95. If spherical co-ordinate of electron in an atom, r, θ and ϕ are $2\sqrt{2}$, $\frac{3\pi}{4}$ and $\frac{\pi}{4}$ respectively, then the cartesian co-ordinates for it is ...

(A) (1, -2, $\sqrt{3}$) (B) (1, $\sqrt{3}$, -2) (C) ($-\sqrt{3}$, 1, $\sqrt{6}$) (D) ($\sqrt{3}$, 1, $\sqrt{6}$)

96. What will be the value of z , if spherical coordinate θ is 45° and cartesian co-ordinate for electron in atom is $(2, -\sqrt{5}, z)$.
- (A) -2 (B) 3 (C) 9 (D) $\sqrt{2}$
97. Which of the following is not a possible value of Ψ at a point around the nucleus ?
- (A) -0.0004 (B) 1.2 (C) 0.00005 (D) 0

Answers : 91. (D), 92. (B), 93. (D), 94. (C), 95. (B), 96. (B), 97. (B)

● Principal Quantum Number

- (1) Value of principal quantum number is positive ($n = 1, 2, 3, 4, 5, \dots$)
- (2) It decides the energy (E_n) of an electron in an atom or ion (for single electron containing atom or ion)
- (3) distance between electron and nucleus can be decided for different values of n . Higher the value of n , more is the distance between electron and nucleus.
- (4) Using this quantum number energy level that is orbit can be decided.
- (5) For n^{th} energy level there are n types of orbital, n^2 number of orbital and $2n^2$ number of electron.

Principal Quantum number (n)	orbit	Total type of orbitals (n)	Total number of orbital (n^2)	Total possible number of electron to be filled ($2n^2$)
1	K	one (s)	1	2
2	L	two (s, p)	4	8
3	M	three (s, p, d)	9	18
4	N	four (s, p, d, f)	16	32
5	O	five (s, p, d, f, g)	25	50
6	P	six (s, p, d, f, g, h)	36	72

● Angular Momentum Quantum Number (l) (Azimuthal or secondary quantum number)

- (1) It is related to principal quantum number (n) and its value ranges from 0 to $(n - 1)$.
- (2) from the value of this quantum number shape (type) of orbital can be decided.
- (3) value of this quantum number (l) indicates angular momentum of the electron.
- (4) Kinetic energy of an electron is due to angular momentum of the electron. Value of Angular Kinetic energy of electron is limited to total energy of electron due to which acceptable value of l depends on acceptable value of n .
- (5) Total energy of electron in multielectron atoms is decided by $(n + l)$.

Principal Quantum number (n)	Acceptable values of l (0 to (n – 1) integer value)	Total Value of l	Type of orbital
1	0	0	s
2	0, 1	1	p
3	0, 1, 2	2	d
4	0, 1, 2, 3	3	f
5	0, 1, 2, 3, 4	4	g
6	0, 1, 2, 3, 4, 5	5	h

● **(Magnetic Quantum Number) (m or m_l)**

(1) electron having angular momentum possess magnetic field and value of magnetism is decided by “ m ”.

(2) Magnetism is originated due to angular momentum hence acceptable value of m are related to value of l .

(3) for any value of l there are $(2l + 1)$ number of m values.

(4) for any value of l , value of m is an integer ranging from $+l$ to $-l$ including zero.

(5) for any value of l (any type of orbital) there are $(2l + 1)$ number of acceptable value of m which indicates number of orbital.

Value of l	Type of orbital	Total number of acceptable value of m ($2l + 1$) (Total number of orbital of each type)	Acceptable value of m , $+l$ to $-l$ integers
0	s	one	0
1	p	three	+1, 0, -1
2	d	five	+2, +1, 0, -1, -2
3	f	seven	+3, +2, +1, 0, -1, -2, -3
4	g	nine	+4, +3, +2, +1, 0, -1, -2, -3, -4
5	h	eleven	+5, +4, +3, +2, +1, 0, -1, -2, -3, -4, -5

● **Spin Quantum Number (s)**

Quantum number n , l and m are originated from Schrödinger’s wave equation, but for complete description of electron spin quantum number is required, which does not originate from Schrödinger’s wave equation. In 1925 A.D. scientist Goudsmitt and Uhlenbeck stated that axial rotation of an electron possess angular momentum. This momentum is quantised and to calculate its value spin quantum number (s) is required. Electron possess two opposite spin clockwise and anticlockwise. For which it has quantum number $+\frac{1}{2}$ and $-\frac{1}{2}$ only two values. Due to angular momentum of electron magnetic field is created,

moreover due to axial rotation of electron property of internal magnetic field is created. These magnetic fields are in two opposite direction due to which they have two spin quantum number values $+\frac{1}{2}$ and $-\frac{1}{2}$.

- 98.** Which of the following cannot be explained by quantum number n , l and m ?
 (A) orbit number (B) doublet, triplet etc. obtained in a spectrum
 (C) Type of orbit (D) cannot explain any of the three
- 99.** How many orbits of multielectron atom or ion can have $2 \leq n + l \leq 4$?
 (A) 5 (B) 9 (C) 12 (D) 10
- 100.** Which of the following set of quantum number is not possible ?
 (A) $n = 1, l = 0, m_l = 0$ (B) $n = 4, l = 3, m_l = 3$
 (C) $n = 2, l = 1, m_l = +2$ (D) $n = 6, l = 2, m_l = -1$
- 101.** On giving energy which of the following quantum number possessing orbital will loose electron first ?
 (A) $n = 4, l = 0$ (B) $n = 3, l = 2$ (C) $n = 3, l = 1$ (D) $n = 2, l = 1$
- 102.** Which of the following quantum number possessing orbital will be filled by electrons first ?
 (A) $n = 3, l = 1$ (B) $n = 3, l = 2$ (C) $n = 3, l = 0$ (D) $n = 2, l = 1$
- 103.** Which of the following quantum number possessing orbital will be filled by electron last ?
 (A) $n = 4, l = 0, m_l = 0$ (B) $n = 3, l = 2, m_l = +1$
 (C) $n = 3, l = 0, m_l = 0$ (D) $n = 3, l = 1, m_l = -1$
- 104.** For different excited state of H-atom, quantum state of which electron shows least energy ?
 (A) $n = 5, l = 2, m_l = +1, s = -\frac{1}{2}$ (B) $n = 6, l = 0, m_l = 0, s = +\frac{1}{2}$
 (C) $n = 4, l = 3, m_l = -2, s = +\frac{1}{2}$ (D) $n = 5, l = 0, m_l = 0, s = -\frac{1}{2}$
- 105.** In atoms other than H atoms, how many equienergetic orbitals are possible in an orbit ?
 (A) n^2 (B) $2l + 1$ (C) n (D) none
- 106.** How many electrons will have quantum number $l = 0$ for all completely filled orbitals between nucleus and P orbit?
 (A) 5 (B) 25 (C) 10 (D) 30
- 107.** What is the maximum possible atomic number of element containing four electrons in ground state with magnetic momentum quantum number $m_l = -1$?
 (A) 23 (B) 18 (C) 24 (D) 16
- 108.** Maximum how many electrons can be filled in an orbital in a given energy state ?
 (A) $4l + 2$ (B) $2n^2$ (C) n^2 (D) $2l + 1$

109. Total how many electrons can have $2 \leq n + l \leq 5$ in multi electron species (atom or ion) ?
 (A) 18 (B) 36 (C) 8 (D) 16
110. Maximum how many electrons can be filled in P orbit ?
 (A) 6 (B) 36 (C) 12 (D) 72
111. What is the minimum possible atomic number of element containing four electrons in ground state with magnetic momentum quantum number $m_l = +1$?
 (A) 18 (B) 14 (C) 12 (D) 16
112. Maximum how many electrons can be filled in all orbitals together between nucleus and O orbit ?
 (A) 60 (B) 30 (C) 32 (D) 16
113. Maximum how many electrons will have $s = +\frac{1}{2}$ for all completely filled orbitals between nucleus and O orbit ?
 (A) 60 (B) 30 (C) 32 (D) 16
114. Maximum how many electrons will have $m_l = 0$ for all completely filled orbitals between nucleus and O orbit ?
 (A) 10 (B) 30 (C) 20 (D) 16
115. Maximum how many electrons will have $m_l = -1$ for all completely filled orbitals between nucleus and O orbit ?
 (A) 6 (B) 30 (C) 12 (D) 16

Answers : 98. (B), 99. (B), 100. (C), 101. (A), 102. (D), 103. (B), 104. (C), 105. (B),
 106. (C), 107. (A), 108. (A), 109. (B), 110. (D), 111. (B), 112. (A), 113. (B),
 114. (C), 115. (A)

● Shape of ns orbitals

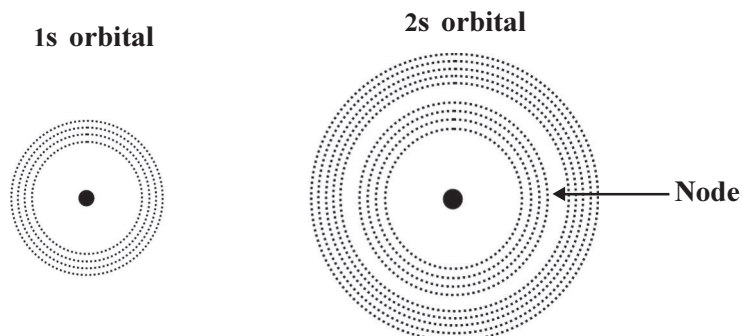
The shapes of orbitals are determined by the values of acceptable solution of Ψ . The electron of Hydrogen atom in the energy level having ($n = 1$) is in the ground state. This energy level has only one orbital. If Schrödinger's equation is solved for $n = 1$ and $l = 0$, the acceptable solution of Ψ is given by

$$\Psi_{\substack{n=1 \\ l=0}} = \frac{1}{\sqrt{\pi}} \left[\frac{1}{a_0} \right]^{\frac{3}{2}} \cdot e^{\frac{-r}{a_0}}, \text{ where } a_0 = \frac{h^2}{4\pi^2 m e^2}, r = \text{distance of electron from nucleus}$$

Note that the value of Ψ depends only on r but not on θ or ϕ . Therefore the value of Ψ at all equidistant points from a nucleus are the same, irrespective of directions. Therefore, values of Ψ^2 also are the same at all equidistant points from nucleus. It means that the probability of finding electron at all such points is the same. If a surface is passed through all such points at which the probability of finding electron is the same, the resulting shape of the surface would be spherical. Therefore, the shapes of the orbitals having $n = 1$ and $l = 0$ values is supposed to be spherical. Similarly, in all other energy levels, the acceptable solutions of Ψ for $l = 0$ contain only r variable and therefore all orbitals having $l = 0$ values are supposed to be spherical in all energy levels. There is one such orbital in each energy level which is represented by symbol ns.

Node : There is a space in orbital where probability of finding an e^- is zero ($\Psi = 0$). This is called Node.

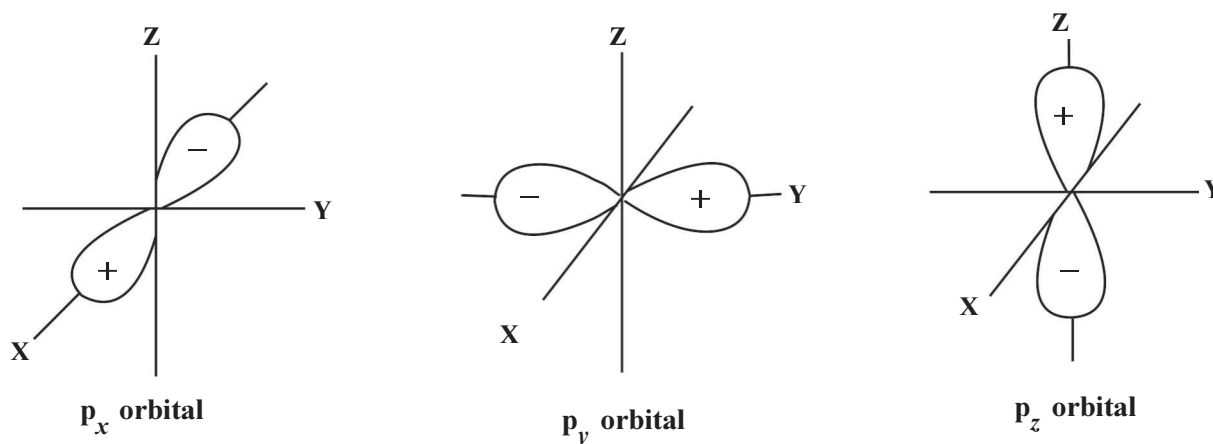
1s and 2s orbitals



• 2p orbitals OR number of 2p orbitals, shape and their directional properties

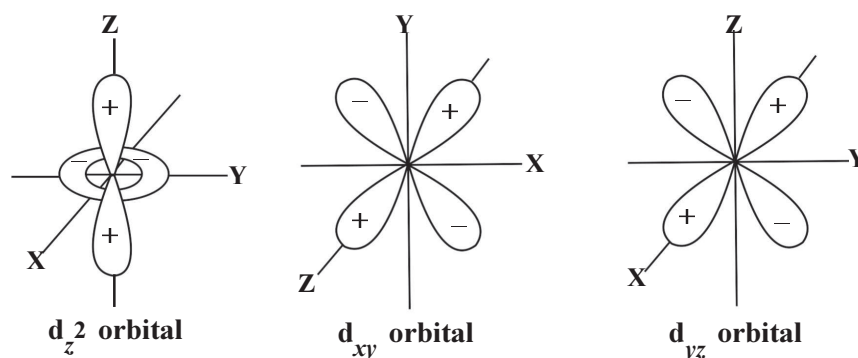
In Schrödinger's equation, the acceptable solutions of Ψ for $n = 2$, we get four solutions. One of these solutions $n = 2, l = 0$ contains only r variable. This indicates 2s orbitals.

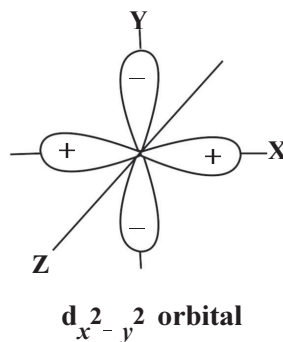
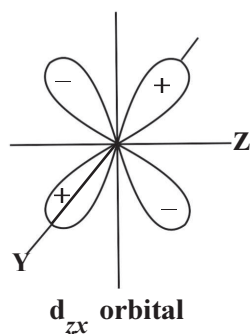
Remaining three solutions are obtained for $n = 2$ and $l = 1$ corresponding to $+1, 0$ and -1 values of m , which indicates three p-orbitals. Out of the three acceptable solution of wave function, two acceptable wave function solution have r, θ and ϕ variable while the third acceptable wave function solution have r and θ variable due to which the three p-orbitals show directional properties (or vectors). Shape of p-orbitals is dumbbell shaped and the three p-orbitals are equienergetic.



• d-orbitals or number of d-orbitals, shape and their directional properties

For $l = 2$, there are five values of m . These values are $+2, +1, 0, -1, -2$. Therefore, there are five acceptable solutions of wave function Ψ for $l = 2$. These wave functions also depend upon r, θ and ϕ , the five d-orbitals have directional character. Their shapes are irregular double dumbbells.





f-orbital : For f orbital $l = 3$, acceptable values of m are as follows, $m = +3, +2, +1, 0, -1, -2, -3$. Therefore in one energy level there are seven types of f orbital :

$$f_{x(x^2-y^2)}, f_{y(x^2-y^2)}, f_{z(x^2-y^2)}, f_{xy^2}, f_{yz^2}, f_{zx^2}, f_{z^3}$$

f orbital are directional and all f-orbital in an energy level are equienergetic.

● Relative energies of atomic orbitals :

All orbitals of the same level are of equal energy in case of H-atom. Which means all orbitals containing same principal quantum number (n) are equienergetic. The order of energies of orbital in H-atom is as follows :

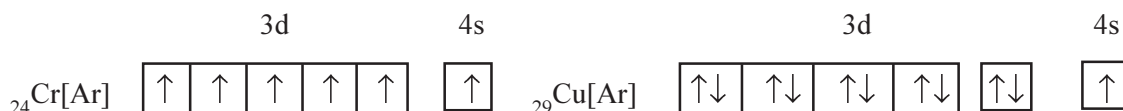
$$1s < 2s = 2p < 3s = 3p = 3d < 4s = 4p = 4d = 4f < 5s = 5p = 5d = 5f = 5g < 6s = 6p = 6d = 6f = 6g = 6h < \dots$$

In atoms other than H-atom in an energy level (for same value of n) orbitals of any one type are equienergetic. For example in second energy level the three p-orbitals are equienergetic ($2p_x = 2p_y = 2p_z$). But order for energy in different orbitals of a given energy level (for same value of n) is $s < p < d < f$. Normally in atoms other than H the order of energies of orbitals of different energy level is determined by the sum of n and l . An orbital having a higher value of $(n + l)$ has higher energy. If two orbitals of different types have equal values of $(n + l)$, then the orbital having a higher value of n has higher energy. In this manner order of energy level in atoms other than H is as follows :

	1s	2s	2p	3s	3p	3d	4p	5s	4d	5p	6s	4f	5d	6p	7s	5f	6d	7p	8s	...
value of n	1	2	2	3	3	4	3	4	5	4	5	6	4	5	6	7	5	6	7	8
value of l	0	0	1	0	1	0	2	1	0	2	1	0	3	2	1	0	3	2	1	0
value of $(n + l)$	1	2	3	3	4	4	5	5	5	6	6	6	7	7	7	7	8	8	8	8

In addition to this, if same type of orbitals are half filled or completely filled it increases the stability of the atom.

Due to this electronic configuration of $_{24}\text{Cr}$ is not $[\text{Ar}] 3d^4 4s^2$ but $[\text{Ar}] 3d^5 4s^1$ in the same way electronic configuration of $_{29}\text{Cu}$ is not $[\text{Ar}] 3d^9 4s^2$ but $[\text{Ar}] 3d^{10} 4s^1$.



● Laws of electron configuration :

(1) Auf-bau's principle : Electrons in an atom enter the orbitals of the lowest energy first. Later on they enter into orbitals of higher energy. The order of energies of orbitals is as under :

$$1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s < 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d < 7p < 8s < \dots$$

(2) Pauli's Exclusion principle : "An orbital in an atom cannot accommodate more than two electrons."
or

"No two electrons in an atom can have the same set of four quantum numbers."

(3) Hund's principle (maximum spin multiplicity principle) : When electrons are filled in equienergetic orbitals, maximum number of electrons remains unpaired and their spins remain parallel as far as possible. That is pairing of electrons in equienergetic orbitals does not take place until each of these orbitals has got one electron each.

- Orbital angular momentum = $\sqrt{l(l+1)} \cdot \frac{h}{2\pi}$
- axial (spin) angular momentum = $\sqrt{s(s+1)} \cdot \frac{h}{2\pi}$
- spin multiplicity = $2S + 1$, where S (Total spin) = $n \times \frac{1}{2}$
 n = number of unpaired e^-
- Total number of radial (spherical) nodes in an orbital = $n - l - 1$
- Total number of angular nodes in an orbital = l
- Total number of nodes (radial and angular) in an orbital = $n - 1$

116. With respect to H atom which of the following equation is acceptable solution of Ψ , $n = 1$, $l = 0$ (for 1S orbital) ?

(A) $\Psi_{n=1, l=0} = \frac{a_0^{-1} \cdot e^{-\frac{r}{a_0}}}{\sqrt{\pi a_0}}$ (B) $\Psi_{n=1, l=0} = \frac{a_0^{-1} \cdot e^{-\frac{r}{a_0}}}{\sqrt{\pi a_0}}$ (C) $\Psi_{n=1, l=0} = \frac{a_0^{-1} \cdot e^{-\frac{r}{a_0}}}{\sqrt{\pi a_0}}$ (D) $\Psi_{n=1, l=0} = \frac{a_0^{-1} \cdot e^{-\frac{r}{a_0}}}{\sqrt{\pi}}$

117. How many acceptable solutions are possible on solving Schrödinger's wave equation for $n = 4$, $l = 2$?

- (A) 16 (B) 5 (C) 4 (D) 6

118. According to p-orbital, filling of electron in orbital is wrong according to which law ?



- (A) Pauli's Exclusion principle (B) Hund's maximum multiplicity law
 (C) Aufbau's principle (D) Mentioned all three

119. Which electronic configuration is wrong for d-orbital ?



120. How many radial (spherical) nodes are possible in an orbital ?

- (A) $n - 1$ (B) l (C) $n - l - 1$ (D) $n + l$

121. How many angular nodes are possible in an orbital ?

- (A) $n - 1$ (B) l (C) $n - l - 1$ (D) $n + l$

122. How many nodes (angular and radial) are possible in an orbital ?

- (A) $n - 1$ (B) l (C) $n - l - 1$ (D) $n + l$

123. For which orbital possibility of electron in xy direction is zero ?

- (A) $2p_x$ (B) $2p_y$ (C) $2p_z$ (D) $3d_{xy}$

124. For which orbital possibility of electron in xy direction is not zero ?

- (A) $3d_{zx}$ (B) $3d_{yz}$ (C) $2p_z$ (D) $3d_{xy}$

125. Calculate mass of sample of dioxygen gas which is isotope to 0.5 kg Neutron and $^{16}_8\text{O}$. (mass of Neutron = $1.67493 \times 10^{-27}\text{kg}$)
 (A) 1982.86 gm (B) 991.4 gm (C) 9.982 gm (D) None
126. Atomic mass of He and Ne are 4 and 20 amu de-broglie wave length of He at -73°C is M times de-broglie wave length of Ne at 727°C , then calculate value of M ?
 (A) 5 (B) 4 (C) 8 (D) 12
127. Using a microscope uncertainty in position of electron is $0.2\text{\AA}$. In the same experiment if velocity is measured calculate the uncertainty in its velocity ? (mass of electron is $9.11 \times 10^{-31}\text{kg}$)
 (A) $2.9 \times 10^6\text{ms}^{-1}$ (B) $2.9 \times 10^7\text{ms}^{-1}$ (C) $3.5 \times 10^6\text{ms}^{-1}$ (D) None
128. Ionization energy of a metal is 416KJmole^{-1} . If radiation of wavelength $4.0 \times 10^{-8}\text{m}$ is bombarded on the surface of the metal then calculate velocity of emitted electron ?
 (mass of electron is $9.109 \times 10^{-31}\text{kg}$)
 (A) $3.65 \times 10^6\text{ms}^{-1}$ (B) $3.065 \times 10^6\text{ms}^{-1}$ (C) $3.30 \times 10^6\text{ms}^{-1}$ (D) $1.04 \times 10^8\text{ms}^{-1}$
129. In atom having atomic number $Z = 16$ out of the last two electrons filled in the ground state. The set of quantum numbers for the second last electron is $n = 3, l = 1, m_l = 0, s = +\frac{1}{2}$ then what would be the set of quantum numbers for last electron ?
 (A) $n = 3, l = 1, m_l = -1, s = +\frac{1}{2}$ (B) $n = 3, l = 0, m_l = 0, s = +\frac{1}{2}$
 (C) $n = 3, l = 0, m_l = 0, s = -\frac{1}{2}$ (D) $n = 3, l = 1, m_l = -1, s = -\frac{1}{2}$
130. Calculate wavelength of an electron in Hydrogen atom in second orbit in its excited state ? Where radius of n^{th} orbit in Hydrogen atom is described by the formula $r_n = 52.9 \times n^2\text{pm}$.
 (A) $6.64 \times 10^{-11}\text{m}$ (B) $6.64 \times 10^{-8}\text{m}$ (C) $6.64 \times 10^{-10}\text{m}$ (D) $6.64 \times 10^{-9}\text{m}$
131. Wavelength of electron in excited state in H atom is 1 nm then what would be the principal quantum number of electron ? Where radius of n^{th} orbit in Hydrogen atom is described by the formula $r_n = 52.9 \times n^2\text{pm}$.
 (A) 5 (B) 3 (C) 2 (D) 4
132. If electron of H-atom is jumping from 3rd energy level excited state to lower energy level then the wavelength of emitted photon is 486.3 nm. What will be the decrease in de-broglie wavelength of electron ? where radius of n^{th} orbit in H atom is described by the formula $r_n = 5.29 \times 10^{-11} \times n^2\text{m}$.
 (A) $6.644\text{\AA}$ (B) $6.644 \times 10^{-10}\text{cm}$ (C) 6.644 pm (D) 6.644 nm

133. Find proper option for given statement ?

Statement A : Electrons are emitted, when radiation of wavelength greater than the threshold wavelength of metal is bombarded on the surface of the metal.

Statement B : Energy of a photon of radiation of wavelength greater than the threshold wavelength of metal is more than the threshold energy of the metal.

- (A) statement A and B are correct and statement B is reason of statement A
 (B) statement A and B are correct and statement B is not the reason of statement A
 (C) statement A and B are incorrect
 (D) statement A is incorrect and statement B is correct

134. Find proper option for given statement

Statement A : In a Hydrogen atom energy of electron increases as it moves away from the nucleus.

Statement B : In a Hydrogen atom, de-broglie wavelength of electron decreases as it moves away from the nucleus.

- (A) statement A and B are correct and statement B is the reason of statement A
 (B) statement A and B are correct and statement B is not the reason of statement A
 (C) statement A and B are incorrect
 (D) statement A is incorrect and statement B is correct

135. Join the 4×5 matrix correctly for column I given orbital and column II number of nodes.

column-I

column-II

- (A) 4s (P) 3 angular node and 0 radial node
 (B) 4p (Q) 0 angular node and 3 radial node
 (C) 4d (R) 2 angular node and 1 radial node
 (D) 4f (S) 1 angular node and 2 radial node
 (T) Total number of nodes 3

- (A) (P) (Q) (R) (S) (T)
 (B) (P) (Q) (R) (S) (T)
 (C) (P) (Q) (R) (S) (T)
 (D) (P) (Q) (R) (S) (T)

136. Join the 3×3 matrix correctly for column I given wavelength and column II quantum number connected to wave function

column-I

column-II

- (A) $\Psi(R)$ (P) n (A) (P) (Q) (R)
 (B) $\Psi(\Theta)$ (Q) l (B) (P) (Q) (R)
 (C) $\Psi(\Phi)$ (R) m (C) (P) (Q) (R)

Answers : 116. (B), 117. (B), 118. (B), 119. (B), 120. (C), 121. (B), 122. (A), 123. (C), 124. (D), 125. (B), 126. (A), 127. (D), 128. (B), 129. (D), 130. (C), 131. (B), 132. (A), 133. (C), 134. (D).

Answer : 135.

Answer : 136.

- (A) (P) (Q) (R) (S) (T)
 (B) (P) (Q) (R) (S) (T)
 (C) (P) (Q) (R) (S) (T)
 (D) (P) (Q) (R) (S) (T)

- (A) (P) (Q) (R)
 (B) (P) (Q) (R)
 (C) (P) (Q) (R)