

2

Atomic Structure

TOPIC 1

Preliminary Models

- 01** Which of the following is never true for cathode rays?

[CBSE AIPMT 1994]

- (a) They possess kinetic energy
(b) They are electromagnetic waves
(c) They produce heat
(d) They produce mechanical pressure

Ans. (b)

Cathode rays are not electromagnetic wave because they do not have electric and magnetic components perpendicular to each other.

TOPIC 2

Bohr's Model and Hydrogen Spectrum

- 02** The energies E_1 and E_2 of two radiations are 25 eV and 50 eV respectively. The relation between their wavelengths, i.e. λ_1 and λ_2 will be [CBSE AIPMT 2011]

- (a) $\lambda_1 = 2\lambda_2$ (b) $\lambda_1 = 4\lambda_2$
(c) $\lambda_1 = \frac{1}{2}\lambda_2$ (d) $\lambda_1 = \lambda_2$

Ans. (a)

$$E_1 = 25 \text{ eV}, E_2 = 50 \text{ eV}$$

$$E_1 = \frac{hc}{\lambda_1} \text{ and } E_2 = \frac{hc}{\lambda_2}$$

$$\text{or } \frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1}$$

$$\text{or } \frac{25}{50} = \frac{\lambda_2}{\lambda_1}$$

$$\text{or } \lambda_1 = 2\lambda_2$$

- 03** The energy absorbed by each molecule (A_2) of a substance is 4.4×10^{-19} J and bond energy per molecule is 4.0×10^{-19} J. The kinetic energy of the molecule per atom will be [CBSE AIPMT 2009]
- (a) 2.0×10^{-20} J (b) 2.2×10^{-19} J
(c) 2.0×10^{-19} J (d) 4.0×10^{-20} J

Ans. (a)

$$\begin{aligned} \text{Kinetic energy (KE) of molecule} &= \text{energy absorbed by molecule} \\ &\quad - \text{bond energy per molecule} \\ &= (4.4 \times 10^{-19}) - (4.0 \times 10^{-19}) \text{ J} \\ &= 0.4 \times 10^{-19} \text{ J} \\ \text{KE per atom} &= \frac{0.4 \times 10^{-19}}{2} \text{ J} \\ &= 2.0 \times 10^{-20} \text{ J} \end{aligned}$$

- 04** The energy of second Bohr orbit of the hydrogen atom is -328 kJ mol^{-1} , hence the energy of fourth Bohr orbit would be [CBSE AIPMT 2005]

- (a) -41 kJ mol^{-1}
(b) $-1312 \text{ kJ mol}^{-1}$
(c) -164 kJ mol^{-1}
(d) -82 kJ mol^{-1}

Ans. (d)

The energy of second Bohr orbit of hydrogen atom (E_2) is -328 kJ mol^{-1}

$$E_n = -\frac{1312}{n^2} \text{ kJ mol}^{-1}$$

$$\therefore E_2 = -\frac{1312}{2^2} \text{ kJ mol}^{-1}$$

If $n=4$

$$\begin{aligned} \therefore E_4 &= -\frac{1312}{4^2} \text{ kJ mol}^{-1} \\ &= -82 \text{ kJ mol}^{-1} \end{aligned}$$

- 05** The frequency of radiation emitted when the electron falls from $n=4$ to $n=1$ in a hydrogen atom will be (Given ionisation energy of H = $2.18 \times 10^{-18} \text{ J atom}^{-1}$ and $h = 6.625 \times 10^{-34} \text{ Js}$)

[CBSE AIPMT 2004]

- (a) $1.54 \times 10^{15} \text{ s}^{-1}$ (b) $1.03 \times 10^{15} \text{ s}^{-1}$
(c) $3.08 \times 10^{15} \text{ s}^{-1}$ (d) $2.00 \times 10^{15} \text{ s}^{-1}$

Ans. (c)

$$\begin{aligned} \text{Ionisation energy of H} &= 2.18 \times 10^{-18} \text{ J atom}^{-1} \\ \therefore E_1 (\text{Energy of 1st orbit of H-atom}) &= -2.18 \times 10^{-18} \text{ J atom}^{-1} \\ \therefore E_n &= \frac{-2.18 \times 10^{-18}}{n^2} \text{ J atom}^{-1} \end{aligned}$$

$Z = 1$ for H-atom

$$\begin{aligned} \Delta E &= E_4 - E_1 \\ &= \frac{-2.18 \times 10^{-18}}{4^2} - \frac{-2.18 \times 10^{-18}}{1^2} \\ &= -2.18 \times 10^{-18} \times \left[\frac{1}{4^2} - \frac{1}{1^2} \right] \end{aligned}$$

$$\begin{aligned} \Delta E &= -2.18 \times 10^{-18} \times -\frac{15}{16} \\ &= +2.0437 \times 10^{-18} \text{ J atom}^{-1} \end{aligned}$$

$$\begin{aligned} \therefore \nu &= \frac{\Delta E}{h} \\ &= \frac{2.0437 \times 10^{-18} \text{ J atom}^{-1}}{6.625 \times 10^{-34} \text{ Js}} \\ &= 3.084 \times 10^{15} \text{ s}^{-1} \text{ atom}^{-1} \end{aligned}$$

- 06** In hydrogen atom, energy of first excited state is -3.4 eV . Then, KE of same orbit of hydrogen atom is [CBSE AIPMT 2002]

- (a) $+3.4 \text{ eV}$ (b) $+6.8 \text{ eV}$
(c) -13.6 eV (d) $+13.6 \text{ eV}$

Ans. (a)

∴ Total energy (E_n) = KE + PE

$$\text{In first excited state} = \frac{1}{2}mv^2 + \left[-\frac{Ze^2}{r} \right]$$

$$= +\frac{1}{2}\frac{Ze^2}{r} - \frac{Ze^2}{r}$$

Energy of first excited state is 3.4 eV

$$-3.4 \text{ eV} = -\frac{1}{2}\frac{Ze^2}{r}$$

$$\therefore \text{KE} = \frac{1}{2}\frac{Ze^2}{r} = +3.4 \text{ eV}$$

07 Who modified Bohr's theory by introducing elliptical orbits for electron path? [CBSE AIPMT 1999]

- (a) Hund (b) Thomson
(c) Rutherford (d) Sommerfeld

Ans. (d)

Sommerfeld modified Bohr's theory. According to him electrons move in elliptical orbits in addition to circular orbits.

08 Bohr radius for the hydrogen atom ($n=1$) is approximately 0.530 Å. The radius for the first excited state ($n=2$) is (in Å) [CBSE AIPMT 1998]

- (a) 0.13 (b) 1.06 (c) 4.77 (d) 2.12

Ans. (d)

$$r \propto n^2 / Z$$

where, n = number of orbit

Z = atomic number

$$\therefore r_1 \propto n_1^2$$

$$r_2 \propto n_2^2 \quad (Z=1 \text{ for H-atom})$$

$$\text{So, } \frac{r_1}{r_2} = \frac{n_1^2}{n_2^2}$$

$$\frac{0.530}{r_2} = \frac{1^2}{2^2}$$

$$\therefore r_2 = 0.530 \times 4 = 2.120 \text{ Å}$$

09 The radius of hydrogen atom in the ground state is 0.53 Å. The radius of Li^{2+} ion (at. no. = 3) in a similar state is [CBSE AIPMT 1995]

- (a) 0.17 Å (b) 0.53 Å
(c) 0.265 Å (d) 1.06 Å

Ans. (a)

We know that r_n (H-like)

$$= \frac{r_n \text{ (H-atom)} \times n^2}{Z}$$

For ground state, $n=1$

$$\therefore r_n (\text{Li}^{2+}) = \frac{0.53 \text{ Å} \times (1)^2}{3}$$

$$(\text{Li}, Z=3) = 0.17 \text{ Å}$$

10 When an electron of charge e and mass m moves with a velocity v about the nuclear charge Ze in circular orbit of radius r , the potential energy of the electrons is given by [CBSE AIPMT 1994]

- (a) $\frac{Z^2 e^2}{r}$ (b) $-\frac{Ze^2}{r}$ (c) $\frac{Ze^2}{r}$ (d) $\frac{mv^2}{r}$

Ans. (b)

Potential energy = work done

$$= \int_{\infty}^r -\frac{Ze^2}{r^2} dr = -\frac{Ze^2}{r}$$

11 If ionisation potential for hydrogen atom is 13.6 eV, then ionisation potential for He^+ will be [CBSE AIPMT 1993]

- (a) 54.4 eV (b) 6.8 eV
(c) 13.6 eV (d) 24.5 eV

Ans. (a)

For hydrogen atom $Z=1$

$$\therefore \text{Ionisation energy, } E_H = \frac{2\pi^2 me^4}{n^2 h^2} \dots (i)$$

For He^+ ion, ($\text{He}^+ = 1s^1$)

so, ($\text{He}^+ = \text{H}$) ionisation energy,

$$E_{\text{He}^+} = \frac{2\pi^2 me^4 Z^2}{n^2 h^2} \dots (ii)$$

Eq (i)/Eq (ii), we get

$$E_{\text{He}^+} = E_H \times Z^2 = 13.6 \times 4 = 54.4 \text{ eV}$$

12 The energy of an electron in the n th Bohr orbit of hydrogen atom is [CBSE AIPMT 1992]

- (a) $-\frac{13.6}{n^4}$ eV (b) $-\frac{13.6}{n^3}$ eV
(c) $-\frac{13.6}{n^2}$ eV (d) $-\frac{13.6}{n}$ eV

Ans. (c)

Energy of an electron in an orbit,

$$E_n = -\frac{2\pi^2 me^4 Z^2}{n^2 h^2} = -\frac{1311.8 Z^2}{n^2} \text{ kJ mol}^{-1}$$

$$E_n = -\frac{21.8 \times 10^{-12} Z^2}{n^2} \text{ erg atom}^{-1}$$

$$E_n = -\frac{21.8 \times 10^{-19} Z^2}{n^2} \text{ J atom}^{-1}$$

$$E_n = -\frac{13.6 Z^2}{n^2} \text{ eV atom}^{-1} = \frac{-13.6}{n^2} \text{ eV atom}^{-1}$$

(∵ $Z=1$ atomic number for hydrogen atom)

13 Which of the following statements do not form a part of Bohr's model of hydrogen atom? [CBSE AIPMT 1989]

- (a) Energy of the electrons in the orbits are quantised
(b) The electron in the orbit nearest the nucleus has the lowest energy
(c) Electrons revolve in different orbits around the nucleus
(d) The position and velocity of electrons in the orbit cannot be determined simultaneously

Ans. (d)

The main postulates of Bohr model of atom are

- (i) The electrons in an atom revolve around the nucleus only in certain selected circular paths, called orbits.
(ii) The energy is emitted or absorbed only when the electrons jump from one energy level to another.
(iii) Only those orbits are permitted in which the angular momentum of the electron is a whole number multiple of $\frac{h}{2\pi}$ (where, h is Planck's constant) that's why only certain fixed orbits are allowed, i.e. the momentum of an electron is quantised.

14 If r is the radius of the first orbit, the radius of n th orbit of H-atom is given by [CBSE AIPMT 1988]

- (a) rn^2 (b) rn
(c) $\frac{r}{n}$ (d) $r^2 n^2$

Ans. (a)

Radius of an orbit,

$$r_n = \frac{n^2 h^2}{4\pi^2 me^2 Z}$$

$$= \frac{0.529 n^2}{Z} \text{ Å}$$

For H-atom, $Z=1$

If $r_1 = r$

(according to question $r_1 = r$)

$$\therefore r_n = \frac{r \times n^2}{1} = rn^2$$

15 The spectrum of helium is expected to be similar to that of [CBSE AIPMT 1988]

- (a) H (b) Na
(c) Li^+ (d) He^+

Ans. (c)

The spectrum of an atom depends on the number of electrons present in it. Here, helium has two electrons, so the spectrum of Li^+ ($Z=3$) is similar to that of helium because both He and Li^+ have two electrons.

Ans. (d)

The wavelength of light is related to its energy by the equation, $E = \frac{hc}{\lambda}$. ($E = hv$)

Given, $\lambda = 45 \text{ nm} = 45 \times 10^{-9} \text{ m}$
 [$\because 1 \text{ nm} = 10^{-9} \text{ m}$]

$$\text{Hence, } E = \frac{6.63 \times 10^{-34} \text{ Js} \times 3 \times 10^8 \text{ m s}^{-1}}{45 \times 10^{-9} \text{ m}} \\ = 4.42 \times 10^{-18} \text{ J}$$

Hence, the energy corresponds to light of wavelength 45 nm is $4.42 \times 10^{-18} \text{ J}$.

23 The value of Planck's constant is $6.63 \times 10^{-34} \text{ Js}$. The speed of light is $3 \times 10^{17} \text{ nm s}^{-1}$. Which value is closest to the wavelength in nanometer of a quantum of light with frequency of $6 \times 10^{15} \text{ s}^{-1}$?

[NEET 2013]

- (a) 10 (b) 25
(c) 50 (d) 75

Ans. (c)

Given, Planck's constant,

$$h = 6.63 \times 10^{-34} \text{ Js}$$

Speed of light, $c = 3 \times 10^{17} \text{ nm s}^{-1}$

Frequency of quantum light

$$v = 6 \times 10^{15} \text{ s}^{-1}$$

Wavelength, $\lambda = ?$

$$\text{We know that, } v = \frac{c}{\lambda} \text{ or } \lambda = \frac{c}{v}$$

$$= \frac{3 \times 10^{17}}{6 \times 10^{15}}$$

$$= 0.5 \times 10^2 \text{ nm} = 50 \text{ nm}$$

24 The measurement of the electron position is associated with an uncertainty in momentum, which is equal to $1 \times 10^{-18} \text{ g cm s}^{-1}$. The uncertainty in electron velocity is (mass of an electron is $9 \times 10^{-28} \text{ g}$)

[CBSE AIPMT 2008]

- (a) $1 \times 10^9 \text{ cm s}^{-1}$
(b) $1 \times 10^6 \text{ cm s}^{-1}$
(c) $1 \times 10^5 \text{ cm s}^{-1}$
(d) $1 \times 10^{11} \text{ cm s}^{-1}$

Ans. (a)

Given, $\Delta p = 1 \times 10^{-18} \text{ g cm s}^{-1}$ (uncertainty in momentum)

$$\text{Mass} = 9 \times 10^{-28} \text{ g}$$

$$\Delta p = m \Delta v$$

$$1 \times 10^{-18} = 9 \times 10^{-28} \times \Delta v$$

(uncertainty in velocity)

$$\Delta v = 1 \times 10^9 \text{ cm s}^{-1}$$

25 If uncertainty in position and momentum are equal, then uncertainty in velocity is

[CBSE AIPMT 2008]

- (a) $\frac{1}{2m} \sqrt{\frac{h}{\pi}}$ (b) $\sqrt{\frac{h}{2\pi}}$
(c) $\frac{1}{m} \sqrt{\frac{h}{\pi}}$ (d) $\sqrt{\frac{h}{\pi}}$

Ans. (a)

According to Heisenberg's uncertainty principle

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

Given, $\Delta x = \Delta p$ ($\Delta x =$ uncertainty in position)

$$(\Delta p)^2 = \frac{h}{4\pi} \quad (\Delta p = m \times \Delta v)$$

$$m^2 \Delta v^2 = \frac{h}{4\pi} \quad m = \text{mass}$$

$$\Delta v^2 = \frac{h}{m^2 4\pi} \Rightarrow \Delta v = \frac{1}{2m} \sqrt{\frac{h}{\pi}}$$

($\Delta v =$ uncertainty in velocity)

26 Given, the mass of electron is $9.11 \times 10^{-31} \text{ kg}$, Planck's constant is $6.626 \times 10^{-34} \text{ Js}$, the uncertainty involved in the measurement of velocity within a distance of 0.1 \AA is

[CBSE AIPMT 2006]

- (a) $5.79 \times 10^6 \text{ ms}^{-1}$ (b) $5.79 \times 10^7 \text{ ms}^{-1}$
(c) $5.79 \times 10^8 \text{ ms}^{-1}$ (d) $5.79 \times 10^5 \text{ ms}^{-1}$

Ans. (a)

By Heisenberg's uncertainty principle

$$\Delta x \times \Delta p_x \geq \frac{h}{4\pi} \text{ or } \Delta x \times \Delta(mv_x) \geq \frac{h}{4\pi}$$

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

$\Delta p =$ uncertainty in momentum

$\Delta x =$ uncertainty in position

$\Delta v =$ uncertainty in velocity

$m =$ mass of particle

Given that,

$$\Delta x = 0.1 \text{ \AA} = 0.1 \times 10^{-10} \text{ m}$$

$$m = 9.11 \times 10^{-31} \text{ kg}$$

$h =$ Planck's constant $= 6.626 \times 10^{-34} \text{ Js}$

$$\pi = 3.14$$

Thus,

$$\Delta v \times 0.1 \times 10^{-10} = \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 9.11 \times 10^{-31}}$$

$$\Delta v = \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 9.11 \times 10^{-31} \times 0.1 \times 10^{-10}} \text{ ms}^{-1}$$

$$= 5.785 \times 10^6 \text{ ms}^{-1}$$

$$= 5.79 \times 10^6 \text{ ms}^{-1}$$

27 The value of Planck's constant is $6.63 \times 10^{-34} \text{ Js}$. The velocity of light is $3.0 \times 10^8 \text{ ms}^{-1}$. Which value is closest to the wavelength in nanometers of a quantum of light with frequency of $8 \times 10^{15} \text{ s}^{-1}$?

[CBSE AIPMT 2003]

- (a) 4×10^1 (b) 3×10^7
(c) 2×10^{-25} (d) 5×10^{-18}

Ans. (a)

$$\text{Frequency } (v) = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ m s}^{-1}}{8 \times 10^{15} \text{ s}^{-1}}$$

$$= 0.375 \times 10^{-7} \text{ m}$$

$$= 3.75 \times 10^1 \text{ nm} \approx 4 \times 10^1 \text{ nm}$$

28 The energy of photon is given as: $\Delta e/\text{atom} = 3.03 \times 10^{-19} \text{ J atom}^{-1}$, then the wavelength (λ) of the photon is

[CBSE AIPMT 2000]

(Given, h (Planck's constant) $= 6.63 \times 10^{-34} \text{ Js}$, c (velocity of light) $= 3.00 \times 10^8 \text{ ms}^{-1}$)

- (a) 6.56 nm (b) 65.6 nm
(c) 656 nm (d) 0.656 nm

Ans. (c)

According to formula, $E = \frac{hc}{\lambda}$ ($v = \frac{c}{\lambda}$)

Energy $E = hv$

$$3.03 \times 10^{-19} = \frac{hc}{\lambda}$$

$$\lambda = \frac{6.63 \times 10^{-34} \times 3.0 \times 10^8}{3.03 \times 10^{-19}}$$

$$= 6.56 \times 10^{-7} \text{ m}$$

$$= 6.56 \times 10^{-7} \times 10^9 \text{ nm}$$

$$= 6.56 \times 10^2 \text{ nm}$$

$$= 656 \text{ nm}$$

29 The de-Broglie wavelength of a particle with mass 1 g and velocity 100 m/s is

[CBSE AIPMT 1999]

- (a) $6.63 \times 10^{-33} \text{ m}$ (b) $6.63 \times 10^{-34} \text{ m}$
(c) $6.63 \times 10^{-35} \text{ m}$ (d) $6.65 \times 10^{-36} \text{ m}$

Ans. (a)

$$p = \frac{h}{\lambda} \text{ (de-Broglie equation)}$$

$$\lambda = \frac{h}{mv} \quad (\because p = mv)$$

$$h = 6.625 \times 10^{-34}$$

$$\approx 6.63 \times 10^{-34} \text{ kg/s}$$

$$\lambda = \frac{6.63 \times 10^{-34} \text{ kg m}^2 / \text{s}}{10^{-3} \text{ kg} \times 100 \text{ m/s}}$$

$$= 6.63 \times 10^{-33} \text{ m}$$

- 30** The uncertainty in momentum of an electron is 1×10^{-5} kg m/s. The uncertainty in its position will be (Given, $h = 6.62 \times 10^{-34}$ kg m²/s)
- [CBSE AIPMT 1999]
- (a) 1.05×10^{-28} m (b) 1.05×10^{-26} m
(c) 5.27×10^{-30} m (d) 5.25×10^{-28} m

Ans. (c)

According to Heisenberg's uncertainty principle

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

Uncertainty in momentum

$$\Delta p = 1 \times 10^{-5} \text{ kg m/s}$$

$$1 \times 10^{-5} \times \Delta x = \frac{6.62 \times 10^{-34}}{4 \times \frac{22}{7}} \quad (\text{Given})$$

$$\begin{aligned} \Delta x &= \frac{6.62 \times 10^{-34} \times 7}{1 \times 10^{-5} \times 4 \times 22} \\ &= 5.265 \times 10^{-30} \text{ m} \\ &\approx 5.27 \times 10^{-30} \text{ m} \end{aligned}$$

- 31** The position of both, an electron and a helium atom is known within 1.0 mm. Further the momentum of the electron is known within 5.0×10^{-26} kg ms⁻¹. The minimum uncertainty in the measurement of the momentum of the helium atom is
- [CBSE AIPMT 1998]
- (a) 50 kg ms⁻¹
(b) 80 kg ms⁻¹
(c) 80×10^{-26} kg ms⁻¹
(d) 5.0×10^{-26} kg ms⁻¹

Ans. (d)

By Heisenberg's uncertainty principle

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

when the position of electron and helium atom is same and momentum of electron is known within a range, therefore the momentum of helium atom is also equal to the momentum of electron, i.e.

$$5 \times 10^{-26} \text{ kg m s}^{-1}$$

- 32** The momentum of a particle having a de-Broglie wavelength of 10^{-17} m is
- [CBSE AIPMT 1996]
- (Given, $h = 6.625 \times 10^{-34}$ m)
- (a) 3.3125×10^{-7} kg m s⁻¹
(b) 26.5×10^{-7} kg m s⁻¹
(c) 6.625×10^{-17} kg m s⁻¹
(d) 13.25×10^{-17} kg m s⁻¹

Ans. (c)

According to de-Broglie relation,

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

where, λ = wavelength
 h = Planck's constant
 p = momentum

Here, $h = 6.625 \times 10^{-34}$ J s

$$\lambda = 10^{-17} \text{ m}$$

$$\begin{aligned} \therefore p &= \frac{h}{\lambda} = \frac{6.625 \times 10^{-34}}{10^{-17}} \\ &= 6.625 \times 10^{-34} \times 10^{17} \\ &= 6.625 \times 10^{-17} \text{ kg m s}^{-1} \end{aligned}$$

- 33** Uncertainty in position of an electron (mass of an electron is $= 9.1 \times 10^{-28}$ g) moving with a velocity of 3×10^4 cm/s accurate upto 0.001% will be (use $\frac{h}{4\pi}$ in uncertainty expression where $h = 6.626 \times 10^{-27}$ erg s)
- [CBSE AIPMT 1995]

- (a) 1.93 cm (b) 3.84 cm
(c) 5.76 cm (d) 7.68 cm

Ans. (a)

According to Heisenberg's uncertainty principle

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

Here, Δx = uncertainty in position

Δv = uncertainty in velocity

h = Planck's constant (6.626×10^{-27} Js)

m = mass of electron (9.1×10^{-28} kg)

Here, $\Delta v = 0.001\%$ of 3×10^4

$$= \frac{0.001}{100} \times 3 \times 10^4 = 0.3 \text{ cm/s}$$

$$\begin{aligned} \therefore \Delta x &= \frac{h}{4\pi m \Delta v} \\ &= \frac{6.626 \times 10^{-27}}{4 \times 3.14 \times 9.1 \times 10^{-28} \times 0.3} = 1.93 \text{ cm} \end{aligned}$$

- 34** In the photoelectron emission, the energy of the emitted electron is
- [CBSE AIPMT 1994]

- (a) greater than the incident photon
(b) same as that of the incident photon
(c) smaller than the incident photon
(d) proportional to the intensity of incident photon

Ans. (c)

In the photoelectric effect, the energy of the emitted electron is smaller than that of the incident photon because some energy of photon is used to eject the electron and remaining energy is used to

increase the kinetic energy of ejected electron.

- 35** The electron was shown experimentally to have wave properties by
- [CBSE AIPMT 1994]
- (a) de-Broglie
(b) N Bohr
(c) Davisson and Germer
(d) Schrödinger

Ans. (c)

The wave nature of an electron is proved by Davisson and Germer experiment. In this experiment the scattering pattern of an electron is similar to that of X-rays.

TOPIC 4

Quantum Mechanical, Model and Electronic Configuration

- 36** The number of angular nodes and radial nodes in 3s orbital are
- [NEET (Oct.) 2020]
- (a) 0 and 2, respectively
(b) 1 and 0, respectively
(c) 3 and 0, respectively
(d) 0 and 1, respectively

Ans. (a)

For 3s-orbital, $n=3, l=0$

Number of radial nodes

$$= (n - l - 1) = 3 - 0 - 1 = 2$$

Number of angular nodes = $l = 0$.

Hence, option (a) is correct.

- 37** 4d, 5p, 5f and 6p-orbitals are arranged in the order of decreasing energy. The correct option is
- [NEET (National) 2019]

- (a) $6p > 5f > 5p > 4d$
(b) $5p > 5f > 4d > 5p$
(c) $5f > 6p > 4d > 5p$
(d) $5f > 6p > 5p > 4d$

Ans. (d)

The order of energy of orbitals can be calculated from $(n + l)$ rule. The lower the value of $(n + l)$ for an orbital, lower is its energy. If two orbitals have same $(n + l)$ value, the orbital with lower value of n has the lower energy.

$$(i) 6p = 6 + 1 = 7 \quad (ii) 5f = 5 + 3 = 8$$

$$(iii) 4d = 4 + 2 = 6 \quad (iv) 5p = 5 + 1 = 6$$

\therefore The order of decreasing energy will be $5f > 6p > 5p > 4d$.

38 Orbital having 3 angular nodes and 3 total nodes is [NEET (Odisha) 2019]

- (a) 5p (b) 3d
(c) 4f (d) 6d

Ans. (c)

Angular node (l) = 3

Total node = radial node + angular node

$$3 = (n - l - 1) + l$$

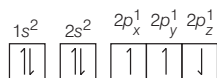
$$3 = n - 1$$

$$\Rightarrow n = 4$$

\therefore Orbital having 3 angular nodes and 3 total nodes is $n = l = 4f$ [$\because l = 3$ for f -orbital]

39 Which one is a wrong statement? [NEET 2018]

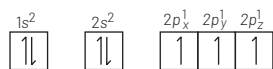
- (a) The electronic configuration of N-atom is



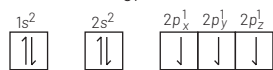
- (b) An orbital is designated by three quantum numbers while an electron in an atom is designated by four quantum numbers
(c) Total orbital angular momentum of electron in 's' orbital is equal to zero
(d) The value of m for d_{z^2} is zero

Ans. (a)

According to Hund's rule "the pairing of electrons in the orbitals of a particular subshell does not takes place until all the orbitals of a subshell are singly occupied. Moreover, the singly orbitals must have the electrons with parallel spin. i.e.



or



\therefore Option (a) is the incorrect option.

40 Two electrons occupying the same orbital are distinguished by [NEET (Phase I) 2016]

- (a) Magnetic quantum number
(b) Azimuthal quantum number
(c) Spin quantum number
(d) Principal quantum number

Ans. (c)

Two electrons occupying the same orbital has equal spin but the directions of their spin are opposite. Hence, spin quantum number, s , (represented $+1/2$ and $-1/2$) distinguishes them.

41 Which is the correct order of increasing energy of the listed orbitals in the atom of titanium?

- (a) 3s 4s 3p 3d (b) 4s 3s 3p 3d
(c) 3s 3p 3d 4s (d) 3s 3p 4s 3d

[CBSE AIPMT 2015]

Ans. (c)

According to Aufbau rule

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

42 What is the maximum numbers of electrons that can be associated with the following set of quantum numbers?

$$n = 3, l = 1 \text{ and } m = -1$$

[NEET 2013]

- (a) 10 (b) 6
(c) 4 (d) 2

Ans. (d)

The orbital of the electron having $n = 3$, $l = 1$ and $m = -1$ is $3p_z$ (as $n l m$) and an orbital can have a maximum number of two electrons with opposite spins.

$\therefore 3p_z$ orbital contains only two electrons or only 2 electrons are associated with $n = 3, l = 1, m = -1$.

43 Maximum number of electrons in a subshell with $l = 3$ and $n = 4$ is

[CBSE AIPMT 2012]

- (a) 14 (b) 16 (c) 10 (d) 12

Ans. (a)

n represents the main energy level and l represents the subshell.

If $n = 4$ and $l = 3$, the subshell is $4f$.

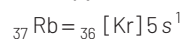
In f -subshell, there are 7 orbitals and each orbital can accommodate a maximum number of two electrons, so maximum number of electrons in $4f$ subshell = $7 \times 2 = 14$.

44 The correct set of four quantum numbers for the valence electron of rubidium atom (at. no. = 37) is

[CBSE AIPMT 2012]

- (a) 5, 1, 1, $+\frac{1}{2}$ (b) 6, 0, 0, $+\frac{1}{2}$
(c) 5, 0, 0, $+\frac{1}{2}$ (d) 5, 1, 0, $+\frac{1}{2}$

Ans. (c)



Its valence electron is $5s^1$.

$$n = 5$$

$$l = 0 \quad (\text{For } s\text{-orbital})$$

$$m = 0 \quad (\text{As } m = -l \text{ to } +l)$$

$$s = +\frac{1}{2}$$

45 If $n = 6$, the correct sequence for filling of electrons will be

[CBSE AIPMT 2011]

- (a) $ns \rightarrow (n-1)d \rightarrow (n-2)f \rightarrow np$
(b) $ns \rightarrow (n-2)f \rightarrow np \rightarrow (n-1)d$
(c) $ns \rightarrow np \rightarrow (n-1)d \rightarrow (n-2)f$
(d) $ns \rightarrow (n-2)f \rightarrow (n-1)d \rightarrow np$

Ans. (d)

$$6s \rightarrow 4f \rightarrow 5d \rightarrow 6p \text{ for } n = 6$$

46 Which of the following is not permissible arrangement of electrons in an atom?

[CBSE AIPMT 2009]

- (a) $n = 4, l = 0, m = 0, s = -1/2$
(b) $n = 5, l = 3, m = 0, s = +1/2$
(c) $n = 3, l = 2, m = -3, s = -1/2$
(d) $n = 3, l = 2, m = -2, s = -1/2$

Ans. (c)

If $n = 3$,

$$l = 0 \text{ to } (3 - 1) = 0, 1, 2$$

$$m = -l \text{ to } +l = -2, -1, 0, +1, +2$$

$$s = \pm \frac{1}{2}$$

Therefore, option (c) is not a permissible set of quantum numbers.

47 Maximum number of electrons in a subshell of an atom is determined by the following [CBSE AIPMT 2009]

- (a) $4l + 2$ (b) $2l + 1$
(c) $4l - 2$ (d) $2n^2$

Ans. (a)

Total number of subshells = $(2l + 1)$

\therefore Maximum number of electrons in the subshell

$$= 2(2l + 1) = 4l + 2$$

48 Consider the following sets of quantum numbers.

	n	l	m	s
(i)	3	0	0	$+1/2$
(ii)	2	2	1	$+1/2$
(iii)	4	3	-2	$-1/2$
(iv)	1	0	-1	$-1/2$
(v)	3	2	3	$+1/2$

Which of the following sets of quantum number is not possible?

[CBSE AIPMT 2007]

- (a) (ii), (iii) and (iv) (b) (i), (ii), (iii) and (iv)
(c) (ii), (iv) and (v) (d) (i) and (iii)

Ans. (d)

The value of l varies from 0 to $(n-1)$ and the value of m varies from $-l$ to $+l$ through zero.

The value of ' s ' $\pm \frac{1}{2}$ which signifies the

spin of electron. The correct sets of quantum number are following

n	l	m	s
(ii) 2	1	1	$-\frac{1}{2}$
(iv) 1	0	0	$-\frac{1}{2}$
(v) 3	2	2	$+\frac{1}{2}$

49 The orientation of an atomic orbital is governed by [CBSE AIPMT 2006]

- (a) azimuthal quantum number
- (b) spin quantum number
- (c) magnetic quantum number
- (d) principal quantum number

Ans. (c)

The orientation of an atomic orbital is governed by magnetic quantum number.

50 The following quantum numbers are possible for how many orbital(s) $n=3, l=2$ and $m=+2$?

[CBSE AIPMT 2001]

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

Ans. (a)

$$n=3, l=2, m=+2, s=\pm 1/2$$

These values of quantum numbers are possible for only one of the five $3d$ -orbitals as $+2$ value of m is possible only for one orbital.

$m = +2$	$+1$	0	-1	-2
<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

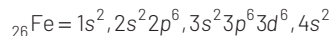
51 Which of the following configuration is correct for iron?

[CBSE AIPMT 1999]

- (a) $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5$
- (b) $1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2, 3d^5$
- (c) $1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2, 3d^7$
- (d) $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^6, 4s^2$

Ans. (d)

Firstly the electrons are filled in increasing order of energy and then rearrange the subshells in increasing order as

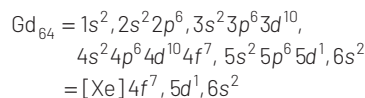


52 The electronic configuration of gadolinium (at. no. = 64) is

[CBSE AIPMT 1997]

- (a) $[\text{Xe}] 4f^8, 5d^9, 6s^2$
- (b) $[\text{Xe}] 4f^7, 5d^1, 6s^2$
- (c) $[\text{Xe}] 4f^6, 5d^2, 6s^2$
- (d) $[\text{Xe}] 4f^3, 5d^5, 6s^2$

Ans. (b)



53 The orbitals are called degenerate when

[CBSE AIPMT 1996]

- (a) they have the same wave functions
- (b) they have the same wave functions but different energies
- (c) they have different wave functions but same energy
- (d) they have the same energy

Ans. (d)

The orbitals having the same energy but different in orientation, are called degenerate orbitals. e.g. $3d$ -orbital, $l=2, m=-2, -1, 0, +1, +2$, i.e. there are five different orientations represented by $d_{xy}, d_{yz}, d_{zx}, d_{x^2-y^2}$ and d_{z^2} .

54 If an electron has spin quantum number $+\frac{1}{2}$ and magnetic quantum

number -1 , it cannot be present in

[CBSE AIPMT 1994]

- (a) d -orbital
- (b) f -orbital
- (c) p -orbital
- (d) s -orbital

Ans. (d)

Spatial orientation of the orbital with respect to standard set of coordinate axis. Magnetic quantum number -1 is possible only when the azimuthal quantum number have value $l=1$, which is possible for p, d and f -subshells but not for s -subshell because the value of l for s -subshell is zero.

55 For which one of the following sets of four quantum numbers, an electron will have the highest energy?

[CBSE AIPMT 1994]

- | n | l | m | s |
|-------|-----|-----|----------------|
| (a) 3 | 2 | 1 | $\frac{1}{2}$ |
| (b) 4 | 2 | -1 | $\frac{1}{2}$ |
| (c) 4 | 1 | 0 | $-\frac{1}{2}$ |
| (d) 5 | 0 | 0 | $-\frac{1}{2}$ |

Ans. (b)

For $n=3, l=2$ the subshell is $3d(n+l=5)$

$n=4, l=2$ the subshell is $4d(n+l=6)$

$n=4, l=1$ the subshell is $4p(n+l=5)$

$n=5, l=0$, the subshell is $5s(n+l=5)$

According to $(n+l)$ rule greater the $(n+l)$ value, greater the energy that is 6.

56 Electronic configuration of calcium atom can be written as

[CBSE AIPMT 1992]

- (a) $[\text{Ne}] 4p^2$
- (b) $[\text{Ar}] 4s^2$
- (c) $[\text{Ne}] 4s^2$
- (d) $[\text{Kr}] 4p^2$

Ans. (b)

To write the electronic configuration of an atom, it is better if we remember the atomic number of noble gases and the orbitals follow the noble gas. The atomic number of Ca is 20 and its nearest noble gas is argon ($\text{Ar} = 18$).

Hence, the electronic configuration of $\text{Ca} = [\text{Ar}] 4s^2$.

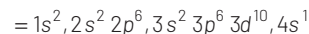
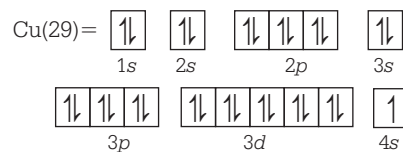
57 The electronic configuration of Cu (at.no. = 29) is

[CBSE AIPMT 1991]

- (a) $1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2, 3d^9$
- (b) $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^1$
- (c) $1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2 4p^6, 5s^2 5p^1$
- (d) $1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2 4p^6, 3d^3$

Ans. (b)

The electronic configuration of Cu (29) is an exceptional case due to exchange of energy and symmetrical distribution of electrons in orbital to acquire more stability.



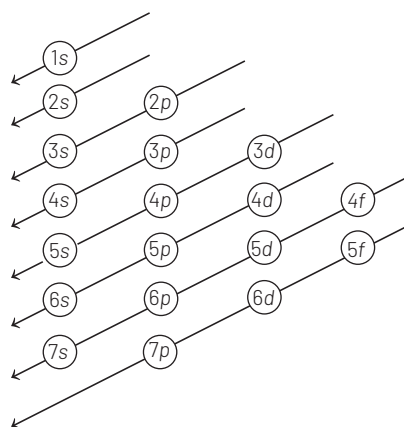
58 The order of filling of electrons in the orbitals of an atom will be

[CBSE AIPMT 1991]

- (a) $3d, 4s, 4p, 4d, 5s$
- (b) $4s, 3d, 4p, 5s, 4d$
- (c) $5s, 4p, 3d, 4d, 5s$
- (d) $3d, 4p, 4s, 4d, 5s$

Ans. (b)

The sequence of energy level can be remembered by the systematic diagram as shown below



Hence, the correct order is

1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 4f, 5d, 6s, 7s.....

- 59** For azimuthal quantum number $l=3$, the maximum number of electrons will be [CBSE AIPMT 1991]
 (a) 2 (b) 6 (c) 0 (d) 14

Ans. (d)

When azimuthal quantum number is 3

$$m = (2l + 1)$$

$$l = 3$$

$$m = (2 \times 3 + 1)$$

$$= 7 \text{ orbitals}$$

then total values of $m = (2 \times 3 + 1) = 7$ orbitals. We know that, one orbital contains two electrons. Hence, total number of electrons = $7 \times 2 = 14$.

Alternative

$$\text{Total number of electrons} = 4l + 2$$

$$= 4 \times 3 + 2 = 12 + 2 = 14 \text{ electrons}$$

- 60** In a given atom no two electrons can have the same values of all the four quantum numbers. This is called [CBSE AIPMT 1991]

- (a) Hund's rule
 (b) Aufbau principle
 (c) Uncertainty principle
 (d) Pauli's exclusion principle

Ans. (d)

According to Pauli's exclusion principle "no two electrons in an atom can have the same values of all the four quantum numbers."

In $1s^2$

$$\text{for I electron } n=1, l=0, m=0, s=+\frac{1}{2}$$

for II electron $n=1$,

$$l=0, m=0, s=-\frac{1}{2}$$

It means if the values of n, l , and m are same, then the value of spin quantum number must be different, i.e. $+1/2$ and $-1/2$.

- 61** The total number of electrons that can be accommodated in all the orbitals having principal quantum number 2 and azimuthal quantum number 1 are [CBSE AIPMT 1990]

- (a) 2 (b) 4
 (c) 6 (d) 8

Ans. (c)

When $n=2$ and $l=1$, then subshell is $2p$.

The number of orbitals in p -subshell

$$= (2l + 1) = (2 \times 1 + 1)$$

$$= 3$$

Total (maximum) number of electrons

$$= 2 \times \text{number of orbitals}$$

$$= 2 \times 3 = 6$$

(as each orbital contains 2 electrons)

- 62** The maximum number of electrons in a subshell is given by the expression [CBSE AIPMT 1989]

- (a) $4l - 2$ (b) $4l + 2$
 (c) $2l + 2$ (d) $2n^2$

Ans. (b)

The number of orbitals in a subshell

$$= (2l + 1)$$

where, l = azimuthal quantum number

Since, each orbital contains maximum two electrons, the number of electrons in any subshell

$$= 2 \times \text{number of orbitals}$$

$$= 2(2l + 1)$$

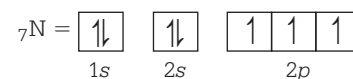
$$= 4l + 2$$

- 63** Number of unpaired electrons in N^{2+} is/are [CBSE AIPMT 1989]

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

Ans. (c)

The electronic configuration of



Hence, the number of unpaired electron in N^{2+} is 1.

- 64** The number of spherical nodes in $3p$ -orbital is/are [CBSE AIPMT 1988]

- (a) one
 (b) three
 (c) two
 (d) None of the above

Ans. (a)

The number of spherical nodes in any orbital ($= n - l - 1$)

For $3p$ -orbital, $n=3$ and $l=1$

$$\therefore \text{Number of spherical nodes} = n - l - 1$$

$$= 3 - 1 - 1$$

$$= 3 - 2 = 1 \text{ node}$$