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Atoms

TOPIC 1

Alpha-Particle Scattering and Rutherford Nuclear Model of Atom

01 When an α-particle of mass m moving with velocity v bombards on a heavy nucleus of charge Ze, its distance of closest approach from the nucleus depends on m as **[NEET 2016]**

(a) $\frac{1}{\sqrt{m}}$ (b) $\frac{1}{m^2}$

(c) m (d) $\frac{1}{m}$

Ans. *(d)*

When an α-particle of mass m moving with velocity v bombards on a heavy nucleus of charge Ze, then there will be no loss of energy as in this case, initial kinetic energy of α-particle = potential energy of α-particle at closest approach.

$$\Rightarrow \quad \frac{1}{2}mv^2 = \frac{2Ze^2}{4\pi\varepsilon_0 r_0}$$

$$\Rightarrow \quad r_0 \propto \frac{1}{m}$$

This is the required distance of closest approach to α-particle from the nucleus.

02 In a Rutherford scattering experiment when a projectile of charge Z_1 and mass M_1 approaches a target nucleus of charge Z_2 and mass M_2, the distance of closest approach is r_0. The energy of the projectile is **[CBSE AIPMT 2009]**

(a) directly proportional to $M_1 \times M_2$

(b) directly proportional to $Z_1 Z_2$

(c) inversely proportional to Z_1

(d) directly proportional to mass M_1

Ans. *(b)*

A particle of mass M_1 and charge Z_1 possess initial velocity u, when it is at a large distance from the nucleus of an atom having atomic number Z_2. At the distance of closest approach, the kinetic energy of particle is completely converted to potential energy. Mathematically,

$$\frac{1}{2}M_1 u^2 = \frac{1}{4\pi\varepsilon_0}\frac{Z_1 Z_2}{r_0}$$

So, the energy of the particle is directly proportional to $Z_1 Z_2$.

03 In Rutherford scattering experiment, what will be the correct angle for α-scattering for an impact parameter, $b = 0$? **[CBSE AIPMT 1994]**

(a) 90° (b) 270° (c) 0° (d) 180°

Ans. *(d)*

Impact parameter is perpendicular distance of the velocity vector of the alpha particle from the central line of the nucleus, when the particle is far away from the nucleus of the atom.

Rutherford calculated analytically, the relation between the impact parameter b and scattering angle θ, which is given by

$$b = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2 \cot\frac{\theta}{2}}{E}$$

where, $E = \frac{1}{2}mv^2$ is kinetic energy of alpha particle, when it is far away from the atom.

According to problem,

$$b = \frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2 \cot\frac{\theta}{2}}{E} = 0$$

As given that $b = 0$

so, $\cot\frac{\theta}{2} = 0 \Rightarrow \frac{\theta}{2} = 90°$ or $\theta = 180°$

TOPIC 2

Bohr Model and Hydrogen Spectra

04 The total energy of an electron in the nth stationary orbit of the hydrogen atom can be obtained by **[NEET (Oct.) 2020]**

(a) $E_n = \frac{13.6}{n^2}$ eV (b) $E_n = -\frac{13.6}{n^2}$ eV

(c) $E_n = -\frac{1.36}{n^2}$ eV (d) $E_n = -13.6 \times n^2$ eV

Ans. *(b)*

Total energy of an electron in the nth stationary orbit of hydrogen atom is given by

$$E_n = \frac{-Rhc}{n^2} = \frac{-13.6}{n^2}\text{ eV}$$

$[\because Rhc = 13.6\text{ eV}]$

05 For which one of the following, Bohr model is not valid? **[NEET (Sep.) 2020]**

(a) Singly ionised helium atom (He^+)

(b) Deuteron atom

(c) Singly ionised neon atom (Ne^+)

(d) Hydrogen atom

Ans. *(c)*

Since, Bohr's model is valid for hydrogen and hydrogen like atoms He^+, deuteron, etc. So, it is not valid for singly ionised neon atom (Ne^+).

Hence, correct option is (c).

06 The radius of the first permitted Bohr orbit for the electron, in a hydrogen atom equals 0.51 Å and its ground state energy equals −13.6 eV. If the electron in the hydrogen atom is replaced by muon (μ^{-1}) [Charge same as electron and mass 207 m_e], the first Bohr radius and ground state energy will be **[NEET (Odisha) 2019]**

(a) 0.53×10^{-13} m, – 3.6 eV
(b) 25.6×10^{-13} m, – 2.8 eV
(c) 2.56×10^{-13} m, – 2.8 keV
(d) 2.56×10^{-13} m, – 13.6 eV

Ans. *(c)*

Key Idea Hydrogen atom can be considered to be the system of two charges, positive charged nucleus and negative charged electron. A system of this kind is equivalent to a single particle of mass m' that revolves around the position of the heavier particle. Then, the reduced mass of electron is

$$m' = \frac{mM}{m+M}$$

where, m = mass of electron and
M = mass of nucleus
Its values is less than m.
Given, radius of first orbit for electron

$$r_1 = 0.51\,\text{Å},$$

ground state energy of electron,

$$E_1 = -13.6\,\text{eV},$$

mass of electron = m_e
mass of muon, $m_\mu = 207 m_e$ and
mass of nucleus, $M = 1836\, m_e$
When electron in hydrogen atom is replaced by muon, the reduced mass of muon is

$$m_\mu' = \frac{m_\mu M}{m_\mu + M} \quad \text{...(i)}$$

Substituting the given values in Eq. (i), we get

$$m_\mu' = \frac{207 m_e \times 1836 m_e}{207 m_e + 1836 m_e}$$

$$\approx 186\, m_e \quad \text{...(ii)}$$

The radius of first orbit in hydrogen atom for electron is given by,

$$r_1 = \frac{h^2 \varepsilon_0}{\pi m_e e^2} \quad \text{...(iii)}$$

The radius of first orbit for muon is

$$r_1' = \frac{h^2\varepsilon_0}{\pi m_\mu' e^2}$$

[$\because$ charge of μ = charge of e^-]

$$= \frac{h^2\varepsilon_0}{\pi \times 186 m_e e^2} \quad \text{[from Eq. (ii)]}$$

$$= \left(\frac{h^2\varepsilon_0}{\pi m_e e^2}\right)\frac{1}{186} = \frac{r_1}{186} \text{[from Eq. (iii)]}$$

$$= \frac{0.51}{186}\text{Å} \quad [\because r_1 = 0.51\,\text{Å}]$$

$$= 2.74\times10^{-13}\text{ m} \quad [\because 1\,\text{Å} = 10^{-10}\text{ m}]$$

The total energy of electron is given by

$$E_n = \frac{-mZ^2e^4}{8\varepsilon_0^2 h^2}\left(\frac{1}{n^2}\right)$$

$$\Rightarrow \quad E_n \propto m$$

For electron in first orbit of hydrogen atom,

$$E_1 = k m_e \quad \text{...(iv)}$$

where, $k = \dfrac{e^4}{8\varepsilon_0^2 h^2}$ = constant.

For muon in first orbit

$$E_1' = k m_\mu'$$
$$= k \times 186 m_e \quad \text{[from Eq. (i)]}$$
$$= 186 k m_e$$
$$= 186 E_1 \quad \text{[from Eq. (iv)]}$$
$$= 186(-13.6)\text{ eV} \quad \text{(given)}$$
$$= -2529.6\text{ eV}$$
$$= -2.5\text{ keV}$$

$\therefore$ The values are closest to that of options (c).

07 The total energy of an electron in an atom in an orbit is –3.4 eV. Its kinetic and potential energies are, respectively: **[NEET (National) 2019]**

(a) –3.4 eV, –6.8 eV (b) 3.4 eV, –6.8 eV
(c) 3.4 eV, 3.4 eV (d) –3.4 eV, –3.4 eV

Ans. *(b)*

According to Bohr's model, the kinetic energy of electron in term of Rydberg constant R is given by

$$\text{KE} = \frac{Rhc}{n^2} \quad \text{... (i)}$$

where, h = Planck's constant,
c = speed of light
and n = principal quantum number.
Similarly, potential energy is given by,

$$\text{PE} = -\frac{2Rhc}{n^2} \quad \text{... (ii)}$$

$\therefore$ Total energy, $E = \text{PE} + \text{KE}$

$$= -\frac{Rhc}{n^2} \quad \text{[from Eqs. (i) and (ii)]}$$

$\Rightarrow$ KE $= -E$ and PE $= 2E$
Given, $E = -3.4$ eV
$\therefore$ KE $= -(-3.4) = 3.4$ eV
and PE $= 2(-3.4) = -6.8$ eV

08 The ratio of kinetic energy to the total energy of an electron in a Bohr orbit of the hydrogen atom, is **[NEET 2018]**

(a) 2 : –1 (b) 1 : –1 (c) 1 : 1 (d) 1 : –2

Ans. *(b)*

Kinetic energy of an electron in a Bohr orbit of a hydrogen atom is given as

$$\text{KE}_n = \frac{Rhc}{n^2} \quad \text{...(i)}$$

Total energy of an electron in a Bohr orbit of a hydrogen atom is given as

$$\text{TE}_n = \frac{-Rhc}{n^2} \quad \text{...(ii)}$$

Dividing Eq. (i) by Eq. (ii), we get

$$\frac{\text{KE}_n}{\text{TE}_n} = \frac{\left(\frac{Rhc}{n^2}\right)}{-\left(\frac{Rhc}{n^2}\right)}$$

$\Rightarrow$ KE$_n$: TE$_n$ = 1 : –1

09 The ratio of wavelengths of the last line of Balmer series and the last line of Lyman series is **[NEET 2017]**

(a) 2 (b) 1
(c) 4 (d) 0.5

Ans. *(c)*

Wavelength of spectral lines are given by

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

For last line of Balmer series,

$$n_1 = 2 \text{ and } n_2 = \infty$$

$$\Rightarrow \quad \frac{1}{\lambda_B} = z^2 R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{R}{4} \quad [\because z = 1]$$

Similarly, for last line of Lyman series,

$$n_1 = 1 \text{ and } n_2 = \infty$$

$$\Rightarrow \quad \frac{1}{\lambda_2} = z^2 R\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = R$$

$$\therefore \quad \frac{\frac{1}{\lambda_B}}{\frac{1}{\lambda_L}} = \frac{\frac{R}{4}}{R} = \frac{1}{4}$$

$$\Rightarrow \quad \frac{\lambda_L}{\lambda_B} = \frac{1}{4} \Rightarrow \frac{\lambda_B}{\lambda_L} = 4$$

10 If an electron in a hydrogen atom jumps from the 3rd orbit to the 2nd orbit, it emits a photon of wavelength λ. When it jumps from the 4th orbit to the 3rd orbit, the corresponding wavelength of the photon will be **[NEET 2016]**

(a) $\dfrac{16}{25}\lambda$ (b) $\dfrac{9}{16}\lambda$
(c) $\dfrac{20}{7}\lambda$ (d) $\dfrac{20}{13}\lambda$

Ans. *(c)*

Key Idea Excess energy of e^- appears as photon.
From Rydberg's formula,

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right) = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36}$$

$$\frac{1}{\lambda'} = R\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = \frac{7R}{144}$$

$$\frac{1}{\lambda}\Big/\frac{1}{\lambda'}=\frac{5R}{36}\div\frac{7R}{144}$$

$$\Rightarrow \quad \frac{\lambda'}{\lambda}=\frac{5R}{36}\times\frac{144}{7R}=\frac{20}{7}$$

$$\Rightarrow \quad \lambda'=\frac{20}{7}\lambda$$

11 A proton and an alpha particle both enter a region of uniform magnetic field B, moving at right angles to the field B. If the radius of circular orbits for both the particles is equal and the kinetic energy acquired by proton is 1 MeV, the energy acquired by the alpha particle will be **[CBSE AIPMT 2015]**

(a) 4 MeV (b) 0.5 MeV
(c) 1.5 MeV (d) 1 MeV

Ans. ***(d)***

Radius in magnetic fields of circular orbit,

$$R=\frac{mV}{qB}=\frac{\sqrt{2mE}}{qB}$$

and total energy of a moving particle in a circular orbit, $E=\frac{q^2B^2R^2}{2m}$

For a proton enter in a region of magnetic field,

$$E_1=\frac{e^2\times B^2\times R^2}{2\times m_P} \quad ...(i)$$

where m_P is the mass of proton.

Similarly, for a α-particle moves in a uniform magnetic field

$$E_2=\frac{(2e)^2\times B^2\times R^2}{2\times(4m_P)}$$

$[\because m_\alpha=4m_P]$ ...(ii)

Dividing Eq. (ii) by Eq. (i), we get

$$\frac{E_2}{E_1}=\frac{(2e)^2\times B^2\times R^2}{2\times(4m_P)}\times\frac{2\times m_P}{e^2\times B^2\times R^2}$$

$$\frac{E_2}{E_1}=1 \Rightarrow E_2=E_1=1\,\text{MeV}$$

12 In the spectrum of hydrogen, the ratio of the longest wavelength in the Lyman series to the longest wavelength in the Balmer series is **[CBSE AIPMT 2015]**

(a) $\frac{4}{9}$ (b) $\frac{9}{4}$ (c) $\frac{27}{5}$ (d) $\frac{5}{27}$

Ans. ***(d)***

In hydrogen atom, wavelength of characteristic spectrum

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

For Lyman series $n_1=1$, $n_2=2$

$$\frac{1}{\lambda_1}=Rz^2\left[\frac{1}{(1)^2}-\frac{1}{(2)^2}\right] \quad ...(i)$$

For Balmer series $n_1=2$, $n_2=3$

$$\frac{1}{\lambda_2}=Rz^2\left[\frac{1}{(2)^2}-\frac{1}{(3)^2}\right] \quad ...(ii)$$

Dividing Eq. (ii) by Eq. (i) we get

$$\frac{\lambda_1}{\lambda_2}=\frac{Rz^2\left[\frac{1}{4}-\frac{1}{9}\right]}{Rz^2\left[1-\frac{1}{4}\right]}=\frac{\frac{5}{36}}{\frac{3}{4}}$$

$$\frac{\lambda_1}{\lambda_2}=\frac{5}{36}\times\frac{4}{3}=\frac{5}{27}$$

13 Consider 3$^{\text{rd}}$ orbit of He^+ (Helium), using non-relativistic approach, the speed of electron in this orbit will be (given $K=9\times10^9$ constant, $Z=2$ and h (Planck's constant) $=6.6\times10^{-34}$ J-s) **[CBSE AIPMT 2015]**

(a) 2.92×10^6 m/s (b) 1.46×10^6 m/s
(c) 0.73×10^6 m/s (d) 3.0×10^8 m/s

Ans. ***(b)***

Energy of electron in the 3rd orbit of He^+ is

$$E_3=-13.6\times\frac{Z^2}{n^2}\text{ eV}=-13.6\times\frac{4}{3^2}\text{ eV}$$

$$=-13.6\times\frac{4}{9}\times1.6\times10^{-19}\text{ J}$$

From Bohr's model,

$$E_3=-KE_3=-\frac{1}{2}m_ev^2$$

$$\Rightarrow \frac{1}{2}\times9.1\times10^{-31}\times v^2$$

$$=-13.6\times\frac{4}{9}\times1.6\times10^{-19}$$

$$\Rightarrow \quad v^2=\frac{136\times16\times4\times2\times10^{-11}}{9\times91}$$

or, $\quad v=1.46\times10^6$ m/s

14 Hydrogen atom in ground state is excited by a monochromatic radiation of $\lambda=975$ Å. Number of spectral lines in the resulting spectrum emitted will be **[CBSE AIPMT 2014]**

(a) 3 (b) 2 (c) 6 (d) 10

Ans. ***(c)***

Energy provided to the ground state electron

$$=\frac{hc}{\lambda}=\frac{6.6\times10^{-34}\times3\times10^8}{975\times10^{-10}}$$

$$=\frac{6.6\times3}{975}\times10^{-16}$$

$$=0.020\times10^{-16}=2\times10^{-18}\text{ J}$$

$$=\frac{20\times10^{-19}}{1.6\times10^{-19}}\text{eV}=\frac{20}{1.6}\text{eV}=12.75\text{eV}$$

It means the electron jumps to $n=4$ from $n=1$.

When electron will fall back, number of spectral lines emitted

$$=\frac{n(n-1)}{2}=\frac{4(4-1)}{2}=6$$

15 Ratio of longest wavelengths corresponding to Lyman and Balmer series in hydrogen spectrum is **[NEET 2013]**

(a) $\frac{5}{27}$ (b) $\frac{3}{23}$ (c) $\frac{7}{29}$ (d) $\frac{9}{31}$

Ans. ***(a)***

Wavelength for Lyman series

$$\lambda_L=\frac{1}{R\left(1-\frac{1}{4}\right)}=\frac{4}{3R}$$

and wavelength for Balmer series

$$\lambda_B=\frac{1}{R\left(\frac{1}{4}-\frac{1}{9}\right)}=\frac{1}{R\left(\frac{5}{36}\right)}=\frac{36}{5R}$$

$$\therefore \frac{\lambda_L}{\lambda_B}=\frac{4}{3R}\times\frac{5R}{36}=\frac{5}{27}\Rightarrow\lambda_L:\lambda_B=5:27$$

16 Monochromatic radiation emitted when electron state on hydrogen atom jumps from first excited state to the ground state irradiates a photosensitive material. The stopping potential is measured to be 3.57 V. The threshold frequency of the material is **[CBSE AIPMT 2012]**

(a) 4×10^{15} Hz (b) 5×10^{15} Hz
(c) 1.6×10^{15} Hz (d) 2.5×10^{15} Hz

Ans. ***(c)***

Concept When an electron in hydrogen atom jumps from first excited state $(n=2)$ to ground state $(n=1)$ energy is released and is given by

$$E=E_{(n=2)}-E_{(n=1)}$$

where, $E_n=-\frac{13.6}{n^2}$eV

Energy released from emission of electron is given by

$$E=-3.4-(-13.6)$$
$$=10.2\text{ eV}$$

Now, from photoelectric equation, work function,

$$\phi=E-eV=h\nu$$

$$\nu=\frac{E-eV}{h}=\frac{(10.2-3.57)e}{6.67\times10^{-34}}$$

$$\nu=\frac{6.63\times1.6\times10^{-19}}{6.67\times10^{-34}}=1.6\times10^{15}\text{ Hz}$$

17 Electron in hydrogen atom first jumps from third excited state to second excited state and then from second excited to the first excited state. The ratio of the wavelengths $\lambda_1 : \lambda_2$ emitted in the two cases is **[CBSE AIPMT 2012]**

(a) 7/5 (b) 27/20
(c) 27/5 (d) 20/7

Ans. ***(d)***

According to question,
for wavelength λ_1, $n_1 = 4$ and $n_2 = 3$
and for λ_2, $n_1 = 3$ and $n_2 = 2$
and we know that, $\frac{hc}{\lambda} = -13.6\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

So, for λ_1

$\Rightarrow \quad \frac{hc}{\lambda_1} = -13.6\left[\frac{1}{(4)^2} - \frac{1}{(3)^2}\right]$

$$\frac{hc}{\lambda_1} = 13.6\left[\frac{7}{144}\right] \quad \text{...(i)}$$

Similarly, for λ_2

$\Rightarrow \quad \frac{hc}{\lambda_2} = -13.6\left[\frac{1}{(3)^2} - \frac{1}{(2)^2}\right]$

$$\frac{hc}{\lambda_2} = 13.6\left[\frac{5}{36}\right] \quad \text{...(ii)}$$

Hence, from Eqs. (i) and (ii), we get

$$\frac{\lambda_1}{\lambda_2} = \frac{20}{7}$$

18 An electron of a stationary hydrogen atom passes from the fifth energy level to the ground level. The velocity 3that the atom acquired as a result of photon emission will be **[CBSE AIPMT 2012]**

(a) $\frac{24hR}{25m}$ (b) $\frac{25hR}{24m}$ (c) $\frac{25m}{24hR}$ (d) $\frac{24m}{25hR}$

(m is the mass of electron, R is Rydberg constant and h is Planck's constant.)

Ans. ***(a)***

Concept According to third postulate of Bohr's model, when an atom makes a transition from higher energy state to lower energy state, the difference of energy is carried away by a photon such that $h\nu = E_{n_i} - E_{n_f}$ or $\frac{hc}{\lambda} = Rhc\left[\frac{1}{n_f^2} - \frac{1}{n_i^2}\right]$

[where, $n_i =$ quantum number of higher energy state and $n_f =$ quantum number of lower energy state.]

Energy difference between fifth and first orbit is $E_5 - E_1 = \frac{hc}{\lambda}$ and

$$Rhc - \frac{Rhc}{25} = \frac{hc}{\lambda}$$

$$\frac{24}{25}R = \frac{1}{\lambda}$$

As, $\quad p = \frac{h}{\lambda}$ and $v = \frac{h}{m\lambda} = \frac{24}{25}\frac{Rh}{m}$

19 The wavelength of the first line of Lyman series for hydrogen atom is equal to that of the second line of Balmer series for a hydrogen like ion. The atomic number Z of hydrogen like ion is **[CBSE AIPMT 2011]**

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

Ans. ***(c)***

For Lyman series for H-atom

$$\frac{hc}{\lambda} = Rhc\left(\frac{1}{1^2} - \frac{1}{2^2}\right)$$

and for H-like ion,

$$\frac{hc}{\lambda} = Z^2 Rhc\left(\frac{1}{2^2} - \frac{1}{4^2}\right)$$

$$\therefore \left(\frac{1}{1^2} - \frac{1}{2^2}\right) = Z^2\left(\frac{1}{4} - \frac{1}{16}\right)$$

$$\left(1 - \frac{1}{4}\right) = Z^2\left(\frac{1}{4} - \frac{1}{16}\right) \Rightarrow Z = 2$$

20 The energy of a hydrogen atom in the ground state is – 13.6 eV. The energy of a He^+ ion in the first excited state will be **[CBSE AIPMT 2010]**

(a) –13.6 eV (b) –27.2 eV
(c) – 54.4 eV (d) – 6.8 eV

Ans. ***(a)***

Energy E of an atom with principal quantum number n is given by

$E = \frac{-13.6}{n^2}Z^2$ for first excited state $n = 2$

and for He^+, $Z = 2$

So, $E = \frac{-13.6 \times (2)^2}{(2)^2} = -13.6\,\text{eV}$

21 The ionisation energy of the electron in the hydrogen atom in its ground state is 13.6 eV. The atoms are excited to higher energy levels to emit radiations of 6 wavelengths. Maximum wavelength of emitted radiation corresponds to the transition between **[CBSE AIPMT 2009]**

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

Ans. ***(d)***

Number of spectral lines

$$N = \frac{n(n-1)}{2} \Rightarrow \frac{n(n-1)}{2} = 6$$

or $\quad n^2 - n - 12 = 0$

or $\quad (n-4)(n+3) = 0$ or $n = 4$

Now as the first line of the series has the maximum wavelength, therefore electron jumps from the fourth orbit to the third orbit.

22 The ground state energy of hydrogen atom is –13.6 eV. When its electron is in the first excited state, its excitation energy is **[CBSE AIPMT 2008]**

(a) 3.4 eV (b) 6.8 eV
(c) 10.2 eV (d) zero

Ans. ***(c)***

In the ground state, $n = 1$

$$E_1 = -\frac{13.6}{1^2} = -13.6\,\text{eV}$$

For the first excited state (i.e. for $n = 2$)

$$E_2 = \frac{-13.6}{2^2} = -3.4\,\text{eV}$$

$$\Delta E = E_2 - E_1 = -3.4 + 13.6 = 10.2\,\text{eV}$$

23 The total energy of electron in the ground state of hydrogen atom is –13.6 eV. The kinetic energy of an electron in the first excited state is **[CBSE AIPMT 2007]**

(a) 3.4 eV (b) 6.8 eV
(c) 13.6 eV (d) 1.7 eV

Ans. ***(a)***

The energy of hydrogen atom when the electron revolves in nth orbit is given by

$$E = \frac{-13.6Z^2}{n^2}\,\text{eV} \quad [Z = 1]$$

In the ground state; $n = 1$

$$E = \frac{-13.6}{1^2} = -13.6\,\text{eV}$$

For $n = 2$,

$$E = \frac{-13.6}{2^2} = -3.4\,\text{eV}$$

So, kinetic energy of electron in the first excited state (i.e. for $n = 2$) is

$$\text{KE} = -E = -(-3.4) = 3.4\,\text{eV}$$

24 In a discharge tube ionisation of enclosed gas is produced due to collisions between **[CBSE AIPMT 2006]**

(a) positive ions and neutral atoms/molecules
(b) negative electrons and neutral atoms/molecules
(c) photons and neutral atoms/molecules
(d) neutral gas atoms/molecules

Ans. *(b)*

In a discharge tube, after being accelerated though a high potential difference the ions in the gas strike the cathode with huge kinetic energy. This collision liberates electrons from the cathode. These free electrons can further liberate ions from gas molecules through collisions. The positive ions are attracted towards the cathode and negatively charged electrons move towards anode. Thus, ionisation of gas results.

25 Ionisation potential of hydrogen atom is 13.6 eV. Hydrogen atoms in the ground state are excited by monochromatic radiation of photon energy 12.1 eV. According to Bohr's theory, the spectral lines emitted by hydrogen will be **[CBSE AIPMT 2006]**

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

Ans. *(b)*

Ionisation energy corresponding to ionisation potential $(E_1 = -13.6\,\text{eV})$

Photon energy incident $(\Delta E) = 12.1$ eV

So, the energy of electron in excited state (E_2) is given by

$$E_2 - E_1 = \Delta E \Rightarrow E_2 = \Delta E + E_1$$

$$\Rightarrow \quad E_2 = -13.6 + 12.1$$

$$\Rightarrow \quad E_2 = -1.5 \text{ eV}$$

i.e. $$E_2 = -\frac{13.6}{n^2}\text{eV}$$

$$-1.5 = \frac{-13.6}{n^2}$$

$$\Rightarrow \quad n^2 = \frac{-13.6}{-1.5} \approx 9$$

$$\therefore \quad n = 3$$

i.e. energy of electron in excited state corresponds to third orbit.

The possible spectral lines is given by

$$\frac{n(n-1)}{2} \Rightarrow \frac{3(3-1)}{2} \Rightarrow 3$$

26 The total energy of an electron in the first excited state of hydrogen is about – 3.4 eV. Its kinetic energy in this state is **[CBSE AIPMT 2005]**

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

Ans. *(d)*

Kinetic energy of electron

$$\text{KE} = \frac{Ze^2}{8\pi\varepsilon_0 r}$$

Potential energy of electron

$$U = -\frac{1}{4\pi\varepsilon_0}\frac{Ze^2}{r}$$

$\therefore$ Total energy $E = \text{KE} + U$

$$= \frac{Ze^2}{8\pi\varepsilon_0 r} - \frac{Ze^2}{4\pi\varepsilon_0 r}$$

or $$E = -\frac{Ze^2}{8\pi\varepsilon_0 r} \quad \text{or} \quad E = -\text{KE}$$

or $$\text{KE} = -E = -(-3.4) = 3.4\,\text{eV}$$

NOTE

Total kinetic energy of a revolving electron in any given orbit is equal to the negative of total energy of electrons in that orbit i.e. $KE = -E$

27 Energy E of a hydrogen atom with principal quantum number n is given by $E = \frac{-13.6}{n^2}$ eV. The energy of a photon ejected when the electron jumps from $n = 3$ state to $n = 2$ state of hydrogen, is approximately **[CBSE AIPMT 2004]**

(a) 1.5 eV (b) 0.85 eV
(c) 3.4 eV (d) 1.9 eV

Ans. *(d)*

Given, $E_n = -\frac{13.6}{n^2}$ eV

Energy of photon ejected when electron jumps from $n = 3$ to $n = 2$ state is given by

$$\Delta E = E_3 - E_2$$

Energy of third orbit

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

Energy of second orbit

$$E_2 = -\frac{13.6}{(2)^2}\text{eV} = -\frac{13.6}{4}\text{eV}$$

So, $$\Delta E = E_3 - E_2 = -\frac{13.6}{9} - \left(-\frac{13.6}{4}\right)$$

$$= 1.9\,\text{eV} \quad \text{(approximately)}$$

28 The Bohr model of atoms **[CBSE AIPMT 2004]**

(a) assumes that the angular momentum of electrons is quantised
(b) uses Einstein's photoelectric equation
(c) predicts continuous emission spectra for atoms
(d) predicts the same emission spectra for all types of atoms

Ans. *(a)*

According to Bohr's hypothesis, electron can revolve only in those orbits in which its angular momentum is an integral multiple of $\frac{h}{2\pi}$, where h is Planck's constant. In these orbits, angular momentum of electron can have magnitude as $\frac{h}{2\pi}, \frac{2h}{2\pi}, \frac{3h}{2\pi}$ .... etc., but never as $\frac{1.5h}{2\pi}, \frac{2.5h}{2\pi}, \frac{3.5h}{2\pi}$ .... etc. This is called the quantisation of angular momentum.

29 Which of the following transitions gives photon of maximum energy? **[CBSE AIPMT 2000]**

(a) $n = 1$ to $n = 2$ (b) $n = 2$ to $n = 1$
(c) $n = 2$ to $n = 6$ (d) $n = 6$ to $n = 2$

Ans. *(b)*

Energy levels of H-atom are given by

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

$$\Rightarrow \quad E_n = -13.6/n^2 \text{ eV}$$

Photons are emitted only when electron jumps from higher energy level (higher n-value) to lower energy level (lower n-value). So, alternative (a) and (c) are wrong.

Energy difference from $n = 2$ to $n = 1$ level is

$$\Delta E_{2\to 1} = 13.6\left(\frac{1}{1^2} - \frac{1}{2^2}\right)\text{eV}$$

$$= 13.6 \times \frac{3}{4} = 10.2\,\text{eV}$$

Energy difference from $n = 6$ to $n = 2$ level is

$$\Delta E_{6\to 2} = 13.6\left(\frac{1}{2^2} - \frac{1}{6^2}\right)$$

$$= 13.6 \times \left(\frac{1}{4} - \frac{1}{36}\right) = 13.6 \times \frac{2}{9}$$

$$= 3.02\,\text{eV}$$

Thus, it is evident that difference is larger for $n = 2$ to $n = 1$ transition. Hence, maximum energy photon or shortest wavelength will be emitted during transition from $n = 2$ to $n = 1$

30 When electron jumps from $n = 4$ to $n = 2$ orbit, we get **[CBSE AIPMT 2000]**

(a) second line of Lyman series
(b) second line of Balmer series
(c) second line of Paschen series
(d) an absorption line of Balmer series

Ans. *(b)*

(a) Second line of Lyman series corresponds to the transition $n = 3 \to n = 1$
(b) Second line of Balmer series corresponds to the transition $n = 4 \to n = 2$
(c) Second line of Paschen series corresponds to the transition $n = 5 \to n = 3$

(d) An absorption line of Balmer series arises when electron jumps from $n=2$ to any other higher state.

Thus, choice (b) is correct.

NOTE

For Lyman series

$$n_2 = 2, 3, 4 \ldots\ldots \to n_1 = 1$$

For Balmer series

$$n_2 = 3, 4, 5, \ldots\ldots \to n_1 = 2$$

For Paschen Series

$$n_2 = 4, 5, 6 \ldots \to n_1 = 3$$

For Brackett series

$$n_2 = 5, 6, 7 \ldots\ldots \to n_1 = 4$$

For Pfund series

$$n_2 = 6, 7, 8 \ldots\ldots \to n_1 = 5$$

31 In the Bohr's model of a hydrogen atom, the centripetal force is furnished by the Coulomb attraction between the proton and the electron. If a_0 is the radius of the ground state orbit, m is the mass and e is the charge on the electron, ε_0 is the vacuum permittivity, the speed of the electron is **[CBSE AIPMT 1998]**

(a) zero (b) $\frac{e}{\sqrt{\varepsilon_0 a_0 m}}$

(c) $\frac{e}{\sqrt{4\pi\varepsilon_0 a_0 m}}$ (d) $\frac{\sqrt{4\pi\varepsilon_0 a_0 m}}{e}$

Ans. ***(c)***

From Coulomb's attraction between the positive proton and negative electron

$$= \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

[For neutral atom]

Centripetal force has magnitude

$$F = \frac{mv^2}{r}$$

So for the revolving electrons

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$\Rightarrow \quad v^2 = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{mr}$$

or $$v = \frac{e}{\sqrt{4\pi\varepsilon_0 mr}}$$

For ground state of H-atom, $r = a_0$

$$\therefore \quad v = \frac{e}{\sqrt{4\pi\varepsilon_0 m a_0}}$$

32 The energy of ground electronic state of hydrogen atom is -13.6 eV. The energy of the first excited state will be **[CBSE AIPMT 1997]**

(a) -54.4 eV

(b) -27.2 eV

(c) -6.8 eV

(d) -3.4 eV

Ans. ***(d)***

The energy of hydrogen like atom in its nth excited state is given by

$$E_n = -13.6\frac{Z^2}{n^2}.$$

For ground state (n=1),

and atomic number $(Z) = 1$

$$E_1 = -\frac{13.6}{(1)^2} = -13.6\,\text{eV}$$

For first excited state (n=2),

$$E_2 = -\frac{13.6}{(2)^2} = -\frac{13.6}{4}$$

$$= -3.4\,\text{eV}$$

Note

In ground state (n = 1) energy of atom is –13.6 eV and energy corresponding to $n = \infty$ is zero. Therefore, energy required to remove the electron from ground state is 13.6 eV.

33 When hydrogen atom is in its first excited level, its radius is **[CBSE AIPMT 1997]**

(a) four times, its ground state radius

(b) twice, its ground state radius

(c) same as its ground sate radius

(d) half of its ground state radius

Ans. ***(a)***

The radius of nth Bohr's orbit of hydrogen and hydrogen like atom

$$r_n = \frac{\varepsilon_0 n^2 h^2}{\pi m e^2 Z}$$

$$\therefore \quad r_n = \frac{n^2 a_0}{Z} \quad \text{or} \quad r_n \propto \frac{n^2}{Z}$$

For ground state, $n = 1$

Atomic number, $Z = 1$

For first excited state, $n = 2$

$$\therefore \quad \frac{r_2}{r_1} = \left(\frac{2}{1}\right)^2 = 4$$

or $$r_2 = 4r_1$$

Therefore, radius of first excited state is 4 times than that of ground state radius in H-atom.

34 When a hydrogen atom is raised from the ground state to an excited state **[CBSE AIPMT 1995]**

(a) PE decreases and KE increases

(b) PE increases and KE decreases

(c) both KE and PE decrease

(d) absorption spectrum

Ans. ***(c)***

Kinetic energy of electron is given by

$$\text{KE} = \frac{kZe^2}{2r}$$

Potential energy of electron is

$$U = -\frac{kZe^2}{r}$$

When a hydrogen atom is raised from the ground, to an excited state both potential energy and kinetic energy decreases.

35 The spectrum obtained from a sodium vapour lamp is an example of **[CBSE AIPMT 1995]**

(a) band spectrum (b) continuous spectrum

(c) emission spectrum

(d) absorption spectrum

Ans. ***(c)***

When continuous light from a source is examined directly in a spectroscope, we observe the emission spectrum of the source. The sodium vapour spectrum, consists of a few isolated bright lines. Each bright line corresponds to a particular wavelength. It is emitted by the atoms in the gaseous state.

When continuous light from a source is made to pass through an absorbing substance and then examined in a spectroscope, we observe absorption spectrum of the substance.

A band spectrum is emitted by chemical compounds in the vapour state. It is therefore a molecule spectrum.

A continuous emission spectrum consists of a wide range of unseparated wavelengths.

36 Doubly ionised helium atoms and hydrogen ions are accelerated from rest through the same potential drop. The ratio of the final velocities of the helium and the hydrogen ion is **[CBSE AIPMT 1994]**

(a) $\frac{1}{2}$ (b) 2

(c) $\frac{1}{\sqrt{2}}$ (d) $\sqrt{2}$

Ans. ***(c)***

If v is the speed acquired by particle when accelerated under a potential difference V, then

$$\text{KE gained by particle} = \frac{1}{2}mv^2 = eV$$

or $$v = \sqrt{\frac{2eV}{m}}$$

So, for two different cases of the He-atom and H-atom,

$$\frac{v_{He}}{v_H} = \frac{\sqrt{\frac{2(e)_{He} V}{m_{He}}}}{\sqrt{\frac{2(e)_H V}{m_H}}}$$

As $m_{He} = 4m_H$ and $(e)_{He} = 2(e)_H$

$\therefore$ $\frac{v_{He}}{v_H} = \frac{1}{\sqrt{2}}$

37 The radius of hydrogen atom in its ground state is 5.3×10^{-11} m. After collision with an electron it is found to have a radius of 21.2×10^{-11} m. What is the principal quantum number n of the final state of the atom ? **[CBSE AIPMT 1994]**

(a) $n = 4$ (b) $n = 2$
(c) $n = 16$ (d) $n = 3$

Ans. *(b)*

Radii of Bohr's stationary orbit is given by

$$r = \frac{n^2 h^2}{4\pi^2 mke^2 Z} \Rightarrow r \propto \frac{n^2}{Z}$$

Considering two situations of electrons,

$$\Rightarrow \frac{(r_f)}{(r_i)} = \frac{n_f^2}{n_i^2}$$

For ground state $n_i = 1$

$$\therefore \frac{21.2 \times 10^{-11}}{5.3 \times 10^{-11}} = n_f^2$$

or $n_f^2 = 4$

$\therefore$ $n_f = 2$

38 Hydrogen atoms are excited from ground state of the principal quantum number 4. Then, the number of spectral lines observed will be **[CBSE AIPMT 1993]**

(a) 3 (b) 6
(c) 5 (d) 2

Ans. *(b)*

Number of spectral lines observed in hydrogen spectrum is given by

$$= \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$$

Where, n = principal quantum number = number of orbits.

39 Which source is associated with a line emission spectrum? **[CBSE AIPMT 1993]**

(a) Electric fire
(b) Neon street sign
(c) Red traffic light
(d) Sun

Ans. *(b)*

In line emission spectrum, every line spectrum consists of a few isolated bright lines, each bright line corresponds to a particular wavelength. It is emitted by atoms in the gaseous state.

e.g. a sodium discharge lamp, a mercury vapour lamp, a neon discharge tube and a helium discharge tube all emit sharp lines of definite wavelengths.

40 The ionisation energy of hydrogen atom is 13.6 eV. Following Bohr's theory, the energy corresponding to a transition between 3rd and 4th orbit is **[CBSE AIPMT 1992]**

(a) 3.40 eV (b) 1.51 eV
(c) 0.85 eV (d) 0.66 eV

Ans. *(d)*

Total energy of electron for hydrogen like atom is given by

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

$$\therefore E_3 = -\frac{13.6}{3^2} \text{ eV} \quad [Z = 1, n = 3]$$

$$= -1.51 \text{ eV}$$

$$E_4 = -\frac{13.6}{4^2} = -0.85 \text{ eV}$$

$$\therefore E_4 - E_3 = 1.51 - 0.85 = 0.66 \text{ eV}$$

41 In terms of Bohr radius a_0, the radius of the second Bohr orbit of a hydrogen atom is given by **[CBSE AIPMT 1992]**

(a) $4a_0$ (b) $8a_0$
(c) $\sqrt{2} a_0$ (d) $2a_0$

Ans. *(a)*

From Bohr's postulate, for any permitted (stationary orbit).

Angular momentum of electron revolving in an orbit is constant

i.e. $mvr = \frac{nh}{2\pi}$ or $v = \frac{nh}{2\pi mr}$ ...(i)

Also, $\frac{mv^2}{r} = \frac{Ze^2}{4\pi\varepsilon_0 r^2} = \frac{kZe^2}{r^2}$ ...(ii)

(where, $k = \frac{1}{4\pi\varepsilon_0}$)

Symbols have their usual meaning.
From Eqs. (i) and (ii),

$$r = \frac{n^2 h^2}{4\pi^2 mkZe^2}$$

For hydrogen atom,

$$Z = 1$$

$$\therefore r = \frac{n^2 h^2}{4\pi^2 mke^2}$$

$$\Rightarrow r_n \propto n^2$$

$$\therefore a_2 = 4a_0$$

Note

For solving the problem, dependence of radius of nth orbit of hydrogen like atom must be kept in mind i.e. $r_n \propto \frac{n^2}{Z}$

[where, n = nth orbit and Z = atomic number]

42 The ground state energy of H-atom is 13.6 eV. The energy needed to ionise H-atom from its second excited state **[CBSE AIPMT 1991]**

(a) 1.51 eV (b) 3.4 eV
(c) 13.6 eV (d) 12.1 eV

Ans. *(a)*

For second excited state, $n = 3$

$\therefore$ Energy needed to ionise H-atom from its second excited state

$$E = \frac{2\pi^2 mke^4}{h^2}\left(\frac{1}{3^2} - \frac{1}{\infty}\right)$$

or we can say that

$$E \propto \frac{Z^2}{n^2}$$

$\begin{pmatrix} Z = \text{atomic number} \\ n = n\text{th orbit} \end{pmatrix}$

So, $E = \frac{13.6}{3^2} \text{ eV} = 1.51 \text{eV}$

43 Consider an electron in the nth orbit of a hydrogen atom in the Bohr model. The circumference of the orbit can be expressed in terms of de-Broglie wavelength λ of that electron as **[CBSE AIPMT 1990]**

(a) $(0.529) n\lambda$ (b) $\sqrt{n\lambda}$
(c) $(13.6)\lambda$ (d) $n\lambda$

Ans. *(d)*

The circumference of an orbit in an atom in terms of wavelength of wave associated with electron is given by

$$2\pi r_n = n\lambda$$

[r_n = radius of any n orbit]

44 The valence electron in alkali metal is a **[CBSE AIPMT 1990]**

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

Ans. *(c)*

The outermost electrons in an atom are called valence electrons. In alkali metals (IA group) outermost electron is present in s-orbital. Alkali metals have one valence electron. e.g. Li, Na, K.

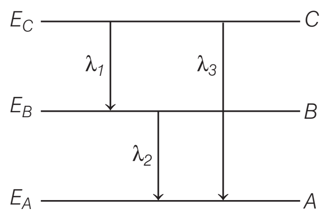
45 Energy levels A, B, C of a certain atom correspond to increasing values of energy i.e. $E_A < E_B < E_C$. If $\lambda_1, \lambda_2, \lambda_3$ are the wavelengths of radiation corresponding to the transitions C to B, B to A and C to A respectively, which of the following relation is correct ?

[CBSE AIPMT 1990]

(a) $\lambda_3 = \lambda_1 + \lambda_2$ (b) $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$

(c) $\lambda_1 + \lambda_2 + \lambda_3 = 0$ (d) $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$

Ans. ***(b)***



Using Bohr's postulate for radiation of spectral line, we have

Radiation of wavelength from C to B

$$E_C - E_B = \frac{hc}{\lambda_1} \quad \text{...(i)}$$

Radiation of wavelength from B to A

$$E_B - E_A = \frac{hc}{\lambda_2} \quad \text{...(ii)}$$

Radiation of wavelength from C to A

$$E_C - E_A = \frac{hc}{\lambda_3} \quad \text{...(iii)}$$

Also, $(E_C - E_A) = (E_C - E_B) + (E_B - E_A)$

$$\therefore \quad \frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$$

or $$\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

$$\Rightarrow \quad \lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$$

46 To explain his theory, Bohr used

[CBSE AIPMT 1989]

(a) conservation of linear momentum
(b) conservation of angular momentum
(c) conservation of quantum frequency
(d) conservation of energy

Ans. ***(b)***

According to Bohr, electron can revolve only in certain discrete non-radiating orbits, called stationary orbits, for which total angular momentum of the revolving electron is an integral multiple of $\frac{h}{2\pi}$, where h is Planck's constant. For orbits, conservation of angular momentum is applicable.

$\therefore$ For any permitted orbit, $mvr = \frac{nh}{2\pi}$

47 The ionisation energy of hydrogen atom is 13.6 eV, the ionisation energy of helium atom would be

[CBSE AIPMT 1988]

(a) 13.6 eV (b) 27.2 eV
(c) 6.8 eV (d) 54.4 eV

Ans. ***(d)***

Ionisation energy is defined as the energy required to knock an electron completely out of an isolated gaseous atom. When electron is raised to the orbit $n = \infty$, it will be completely out of the atom.

Ionisation energy of helium,

$$E = \frac{2\pi^2 mZ^2 k^2 e^4}{h^2}\left[\frac{1}{1^2} - \frac{1}{\infty}\right]$$

$$= \frac{2\pi^2 m(2)^2 k^2 e^4}{h^2}\left[\frac{1}{1^2} - \frac{1}{\infty}\right]$$

Ionisation energy for hydrogen atom

$$= 13.6 \text{ eV} = \frac{2\pi^2 mk^2 e^2}{h^2} \times 4 \times \left[\frac{1}{1^2} - \frac{1}{\infty^2}\right]$$

$$= 4 \times 13.6 = 54.4 \text{ eV}$$