SOLVED EXAMPLES

Ex.1 A α particle after passing through a potential difference of V volt collides with a nucleus. If the atomic number of the nucleus is Z then the distance of closest approach of α-particle to the nucleus will be-

(A) $14.4\ \frac{Z}{V}$ Å (B) $14.4\ \frac{Z}{V}$ m

(C) $14.4\ \frac{Z}{V}$ cm (D) All of the above

Sol. $E_k = U,\ 2eV = \frac{k(Ze)(2e)}{d}$

$d = \frac{k\,Ze}{V} = 9 \times 10^9 \times 1.6 \times 10^{-19}\left(\frac{Z}{V}\right)$,

$d = 14.4 \times 10^{-10}\left(\frac{Z}{V}\right) m = 14.4\left(\frac{Z}{V}\right)$ Å

Ex.2 The radius of hydrogen atom in the ground state is 5.3×10^{-11} m. If this atom collides with an electron then its values becomes 21.2×10^{-11} m. The value of principal quantum number will be-

(A) 2 (B) 16

(C) 3 (D) 4

Sol. $\because\ \frac{r_2}{r_1} = \left(\frac{n_2}{n_1}\right)^2,\ \therefore n_2^2 = \frac{n_1^2 r_2}{r_1}$

$\therefore\ n_2 = n_1\sqrt{\frac{r_2}{r_1}} \Rightarrow n_2 = 1\sqrt{\frac{21.2\times10^{-11}}{5.3\times10^{-11}}}$

$\Rightarrow n_2 = 2$

Ex.3 An electron revolves round a nucleus of charge Ze. In order to excite the electron from the state n = 3 to n = 4, the energy required is 66.0 eV. Z will be -

(A) 25 (B) 10 (C) 4 (D) 5

Sol. Energy of hydrogen atom

$= 13.6\left(\frac{1}{3^2} - \frac{1}{4^2}\right)eV = 13.6 \times \frac{7}{144}\ eV = .66\ eV$

The ionisation potential of hydrogen

= 13.6 eV

$E_n \propto Z^2$

$\therefore\ Z^2 = \frac{66}{0.66} = 100,\ Z = 10$

Ex.4 A hydrogen atom rises from its n = 1 state to the n = 4 state by absorbing energy. If the potential energy of the atom in the n = 1 state be –13.6 eV, then potential energy in the n = 4 state will be -

(A) 3.4 eV (B) –1.54 eV

(C) 0.85 eV (D) –0.85 eV

Sol. $E_n = -\frac{Rch}{n^2}$

Given $E_1 = -13.6$ eV = –Rch

E_4 = Energy of 4th state $= -\frac{Rch}{4^2} = \frac{E_1}{16}$,

$E_4 = -\frac{13.6}{16} = -0.85$ eV

Ex.5 The wavelength of the first line of lymen series for hydrogen is identical to that of the second line of Balmer series for some hydrogen like ion x. Energies of two levels of x will be : (Ground state binding energy of hydrogen atom = 13.6 eV)

(A) –54.4 eV, –6.07 eV

(B) –13.6 eV, –3.4 eV

(C) –3.4 eV, –13.6 eV

(D) –54.4 eV, –13.6 eV

Sol. We know that

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

For first line of Lyman series in hydrogen atom

$$\frac{1}{\lambda_1} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3R}{4}$$

For second line of Balmer series of hydrogen like ion x

$$\frac{1}{\lambda_2} = Z^2R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = \frac{3Z^2R}{16}$$

Given that, $\lambda_1 = \lambda_2$

$\therefore\ \frac{3R}{4} = \frac{3Z^2R}{16} \Rightarrow Z = 2$

Energy of nth state of ion X is given by

$E_x = -\frac{13.4}{n^2} \times Z^2,\ (E_x)_1 = -\frac{13.4\times4}{1}$

= – 54.4 eV

$(E_x)_2 = -\frac{13.4\times4}{4} = -13.6$ eV

Ex.6 The wavelength of the first member of the Balmer series in hydrogen spectrum is 6563 Å. Calculate the wavelength of first member of Lyman series in the same spectrum.

(A) 1000 Å (B) 1215.37 Å

(C) 1512 .37 Å (D) None

Sol. For the first member of the Balmer series

$$\bar{\nu} = \frac{1}{\lambda_1} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$$= \frac{5}{36} R \quad .... (1)$$

For the first member of Lyman series

$$\bar{\nu} = \frac{1}{\lambda_2} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$$

$$= \frac{3R}{4} \quad .... (2)$$

Dividing eq. (1) by eq.(2) , we get

$$\frac{\lambda_2}{\lambda_1} = \frac{5}{27} \quad \text{or} \quad \lambda_2 = \frac{5}{27}\lambda_1$$

$$\lambda_2 = \frac{5 \times 6563}{27} = 1215.37 \text{ Å}$$

Ex.7 The radius of first orbit of hydrogen atom is 0.53 Å and the electron is executing 6.54×10^{15} revolutions per second. The magnetic moment of electron will be-

(A) 9.3×10^{-24} Amp-m^2
(B) 6.54×10^{-27} Amp-m^2
(C) 6.54×10^{-24} Amp-m^2
(D) 5.3×10^{-24} Amp - m^2

Sol. $\mu = iA = efA = ef\pi r^2$

$\mu = 1.6 \times 10^{-19} \times 6.54 \times 10^{15} \times 3.14 \times (0.53 \times 10^{-10})^2$

$\Rightarrow \mu = 9.3 \times 10^{-24}$ Amp-m^2

Ex.8 The wavelength of first and second lines of sodium are 5890 Å and 5896 Å respectively. Its first excitation potential will be-

(A) 4.1 V (B) 10.2 V
(C) 2.1 V (D) 3.7 V

Sol. In sodium spectrum only two lines are obtained whose wavelengths are 5890 Å and 5896 Å respectively.

The excitation energy between there energy levels will be-

$$\Delta E = \frac{hc}{e}\left(\frac{1}{\lambda_1} - \frac{1}{\lambda_2}\right), \quad \Delta E = \frac{hc}{\lambda}\left(\frac{\lambda_1 - \lambda_2}{\lambda_1 \lambda_2}\right)$$

$$\Delta E = \frac{6.62 \times 10^{-34} \times 3 \times 10^8 \times 6 \times 10^{-10}}{1.6 \times 10^{-19} \times 5896 \times 5896 \times 10^{-20}}$$

$\Rightarrow \Delta E = 2.1$ eV,

Excitation potential $\Delta V = 2.1$ volt

Ex.9 The radius of first orbit of hydrogen atom is 0.53 Å. The radius of its fourth orbit will be-

(A) 0.193 Å (B) 4.24 Å
(C) 2.12 Å (D) 8.48 Å

Sol. $r_n = 0.53\, n^2$, $n = 4$

$\Rightarrow r_4 = 0.53 \times 16$

$\Rightarrow r_4 = 8.48$ Å

Ex.10 The wavelength of D_1 and D_2 lines of sodium are 5890 Å and 5896 Å respectively, if their mean wavelength is 6000 Å then the difference of exicted energy states will be

(A) 2×10^3 eV (B) 2×10^{-3} eV
(C) 2×10^6 eV (D) 2 eV

Sol. $E = \frac{hc}{\lambda} \quad \therefore \quad \Delta E = \frac{hc}{\lambda^2}\Delta\lambda$

$$\Delta E = \frac{6.62 \times 10^{-34} \times 3 \times 10^8 \times 6 \times 10^{-10}}{6000 \times 6000 \times 10^{-20}}$$

$\Rightarrow \Delta E = 3.31 \times 10^{-22}$ J

$$\Rightarrow \Delta E = \frac{3.31 \times 10^{-22}}{16 \times 10^{-19}} \approx 2 \times 10^{-3} \text{ eV}$$

Ex.11 An electron makes transition from n = 4 state to n = 1 state in hydrogen atom. The momentum of recoil hydrogen atom in kg-m/s will be-

(A) 12.75×10^{-19} (B) 13.6×10^{-19}
(C) 6.8×10^{-27} (D) zero

Sol. According to law of conservation of momentum of recoil atom

= momentum of photon = $\frac{E_4 - E_1}{C}$

$$\Rightarrow P = \frac{12.75 \times 1.6 \times 10^{-19}}{3 \times 10^8}$$

$= 6.8 \times 10^{-27}$ kg-m/s

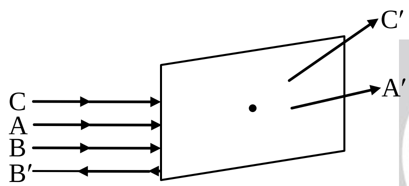
LEVEL # 1

Questions based on Scattering experiment

Q.1 The path of the scattered α-particles is -
(A) circular (B) parabolic
(C) elliptical (D) hyperbolic

Q.2 Which of the following forces is responsible for α - particle scattering ?
(A) Gravitational (B) Nuclear
(C) Coulomb (D) Magnetic

Q.3 A beam of α-particle is incident on a gold foil. corresponding to the incident beams A, B and C, the emergent beams A′, B′ and C′. The transmission and deflection of α-particles through the foil take place such that -



(A) The number of α-particle in A′ is maximum and in B′ minimum
(B) The number of α-particles in A′ is minimum and in C′ maximum
(C) The number of α-particles in A′, B′ and in C′ is the same.
(D) The number of α-particles in B′ is minimum and in C′ maximum

Q.4 In Rutherford's experiment, the number of alpha particles scattered through an angle of 60º by a silver foil is 200 per minute. When the silver foil is replaced by a copper foil of the same thickness, the number of α-particles scattered through an angle of 60º per minute is -
(A) $200 \times \frac{Z_{Cu}}{Z_{Ag}}$ (B) $200\left(\frac{Z_{Cu}}{Z_{Ag}}\right)^2$
(C) $200 \times \frac{Z_{Ag}}{Z_{Cu}}$ (D) $200 \times \left(\frac{Z_{Ag}}{Z_{Cu}}\right)^2$

Q.5 In Rutherford's α-particle scattering experiment, the ratio of number of α-particles scattered through an angle of 60º and 120º is -
(A) 1 : 2 (B) $\sqrt{3}$: 1
(C) 3 : 1 (D) 9 : 1

Questions based on Distance of closest approach

Q.6 An α-particle of energy 5 MeV is scattered through 180º by a stationary uranium nucleus. The distance of closest approach is of the order of -
(A) 1Å (B) 10^{-10} cm
(C) 10^{-12} cm (D) 10^{-15} cm

Questions based on Radius and velocity of electron in circular orbit

Q.7 The radius of first orbit of hydrogen atom is 0.53Å. The radius of its fourth orbit will be -
(A) 0.193 Å (B) 4.24 Å
(C) 2.12 Å (D) 8.48 Å

Q.8 The ratio of the radius of a hydrogen like atom in the ground state & that of one in the second excited state is -
(A) 1 : 9 (B) 1 : 4
(C) 1 : 3 (D) 1 : 2

Q.9 If the radius of the first orbit of hydrogen atom is 5.29×10^{-11} meter, the radius of the second orbit will be -
(A) 21.16×10^{-11} m (B) 15.87×10^{-11} m
(C) 10.58×10^{-11} m (D) 2.64×10^{-11} m

Q.10 The velocity of an electron in ground state of H-atom is nearly
(A) 2×10^5 m/s (B) 2×10^6 m/s
(C) 2×10^7 m/s (D) 2×10^8 m/s

Q.11 The ratio of the radii of Bohr orbits in hydrogen atom in increasing order is -
(A) 2 : 4 : 8 : 16 (B) 2 : 3 : 4 : 5
(C) 1 : 3 : 6 : 9 (D) 1 : 4 : 9 : 16

Q.12 The radius of electron's second stationary orbit in Bohr's atom is R. The radius of the third orbit will be-

(A) 3R (B) 2.25 R

(C) 9 R (D) R/3

Q.13 The ratio of the area of orbit of first excited state of electron to the area of orbit of ground level, for hydrogen atom, will be -

(A) 2 : 1 (B) 4 : 1

(C) 8 : 1 (D) 16 : 1

Q.14 The electron in a hydrogen atom jumps from ground state to the higher energy state where its velocity is reduced to one-third its initial value. If the radius of the orbit in the ground state is r, the radius of new orbit will be -

(A) 3r (B) 9r

(C) $\frac{r}{3}$ (D) $\frac{r}{9}$

Q.15 The ratio of velocities of electron in H-atom in its first, second & third orbit respectively will be -

(A) 6 : 3 : 1 (B) 3 : 2 : 1

(C) 6 : 3 : 2 (D) 1 : 3 : 6

Q.16 From Bohr's theory the product of the radius and the velocity of the electron in different orbits is -

(A) constant

(B) proportional to the square root of radius

(C) proportional to the radius

(D) proportional to the square of the radius

Questions based on **Energy of electron in Bohr's circular orbit**

Q.17 Ionisation energy of a hydrogen like ion A is greater than that of another hydrogen like ion B. Let r,u, E and L represent the radius of the orbit, speed of the electron, energy of the atom and orbital angular momentum of the electron respectively. In ground state -

(A) $r_A > r_B$ (B) $u_A > u_B$

(C) $E_A > E_B$ (D) $L_A > L_B$

Q.18 Which of the following parameters are the same for all hydrogen-like atoms and ions in their ground states ?

(A) radius of the orbit

(B) speed of the electron

(C) energy of the atom

(D) orbital angular momentum of the electron

Q.19 Choose the correct relation from the following for hydrogen like atoms -

(A) $r_n = n^2r_1$, $E_n = E_1/n^2$, $v_n = v_1/n$

(B) $r_n = r_1/n^2$, $E_n = n^2E_1$, $v_n = v_1/n$

(C) $r_n = r^2/n^2$, $E_n = E_1/n^2$, $v_n = v_1/n^2$

(D) $r_n = n^2r$, $E_n = n^2E_1$, $v_n = n^2v_1$.

Q.20 The angular velocity of an electron moving in the nth orbit of Bohr hydrogen atom is -

(A) directly proportional to n

(B) inversely proportional to n

(C) inversely proportional to n^2

(D) inversely proportional to n^3

Q.21 The ratio of frequency of revolution of electrons in first and second Bohr's orbit of He-atom is -

(A) 4 : 1 (B) 1 : 4

(C) 8 : 1 (D) 1 : 8

Q.22 The ratio of the energies of the hydrogen atom in its first to second excited state is -

(A) 1/4 (B) 4/9

(C) 9/4 (D) 4

Q.23 The angular momentum of electron in hydrogen atom is proportional to -

(A) $\sqrt{r}$ (B) 1/r (C) r^2 (D) $1/\sqrt{r}$

Q.24 Which of the following products in a hydrogen atom are independent of the principal quantum number n ? The symbols have their usual meanings ?

(A) vn (B) Er (C) En (D) vr

Q.25 The energy of an atom (or ion) in its ground state is – 54.4 eV. It may be -

(A) hydrogen (B) deuterium

(C) He^+ (D) Li^{++}

Q.26 The kinetic energy of an electron in second Bohr orbit of hydrogen atom will be -

(A) 13.6 eV (B) 6.8 eV
(C) 3.4 eV (D) 1.7 eV

Q.27 When a hydrogen atom is raised from the ground state to an excited state -

(A) the P.E. decreases and K.E. increases
(B) the P.E. increases and K.E. decreases
(C) both K.E. and P.E. increases
(D) both K.E. and P.E. decrease

Q.28 The first excitation potential of given atom is 10.2 volt. Then ionization potential must be -

(A) 20.4 volt (B) 13.6 volt
(C) 30.6 volt (D) 40.8 volt

Q.29 If E_n and J_n are the magnitude of total energy and angular momentum of electron in the nth Bohr orbit respectively, then -

(A) $E \propto J_n^2$ (B) $E_n \propto \frac{1}{J_n^2}$
(C) $E \propto J_n$ (D) $E_n \propto \frac{1}{J_n}$

Q.30 The angular momentum of an electron in a given orbit is J. Its kinetic energy will be -

(A) $\frac{1}{2}\frac{J^2}{mr^2}$ (B) $\frac{Jv}{r}$
(C) $\frac{J^2}{2m}$ (D) $\frac{J^2}{2\pi}$

Q.31 The minimum energy in electron volt required to skip a ten times ionised sodium atom (i.e. Z = 11) of its last electron is -

(A) 13.6 eV (B) $\frac{13.6}{11}$ eV
(C) 13.6 × 11 eV (D) $13.6 \times (11)^2$ eV

Q.32 Total energy of electron in the first orbit of hydrogen atom is equal to the -

(A) total energy of electron in 2nd orbit of He^+
(B) total energy of electron in 3rd orbit of He^+
(C) total energy of electron in 2nd orbit of Li^{++}
(D) total energy of electron in 4^{th} orbit to Li^{++}

Q.33 As per Bohr model, the minimum energy (in eV) required to remove an electron from the ground state of doubly ionized Li atom (Z = 3) -

(A) 1.51 (B) 13.6
(C) 40.8 (D) 122.4

Q.34 An electron jumps from the 4th orbit to the 2nd orbit of hydrogen atom. Given : the Rydberg's constant $R = 10^5\ cm^{-1}$. The frequency in Hz of the emitted radiation will be -

(A) $\frac{3}{16}\times10^5$ (B) $\frac{3}{6}\times10^{15}$
(C) $\frac{9}{16}\times10^{15}$ (D) $\frac{3}{4}\times10^{16}$

Q.35 A hydrogen atom in ground state absorbs 10.2 eV of energy. The orbital angular momentum of the electron is increased by -

(A) 1.05×10^{-34} J-s (B) 2.11×10^{-34} J-s
(C) 3.16×10^{-34} J-s (D) 4.22×10^{-34} J-s

Q.36 The binding energy of H-atom in its ground state is 13.6 eV. The energies required to remove an electron from the three lowest orbits of the H-atom are respectively(in eV) -

(A) 13.6 , 10.2 , 3.4 (B) 13.6 , 3.4 , 1.5
(C) 10.2, 1.9, 0.7 (D) 13.6, 6.8 , 1.5

Q.37 The energy of an electron in the first Bohr orbit for hydrogen is –13.6 eV. Which one (s) of the following is (are) possible excited state (s) for electrons in Bohr orbits of hydrogen –

(A) – 3.4 eV (B) – 6.8 eV
(C) – 1.7 eV (D) 13.6 eV

Q.38 The binding energy of the hydrogen atom in the first excited state is –

(A) 13.6 eV (B) 10.2 eV
(C) 3.40 eV (D) 1.51 eV

Q.39 How much energy is required to remove the electron from a He^+ ion in its ground state ?

(A) 1.5 eV (B) 13.6 eV
(C) 54.4 eV (D) 122.4 eV

Q.40 The potential energy (U) and the kinetic energy (K) of an electron in the ground state of hydrogen atom is -

(A) U = – 13.6 eV ; K = – 13.6 eV
(B) U = – 27.2 eV ; K = – 13.6 eV
(C) U = – 27.2 eV ; K = + 13.6 eV
(D) U = – 6.8 eV ; K = – 6.8 eV

Questions based on Spectral lines

Q.41 A spectral line is emitted when an electron -

(A) rotates in the circular orbit
(B) rotates in the elliptical orbit
(C) jumps from lower orbit to higher orbit
(D) jumps from higher orbit to lower orbit

Q.42 Which of the following is true ?

(A) Lyman series is a continuous spectrum
(B) Paschen series is a line spectrum in the infrared
(C) Balmer series is a line spectrum in the ultraviolet
(D) The spectral series formula can be derived from the Rutherford model of the hydrogen atom

Q.43 The minimum wavelength in Lyman series is -

(A) $\frac{1}{R}$ (B) R (C) $\frac{1}{R_C}$ (D) R_c

Q.44 Out of the following transitions, the frequency of emitted photon will be maximum for -

(A) n = 5 to n = 3 (B) n = 6 to n = 2
(C) n = 2 to n = 1 (D) n = 1 to n = 2

Q.45 If an electron jumps from third orbit to second orbit in hydrogen atom, then the wavelength of emitted photons, will be -

(A) $\frac{36}{5R}$ (B) $\frac{5R}{36}$
(C) $\frac{4R}{34}$ (D) $\frac{34}{4R}$

Q.46 The wavelength of first line of Balmer series is 6563 Å. The wavelength of first line of Lyman series will be -

(A) 1215.4 Å (B) 2500 Å
(C) 7500 Å (D) 600 Å

Q.47 The wavelength of radiation required to excite an electron from first to third Bohr orbit in a doubly ionised lithium atom will be -

(A) 113.74 m (B) 113.74 cm
(C) 113.74 Å (D) 113.74 mm

Q.48 Any series of atomic hydrogen yet to be discovered will probably be found in the following region of the spectrum -

(A) X-ray (B) Ultraviolet
(C) Visible (D) far infrared

Questions based on Reduced mass concept

Q.49 The electron and positron form a positronium atom (e^-, e^+ revolve round the centre of mass of the system). Then, the ground state energy of this system is -

(A) –13.6 eV (B) –27.2 eV
(C) –6.8 eV (D) zero

Q.50 The radius of first orbit of muon-proton system will be , if muon is 207 times heavier than electron -

(A) $\frac{0.529}{(186)^2}$ Å (B) $\frac{0.529}{(186)}$ Å
(C) 0.529 × 186 Å (D) 0.529 × $(186)^2$Å

Q.51 The energy in the ground states of muon-proton system will be -

(A) –13.6 × 207 MeV (B) –13.6 × 186 eV
(C) 13.6 × 186 MeV (D) 13.6 × 207 eV

Questions based on Recoiling of atom

Q.52 An electron jumps from n = 4 to n = 1 state in H-atom. The recoil momentum of H-atom (in eV/C) is -

(A) 12.75 (B) 6.75
(C) 14.45 (D) 0.85

Q.53 An excited hydrogen atom initially at rest in n = 3 state, emits a photon by making a transition to ground to state. Then the momentum of the hydrogen atom will be (in N.s) -

(A) 6.45×10^{-27} (B) 6.63×10^{-34}
(C) 2.15×10^{-27} (D) none of the above