CHAPTER 12

Atoms

12.2 Alpha-Particle Scattering and Rutherford's Nuclear Model of Atom

1. 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

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

(NEET-I 2016)

2. An alpha nucleus of energy $\frac{1}{2}mv^2$ bombards a heavy nuclear target of charge Ze. Then the distance of closest approach for the alpha nucleus will be proportional to

(a) $\frac{1}{Ze}$ (b) v^2 (c) $\frac{1}{m}$ (d) $\frac{1}{v^4}$ *(2010)*

3. 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

(a) directly proportional to z_1z_2
(b) inversely proportional to z_1
(c) directly proportional to mass M_1
(d) directly proportional to $M_1 \times M_2$ *(2009)*

4. An electron is moving round the nucleus of a hydrogen atom in a circular orbit of radius r. The Coulomb force $\vec{F}$ between the two is

(a) $K\frac{e^2}{r^2}\hat{r}$ (b) $-K\frac{e^2}{r^3}\hat{r}$

(c) $K\frac{e^2}{r^3}\vec{r}$ (d) $-K\frac{e^2}{r^3}\vec{r}$

$\left(\text{where } K = \frac{1}{4\pi\varepsilon_0}\right)$ *(2003)*

12.3 Atomic Spectra

5. The ratio of wavelengths of the last line of Balmer series and the last line of Lyman series is

(a) 1 (b) 4
(c) 0.5 (d) 2 *(NEET 2017)*

6. Given the value of Rydberg constant is $10^7\ m^{-1}$, the wave number of the last line of the Balmer series in hydrogen spectrum will be

(a) $0.25 \times 10^7\ m^{-1}$ (b) $2.5 \times 10^7\ m^{-1}$
(c) $0.025 \times 10^4\ m^{-1}$ (d) $0.5 \times 10^7\ m^{-1}$

(NEET-I 2016)

7. Ratio of longest wavelengths corresponding to Lyman and Balmer series in hydrogen spectrum is

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

(NEET 2013)

8. 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

(a) 3 (b) 4
(c) 1 (d) 2 *(2011)*

9. Which source is associated with a line emission spectrum?

(a) Electric fire (b) Neon street sign
(c) Red traffic light (d) Sun *(1993)*

12.4 Bohr Model of the Hydrogen Atom

10. For which one of the following, Bohr model is not valid?

(a) Hydrogen atom
(b) Singly ionised helium atom (He^+)
(c) Deuteron atom
(d) Singly ionised neon atom (Ne^+) *(NEET 2020)*

11. The total energy of an electron in an atom in an orbit is – 3.4 eV. Its kinetic and potential energies are, respectively

(a) 3.4 eV, 3.4 eV (b) – 3.4 eV, – 3.4 eV
(c) – 3.4 eV, – 6.8 eV (d) 3.4 eV, – 6.8 eV
(NEET 2019)

12. 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^-) [charge same as electron and mass 207 m_e], the first Bohr radius and ground state energy will be
(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 *(Odisha NEET 2019)*

13. The ratio of kinetic energy to the total energy of an electron in a Bohr orbit of the hydrogen atom, is
(a) 1 : 1 (b) 1 : –1
(c) 2 : –1 (d) 1 : –2 *(NEET 2018)*

14. Consider 3rd orbit of He^+ (Helium), using non-relativistic approach, the speed of electron in this orbit will be [given $K = 9 \times 10^9$ constant, $Z = 2$ and h (Planck's constant) = 6.6×10^{-34} J s]
(a) 0.73×10^6 m/s (b) 3.0×10^8 m/s
(c) 2.92×10^6 m/s (d) 1.46×10^6 m/s
(2015 Cancelled)

15. An electron in hydrogen atom makes a transition $n_1 \rightarrow n_2$ where n_1 and n_2 are principal quantum numbers of the two states. Assuming Bohr's model to be valid, the time period of the electron in the initial state is eight times that in the final state. The possible values of n_1 and n_2 are
(a) $n_1 = 6$ and $n_2 = 2$ (b) $n_1 = 8$ and $n_2 = 1$
(c) $n_1 = 8$ and $n_2 = 2$ (d) $n_1 = 4$ and $n_2 = 2$
(Karnataka NEET 2013)

16. Monochromatic radiation emitted when electron on hydrogen atom jumps from first excited 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
(a) 4×10^{15} Hz (b) 5×10^{15} Hz
(c) 1.6×10^{15} Hz (d) 2.5×10^{15} Hz *(2012)*

17. An electron in the hydrogen atom jumps from excited state n to the ground state. The wavelength so emitted illuminates a photosensitive material having work function 2.75 eV. If the stopping potential of the photoelectron is 10 V, then the value of n is
(a) 2 (b) 3
(c) 4 (d) 5 *(Mains 2011)*

18. Out of the following which one is not a possible energy for a photon to be emitted by hydrogen atom according to Bohr's atomic model?
(a) 0.65 eV (b) 1.9 eV
(c) 11.1 eV (d) 13.6 eV *(Mains 2011)*

19. 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
(a) –13.6 eV (b) –27.2 eV
(c) –54.4 eV (d) –6.8 eV *(2010)*

20. The electron in the hydrogen atom jumps from excited state (n = 3) to its ground state (n = 1) and the photons thus emitted irradiate a photosensitive material. If the work function of the material is 5.1 eV, the stopping potential is estimated to be (the energy of the electron in n^{th} state $E_n = \frac{-13.6}{n^2}$ eV)
(a) 5.1 V (b) 12.1 V
(c) 17.2 V (d) 7 V *(Mains 2010)*

21. The ground state energy of hydrogen atom is –13.6 eV. When its electron is in the first excited state, its excitation energy is
(a) 10.2 eV (b) 0
(c) 3.4 eV (d) 6.8 eV *(2008)*

22. 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
(a) 6.8 eV (b) 13.6 eV
(c) 1.7 eV (d) 3.4 eV *(2007)*

23. The total energy of an electron in the first excited state of hydrogen atom is about –3.4 eV. Its kinetic energy in this state is
(a) 3.4 eV (b) 6.8 eV
(c) –3.4 eV (d) –6.8 eV *(2005)*

24. The Bohr model of atoms
(a) Assumes that the angular momentum of electrons is quantized.
(b) Uses Einstein's photoelectric equation.
(c) Predicts continuous emission spectra for atoms.
(d) Predicts the same emission spectra for all types of atoms. *(2004)*

25. In which of the following systems will the radius of the first orbit (n = 1) be minimum?
(a) doubly ionized lithium
(b) singly ionized helium
(c) deuterium atom (d) hydrogen atom *(2003)*

26. The energy of hydrogen atom in n^{th} orbit is E_n then the energy in n^{th} orbit of singly ionised helium atom will be
(a) $4E_n$ (b) $E_n/4$
(c) $2E_n$ (d) $E_n/2$ *(2001)*

27. The life span of atomic hydrogen is
(a) fraction of one second
(b) one year
(c) one hour (d) one day *(2000)*

28. In the Bohr 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 and ε_0 is the vacuum permittivity, the speed of the electron is

(a) $\frac{e}{\sqrt{4\pi\varepsilon_0 a_0 m}}$ (b) $\frac{e}{\sqrt{\varepsilon_0 a_0 m}}$

(c) 0 (d) $\frac{\sqrt{4\pi\varepsilon_0 a_0 m}}{e}$ *(1998)*

29. The energy of the ground electronic state of hydrogen atom is –13.6 eV. The energy of the first excited state will be

(a) –27.2 eV (b) –52.4 eV
(c) –3.4 eV (d) –6.8 eV *(1997)*

30. When hydrogen atom is in its first excited level, its radius is .... of the Bohr radius.

(a) twice (b) 4 times
(c) same (d) half *(1997)*

31. According to Bohr's principle, the relation between principal quantum number (n) and radius of orbit (r) is

(a) $r \propto \frac{1}{n}$ (b) $r \propto \frac{1}{n^2}$
(c) $r \propto n$ (d) $r \propto n^2$ *(1996)*

32. When a hydrogen atom is raised from the ground state to an excited state,

(a) both K.E. and P.E. increase
(b) both K.E. and P.E. decrease
(c) the P.E. decreases and K.E. increases
(d) the P.E. increases and K.E. decreases. *(1995)*

33. In terms of Bohr radius a_0, the radius of the second Bohr orbit of a hydrogen atom is given by

(a) $4a_0$ (b) $8a_0$
(c) $\sqrt{2}a_0$ (d) $2a_0$ *(1992)*

34. The ionization energy of hydrogen atom is 13.6 eV. Following Bohr's theory, the energy corresponding to a transition between 3rd and 4th orbit is

(a) 3.40 eV (b) 1.51 eV
(c) 0.85 eV (d) 0.66 eV *(1992)*

35. The ground state energy of H-atom is –13.6 eV. The energy needed to ionize H-atom from its second excited state

(a) 1.51 eV (b) 3.4 eV
(c) 13.6 eV (d) none of these *(1991)*

36. To explain his theory, Bohr used

(a) conservation of linear momentum
(b) quantisation of angular momentum
(c) conservation of quantum frequency
(d) none of these *(1989)*

37. The ionisation energy of hydrogen atom is 13.6 eV, the ionisation energy of a singly ionised helium atom would be

(a) 13.6 eV (b) 27.2 eV
(c) 6.8 eV (d) 54.4 eV *(1988)*

12.5 The Line Spectra of the Hydrogen Atom

38. 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

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

(NEET-II 2016)

39. Hydrogen atom in ground state is excited by a monochromatic radiation of λ = 975 Å. Number of spectral lines in the resulting spectrum emitted will be

(a) 3 (b) 2
(c) 6 (d) 10 *(2014)*

40. 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

(a) $\frac{7}{5}$ (b) $\frac{27}{20}$ (c) $\frac{27}{5}$ (d) $\frac{20}{7}$ *(2012)*

41. An electron of a stationary hydrogen atom passes from the fifth energy level to the ground level. The velocity that the atom acquired as a result of photon emission will be

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

(2012)

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

42. The transition from the state n = 3 to n = 1 in a hydrogen like atom results in ultraviolet radiation. Infrared radiation will be obtained in the transition from

(a) $2 \rightarrow 1$ (b) $3 \rightarrow 2$
(c) $4 \rightarrow 2$ (d) $4 \rightarrow 3$ *(Mains 2012)*

43. The ionization 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

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

(2009)

44. Ionization 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
(a) one (b) two
(c) three (d) four. *(2006)*

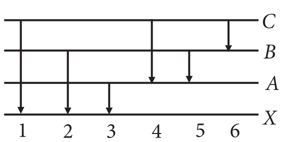
45. Energy levels A, B and C of a certain atom corresponding to increasing values of energy *i.e.*, $E_A < E_B < E_C$. If λ_1, λ_2 and λ_3 are wavelengths of radiations corresponding to transitions C to B, B to A and C to A respectively, which of the following relations is correct?
(a) $\lambda_3 = \lambda_1 + \lambda_2$ (b) $\lambda_3 = \dfrac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$
(c) $\lambda_1 + \lambda_2 + \lambda_3 = 0$ (d) $\lambda_3^2 = \lambda_1^2 + \lambda_2^2$
(2005, 1990)

46. Maximum frequency of emission is obtained for the transition
(a) $n = 2$ to $n = 1$ (b) $n = 6$ to $n = 2$
(c) $n = 1$ to $n = 2$ (d) $n = 2$ to $n = 6$ *(2000)*

47. When an electron does transition from $n = 4$ to $n = 2$, then emitted line spectrum will be
(a) first line of Lyman series
(b) second line of Balmer series
(c) first line of Paschen series
(d) second line of Paschen series. *(2000)*

48. An electron makes a transition from orbit $n = 4$ to the orbit $n = 2$ of a hydrogen atom. What is the wavelength of the emitted radiations? (R = Rydberg's constant)
(a) $\dfrac{16}{4R}$ (b) $\dfrac{16}{5R}$ (c) $\dfrac{16}{2R}$ (d) $\dfrac{16}{3R}$ *(1995)*

49. The figure indicates the energy level diagram of an atom and the origin of six spectral lines in emission (*e.g.*, line no. 5 arises from the transition from level B to A).



Which of the following spectral lines will occur in the absorption spectrum?
(a) 4, 5, 6 (b) 1, 2, 3, 4, 5, 6
(c) 1, 2, 3 (d) 1, 4, 6 *(1995)*

50. Hydrogen atoms are excited from ground state of the principle quantum number 4. Then the number of spectral lines observed will be
(a) 3 (b) 6
(c) 5 (d) 2 *(1993)*

12.6 de Broglie's Explanation of Bohr's Second Postulate of Quantisation

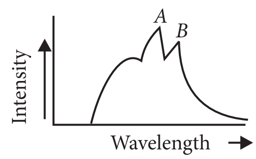
51. Consider an electron in the n^{th} orbit of a hydrogen atom in the Bohr model. The circumference of the orbit can be expressed in terms of de Broglie wavelength λ of that electron as
(a) $(0.529)n\lambda$ (b) $\sqrt{n}\lambda$
(c) $(13.6)\lambda$ (d) $n\lambda$ *(1990)*

12.A X-Rays

52. The interplanar distance in a crystal is 2.8×10^{-8} m. The value of maximum wavelength which can be diffracted
(a) 2.8×10^{-8} m (b) 5.6×10^{-8} m
(c) 1.4×10^{-8} m (d) 7.6×10^{-8} m *(2001)*

53. The minimum wavelength of the X-rays produced by electrons accelerated through a potential difference of V volts is directly proportional to
(a) $\dfrac{1}{\sqrt{V}}$ (b) $\dfrac{1}{V}$ (c) $\sqrt{V}$ (d) V^2
(1996)

54. The figure represents the observed intensity of X-rays emitted by an X-ray tube,1 as a function of wavelength. The sharp peaks A and B denote



(a) white radiations (b) characteristic radiations
(c) band spectrum (d) continuous spectrum
(1995)

ANSWER KEY

1. (c)	**2.** (c)	**3.** (a)	**4.** (d)	**5.** (b)	**6.** (a)	**7.** (c)	**8.** (d)	**9.** (b)	**10.** (d)
11. (d)	**12.** (c)	**13.** (b)	**14.** (d)	**15.** (d)	**16.** (c)	**17.** (c)	**18.** (c)	**19.** (a)	**20.** (d)
21. (a)	**22.** (d)	**23.** (a)	**24.** (a)	**25.** (a)	**26.** (a)	**27.** (a)	**28.** (a)	**29.** (c)	**30.** (b)
31. (d)	**32.** (d)	**33.** (a)	**34.** (d)	**35.** (a)	**36.** (b)	**37.** (d)	**38.** (c)	**39.** (c)	**40.** (d)
41. (a)	**42.** (d)	**43.** (c)	**44.** (c)	**45.** (b)	**46.** (a)	**47.** (b)	**48.** (d)	**49.** (c)	**50.** (b)
51. (d)	**52.** (b)	**53.** (b)	**54.** (b)						

Hints & Explanations

1. **(c) :** Distance of closest approach when an α-particle of mass m moving with velocity v is bombarded on a heavy nucleus of charge Ze, is given by

$$r_0 = \frac{Ze^2}{2\pi\varepsilon_0 mv^2} \quad \therefore\ r_0 \propto \frac{1}{m}$$

2. **(c)**

3. **(a) :** Energy of the projectile is the potential energy at closest approach, $\frac{1}{4\pi\varepsilon_0}\frac{z_1 z_2}{r}$

Therefore energy $\propto z_1 z_2$

4. **(d) :** The charge on hydrogen nucleus

$q_1 = +e$

charge on electron, $q_2 = -e$

Coulomb force, $F = K\frac{q_1 q_2}{r^2} = K\frac{(+e)(-e)}{r^2}$

$$\vec{F} = -\frac{Ke^2}{r^3}\vec{r} = -\frac{Ke^2}{r^2}\hat{r}$$

5. **(b) :** The wavelength of last line of Balmer series

$$\frac{1}{\lambda_B} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{R}{4}$$

The wavelength of last line of Lyman series

$$\frac{1}{\lambda_L} = R\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = R$$

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

6. **(a) :** Here, $R = 10^7\ \text{m}^{-1}$

The wave number of the last line of the Balmer series in hydrogen spectrum is given by

$$\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = \frac{R}{4} = \frac{10^7}{4} = 0.25\times10^7\ \text{m}^{-1}$$

7. **(c) :** The wavelength of different spectral lines of Lyman series is given by

$$\frac{1}{\lambda_L} = R\left[\frac{1}{1^2} - \frac{1}{n^2}\right] \text{ where } n = 2, 3, 4, ...$$

where subscript L refers to Lyman.

For longest wavelength, $n = 2$

$$\therefore\ \frac{1}{\lambda_{L_{\text{longest}}}} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3}{4}R \quad ...(i)$$

The wavelength of different spectral series of Balmer series is given by

$$\frac{1}{\lambda_B} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right] \text{ where } n = 3, 4, 5, ...$$

where subscript B refers to Balmer.

For longest wavelength, $n = 3$

$$\therefore\ \frac{1}{\lambda_{B_{\text{longest}}}} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = R\left[\frac{1}{4} - \frac{1}{9}\right] = \frac{5R}{36} \quad ...(ii)$$

Divide (ii) by (i), we get

$$\frac{\lambda_{L_{\text{longest}}}}{\lambda_{B_{\text{longest}}}} = \frac{5R}{36}\times\frac{4}{3R} = \frac{5}{27}$$

8. **(d) :** The wavelength of the first line of lyman series for hydrogen atom is

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

The wavelength of the second line of Balmer series for hydrogen like ion is

$$\frac{1}{\lambda'} = Z^2 R\left[\frac{1}{2^2} - \frac{1}{4^2}\right]$$

According to question $\lambda = \lambda'$

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

or $\frac{3}{4} = \frac{3Z^2}{16}$ or $Z^2 = 4$ or $Z = 2$

9. **(b) :** Neon street sign is a source of line emission spectrum.

10. **(d) :** Bohr's atomic model is valid for single electron species only. A singly ionised neon contains more than one electron. Hence option (d) is correct.

11. **(d) :** Total energy of electron in n^{th} orbit, $E_n = \frac{-13.6Z^2}{n^2}\,\text{eV}$

Kinetic energy of electron in n^{th} orbit, $\text{K.E.} = \frac{13.6Z^2}{n^2}\,\text{eV}$

Potential energy of electron in n^{th} orbit, $\text{P.E.} = \frac{-27.2Z^2}{n^2}\,\text{eV}$

Thus, total energy of electron, $E_n = -\text{K.E.} = \frac{\text{P.E.}}{2}$

$\therefore$ K.E. = 3.4 eV [Given $E_n = -3.4$ eV]

P.E. = 2 × –3.4 = – 6.8 eV

12. **(c) :** Given, radius of first Bohr orbit for electron in a hydrogen atom, $r = 0.51$ Å

and its ground state energy, $E_n = -13.6$ eV

Charge of muon = charge of electron

Mass of muon = 207 × (mass of electron)

Therefore, when electron is replaced by muon then, first

Bohr radius, $r_1' = \frac{0.51\ \text{Å}}{207} = 2.56\times10^{-13}$ m

and ground state energy, $E_1' = -13.6 \times 207$
$= -2815.2$ eV $= -2.815$ keV

13. (b) : In a Bohr orbit of the hydrogen atom,
Kinetic energy = – (Total energy)
So, Kinetic energy : Total energy = 1 : –1

14. (d) : Energy of electron in He^+ 3rd orbit

$$E_3 = -13.6 \times \frac{Z^2}{n^2}\text{ eV} = -13.6 \times \frac{4}{9}\text{ eV}$$

$$= -13.6 \times \frac{4}{9} \times 1.6 \times 10^{-19}\text{ J} \simeq -9.7 \times 10^{-19}\text{ J}$$

As per Bohr's model,
Kinetic energy of electron in the 3rd orbit $= -E_3$

$$\therefore \; 9.7 \times 10^{-19} = \frac{1}{2} m_e v^2$$

$$v = \sqrt{\frac{2 \times 9.7 \times 10^{-19}}{9.1 \times 10^{-31}}} = 1.46 \times 10^6\text{ m s}^{-1}$$

15. (d)

16. (c) : For hydrogen atom, $E_n = -\frac{13.6}{n^2}$ eV
For ground state, $n = 1$

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

For first excited state, $n = 2$

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

The energy of the emitted photon when an electron jumps from first excited state to ground state is
$h\upsilon = E_2 - E_1 = -3.4$ eV $-$ (-13.6 eV) $= 10.2$ eV
Maximum kinetic energy,
$K_{max} = eV_s = e \times 3.57$ V $= 3.57$ eV
According to Einstein's photoelectric equation
$K_{max} = h\upsilon - \phi_0$
where ϕ_0 is the work function and $h\upsilon$ is the incident energy
$\phi_0 = h\upsilon - K_{max} = 10.2$ eV $- 3.57$ eV $= 6.63$ eV

$$\text{Threshold frequency, } \upsilon_0 = \frac{\phi_0}{h} = \frac{6.63 \times 1.6 \times 10^{-19}\text{ J}}{6.63 \times 10^{-34}\text{ J s}}$$

$$= 1.6 \times 10^{15}\text{ Hz}$$

17. (c) : Here, Stopping potential, $V_0 = 10$ V
Work function, $W = 2.75$ eV
According to Einstein's photoelectric equation

$$eV_0 = h\upsilon - W \quad \text{or} \quad h\upsilon = eV_0 + W$$

$$= 10\text{ eV} + 2.75\text{ eV} = 12.75\text{ eV} \quad \text{...(i)}$$

When an electron in the hydrogen atom makes a transition from excited state n to the gound state ($n = 1$), then the frequency (υ) of the emitted photon is given by

$$h\upsilon = E_n - E_1 \Rightarrow h\upsilon = -\frac{13.6}{n^2} - \left(-\frac{13.6}{1^2}\right)$$

$$\left[\because \text{ For hydrogen atom, } E_n = -\frac{13.6}{n^2}\text{ eV}\right]$$

According to given problem

$$-\frac{13.6}{n^2} + 13.6 = 12.75 \quad \text{(Using(i))}$$

$$\frac{13.6}{n^2} = 0.85 \Rightarrow n^2 = \frac{13.6}{0.85} = 16$$

or $n = 4$

18. (c) : The energy of n^{th} orbit of hydrogen atom is given as

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

$$\therefore \; E_1 = -13.6\text{ eV}; \; E_2 = -\frac{13.6}{2^2} = -3.4\text{ eV}$$

$$E_3 = -\frac{13.6}{3^2} = -1.5\text{ eV}; E_4 = -\frac{13.6}{4^2} = -0.85\text{ eV}$$

$\therefore$ $E_3 - E_2 = -1.5 - (-3.4) = 1.9$ eV
$E_4 - E_3 = -0.85 - (-1.5) = 0.65$ eV

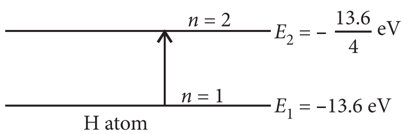
19. (a)

20. (d) : Energy released when electron in the atom jumps from excited state ($n = 3$) to ground state ($n = 1$) is
$E = h\upsilon = E_3 - E_1$

$$= \frac{-13.6}{3^2} - \left(\frac{-13.6}{1^2}\right) = \frac{-13.6}{9} + 13.6 = 12.1\text{ eV}$$

Therefore, stopping potential
$eV_0 = h\upsilon - \phi_0 = 12.1 - 5.1 = 7$ eV
$V_0 = 7$ V [$\because$ work function $\phi_0 = 5.1$]

21. (a) :



1st excitation energy $E_{n2} - E_{n1} = (-3.4 + 13.6)$
$= 10.2$ eV

22. (d) : Energy of n^{th} orbit of hydrogen atom is given by $E_n = \frac{-13.6}{n^2}$ eV
For ground state, $n = 1$

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

For first excited state, $n = 2$

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

Kinetic energy of an electron in the first excited state is
$K = -E_2 = 3.4$ eV.

23. (a) : $\text{K.E.} = \left|\frac{1}{2}\text{P.E.}\right|$

$\therefore$ Total energy

$$= \left|\frac{1}{2}\text{P.E.}\right| - \text{P.E.} = \frac{-\text{P.E.}}{2} = -3.4 \text{ eV}.$$

$\therefore$ K.E. = + 3.4 eV

24. (a)

25. (a) : Radius of first orbit, $r \propto \frac{1}{Z}$,

for doubly ionized lithium Z (= 3) will be maximum, hence for doubly ionized lithium, r will be minimum.

26. (a) : $E \propto \frac{Z^2}{n^2}$

27. (a)

28. (a) : Centripetal force = force of attraction of nucleus on electron

$$\frac{mv^2}{a_0} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{a_0^2} \Rightarrow v = \frac{e}{\sqrt{4\pi\varepsilon_0 a_0 m}}$$

29. (c) : Energy of the ground electronic state of hydrogen atom $E = -13.6$ eV.

We know that energy of the first excited state for second orbit (where $n = 2$)

$$E_n = -\frac{13.6}{(n)^2} = -\frac{13.6}{(2)^2} = -3.4 \text{ eV}$$

30. (b) : When a hydrogen atom is in its excited level, then $n = 2$.

Therefore radius of hydrogen atom in its first excited level $(r) = n^2 r_0 = (2)^2 r_0 = 4r_0$.

31. (d) : According to Bohr's principle, radius of orbit

$$(r) = 4\pi\,\varepsilon_0 \times \frac{n^2h^2}{4\pi^2me^2};\ r \propto n^2$$

where n = principal quantum number.

32. (d)

33. (a) : As $r \propto n^2$, therefore, radius of 2nd Bohr's orbit = $4a_0$

34. (d) : $E = E_4 - E_3$

$$= -\frac{13.6}{4^2} - \left(-\frac{13.6}{3^2}\right) = -0.85 + 1.51 = 0.66 \text{ eV}$$

35. (a) : Second excited state corresponds to $n = 3$

Energy needed to ionize,

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

36. (b) : Bohr used quantisation of angular momentum.

For stationary orbits, Angular momentum $mvr = \frac{nh}{2\pi}$

where n = 1, 2, 3,...etc.

37. (d) : $E \propto Z^2$ and Z for singly ionised helium is 2 (*i.e.*, 2 protons in the nucleus)

$\therefore$ $(E)_{\text{He}} = 4 \times 13.6 = 54.4$ eV

38. (c) : When electron jumps from higher orbit to lower orbit then, wavelength of emitted photon is given by,

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

so, $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = \frac{5R}{36}$ and $\frac{1}{\lambda'} = R\left(\frac{1}{3^2} - \frac{1}{4^2}\right) = \frac{7R}{144}$

$$\therefore\ \lambda' = \frac{144}{7} \times \frac{5\lambda}{36} = \frac{20\lambda}{7}$$

39. (c) : Energy of the photon, $E = \frac{hc}{\lambda}$

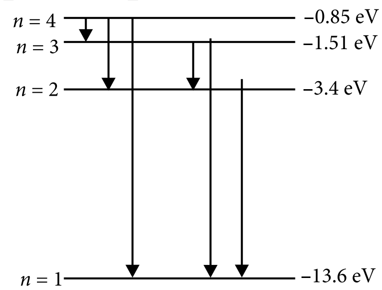
$$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{975 \times 10^{-10}} \text{ J}$$

$$= \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{975 \times 10^{-10} \times 1.6 \times 10^{-19}} \text{ eV} = 12.75 \text{ eV}$$

After absorbing a photon of energy 12.75 eV, the electron will reach to third excited state of energy −0.85 eV, since energy difference corresponding to n = 1 and n = 4 is 12.75 eV.

$\therefore$ Number of spectral lines emitted

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



40. (d)

41. (a) : According to Rydberg formula

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

Here, $n_f = 1$, $n_i = 5$

$$\therefore\ \frac{1}{\lambda} = R\left[\frac{1}{1^2} - \frac{1}{5^2}\right] = R\left[\frac{1}{1} - \frac{1}{25}\right] = \frac{24}{25}R$$

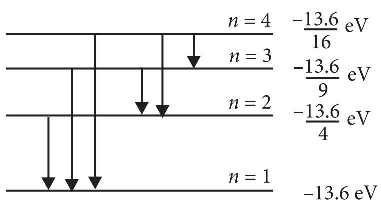
According to conservation of linear momentum, we get

Momentum of photon = Momentum of atom

$$\frac{h}{\lambda} = mv \text{ or } v = \frac{h}{m\lambda} = \frac{h}{m}\left(\frac{24R}{25}\right) = \frac{24hR}{25m}$$

42. (d)

43. (c) :



The maximum wavelength emitted here corresponds to the transition $n = 4 \rightarrow n = 3$ (Paschen series 1st line)

44. (c) : Ionisation potential of hydrogen atom is 13.6 eV. Energy required for exciting the hydrogen atom in the ground state to orbit n is given by

$$E = E_n - E_1$$

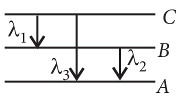
i.e., $12.1 = -\dfrac{13.6}{n^2} - \left(\dfrac{-13.6}{1^2}\right) = -\dfrac{13.6}{n^2} + 13.6$

or, $-1.5 = \dfrac{-13.6}{n^2}$ or, $n^2 = \dfrac{13.6}{1.5} = 9$ or, $n = 3$

Number of spectral lines emitted

$$= \frac{n(n-1)}{2} = \frac{3\times 2}{2} = 3.$$

45. (b) :



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

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

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

46. (a) : $\upsilon \propto \left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$

47. (b) : Jump to second orbit leads to Balmer series. The jump from 4th orbit shall give rise to second line of Balmer series.

48. (d) : Transition of hydrogen atom from orbit $n_1 = 4$ to $n_2 = 2$.

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

$$= R\left[\frac{1}{4} - \frac{1}{16}\right] = R\left[\frac{4-1}{16}\right] = \frac{3R}{16} \quad \Rightarrow \quad \lambda = 16/3R$$

49. (c) : Absorption spectrum involves only excitation of ground level to higher level. Therefore spectral lines 1, 2, 3 will occur in the absorption spectrum.

50. (b)

51. (d) : The circumference of an orbit in an atom in terms of wavelength of wave associated with electron is given by the relation,

Circumference = $n\lambda$, where n = 1, 2, 3, ...

52. (b) : $2d\sin\phi = n\lambda$; $(\sin\phi)_{max} = 1$

i.e., $\lambda_{max} = 2d$

$\Rightarrow \lambda_{max} = 2 \times 2.8 \times 10^{-8} = 5.6 \times 10^{-8}$ m.

53. (b) : $\dfrac{hc}{\lambda} = eV$ or $\lambda = \dfrac{hc}{eV} \propto \dfrac{1}{V}$

54. (b)

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