CHAPTER : 12

ATOMS

STUDY NOTES

- Every element is made up of atoms. Each atom is made of electrons, protons and neutrons.
- The number of proton in an atom is denoted by Z which is also called as atomic number, number of electron is same as number of protons; the number of neutrons are denoted by N and the mass number of atom is denoted by A.

  $N = A - Z$
- Various models were given to describe the atomic structure:
  - ❖ Thomson's Model (also known as plum pudding model)
  - ❖ Rutherford's Model
  - ❖ Bohr's Atomic Model
- **Thomson's Model of Atom:**
- According to Thomson's Atomic Model, an atom is a sphere having a uniform positive charge in which electrons are embedded.
  - ❖ Total positive charge is equal to the total negative charge hence, atom is electrically neutral as a whole.
  - ❖ As the whole solid sphere is uniformly positively charged, the positive charge cannot come out and only the negatively charged electrons which are small, can be emitted.
- **Rutherford's α-particle scattering experiment:**
- Rutherford performed experiments on the scattering of α-particles by extremely thin gold foil and made the following observations:
  - (i) Most of the α-particles pass through the foil.
  - (ii) Some of them are deflected through small angles.
  - (iii) A few α-particles are deflected through the angle more than 90°.
  - (iv) A few α-particles returned back i.e. deflected by 180°.
  - (v) The minimum distance from the nucleus up to which α-particle approach, is called distance of closest approach a_0 and $a_0 = \frac{1}{4\pi\epsilon_0}\frac{Ze^2}{K.E}$; K.E. → Kinetic energy of α-particle.
  - (vi) Number of scattered particle (N) $\propto \frac{1}{\sin^4(\theta/2)}$

    θ → scattering angle
  - (vii) **Impact parameter (b):** The perpendicular distance of the velocity vector ($\vec{v}$) of the α-particle from the centre of the nucleus when it is far away from the nucleus is known as the impact parameter

    $$b = \frac{Ze^2\cot(\theta/2)}{4\pi\varepsilon_0\left(\frac{1}{2}mv^2\right)} \quad \Rightarrow b \propto \cot(\theta/2)$$
- **Rutherford's Atomic Model:**
  - ❖ Nucleus is positively charged, constitutes 10^{-5} times the size of atom.
  - ❖ Size of the nucleus is 10^{-15} m.
  - ❖ Electrons revolve around the nucleus in a circular orbit

❖ He could not explain the stability of the atom.
❖ He could not explain the radiation produced due to the accelarated motion of the electron.

- **Bohr's Atomic Model:**

He gave some postulates describing the motion of electron in an atom, as follows:

(i) The electrons revolve around the nucleus in circular orbits. Electrostatic force of attraction between the electron and nucleus is balanced by centripetal force.

(ii) The radius of the orbit of an electron can only take certain fixed values such that the angular momentum of the electron in these orbits is an integral multiple of $h/2\pi$, h being the Planck's constant.

(iii) These orbits are called stable orbits and electrons in these orbits do not emit radiation.

(iv) An electron can make a transition from one of its orbits to another orbit having lower energy. In doing so, it emits a photon of energy equal to the difference in its energies in the two orbits.

❖ Radius of n^{th} orbit

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

❖ Velocity in n^{th} orbit

$$v_n = \frac{Ze^2}{2\varepsilon_0 nh} \quad \text{or} \quad v_n = \left(\frac{c}{137}\right)\frac{Z}{n}; \text{ Here } c = 3 \times 10^8 \text{m/s}$$

❖ For H-atom, Z = 1

$$\Rightarrow r_n = a_0 n^2$$

$$\text{Here } a_0 = \frac{h^2 \varepsilon_0}{\pi m_e e^2} = 0.53 \text{ Å}$$

$$\Rightarrow r_n \propto \frac{n^2}{Z}$$

$$\Rightarrow E_n = \frac{-m_e Z^2 e^4}{8\varepsilon_0 h^2 n^2}$$

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

- **Excitation Energy:**
  ❖ Energy required to take an electron from ground state to excited state.

- **Ionization Energy of an atom:**

It is the minimum amount of energy required to be given to an electron in the ground state of that atom to set the electron free.

- **Rydberg Formula:**

$$\frac{1}{\lambda} = R_H Z^2 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \quad \text{were } (n_2 > n_1)$$

λ is the wavelength of radiation emitted when electron makes a transition from n_2 to n_1.

- $R_H = \frac{m_e e^4}{8c\varepsilon_0^2 h^3} = 1.097 \times 10^7 \text{ m}^{-1}$

called as Rydberg constant.

- The transition of electrons from higher energy states or orbits to lower energy orbits results in various spectral series. For Hydrogen atom there are five such spectral series, these are:

❖ Lyman Series ❖ Balmer Series ❖ Paschen Series
❖ Brackett Series ❖ Pfund Series

Name of the Series	n_2	n_1	Region of EM Spectrum
1. Lymen Series	2, 3, 4, ...∞	1	Ultraviolet region
2. Balmer Series	3, 4, 5, ... ∞	2	Visible region
3. Paschen Series	4, 5, 6, ... ∞	3	Infrared region
4. Brackett Series	5, 6, 7, ...∞	4	Infrared region
5. Pfund Series	6, 7, 8, ...∞	5	Infrared region

- Wavelength (λ) = $\frac{n_1^2\, n_2^2}{(n_2^2 - n_1^2)R} = \frac{n_1^2}{\left(1 - \frac{n_1^2}{n_2^2}\right)R}$
- Maximum wavelength:

  $n_1 = n$ and $n_2 = n + 1$

  $\lambda_{max} = \frac{n^2 (n+1)^2}{(2n + 1)R}$

❖ Minimum wavelength:

$n_1 = \infty$ and $n_1 = n$

$\lambda_{min} = \frac{n^2}{R}$

- **Drawbacks of Bohr's Atomic Model:**

  (i) It is valid only for one electron atoms, e.g., H, He^+, Li^{2+}.

  (ii) Orbits were taken as circular orbit but according to Sommerfield these are elliptical.

  (iii) Intensity of spectral lines could not be explained.

  (iv) Nucleus was taken as stationary but it also rotates on its own axis.

  (v) It could not explained the fine structure of spectral line.

  (vi) This could not explain Zeeman effect (splitting of spectral lines in magnetic field) and Stark effect (splitting up in electric field).

QUESTION BANK

MULTIPLE CHOICE QUESTIONS

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

   (a) v^2 (b) 1/m (c) $1/v^2$ (d) 1/Ze

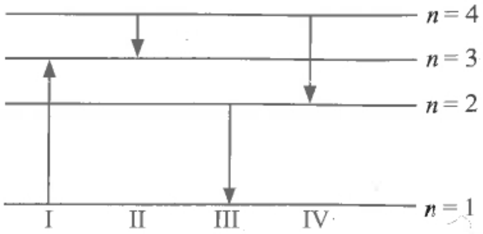
2. A diatomic molecule is made of two masses m_1 and m_2 which are separated by a distance r. If we calculate its rotational energy by applying Bohr's rule of angular momentum quantization, its energy will be (n is an integer) given by

   (a) $\frac{(m_1+m_2)^2 n^2h^2}{2m_1^2m_2^2r^2}$ (b) $\frac{n^2h^2}{(2m_1+m_2)r^2}$ (c) $\frac{2n^2h^2}{(m_1+m_2)r^2}$ (d) $\frac{(m_1+m_2)n^2h^2}{8\pi^2m_1m_2r^2}$

3. If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{++} is:

   (a) 30.6 eV (b) 13.6 eV (c) 3.4 eV (d) 6.8 eV

4. The diagram shows the energy levels for an transition from electron in a certain atom. Which transition shown represents the emission of a photon with the most energy?



(a) III (b) IV (c) I (d) II

5. If one were to apply Bohr model to a particle of hydrogen mass 'm' and charge 'q' moving in plane under the influence of a magnetic field 'B', the energy of the charged particle in the nth level will be

(a) $n\left(\frac{hqB}{4\pi m}\right)$ (b) $n\left(\frac{hqB}{\pi m}\right)$ (c) $n\left(\frac{hqB}{2\pi m}\right)$ (d) $n\left(\frac{hqB}{8\pi m}\right)$

6. As an electron makes a transition from an excited state to the ground state of a hydrogen-like atom/ion
   (a) its kinetic energy increases but potential energy and total energy decrease
   (b) kinetic energy, potential energy and total energy decrease
   (c) kinetic energy decreases, potential increases but total energy remains same
   (d) kinetic energy and total energy decrease potential energy increases

7. In a hydrogen-like atom, an electron makes transition from an energy level with quantum number n to another with quantum number (n-1). If n>>1, the frequency of radiation emitted is proportional to

(a) $\frac{1}{n}$ (b) $\frac{1}{n^2}$ (c) $\frac{1}{n^{3/2}}$ (d) $\frac{1}{n^3}$

8. Which of the following atoms has the lowest ionisation potential?

(a) ${}^{14}_{7}N$ (b) ${}^{133}_{55}Cs$ (c) ${}^{40}_{18}Ar$ (d) ${}^{16}_{H}O$

9. The wavelengths involved in the spectrum of deuterium (${}_1H^2$) are slightly different from that of hydrogen spectrum, because
   (a) sizes of the two nuclei are different
   (b) masses of the two nuclei are different
   (c) attraction between the electron and the nucleus is different in the two cases.
   (d) nuclear forces are different in the two cases.

10. Energy required for the electron excitation in Li^{++} from the first to the third Bohr orbit is

(a) 12.1 eV (b) 36.3 eV (c) 108.8 eV (d) 122.4 eV

11. An elementary particle of mass m and charge +e is projected with velocity v at a much more massive particle of charge Ze, where Z > 0. What is the closed possible approach of the incident particle?

(a) $Ze^2/2\pi\varepsilon_0 mv^2$ (b) $Ze^2/4\pi\varepsilon_0 r_n$ (c) $Ze^2/8\pi\varepsilon_0 r_n$ (d) $-Ze^2/8\pi\varepsilon_0 e_n$

12. If an α-particle collides head on with a nucleus,what is impact parameter?

(a) zero (b) infinite (c) 10^{-10}m (d) 10^{10} m

13. An electron in a hydrogen atom after absorbing an energy photon jumps from energy state n_1 to n_2. Then it returns to ground state after emitting six different wavelengths in the emission spectrum. The y of emitted photons is either equal to or less than the absorbed photons. Then n_1 and n_2 are:

(a) $n_2 = 4, n_1 = 3$ (b) $n_2 = 5, n_1 = 3$ (c) $n_2 = 4, n_1 = 2$ (d) $n_2 = 4, n_1 = 1$

14. A gas of monoatomic hydrogen is bombarded with a stream of electrons that have been accelerated from rest through a potential difference of 12.75 V. In the emission spectrum one cannot observe any line of

(a) Lyman series (b) Balmer series (c) Paschen series (d) Pfund series

15. As per Bohr's model of hydrogen atom, the atomic radius of the first electron orbit is 0.53 angstrom. What will be the radius (in angstrom) of 2^{nd} excited state of doubly ionized Lithium atoms?

(a) 4.77 (b) 1.59 (c) 3.18 (d) 2.65

16. Energy of characteristic X-ray is a consequence of

(a) energy of projectile electron
(b) thermal energy of target
(c) transition in target atoms
(d) none of these

17. In X-ray experiment K_α ,K_β denote

(a) characteristic lines
(b) continuous wavelength
(c) α, β-emissions respectively
(d) none of these

18. Wavelength of K_α line of X-ray spectra varies with atomic number as

(a) $\lambda \propto Z$ (b) $\lambda \propto \sqrt{Z}$ (c) $\lambda \propto \frac{1}{Z^2}$ (d) $\lambda \propto \frac{1}{\sqrt{Z}}$

19. How much energy is needed to excite an electron in H-atom from ground state to first excited state?

(a) –13.6 eV (b) –10.2 eV (c) 10.2 eV (d) 13.6 eV

20. An electron orbiting in H atom has energy level –3.4 eV. Its angular momentum will be

(a) 2.1×10^{-34} Js (b) 2.1×10^{-20} Js (c) 4×10^{-20} Js (d) 4×10^{-34} Js

21. The ground state energy of a hydrogen atom is –13.6 eV. What is the potential energy of the electron in 5^{th} excited state?

(a) –0.38 eV (b) 0.76 eV (c) 0.38 eV (d) –0.76 eV

22. An electron absorbs an energy photon such that it reaches 4^{th} excited state of the hydrogen spectrum. What will be the longest wavelength (in angstrom) for series ending in this state?

(a) 74583 (b) 22790 (c) 40519 (d) 18753

23. The wavelengths of K_α X-rays for lead isotopes Pb^{208}, Pb^{206} and Pb^{204} are λ_1, λ_2 and λ_3 respectively. Then

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

24. The simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons. This is because

(a) of the electrons not being subject to a central force
(b) of the electrons colliding with each other
(c) of screening effects
(d) the force between the nucleus and an electron will no longer be given by Coulomb's law

25. Hard X-rays for the study of fractures in bones should have a minimum wavelength of 10^{-11} m. The accelerating voltage for electrons in X-ray machine should be

(a) <124.2kV
(b) >124.2kV
(c) between 60 kV and 70 kV
(d) –100 kV

26. According to the simple Bohr model, the angular momentum of electron in the ground state of the H-atom is $h/2\pi$. Angular momentum is a vector that can have infinitely many orbits with the vector pointing in all possible directions. In reality, this is not true,

(a) because Bohr model gives incorrect values of angular momentum
(b) because only one of these would have a minimum energy
(c) angular momentum must be in the direction of spin of electron
(d) because electrons go around only in horizontal orbits

27. During X-ray formation, if voltage is increased

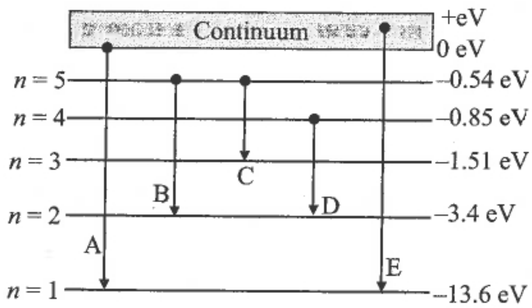
(a) minimum wavelength decreases
(b) minimum wavelength increases
(c) intensity decreases
(d) intensity increases.

28. A particular hydrogen like ion emits radiation of frequency 2.92×10^{15} Hz when it makes transition from $n = 3$ to $n = 1$. The frequency in Hz of radiation emitted in transition from $n = 2$ to $n = 1$ will be :
(a) 4.38×10^{15} (b) 6.57×10^{15} (c) 0.44×10^{15} (d) 2.46×10^{15}

29. An electron and proton are separated by a large distance. The electron starts approaching the proton with energy 3 eV. The proton captures the electron and forms a hydrogen atom in second excited state. What is the energy of the resulting photon?
(a) 1.51 eV (b) 1.41 eV (c) 4.51 eV (d) 3.3 eV

30. If λ_1 and λ_2 are the wavelengths of the third member of Lyman and first member of the Paschen series respectively, then the value of $\lambda_1 : \lambda_2$
(a) 7:135 (b) 7:108 (c) 1:9 (d) 1:3

31. In the given figure, the energy levels of hydrogen atom have been shown along with some transitions marked A, B, C, D and E. The transitions A, B and C respectively represent :



(a) The series limit of Lyman series, second member of Balmer series and second member of Paschen series.
(b) The ionization potential of hydrogen, second member of Balmer series and third member of Paschen series.
(c) The series limit of Lyman series, third member of Balmer series and second member of Paschen series.
(d) The first member of the Lyman series, third member of Balmer series and second member of the Paschen series.

32. Hydrogen ion and singly ionized helium atom are accelerated, from rest, through the same potential difference. The ratio of final speeds of hydrogen and helium ions is close to :
(a) 1:2 (b) 5:7 (c) 2:1 (d) 10:7

33. The time period of revolution of an electron in its ground state orbit in a hydrogen atom is 1.6×10^{-16} s. The frequency of revolution of the electron in its first excited state (in s^{-1}) is :
(a) 5.6×10^{12} (b) 7.8×10^{14} (c) 1.6×10^{12} (d) 6.2×10^{12}

34. An excited He^+ ion emits two photons in succession, with wavelengths 108.5 nm and 30.4 nm, in making a transition to ground state. The quantum number n, corresponding to its initial excited state is (for photon of wavelength λ energy $E = 1240$ eV/λ (in nm))
(a) $n = 4$ (b) $n = 7$ (c) $n = 5$ (d) $n = 6$

35. In Li^{++}, electron in first Bohr orbit is excited to a level by a radiation of wavelength λ. When the ion gets deexcited to the ground state in all possible ways (including intermediate emissions), a total of six spectral lines are observed. What is the value of λ?
(Given : $H = 6.63 \times 10^{-34}$ Js; $c = 3 \times 10^8$ ms^{-1})
(a) 10.8 nm (b) 12.3 nm (c) 9.4 nm (d) 11.4 nm

36. Taking the wavelength of first Balmer line in hydrogen spectrum ($n = 3$ to $n = 2$) as 660 nm, the wavelength of the 2nd Balmer line ($n = 4$ to $n = 2$) will be :
(a) 642.7 nm (b) 488.9 nm (c) 889.2 nm (d) 388.9 nm

37. N_2 molecule consists of two nitrogen atoms. In the molecule, nuclear force between the nuclei of the two atoms
(a) is not important because nuclear forces are short-ranged
(b) is as important as electrostatic force for binding the two atoms

(c) cancels the repulsive electrostatic force between the nuclei

(d) is not important because oxygen nucleus have equal number of neutrons and protons

38. A set of atoms in an excited state decays

(a) in general to any of the states with lower energy.

(b) into a lower state only when excited by an external electric field

(c) all together simultaneously into a lower state

(d) to emit photons only when they collide

39. The Bohr model for the spectra of a H-atom

(a) will not be applicable to hydrogen in the molecular form

(b) will not be applicable as it is for a single-ionized He-atom

(c) is valid only at room temperature

(d) predicts continuous as well as discrete spectral lines

40. The magnetic field at the centre of a hydrogen atom due to the motion of the electron in the first Bohr orbit is B. The magnetic field at the centre due to the motion of the electron in the second Bohr orbit will be

(a) B/4 (b) B/32 (c) B/8 (d) B/64

41. In hydrogen and hydrogen like atoms the ratio of difference of energies $E_{4n} - E_{2n}$ and $E_{2n} - E_n$ varies with atomic number Z and principle quantum number n as:

(a) Z^2/n^2 (b) Z^4/n^4 (c) Z/n (d) none of these

42. According to Bohr's theory of hydrogen atom, the product of the binding energy of the electron in the nth orbit and its radius in the n^{th} orbit :

(a) is proportional to n^2

(b) is inversely proportional to n^3

(c) has a constant value of 10.2 eV-Å

(d) has a constant value 7.2 eV-Å

43. When an electron in the hydrogen atom in ground state absorbs a photon of energy 12.1 eV, its angular momentum :

(a) decreases by 2.11×10^{-34} J-s

(b) decreases by 1.055×10^{-34} J-s

(c) increases by 2.11×10^{-34} J-s

(d) increases by 1.055×10^{-34} J-s

44. A potential difference of 10^3 V is applied across an X-ray tube. The ratio of the de-Broglie wavelength of the incident electrons to the shortest wavelength of X-rays produced is:

(a) 1/20 (b) 1/100 (c) 1 (d) $1/10^4$

45. de-Broglie wavelength of an electron in the n^{th} Bohr orbit is λ_n , and the angular momentum is L_n, then:

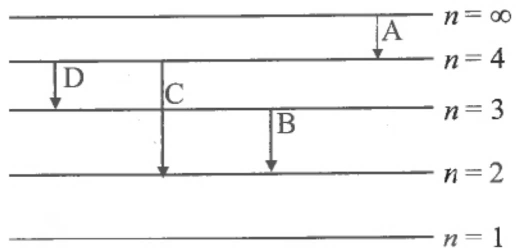
(a) L_n is directly proportional to λ_n

(b) λ_n is directly proportional to $1/L_n$

(c) λ_n is directly proportional to $(L_n)^2$

(d) None of these

46. Consider the electronic energy level diagram of H-atom. Photons associated with shortest and longest wavelengths would be emitted from the atom by the transitions labelled:



(a) D and C respectively

(b) C and A respectively.

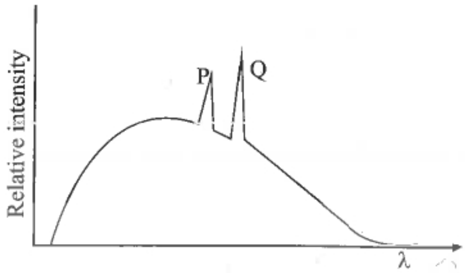
(c) C and D respectively

(d) A and C respectively

47. In a hydrogen atom, the binding energy of the electron in the electron is E_1, then the frequency of revolution of the electron in the nth orbit is

(a) $2E_1/nh$ (b) E_1/nh (c) $2E_1n/h$ (d) E_1n/h

48. In a characteristic X-ray spectra of some atom superimposed on continuous X - ray spectra :



(a) P represents K_α line
(b) Q represents K_β line
(c) Q and P represent $K\alpha$ and K_β lines respectively
(d) Position of K_α and K_β depend on the particular atom

49. Difference between n^{th} and $(n + 1)$ th Bohr's radius of 'H' atom is equal to its $(n - 1)$ th Bohr's radius. The value of n is
(a) 1
(b) 3
(c) 2
(d) 4

50. When a hydrogen atom emits a photon during the transition $n = 5$ to $n = 1$, its recoil speed is approximately:
(a) 4 m/s
(b) 3 mm/s
(c) 800 m/s
(d) 0.1 mm/s

51. The minimum kinetic energy of an electron, hydrogen ion, helium ion required for ionization of a hydrogen atom is E_1 in case an electron collides with a hydrogen atom. It is E_2 if a hydrogen ion is collided and E_3 when a helium ion is collided. Then :
(a) $E_1 = E_2 = E_3$
(b) $E_1 > E_2 > E_3$
(c) $E_1 < E_2 < E_3$
(d) $E_1 > E_3 > E_2$

52. Magnetic field at the centre (at nucleus) of the hydrogen like atoms (atomic number =Z) due to the motion of electron in nth orbit is proportional to :
(a) $(n^3)/(Z^5)$
(b) $(n^4)/Z$
(c) $(Z^2)/(n^3)$
(d) $(Z^3)/(n^5)$

53. The X-ray beam coming from an X-ray tube will be:
(a) monochromatic
(b) having all wavelengths smaller than a certain maximum wavelength
(c) having all wavelengths larger than a certain minimum wavelength
(d) having all wavelengths lying between a minimum and a maximum wavelength

54. An artificial satellite moving in a circular orbit around the earth has a total (kinetic + potential) energy E_0. Its potential energy is :
(a) $-E_0$
(b) 1.5 E_0
(c) $2E_0$
(d) E_0

55. In a hypothetical Bohr hydrogen, the mass of the electron is doubled. The energy E_0 and radius r_0 of the first orbit will be (a_0 is the Bohr's first orbit radius of hydrogen)
(a) $E_0 = -27.2\text{eV}, r_0 = a_0/2$
(b) $E_0 = -27.2\text{eV}, r_0 = a_0$
(c) $E_0 = -13.6\text{ eV}, r_0 = a_0$
(d) $E_0 = -13.6\text{eV}, r_0 = a_0/2$

56. The acceleration of electron in the first orbit of hydrogen atom is
(a) $\frac{4\pi^2 m}{h^3}$
(b) $\frac{h^2}{4\pi^2 mr}$
(c) $\frac{h^2}{4\pi^2 m^2 r^3}$
(d) $\frac{m^2 h^2}{4\pi^2 r^3}$

57. Assume a hypothetical world where angular momentum is quantized to even multiple. Find the expression for the energy of the nth orbit of hydrogen atom
(a) $-3.4/n^2$
(b) $-13.6/n^2$
(c) $-27.2/n^2$
(d) none of these

58. Bohr postulates are not applicable to
(a) singly ionised helium atom (He^+)
(b) Deuteron atom
(c) singly ionised neon atom (Ne^+)
(d) Hydrogen atom

59. The value of Planck's constant is 6.63×10^{-34} Js. The speed of light 3×10^{17} nm s^{-1}. Which value is closest to the wavelength in nanometers of a quantum of light with frequency of 6×10^{15} s^{-1}?
(a) 10
(b) 25
(c) 50
(d) 75

60. 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) $1/m$ (b) $1/\sqrt{m}$ (c) $1/m^2$ (d) m

61. 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) $\frac{20}{13}\lambda$

62. According to Bohr's theory, the velocity of the electron in the n^{th} orbit of an atom of atomic number Z is proportional to

(a) n^2/Z^2 (b) Z^2/n^2 (c) Z/n (d) Z^2n^2

63. The maximum number of photons emitted by an H-atom, if atom is excited to states with principal quantum number four is

(a) 4 (b) 6 (c) 2 (d) 1

64. The velocity of a helium nucleus travelling in a curved path in a magnetic field is V. The velocity of a proton moving in the same curved path in the same magnetic field is:

(a) V (b) 4 V (c) 2 V (d) V/2

65. In one revolution round the hydrogen nucleus, an electron makes five crests. The electron belongs to

(a) $n = 1$ (b) $n = 4$ (c) $n = 5$ (d) $n = 6$

66. According to Bohr's theory of hydrogen atom, for an electron of mass m in the n^{th} allowed orbit, then

(a) linear momentum is proportional to (m/n)
(b) radius is proportional to n/m
(c) the kinetic energy is proportional to (m/n^2)
(d) the angular momentum is proportional to n^2m

67. Out of the following, which one is not a possible energy for a photon to be emitted by a hydrogen atom according to Bohr's atomic model?

(a) 0.65 eV (b) 1.9 eV (c) 11.1 eV (d) 13.6 eV

68. 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 photoelectrons is 10 V, then the value of n is

(a) 2 (b) 3 (c) 4 (d) 5

69. In Rutherford scattering experiment the distance of closest approach of an α-particle is d_0. If we swap α-particle with a proton how much KE in comparison to α-particle will it require to have the same distance of closest approach? (K_α denotes kinetic energy of α particle)

(a) $2K_\alpha$ (b) K_α (c) $(½)K_\alpha$ (d) $4K_\alpha$

70. If scattering particles are 84 for 90 degrees angle then what will be this at 60 degrees angle?

(a) 224 (b) 98 (c) 336 (d) 256

71. From Geiger-Marsden experiment, we found out that the number of scattered particles falling on unit area of screen is not proportional to

(a) the thickness of the foil
(b) the square of the nuclear charge of the scattering material
(c) the scattering angle θ
(d) mass of the α-nucleus

72. What is the ratio between the speed of the electron in the ground state orbit of a hydrogen atom and speed of light in vaccum?

(a) 1/64 (b) 1/67 (c) 1/100 (d) 1/137

73. The K_α X-ray emission line of tungsten occurs at $\lambda = 0.02$ nm. The energy difference between K and L levels in this atoms is about:

(a) 0.51 MeV (b) 1.2 MeV (c) 59 keV (d) 13.6 eV

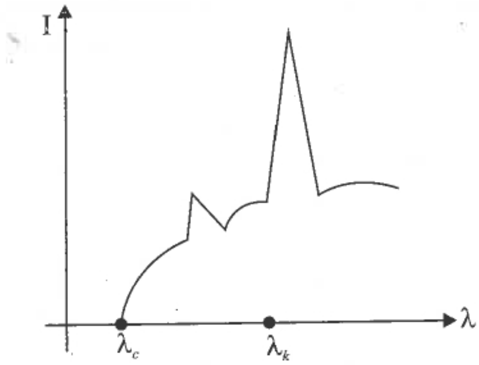
74. X-rays are produced in an X-ray tube operating at a given accelerating voltage. The wavelength of the continuous X-rays has values from :

(a) 0 to ∞
(b) λ_{min} to ∞ where $\lambda_{min} > 0$
(c) 0 to λ_{max} where $\lambda_{max} < \infty$
(d) λ_{min} to λ_{max} where $0 < \lambda_{min} < \lambda_{mix} < \infty$

75. In hydrogen spectrum the wavelength of H_α line is 656 nm; whereas in the spectrum of a distant galaxy H_α line wavelength is 706 nm. Estimated speed of galaxy with respect to earth is

(a) 2×10^8 m/s
(b) 2×10^7 m/s
(c) 2×10^6 m/s
(d) 2×10^5 m/s

76. The intensity of X-rays from a coolidge tube is plotted against wavelength λ shown in the figure. The minimum wavelength found is λ_c and the wavelength of the K_α line is λ_k. As the accelerating voltage is increased :



(a) $\lambda_k - \lambda_c$ increases
(b) $\lambda_k - \lambda_c$ decreases
(c) λ_k increases
(d) λ_k decreases

77. A hydrogen atom and a Li^{2+} ion are both in the second excited state. If l_H and l_{Li} are their respective electronic angular momenta, and E_H and E_{Li} their respective energies, then :

(a) $l_H > l_{Li}$ and $|E_H| > |E_{Li}|$
(b) $l_H = l_{Li}$ and $|E_H| < |E_{Li}|$
(c) $l_H = l_{Li}$ and $|E_H| > |E_{Li}|$
(d) $l_H < l_{Li}$ and $|E_H| > |E_{Li}|$

78. The electric potential between a proton and an electron is given by $V = V_0 \ln\left(\frac{r}{r_0}\right)$ where r_0 is a constant.

Assuming Bohr's model to be applicable, write variation of r_n with n being the principal quantum number?

(a) r_n proportional to n
(b) r_n proportional to $1/n$
(c) r_n proportional to n^2
(d) r_n proportional to $1/n^2$

79. Two H atoms in the ground state collide inelastically. The maximum amount by which their combined kinetic energy is reduced is

(a) 10.20 eV
(b) 20.40 eV
(c) 13.6 eV
(d) 27.2 eV

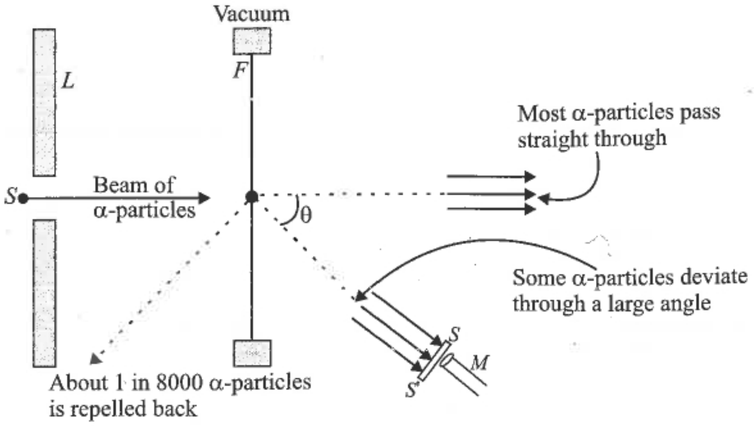
80. During an experiment , a beam of free electrons is aimed towards free protons. They got scattered but a pair of an electron and a proton did not combined to produce a H-atom,

(a) because of energy conservation
(b) because of charge conservation
(c) because of momentum conversation
(d) because of angular momentum conservation.

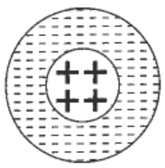
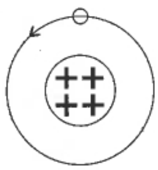
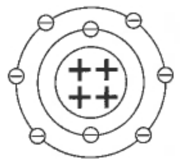
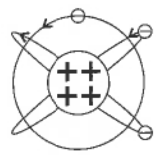
INPUT TEXT BASED MCQs

1. *Ernst Rutherford, in 1911,along with H. Geiger and E. Marsden performed some experiments. In one of their experiments,they directed a beam of 5.5 MeV α-particles emitted from a radioactive source at a thin metal foil made of gold. The scattered alpha-particles were observed through a rotatable detector consisting of zinc sulphide screen and a microscope. The scattered α-particles on striking the screen produced brief light flashes or scintillations. The study of these flashes suggested many of the α-particles pass through the foil. It means that they do not suffer any collisions. Only about* 0.14% *of the incident a-particles scatter by more than* 1°; *and*

about 1 in 8000 deflect by more than 90°. These observations led to many arguments and conclusions which laid down the structure of the nuclear model of atom.



(i) Rutherford's atomic model can be visualised as

(a)  (b)  (c)  (d) 

(ii) Gold foil used in Geiger-Marsden experiment is about 10^{-8} m thick. This ensures

(a) gold foil's gravitational pull is small or possible

(b) gold foil is deflected when α-particle stream is not incident centrally over it

(c) gold foil provides no resistance to passage of α-particles

(d) most-particle will not suffer more than 1° scattering during passage through gold foil

(iii) In Geiger-Marsden scattering experiment, the trajectory traced by an α-particle depends on

(a) number of collision (b) number of scattered α-particles

(c) impact parameter (d) none of these

(iv) In the Geiger-Marsden scattering experiment, in case of head-on-collision, the impact parameter should be

(a) maximum (b) minimum (c) infinite (d) zero

(v) The fact only a small fraction of the number of incident particles rebound back in Rutherford scattering indicates that

(a) number of α-particles undergoing head-on-collision is small

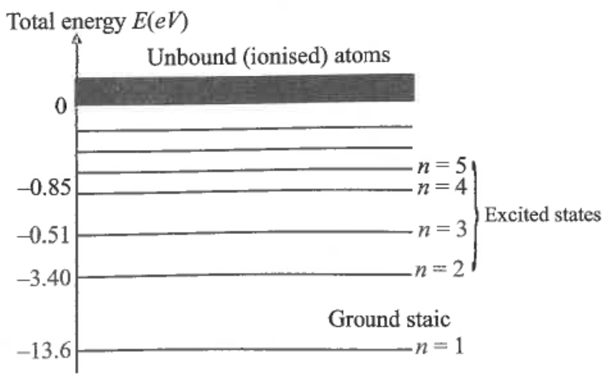
(b) mass of the atom is concentrated in a small volume

(c) mass of the atom is concentrated in a large volume

(d) both (a) and (b)

2. *At room temperature, most of the hydrogen atoms are in ground state. When a hydrogen atom receives energy by processes such as electron collisions, the atom may acquire sufficient energy to raise the electron to higher energy states. The atom is then said to be in an excited state. From these excited states the electron can then fall back to a state of lower energy, emitting a photon in the process.*

In a mixture of H-He$^+$ gas (He$^+$ is single ionized He atom). H-atoms and He$^+$ ions are excited to their respective first excited states. Subsequently, H atoms transfer their total excitation energy to He$^+$ ions (by collisions).



(i) The quantum number n of the state finally populated in He^+ ions is

(a) 2 (b) 3 (c) 4 (d) 5

(ii) The wavelength of light emitted in the visible region by He^+ ions after collisions with H-atoms is

(a) 6.5×10^{-7} m (b) 5.6×10^{-7} m (c) 4.8×10^{-7} m (d) 4.0×10^{-7} m

(iii) The ratio of kinetic energy of the electrons for the H-atoms to that of He^+ ion for $n = 2$ is

(a) $\frac{1}{4}$ (b) $\frac{1}{2}$ (c) 1 (d) 2

(iv) The radius of the ground state orbit of H-atoms is

(a) $\frac{\varepsilon_0}{h\pi me^2}$ (b) $\frac{h^2\varepsilon_0}{\pi me^2}$ (c) $\frac{\pi me^2}{h}$ (d) $2\frac{\pi h\varepsilon_0}{me^2}$

(v) Angular momentum of an electron in H-atom in first excited state is

(a) $\frac{h}{\pi}$ (b) $\frac{h}{2\pi}$ (c) $\frac{2\pi}{h}$ (d) $\frac{\pi}{h}$

ANSWERS

1. (b)	**2.** (d)	**3.** (a)	**4.** (a)	**5.** (a)	**6.** (a)	**7.** (d)	**8.** (b)	**9.** (b)	**10.** (c)
11. (a)	**12.** (a)	**13.** (d)	**14.** (d)	**15.** (b)	**16.** (c)	**17.** (a)	**18.** (c)	**19.** (c)	**20.** (a)
21. (d)	**22.** (c)	**23.** (a)	**24.** (a)	**25.** (a)	**26.** (a)	**27.** (a)	**28.** (d)	**29.** (c)	**30.** (a)
31. (c)	**32.** (c)	**33.** (b)	**34.** (c)	**35.** (a)	**36.** (b)	**37.** (a)	**38.** (a)	**39.** (a)	**40.** (b)
41. (d)	**42.** (d)	**43.** (c)	**44.** (c)	**45.** (a)	**46.** (c)	**47.** (a)	**48.** (c)	**49.** (d)	**50.** (a)
51. (c)	**52.** (d)	**53.** (c)	**54.** (c)	**55.** (a)	**56.** (c)	**57.** (a)	**58.** (c)	**59.** (c)	**60.** (a)
61. (c)	**62.** (c)	**63.** (b)	**64.** (c)	**65.** (c)	**66.** (c)	**67.** (c)	**68.** (c)	**69.** (c)	**70.** (c)
71. (d)	**72.** (d)	**73.** (c)	**74.** (b)	**75.** (b)	**76.** (a)	**77.** (b)	**78.** (a)	**79.** (a)	**80.** (a)

Input Text Based MCQs

1. (i) (d), (ii) (d), (iii) (c), (iv) (b), (v) (d) **2.** (i) (c), (ii) (c), (iii) (a), (iv) (b), (v) (a)