1 Mark Questions

1. The ground state energy of hydrogen atom is −13.6 eV. What are the kinetic and potential energies of electron in this state?
2. When is H_α-line of the Balmer series in the emission spectrum of hydrogen atom obtained?
3. What is the maximum number of spectral lines emitted by a hydrogen atom when it is in the third excited state?
4. Why is the classical (Rutherford) model for an atom of electron orbitting around the nucleus not able to explain the atomic structure?
5. Define ionisation energy. What is its value for a hydrogen atoms?
6. Find the ratio of energies of photons produced due to transition of an electron of hydrogen atom from its
   (i) second permitted energy level to the first permitted level and
   (ii) the highest permitted energy level to the first permitted level.
7. What is the ratio of radii of the orbits corresponding to first excited state and ground state, in a hydrogen atom?
8. The radius of innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. What is the radius of orbit in the second excited state?
9. Write the expression for Bohr's radius in hydrogen atom.
10. State Bohr's quantisation condition for defining stationary orbits

2 Marks Questions

11. Explain briefly how Rutherford scattering of α-particle by a target nucleus can provide information on the size of the nucleus.
12. Obtain the expression for the ratio of the de-Broglie wavelengths associated with the electron orbiting in the second and third excited states of hydrogen atom.
13. A hydrogen atom in the ground state is excited by an electron beam of 12.5 eV energy. Find out the maximum number of lines emitted by the atom from its excited state.
14. State Bohr's quantisation condition of angular momentum. Calculate the shortest wavelength of the Brackett series and state to which part of the electromagnetic spectrum does it belong.
15. Calculate the orbital period of the electron in the first excited state of hydrogen atom
16. Calculate the ratio of the frequencies of the radiation emitted due to transition of the electron in a hydrogen atom from its (i) second permitted energy level to the first level and (ii) highest permitted energy level to the second permitted level
17. Find out the wavelength of the electron orbiting in the ground state of hydrogen atom.
18. Find the wavelength of the electron orbiting in the first excited state in hydrogen atom.
19. A 12.5 eV electron beam is used to excite gaseous hydrogen atom at room temperature. Determine the wavelength and the corresponding series of the lines emitted.

20. The short wavelength limit for the Lyman series of the hydrogen spectrum is 913.4 Å. Calculate the short wavelength limit for Balmer series of the hydrogen spectrum.

21. The ground state energy of hydrogen atom is −13.6 eV. If an electron makes a transition from an energy level − 1.51 eV to − 3.4 eV, then calculate the wavelength of the spectral line emitted and name the series of hydrogen spectrum to which it belongs.

22. State Bohr postulate of hydrogen atom that gives the relationship for the frequency of emitted photon in a transition.

23. An electron jumps from fourth to first orbit in an atom. How many maximum number of spectral lines can be emitted by the atom? To which series these lines correspond?

24. Calculate the de-Broglie wavelength of the electron orbiting in the $n = 2$ states of hydrogen atom.

25. Use de-Broglie's hypothesis to write the relation for the nth radius of Bohr orbit in terms of Bohr's quantization condition of orbital angular momentum.

26. An α-particle moving with initial kinetic energy K towards a nucleus of atomic number Z approaches a distance d at which it reverses its direction. Obtain the expression for the distance of closest approach d in terms of the kinetic energy of α-particle K.

27. Find the ratio between the wavelengths of the 'most energetic' spectral lines in the Balmer and Paschen series of the hydrogen spectrum.

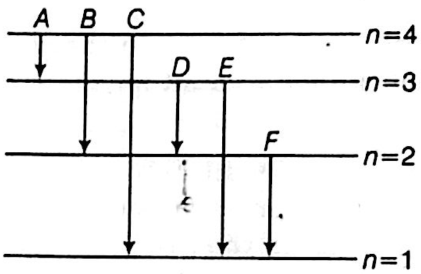
28. Calculate the shortest wavelength of the spectral lines emitted in Balmer series. [Given, Rydberg constant, $R = 10^7$ m^{-1}]

29. In the study of Geiger-Marsden experiment on scattering of α-particles by a thin foil of gold, draw the trajectory of α-particles in the coulomb field of target nucleus. Explain briefly how one gets the information on the size of the nucleus from this study.

30. Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.

31. Calculate the shortest wavelength in the Balmer series of hydrogen atom. In which region (infrared, visible, ultraviolet) of hydrogen spectrum does this wavelength lie?

32. The figure shows energy level diagram of hydrogen atom.



(i) Find out the transition which results in the emission of a photon of wavelength 496 nm.

(ii) Which transition corresponds to the emission of radiation of maximum wavelength? Justify your answer.

33. Using Rutherford model of the atom, derive the expression for the total energy of the electron in hydrogen atom. What is the significance of total negative energy possessed by the electron?

34. Using Bohr's postulates of the atomic model, derive the expression for radius of nth electron orbit. Hence, obtain the expression for Bohr's radius.

35. Define ionisation energy. How would the ionisation energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge?

36. In the ground state of hydrogen atom, its Bohr radius is given as 5.3×10^{-11} m. The atom is excited such that the radius becomes 21.2×10^{-11} m. Find (i) the value of the principal quantum number and (ii) the total energy of the atom in this excited state.

37. (i) In hydrogen atom, an electron undergoes transition from second excited state to the first excited state and then to the ground state. Identify the spectral series to which these transitions belong.

(ii) Find out the ratio of the wavelengths of the emitted radiations in the two cases.

38. Explain, in brief, why Rutherford's model cannot account for the stability of an atom.

39. Using the relevant Bohr's postulates derive the expression for the radius of the electron in the nth orbit of the electron in hydrogen atom.

3 Marks Questions

40. A photon emitted during the de-excitation of electron from a state n to the first excited state in a hydrogen atom, irradiates a metallic cathode of work function 2eV, in a photocell, with a stopping potential of 0.55 V. Obtain the value of the quantum number of the state n.

41. (i) Draw the energy level diagram for the line spectra representing Lyman series and Balmer series in the spectrum of hydrogen atom.

(ii) Using the Rydberg formula for the spectrum of hydrogen atom, calculate the largest and shortest wavelengths of the emission lines of the Balmer series in the spectrum of hydrogen atom.

(Use the value of Rydberg constant, $R = 1.1 \times 10^7\ m^{-1}$)

42. (i) State Bohr's postulate to define stable orbits in hydrogen atom. How does de-Broglie's hypothesis explain the stability of these orbits?

(ii) A hydrogen atom initially in the ground state absorbs a photon which excites it to the $n = 4$ level. Estimate the frequency of the photon.

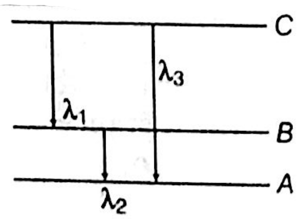
43. Define the distance of closest approach. An α-particle of kinetic energy K is bombarded on a thin gold foil. The distance of the closest approach is r. What will be the distance of closest approach for an α-particle of double the kinetic energy?

Write two important limitations of Rutherford nuclear model of the atom.

44. The kinetic energy of the electron orbiting in the first excited state of hydrogen atom is 3.4 eV. Determine the de-Broglie wavelength associated with it.

45. (i) State Bohr's quantisation condition for defining stationary orbits. How does de-Broglie's hypothesis explain the stationary orbits?

(ii) Find the relation between the three wavelengths λ_1, λ_2 and λ_3 from the energy level diagram shown below.



46. A 12.5 eV electron beam is used to bombard gaseous hydrogen at room temperature. Upto which energy level the hydrogen atoms would be excited?

Calculate the wavelengths of the first member of Lyman and first member of Balmer series.

47. (i) Using Bohr's total postulates, derive the expression for the total energy of the electron in the stationary states of hydrogen atom.

(ii) Using Rydberg's formula, calculate the wavelength of spectral lines of the first members of the Lyman series and of the Balmer series.

48. The value of ground state energy of hydrogen atom is -13.6 eV.

(i) Find the energy required to move an electron from the ground state to the first excited state of the atom.

(ii) Determine (a) the kinetic energy and (b) orbital radius in the first excited state of the atom. (Given, the value of Bohr's radius $= 0.53$ Å)

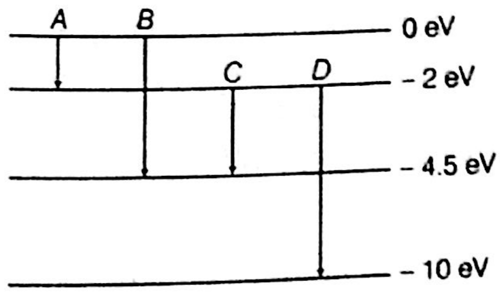
49. (i) The radius of the innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. Calculate its radius in $n = 3$ orbit.

(ii) The total energy of an electron in the first excited state of the hydrogen atom is -3.4 eV. Find out its (a) kinetic energy and (b) potential energy in this state.

50. Using Bohr's postulates, obtain the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence, draw the energy level diagram showing how the line spectra corresponding to Balmer series occur due to transition between energy levels.

51. Using Bohr's postulates for hydrogen atom, show that the total energy (E) of the electron in the stationary states can be expressed as the sum of kinetic energy (K) and potential energy (U), where $K = -2U$. Hence, deduce the expression for the total energy in the nth energy level of hydrogen atom.

52. (i) The energy levels of an atom are as shown in figure below. Which of them will result in the transition of a photon of wavelength 275 nm?



(ii) Which transition corresponds to emission of radiation of maximum wavelength?

53. (i) Using Bohr's second postulate of quantisation of orbital angular momentum show that the circumference of the electron in the nth orbital state in hydrogen atom is n-times the de-Broglie wavelength associated with it.

(ii) The electron in hydrogen atom is initially in the third excited state. What is the maximum number of spectral lines which can be emitted when it finally moves to the ground state?

54. The ground state energy of hydrogen atom is -13.6 eV. If an electron makes a transition from an energy level -0.85 eV to -1.51 eV, calculate the wavelength of the spectral line emitted. To which series of hydrogen spectrum does this wavelength belong?

55. In a Geiger-Marsden experiment, calculate the distance of closest approach to the nucleus of $Z = 80$, when an α-particle of 8 MeV energy impinges on it before it comes to momentarily rest and reverses its direction.

How will the distance of closest approach be affected when the kinetic energy of the α-particle is doubled?

56. Using the postulates of Bohr's model of hydrogen atom, obtain an expression for the frequency of radiation emitted when the atom makes a transition from the higher energy state with quantum number n_i to the lower energy state with quantum number $n_f (n_f < n_i)$.

57. The electron in a given Bohr orbit has a total energy of – 1.5 eV. Calculate its

(i) kinetic energy

(ii) potential energy

(iii) wavelength of radiation emitted, when this electron makes a transition to the ground state. [Given, energy in the ground state = – 13.6 eV and Rydberg's constant $= 1.09 \times 10^7 \text{ m}^{-1}$]

58. Using postulates of Bohr's theory of hydrogen atom, show that

(i) radii of orbits increases as n^2 and

(ii) the total energy of electron increases as $\frac{1}{n^2}$, where n is the principal quantum number of the atom.

59. Draw a schematic arrangement of the Geiger-Marsden experiment for studying α-particle scattering by a thin foil of gold. Describe briefly by drawing trajectories of the scattered α-particles. How this study can be used to estimate the size of the nucleus?

60. State the basic assumption of the Rutherford model of the atom. Explain in brief why this model cannot account for the stability of an atom?

61. Using the relevant Bohr's postulates, derive the expressions for the

(i) speed of the electron in the nth orbit,

(ii) radius of the nth orbit of the electron in hydrogen atom.

62. State any two postulates of Bohr's theory of hydrogen atom. What is the maximum possible number of spectral lines observed when the hydrogen atom is in its second excited state? Justify your answer. Calculate the ratio of the maximum and minimum wavelengths of the radiations emitted in this process.

5 Marks Questions

63. Using Bohr's postulates, derive the expression for the frequency of radiation emitted when electron in hydrogen atom undergoes transition from higher energy state (quantum number n_i) to the lower state, (n_f). When electron in hydrogen atom jumps from energy state $n_i = 4$ to $n_f = 3, 2, 1$. Identify the spectral series to which the emission lines belong.

64. (i) Using postulates of Bohr's theory of hydrogen atom, show that

(a) the radii of orbits increase as n^2 and

(b) the total energy of the electron increases as $1/n^2$, where n is the principal quantum number of the atom.

(ii) Calculate the wavelength of H_α-line in Balmer series of hydrogen atom. Given, Rydberg constant, $R = 1.097 \times 10^7 \text{ m}^{-1}$.

1 Mark Questions

1. The existance of a positively charged nucleus in an atom was first suggested by the experiment of
   (a) J J Thomson
   (b) Rutherford
   (c) Chadwick
   (d) Hahn and Strassman

2. Rutherford's atomic model could account for
   (a) stability of atoms
   (b) origin of spectra
   (c) the positive charged central core of an atom
   (d) concept of stationary orbits

3. In the lowest energy level of hydrogen atom, the electron has the angular momentum
   (a) $\frac{\pi}{h}$ (b) $\frac{h}{\pi}$ (c) $\frac{h}{2\pi}$ (d) $\frac{2\pi}{h}$

4. According to Bohr's theory (assuming infinite mass of the nucleus), the frequency of the second line of the Balmer series is
   (a) 6.16×10^{14} Hz (b) 6.16×10^{13} Hz
   (c) 6.16×10^{10} Hz (d) 6.16×10^{16} Hz

5. 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) $4 \rightarrow 3$

6. According to the Bohr's atomic model, the relation between principal quantum number (n) and radius of orbit (r) is
   (a) $r \propto n^2$ (b) $r \propto \frac{1}{n^2}$ (c) $r \propto \frac{1}{n}$ (d) $r \propto n$

7. When an electron jumps from the orbit $n=2$ to $n=4$, then wavelength of the radiations absorbed will be (R is Rydberg's constant)

(a) $\frac{16}{3R}$ (b) $\frac{16}{5R}$ (c) $\frac{5R}{16}$ (d) $\frac{3R}{16}$

8. An electron of a stationary hydrogen atom passes from the 5th 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) $\frac{24m}{25hR}$

9. If ν_1 is the frequency of the series limit of Lyman series, ν_2 is the frequency of the first line of Lyman series and ν_3 is the frequency of the series limit of the Balmer series. Then,

(a) $\nu_1 - \nu_2 = \nu_3$ (b) $\nu_1 = \nu_2 - \nu_3$

(c) $\frac{1}{\nu_2} = \frac{1}{\nu_1} + \frac{1}{\nu_3}$ (d) $\frac{1}{\nu_1} = \frac{1}{\nu_2} + \frac{1}{\nu_3}$

10. Which state of triply ionised Beryllium (Be^{3+}) has the same orbital radius as that of the ground state of hydrogen?

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

11. The orbital frequency of an electron in the hydrogen atom is proportional to

(a) n^3 (b) n^{-3} (c) n (d) n^0

12. The angular momentum (L) of an electron moving in a stable orbit around nucleus is

(a) half integral multiple of $\frac{h}{2\pi}$

(b) integral multiple of h

(c) integral multiple of $\frac{h}{2\pi}$

(d) half integral multiple of h

1 Mark Questions

1. Why is it found experimentally difficult to detect neutrinos in nuclear β-decay?
2. Define the activity of a given radioactive substance. Write its SI unit.
3. What is the relationship between the half-life and mean life of a radioactive nucleus?
4. How is the radius of a nucleus related to its mass number?
5. A nucleus undergoes β-decay. How does its
   (i) mass number and
   (ii) atomic number change?
6. A nucleus $^{238}_{92}U$ undergoes α-decay and transforms to thorium. What is
   (i) the mass number and
   (ii) atomic number of the nucleus produced?

2 Marks Questions

7. Complete the following nuclear reactions
   (i) $^{10}_{5}B + ^{1}_{0}n \rightarrow ^{4}_{2}He + ...$
   (ii) $^{94}_{42}Mo + ^{2}_{1}H \rightarrow ^{95}_{43}Te + ...$
8. In both β^- and β^+-decay process, the mass number of nucleus remains the same, whereas the atomic number Z increases by one in β^--decay and decrease by one in β^+-decay. Explain giving reasons.

9. Derive the expression for the law of radioactive decay of a given sample having initially N_0 decaying to the number N present at any subsequent time t.
Plot a graph showing the variation of the number of nuclei *versus* the time lapsed. Mark a point on the plot in terms of $T_{1/2}$ value the number present $N = N_0 / 16$.

10. In a given sample, two radio isotopes A and B are initially present in the ratio of 1 : 4. The half-lives of A and B are 100 yr and 50 yr, respectively. Find the time after which the amounts of A and B become equal.

11. How the size of a nucleus is experimentally determined? Write the relation between the radius and mass number of the nucleus. Show that the density of nucleus is independent of its mass number.

3 Marks Questions

12. Define the term decay constant of a radioactive sample. The rate of disintegrations of a given radioactive nucleus is 10000 disintegrations/s and 5000 disintegrations/s after 20 h and 30 h, respectively from start. Calculate the half life and initial number of nuclei at $t = 0$.

13. (a) Write the relation between half-life and average life of a radioactive nucleus.

(b) In a given sample two isotopes A and B are initially present in the ratio of 1 : 2.

Their half lives are 60 years and 30 years respectively. How long will it take so that the sample has these isotopes in the ratio of 2 : 1?

14. Why is it difficult to detect the presence of an anti-neutrino during β-decay? Define the term decay constant of a radioactive nucleus and derive the expression for its mean life in terms of the decay constant.

15. (a) Explain the processes of nuclear fission and nuclear fusion by using the plot of binding energy per nucleon (BE/A) *versus* the mass number A.

(b) A radioactive isotope has a half-life of 10 yr. How long will it take for the activity to reduce to 3.125%?

16. (i) A radioactive nucleus A undergoes a series of decays as given below:

$$A \xrightarrow{\alpha} A_1 \xrightarrow{\beta} A_2 \xrightarrow{\alpha} A_3 \xrightarrow{\gamma} A_4$$

The mass number and atomic number of A_2 are 176 and 71, respectively. Determine the mass and atomic numbers of A_4 and A.

(ii) Write the basic nuclear processes underlying β^+ and β^- decays.

17. (i) Write the basic nuclear process involved in the emission of β^+ in a symbolic form by a radioactive nucleus.

(ii) In the reactions given below:

(a) ${}^{11}_{6}C \rightarrow {}^{z}_{y}B + x + \nu$

(b) ${}^{12}_{6}C \rightarrow {}^{12}_{6}C + {}^{20}_{a}Ne + {}^{c}_{b}He$

Find the values of x, y and z and a, b and c.

18. (i) Deduce the expression, $N = N_0 e^{-\lambda t}$ for the law of radioactive decay.

(ii) Write symbolically the process expressing the β^+-decay of ${}^{22}_{11}Na$. Also, write the basic nuclear process underlying this decay.

(iii) Is the nucleus formed in the decay of the nucleus ${}^{22}_{11}Na$ is isotope or isobar?

19. (i) Complete the following nuclear reactions:

(a) ${}^{208}_{84}Po \rightarrow {}^{204}_{82}Pb + ...$

(b) ${}^{32}_{15}P \rightarrow {}^{32}_{16}S + ...$

(ii) Write the basic process involved in nuclei responsible for (a) β^- and (b) β^+-decay.

(iii) Why is it found experimentally difficult to detect neutrinos?

20. (i) Define the term activity of a sample of radioactive nucleus. Write its SI unit.

(ii) The half-life of $^{238}_{92}U$ undergoing α-decay is 4.5×10^9 yr. Determine the activity of 10g sample of $^{238}_{92}U$. Given that 1 g of $^{238}_{92}U$ contains 25.3×10^{20} atoms.

21. (i) Define the terms (a) half-life (b) average life. Find out the relationship with the decay constant (λ).

(ii) A radioactive nucleus has a decay constant $\lambda = 0.3465 \text{ (day)}^{-1}$. How long would it take the nucleus of decay to 75% of its initial amount?

22. (i) The number of nuclei of a given radioactive sample at time $t = 0$ and $t = T$ are N_0 and N_0/n, respectively. Obtain an expression for the half-life ($T_{1/2}$) of the nucleus in terms of n and T.

(ii) Write the basic nuclear process underlying β-decay of a given radioactive nucleus.

23. (i) Define the term 'activity' of a given sample of radionuclide. Write the expression for the law of radioactive decay in terms of the activity of a given sample.

(ii) A radioactive isotope has a half-life of T years. How long will it take the activity to reduce to 3.125% of its original value?

(iii) When a nucleus (X) undergoes β-decay, the transforms to the nucleus (Y), does the pair (X, Y) form isotopes, isobars or isotones? Justify your answer.

24. State the law of radioactive decay. Plot a graph showing the number N of undecayed nuclei as a function of time t for a given radioactive sample having half-life $T_{1/2}$. Depict in the plot, the number of undecayed nuclei at

(i) $t = 3\,T_{1/2}$ (ii) $t = 5\,T_{1/2}$.

25. (i) Define activity of a radioactive material and write its SI unit.

(ii) Plot a graph showing variation of activity of a given radioactive sample with time.

(iii) The sequence of stepwise decay of a radioactive nucleus is

$$D \xrightarrow{\beta\text{-particle}} D_1 \xrightarrow{\alpha\text{-particle}} D_2$$

If the atomic number and mass number of D_2 are 71 and 176 respectively, what are their corresponding values for D?

26. (i) Write symbolically the β^--decay process of $^{32}_{15}P$.

(ii) Derive an expression for the average life of a radionuclide. Give its relationship with the half-life

27. What is the basic mechanism for the emission of β^- and β^+-particles in a nuclei? Give an example by writing explicitly a decay process for β-emission. Is

(i) the energy of the emitted β-particles continuous or discrete?

(ii) the daughter nucleus obtained through β-decay, an isotope or an isobar of the parent nucleus?