Unit VIII

ATOMS AND NUCLEI

KEY POINTS

- Gieger-Marsden α-scattering experiment established the existence of nucleus in an atom.

  Bohr's atomic model

  (i) Electrons revolve round the nucleus in certain fixed orbits called stationary orbits.

  (ii) In stationary orbits, the angular momentum of electron is integral multiple of $h/2\pi$.

  (iii) While revolving in stationary orbits, electrons do not radiate energy. The energy is emitted (or absorbed) when electrons jump from higher to lower energy orbits, (or lower to higher energy orbits). The frequency of the emitted radiation is given by $h\nu = E_f - E_i$. An atom can absorb radiations of only those frequencies that it is capable of emitting.

- As a result of the quantisation condition of angular momentum, the electron orbits the nucleus in circular paths of specific radii. For a hydrogen atom it is given by

$$r_n = \left(\frac{n^2}{m}\right)\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_0}{e^2} = \frac{n^2h^2\varepsilon_0}{\pi m e^2}$$

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

  The total energy is also quantised : $E_n = \dfrac{-me^4}{8n^2\varepsilon_0^2h^2} = -\,13.6\text{eV}/n^2$

  The $n = 1$ state is called the ground state.

  In hydrogen atom, the ground state energy is – 13.6 eV.

- de Broglie's hypothesis that electron have a wavelength $\lambda = h/mv$ gave an explanation for the Bohr's quantised orbits.
- Neutrons and protons are bound in nucleus by short range strong nuclear force. Nuclear force does not distinguish between nucleons.
- The nuclear mass 'M' is always less than the total mass of its constituents. The difference in mass of a nucleus and its constituents is called the **mass defect.**

$$\Delta M = [Zm_p + (A - Z)m_n] - M$$

and $$\Delta E_b = (\Delta M)c^2$$

The energy ΔE_b represents the binding energy of the nucleus.

For the mass number ranging from A = 30 to 170 the binding energy per nucleon is nearly constant at about 8MeV per nucleon.

- **Radioactive Decay Law :** The number of atoms of a radioactive sample disintegrating per second at any time is directly proportional to the number of atoms present at that time. Mathematically :

$$\frac{dN}{dt} = -\lambda N \text{ or } N_{(t)} = N_0 e^{-\lambda t}$$

where λ is called decay constant. It is defined as the reciprocal of the mean time during which the number of atoms of a radioactive substance decreases to $\frac{1}{e}$ of their original number.

- Number of radioactive atoms N in a sample at any time t can be calculated using the formula.

$$N = N_0 \left(\frac{1}{2}\right)^{t/T}$$

Here No = no. of atoms at time t = 0 and T is the half-life of the substance.

Half life : The half life of a radio active substances is defined as the time during which the number of atoms disintegrate to one half of its initial value.

$$T_{1/2} = \frac{\ln 2}{\lambda} = \ln 2 \times \text{mean life}$$

or $$0.693/\lambda = \frac{0.693}{\lambda}$$

Here λ= decay constant $= \frac{1}{\text{mean life}}$

- Radius r of the nucleus of an atom is proportional to the cube root of its mass number thereby implying that the nuclear density is the same. (Almost) for all substances/nuclei.
- α-decay : ${}_Z X^A \rightarrow {}_{Z-2}Y^{A-4} + {}_2He^4 + Q$

β-decay : ${}_Z X^A \rightarrow {}_{Z+1}Y^A + {}_{-1}e^0 + \bar{\nu} + Q$

γ-decay : When α or β-decay, the nucleus in excited state; the nucleus goes to lower energy state or ground state by the emission of γ-ray(s).

QUESTIONS

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. What is the rest mass of photon?

Ans. Zero

2. A good mirror reflects 80% of light incident on it. Which of the following is correct ?

(a) Energy of each reflected photon decreases by 20%.

(b) Total no. of reflected photons decreases by 20%. Justify your answer.

Ans. (b) Total no. of reflected photons decreases by 20%.

3. Why in a photocell the cathode is coated with alkali metals ?

Ans. Lower work function, sensitive to visible light.

4. Name the phenomenon which shows quantum nature of electromagnetic radiation.

Ans. Photoelectric effect.

5. Write Einstein's photoelectric equations and specify each term.

Ans. $\frac{1}{2}mv_{max}^2 = h\upsilon - h\upsilon_0$

Max. K.E. of Photoelectrons = Energy of incident light – work function.

6. The Stopping potential in an experiment on photo electric effect is 1.5V : What is the maximum K.E. of photoelectrons emitted.

Ans.

$$eV_0 = (K.E)\ max$$

$$\Rightarrow \quad (K.E.)max = 1.6 \times 10^{-19} \times 1.5 = 2.4 \times 10^{-19} J$$

7. A metal emits photoelectrons when red light falls on it. Will this metal emit photoelectrons when blue light falls on it? Why?

Ans. Yes, blue light has higher frequency hence possess higher energy.

8. What is the value of impact parameter for a head on collision?

Ans. Zero

9. The photoelectric cut off voltage in a certain photoelectric experiment is 1.5V. What is the max. kinetic energy of photoelectrons emitted?

Ans. K.E = eV, \ K.E = 1.5 *e* Joule

$= 1.5 \times 1.6 \times 10^{-19}$J

$= 2.4 \times 10^{-19}$J

10. What is the de-Broglie wavelength of a 3 kg object moving with a speed of 2m/s?

Ans. $\lambda = \frac{h}{mv} = \frac{6.6 \times 10^{-34}}{3 \times 2} = 1.1 \times 10^{-34}$m.

11. What factors determine the maximum velocity of the photoelectrons from a surface?

Ans. (a) frequency of incident radiation

(b) work function of surface.

12. How will you justify that the rest mass of photons is zero ?

Ans. $m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$, rest mass for $m_0 = \sqrt{1 - \frac{v^2}{c^2}}$ photon $v = c \Rightarrow m_0 = 0$.

13. Work functions of caesium and lead are 2.14 eV and 4.25 eV respectively. Which of the two has a higher threshold wavelength?

Ans. Work function, $\phi_0 = hv_0 = h\frac{c}{\lambda_0}$ or $\lambda_0 \ \alpha \frac{1}{\phi_0}$

Hence caesium has a higher threshold wavelength for photoelectric emission.

14. What is the de-Broglie wavelength of a neutron at absolute temperature T K ?

Ans. $\lambda = \frac{h}{\sqrt{2m_n E_k}} = \frac{h}{\sqrt{2m_n \frac{3}{2} k_B T}} = \frac{h}{\sqrt{3m_n k_B T}}$, $K_B \rightarrow$ Boltzmann's Constant

15. Define atomic mass unit. Write its energy equivalent in MeV.

Ans. 1 a.m.u is $\frac{1}{12}$ of the mass of a carbon isotope

$^{12}C_6$ 1 u = 931 MeV

16. What was the drawback of Rutherford's model of atom?

Ans. Rutherford's model of atom failed to explain the stability of atom.

17. What are the number of electrons and neutrons in $^{236}_{92}U$ atom?

Ans. No. of electrons 92

No. of neutrons 236 – 92 = 144.

18. Name the series of hydrogen spectrum which has least wavelength.

Ans. Lyman series

19. Any two protons repel each other, then how is this possible for them to remain together in a nucleus.

Ans. Nuclear force between two protons is 100 times stronger than the electrostatic force.

20. Define radioactive decay constant.

Ans. The decay constant of radioactive substance is defined as the reciprocal of that time in which the number of atoms of substance becomes $\frac{1}{e^{th}}$ times the atoms present initially.

21. You are given reaction : ${}_1H^2 + {}_1H^2 \rightarrow {}_2He^4 + 24$ MeV. What type of nuclear reaction is this?

Ans. Nuclear Fusion.

22. After losing two electrons, to which particle does a helium atom get transformed into?

Ans. α particle.

23. What is the ratio of velocities of electron in I, II and III Bohr Orbits ?

Ans. $\frac{1}{1}:\frac{1}{2}:\frac{1}{3}$ or 6 : 3 : 2

24. Which atomic part was discovered by Rutherford ?

Ans. Nucleus

25. In nuclear reaction ${}_1^1H \rightarrow {}_0^1n + {}_Q^Px$ find P, Q and hence identify X.

Ans. P = 0, Q = 1

X is ${}_1e^0$ a positron.

26. Binding energies of deutron $\left({}_1^2H\right)$ and α-particle (${}_2He^4$) are 1.25 MeV/nucleon and 7.2 MeV/nucleon respectively. Which nucleus is more stable?

Ans. Binding energy of ${}_2He^4$ is more than deutron ${}_1H^2$. Hence ${}_2He^4$ is more stable.

27. α-particles are incident on a thin gold foil. For what angle of deviation will the number of deflected α-particles be minimum?

Ans. 180°

28. If the amount of a radioactive substance is increased four times then how many times will the number of atoms disintegrating per unit time be increased?

Ans. Four times ∵ R = – λN

29. An electron jumps from fourth to first orbit in an atom. How many maximum number of spectral lines can be emitted by the atom?

Ans. Possible transitions are

$n_i = 4$ to $n_f = 3, 2, 1$

$n_i = 3$ to $n_f = 2.1$

$n_i = 2$ to $n_f = 1$

Total transitions = 6

For many electron system.

$$\left[\text{Max number of spectral lines} = \frac{n(n-1)}{2} = \frac{4 \times 3}{2} = 6\right]$$

30. Under what conditions of electronic transition will the emitted light be monochromatic?

Ans. Only fixed two orbits are involved and therefore single energy evolve.

31. Why does only a slow neutron (.03eV energy) cause the fission in the uranium nucleus and not the fast one?

Ans. Slow neutron stays in the nucleus for required optimum time and disturbs the configuration of nucleus.

32. Write the relation for distance of closest approach.

Ans. $$\gamma_0 = \frac{(Ze)(2e)}{4\pi \in_0 \left(\frac{1}{2} mv^2\right)}.$$

33. In Bohr's atomic model, the potential energy is negative and has a magnitude greater than the kinetic energy, what does this imply?

Ans. The revolving electron is bound to the nucleus.

34. Name the physical quantity whose dimensions are same as Planck's constant.

Ans. Angular momentum

35. Define ionisation potential.

Ans. The minimum accelerated potential which would provide an electron sufficient energy to escape from the outermost orbit.

36. The ionisation potential of hellium atom is 24.6 V. How much energy will be required to ionise it?

Ans. 24.6 eV

37. What is the energy possessed by an electron whose principal quantum number is infinite?

Ans. Zero $n = \infty$

$$\because \quad E_n = -\frac{13.6}{n^2} \text{ eV} = 0.$$

38. What is the SI unit of work function?

Ans. Joule

39. Name the spectral series of hydrogen atom which lie in *uv* region.

Ans. Lyman Series

40. Name two series of hydrogen spectrum lying in the infra red region.

Ans. Paschan & P fund series

41. What is the order of velocity of electron in a hydrogen atom in ground state.

Ans. 10^6 ms^{-1}

42. Write a relation for the wavelength in Paschan series lines of hydrogen spectrum.

Ans. $\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right), \quad n = 4, 5...$

43. Arrange radioactive radiation in the increasing order of penetrating power.

Ans. α, β, γ

44. Write a relation between average life and decay constant.

Ans. $\tau = \frac{1}{\lambda}$ = average life

45. Write two units for activity of radioactive element and relate them with number of disintegration per second.

Ans.

1 Curie (Ci) = 3.7×10^{10} decay/s

1 becquerel (Bq) = 1 decay/s

46. The half life of a radioactive element A is same as the mean life time of another radioactive element B. Initially, both have same number of atoms. B decay faster than A. Why?

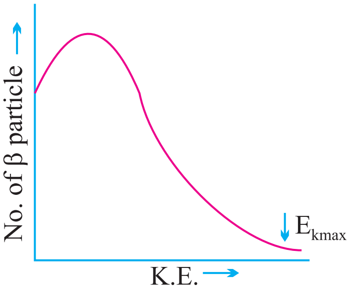
Ans. $T_A = \tau_B = 1.44T_B$

$\therefore$ $T_A > T_B$

$\therefore$ $\lambda_A < \lambda_B$

Therefore B decay faster than A.

47. Draw the graph showing the distribution of kinetic energy of electrons emitted during β decay.



48. Compare radii of two nuclei of mass numbers 1 and 27 respectively.

Ans. $$\frac{R_1}{R_2} = \left(\frac{1}{27}\right)^{1/3} = \frac{1}{3}$$

$$R_1 : R_2 = 1 : 3$$

49. Which element has highest value of Binding Energy per nucleon.

Ans. $^{56}Fe_{26}$

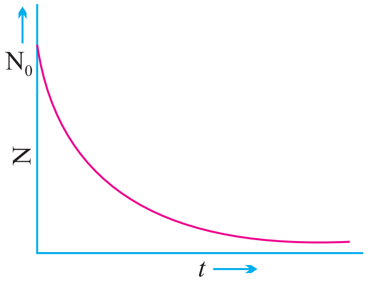
50. Mention the range of mass number for which the Binding energy curve is almost horizontal.

Ans. For A = 30 to 120 (A is mass number)

51. What is the ratio of nuclear densities of the two nuclei having mass numbers in the ratio 1 : 4?

Ans. 1 : 1 Because nuclear density is independent of mass number.

52. Draw a graph of number of undecayed nuclei to the time, for a radioactive nuclei.



53. Write an equation to represent α decay.

Ans. ${}_{Z}^{A}X \rightarrow {}_{Z-2}^{A-4}Y + {}_{2}^{4}He + Q$

Atoms and Nuclie

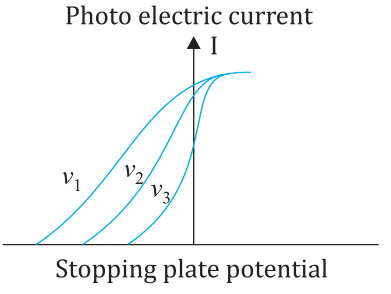
1. If a nucleus has mass defect 0.2 g. What will be its binding energy.
2. The Binding energy of helium nucleus is 28.17 max. Find its binding energy per nucleon.
3. Binding energy per nucleon for an element is 7.14 Mev. If the binding energy of the element is 28.6+ MeV. Calculate the no. of nucleons in the nucleus.
4. Calculate the mass defect of a helium nucleus. If its actual mass (atomic) is 4.001624 amu. The mass of one portion and one neutron together is 2.015941 amu.

VERY SHORT ANSWER QUESTIONS (1 Mark)

1. Illustrate by giving suitable examples, how you can show that electromagnetic waves carry both energy and momentum.
2. Define the term "threshold frequency", in the context of photoelectric emission.
3. Define the term "intensity" in photon picture of light.
4. Define intensity of radiation based on photon picture of light.
5. Plot a graph showing the variation of photoelectric current versus intensity of light.
6. Plot a graph of stopping potential (V_0) versus the frequency (ν) of incident radiation in photoelectric emission.
7. Plot a graph of the de-Broglie wavelength associated with a photon versus its momentum.
8. Plot a graph of the de-Broglie wavelength associated with electron as a function of accelerating potential.
9. A proton is accelerated through a potential difference V, subjected to a uniform magnetic field acting normal to the velocity of the proton. If

the potential differences is doubled, how will the radius of the circular path described by the proton in the magnetic field change?

10. On the basis of the graphs shown in the figure, answer the following questions:

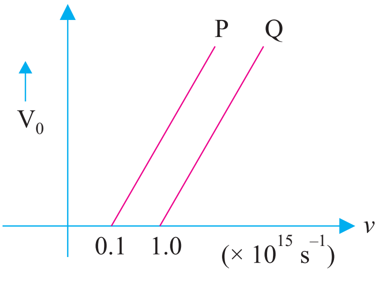


(*a*) Which physical parameter is kept constant for the three curves?

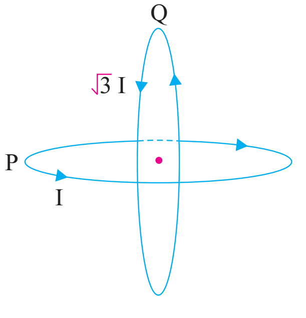
(*b*) Which is the highest frequency among, v_1, v_2 and v_3?

11. In the photoelectric emission, when the frequency of incident radiation is doubled, will the maximum kinetic energy of photoelectrons also be doubled? Justify your answer.

12. The figure shows the variation of stopping potential V_0 with the frequency v of the incident radiations for two photosensitive metals P and Q. Which metal has smaller threshold wavelength? Justify your answer.



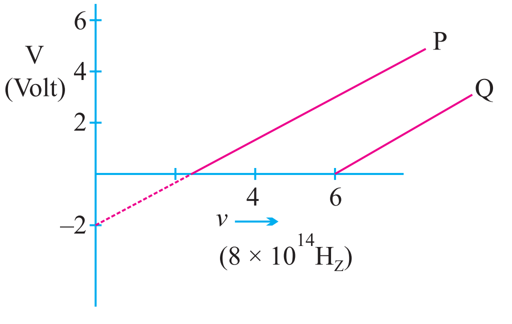
13. Plot a graph of de-Broglie wavelength associated with electron as a function of its kinetic energy.



SHORT ANSWER QUESTIONS (2 Marks)

1. Write one similarity and one difference between matter wave and an electromagnetic wave.
2. Does a photon have a de-Broglie wavelength? Explain.
3. A photon and an electron have energy 200 eV each. Which one of these has greater de-Broglie wavelength?
4. The work function of the following metal is given Na = 2.75 eV, K = 2.3 eV, Mo = 4.14 eV, Ni = 5.15 eV which of these metal will not give a photoelectric emission for radiation of wave length 3300 A° from a laser source placed at 1m away from the metal. What happens if the laser is brought nearer and placed 50 cm away.
5. Represent graphically Variation of the de-Broglie wavelength with linear momentum of a particle.

6. In a photoelectric effect experiment, the graph between the stopping potential V and frequency of the incident radiation on two different metals P and Q are shown in Fig. :



(i) Which of the two metals has greater value of work function?

(ii) Find maximum K.E. of electron emitted by light of frequency $v = 8 \times 10^{14}$ Hz for metal P.

7. Do all the photons have same dynamic mass? If not, Why?
8. Why photoelectrons ejected from a metal surface have different kinetic energies although the frequency of incident photons are same?

9. Find the ratio of de-Broglie wavelengths associated with two electrons 'A' and 'B' which are accelerated through 8V and 64 volts respectively.

10. Explain the terms stopping potential and threshold frequency.

11. How does the maximum kinetic energy of emitted electrons vary with the increase in work function of metals?

12. Define distance of the 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?

13. An a particle and a proton are accelerated by same potential. Find ratio fo their de Broglie wavelengths. **Ans.** $[1:2\sqrt{2}]$

14. Which of the following radiations α, β and γ are :

(i) similar to x-rays?

(ii) easily absorbed by matter

(iii) travel with greatest speed?

(iv) similar to the nature of cathode rays?

15. Some scientist have predicted that a global nuclear war on earth would be followed by 'Nuclear winter'. What could cause nuclear winter?

16. If the total number of neutrons and protons in a nuclear reaction is conserved how then is the energy absorbed or evolved in the reaction?

17. In the ground state of hydrogen atom orbital radius is 5.3×10^{-11} m. The atom is excited such that atomic radius becomes 21.2×10^{-11} m. What is the principal quantum number of the excited state of atom?

18. Calculate the percentage of any radioactive substance left undecayed after half of half life.

19. Why is the density of the nucleus more than that of atom?

20. The atom $_8O^{16}$ has 8 protons, 8 neutrons and 8 electrons while atom $_4Be^8$ has 4 proton, 4 neutrons and 4 electrons, yet the ratio of their atomic masses is not exactly 2. Why?

21. What is the effect on neutron to proton ratio in a nucleus when β^- particle is emitted ? Explain your answer with the help of a suitable nuclear reaction.

22. Why must heavy stable nucleus contain more neutrons than protons?

23. Show that the decay rate R of a sample of radio nuclide at some instant is related to the number of radio active nuclei N at the same instant by the expression R = – Nλ.

24. What is a nuclear fusion reaction? Why is nuclear fusion difficult to carry out for peaceful purpose?

25. Write two characteristic features of nuclear forces which distinguish them from coulomb force.

26. Half life of certain radioactive nuclei is 3 days and its activity is 8 times the 'safe limit'. After how much time will the activity of the radioactive sample reach the 'safe limit'?

27. Derive $mvr = \frac{nh}{2\pi}$ using de-Broglie equation.

28. Draw graph of number of scattered particles to scattering angle in Ratherford's experiment.

29. If the energy of a photon is 25 eV and work function of the material is 7eV, find the value of slopping potential.

30. What is the shortest wavelength present in the (i) Paschen series (ii) Balmer series of spectral lines?

Ans. (i) 820nm, (ii) 365 nm

31. The radius of the inner most electron orbit of a hydrogen atom 0.53 Å. What are the radii of the n = 2 and n = 3 orbits. [**Hint:** $r = n^2 r_0$)

32. The ground state energy of hydrogen atom is –13.6 eV. What are the kinetic and potential energies of the electron in this state?

[**Hint :** K.E = – (T.E), P.E. = 2T.E]

33. Why is the wave nature of matter not more apparent to our daily observations ?

34. From the relation $R = R_0 A^{1/3}$ where R_0 is a constant and A is the mass number of a nucleus, show that nuclear matter density is nearly constant.

Ans. Nuclear matter density = $\frac{\text{Mass of nucleus}}{\text{Volume of nucleus}}$

$$= \frac{mA}{\frac{4}{3}\pi R^3} = \frac{mA}{\frac{4}{3}\pi R_0^3 A}$$

$$= \frac{m}{\frac{4}{3}\pi R_0^3} = 2.3 \times 10^{17} \text{ kg / m}^3$$

$$= \text{Constant}$$

35. Find the energy equivalent of one atomic mass unit in joules and then in MeV.

Ans. E = Δmc^2 $\Delta m = 1.6605 \times 10^{-27}$ kg

$$= 1.6605 \times 10^{-27} \times (3 \times 10^8)^2$$

$$= 1.4924 \times 10^{-4} J$$

$$= \frac{1.4924 \times 10^{-10}}{1.6 \times 10^{-19}} eV$$

$$= 0.9315 \times 10^9 \text{ eV}$$

$$= 931.5 \text{ MeV}$$

36. Write four properties of nuclear force.

SHORT ANSWER QUESTIONS (3 Marks)

1. Explain the working of a photocell? Give its two uses.
2. Find the de-Broglie wavelength associated with an electron accelerated through a potential difference V.
3. What is Einstein's explanation of photo electric effect? Explain the laws of photo electric emission on the basis of quantum nature of light.
4. Light of intensity I and frequency v is incident on a photosensitive surface and causes photoelectric emission. Justify with the help of graph, the effect on photoelectric current when
   (i) the intensity of light is gradually increased
   (ii) the frequency of incident radiation is increased
   (iii) the anode potential is increased
   In each case, all other factors remain the same.
5. Write Einstein's photoelectric equation. State Clearly the three salient features observed in photoelectric effect which can be explained on the basis of the above equation.
6. Explain the effect of increase of (i) frequency (ii) intensity of the incident radiation on photo electrons emitted by a metal.
7. X-rays of wave length λ fall on a photo sensitive surface emitting electrons. Assuming that the work function of the surface can be neglected, prove that the de-Broglie wavelength of electrons emitted will be $\sqrt{\frac{h\lambda}{2mc}}$.

Ans. $E = \frac{hc}{\lambda} = \frac{P^2}{2m} \therefore P = \sqrt{\frac{2mnc}{\lambda}}, \lambda_e = \frac{h}{P} = \sqrt{\frac{h\lambda}{2mc}}$

8. A particle of mass M at rest decays into two particles of masses m_1 and m_2 having velocities V_1 and V_2 respectively. Find the ratio of de-Broglie wavelengths of the two particles.

Ans. 1 : 1

9. Give one example of a nuclear reaction. Also define the Q-value of the reaction. What does $Q > 0$ signify?

10. Explain how radio-active nucleus can emit β-particles even though nuclei do not contain these particles. Hence explain why the mass number of radioactive nuclide does not change during β-decay.

11. Define the term half life period and decay constant. Derive the relation between these terms.

12. State the law of radioactive decay. Deduce the relation $N = N_0 e^{-\lambda t}$, where symbols have their usual meaning.

13. Give the properties of α-particles, β-particles and γ-rays.

14. With the help of one example, explain how the neutron to proton ratio changes during alpha decay of a nucleus.

15. Distinguish between nuclear fusion and fission. Give an example of each.

16. A radioactive nucleus A undergoes a series of decays according to following scheme

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

The mass number and atomic number of A_4 are 172 and 69 respectively. What are these numbers for A ?

Ans. Mass no. of A = 180, Atomic no. of A = 72

17. Obtain a relation for total energy of the electron in terms of orbital radius. Show that total energy is negative of K.E. and half of potential energy.

$$E = \frac{-e^2}{8\pi\varepsilon_0 r}$$

18. Draw energy level diagram for hydrogen atom and show the various line spectra originating due to transition between energy levels.

19. The total energy of an electron in the first excited state of the hydrogen atom is about – 3.4 eV. What is

(a) the kinetic energy,

(b) the potential energy of the electron?

(c) Which of the answers above would change if the choice of the zero of potential energy in changed to (i) + 0.5 eV (ii) – 0.5 eV.

Ans. (a) When P.E. is chosen to be zero at infinity E = – 3.4 eV, using E = – K.E., the K.E. = + 3.4 eV.

(b) Since P.E. = – 2E, PE = – 6.8 eV.

(c) If the zero of P.E. is chosen differently, K.E. does not change. The P.E. and T.E. of the state, however would alter if a different zero of the P.E. is chosen.

(i) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be – 3.4 – 0.5 = – 3.9 eV.

(ii) When P.E. at ∞ is + 0.5 eV, P.E. of first excited state will be – 3.4 – (– 0.5) = – 2.9 eV.

20. What is beta decay? Write an equation to represent β^- and β^+ decay. Explain the energy distribution curve is β decay.

21. Using energy level diagram show emission of γ rays by $^{60}_{27}Co$ nucleus and subsequent β decay to obtain $^{60}_{28}Ni$.

LONG ANSWER QUESTIONS (5 Marks)

1. State Bohr's postulates. Using these postulates, derive an expression for total energy of an electron in the n^{th} orbit of an atom. What does negative of this energy signify?

2. Define binding energy of a nucleus. Draw a curve between mass number and average binding energy per nucleon. On the basis of this curve, explain fusion and fission reactions.

3. State the law of radioactive disintegration. Hence define disintegration constant and half life period. Establish relation between them.

4. What is meant by nuclear fission and fusion. Draw Binding Energy Vs Mass Number curve and explain four important features of this curve.

5. Briefly explain Rutherford's experiment for scattering of α particle with the help of a diagram. Write the conclusion made and draw the model suggested.

NUMERICALS

1. Ultraviolet light of wavelength 350 nm and intensity 1 W/m^2 is directed at a potassium surface having work function 2.2eV.

(i) Find the maximum kinetic energy of the photoelectron.

(ii) If 0.5 percent of the incident photons produce photoelectric effect, how many photoelectrons per second are emitted from the potassium surface that has an area $1 cm^2$.

$$E_{Kmax} = 1.3 \text{ eV};\ n = 8.8\times10^{11} \frac{\text{photo electron}}{\text{second}} \text{ or } r = \frac{Nh\nu}{t} = nh\nu$$

2. A metal surface illuminated by 8.5×10^{14} Hz light emits electrons whose maximum energy is 0.52 eV the same surface is illuminated by 12.0×10^{14} Hz light emits elections whose maximum energy is 1.97eV. From these data find work function of the surface and value of Planck's constant. [Work Function = 3eV]

3. An electron and photon each have a wavelength of 0.2 nm. Calculate their momentum and energy.

(i) 3.3×10^{-24} kgm/s

(ii) 6.2 keV for photon

(iii) 38eV for electron

4. What is the (i) Speed (ii) Momentum (ii) de-Broglie wavelength of an electron having kinetic energy of 120eV?

Ans. (a) 6.5×10^6 m/s; (b) 5.92×10^{-24} kg m/s; (c) 0.112 nm.

5. If the frequency of incident light in photoelectric experiment is doubled then does the stopping potential become double or more than double, justify? (More than double)

Long Answer Question :

6. **(A)** Why wave theory of light could not explain the photoelectric effect? State two reasons. Draw graph between

(i) frequency ν vs stopping potential V_0.

(ii) Intensity vs photoelectric current.

(iii) anode potential vs photoelectric current.

6.(B) A proton is accelerated through a potential difference V. Find the percentage increase or decrease in its de-Broglie wavelength if potential difference is increased by 21%.

(9.1%)

7. For what kinetic energy of a neutron will the associated de-Broglie wavelength be 5.6×10^{-10}m?

Ans.
$$\sqrt{2m_n \times \text{K.E.}} = \frac{h}{\lambda}$$

$$\Rightarrow \quad \text{K.E.} = \left(\frac{h}{\lambda}\right)^2 \frac{1}{2m_n}$$

$$= \left(\frac{6.625\times10^{-34}}{5.6\times10^{-10}}\right)^2 \frac{1}{2\times1.67\times10^{-27}}$$

$$= 3.35 \times 10^{-21}\text{J}$$

8. A nucleus of mass M initially at rest splits into two fragments of masses $\frac{M}{3}$ and $\frac{2M}{3}$. Find the ratio of de-Broglie wavelength of the fragments.

Ans. Following the law of conservation of momentum,

$$\frac{M}{3}v_1 + \frac{2M}{3}v_2 = 0$$

or
$$\left|\frac{M}{3}v_1\right| = \left|\frac{2M}{3}v_2\right|$$

$$\lambda = \frac{h}{mv} \Rightarrow \left|\frac{\lambda_1}{\lambda_2}\right| = \left|\frac{2\frac{M}{3}v_2}{\frac{M}{3}v_1}\right| = 1$$

9. An electron and a proton are possessing same amount of K.E., which of the two have greater de-Broglie, wavelength? Justify your answer.

Ans.
$$E_e = \frac{1}{2}m_e v_e^2$$

and
$$E_p = \frac{1}{2}m_p v_p^2$$

$$\Rightarrow \quad m_e v_e = \sqrt{2E_e m_e} \text{ and } m_p v_p = \sqrt{2E_p m_p}$$

But, $E_e = E_p \Rightarrow \frac{\lambda_e}{\lambda_p} = \sqrt{\frac{m_p}{m_e}} > 1$

$\therefore$ $\lambda_e > \lambda_p$.

10. The electron in a given Bohr orbit has a total energy of –1.51 eV. Calculate the wavelength of radiation emitted, when this electon makes a transition to the ground state.

Ans. 1028 A°

11. Calculate the radius of the third Bohr orbit of hydrogen atom and energy of electron in third Bohr orbit of hydrogen atom.

Ans. (–1.51 eV)

12. Calculate the longest and shortest wavelength in the Balmer series of Hydrogen atom. Rydberg constant = 1.0987×10^7 m^{-1}.

Ans. λ_l = 6553 A°, λ_s = 3640A°

13. What will be the distance of closest approach of a 5 MeV a-particle as it approaches a gold nucleus? (given Atomic no. of gold = 79)

Ans. 4.55×10^{-14}m

14. A 12.5 MeV alpha – particle approaching a gold nucleus is deflected 180°. What is the closest distance to which it approaches the nucleus?

Ans. 1.82×10^{-14}m

15. Determine the speed of the electron in $n = 3$ orbit of hydrogen atom.

Ans. $7.29 \times 10^5 ms^{-1}$

16. There are $4\sqrt{2}\times10^6$ radioactive nuclei in a given radio active element. If half life is 20 seconds, how many nuclei will remain after 10 seconds?

Ans. 4×10^6

17. The half life of a radioactive substance is 5 hours. In how much time will 15/16 of the material decay?

Ans. 20 hours

18. At a given instant, there are 25% undecayed radioactive nuclei in a sample. After 10 seconds, the number of undecayed nuclei reduces 12.5%. Calculate the mean life of nuclei.

Ans. 14.43

19. Binding energy of $_2He^4$ and $_3Li^7$ nuclei are 27.37 MeV and 39.4 MeV respectively. Which of the two nuclei is more stable? Why?

Ans. $_2He^4$ because its BE/nucleon is greater.

20. Find the binding energy and binding energy per nucleon of nucleus $_{83}B^{209}$.

Given : mass of proton = 1.0078254 u. mass of neutron = 1.008665 u.

Mass of $_{83}Bi^{209}$ = 208.980388u.

Ans. 1639.38 MeV and 7.84 MeV/Nucleon

21. Is the fission of iron ($_{26}Fe^{56}$) into ($_{13}Al^{28}$) as given below possible?

$_{26}Fe^{56} \rightarrow {}_{13}Al^{28} + {}_{13}Al^{28} + Q$

Given mass of $_{26}Fe^{56}$ = 55.934940 and $_{13}Al^{28}$ = 27.98191 U

Ans. Since Q value comes out negative, so this fission is not possible

22. Find the maximum energy that β-particle may have in the following decay :

$_8O^{19} \rightarrow {}_9F^{19} + {}_{-1}e^0 + \vec{v}$

Given m ($_8O^{19}$) = 19.003576 a.m.u.

m ($_9F^{19}$) = 18.998403 a.m.u.

m ($_{-}e^0$) = 0.000549 a.m.u.

Ans. 4.3049 MeV

23. The value of wavelength in the lyman series is given as

$$\lambda = \frac{913.4 n_i^2}{n_i^2 - 1} \text{ Å}$$

Calculate the wavelength corresponding to transition from energy level 2, 3 and 4. Does wavelength decreases or increase.

Ans.

$$\lambda_{21} = \frac{913.4 \times 2^2}{2^2 - 1} = 1218 \text{ Å}$$

$$\lambda_{31} = \frac{913.4 \times 3^2}{3^2 - 1} = 1028 \text{ Å}$$

$$\lambda_{41} = \frac{913.4 \times 4^2}{4^2 - 1} = 974.3 \text{ Å}$$

$\lambda_{41} < \lambda_{31} < \lambda_{21}$

24. The half life of $^{238}_{92}U$ undergoing α decay is 4.5×10^9 years what is the activity of 1g. sample of $^{238}_{92}U$.

Ans.

$$T_{1/2} = 4.5 \times 10^9\ y$$
$$= 4.5 \times 10^9 \times 3.16 \times 10^7 s$$
$$= 1.42 \times 10^{17}\ s$$

$$1g \text{ of } ^{238}_{92}U \text{ contains} = \frac{1}{238} \times 6.025 \times 10^{23} \text{ atom}$$
$$= 25.3 \times 10^{20} \text{ atoms}$$

$\therefore$ $$\text{decay rate} = R = \lambda N = \frac{0.693}{T} \times N$$
$$= \frac{0.693 \times 25.3 \times 10^{20}}{1.42 \times 10^{17}} s^{-1}$$
$$= 1.23 \times 10^4 \text{ bq.}$$

Answer to 2 Marks Question

1. Similarity : Both follow wave equation (partial differential equation) dissimilarity : Matter waves

(a) cannot be radiated in empty space.

(b) are associated with the particles, not emitted by it

2. Yes, $\lambda = \dfrac{hc}{E}$

3. $\lambda = \dfrac{h}{p}$ for photon $P = \dfrac{E}{C}$ and $\lambda = \dfrac{hc}{E}$ for electron $P = \sqrt{2M\ E}$

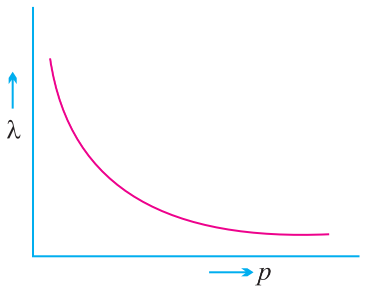
$\lambda_{photon} = 2.4 \times 10^{-8}$m, $\lambda_{electron} = 3.6 \times 10^{-10}$m

4. $\lambda = 3300A^o$, $E = \dfrac{hc}{\lambda} = \dfrac{6.6 \times 10^{-34} \times 3 \times 10^8}{3300 \times 10^{-10} \times 1.6 \times 10^{-19}} eV \approx 3.8$ eV

Work function of M_o & Ni > 3.8 eV hence no photoelectron emission from M_o and Ni.

5. $$\lambda = \frac{h}{p}$$

$\Rightarrow$ $$\lambda \ \alpha \ \frac{1}{p}$$



6. Q

K.E.$_{max}$ ≈ 1.3 eV As $\frac{h\nu_0}{e} = -2V$

7. $E = mc^2$, $h\nu = mc^2$, $m = \frac{h\nu}{c^2}$, no, it depends upon frequency.

8. $KE = h\nu - h\nu_0$. The electrons in the atom of metal occupy different energy levels, thus have different minimum energy required to be 'ejected' from the atom. So the e^- with higher energy will have higher kinetic energy.

9. Decreases, $\lambda = \frac{1}{\sqrt{V}} \therefore \frac{\lambda_1}{\lambda_2} = \frac{2\sqrt{2}}{1}$

11. $KE_{max} = h\nu - w_0 \Rightarrow KE_{max}$ decreases with increase in w_0.

12. Distance of closest approach is defined as the minimum distance between the charged particle and the nucleus at which initial kinetic energy of the particle is equal to electrostatic potential energy.

for α particle, $\frac{K\,Ze(2e)}{r} = \frac{1}{2}mv_\alpha^2$

$$r \propto \frac{1}{K.E.}$$

$\therefore$ r will be halved.

14. (i) Similar to x-rays — γ-rays.

(ii) α-particle.

(iii) γ-rays.

(iv) β-particle.

15. Nuclear radioactive waste will hang like a cloud in the earth atmosphere and will absorb sun radiations.

16. The total binding energy of nuclei on two sides need not be equal. The difference in energy appears as the energy released or absorbed.

17. $n = 2$ as $r_n \propto n^2$

18. From relation $\frac{N}{N_0} = \left(\frac{1}{2}\right)^{t/T}$ when $t = T/2$

$$\frac{N}{N_0} = \left(-\right)^{1/2}$$

or $$\frac{N}{N_0} = \frac{1}{\sqrt{2}} = \frac{100}{\sqrt{2}} = 70.9 \ \%$$

19. Because radius of atom is very large than radius of nucleus.

20. Due to mass defect or different binding energies.

21. Decreases as number of neutrons decreases and number of protons increases. $N \rightarrow P + {}_{-1}e^0$

22. To counter repulsive coulomb forces, strong nuclear force required between neutron-neutron, neutron-proton and proton-proton.

23. $N = N_0 e^{-\lambda t}$ differentiating both sides we get $\frac{dN}{dt} = -\lambda N_0 e^{-\lambda t} = -\lambda N$ *i.e.*, decay rate

$$R = -\frac{dN}{dt} = \lambda N$$

24. For fusion, temperature required is from 10^6 to 10^7 K. So, to carry out fusion for peaceful purposes we need some system which can create and bear such a high temperature.

25. Nuclear forces are short range forces (within the nucleus) and do not obey inverse square law while coulomb forces are long range (infinite) and obey inverse square law.

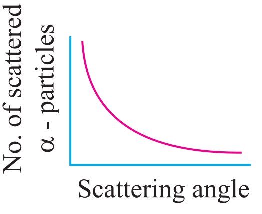
26. $$\left(\frac{A}{8A}\right) = \left(\frac{1}{2}\right)^{t/T_{1/2}}$$

or $$\left(\frac{1}{2}\right)^{3} = \left(\frac{1}{2}\right)^{t/3}$$

or $$3 = \frac{t}{3}$$

$\Rightarrow$ $$t = 9 \text{ days.}$$

28.



29. $$V_0 = (E - \phi_0)/e = \frac{(25-7)eV}{e} = 18V.$$

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