SHIKSHA CLASSES

Subject : Physics **BOARD ANSWER PAPER** **Total Marks : 20**
Class : XII **Topic: 15. Structure of Atoms and Nuclei**

Section (A)

Q.1. (a) Select and write the most appropriate answer from given alternatives in each sub-question [5]

1. The wavelength limit (series Limit) present in the P-fund series is ($R=1.097 \times 10^7 \, m^{-1}$)

Ans : c) 2278×10^{-9} m

$$\frac{1}{\lambda} = R\left[\frac{1}{5^2} - \frac{1}{n^2}\right] \text{ for series limit}$$

$x = \infty$

$$\lambda_{Min} = \frac{25}{R} = 2278 \times 10^{-9} \, m$$

2. A hydrogen atom initially in the ground level absorbs a photon and is excited to n=4 level then the wavelength of photon is -

Ans : c) $970 A^0$

$$\text{Hint : } E = E_2 = E_1 = 13.6\left(\frac{1}{1^2} - \frac{1}{4^2}\right)$$

$$= 13.6 \times \frac{15}{16} \times 1.6 \times 10^{-19}$$

$$\boxed{E = 2.04 \times 10^{-18} J}$$

$$\lambda = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^8}{2.04 \times 10^{-18}}$$

$\lambda = 9.7 \times 10^{-8}$ m = 970 A^0

3. A radioactive element x with half life 2 hrs.decays giving a stable element y. After a time t, ratio of x and y atoms is 1:16. Time t is

Ans : a) 8 hours

initial amount of radioactive element

$= x + y = 1 + 16 = 17$

Now $N = N_0 \left(\frac{1}{2}\right)^n$

$$\therefore 1 = 16\left(\frac{1}{2}\right)^n = \left(\frac{1}{2}\right)^4 = \left(\frac{1}{2}\right)^n$$

$$\boxed{n = 4}$$

Required lime period

$$t = nT_{\frac{1}{2}} = 4 \times 2$$

T = 8 hours

4. In nuclear reaction there is conservation of

Ans : **(d)** mass energy and momentum

5. The radius of nucleus of mass number 3 is R. Then the radius of nucleus of mass number 81 is ------.

Ans : a) 3 R

Nuclear radius is proportional to $A^{1/3}$ where, A is mass number of nucleus.

i.e., $R \propto A^{1/3}$

$$\frac{R_1}{R_2} = \left[\frac{A_1}{A_2}\right]^{1/3}$$

$$\frac{R}{R_2} = \left[\frac{3}{81}\right]^{1/3}$$

$$or \frac{R}{R_2} = \frac{1}{3} \; or \; R_2 = 3R$$

(b) Very short answer type Question [2]

1) Define ionization energy.

Ans. : **Ionization energy :** The minimum amount of energy required to be provided to an electron to pull it out of the metal from the surface is called the.

2) Define decay constant.

Ans. : The decay constant of radioactive element is the ratio of number of nuclei decaying perunit time to the number of unchanged nuclei present at that time.

Section (B)

Q.2 Attempt any three. [6]

1) Write short notes on Thomson's model.

Ans. : Thomson atomic model was proposed by William Thomson in the year 1900. This model explained the description of an inner structure of the atom theoretically. It was strongly supported by Sir Joseph Thomson, who had discovered the electron earlier.

Postulates of Thomson's atomic model

Postulate 1: An atom consists of a positively charged sphere with electrons embedded in it

Postulate 2: An atom as a whole is electrically neutral because the negative and positive charges are equal in magnitude

Thomson atomic model is compared to watermelon. Where he considered:

i) Watermelon seeds as negatively charged particles

ii) The red part of the watermelon as positively charged

Limitations of Thomson's atomic model

i) It failed to explain the stability of an atom because his model of atom failed to explain how a positive charge holds the negatively charged electrons in an atom. Therefore, This theory also failed to account for the position of the nucleus in an atom

ii) Thomshon's model failed to explain the scattering of alpha particles by thin metal foils

2) State limitations of Bohr's model.

Ans. : Limitations of Bohr Atomic Model Theory

i) It violates the Heisenberg Uncertainty Principle. The Bohr atomic model theory considers electrons to have both a known radius and orbit i.e. known position and momentum at the same time, which is impossible according to Heisenberg.

ii) The Bohr atomic model theory made correct predictions for smaller sized atoms like hydrogen, but poor spectral predictions are obtained when larger atoms are considered.

iii) It failed to explain the Zeeman effect when the spectral line is split into several components in the presence of a magnetic field.

iv) It failed to explain the Stark effect when the spectral line gets split up into fine lines in the presence of an electric field.

3) An electron make a transition from orbit n=4 to the orbit n=2 of a hydrogen atom. What is the wave number of emitted radiation ?

Ans. : Transition of hydrogen atom from orbit $= n_1 = 2 \,\&\, n_2 = 4$

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

$$= R\left[\frac{1}{2^2} - \frac{1}{4^2}\right] = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= R\left[\frac{1}{4} - \frac{1}{16}\right]$$

$$= R\left[\frac{16-4}{64}\right]$$

$$= R\left[\frac{12}{64}\right]\frac{1}{\lambda} = R\left[\frac{3}{16}\right] = \frac{3R}{16}$$

4. Calculate the de Broglie wavelength of a proton if it is moving with the speed of 2×10^5 m/s

(m_p=1.673 × 10^{-27} kg)

Ans : Given data :

$V = 2 \times 10^5$ m/sec

$M_p = 1.673 \times 10^{-27}$ Kg $\qquad \lambda = \frac{h}{mv}$

$$\lambda = \frac{6.63\times10^{-34}}{1.673\times10^{-27}\times2\times10^5}$$

$$\lambda = \frac{6.63\times10^{-34}}{3.346\times10^{-27}}$$

$\lambda = 1.98 \times 10^{-12}$

$\lambda = 0.0198$ A^0

Section (C)

Q.3 Attempt any one. **[3]**

1. State the postulates of Bohr's theory of hydrogen atom. Write the necessary equations.

Ans : **Postulate :** The electron in a hydrogen atom revolves in circular orbit around the nucleus with nucleus at the centre of orbit the necessary centripetal force for circular motion is provided by electrostatic force of attraction between the positively charged nucleus and negatively charged electron

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0} \quad \frac{e^2}{r^2}$$

Postulate 2 : The electron revolves around the nucleus only in those orbit for which the angular momentum is equal to an integral multiple of h/2π.

Where h = planck's constant.

$$\text{angular momentum} = \frac{nh}{2\pi}$$

$$\therefore \quad mvr = \frac{nh}{2\pi}$$

iii) When electron jumps from orbits of higher energy so an orbit of lower energy it radiants energy in the form of quanta or photons the energy of emitted photon is equal to the difference between energy of two orbits in which transition is taking place.

Energy radiaved = hυ

$\therefore$ hυ = En – Ep

2. A hydrogen atom undergoes a transition from a state with $n = 4$ to a state with $n = 1$ calculate the change in the angular momentum of the electron and the wavelength of the electron and the wavelength of the entitled radiation.

(h=6.63 × 10^{-34} JS, R=1.097 × 10^{7} m^{-1})

Ans : **Given :** $h = 6.63 \times 10^{-34}$

$R = 1.097 \times 10^{7}\ m^{-1}$

$n = 4 \ \ \& \ \ n = 1$

i) Change in angular momentum

$$= mvr = \frac{4h}{2\pi}$$

$$= \frac{4h}{2\pi} - \frac{h}{2\pi} \ = \frac{3h}{2\pi}$$

$$= \frac{3 \times 6.63 \times 10^{-34}}{2 \times 3.14}$$

$$= \frac{19.89}{6.28} \times 10^{-34} \ = 3.16 \times 10^{-34}$$

Wavelength of entitled radiation

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

$$\frac{1}{\lambda} = 1.097 \times 10^{-7} \left(\frac{1}{1^2} - \frac{1}{4^2}\right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^{-7} \left(\frac{15}{16}\right)$$

$$\lambda = 0.9726 \times 10^{-7}\ m$$

Section (D)

Q.4 Attempt any one. **[4]**

1) a. State the law of radioactive decay. Hence derive the relation $N = N_0 e^{-\lambda t}$ where the symbols have their usual meanings.

Ans: **Law of radioactive decay :** The number of nuclei under going the decay per unit time is proportional to the number of unchanged nuclei present at that instant.

$$\frac{dN}{dt} \propto N \quad \text{or} \quad \frac{dN}{dt} = -\lambda \ N$$

λ - decay constant

$$\text{From eqution (i)} \ \frac{dN}{N} = -\lambda dt$$

Integrating both sides

$$\int \frac{dN}{N} = \int -\lambda\, dt$$

$$\log_e N = -\lambda t + c$$

Where C is constant of integration. Whose value depends upon intial conditions.

At t = 0;

$N = N_0$ (no. of original nuclei)

$\therefore \quad \log_e N_O = O + C$

Substituting the value in above expression

$\log_e N = -\lambda t + \log_e N_O$

$\log_e N - \log_e N_O = -\lambda t$

$\log_e N - \log_e N_O = -\lambda t$

$$\log_e = \left(\frac{N}{N_0}\right) = -\lambda t$$

$$\frac{N}{N_0} = e^{-\lambda t} \quad \text{or } N = N_O e^{-\lambda t}$$

Where $N = N_O$ of nuclei present at any instant 't'

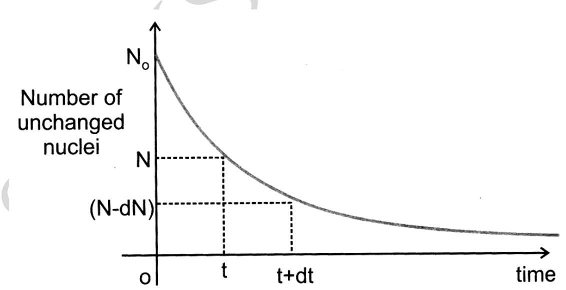
No. =- No. of original nuclei

λ = decay constant

b. Show graphically how the number of nuclei (N) of radioactive element varies with time (t).

Protactinium $^{233}_{91}Pa$ decays to $\left(\frac{1}{5}\right)^{th}$ of it's initial quantity in 62.7 days. Calculate the decay constant, mean life and halflife.

Ans: **Graph :** the no. of nuclei of given radioactive substance decrease exponentially with time.



Protactinium $^{233}_{91}$Pa decay

1) decay constant =

$N = No\ e^{-\lambda t}$

$N = \frac{1}{5}$ of No $\quad t = 62.7$ days

$$\frac{1}{5} = e^{-62.7} \qquad 5 = e^{62.7\lambda}$$

$62.7\,\lambda = \log_e 5$

$62.7\,\lambda = 2.303 \times \log_{10} 5$

$62.7\,\lambda = 2.303 \times 0.6990$

$\lambda = 0.02056$ p.r. day

2. Half life - $t_{1/2} = \frac{0.693}{\lambda}$

$$= \frac{0.693}{0.0256}$$

$t_{1/2} = 27.07$ day

3. Mean life : $\frac{1}{\lambda} = \frac{1}{0.0256}$

meanlife = 39.06 day

OR

2) a. Derive an expression for the radius of the n^{th} Bohr orbit in a hydrogen atom. Hence,show that the radius of the orbit is directly proportional to the square of the principle quantum number. What is series limit ?

Ans: Expression for radius of n^{th} Bohr orbit of hydrogen atom.

Consider and electron revolving around the nucleus in circular orbit of radius 'r' According to Bohr's First orbit.

Centripetal Force = Electrostatic Force of attraction

$$\frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0}\frac{e^2}{r^2}$$

$$\text{or } v^2 = \frac{e^2}{4\pi\varepsilon_0 mr}$$

According so 2nd Bohr possulates

$$\text{Angular momentum} = \frac{nh}{2\pi}$$

$$mvr = \frac{nh}{2\pi}$$

$$v = \frac{nh}{2\pi mr}$$

$$v^2 = \frac{n^2h^2}{4\pi^2m^2r^2}$$

Comparing equation (ii) & (iii) we get

$$\frac{e^2}{4\pi\varepsilon_0 mr} = \frac{n^2h^2}{4\pi^2m^2r^2}$$

$$r = \left(\frac{h^2\varepsilon_0}{\pi me^2}\right)n^2$$

This equation gives the radius of Bohr orbit

$$n = 1 \quad r_n = \left(\frac{h^2\varepsilon_0}{\pi me^2}\right)n^2$$

or $r_n = r_1 n^2$ ..... (vi)

$r \propto n^2$

The radius of Bohrs orbit is directly propostional so the square of principal quantums number

The smallest wavelength emitted in a series is called series limit.

b. The short wavelength limit of the Lyman series is 911.3 A^0. Calculate the short wavelength limit of the Balmer series.

Ans: Calculate short wavelength limit of lymen series.

lymen series - 911. 3 A^0

$$\lambda_B = \frac{4}{R} = 4\times 911.3 (4\times\lambda L)$$

$\lambda_B = 3645.2\ A^0$

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