Next in the series is MODERN PHYSICS

By modern Physics we mean that Dual Nature, Atoms and Nuclei

For any competition this chapter is very important as it fetches about 10% by studying very less. Actually this topic has got very few equations to learn. We will take all the topics in sequence.

What was the need for this chapter ? Actually the photoelectric effect of light could not be explained by wave nature of LIGHT, so it is considered a particle. The ONLY aspect one has to understand the basis of particle nature is ONE electron in this effect will collide with only one electron.

First we take Dual Nature, in which we presume that electron has nature of particle as well as wave. As a particle we have its mass given as 9.1×10^{-31} kg and charge as 1.6×10^{-19} C. But certain aspects can be proved only taken it as wave.

In that case KE = ½ mv^2 and momentum = mv with energy as ½(pv)

While in case of photon rest mass is zero and it has momentum of p.

Common term for both is to equated with wave length $\lambda = \dfrac{h}{p}$

For a particle nature $\lambda = \dfrac{h}{mv}$

For wave nature its momentum is p and wave length $\lambda = \dfrac{h}{p}$ and energy $E = pc$

We have terms in Dual nature as

Work Function: W The minimum energy required by electron to reach the surface. Now the wave length λ_0, whose energy equals to work function is termed as threshold wave length. Similarly the threshold frequency is the frequency, corresponding to which energy equals to work function.

Mathematically $W = h\nu_0 = \dfrac{hc}{\lambda_0}$

Second point to know is the stopping potential V_0. It is reverse potential which will stop the photoelectric current completely. In other words it is a measure of kinetic energy of photoelectron emitted.

Mathematically $KE = \dfrac{1}{2}mv^2 = eV_0$

Then we have principle of conservation of energy depicted by Einstein equation. in various forms.

$$h\nu = h\nu_0 + eV_0 = W + eV_0 = h\nu_0 + \frac{1}{2}mv^2 = W + \frac{1}{2}mv^2$$

Graph of frequency Vs Stopping Potential can get value of Plank constant and threshold frequency.

Intensity in particle nature is number of photons per unit area per second, while in wave nature, it is proportional to square of Amplitude. Hence increasing the intensity increases the number of photoelectrons emitted. Thus increasing the saturation current I = venA

On the other hand if frequency is increased, individual energy of photon is increased, but BOT number of photons, in such a case as expected, stopping potential increases and NOT the saturation current.

By Davisson Germer method, the scientist actually calculate the hypothetical or calculated wave length, with actual. Both were found to be very closed so it is said that de Broglie Hypothesis is valid.

Wave length as per de Broglie $\lambda = \dfrac{h}{mv}$; Now as $KE = \dfrac{1}{2}mv^2 \Rightarrow v = \sqrt{\dfrac{2E}{m}}$

We find $\lambda = \dfrac{h}{m\sqrt{\dfrac{2eE}{m}}} = \dfrac{h}{\sqrt{2mE}}$ at times we are given KE = eV, we use it accordingly then.

Next is Atoms, we have studies Dalton, Thompson, Rutherford and their drawbacks, here Bohr gave hypothesis.

In the Ruther ford experiment we can calculate the distance of closest approach.

Logic for this that at large distance we have only Kinetic energy, and at closest point we have only potential energy

Mathematically,

Kinetic energy of $\alpha = \frac{1}{2}mv^2$

Potential energy $= \frac{1}{4\pi\varepsilon_0}.\frac{(Ze).(2e)}{r_0}$

Equating both we get, $r_0 = \frac{4Ze^2}{(4\pi\varepsilon_0)mv^2}$

With Bohr hypothesis we can calculate the potential energy, and kinetic energy of electron. Final energy come to be negative, which confirms the stability of the system.

Now we try to find the velocity and radius of electron orbit.

$v = \frac{2\pi k Z e^2}{nh}$ Now we can say $v \propto \frac{Z}{n}; r = \frac{n^2 h^2}{4\pi^2 m k Z e^2}$ Now we can say $r \propto \frac{n^2}{Z}$

$KE = \frac{1}{2}mv^2 = \frac{2\pi^2 mk^2 Z^2 e^4}{n^2 h^2}$; $\quad PE = -\frac{4\pi^2 mk^2 Z^2 e^4}{n^2 h^2}$

Total energy for electron is sum; $TE = E_n = -\frac{2\pi^2 mk^2 Z^2 e^4}{n^2 h^2} = -KE = \frac{PE}{2}$

Energy $\propto \frac{Z^2}{n^2}$

Here – ve sign indicates stability

We also try to find the wavelength of radiation emitted as the difference in energy

$\Delta E = E_{n_1} - E_{n_2} = h\nu$

$\Rightarrow \; h\nu = \frac{2\pi^2 mk^2 e^4}{h^2}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$\Rightarrow \; \nu = \frac{2\pi^2 mk^2 e^4}{h^3}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

Defining $\bar{\nu} = \frac{1}{\lambda} = \frac{\nu}{c} = \frac{2\pi^2 mk^2 e^4}{ch^3}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$= R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ where $R = 10947900\ m^{-1}$ is called Rydberg constant.

LYMAN When electron jumps from $n_1 = 1$ to $n_2 = 2,3,4$.. we get spectral lines called Lyman series. They lie in the UV region of EM spectrum

BALMER When electron jumps from $n_1 = 2$ to $n_2 = 3,4,5$ we get Balmer series. This series lies in the Visible region of EM spectrum

Similarly we have Paschen, Bracket and Pfund series all of these lie in the infrared region. In these series n_1 starts from 3,4and 5 and subsequently n_2 are also starting from 4, 6 and 6.

Range of main series

Lyman: 1216 – 912 A^0

Balmer: 6563 –3646 A^0

Paschen: 18751 –8220 A^0

Obviously visible radiations fall only in Balmer series.

NUCLEUS

When the nucleus is big enough! It contains proton and neutron, Neutron is neutral but proton is positively charged, now as the number of protons increase the electrical repulsion increase. So why does heavy nucleus stays stable!

Answer is existence of strong nuclear forces which are :

Always attractive and also independent of charge!

These are short ranged forces.

So more number of neutrons, more attractive force and hence more stability, But still if the number of protons increase beyond the size of nucleus and number of neutrons, we can have unstable nucleus. Which breaks into smaller nucleus. This process is called fission, whereby an unstable nucleus breaks into two or more stable nucleus.

Similarly joining of two small nucleus to form large nucleus is called the fusion, which is responsible for the energy of SUN.

In decay on nucleus, it is first order chemistry reaction, also half life is similarly defined.

We have $N = N_0 e^{-\lambda t}$ and $t_{\frac{1}{2}} = \frac{0.693}{\lambda}$ and for $-\frac{dN}{dt} \propto N \Rightarrow \frac{dN}{dt} = -\lambda N$

NEET QUESTION

The de-Broglie wavelength of a neutron in thermal equilibrium with heavy water at a temperature T Kelvin and mass m, is:

(A) $\frac{h}{\sqrt{mkT}}$ (B) $\frac{h}{\sqrt{3mkT}}$ (C) $\frac{2h}{\sqrt{3mkT}}$ (D) $\frac{2h}{\sqrt{mkT}}$

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

A 2 B 1 C 4 D 0.5

Radioactive material 'A' has decay constant $'8\lambda'$ and material 'B' has decay constant$'\lambda'$. Initially they have same number of nuclei. After what time, the ratio of number of nuclei of material 'B' to that 'A' will be 1/e ?

(A) $\frac{1}{\lambda}$ (B) $\frac{1}{7\lambda}$ (C) $\frac{1}{8\lambda}$ (D) $\frac{1}{9\lambda}$

The photoelectric threshold wavelength of silver is 3250 10^{-10} m. The velocity of the electron ejected from a silver surface by ultraviolet light of wavelength 2536 10^{-10} m is

A $\approx 6 \times 10^5$ m/s B $\approx 0.6 \times 10^6$ $m/$

C $\approx 61 \times 10^3$ $m/$ D ≈ 0.3 10^6 $m/$

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Electrons of mass m with de-Broglie wavelength λ fall on the target in an X-ray tube. The cutoff wavelength λ_0 of the emitted X-ray is :-

(A) $\frac{2m^2c^2\lambda^3}{h^2}$ (B) λ (C) $\frac{2mc\lambda^2}{h}$ (D) $\frac{2h}{mc}$

Photons with energy 5 eV are incident on a cathode C in a photoelectric cell. The maximum energy of emitted photoelectrons is 2 eV. When photons of energy 6 eV are incident on C, no photoelectrons will reach the anode A, if the stopping potential of A relative to C is :-

1 − 1 V 2 − 3 V 3 3 V 4 4 V

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) $\frac{20}{7}\lambda$ (B) $\frac{20}{13}\lambda$ (C) $\frac{16}{25}\lambda$ (D) $\frac{9}{16}\lambda$

The half-life of a radioactive substance is 30 minutes. The time in minutes taken between 40% decay and 85% decay of the same radioactive substance is :-

A 45 B 60 C 15 D 30