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Modern Physics - Solutions

Sol.1.

(i) $E_2 = -13.6 / 4 Z^2$, $E_3 = -13.6 / 9 Z^2$

$E_3 - E_2 = -13.6 Z^2 (1/9 - 1/4) = +13.6 \times 5 / 36 Z^2$

But $E_3 - E_2 = 47.2$ eV (Given)

$\therefore 13.6 \times 5 / 36 Z^2 = 47.2 \therefore Z = \sqrt{47.2 \times 36 / 13.6 \times 5} = 5$

(ii) $E_4 = -13.6 / 16 Z^2$

$\therefore E_4 - E_3 = -13.6 Z^2 [1/16 - 1/9] = -13.6 Z^2 [9 - 16 / 9 \times 16]$

$= +13.6 \times 25 \times 7 / 9 \times 16 = 16.53$ eV

(iii) $E_1 = -13.6 / 1 \times 25 = -340$ eV

$\therefore E = E_\infty - E_1 = 340$ eV $= 340 \times 1.6 \times 10^{-19}$ J $[E_\infty = 0$ eV$]$

But $E = hc / \lambda$

$\therefore \lambda = hc / E = 6.6 \times 10^{-34} \times 3 \times 10^8 / 340 \times 10^{-19} \times 1.6 \times 10^{-19}$ m

(iv) Total Energy of 1st orbit = - 340 eV

We know that – (T.E.) = K.E. [in case of electron revolving around nucleus]

And 2T.E. = P.E.

$\therefore$ K.E. = 340 eV ; P.E. = - 680 eV

KEY CONCEPT :

Angular momentum in 1st orbit:

According to Bohr's postulate,

$mvr = nh / 2\pi$

For n = 1,

$mvr = h / 2\pi = 6.6 \times 10^{-34} / 2\pi = 1.05 \times 10^{-34}$ J-s.

(v) Radius of first Bohr orbit

$r_1 = 5.3 \times 10^{-11} / Z = 5.3 \times 10^{-11} / 5$

$= 1.06 \times 10^{-11}$ m

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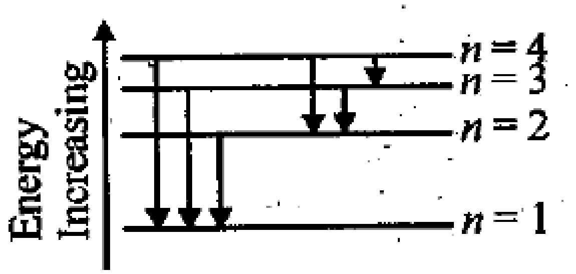
Sol.2.

$E = 12400 / \lambda \text{ (in Å) eV} = 12400 / 975 = 12.75 \text{ eV}$ ... (i)

Also

$13.6 [1 / n^2_1 - 1 / n^2_2] = 12.75 \Rightarrow [1/1 - 1/n^2_2] = 12.75 / 13.6 \Rightarrow n_2 = 4$

For every possible transition one downward arrow is shown therefore the possibilities are 6.



Note : For longest wavelength, the frequency should be smallest.

This corresponds to the transition from n = 4 to n = 3, the energy will be $E_4 = 13.6 / 4^2$; $E_3 = - 13.6 / 3^2$

$\therefore E_4 - E_3 = 13.6 / 4^2 - (- 13.6 / 3^2) = 13.6 [1/9 - 1/16]$

$= 0.66 \text{ eV} = 0.66 \times 1.6 \times 10^{-19} \text{ J} = 1.056 \times 10^{-19} \text{ J}$

Now, $E = 12400 / \lambda \text{ (inÅ) eV} \therefore \lambda = 18787$ Å

Sol.3.

(i) In a nucleus, number of electrons = 0 (∵ electrons don't reside in the nucleus atom)

(ii) number of protons = 11

(iii) number of neutrons = 24 – 11 = 13

Sol.4.

$^{238}_{92}U \longrightarrow {}^{234}_{90}X + {}^{4}_{2}He \qquad {}^{234}_{90}X \longrightarrow {}^{234}_{91}Y + {}^{0}_{-1}e$

(i) Atomic number = 91

(ii) Mass number = 234

Sol.5.

$hc / \lambda_1 - hc / \lambda_0 = K.E._1$ ....(i)

And $hc / \lambda_2 - hc / \lambda_0 = K.E._2$ ....(ii)

$\Rightarrow hc / \lambda_1 - hc / \lambda_2 = K.E._1 - K.E_2$

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$\Rightarrow hc\ [\lambda_2 - \lambda_1 / \lambda_1 \lambda_2] = K.E._1 - K.E_2$

$\therefore h = (K.E._1 - K.E._2)\lambda_1 \lambda_2 / c\ (\lambda_2 - \lambda_1)$

$= (1.8 - 4) \times 1.6 \times 10^{-19} \times 800 \times 10^{-10} \times 700 \times 10^{-10} / 3 \times 10^{8} \times (700 - 800) \times 10^{-10}$

$= 6.6 \times 10^{34}$ J.s.

Sol.6.

(i) $E_n = -$ I.E. / n^2 for Bohr's hydrogen atom.

Here, I.E. $= 4R \therefore E_n = -4R / n^2$

$\therefore E_2 - E_1 = -4R / 2^2 - (-4R / l^2) = 3R$ ...(i)

$E_2 - E_1 = hv = hc / \lambda$ ....(iii)

From (i) and (ii)

$hc / \lambda = 3R$

$\therefore \lambda = hc / 3R = 6.6 \times 10^{-34} \times 3 \times 10^8 / 2.2 \times 10^{-18} \times 3 = 300$Å

(ii) The radius of the first orbit

Bohr's radius of hydrogen atom $= 5 \times 10^{-11}$ m (given)

$|E_n| = +0.22 \times 10^{-17} Z^2 = 4R = 4 \times 2.2 \times 10^{-18}$

$\therefore Z = 2$

$\therefore r_n = r_0 / Z = 5 \times 10^{-11} / Z = 5 \times 10^{-11} / 2 = 2.5 \times 10^{-11}$ m

Sol.7.

(i) $E_n = -13.6 / n^2 Z^2$ eV / atom

For Li^{2+}, $Z = 3 \therefore E_n = -13.6 \times 9 / n^2$ eV / atom

$\therefore E_1 = -13.6 \times 9 / 1$ and $E_3 = -13.6 \times 9 / 9 = -13.6$

$\Delta E = E_3 - E_1 = -13.6 - (-13.6 \times 9)$

$13.6 \times 8 = 108.8$ eV /atom

$\Lambda = 12400 / E$ (in eV) Å $= 12400 / 108.8 = 114$ Å

(ii) The spectral line observed will be three namely $3 \longrightarrow 1$,

$3 \longrightarrow 2, \longrightarrow 1$.

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Sol.8.

K.E. = 0.0327 eV = 0.327 x 1.6 x 10^{-19} J

½ $m_n v^2_n$ = 0.0327 x 1.6 x 10^{-19}

⇒ v_n [2 x 0.0327 x 1.6 x 10^{-19}/ 1.675 x $10^{-27}]^{1/2}$

⇒ v_n = 0.25 x 10^4 m/s

Time taken by the neutron to travel 10 m will be

t = d / v_n = 10 / 0.25 x 10^4 = 4 x 10^{-3} s

Let the number of neutron initially be a.

λ = 0.693 / t_1 / 2 = 0.693 / 700 s^{-1}

We know that

t = 2.303 / λ log a / a – x

⇒ 4 x 10^{-3} / 2.303 x 0.693 / 700 = 1=$\log_{10}$ a / a – x

⇒ $\log_{10}$ a / a – x = 1.72 x 10^{-6} ⇒ a / a – x = 1.000004

⇒ x / a = 3. 96 x 10^{-6}

Sol.9.

I = 0.125 V – 7.5

⇒ dl = 0.125 dV or dV / dl = 1 / 0.125 = 8

We know that plate resistance, r_p = dV / dl = 8mΩ

The trans conductance , g_m = [dl / dV_g] v = constt

At V_g = - 1 volt , V = 300 volt, the plate current

I = [0.125 x 300 – 7.5] mA = 30 mA

Also it is given that V_g = - 3V, V = 300 V and I = 5mA

∴ g_m = [30 – 5 / - 1 – (- 3)] = 25 / 2 x 10^{-3} = 12.5 x 10^{-3} s

The characteristics are given in the form of parallel lines.

Amplification factor

= r_p g_m = 8 x 10^3 x 12. 5 x 10^{-3} = 100

Sol.10.

(i) Let m be the mass of electron. Then the mass of meson is 208 m. According to Bohr's postulate, the angular momentum of mu-meson should be an integral multiple of h/2π.

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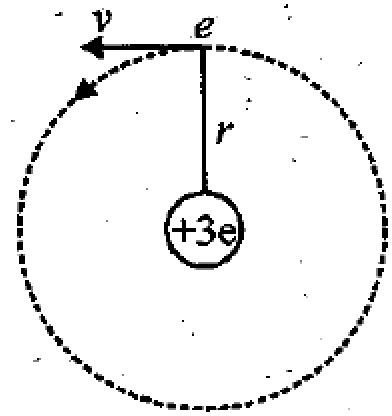

$\therefore$ (208M) vr = nh/ 2π

$\therefore$ v = nh / 2π x 208 mr = nh / 416 πmr ...(i)

Note : Since mu-meson is moving in a circular path, therefore, it needs centripetal force which is provided by the electrostatic force between the nucleus and mumesion.

$\therefore$ $(208m)v^2 / r = 1 / 4\pi\varepsilon_0 \times 3e \times e / r^2$

$\therefore$ $r = 3e^2 / 4\pi\varepsilon_0 \times 208\, mv^2$

Substituting the value of v from (1), we get

$r = 3e^2 \times 416\, \pi mr \times 416\, \pi mr / 4\, \pi\varepsilon_0 \times 208mn^2\, h^2$

$\Rightarrow r = n^2\, h^2\, \varepsilon_0 / 624\, \pi me^2$ ...(i)

(ii) The radius of the first orbit of the hydrogen atom

$= \varepsilon_0\, h^2 / \pi me^2$ ....(ii)

To find the value of n for which the radius of the orbit is approximately the same as that of the first Bohr orbit for hydrogen atom, we equate eq. (i) and (ii)

$N^2\, h^2 / 624\, \pi me^2 = \varepsilon_0 h^2 / \pi me^2 \Rightarrow n = \sqrt{624} \approx 25$

(iii) $1 / \lambda = 208\, R \times Z^2\, [1 / n^2{}_1 - 1 / n^2{}_2]$

$\Rightarrow 1 / \lambda = 208 \times 1.097 \times 10^7 \times 3^2\, [1/1^2 - 1/ 3^2]$

$\Rightarrow \lambda = 5.478 \times 10^{-11}$ m

Sol.11.

$E_1 = 12400 / 4144 = 2.99$ eV, $E_2 = 12400 / 4972 = 2.49$ eV,

$E_3 = 12400 / 6216 = 1.99$ eV.

$\Rightarrow$ Only first two wavelengths are capable of ejecting photoelectrons.

Energy incident per second

$= 3.6 / 3 \times 10^{-3} \times 10^{-4} = 1.2 \times 10^{-7}$ J /s

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$\therefore n_1 = 1.2 \text{ x } 10^{-7} / 2.99 \text{ x } 1.6 \text{ x } 10^{-19} = 2.5 \text{ x } 10^{11}$

$n^2 = 1.2 \text{ x } 10^{-7} / 2.99 \text{ x } 1.6 \text{ x } 10^{-19} = 3 \text{ x } 10^{11}$

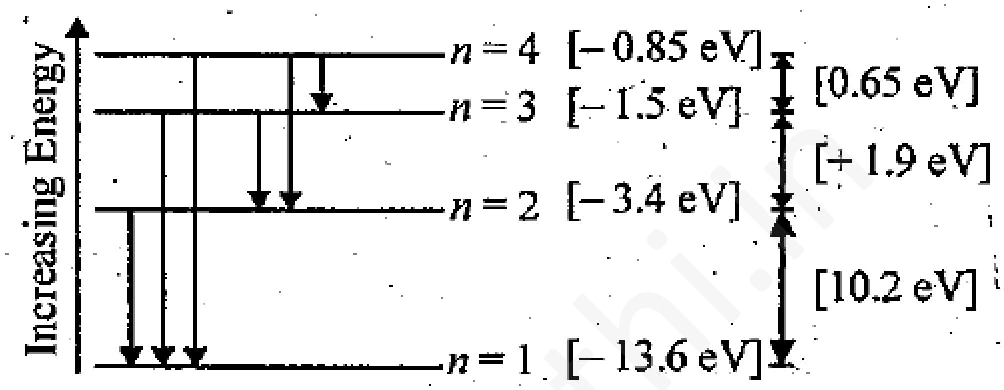
Total number of photons = $2\ (n_1 + n_2)$

$= 3.01 \text{ x } 10^{11} + 2.51 \text{ x } 10^{11} = 5.52 \text{ x } 10^{11}$

∴ Total number of photoelectrons ejected in two seconds = $11 \text{ x } 10^{11}$

Sol.12.

(i) The transition of six different photon energies are shown.



Since after absorbing monochromatic light, some of the emitted photons have energy more and some have less than 2.7 eV, this indicates that the excited level B is n = 2. (This is because if n = 3) is the excited level then energy less than 2.7 eV is not possible)

(ii) For hydrogen like atoms we have

$E_n = - 13.6 / n^2 Z^2$ eV / atom

$E^4 – E^2 = - 13.\ 6 /16\ Z^2 – (- 13.6\ 4)\ Z^2 = 2.7$

$\Rightarrow Z^2 \text{ x } 13.6\ [1/4 – 1/16] = 2.7$

$\Rightarrow Z^2 = 2.7\ 13.6 \text{ x } 4 \text{ x } 16 / 12 \Rightarrow$ I.E. $= 13.\ 6\ Z^2\ (1/ 1^2 – 1/ \infty^2)$

$= 13.\ 6 \text{ x } 2.7 / 13.\ 6 \text{ x } 4 \text{ x } 16 / 12\ \ 14.46$ eV

(iii) Max. Energy

$E_4 – E_3\ 13.6\ Z^2\ (1 / 4^2 – 1 / 1^2)$

$= 13.6 \text{ x } 2.7 / 13.6 \text{ x } 4 \text{ x } 16 / 12 \text{ x } 15 / 16 = 13.\ 5$ eV

Min. Energy

$E_4 – E_3 = - 13.6Z^2\ (1/ 4^2 – 1 / 3^2)$

$= 13.6 \text{ x } 2.7 / 13.6 \text{ x } 4 \text{ x } 16 / 12 \text{ x }\ 7 / 9 \text{ x } 16 = 0.7$ eV

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Sol.13.

For hydrogen like atom energy of the nth orbit is

$E_n = 13.6\ n^2\ Z^2$ eV / atom

For transition from n = 5 to n = 4,

Hv = 13.6 x 9 [1 / 16 – 1 / 25] = 13.6 x 9 x 9 / 16 x 25 = 2.754 eV

For transition from n = 4 to n = 3,

hv' = 13. 6 x 9 [1/9 – 1 / 16] = 13. 6 x 9 x 7 / 9 x 16 = 5.95 eV

For transition n = 4 to n = 3, the frequency is high and hence wavelength is short.

For photoelectric effect, hv' – W = eV_0, where W = work function

$5.95 \times 1.6 \times 10^{-19} - W = 1.6 \times 10^{-19} \times 3.95$

$\Rightarrow W = 2 \times 1.6 \times 10^{-19} = 2eV$

Again applying hv – W = eV'

We get, $2.754 \times 1.6 \times 10^{-19} - 2 \times 1.6 \times 10^{-19} = 1.6 \times 10^{-19}\ V'_0$

$\Rightarrow V_0' = 0.754$ V

Sol.14.

Energy required per day

$E = P \times t = 200 \times 10^6 \times 24 \times 60 \times 60$

$= 1.728 \times 10^{13}$ J

Energy released per fusion reaction

= [2 (2.0141) – 4.0026] x 931.5 MeV

$= 23.85$ MeV $= 23.85 \times 106 \times 1.6 \times 10^{-19}$

$= 38.15 \times 10^{-13}$J

∴ No. of fusion reactions required

$= 1.728 \times 10^{13} / 38.15 \times 10^{-13} = 0.045 \times 10^{26}$

∴ No. of deuterium atoms required

$= 2 \times 0.045 \times 10^{26} = 0.09 \times 10^{26}$

Number of moles of deuterium atoms

$= 0.09 \times 10^{26} / 6.02 \times 10^{23} = 14.95$

∴ Mass in gram of deuterium atoms

= 14. 95 x 2 = 29.9 g

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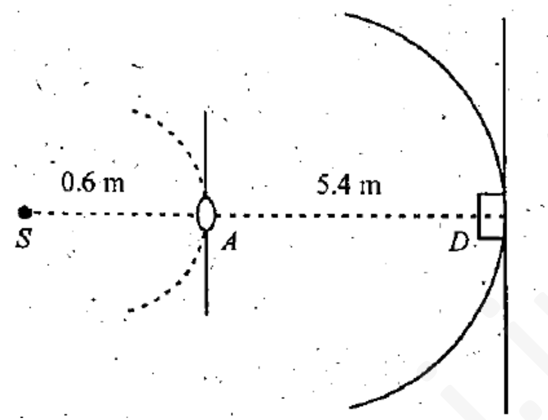
But the efficiency is 25%

Therefore, the actual mass required = 119.6 g

Sol.15.

Energy of one photon, $E = hc / \lambda = (6.6 \times 10^{-34})\ (3.0 \times 10^{8}) / 6000 \times 10^{-10}$

$= 3.3 \times 10^{-19}$ J



Power of the source is 2 W or 2 J/s. Therefore, number of photons emitting per second,

$N_1 = 2 / 3.3 \times 10^{-19} = 6.06 \times 10^{18}$ / s

At distance 0.6 m, number of photons incident unit area per unit time:

$n_2 = n_1 / 4\pi(0.6)^2 = 1.34 \times 10^{18}$ / m^2 / s

Area of aperture is,

$S_1 = \pi / 4\ d^2\ (0.1)^2 = 7.85 \times 10^{-3}$ m^2

∴ Total number of photons incident per unit time on the aperture,

$N_3 = n_2\ s_1 = (1.34$ xc $10^{18})\ (7.85 \times 10+-3)$ /s

$= 1.052 \times 10^{16}$ / s

The aperture will become new source of light.

Now these photons are further distributed in all directions. Hence, at the location of detector, photons incident per unit area unit time :

$N_4 = n_3 / 4\pi\ (6 - 0.6)^2 = 1.052 \times 10^{16} / 4\pi\ (5.4)^2$

$= 2.87 \times 10^{13}\ s^{-1}\ m^{-2}$

This is the photon flux at the centre of the screen. Area of detector is 0.5 cm^2 or 0.5×10^{-4} m^2 . Therefore, total number of photons incident on the detector per unit time:

$n_5 = (0.5 \times 10^{-4})\ (2.87 \times 10^{13}\ d) = 1.435 \times 10^{9}\ s^{-1}$

The efficiency of photoelectron generation is 0.9. Hence, total photoelectrons generated per unit time :

$n_6 = 0.9\ n_5 = 1.2915 \times 10^{9}\ s^{-1}$

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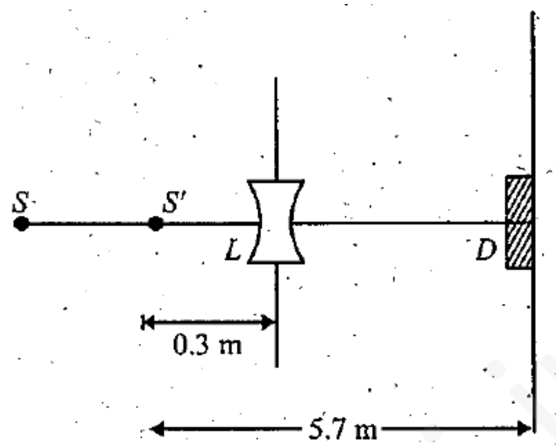
or, photocurrent in the detector :

$i = (e)n_6 = (1.6 \times 10^{-19})(1.2915 \times 10^9) = 2.07 \times 10^{-10}$ A

(b) Using the lens formula :

$1/v - 1/-0.6 = 1/-0.6$ or $v = -0.3$ m

i.e, image of source (say S', is formed at 0.3 m from the lens,)



Total number of photons incident per unit on the lens are still n_3 or 1.052×10^{16}s. 80% of it transmits to seconds medium Therefore, at a distance of 5.7 m from S' number of photons incident per unit are per unit time will be :

$N_1 = (80 / 100)\,(1.05 \times 10^{16}) / (4\pi)\,(5.7)^2$

This is the photon flux at the detector.

New value of photocurrent is :

$i = (2.06 \times 10^{13})\,(0.5 \times 10^{-4})\,(0.9)\,(1.6 \times 10^{-19})$

$= 1.483 \times 10^{-10}$ A

(c) For stopping potential

$hc/\lambda = (E_K)_{max} + W = eV_0 + W$

$\therefore eV_0 = hc/\lambda - W = 3.315 \times 10^{-19} / 1.6 \times 10^{-19} - 1 = 1.07$eV

$\therefore V_0 = 1.07$ Volt

Note : The value of stopping potential is not affected by the presence of concave lens as it changes the intensity and not the frequency of photons. The stopping potential depends on the frequency of photons.

Sol.16.

(a) ${}^{A}_{92}\mathrm{X} \longrightarrow {}^{228}_{x}\mathrm{Y} + {}^{4}_{2}\mathrm{He}$

$A = 228 + 4 = 232;\ 92 = Z + 2 \Rightarrow Z = 90$

(b) Let v be the velocity with which α – particle is emitted.

Then

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$mv^2 / r = qvB \Rightarrow / m = 2 \times 1.6 \times 10^{-19} \times 0.11 \times 3 / 4.003 \times 10^{-27}$

$\Rightarrow v = 1.59 \times 10^{7}\ ms^{-1}$

Applying law of conservation of linear momentum during α – decay we get

$M_y v_y = m_\alpha v_\alpha$ ...(1)

The total kinetic energy of α – particle and Y is

$E = K.E._\alpha + K.E._y = ½ m_\alpha v_\alpha^2 + ½ m_y v_y^2$

$= ½ m_\alpha v^2_\alpha + ½ m_y [m_\alpha v_\alpha / m_y] = ½ m_\alpha v_\alpha^2 + m_\alpha v_\alpha^2 + m_\alpha^2 v_\alpha^2 / 2m_y$

$= ½ \times 4.033 \times 1.6 \times 10^{-27} \times (1.59 \times 10^7)^2 [1 + 4.003 / 228.03]J$

$= 8.55 \times 10^{-13}$ J

= 5.34 MeV

∴ Mass equivalent of this energy

= 5.34 / 931.5 = 0.0051 a.m.u.

Also, $m_x + m_\alpha$ + mass equivalent of energy (E)

= 228 . 03 + 4.003 + 0.0057 = 232 . 03874 u.

The number of nucleus = 92 protons + 140 neutron.

∴ Binding energy of nucleus X

= [92 x 1.008 + 140 x 1.009] – 232 . 0387 = 1.9571 u

= 1.9571 x 931.5 = 1823 MeV.

Sol.17.

(a) The energy of photon causing photoelectric emission

= work function of sodium metal + KE of the fastest photoelectron

= 1.82 + 0.73 = 2.55 eV

(b) We know that $E_n = - 13.6 / n^2$ eV / atom for hydrogen atom.

Let electron jump from n_2 to n_1 then

$E_{n_2} - E_{n_1} = - 13.6 / n_2^2 – (13. 6 / n^2_1)$

$\Rightarrow 2.55 = 13. 6 (1/ n^2_1 – 1/ n^2_2)$

By hit and trial we get $n_2 = 4$ and $n_1 = 2$

[angular momentum mvr = nh/ 2π]

(c) Change in angular momentum

$= n_1 h / 2 \pi – n_2 h / 2 \pi = h / 2 \pi (2 – 4) = h / 2 \pi \times (-2) = - h / x$

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(d) The momentum of emitted photon can be found by de Broglie relationship

$\lambda = h / p \Rightarrow p = h / \lambda = hc / c = E / c$ $\therefore p = 2.55 \times 1.6 \times 10^{-19} / 3 \times 10^{8}$

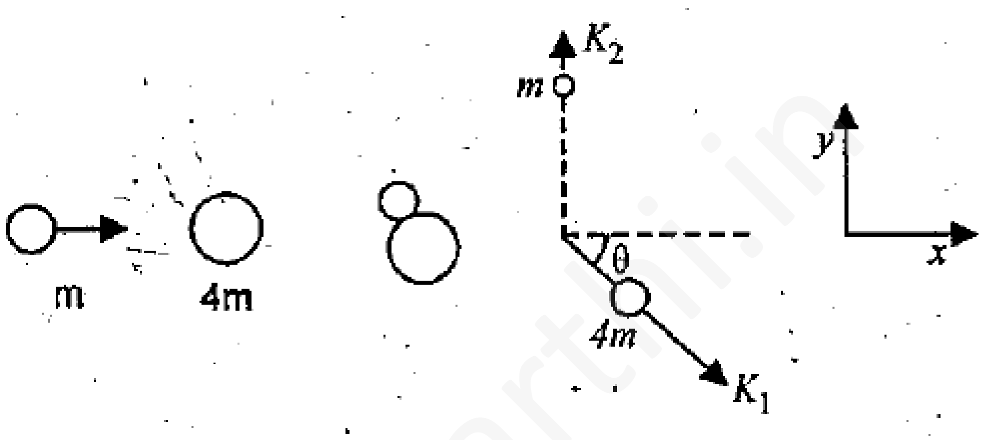
Note : The atom was initially at rest the recoil momentum of the atom will be same as emitted photon (according to the conservation of angular momentum).

Let m be the mass and v be the recoil velocity of hydrogen atom then

$m \times v = 2.55 \times 1.6 \times 10^{-19} / 3 \times 10^{8}$

$\Rightarrow v = 2.55 \times 1.6 \times 10^{-19} / 3 \times 10^{8} \times 1.67 \times 10^{-27} = 8.14$ m/s

Sol.18.



Applying conservation of linear momentum in horizontal direction

(Initial Momentum $)_x$ = (Final Momentum$)_x$

$(P_1)_x = (P_f)_x$

$\Rightarrow \sqrt{2Km} = \sqrt{2(4m)K_1} \cos\theta$ ...(i)

Now applying conservation of linear momentum in Y – direction

$(P_i)_y = (P_f)_y$

0 $= \sqrt{2K_2 m} - \sqrt{2(4m)K_1} \sin\theta$
1

$\Rightarrow \sqrt{2K_2 m} = \sqrt{2(4m)K_1} \sin\theta$ .... (ii)

Squaring and adding (i) and (ii)

$2Km + 2Km_2 m = 2(4m)K_1 + 2(4m)K_1$

$K_1 + K_2 = 4K_1 \Rightarrow K = 4K_1 - K_2 \Rightarrow 4K_1 - K_2 = 65$ ...(iii)

When collision takes place, the electron gains energy and jumps to higher orbit.

Applying energy conservation

$K = K_1 + K_2 + \Delta E$

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$\Rightarrow 65 = K_1 + K_2 + \Delta E$ ....(iv)

Possible value of ΔE for He^+

Case (1)

$\Delta E_1 = -13.6 - (-54.4) = 40.8$ eV

$\Rightarrow K_1 + K_2 = 24.2$ eV from (4)

Solving with (3), we get

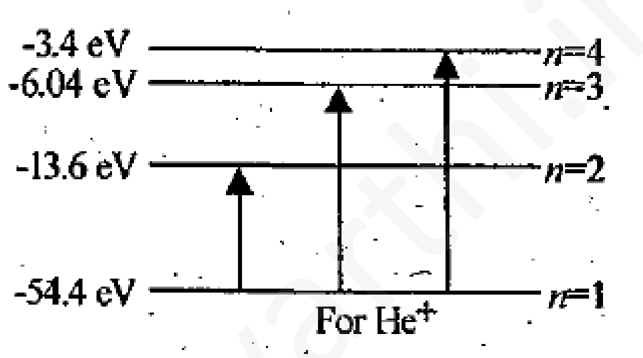
$K_2 = 6.36$ eV ; $K_1 = 17.84$ eV

Case (2)

$\Delta E_2 = -6.04 - (-54.4) = 48.36$ eV

$\Rightarrow K_1 + K_2 = 16.64$ eV from (4)

Solving with (3), we get $K_2 = 0.312$ eV; $K_1 = 16.328$ eV



Case (3)

$\Delta E_3 = -3.4 - (-54.4) = 51.1$ eV

$\Rightarrow K_1 + K_2 = 14$ eV

Solving with (3), we get

$K_2 = 15.8$ eV ; $K_1 = -1.8$ eV

But K.E. can never be negative therefore case (3) is not possible.

Therefore, the allowed values of kinetic energies are only that of case (1) and case (2) and electron can jump upto n = 3 only.

(ii) Thus when electron jumps back there are three possibilities

$n_3 \longrightarrow n_1$ or $n_3 \longrightarrow n_2$ and $n_2 \longrightarrow n_1$

The frequencies will be

$y_1 = E_3 - E_2 / h$; $v_2 = E_3 - E_1 / h$; $v_3 = E_2 - E_1 / h$

i.e., 1.82×10^{15} Hz; 11.67×10^{15} Hz; 9.84×10^{15} Hz

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Sol.19.

$t_{1/2} = 15$ hours

Activity initially $A_0 = 10^{-6}$ Curie (in small quantity of solution of ^{24}Na) = 3.7×10^4 dps

Observation of blood of volume 1 cm^3

After 5 hours, A = 296 dpm

The initial activity can be found by the formula

$t = 2.303 / \lambda \log_{10} A_0 / A \Rightarrow 5 = 2.303 / 0.693 / 15 \quad x \log_{10} A_0 / 296$

$\Rightarrow \log_{10} A_0 / 296 = 5 \times 0.693 / 2.303 \times 15 = 0.3010 / 3 = 0.10033$

$\Rightarrow A_0 / 296 = 1.26 \Rightarrow A_0 = 373$ dpm = 373 / 60 dps

This is the activity level in 1 cm^3. Comparing it with the initial activity level of 3.7×10^4 dps we find the volume of blood.

$V = 3.7 \times 10^4 / 373 / 60 = 5951.7\ cm^3 = 5.951$ litre

Sol.20.

For hydrogen like atoms

E_n - 13.6 / $n^2 Z^2$ eV / atom

Given $E_n - E_2 = 10.2 + 17 = 27.2$ eV ...(i)

$E_n - E_3 = 4.24 + 5.95 = 10.2$ eV

$\therefore E_3 - E_2 = 17$

But $E_3 - E_2 = -13.6 / 9 Z^2 - (-13.6 / 4 Z^2)$

$= -13.6 Z^2 [1/9 - 1/4]$

$= -13.6 Z^2 [4 - 9 / 36] = 13.6 \times 5 / 36 Z^2$

$\therefore 13.6 \times 5 / 36 Z^2 = 17 \Rightarrow Z = 3$

$E_n - E_2 = 13.6\ n_2 \times 3^2 - [-13.6 / 2^2 \times 3^2]$

$= -13.6 [9 / n^2 - 9 / 4] = -13.6 \times 9 [4 - n^2 / 4n^2]$ ...(ii)

From eq. (i) and (ii),

$-13.6 \times 9 [4 - n^2 / 4n^2] = 27.2$

$\Rightarrow -122.4 (4 - n^2) = 108.8\ n^2$

$\Rightarrow n^2 = 489.6 / 13.6 = 36 \Rightarrow n = 6$

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Sol.21.

(i) $E_n = -3.4$ eV

The kinetic energy is equal to the magnitude of total energy in this case.

$\therefore$ K.E. = + 3.4 eV

(ii) The de Broglie wavelength of electron

$\Lambda = h / \sqrt{2mK} = 6.64 \times 10^{-34} / \sqrt{2 \times 9.1 \times 10^{-31} \times 3.4 \times 1.6 \times 10^{-19}}$ eV

$= 0.66 \times 10^{-9}$ m

Sol.22.

(i) From the given information, it is clear that half life of the radioactive nuclei is 10 sec (since half the amount is consumed in 10 second 12.5% i half of 25% pls. note). Mean life
$\tau = 1/\lambda = 1/ 0.693 / t_{1/2} = t_{1/2} / 0.693 = 10 / 0.693 = 14.43$ sec

(ii) $N = N_0 e^{\lambda t}$

$N / N_0 = 6.25 / 100$

$\Lambda = 0.0693\ s^{-1}$

$6.25 / 100 = e^{-0.0693t}$

$e^{+0.693t} = 100 / 6.25 = 16$

$0.0693t = \text{In } 16 = 2.773$

Or $t = 2.733 / 0.0693 = 40$ sec.

Sol.23.

Number of atoms of ^{238}U initially / Numbarof atoms of ^{238}U finally $= 4 / 3 = a / (a - x)$

[$\because$ Initially one part lead is present with three parts Uranium]

$\therefore t = 2.303 / \lambda \log \alpha / (\alpha - x) = 2.303 \times 4.5 \times 10^9 / 0.693 \log 4/3$

$= 1.868 \times 10^9$ years.

Sol.24.

As nodes are formed at each of the atomic sites, hence

$2Å = n (\lambda / 2)$ ...(1)

[$\because$ Distance between successive nodes $= \lambda / 2$]

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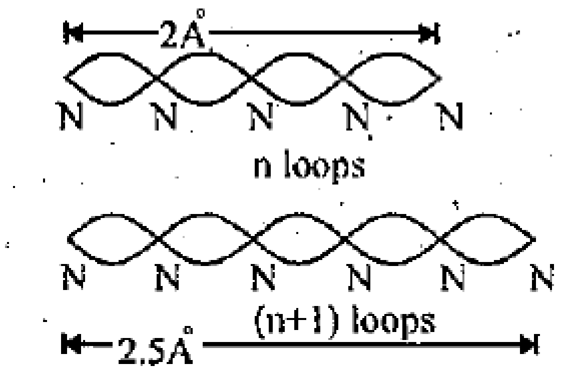

and 2.5 Å = (n + 1) λ /2

∴ 2.5 /2 = n + 1 / n , 5/ 4 = n + 1 / n or n = 4

Hence, from equation (1),

2Å = 4 λ / 2 i.e., λ = 1 Å

Now, de Broglie wavelength is given by

$\lambda = h / \sqrt{2mK}$ or $K = h^2 / \lambda^2 2m$

$\therefore K = (6.63 \times 10^{-34})^2 / (1 \times 10^{-10})^2 \times 2 \times 9.1 \times 10^{-31} \times 1.6 \times 10^{-19}$ eV

$= (6.63)^2 / 8 \times 9.1 \times 1.6 \times 10^2$ eV = 151 eV

d will be minimum, when

n = 1, $d_{min} = \lambda / 2 = 1Å / 2 = 0.5Å$

Sol 25.

The reaction involved in α – decay is

$^{248}_{96}Cm \longrightarrow {}^{244}_{94}Pu + {}^{4}_{2}He$

Mass defect

Δm = Mass of $^{248}_{96}Cm$ – Mass of $^{244}_{94}Pu$ – Mass of $^{4}_{2}He$

= (248. 072220 – 244.064100 – 4.002603)u

= 0.005517 u

Therefore, energy released in α – decay will be

E_α = (0. 005517 x 931) MeV = 5.136 MeV

Similarly, $E_{fission}$ = 200 MeV (given)

Mean life is given ass $t_{mean} = 10^{13}$ s = 1/ λ

∴ Disintegration constant $\lambda = 10^{-13}\ s^{-1}$

Rate of decay at the moment when number of nuclei are 10^{20} is

$dN / dt = \lambda N = (10^{-13})(10^{20}) = 10^7$ dps

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Of these distintegrations, 8% are in fission and 92% are in α – decay.

Therefore, energy released per second

$= (0.08 \times 10^7 \times 200 + 0.92 \times 10^7) \times 5.136)$ MeV

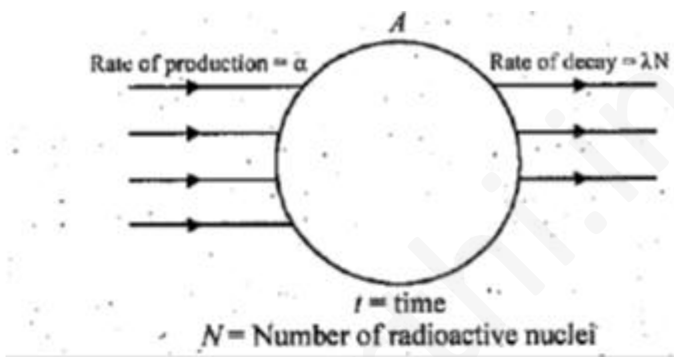
$= 2.074 \times 10^8$ MeV

∴ Power output (in watt) = Energy released per second (J/s)

$= (2.074 \times 10^8)(1.6 \times 10^{-13})$

∴ Power output $= 3.32 \times 10^{-5}$ watt.

Sol 26.



(a) Let at time 't' number of radioactive are N.

Net rate of formation of nuclei of A.

$dN/dt = \alpha - \lambda N$ or $dN / \alpha - \lambda N = dt$

or $\int_{N_0}^{N} \frac{dN}{\alpha - \lambda N} = \int_0^t dt$

Solving this equation, we get

$N = 1/\lambda\,[\alpha - (\alpha - \lambda N_0)e^{-\lambda t}]$ .....(1)

(b) Substituting $\alpha = 2\lambda N_0$ and

$t = t_{1/2} = 1n(2)/\lambda$ in equation (1),

we get, $N = 3/2\ N_0$

(ii) Substituting $\alpha = 2\lambda N_0$ and $t \longrightarrow \infty$ in equation (1), we get

$N = \alpha/\lambda = 2N_0$

Sol 27.

The energy of the incident photon is

$E_1 = hc/\lambda = (4.14 \times 10^{-15}\ \text{eVs})(3 \times 10^8\ \text{m/s}) / (400 \times 10^{-9}\ \text{m}) = 3.1$ eV

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The maximum kinetic energy of the electrons is $E_{max} = E_1 - W = 3.1 \text{ eV} - 1.9 \text{ eV} = 1.2 \text{ eV}$

It is given that,

$$\begin{pmatrix} \textit{Emitted electrons} \\ \textit{of maximum energy} \end{pmatrix} + {}_2He^{2+} \longrightarrow \begin{matrix} He^{+} \\ in4\,\text{th}\,excited\ state \\ +\,photon \end{matrix}$$

The fourth excited state implies that the electron enter I the n = 5 state.

In this state its energy is

$E_5 = -\,(13.6 \text{ eV})Z^2 / n^2 = -\,(13.6\text{eV})(2)^2 / 5^2$

$= -\,2.18 \text{ eV}$

This energy of the emitted photon in the above combination reaction is

$E = E_{max} + (-\,E_5) = 1.2 \text{ eV} + 2.18 \text{ eV} = 2.4 \text{ eV}$

Note : After the recombination reaction, the electron may undergo transition from a higher level to a lower level thereby emitting photons.

The energies in the electronic levels of He^+ are

$E_4 = (-\,13.6 \text{ eV})(2^2) / 4^2 = -\,3.4 \text{ eV}$

$E_3 = (-\,13.6\text{eV})(2^2) / 3^2 = -6.04 \text{ eV}$

$E_2 = (-13.6\text{eV})(2^2) / 2^2 = -\,13.6 \text{ eV}$

The possible transitions are

$n = 5 \longrightarrow n = 4$

$\Delta E = E_5 - E_4 = [-\,2.18 - (-\,3.4)] \text{ eV} = 1.28 \text{ eV}$

$n = 5 \longrightarrow n = 3$

$\Delta E = E_5 - E_3 = [-\,2.18 - (-6.04)] \text{ eV} = 3.84 \text{ eV}$

$n = 5 \longrightarrow n = 2$

$\Delta E = E_5 - E_2 = [-\,2.18 - (-\,13.6)] \text{ eV} = 11.4 \text{ eV}$

$n = 4 \longrightarrow n = 3$

$\Delta E = E_4 - E_3 = [-\,3.4 - (-\,6.04)] \text{ eV} = 2.64 \text{ eV}$

Sol 28.

Energy for an orbit of hydrogen like atoms is

$E_n = -\,13.6\, Z^2 / n^2$

For transition from 2n orbit to 1 orbit

Maximum energy $= 13.6\, Z^2 (1/1 - 1/(2n)^2)$

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$\Rightarrow 204 = 13.6\, Z^2 (1/1 - 1/4n^2)$ ....(i)

Also for transition $2n \longrightarrow n$.

$40.8 = 13.6\, Z^2 (1/n^2 - 1/4n^2) \Rightarrow 40.8 = 13.6\, Z^2 (3/4n^2)$

$\Rightarrow 40.8 = 40.8\, Z^2 / 4n^2 = Z^2$ or $2n = Z$ ..... (ii)

From (i) and (ii)

$204 = 13.6\, Z^2 (1 - 1/Z^2) = 13.6\, Z^2 - 13.6$

$13.6\, Z^2 = 204 + 13.6 = 217.6$

$Z^2 = 217.6 / 13.6 = 16, Z = 4, n = Z / 2 = 4 / 2 = 2$

orbit no. $= 2n = 4$

For minimum energy = Transition from 4 to 3.

$E = 13.6 \times 4^2 (1/3^2 - 1/4^2) = 13.6 \times 4^2 (7 / 9 \times 16)$

$= 10.5$ eV.

Hence $n = 2, Z = 4, E_{min} = 10.5$ eV

Sol 29.

No. of photons /sec

= Energy incident on platinum surface per second / Energy of on photon

No. of photon incident per second

$= 2 \times 10 \times 10^{-4} / 10.6 \times 1.6 \times 10^{-19} = 1.18 \times 10^{14}$

As 0.53% of incident photon can eject photoelectrons

$\therefore$ No. of photoelectrons ejected per second

$= 1.18 \times 10^{14} \times 0.53 / 100 = 6.25 \times 10^{11}$

Minimum energy = 0 eV,

Maximum energy = (10.6 – 5.6) eV = 5eV

Sol 30.

The formula for η of power will be

$\eta = P_{out} / P_{in}$

$\therefore P_{in} = P_{out} / \eta = 1000 \times 10^6 / 0.1 = 10^{10}$ W

Energy required for this power is given by

$E = p \times t$

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$= 10^{10} \times 86,400 \times 365 \times 10$

$= 3.1536 \times 10^{18}$ J

$200 \times 1.6 \times 10^{-13}$ J of energy is released by 1 fission

$\therefore 3.1536 \times 10^{18}$ J of energy is released by

$3.1536 \times 10^{18} / 200 \times 1.6 \times 10^{-13}$ fission

$= 0.9855 \times 10^{29}$ fission

$= 0.985 \times 10^{29}$ of U^{235} atoms.

6.023×10^{23} atoms of Uranium has

$235 \times 0.9855 \times 10^{29} / 6.023 \times 10^{23}$ g = 38451 kg

Sol 31.

Let the reaction be

$${}^{A}_{Z}X \longrightarrow {}^{A\ \ -4}_{Z\ \ -2}Y + {}^{4}_{2}He$$

Here, $m_y = 223.61$ amu and $m_\alpha = 4.002$ amu

We know that

$\lambda = h / mv \Rightarrow m^2 v^2 = h^2 / \lambda^2 = p^2$

$\Rightarrow$ But E.K. $= p^2 / 2m$. Therefore K.E. $= h^2 / 2m\lambda^2$ ...(i)

Applying eq. (i) for Y and α, we get

$K.E._\alpha = (6.6 \times 10^{-34})^2 / 2 \times 4.002 \times 1.67 \times 10^{-27} \times 5.76 \times 10^{-15} \times 5.76 \times 10^{-15}$

$= 0.0982243 \times 10^{-11} = 0.982 \times 10^{12}$ J

Similarly $(E.K.)_y = 0.0178 \times 10^{-12}$ J

Total energy $= 10^{-12}$

We know that $E = \Delta mc^2$

$\therefore \Delta m = E / c^2 = 10^{-12} / (3 \times 10^8)^2$ kg

1.65×10^{-27} kg = 1 amu

$\because 10^{-12} / (3 \times 10^8)^2$ kg $= 10^{-12}$ amu $/ 1.67 \times 10^{-27} \times (3 \times 10^8)^2$

$= 10^{-12}$ amu $/ 1.67 \times 9 \times 10^{-27} \times 10^{16} = 0.00665$ amu

The mass of the parent nucleus X will be

$M_x = m_y + m_\alpha + \Delta m$

$= 223.61 + 4.002 + 0.00665 = 227.62$ amu

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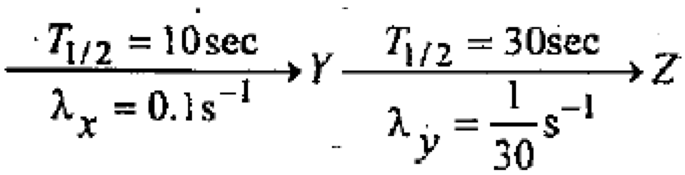
Q 32.

X



The rate of equation for the population of X, Y and Z will be

$dN_x / dt = - \lambda_x N_x$ ...(i)

$dN_y / dt = - \lambda_y N_y + \lambda_x N_x$ ....(ii)

$dN / dt = - \lambda_y N_y$ ...(iii)

⇒ On integration, we get

$N_x = N_0 / \lambda_x - \lambda_y [\, e^{-\lambda yt} - e^{\lambda xt}]$

To determine the maximum N_y, we find

$dN_y / dt = 0$

From (ii)

$- \lambda_y N_y + \lambda_x N_x = 0$

$\Rightarrow \lambda_x N_x = \lambda_y N_y$ ....(v)

$\Rightarrow \lambda_x (N_0\, e^{-\lambda xy}) = \lambda_y [\lambda_x N_0 / \lambda_x - \lambda_y (e^{-\lambda yt} - e^{\lambda xt})]$

$\Rightarrow \lambda_x - \lambda_y / \lambda_y = e^{-\lambda yt} - e^{-\lambda xt} / e^{-\lambda xt} \Rightarrow \lambda_x / \lambda_y = e^{(\lambda x / \lambda y)t}$

$\Rightarrow \log_e \lambda_x / \lambda_y = (\lambda_x - \lambda_y)t$

$\Rightarrow t = \log_e (\lambda_x / \lambda_y) / \lambda_x - \lambda_y = \log_e [0.1 / (1/30)] / 0.1 - 1/30 = 15 \log_e 3$

$\therefore N_x = N_0\, e\text{-}0.1(15 \log_e 3) = N_0\, e^{\log_e (3\text{-}1.5)}$

$\Rightarrow N_x = N_0\, 3^{-15} = 10^{20} / 3\sqrt{3}$

Since, $dN_y / dt = 0$ at $t = 15 \log_e 3$, $\therefore N_y = \lambda_x N_x / \lambda_y = 10^{20} / \sqrt{3}$

And $N_2 = N_0 - N_{x\,-} N_y$

$= 10^{20} - (10^{20} / 3\sqrt{3}) - 10^{20} / \sqrt{3} = 10^{20} (3\sqrt{3} - 4 / 3\sqrt{3})$

Sol 33.

(a) If x is the difference in quantum number of the states than ${}^{x+1}C_2 = 6 \Rightarrow x = 3$

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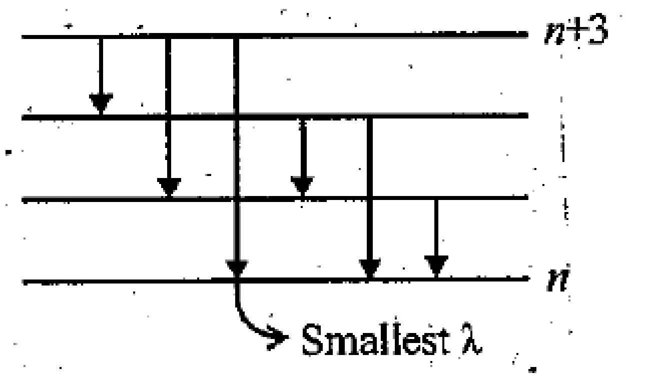


Now, we have $-z^2$ (13.6eV) / n^2 = - 0.85eV ...(i)

And $-z^2$ (13.6 eV) / $(n + 3)^2$ = - 0.544 eV ...(ii)

Solving (i) and (ii) we get n = 12 and z = 3

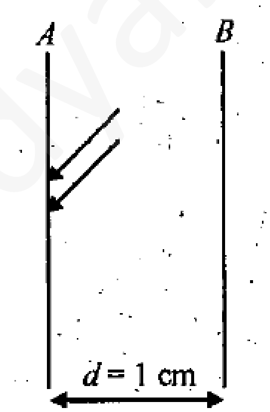
(b) Smallest wavelength λ is given by

hc / λ = (0.85 – 0.544) eV

Solving, we get λ = 4052 nm.

Sol 34.

(a) Number of electron falling on the metal plate A = 10^{16} x (5 x 10^{-4})



∴ Number of photoelectrons emitted from metal plate A upto 10 seconds is

N_e = (5 x 10^4) x 10^{16}/ 10^6 x 10 = 5 10^7

(b) Charge on plate B at t = 10 sec

Q_b = 33.7 x 10^{-12} – 5 x 10^7 x 1. 6 x 10^{-19} = 25.7 x 10^{-12} C

Also Q_a = 8 x 10^{-12} C

E = σ_B / $2\varepsilon_0$ – σ A / $2\varepsilon_0$ = 1 / 2A ε_0 (Q_B - Q_A)

= 17.7 x 10^{-12} / 5 x 10^{-4} x 8.85 x 10^{-12} = 2000 N/C

(c) K.E. of most energetic particles

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$= (h\nu - \phi) + e\,(Ed) = 23$ eV

Note : $(h\nu - \phi)$ is energy of photoelectrons due to light e (Ed) is the energy of photoelectrons due to work done by photoelectrons between the plates.

Sol 35.

According to Bohr's model, the energy released during transition from n_2 to n_1 is given by

$\Delta E = h\nu = Rhc\,(Z - b)^2\,[1 / n^2_1 - 1 / n^2_2]$

For transition from L shell to K shell

$B = 1, n_2 = 2, n_1 = 1$

$\therefore (Z - 1)^2\, Rhc\, [1/1 - 1 / 4] = h\nu$

On putting the value of $R = 1.1 \times 10^7\ m^{-1}$ (given),

$c = 3 \times 10^8$ m/s, we get

$Z = 42$

Sol 36.

$\lambda = \log_e A_0 / A / t = 1 / 2 \log_e n / 0.75\, n$

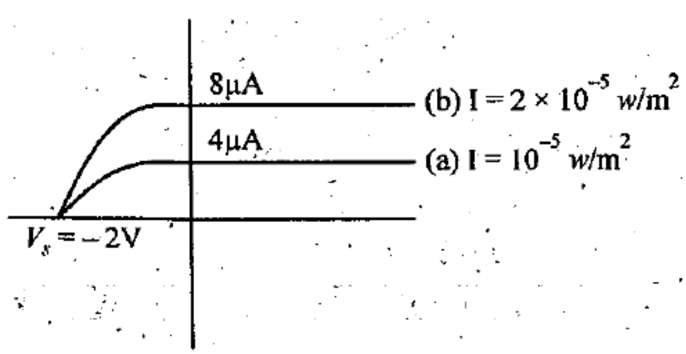
$\Rightarrow$ Mean Life $= 1 / \lambda = 2 / \log_e 4 / 3$

Sol 37.

(a) $eV_0 = h\nu - h\nu_0 = 5 - 3 = 2$ eV

$\therefore V_0 = 2$ volt.

(b) Note : When the intensity is doubled, the saturation current is also doubled,



Sol 38.

a = Initial Uranium atom

(a – x) = Uranium toms left

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$(a - x) = a (1 / 2)^n$

and $n = t / t_{1/2} = 1.5 \times 10^9 / 4.5 \times 10^9 = 13$

$\therefore a - x = a (1/2)^{1/3}$

$\Rightarrow a / a\text{-}x = 1 / (1 / 2)^{1/3} = 2^{1/3} / 1 = 1.26$

$\Rightarrow x / a - x = 1.26 - 1 = 0.26$

Sol 39.

KEY CONCEPT:

The wavelength λ, of photon for different lines of Balmer series is given by

$hc / \lambda = 13.6 [1 / 2^2 - 1 / n^2]$ eV, where n = 3, 4, 5

Using above relation, we get the value of λ = 657 nm, 487 nm between 450 nm and 700 nm. Since 487 nm, is smaller than 657 nm electron of max. E.K. will be emitted for photon corresponding to wavelength 487 nm with

$(K.E.) = hc / \lambda - W = (1242 / 487 - 2) = 0.55$ eV

Sol 40.

The de Broglie wave length is given by

$\lambda = h / mv \Rightarrow \lambda = h / \sqrt{2mK}$

Case (i) $0 \leq x \leq 1$

For this, potential energy is E_0 (given)

Total energy = $2E_0$ (given)

$\therefore$ Kinetic energy = $2 E_0 - E_0 = E_0$

$\lambda_1 = h / \sqrt{2mE_0}$ ...(i)

Case (ii) $x > 1$

For this, potential energy = 0 (given)

Here also total energy = $2E_0$ (given)

$\therefore$ Kinetic energy = $2E_0$

$\therefore \lambda_2 = h / \sqrt{2m (2E_0)}$ ...(ii)

Diving (i) and (ii)

$\lambda_1 / \lambda_2 = \sqrt{2E_0 / E_0} \Rightarrow \lambda_1 / \lambda_2 = \sqrt{2}$

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Sol 41.

(a) KEY CONCEPT : We know that radius of nucleus id given by formula

$r = r_0 A^{1/3}$ where r_0 = consft, and A = mass number.

For the nucleus $r_1 = r_0\, 4^{1/3}$

For unknown nucleus $r_2 = r_0\, (A)^{1/3}$

$\therefore r_2 / r_1 = (A/4)^{1/3}$, $(14)^{1/3} = (A/4)^{1/3} \Rightarrow A = 56$

$\therefore$ No of proton = A – no. of neutrons = 56 – 30 = 26

(b) We know that $v = Rc\,(Z - b)^2\,[1 / n^2_1 - 1 / n^2_2]$

Here, $R = 1.1 \times 10^7$, $c = 3 \times 10^8$, $Z = 26$

$b = 1$ (for K_α), $n_1 = 1$, $n_2 = 2$

$\therefore\; v = 1.1 \times 10^7 \times 3 \times 10^8\,[26 - 1]^2\,[1/1 - 1/4]$

$= 3.3 \times 10^{15} \times 25 \times 25 \times 3/4 = 1.546 \times 10^{18}$ Hz

Sol 42.

Note : nth line of Lyman series means electron jumping from (n + 1)th orbit to 1st orbit.

For an electron to revolve in (n + 1)th orbit.

$2\pi r = (n + 1)\lambda$

$\Rightarrow \lambda = 2\pi / (n + 1) \times r = 2\pi / (n + 1)\,[0.529 \times 10^{-10}]\,(n + 1)^2 / Z$

$\Rightarrow\; 1 / \lambda = Z / 2\pi\,[0.529 \times 10^{-10}]\,(n + 1)$ ...(i)

Also we know that when electron jumps from (n + 1)th orbit to 1st orbit

$1/\lambda = RZ^2\,[1 / 1^2 - 1 / (n + 1)^2 = 1.09 \times 10^7 Z^2\,[1 - 1 / (n + 1)^2]$

From **(i)** and (ii)

$Z / 2\pi\,(0.529 \times 10^{-10})\,(n + 1) = 1.09 \times 10^7 Z^2\,[1 - 1 / (n + 1)^2]$

On solving, we get n = 24

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