

18.8 FORMULAE:

- (1) Energy of Photon/ Quanta absorbed or emitted
OR

Energy of excitation

$$E = E_i - E_f$$

- (2) Angular momentum of electron

$$mv r = \frac{nh}{2\pi} \quad \text{or} \quad L = nh$$

$$mv r = L$$

$$\boxed{Pr = L}$$

- (3) Liner momentum of electron

$$mv = \frac{nh}{2\pi r} \quad \text{or} \quad L = \frac{nh}{r}$$

- (4) Radius of nth orbit of hydrogen atom

$$r_n = \frac{n^2 h^2}{4\pi^2 m K e^2} \quad \text{or} \quad r_n = n^2 r_l$$

$$\text{or} \quad r_l = 0.53 A^\circ$$

$$r_n = n^2 \left(\frac{4\pi \epsilon_0 \hbar^2}{me^2} \right)$$

- (5) Binding energy of electron

$$E_n = \frac{E_l}{n^2}$$

$$E_l = -13.6 \text{ eV}$$

- (6) Wavelength of emitted/ absorbed radiation

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

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

- (7) Wavelength of photon/ radiatation from excitation potential

$$\lambda = \frac{hc}{eV}$$

- (8) Energy from excitation potential

$$E = eV$$

18.9 SOLVED NUMERICALS OF BOOK:**PROBLEM # 18.1**

Calculate the following (a) the orbit radius (b) the angular momentum (c) the linear momentum (d) the Kinetic energy (f) the potential energy (e) the total energy for the Bohr Hydrogen atom in ground state.

Data:

(a) $n = 1$

(b) $L = ?$

(c) $P = ?$

(d) $K.E = ?$

(e) $U = ?$

(f) $E = ?$

Solution:

(a) $r_1 = \frac{n^2 h^2}{4\pi^2 m k e^2}$

$$r_1 = \frac{(1)^2 (6.63 \times 10^{-34})^2}{4(3.14)^2 (9.1 \times 10^{-31})(9 \times 10^9)(1.6 \times 10^{-19})^2}$$

$$r_1 = 0.53 \times 10^{-10} \text{ m}$$

$$r_1 = 0.53 \text{ Å}$$

(b) $L = n^2 h^2$
$$L = (1)^2 (1.05 \times 10^{-34})$$

$$L = 1.05 \times 10^{-34} \text{ kgm/s}$$

(c) $L = nh$

$mvr = nh$

$mv = \frac{nh}{r}$

$p = \frac{nh}{r}$

$$p = \frac{(1)(1.05 \times 10^{-34})}{0.53 \times 10^{-10}}$$

$$p = 1.98 \times 10^{-24} \text{ Js}$$

(d) $K.E = \frac{1}{2} \frac{ke^2}{r_1}$
$$K.E = \frac{(9 \times 10^9)(1.6 \times 10^{-19})^2}{2 \times 0.53 \times 10^{-10}}$$

$$K.E = 2.17 \times 10^{-18} \text{ J}$$

$$K.E = \frac{2.17 \times 10^{-18}}{1.6 \times 10^{-19}}$$

$$K.E = 13.6 \text{ eV}$$

(e) $U = \frac{ke^2}{r_1}$

$$U = \frac{(9 \times 10^9)(1.6 \times 10^{-19})^2}{0.53 \times 10^{-10}}$$

$$U = -4.34 \times 10^{-18} \text{ J}$$

$$U = \frac{-4.34 \times 10^{-18}}{1.6 \times 10^{-19}}$$

$$U = -27.2 \text{ eV}$$

(f) $E = K.E + P.E$

$$E = 13.6 - 27.2$$

$$E = -13.6 \text{ eV}$$

PROBLEM # 18.2

What is the wavelength of the radiation that is emitted when a Hydrogen atom undergoes a transition from the state, $n = 3$ to $n = 1$.

DATA:

$$\lambda = ?$$

$$n_i = 3$$

$$n_f = 1$$

SOLUTION:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{3^2} - \frac{1}{1^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{9} - 1 \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{8}{9}$$

$$\frac{1}{\lambda} = 9.75 \times 10^6$$

$$\lambda = \frac{1}{9.75 \times 10^6}$$

$$\lambda = 1.0255 \times 10^{-7} \text{ m}$$

$$OR \quad \boxed{\lambda = 102.5 \text{ nm}}$$

PROBLEM # 18.3

Light of wave length 486.3nm is emitted by a Hydrogen atom in Balmer series. What transitions of the Hydrogen atom is responsible for this radiation.

DATA:

$$\lambda = 486.3 \text{ nm} = 486.3 \times 10^{-9} \text{ m}$$

$$n_f = 2$$

$$n_i = ?$$

SOLUTION:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{486.3 \times 10^{-9}} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{486.3 \times 10^{-9} \times 1.097 \times 10^7} = \left(0.25 - \frac{1}{n_i^2} \right)$$

$$0.1874 = 0.25 - \frac{1}{n_i^2}$$

$$\frac{1}{n_i^2} = 0.25 - 0.1874$$

$$\frac{1}{n_i^2} = 0.0625$$

$$n_i^2 = 15.98$$

$$n_i = 3.99$$

$$OR \quad \boxed{n_i = 4}$$

PROBLEM # 18.4

In the Hydrogen atom an electron undergoes a transition from a state whose binding energy is 0.54eV to another state whose excitation energy is 10.2eV. (a) What are the quantum numbers of the states. (b) Compare the wavelength of the emitted Photon. (c) To what series does it belong. (2005)

DATA:

$$\begin{aligned} E_i &= -0.54 \text{ eV} \\ \Delta E &= 10.2 \text{ eV} \end{aligned}$$

(a) $n_i = ?$

$n_f = ?$

(b) $\lambda = ?$

(c) Series = ?

SOLUTION:

$$\begin{aligned} (a) \Delta E &= E_f - E_i \\ 10.2 &= E_f - (-13.6) \\ 10.2 &= E_f + 13.6 \end{aligned}$$

$$\begin{aligned} E_f &= 10.2 - 13.6 \\ E_f &= -3.4 \text{ eV} \end{aligned}$$

as $E_i = -0.54 \text{ eV}$

$$E_i = \frac{-13.6}{n_i^2}$$

$$-0.54 = \frac{-13.6}{n_i^2}$$

$$n_i^2 = \frac{13.6}{0.54}$$

$$\boxed{n_i = 5}$$

and $E_f = -3.4 \text{ eV}$

$$E_f = \frac{-13.6}{n_f^2}$$

$$-3.4 = \frac{-13.6}{n_f^2}$$

$$n_f = \frac{13.6}{3.4}$$

$$\boxed{n_f = 2}$$

$$(b) \frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{5^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 (0.25 - 0.04)$$

$$\frac{1}{\lambda} = 2.3037 \times 10^6$$

$$\lambda = 4.34 \times 10^{-7} \text{ m}$$

OR $\boxed{\lambda = 434 \text{ nm}}$

(c) Since ground state of Hydrogen atom is 2, therefore it is Balmer series.

PROBLEM # 18.5

Photon of 12.1 eV absorbed by a hydrogen atom, originally in the ground state raises the atom to an excited state. What is the quantum number of this state? (2013)

DATA:

$\Delta E = 12.1 \text{ eV}$

$n_f = 1$

$n_i = ?$

SOLUTION:

$$E_f = \frac{-13.6 \text{ eV}}{n_f^2}$$

$$E_f = \frac{-13.6 \text{ eV}}{1^2}$$

$E_f = -13.6 \text{ eV}$

$\Delta E = E_i - E_f$

$12.1 = E_i - 13.6$

$E_i = -1.5 \text{ eV}$

$$E_i = \frac{-13.6}{n_i^2} \text{ eV}$$

$$+ 1.5 \text{ eV} = \frac{-13.6}{n_i^2} \text{ eV}$$

$$\frac{n_i^2}{1.5} = \frac{13.6}{-1.5}$$

$$\frac{n_i^2}{1.5} = 9$$

$$\boxed{n_i = 3}$$

PROBLEM # 18.6

Find the wavelength of the first three spectral lines in the Lyman series of Hydrogen atom.

DATA:

$$n_f = 1$$

(1) For 1st spectral line

$$n_i = 2$$

$$\lambda_1 = ?$$

(2) For 2nd spectral line

$$n_i = 3$$

$$\lambda_2 = ?$$

(3) For 3rd spectral line

$$n_i = 4$$

$$\lambda_3 = ?$$

SOLUTION:

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

$$(i) \quad \frac{1}{\lambda_1} = 1.097 \times 10^7 \left(\frac{1}{1^2} - \frac{1}{2^2} \right)$$

$$\frac{1}{\lambda_1} = 8.2275 \times 10^6$$

$$\lambda_1 = 1.215 \times 10^{-7} \text{ m}$$

$$OR \quad \boxed{\lambda_1 = 121.5 \text{ nm}}$$

$$(ii) \quad \frac{1}{\lambda_2} = 1.097 \times 10^7 \left(\frac{1}{1^2} - \frac{1}{3^2} \right)$$

$$\frac{1}{\lambda_2} = 9.75 \times 10^6$$

$$\lambda_2 = 1.025 \times 10^{-7} \text{ m}$$

$$OR \quad \boxed{\lambda_2 = 102.5 \text{ nm}}$$

$$(iii) \quad \frac{1}{\lambda_3} = 1.097 \times 10^7 \left(\frac{1}{1^2} - \frac{1}{4^2} \right)$$

$$\frac{1}{\lambda_3} = 10.28 \times 10^6$$

$$\lambda_3 = 9.72 \times 10^{-8} \text{ m}$$

$$OR \quad \boxed{\lambda_3 = 97.2 \text{ nm}}$$

PROBLEM # 18.7

In an experiment the excitation potential of Hydrogen atom are found, 10.21V, and 12.10 V, three spectral lines are emitted. Find their wave lengths.

DATA:

$$(i) \quad V_1 = 12.10 - 10.21 = 1.9 \text{ V}, \lambda_1 = ?$$

$$(ii) \quad \lambda_2 = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 10.21}$$

$$\lambda_2 = 1.218 \times 10^{-7} \text{ m}$$

$$(iii) \quad V_3 = 12.10 \text{ V}, \lambda_3 = ?$$

$$OR \quad \boxed{\lambda_2 = 121.8 \text{ nm}}$$

SOLUTION:

$$\lambda = \frac{hc}{eV}$$

$$(i) \quad \lambda_1 = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 1.9}$$

$$\lambda_1 = 6.54 \times 10^{-7} \text{ m}$$

$$OR \quad \boxed{\lambda_1 = 654 \text{ nm}}$$

$$(iii) \quad \lambda_3 = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.6 \times 10^{-19} \times 12.10}$$

$$\lambda_3 = 1.027 \times 10^{-7} \text{ m}$$

$$OR \quad \boxed{\lambda_3 = 102.7 \text{ nm}}$$

PROBLEM # 18.8

What minimum energy is needed in an X-ray tube in order to produce X-rays with a wavelength of 0.1×10^{-10} m?

DATA:

$$\lambda = 0.1 \times 10^{-10} \text{ m}$$

$$E = ?$$

SOLUTION:

$$E = \frac{hc}{\lambda}$$

$$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{0.1 \times 10^{-10} \times 1.6 \times 10^{-19}}$$

$$\boxed{E = 124312.5 \text{ eV}}$$

PROBLEM # 18.9

A certain atom emits spectral lines at 300 nm, 400 nm and 1200 nm. Assuming that three energy levels are involved in the corresponding transitions, calculate the quantum of energy emitted of each wavelength.

DATA:

$$\lambda_1 = 300 \text{ nm} = 300 \times 10^{-9} \text{ m}, E_1 = ?$$

$$\lambda_2 = 400 \text{ nm} = 400 \times 10^{-9} \text{ m}, E_2 = ?$$

$$\lambda_3 = 1200 \text{ nm} = 1200 \times 10^{-9} \text{ m}, E_3 = ?$$

SOLUTION:

$$E = \frac{hc}{\lambda}$$

$$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{300 \times 10^{-9} \times 1.6 \times 10^{-19}}$$

$$\boxed{E_1 = 4.14 \text{ eV}}$$

$$E_2 = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{400 \times 10^{-9} \times 1.6 \times 10^{-19}}$$

$$\boxed{E_2 = 3.1 \text{ eV}}$$

$$E_3 = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1200 \times 10^{-9} \times 1.6 \times 10^{-19}}$$

$$\boxed{E_3 = 1.036 \text{ eV}}$$

PROBLEM # 18.10

Calculate the energy of photons whose frequencies are:

(i) $\nu_1 = 4 \times 10^{14} \text{ Hz}$

(ii) $\nu_2 = 20 \text{ GHz}$

(iii) $\nu_3 = 30 \text{ MHz}$

(a) Express your answer in electron Volt.

(b) Describe the corresponding wavelengths of the Photons described above.

DATA:

(a) (i) $\nu_1 = 4 \times 10^{14} \text{ Hz}$, $E_1 = ?$

(ii) $\nu_2 = 20 \text{ GHz} = 20 \times 10^9 \text{ Hz}$, $E_2 = ?$

(iii) $\nu_3 = 30 \text{ MHz} = 30 \times 10^6 \text{ Hz}$, $E_3 = ?$

(b) (i) $\lambda_1 = ?$

(ii) $\lambda_2 = ?$

(iii) $\lambda_3 = ?$

SOLUTION:

(a) $E = h\nu$

$$(i) E_1 = \frac{6.63 \times 10^{-34} \times 4 \times 10^{14}}{1.6 \times 10^{-19}}$$

$E = 11.6575 \text{ eV}$

$$(ii) E_2 = \frac{6.63 \times 10^{-34} \times 20 \times 10^9}{1.6 \times 10^{-19}}$$

$E_2 = 8.29 \times 10^{-15} \text{ eV}$

$$(iii) E_3 = \frac{6.63 \times 10^{-34} \times 30 \times 10^6}{1.6 \times 10^{-19}}$$

$E_3 = 1.24 \times 10^{-7} \text{ eV}$

(b) $\lambda = \frac{c}{\nu}$

$$(i) \lambda_1 = \frac{3 \times 10^8}{4 \times 10^{14}} = 7.5 \times 10^{-7} \text{ m}$$

$\lambda_1 = 750 \text{ nm}$

$$(ii) \lambda_2 = \frac{3 \times 10^8}{20 \times 10^9}$$

$\lambda_2 = 0.015 \text{ m}$

$$(iii) \lambda_3 = \frac{3 \times 10^8}{30 \times 10^6}$$

$\lambda_3 = 10 \text{ m}$

18.10 SOLVED NUMERICALS OF PAPERS:**YEAR 2013**

Q.2(v) (Self Test): Hydrogen atom in the ground state excited by absorbing a photon of 12.15eV. Find the quantum number of this state.
(Similar to Q No. 18.5 of Book)

Answer $n = 3$

YEAR 2012

Q.2(xi) (Self Test): Find the value of the shortest and the longest wavelength of emitted photons in hydrogen spectra in Balmer series ($R_{\infty} = 1.097 \times 10^7 \text{ m}^{-1}$)

Answer

$$\lambda_{\min} = 3.646 \times 10^{-7} \text{ m} \\ = 364.6 \text{ nm}$$

$$\lambda_{\max} = 6.563 \times 10^{-7} \text{ m} \\ = 656.3 \text{ nm}$$

YEAR 2011

Q.2(xi) Calculate the energy of longest wavelength radiation emitted in the paschen series in Hydrogen atom spectra

($R_H = 1.0968 \times 10^7 \text{ m}^{-1}$, $h = 6.63 \times 10^{-34} \text{ Jsec}$, $c = 3 \times 10^8 \text{ m/s}$)

DATA:

$n_f = 3$ (For Paschen series).

$n_i = 4$ (For Longest wavelength)

$$R_H = 1.0968 \times 10^7 \text{ m}^{-1}$$

$$h = 6.63 \times 10^{-34} \text{ Jsec}$$

$$c = 3 \times 10^8 \text{ m/sec}$$

$$E = ?$$

SOLUTION:

$$\text{Using } \frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{\lambda} = 1.0968 \times 10^7 \left(\frac{1}{3^2} - \frac{1}{4^2} \right)$$

$$\frac{1}{\lambda} = 1.0968 \times 10^7 \left(\frac{1}{9} - \frac{1}{16} \right)$$

$$\frac{1}{\lambda} = 1.0968 \times 10^7 (0.1111 - 0.0625)$$

$$\frac{1}{\lambda} = 1.0968 \times 10^7 (0.0486)$$

$$\frac{1}{\lambda} = 5.33045 \times 10^5$$

$$\frac{1}{\lambda} = \frac{1}{5.33045 \times 10^5}$$

$$\lambda = 1.876 \times 10^{-6} \text{ m} \quad \text{---(1)}$$

Now

$$E = h\nu$$

$$\text{Or} \quad E = \frac{hc}{\lambda}$$

$$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1.876 \times 10^{-6}}$$

$$\boxed{E = 1.0608 \times 10^{-19} \text{ Joule}}$$

$$\text{Or} \quad E = \frac{1.0608 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ ev}$$

$$\boxed{E = 0.663 \text{ ev}}$$

YEAR 2010

Q.2(x) Find the shortest wavelength of photon emitted in the Balmer series and determine its energy in ev ($R_H = 1.097 \times 10^7 / m$)

DATA:

$$n_f = 2 \text{ (For Balmer Series)}$$

$$n_i = \infty \text{ (For Shortest Wavelength)}$$

$$(a) \lambda = ?$$

SOLUTION:

$$R_H = 1.097 \times 10^7 / m$$

Using

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{\lambda} = R_H \left(\frac{1}{2^2} - \frac{1}{\infty} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{4} - 0 \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times 0.25$$

$$\frac{1}{\lambda} = 2.7425 \times 10^6$$

$$\frac{1}{\lambda} = \frac{1}{2.7425 \times 10^6}$$

$$\boxed{\lambda = 3.6463 \times 10^{-7} m}$$

Or $\lambda = 364.63 \times 10^{-9} m$

$$\boxed{\lambda = 364.63 m}$$

As $E = h\nu$

$$E = \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} 3 \times 10^8}{3.6463 \times 10^{-7}}$$

$$\boxed{E = 5.45 \times 10^{-19} J}$$

Or $E = \frac{5345 \times 10^{-19}}{1.6 \times 10^{-19}} \text{ ev}$

$$\boxed{E = 3.406 \text{ ev}}$$

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YEAR 2008

Q.8(d) Calculate the longest and the shortest wavelengths of emitted photons in hydrogen spectra in Balmer series where $R_\infty = 1.097 \times 10^7 \text{ m}^{-1}$

DATA:

$$n_f = 2$$

$$R_\infty = 1.097 \times 10^7 \text{ m}^{-1}$$

$$(a) \lambda_{\max} = ?$$

$$(b) \lambda_{\min} = ?$$

SOLUTION:

As we know that

$$\frac{1}{\lambda} = R_\infty \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right) \quad (1)$$

FOR LONGEST WAVELENGTH

$$n_i = 3$$

$$\therefore (1) \Rightarrow \frac{1}{\lambda_{\max}} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{3^2} \right)$$

$$\frac{1}{\lambda_{\max}} = 1.097 \times 10^7 \left(\frac{1}{4} - \frac{1}{9} \right)$$

$$\frac{1}{\lambda_{\max}} = 1.097 \times 10^7 (0.25 - 0.1111)$$

$$\frac{1}{\lambda_{\max}} = 1.5237 \times 10^6$$

$$\lambda_{\max} = \frac{1}{1.5237 \times 10^6}$$

$$\boxed{\lambda_{\max} = 6.5673 \times 10^{-7} \text{ m}} \quad [\because 10^{-9} \text{ m} = \text{nm}]$$

$$OR \quad \boxed{\lambda_{\max} = 656.73 \text{ nm}}$$

FOR LONGEST WAVELENGTH

$$n_i = \infty$$

$$\therefore (1) \Rightarrow \frac{1}{\lambda_{\min}} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{\infty} \right)$$

$$\frac{1}{\lambda_{\min}} = 1.097 \times 10^7 \left(\frac{1}{4} - 0 \right)$$

$$\frac{1}{\lambda_{\min}} = 1.097 \times 10^7 (0.25)$$

$$\frac{1}{\lambda_{\min}} = 2.7425 \times 10^6$$

$$\lambda_{\min} = \frac{1}{2.7425 \times 10^6}$$

$$\boxed{\lambda_{\min} = 3.64631 \times 10^{-7} \text{ m}}$$

$$OR \quad \boxed{\lambda_{\min} = 364.631 \text{ nm}}$$

YEAR 2007

Q.7(d) Calculate the Binding Energy of a Hydrogen atom.

Given that $m = 9.11 \times 10^{-31}$ kg, $e = 1.6 \times 10^{-19}$ coul.

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2 \quad h = 6.63 \times 10^{-34} \text{ J sec.}$$

DATA:

$$n = 1$$

$$E_n = ?$$

SOLUTION:

As we know that

$$E_n = -\frac{1}{n^2} \left(\frac{me^4}{32\pi^2 \epsilon_0^2 \hbar^2} \right)$$

$$m = 9.11 \times 10^{-31} \text{ kg}$$

$$e = 1.6 \times 10^{-19} \text{ coul.}$$

$$\pi = 3.1415$$

$$\epsilon_0 = 8.85 \times 10^{-12} \text{ C}^2/\text{Nm}^2$$

$$h = 6.63 \times 10^{-34} \text{ J sec}$$

$$\hbar = \frac{h}{2\pi} = 1.05 \times 10^{-34} \text{ Jsec}$$

$$E_n = -\frac{1}{(1)^2} \left[\frac{9.11 \times 10^{-31} \times (1.6 \times 10^{-19})^4}{32(3.1415)^2 (8.85 \times 10^{-12})^2 (1.05 \times 10^{-34})^2} \right]$$

$$E_n = -2.18932 \times 10^{-18} \text{ Joule}$$

but

$$1.6 \times 10^{-19} \text{ J} = 1 \text{ ev}$$

$$\therefore E_n = \frac{-2.18732 \times 10^{-18}}{1.6 \times 10^{-19}} \text{ ev}$$

$$E_n = -13.6 \text{ ev}$$

YEAR 2005

- Q.7(d) In a Hydrogen atom an electron experiences transition from a state whose binding energy 0.54 ev to the state whose excitation energy is 10.2ev ($R_H = 1.097 \times 10^7 \text{ m}^{-1}$) calculate
- The quantum numbers of two states.
 - The wavelength of the photon emitted.

DATA:

$$\text{Binding Energy} = E_n = E_i = -0.54 \text{ ev}$$

$$\text{Excitation Energy} = \Delta E = 10.2 \text{ ev}$$

$$\text{a) Quantum Numbers} = ?$$

$$n_i = n = ? \quad n_f = p = ?$$

$$\text{b) Wavelength} = \lambda = ?$$

SOLUTION:

$$\text{As } E_n = \frac{E_1}{n_i^2}$$

But

$$E_i = -0.54 \text{ ev}$$

$$\text{and } E_1 = -13.6 \text{ ev}$$

$$+ 0.54 = \frac{-13.6}{n_i^2}$$

$$n_i^2 = \frac{13.6}{0.54}$$

$$\boxed{n_i = 5}$$

Now For Hydrogen

$$\Delta E = E_f - E_i$$

$$E_f = \Delta E + E_i$$

$$E_f = 10.2 - 13.6$$

$$E_f = -3.4 \text{ ev}$$

From (1)

$$E_f = \frac{E_1}{n_f^2}$$

$$n_f^2 = \frac{E_i}{E_f} = \frac{-13.6}{-3.4}$$

$$n_f^2 = 4$$

$$\boxed{n_f = 2}$$

b) For wave length

$$\text{As } \frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{n^2} - \frac{1}{5^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{4} - \frac{1}{25} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 (0.25 - 0.04)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 (0.21)$$

$$\lambda = \frac{1}{2.3037 \times 10^6}$$

$$\boxed{\lambda = 4.3408 \times 10^{-7} \text{ m} = 434.08 \times 10^{-9} \text{ m}}$$

$$\text{OR } \boxed{\lambda = 434.08 \text{ nm}}$$

$$[\because 10^{-9} \text{ m} = \text{nm}]$$

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YEAR 2004

Q.7(d) What minimum energy is required in an X – ray with a wavelength of $0.1 \times 10^{-10} \text{ m}$ ($h = 6.63 \times 10^{-34} \text{ J sec}$)

DATA:

$$\lambda = 0.1 \times 10^{-10} \text{ m}$$

$$h = 6.63 \times 10^{-34} \text{ J sec}$$

$$\text{minimum energy} = E = ?$$

SOLUTION:

As we know that

$$E = h\nu$$

$$E = \frac{hc}{\lambda} \quad \left[\because \nu = \frac{c}{\lambda} \right]$$

$$\text{but } C = 3 \times 10^8 \text{ m/sec}$$

$$\therefore E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{0.1 \times 10^{-10}}$$

$$\boxed{E = 1.989 \times 10^{-14} \text{ J}}$$

$$\text{but } 1.6 \times 10^{-19} \text{ J} = 1 \text{ eV}$$

$$\therefore E = \frac{1.989 \times 10^{-14}}{1.6 \times 10^{-19}} \text{ eV}$$

$$\boxed{E = 1.243 \times 10^5 \text{ eV}}$$

YEAR 2003.P.E.

An electron in the Hydrogen atom experiences a transition from $n=2$ energy state to the ground state (corresponding to $n=1$), find the wavelength in the ultraviolet region. ($R_H = 1.097 \times 10^7 \text{ m}^{-1}$).

DATA:

$$n_i = 2$$

$$n_f = 1$$

$$\lambda = ?$$

SOLUTION:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

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

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times \frac{3}{4}$$

$$\frac{1}{\lambda} = 8227500$$

$$\lambda = 121.5 \times 10^{-9} \text{ m.}$$

OR

$$\boxed{\lambda = 121.5 \text{ nm}}$$

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YEAR 2002.PM

What is the wave length of light capable of ionizing a hydrogen atom?

What energy in electron volt is needed to ionize it.

Given $h=6.63 \times 10^{-34} \text{ J.S}$ $c = 3 \times 10^8 \text{ m/s}$, $R_H = 1.097 \times 10^7 \text{ m}$.

DATA:

$$n_i = \infty$$

$$n_f = 1$$

$$\lambda = ?$$

$$E \text{ in eV} = ?$$

SOLUTION:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

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

$$\frac{1}{\lambda} = 1.097 \times 10^7$$

$$\lambda = 91.15 \text{ nm}$$

$$E = \frac{hc}{\lambda}$$

$$E = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{91.15 \times 10^{-9} \times 1.6 \times 10^{-19}}$$

$$E = 13.6 \text{ eV}$$

YEAR 2000.

What is the wave length of the radiation that is emitted when Hydrogen atom undergoes a transition from $n = 3$ to $n = 2$. ($R_H = 1.97 \times 10^7 \text{ m}$).

DATA:

$$n_i = 3$$

$$n_f = 2$$

$$\lambda = ?$$

SOLUTION:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \left(\frac{1}{2^2} - \frac{1}{3^2} \right)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7 \times 0.14$$

$$\lambda = 656.3 \text{ nm}$$

YEAR 1997.

The energy of an electron in an excited Hydrogen atom is 3.4eV. Calculate the angular momentum of the electron according to Bohr's theory. ($h=6.63 \times 10^{-34} \text{ J-sec}$).

DATA:

$$E_i = -3.4 \text{ eV}$$

$$L = ?$$

SOLUTION:

$$E_i = \frac{-13.6 \text{ eV}}{n_i^2}$$

$$n_i^2 = \frac{-13.6 \text{ eV}}{E_i}$$

$$n_i^2 = \frac{-13.6 \text{ eV}}{-13.4 \text{ eV}}$$

$$n_i = 2$$

$$L = \frac{n_i h}{2\pi}$$

$$L = 2.11 \times 10^{-34} \text{ Jec.}$$

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

YEAR 1995.

Find the wave length of light which is capable of ionizing a Hydrogen atom.
 $R = 1.097 \times 10^7 \text{ m}$.

DATA:

$$n_i = \infty$$

$$n_f = 1$$

$$\lambda = ?$$

SOLUTION:

$$\frac{1}{\lambda} = R_H \left(\frac{1}{n_f^2} - \frac{1}{n_i^2} \right)$$

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

$$\frac{1}{\lambda} = 1.097 \times 10^7 (1 - 0)$$

$$\frac{1}{\lambda} = 1.097 \times 10^7$$

$$\boxed{\lambda = 91.15 \text{ nm}}$$

YEAR 1993.

The energy of the lowest level of Hydrogen atom is -13.6 eV . Calculate the energy of the emitted photons on transition from $n=4$ to $n=2$.

DATA:

$$E_f = -13.6 \text{ eV}$$

$$n_i = 4$$

$$n_f = 2$$

$$\Delta E = ?$$

SOLUTION:

$$\Delta E = E_i - E_f$$

$$\Delta E = \frac{-13.6 \text{ eV}}{n_i^2} - \frac{(-13.6 \text{ eV})}{n_f^2}$$

$$\Delta E = \frac{-13.6 \text{ eV}}{4^2} - \frac{13.6 \text{ eV}}{2^2}$$

$$\boxed{\Delta E = 2.5 \text{ eV}}$$

YEAR 1990.

A blood corpuscle has a diameter about $9 \times 10^{-6} \text{ m}$. in which excited orbit should a hydrogen atom be, so that it is just about as big as the blood corpuscle? ($r_1 = 0.53 \text{ \AA}$)

DATA:

$$d = 9 \times 10^{-6} \text{ m}$$

$$r_1 = 0.53 \text{ \AA}$$

$$OR \quad r_1 = 0.53 \times 10^{-10} \text{ m}$$

$$n = ?$$

SOLUTION:

$$r_n = \frac{d}{2}$$

$$r_n = \frac{9 \times 10^{-6}}{2}$$

$$r_n = 4.5 \times 10^{-6} \text{ m}$$

$$\text{As } r_n = n^2 r_1$$

$$OR \quad n^2 = \frac{r_n}{r_1} = \frac{4.5 \times 10^{-6}}{0.53 \times 10^{-10}}$$

$$\boxed{n = 291} \quad \text{approx.}$$