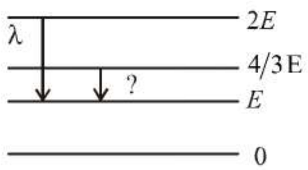
Structure of Atom

1. The ground state energy of hydrogen atom is –13.6 eV. Calculate the energy of second excited state of He^{+} ion in eV.
2. What is the work function (in eV) of the metal if the light of wavelength 4000Å generates photoelectrons of velocity $6\times10^{5}\ ms^{-1}$ from it ?
(Mass of electron$=9\times10^{-31}$ kg;
Velocity of light $=3\times10^{8}\ ms^{-1}$;
Planck's constant$=6.626\times10^{-34}$ Js;
Charge of electron $=1.6\times10^{-19}\ JeV^{-1}$)
3. Monochromatic radiation of specific wavelength is incident on H-atoms in ground state. H-atoms absorb energy and emit subsequently radiations of six different wavelength. Find wavelength of incident radiations in nm.
4. In a measurement of quantum efficiency of photosynthesis in green plants, it was found that 10 quanta of red light of wavelength 6850 Å were needed to release one molecule of O_2. The average energy storage in this process for 1 mole O_2 evolved is 112 kcal.
What is the energy conversion efficiency in this experiment?
[Given: 1 cal = 4.18 J; $N_A = 6\times10^{23}$; $h = 6.63\times10^{-34}$ Js]
5. The given diagram indicates the energy levels of certain atoms. When the system moves from 2E level to E a photon of wave length λ is emitted. Calculate the wave-length of photon produced during its transition from $\frac{4E}{3}$ level to E in terms of λ.



6. An element undergoes a reaction as shown:
$X + 2e^{-} \longrightarrow X^{2-}$, energy released = 30.87 eV/atom. If the energy released, is used to dissociate 4 g of H_2 molecules, equally into H^{+} and H^{*}, where H^{*} is excited state of H atoms where the electron travels in orbit whose circumference equal to four times its de Broglie's wavelength. Determine the least moles of X that would be required.
Given: I.E. of H = 13.6 eV/atom, bond energy of H_2 = 4.526 eV/molecule.
7. Two fast moving particles X and Y are associated with de Broglie wavelengths 1 nm and 4 nm respectively. If mass of X is nine times the mass of Y, then calculate ratio of kinetic energies of X and Y.
8. An electron has a speed of 30,000 cm sec^{-1} accurate upto 0.001%. What is the uncertainty (in cm) in locating it's position?
9. What is the sum of radial and angular nodes in the following orbitals of H-atom?
(I) ψ_{2p_x} (II) ψ_{2} (III) ψ_{3d_x} (IV) $\psi_{3d_{x^2-y^2}}$
10. Determine the Bohr orbit of Li^{2+} ion in which electron is moving at speed equal to the speed of electron in the first Bohr orbit of H-atom.
11. A certain dye absorbs lights of λ = 400 nm and then fluorescence light of wavelength 500 nm. Assuming that under given condition 40% of the absorbed energy is re-emitted as fluorescence, calculate the ratio of quanta absorbed to number of quanta emitted out.
12. Infrared lamps are used in restaurants to keep the food warm. The infrared radiation is strongly absorbed by water, raising its temperature and that of the food. If the wavelength of infrared radiation is assumed to be 1500 nm, and the number of quanta of infrared radiation produced per second by an infrared lamp (that consumes energy at the rate of 100 W and is 12% efficient only) is $(x \times 10^{19})$, then find the value of x is. (Given : $h = 6.625\times10^{-34}$ Js)
13. When an electron makes transition from $(n + 1)$ state to n state the wavelength of emitted radiations is related to n $(n >>> 1)$ according to $\lambda \propto n^{x}$.
What is the value of x?
14. A gas absorbs a photon of 355 nm and emits at two wavelengths. If one of the emissions is at 680 nm, then find the wavelength of the other in nm.
15. Calculate the minimum potential (eV) which must be applied to a free electron so that it has enough energy to excite, upon impact, the electron in a hydrogen atom from its ground state to a state of $n = 5$.

SOLUTIONS

1. **(–6.04)** According to Bohr's model energy in n^{th} state

$$= -13.6\times\frac{Z^2}{n^2}\text{ eV}$$

For second excited state, of He^+, $n = 3$

$$\therefore E_3(He^+) = -13.6\times\frac{2^2}{3^2}\text{ eV} = -6.04\text{ eV}$$

2. **(2.1)** $E = h\nu = \dfrac{hc}{\lambda}$

$$E = \frac{6.626\times10^{-34}\times3\times10^8}{4000\times10^{-10}\times1.6\times10^{-19}} = 3.1\text{ eV}$$

$$= \frac{1}{2}mv^2 = \frac{1}{2}\times9\times10^{-31}\times36\times10^{10}\text{ J}$$

$= 1.62\times10^{-19}$ J

$= 1$ eV

According to photoelectric effect

K.E. $= h\nu - h\nu_0$

$h\nu_0 = h\nu -$ K.E.

Work function $(W_0) = E -$ K.E.

$= 3.1 - 1 = 2.1$ eV

3. **(97.25)** $\dfrac{n(n-1)}{2} = 6$; $n = 4$,

$n = 4$, $E_4 = -0.85$ eV

$n = 1$, $E_1 = -13.6$ eV

$\therefore$ $\Delta E = 12.75$ eV

$$12.75\text{ eV} = \frac{1240\text{ eVnm}}{\lambda}\text{ (since h = 1240 eVnm)}$$

$\lambda = 97.25$ nm

4. **(26.9)** $E = \dfrac{hc}{\lambda} = 2.9\times10^{-19}$ J

Total energy of 10 quanta

$\Rightarrow 10\times2.9\times10^{-19} \Rightarrow 29\times10^{-19}$ J

Energy stored for process

$$= \frac{112\times4.18\times10^3}{6\times10^{23}} = 7.80\times10^{-19}\text{ J}$$

$$\%\text{ efficiency} = \frac{7.8\times10^{-19}}{29\times10^{-19}}\times100 \Rightarrow 26.9\%$$

5. **(3)** From the given data, when the system moves from 2E level to E level, we have

$$2E - E = \frac{hc}{\lambda}$$

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

When the system moves from $\dfrac{4E}{3}$ level to E level, we have

$$\frac{4}{3}E - E = \frac{hc}{\lambda_1}$$ [λ_1 is the wave length of photon emitted]

or $\dfrac{E}{3} = \dfrac{hc}{\lambda_1}$

or $\dfrac{hc}{\lambda.3} = \dfrac{hc}{\lambda_1}$ $\qquad \left[\because E = \dfrac{hc}{\lambda}\right]$

or $\dfrac{1}{3\lambda} = \dfrac{1}{\lambda_1}$

or $\dfrac{\lambda_1}{\lambda} = 3$

or $\lambda_1 = 3\lambda$

6. **(2)** $2\pi r = 4\lambda$; $n = 4$

Total energy required + total energy released = 0

$$2\times4.526\times N_A + 2\times13.6\times N_A + 2\times13.6\times\left(1-\frac{1}{16}\right)\times N_A - 30.87\times x\times N_A = 0$$

$x = 2$

$\therefore$ moles of x required = 2

7. **(1.77)** de-Broglie wavelength $\lambda = \dfrac{h}{m\nu}$

$$\frac{\lambda_1}{\lambda_2} = \frac{m_2\nu_2}{m_1\nu_1};\ \frac{1}{4} = \frac{1}{9}\times\frac{\nu_2}{\nu_1}$$

$$\frac{\nu_2}{\nu_1} = \frac{9}{4}$$

$$\frac{\nu_1}{\nu_2} = \frac{4}{9}$$

$$KE = \frac{1}{2}m\nu^2$$

$$\frac{KE_1}{KE_2} = \frac{m_1}{m_2}\times\frac{\nu_1^2}{\nu_2^2} = \frac{9}{1}\times\left(\frac{4}{9}\right)^2 = \frac{16}{9} = 1.77$$

8. **(2)** $\Delta v = \dfrac{0.001}{100}\times30{,}000 = 0.3\text{ cm sec}^{-1}$

According to uncertainty principle,

$$\Delta x\,.\,\Delta p \approx \frac{h}{4\pi};\qquad \Delta x.\Delta v \approx \frac{h}{4\pi m}$$

$$\Delta x\times9.1\times10^{-28}\times0.3 \approx \frac{6.625\times10^{27}\times7}{4\times22}$$

$\Delta x \approx 1\ 93$ cm ≈ 2

9. **(6)** Radial nodes = $n - l - 1$

$\Rightarrow$ (I) $n = 2, l = 1$, radial node $= 2 - 1 - 1 = 0$

Angular node = 1 (YZ plane)

(II) $n = 2, l = 0$, Radial node $= 2 - 0 - 1 = 1$

Angular node = 0

(III) $n = 3, l = 2$, Radial node $= 3 - 2 - 1 = 0$, and

Angular node = 2 (XY and YZ planes)

(IV) $n = 3, l = 2$, Radial node = 0, and

Angular nodes = 2

Total = I + II + III + IV = 1 + 1 + 2 + 2 = 6

10. **(3)** In the 1st Bohr orbit of H :

$v = 2.18 \times 10^6\ ms^{-1}$.

Now, let us consider that in Li^{2+} the electron is in n^{th} orbit. Speed of electron in n^{th} Bohr orbit of Li^{2+} is

$$v = (Li^{2+}) = 2.18 \times 10^6 \times \frac{3}{n}$$

Now, applying the condition of equal speed :

$$2.18 \times 10^6 \times \frac{3}{n} = 2.18 \times 10^6 \Rightarrow n = 3$$

11. **(2)** $E_{abs} \times \frac{40}{100} = E_{Emitted}$.

$$n_{ab} \times \frac{hc}{400} \times \frac{40}{100} = n_{em} \times \frac{hc}{500}$$

$$\frac{n_{ab}}{n_{em}} = \frac{400}{500} \times \frac{100}{40} = 2$$

12. **(9)** $P = \dfrac{n\frac{hc}{\lambda}}{t}$

$$\frac{100 \times 12}{100} = (x \times 10^{19}) \times \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{1500 \times 10^{-9} \times 1}$$

$x = 9$

13. **(3)** $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n^2} - \frac{1}{(n+1)^2}\right)$

$$\frac{1}{\lambda} = RZ^2 \frac{(n+1)^2 - n^2}{n^2(n+1)^2}$$

$$\frac{1}{\lambda} = RZ^2 \frac{(n+1+n)(n+1-n)}{n^2(n+1)^2}$$

$$\frac{1}{\lambda} = RZ^2 \frac{(2n+1)}{n^2(n+1)^2}$$

$\lambda \propto n^3$

$x = 3$

14. **(743)** Energy of absorbed photon = Sum of the energies of emitted photon

$$\frac{hc}{\lambda} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$$

or $\frac{1}{\lambda} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

$$\frac{1}{355 \times 10^{-9}} = \frac{1}{680 \times 10^{-9}} + \frac{1}{\lambda_2}$$

$$\frac{1}{\lambda_2} = \frac{1}{355 \times 10^{-9}} - \frac{1}{680 \times 10^{-9}} = 1.346 \times 10^6$$

or $\lambda_2 = 1/1.346 \times 10^6 = 743 \times 10^{-9}$m

= 743 nm

15. **(13.05)** For hydrogen atom;

$$\Delta E = E_5 - E_1$$

$$= \frac{-13.6}{(5)^2} - \left(-\frac{13.6}{(1)^2}\right)$$

$$= \frac{-13.6}{25} + 13.6$$

$= -0.544 + 13.6$

$= 13.05$ eV