Structure of Atom

SOL 1.

Let the % of isotope with At. wt. 10.01 = x

∴ % of isotope with At. wt. 11.01 = (100 - x)

At. wt. of boron = x *10.01 + (100 - x) *11.01/100

=> 10.81 = x *10.01 + (100 - x) *11.01/100

∴ x = 20

Hence % of isotope with At. wt. 10.01 = 20%

∴ % of isotope with At. wt. 11.01 = 100 – 20 = **80%**.

SOL 2.

Elements usually have one or more isotopes and these isotopes have different atomic masses. So atomic weights are fractional number.

SOL 3.

TIPS/Formulae: $\Delta E = E_3 - E_2 = hv = hc/\lambda$ or $\lambda = hc/E_3 - E_2$

Given $E_2 = -5.42 * 10^{-12}$ erg

$E_3 = -2.41 * 10^{-12}$ erg

∴ $6.626 *10^{-27} *3 *10^{10}/-2.41 *10^{-12} - (-5.42 * 10^{-12}) = 19.878 *10^{-17}/3.01 *10^{-12} = 6.604 * 10^{-5}$ cm = **6.604 Å**

SOL 4.

TIPS/Formulae: (i) Energy of n^{th} orbit $E_n = E_1/n^2$

(ii) Difference in energy = $E_1 - E_2 = hv = hc/\lambda$ or $\lambda = hc/E_1 - E_2$

Given $E_1 = 2.17 * 10^{-11}$

∴ Energy of second orbit = $E_2 = 2.17 *10^{-11}/2^2 = 0.5425 *10^{-11}$ erg

$\Delta = E_1 - E_2 = 2.17 * 10^{-11} - 0.5425 * 10^{-11} = 1.0275 * 10^{-11}$ erg

$\lambda = 6.62 *10^{-27} *3 *10^{10}/1.6275 *10^{-11} = 12.20 * 10^{-6}$ cm = **1220 Å**

SOL 5.

To calculate the energy required to remove electron from atom, $n = \infty$ is to be taken.

Energy of an electron in nth orbit of hydrogen is given by

$E = 21.7 * 10^{-12} * 1/n^2$ ergs

∴ $\Delta E = 21.7 * 10^{-12} (1/2^2 - 1/\infty^2)$

$= -21.7 * 10^{-12} (1/4 - 0) = 21.7 * 10^{-12} * 1/4$

$= -5.42 * 10^{-12}$ ergs

∴ $\Delta E = hc/\lambda$ (∵ $v = c/\lambda$)

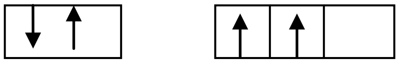
Or $\lambda = hc/\Delta E$

Substituting the values, $\lambda = 6.627 *10^{-27} *3 *10^{10}/5.42 * 10^{-12}$

$= 3.67 * 10^{-5}$ cm

SOL 6.

Ground state electronic configuration of Si|



3s $3p_x$ $3p_y$ $3p_z$

is in accordance with Hund's rule which states that electron pairing in any orbital (s, p, d or f) cannot take place until each orbital of the same sub-level contain 1 electron each of like spin.

SOL 7.

For n = 3 and l = 2 (i.e., 3d orbital), the values of m varies from -2 to +2, -1, 0, +1, +2 and for each 'm' there are 2 values of 's', i.e. +½ and –½ .

∴ Maximum no. of electrons in all the five d-orbitals is **10**.

SOL 8.

E_n of H = $-21.76 * 10^{-19}/n^2$ J

∴ E_n of He^+ = $-21.76 * 10^{-19}/n^2 * Z^2$ J

∴ E_3 of He^+ = $-21.76 * 10^{-19} * 4/9$ J

Hence energy equivalent to E_3 must be supplied to remove the electron from 3rd orbit of He^+. Wavelength corresponding to this energy can be determined by applying the relation.

$E = hc/\lambda$

or $\lambda = hc/E = 6.625 * 10^{-34} * 3 */ 10^8 * 9/21.76 * 10^{-19} * 4 = 2055 * 10^{-10}$ m **= 2055 Å**

SOL 9.

TIPS/Formulae: $\Delta E = RhcZ^2 (1/n_1^2 – 1/n_2^2)$

Here, $R = 1.0967 * 10^7 \text{ m}^{-1}$

$h = 6.626 * 10^{-34}$ J sec, $c = 3 * 10^8$ m/sec

$n_1 = 1$, $n_2 = 2$ and for H-atom, Z = 1

$E_2 – E_1 = 1.0967 * 10^7 * 6.626 * 10^{-34} * 3 * 10^8 (1/1 – 1/4)$

$\Delta E = 1.0967 * 6.626 * 3 * ¾ * 10^{-19}$ J

$= 16.3512 * 10^{-19}$ J

$= 16.3512 * 10^{-19}/1.6 * 10^{-19}$ eV = **10.22 eV**

$\Delta E = hc/\lambda = RhcZ^2 (1/n_1^2 - 1/n_2^2)$

$1/\lambda = RZ^2 (1/1 – 1/4) = RZ^2 * 3/4$

Given, $\lambda = 3 * 10^{-8 = \text{m}}$

∴ $1/3 * 10^{-8} = 1.0967 = Z^2 * 3/4 * 10^7$

∴ $Z^2 = 10^8 * 4/3 * 3 * 1.0967 * 10^7 = 40/9 * 1.0967 = 4$

∴ Z = 2

So it corresponds to He^+ which has 1 electron like hydrogen.

SOL10.

For He^+ ion, we have

$1/\lambda = Z^2 R_H [1/n_1^2 - 1/n_2^2]$

$= (2)^2 R_H [1/(2)^2 – 1/(4)^2] = R_H\ 3/4$ ....(i)

Now for hydrogen atom $1/\lambda = R_H [1/n_1^2 - 1/n_2^2]$ ....(ii)

Equating equation (i) and (ii), we get

$1/n_1^2 - 1/n_2^2 = 3/4$

Obviously, $n_1 = 1$ and $n_2 = 2$

Hence, the transition **n = 2 to n = 1** in hydrogen atom will have the same wavelength as the transition, n = 4 to n = 2 in He^+ species.

SOL 11.

TIPS/Formulae: Number of waves = n(n - 1)/2 where n = Principal quantum number or number of orbit number of waves = 3(3 - 1)/2 = 3 * 2/2 = 3

ALTERNATIVE SOLUTIONS:

In general, the number of waves made by a Bohr electron in an orbit is equal to its quantum number.

According to Bohr's postulate of angular momentum, in the 3rd orbit

Mur = n h/2π

Mur = 3 (h/2π) .....(i) [n = 3]

According to de Broglie relationship

λ = h/mu ....(ii)

Substituting (ii) in (i), we get

(h/λ) r = 3 (h/2π) or 3λ = 2πr

[∵ mu = h/λ]

Thus the circumference of the 3rd orbit is equal to 3 times the wavelength of electron i.e. the electron makes **three** revolution around the 3rd orbit.

ALTERNATIVE SOLUTION:

r_n for H = $r_1 * n^2$

r_3 for H = $0.529 * 9 * 10^{-8}$ cm

$= .529 * 9 * 10^{-10}$ m (∵ $r_1 = 0.529$ Å)

Also $u_n = Z\ u_1/n$;

∴ $u_3 = 2.19 * 10^8/3\ cm\ sec^{-1} = 2.19 * 10+16/3\ m\ sec^{-1}$

(∵ $u_1 = 2.19 * 10^8\ cm\ sec^{-1}$)

∴ No. of waves in one round

$= 2\pi\ r_3/\lambda = 2\pi\ r_3/h/mv_3 = 2\pi\ r_3 * m/h$

$= 2 * 22 * 0.529 * 9 * 10^{-10} * 2.19 * 10^6 * 9.108 * 10^{-31}/7 * 3 * 6.62 * 10^{-34}$ **= 3**

SOL 12.

Bond energy of I_2 240kJ $mol^{-1} = 240 * 10^3\ J\ mol^{-1}$

$= 240 * 10^3/6.023 * 10^{23}$ J $molecule^{-1}$

$= 3.984 * 10^{-19}$ J $molecule^{-1}$

Energy absorbed = $hc/\lambda = 6.626 * 10^{-34}\ Js * 3 * 10^8\ ms^{-1}/4500 * 10^{-10}$ m

$= 4.417 * 10^{-19}$ J
Kinetic energy = Absorbed energy – Bond energy
∴ Kinetic energy = $4.417 *10^{-19} – 3.984 *10^{-19}$ J
$= 4.33 * 10^{-20}$ J
∴ Kinetic energy of each atom of iodine
$= 4.33 *10^{-20}/2 =$ **$2.165 *10^{-20}$**

SOL 13.

The shortest wavelength transition in the Barlmer series corresponds to the transition $n = 2 \rightarrow n = \infty$. Hence, $n_1 = 2$, $n_2 = \infty$ Balmer

$\bar{v} = R_H \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = (109677\ cm^{-1})\ (1/2^2 - 1/\infty^2) =$ **$27419.25\ cm^{-1}$**

SOL 14.

Work done while bringing an electron infinitely slowly from infinity to proton of radius a_0 is given as follows

$W = - e^2/4\pi\varepsilon_0.a_0$

NOTE : This work done is equal to the total energy of an electron in its ground state in the hydrogen atom. At this stage, the electron is not moving and do not possess any K.E., so this total energy is equal to the potential energy.

T.E. = P.E + K.E. = $e^2/4\pi\varepsilon_0.a_0$ ....(i)

In order the electron to be captured by proton to form a ground state hydrogen atom it should also attain

K.E. = $e^2/8\pi\varepsilon_0 a_0$

(it is given that magnitude of K.E. is half the magnitude of P.E. Note that P.E. is –ve and K.E is +ve)

∴ T.E. = P.E + K.E. = $- e^2/4\pi\varepsilon_0 a_0 + e^2/8\pi\varepsilon_0 a_0$

or T.E. = $- e^2/8\pi\varepsilon_0 a_0$

P.E. = 2 * T.E. = $2 * -e^2/8\pi \in_0 a_0$ or P.E. = **$-e^2/8\pi \in_0 a_0$**

SOL 15.

As the ∝-particle travelling with velocity, ‘u’, stops at a distance 10^{-13} m, its K.E. becomes zero and gets converted into P.E.

∴ $1/2\ mu^2 = 1/4\pi\ \varepsilon_0 * 2Ze^2/r$ or $u^2 = Ze^2/4\pi\varepsilon_0\ m.r$

Here, Z = 29 for Cu atom

=> $u^2\ 29 *(1.6 *10^{-19})^2/3.14 *8.85 *10^{-12} *(4 *1.672 *10^{-27}) *10^{-13}$

∴ **$u = 6.3 * 10^6\ m\ sec^{-1}$**

SOL 16.

$1/2\ mu^2 = eV$; also $\lambda = h/mu$ or $u = h/m\lambda$

∴ $1/2\ m\ h^2/m^2\ \lambda^2 = eV$ or $V = 1/2\ \ h^2/m\lambda^2\ e$

$V = 1 *(6.62 *10^{-34})^2/2 *9.108 * 10^{-31} *(1.54 *10^{-10})^2 *1.602 * 10^{-19} =$ **63.3 volt**

SOL 17.

Determination of number of moles of hydrogen gas,

N = PV/RT = 1 *1/0.082 *298 = 0.0409

The concerned reaction is $H_2 \rightarrow 2H$; $\Delta H = 436$ kJ mol^{-1}

Energy required to bring 0.0409 moles of hydrogen gas to atomic state = 436 *0.0409 = **17.83 kJ**

Calculate of total number of hydrogen atom in 0.0409 mole of H_2 gas

1 mole of H_2 gas has $6.02 * 10^{23}$ molecules

0.0409 mole of H_2 gas = $6.02 * 10^{23}/1 * 0.0409$ molecules

Since 1 molecule of H_2 gas has 2 hydrogen atoms $6.02 * 10^{23} * 0.0409$ molecules of H_2 gas = $2 * 6.02 * 10^{23} * 0.0409 = 4.92 * 10^{22}$ atoms of hydrogen since energy required to excite an electron from the ground state to the next excited state is given by

$E = 13.6 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$ eV = 13.6 * (1/1 – 1/4) = 13.6 * 3/4 = 10.2eV

= $1.632 * 10^{-21}$ kJ

Therefore energy required to excite $4.92 * 10^{22}$ electrons

= $1.632 * 10^{-21} * 4.92 * 10^{22}$ kJ = 8.03 * 10 = 80.3 kJ

Therefore total energy required = 17.83 + 80.3 = **98.17 kJ**

SOL 18.

For maximum energy, $n_1 = 1$ and $n_2 = \infty$

$1/\lambda = R_H Z^2 \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

Since R_H is a constant and transition remains the same

$1/\lambda \propto Z^2$; $\lambda_{He}/\lambda_H = \frac{2_H^2}{2_{He}^2} = 1/4$

Hence, λ_{He} = 1/4 * 91.2 = **22.8 nm**

SOL 19.

Ψ_{2s}^2 = probability of finding electron within 2s sphere $\Psi_{2s}^2 = 0$ (at node)

($\because$ Probability of finding an electron is zero at node)

$\therefore 0 = 1/32\pi\ (1/a_0)^3\ (2 - r_0/a_0)^2 \cdot e^{-\frac{2r_v}{a_0}}$

(Squaring the given value of Ψ_{2s})

or $[2 - r_0/a_0] = 0$; $\therefore 2 - r_0/a_0$; $\mathbf{2a_0} = r_0$

SOL 20.

$\lambda = h/mu = 6.627 * 10^{-34}/0.1 * 100$

or λ = **$6.627 * 10^{-35}$ m = $6.627 * 10^{-25}$ Å**

SOL 21.

For hydrogen atom, Z = 1, n = 1

V = $2.18 * 10^6 * Z/n$ ms^{-1} = $2.18 * 10^6$ ms^{-1}

de Broglie wavelength,

$\lambda = h/mv = 6.626 * 10^{-34} / 9.1 * 10^{-31} * 2.18 * 10^{6}$

$=$ **$3.34 * 10^{-10}$ m** $= 3.3$ Å

For 2p, $l = 1$

∴ Orbital angular momentum $= \sqrt{l(l + 1)}\ h/2\pi =$ **$\sqrt{2}\ h/2\pi$**