Chapter 2. Structure of Atom

Question-1

Calculate the frequency and energy associated with photon of radiations having a wavelength of 6200 A^o. Plank's constant = 6.625 $\times 10^{-27}$ ergs sec.

Solution:

We know that c = $\nu\lambda$ or $\nu = \frac{c}{\lambda}$

The value of c for all electromagnetic radiation = 3.0 $\times 10^{8}$ m sec^{-1}.

λ = 6200 A^o = 6200 $\times 10^{-8}$ cm

= 6200 $\times 10^{-10}$ m

= 62 $\times 10^{-8}$ m

$\nu = \frac{3 \times 10^{8}}{62 \times 10^{-8}}$ = 4.839 $\times 10^{14}$ cycles sec^{-1}.

The energy (E) associated with a radiation is given by

E = hν

E = 6.625 $\times 10^{-27}$ $\times$ 4.839 $\times 10^{14}$

= 2.914 $\times 10^{-12}$ ergs

= $\frac{2.914 \times 10^{-12}}{10^{7}}$ Joules

= 2.914 $\times 10^{-19}$ Joules.

Question-2

Calculate the wave number of lines having the frequency of 5 $\times 10^{16}$ cycles per sec.

Solution:

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

ν = 5 $\times 10^{16}$ cycles/sec

$\bar{\nu}$ = ?

We know that

$\bar{\nu} = \frac{\nu}{c} = \frac{5 \times 10^{16}}{3 \times 10^{8}}$ = 1.666 $\times 10^{8}$ m^{-1}.

Question-3

In a hydrogen atom, an electron jumps from a third orbit to the first orbit. Find out the frequency and wavelength of the spectral line.

Solution:

(i) When an electron jumps from a higher orbit n_2 to the lower orbit n_1, the frequency υof the radiation is given by

$$\upsilon = 3.29 \times 10^5 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \text{ cycles sec}^{-1}$$

Here, $n_1 = 1$ and $n_2 = 3$

$$\upsilon = 3.29 \times 10^5 \left[\frac{1}{(1)^2} - \frac{1}{(3)^2}\right] \text{ cycles sec}^{-1}$$

$$= 3.29 \times 10^5 \left[1 - \frac{1}{9}\right] \text{ cycles sec}^{-1}$$

$$= 3.29 \times 10^5 \times 0.889 \text{ cycles sec}^{-1}$$

$$= 2.925 \times 10^{15} \text{ cycles sec}^{-1}$$

Now wavelength $\lambda = \frac{c}{\upsilon}$

$$\lambda = \frac{3 \times 10^8}{2.925 \times 10^{15}} = 1.0256 \times 10^{-7} \text{ m}$$

$$= 1.0256 \times 10^{-7} \times 10^{10} \text{ A}^o = 1025.6 \text{ A}^o.$$

Thus the wavelength of light emitted falls in the UV region of the electromagnetic spectrum.

Question-4

$R_H = 1.09678 \times 10^7\ m^{-1}$, $c = 3 \times 10^8\ ms^{-1}$, $h = 6.625 \times 10^{-34}$ Js.

Solution:

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

For lowest frequency in Lyman series

$n_1 = 1, n_2 = 2$

For H, Z = 1

$\frac{1}{\lambda} = 1.09678 \times 10^7 \times 1\left(1 - \frac{1}{4}\right) = \frac{1.09678 \times 3 \times 10^7}{4}$

$\lambda = \frac{4 \times 10^{-7}}{3 \times 1.09678} = 1215 \times 10^{-10}$ m or **1215 A^o**.

Again, c = λ

$\upsilon^- = \frac{c}{\lambda} = \frac{3 \times 10^8}{1215 \times 10^{-10}} = 0.002469 \times 10^{18}$ Hz = **2.469×10^{15} Hz**

Energy E = hυ

$E = 6.625 \times 10^{-34} \times 2.469 \times 10^{15} = 10.22$ eV

For Li^{2+}, Z = 3

$Li^{2+} = (3)^2 \times 10.22 = 9 \times 10.22 =$ **91.98 eV.**

Question-5

Calculate the uncertainty in the position of a particle when the uncertainty in the momentum is (a) 1 ×10^{-2} (b) zero.

Solution:

(a) According to the uncertainty principle,

$\Delta x.\ \Delta p \approx \frac{h}{4\pi}$

Putting the values of

h = 6.62 ×10^{-34} Joules-sec

Δp = 1 ×10^{-7} Kg-m-sec^{-1}

$\Delta x \times 10^{-7} = \frac{6.62 \times 10^{-34}}{4 \times 3.142}$

$\Delta x = \frac{6.62 \times 10^{-34}}{4 \times 3.142 \times 10^{-7}}$ m

= 0.527 ×10^{-27} m

(b) We know that $\Delta x = \frac{h}{4\pi \times \Delta p}$

When $\Delta P = 0$, the denominator in the above expression becomes zero; hence the uncertainty in position becomes infinity.

Question-6

(iii) 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^1.

Solution:

(a) electronic configuration of elements with atomic number

19 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1

28 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^8, 4s^2

29 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^1

(b) (i) Atomic number of the element is 2+2+6+2+6+1=19

Therefore, the element is **potassium**.

(ii) Atomic number of the element is 2+2+6+2+6+5+1=24

Therefore, the element is **chromium**.

(iii) Atomic number of the element is 2+2+6+2+6+10+1=29

Therefore, the element is **copper**.

Question-7

An electron is in a 4f orbital. What possible values for the quantum numbers n, l, m and s can it have?

Solution:

For an electron in a 4f orbital,

n = 4, l = 3, m = -3, -2, -1, 0, +1, +2, +3, s = $+\frac{1}{2}$ and $-\frac{1}{2}$ for each value of m.

Question-8

A neutral atom has 2K, 8L, 5M electrons. Find out the following from the data:

(a) atomic number,

(b) total number of s electrons,

(c) total number of p electrons,

(d) number of protons in the nucleus, and

(e) valency of element.

Solution:

(a) Atomic number = No. of protons = No. of electrons

Total no. of electrons = 2 + 8 + 5 = 15

Hence atomic number = **15**

(b) Total number of s electrons. To find out it, we are to write electronic configuration of At. No. = 15

$1s^2, 2s^2, 2p^6, 3s^2, 3p^3$

∴Total electrons = **6**

(c) Total number of p electrons = **9**

(d) Number of protons in the nucleus = Number of electrons in extra-nuclear part

∴ Number of protons = 15

(e) Valency of element. The arrangement of electrons in orbits is 2, 8, 5. As the atom tends to gain three electrons, therefore it is **trivalent electronegative (-3)**.

Question-9

$15P^{31}$, $_1H^1$, $_{18}Ar^{40}$, $_{14}Si^{30}$, $_{16}S^{32}$, $_{19}K^{40}$, $_{20}Ca^{40}$, $_1H^2$, $_1H^3$.

Solution:

(a) $_1H^1$, $_1H^2$, $_1H^3$ - isotopes (same number of atomic number)

(b) $_{18}Ar^{40}$, $_{19}K^{40}$, $_{20}Ca^{40}$ - isobars (same number of mass number)

(c) $_{15}P^{31}$, $_{14}Si^{30}$, $_{16}S^{32}$ - isotones (same number of neutrons)

Question-10

Which are isosters?

Solution:

Molecules having same numbers of atoms and also same number of electrons are called isosters.

Example: N_2 and CO

N_2 = 14 electrons

CO = 6 + 8 = 14 electrons.