

Chapter 2. Structure of Atom

Question-1

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

Solution:

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

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

$$\lambda = 6200 \text{ \AA} = 6200 \times 10^{-8} \text{ cm}$$

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

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

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

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

$$E = h\nu$$

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

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

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

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

Question-2

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

Solution:

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

$$\nu = 5 \times 10^{16} \text{ cycles/sec}$$

$$\bar{\nu} = ?$$

We know that

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

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 ν of the radiation is given by

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

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

$$\begin{aligned} \nu &= 3.29 \times 10^5 \left[\frac{1}{(1)^2} - \frac{1}{(3)^2} \right] \text{ cycles sec}^{-1} \\ &= 3.29 \times 10^5 \left[1 - \frac{1}{9} \right] \text{ cycles sec}^{-1} \\ &= 3.29 \times 10^5 \times 0.889 \text{ cycles sec}^{-1} \\ &= 2.925 \times 10^{15} \text{ cycles sec}^{-1} \end{aligned}$$

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

$$\begin{aligned} \lambda &= \frac{3 \times 10^8}{2.925 \times 10^{15}} = 1.0256 \times 10^{-7} \text{ m} \\ &= 1.0256 \times 10^{-7} \times 10^{10} \text{ \AA} = 1025.6 \text{ \AA} \end{aligned}$$

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

Question-4

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

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, $Z = 1$

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

$$\lambda = \frac{4 \times 10^{-7}}{3 \times 1.09678} = 1215 \times 10^{-10} \text{ m or } \mathbf{1215 \text{ \AA}}$$

Again, $c = \lambda \nu$

$$\nu = \frac{c}{\lambda} = \frac{3 \times 10^8}{1215 \times 10^{-10}} = 0.002469 \times 10^{18} \text{ Hz} = \mathbf{2.469 \times 10^{15} \text{ Hz}}$$

Energy $E = h\nu$

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

For Li^{2+} , $Z = 3$

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

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,

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

Putting the values of

$$h = 6.62 \times 10^{-34} \text{ Joules-sec}$$

$$\Delta p = 1 \times 10^{-7} \text{ Kg-m-sec}^{-1}$$

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

$$\Delta x = \frac{6.62 \times 10^{-34}}{4 \times 3.142 \times 10^{-7}} \text{ m}$$
$$= 0.527 \times 10^{-27} \text{ m}$$

(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.



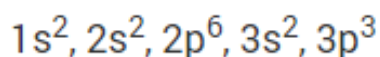
Solution:

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

$$\text{Total no. of electrons} = 2 + 8 + 5 = 15$$

Hence atomic number = **15**

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



∴ 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



Solution:

(a) ${}_1\text{H}^1, {}_1\text{H}^2, {}_1\text{H}^3$ - isotopes (same number of atomic number)

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

(c) ${}_{15}\text{P}^{31}, {}_{14}\text{Si}^{30}, {}_{16}\text{S}^{32}$ - 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

$\text{N}_2 = 14$ electrons

$\text{CO} = 6 + 8 = 14$ electrons.

