Atomic Structure

Problem 1: The wavelength of a violet light is 400nm. Calculate its frequency and wave number.

Here,
wave length, $\lambda = 400nm$
$= 400 \times 10^{-9}$ m
frequency, $\nu = ?$
wave number, $\bar{\nu} = ?$
light's velocity
, $c = 3 \times 10^8 ms^{-1}$

We know,
$c = \nu\lambda$
$\Rightarrow \nu = \frac{c}{\lambda}$
$= \frac{3 \times 10^8}{400 \times 10^{-9}}$
$\therefore \nu = 7.5 \times 10^{14}$ Hz
(Ans)

Again,
$\bar{\nu} = \frac{1}{\lambda}$
$= \frac{1}{400 \times 10^{-9}}$
$\therefore \bar{\nu} = 2.5 \times 10^6 m^{-1}$
(Ans)

Problem 2: The frequency of strong yellow line in the spectrum of sodium is $5.09 \times 10^{14} sec^{-1}$. Calculate the wavelength of the light in nanometers.

Here,
frequency, $\nu = 5.09 \times 10^{14} s^{-1}$
wavelength, $\lambda = ?$
light's velocity
, $c = 3 \times 10^8 ms^{-1}$
$1m = 10^9 nm$

We know,
$c = \nu\lambda$
$\Rightarrow \lambda = \frac{c}{\nu} = \frac{3 \times 10^8}{5.09 \times 10^{14}}$
$\Rightarrow \lambda = 5.89 \times 10^{-7}$ m
$= 5.89 \times 10^{-7} \times 10^9$ nm
$\therefore \lambda = 589$ nm
(Ans)

Problem 3: Find the wavelength in A° of the line in Balmer series that is associated with drop of the electron from the fourth orbit. The value of Rydberg constant is 1,09,676 cm^{-1}

Since line is in ~~of~~ the Balmer series so $n_1 = 2$ and $n_2 = 4$

Here,
Rydberg constant, $R = 1,09,676\ cm^{-1}$
$n_1 = 2$
$n_2 = 4$
wavelength, $\lambda = ?$

We Know,

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= 109676\left[\frac{1}{2^2} - \frac{1}{4^2}\right]$$

$$= 109676\left[\frac{1}{4} - \frac{1}{16}\right]$$

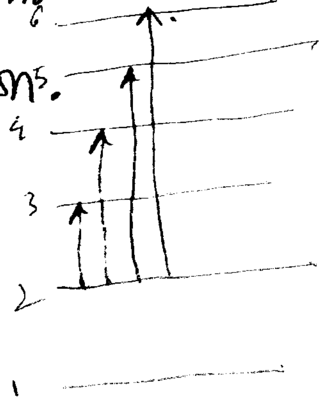
$$= 109676 \times \frac{3}{16}$$

$$\Rightarrow \lambda = \frac{16}{3 \times 109676} = 4.863 \times 10^{-5}\ cm$$

$$= 4.863 \times 10^{-5} \times 10^{8}\ A^{\circ}$$

$$\therefore \lambda = 4863\ A^{\circ}$$ (Ans)

Prolem 4: Find the wavelength in A° of the third line in Balmer series that is associated with drop of the electrons.



Since the line is in Balmer series so $n_1 = 2$ and the third line of in the Balmer series, $n_2 = 5$

We Know, $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$

Here,
Rydberg constant, $R = 109676\ cm^{-1}$
wavelength, $\lambda = ?$

$= 109676\left[\frac{1}{2^2} - \frac{1}{5^2}\right]$

$= 109676 \times \frac{21}{100}$

$\Rightarrow \lambda = \frac{100}{109676 \times 21} = 4.342 \times 10^{-5}\ cm$

$= 4.342 \times 10^{-5} \times 10^{8}\ A^{\circ}$

$\therefore \lambda = 4342\ A^{\circ}$ (Ans)

Problem: Calculate the first five Bohr radii

Here,
$n_1 = 1$, $r_1 = ?$
$n_2 = 2$, $r_2 = ?$
$n_3 = 3$, $r_3 = ?$
$n_4 = 4$, $r_4 = ?$
$n_5 = 5$, $r_5 = ?$

$r_n = n^2 \times 0.529 \times 10^{-8}\ cm$

$r_1 = 1^2 \times 0.529 \times 10^{-8}\ cm$

$\therefore r_1 = 5.29 \times 10^{-9}\ cm$ (Ans)

$r_2 = 2^2 \times 0.529 \times 10^{-8}$

$\therefore r_2 = 2.116 \times 10^{-8}\ cm$ (Ans)

$r_3 = 3^2 \times 0.529 \times 10^{-8}$

$\therefore r_3 = 4.761 \times 10^{-8}\ cm$ (Ans)

$r_4 = 4^2 \times 0.529 \times 10^{-8}$

$\therefore r_4 = 8.464 \times 10^{-8}\ cm$ (Ans)

$r_5 = 5^2 \times 0.529 \times 10^{-8}$

$\therefore r_5 = 1.3225 \times 10^{-7}\ cm$ (Ans)

Problem: Calculate the five lowest energy levels of the hydrogen atom

We know, $E_n = -\frac{2.179\times10^{-18}}{n^2}$ J per atom

Here
$n_1 = 1$, $E_1 = ?$
$n_2 = 2$, $E_2 = ?$
$n_3 = 3$, $E_3 = ?$
$n_4 = 4$, $E_4 = ?$
$n_5 = 5$, $E_5 = ?$

$$E_1 = -\frac{2.179\times10^{-18}}{1^2}$$

$$E_2 = -\frac{2.179\times10^{-18}}{2^2}$$

$$E_3 = -\frac{2.179\times10^{-8}}{3^2}$$

$$E_4 = -\frac{2.179\times10^{-8}}{4^2}$$

$$E_5 = -\frac{2.179\times10^{-8}}{5^2}$$

Atomic Structure
Practice Problems

Problem 1 Calculate the radius of third orbit of hydrogen.
($h = 6.625 \times 10^{-27}$ erg-sec, $m = 9.9091 \times 10^{-28}$ g, $e = 4.8 \times 10^{-10}$ esu)

We Know,

$$r = \frac{n^2h^2}{4\pi^2 me^2}$$

$$= \frac{3^2 \times 6.625 \times 10^{-27}}{4\pi^2 \times 9.9091}$$

Here, $n = 3$
$h = 6.625 \times 10^{-27}$ erg-sec
$m = 9.9091 \times 10^{-28}$ g
$e = 4.8 \times 10^{-10}$ esu

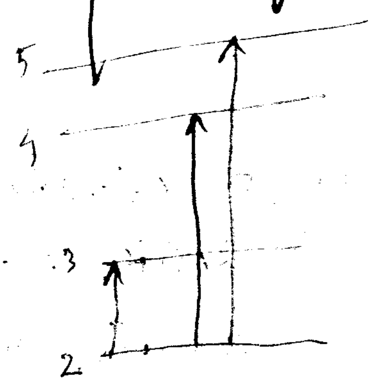
$$\therefore r = n^2 \times 0.529 \times 10^{-8} \text{ cm}$$

$$= 3^2 \times 0.529 \times 10^{-8} \text{ cm}$$

Problem 2 Calculate the wavelength ~~associated~~ of the first line in Balmer series of hydrogen spectrum.

Here,
Rydberg constant, $R = 109677 \text{ cm}^{-1}$
wavelength, $\lambda = ?$

Since the line is in the Balmer series so $n_1 = 2$ and the first line in the Balmer series, $n_2 = 3$



We Know

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

$$= 109677\left[\frac{1}{2^2} - \frac{1}{3^2}\right]$$

$$= 109677 \times \frac{9-4}{36}$$

$$= 109677 \times \frac{5}{36}$$

$$\Rightarrow \lambda = \frac{36}{5 \times 109677}$$

$$\therefore \lambda = 6.56 \times 10^{-5} \text{ cm} \quad \text{(Ans)}$$

Wave Mechanical Concept of the Atom
Practise Problems

Problem 3 Calculate the wavelength associated with an electron moving with a velocity of $1 \times 10^{8} cm\, sec^{-1}$

We know, $E = mc^2 = 9.1 \times 10^{-31} \times (1 \times 10^{6})^2$

$\therefore E = 9.1 \times 10^{-19}$ J

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

$\Rightarrow \lambda = \frac{hc}{E} = \frac{6.63 \times 10^{-34} \times 3 \times 10^{8}}{9.1 \times 10^{-19}}$

$\therefore \lambda = 2.183 \times 10^{-7}$ m

(Ans)

Here,
mass, $m = 9.1 \times 10^{-28}$ g
$= 9.1 \times 10^{-31}$ kg
velocity, $c = 1 \times 10^{8} cm\, sec^{-1}$
$= 1 \times 10^{6} m\, sec^{-1}$
light's velocity, $c' = 3 \times 10^{8} ms^{-1}$
$\lambda = ?$
$h = 6.63 \times 10^{-34} kgm^2 sec^{-1}$

Problem 4 A particle having a wavelength 6.6×10^{-4} cm is moving with a velocity of $10^{6} cm\, sec^{-1}$. Find the mass of the particle

We know, $\lambda = \frac{h}{mc}$ $\cancel{= \frac{6.62 \times 10^{-27}}{}}$

$\Rightarrow m = \frac{h}{\lambda c} = \frac{6.62 \times 10^{-27}}{6.6 \times 10^{-4} \times 10^{6}}$

$\therefore m = 1.003 \times 10^{-29}$ g (Ans)

Here, Planck's constant, $h = 6.62 \times 10^{-27}$ erg-s
$\lambda = 6.6 \times 10^{-4}$ cm
$c = 10^{6} cm\, sec^{-1}$

Problem 5 Calculate the wavelength of an electron having kinetic energy equal to 4.55×10^{-25} J.

We know, $E_K = mc^2$

$\Rightarrow c = \sqrt{\frac{E_K}{m}} = \sqrt{\frac{4.55 \times 10^{-25}}{9.1 \times 10^{-31}}}$

$\therefore c = 707.11 ms^{-1}$

Again, $\lambda = \frac{hc}{E_K} = \frac{6.6 \times 10^{-34} \times 707.11}{4.55 \times 10^{-25}}$

$\therefore \lambda = 1.0297 \times 10^{-6}$ m

(Ans)

or, $\lambda = \frac{h}{mc}$
$\therefore \lambda =$ same

Here, $h = 6.6 \times 10^{-34} kgm^2 s^{-1}$
mass of electron, $m = 9.1 \times 10^{-31}$ kg
$K_E = 4.55 \times 10^{-25}$ J
$\lambda = ?$

Problem 6. Calculate the uncertainty in position of an electron if the uncertainty in velocity is 5.7×10^5 m sec^{-1}.

We know,

Here, $\Delta v = 5.7 \times 10^5$ m sec^{-1}

$m = 9.1 \times 10^{-31}$ kg

$h = 6.63 \times 10^{-34}$ kg m^2 sec^{-1}

$$\Delta x \times \Delta p = \frac{h}{4\pi}$$

$$\Rightarrow \Delta x \times m\Delta v = \frac{h}{4\pi}$$

$$\Rightarrow \Delta x = \frac{h}{4\pi m \Delta v}$$

$$= \frac{6.63 \times 10^{-34}}{4\pi \times 9.1 \times 10^{-31} \times 5.7 \times 10^5}$$

$$\therefore \Delta x = 1.02 \times 10^{-10} \text{ m} \quad \text{(Ans)}$$

Problem: 7 What is the wavelength associated with a particle of mass 0.1 g moving with a speed of 1×10^5 cm sec^{-1}

Here, $h = 6.6 \times 10^{-27}$ erg-sec

$m = 0.1$ g

$c = 1 \times 10^5$ cm sec^{-1}

$\lambda = ?$

We know, $\lambda = \dfrac{h}{mc} = \dfrac{6.6 \times 10^{-27}}{0.1 \times 1 \times 10^5}$

$$\therefore \lambda = 6.6 \times 10^{-31} \text{ cm} \quad \text{(Ans)}$$

Problem 8 The uncertainty in the position of a moving bullet of mass 0.01 Kg is 1.0×10^{-5} m. calculate the uncertainty in its velocity.

Here,

$m = 0.01$ Kg

$\Delta x = 1.0 \times 10^{-5}$ m

$\Delta v = ?$

$h = 6.63 \times 10^{-31}$ Kg m^2 s^{-1}

We know, $\Delta x \times m\Delta v = \dfrac{h}{4\pi}$

$$\Rightarrow \Delta v = \frac{h}{4\pi \Delta x m}$$

$$= \frac{6.63 \times 10^{-34}}{4\pi \times 1.0 \times 10^{-5} \times 0.01}$$

$$\therefore \Delta v = 5.28 \times 10^{-28} \text{ ms}^{-1} \quad \text{(Ans)}$$

Problem 9 What is the mass of photon of sodium light with a wavelength of 5890 A°?

We Know,

$\lambda = \frac{h}{mv}$

$\Rightarrow m = \frac{h}{\lambda v} = \frac{6.6 \times 10^{-27}}{5890 \times 10^{-8} \times 3 \times 10^{10}}$

$\therefore m = 3.74 \times 10^{-33}$ g (Ans)

Here,

$h = 6.6 \times 10^{-27}$ erg-sec

$\lambda = 5890 \times 10^{-8}$ cm

$v = 3 \times 10^{10}$ cm/sec

$m = ?$

Problem 10 The uncertainty in the position and velocity of a particle are 10^{-10} m and 5.27×10^{-24} m sec^{-1} respectively. Calculate the mass of the particle.

We Know, $\Delta x \times m\Delta v = \frac{h}{4\pi}$

$\Rightarrow m = \frac{h}{4\pi \Delta x \Delta v}$

$= \frac{6.6 \times 10^{-34}}{4\pi \times 10^{-10} \times 5.27 \times 10^{-24}}$

$\therefore m = 0.0997$ kg (Ans)

Here,

$h = 6.6 \times 10^{-34}$ kg m^2 sec^{-1}

$\Delta x = 10^{-10}$ m

$\Delta v = 5.27 \times 10^{-24}$

$m = ?$

Problem 11 The velocity of a ball being bowled by Mohammad Rafiq is 25 ms^{-1}. Calculate the wavelength of the matter-wave associated with the ball.

We Know, $\lambda = \frac{h}{mc}$

$= \frac{6.625 \times 10^{-27}}{158.5 \times 2500}$

$\therefore \lambda = 1.67 \times 10^{-32}$ cm

(Ans)

Here,

$m = 158.5$ g

$h = 6.625 \times 10^{-27}$ erg.

$c = 25$ ms^{-1}

$= 2500$ cms^{-1}

$\lambda = ?$

Problem: 12 (a) An Atom of an element contains 13 electrons. It nucleus has 14 neutrons. Find out its atomic number and approximate atomic weight. Indicate the arrangement of electrons and the electro valency of the element

~~Problem 12 (a) electrons = 13~~

(b) An Isotope of the above element has atomic weight 2 units higher. What will be the number of protons neutrons and electrons in the isotope?

(a) electrons = 13

neutrons = 14

atomic number = ?

atomic weight = ?

We Know,

atomic number = electrons

so atomic number = 13 (Ans)

Again, atomic number + neutrons = atomic weight

$\therefore$ atomic weight = 13 + 14 = 27 (Ans)

arrangement of electrons = $1s^2 2s^2 2p^6 3s^2 3p^1$

electrovalency of the element = +3

valency = 3

(b) as atomic weight 2 units higher.
so atomic weight $= 27+2 = 29$

We know,
atomic number = protons ~~= 13~~
so protons $= 13$ (Ans)

as protons = electrons
so electrons $= 13$ (Ans)

We know
protons + neutrons = atomic weight
neutrons = atomic weight − protons
$= 29 - 13$
$= 16$ (Ans)

Problem 13 (a) How many electrons are there in hydrogen and chlorine atom (atomic number 17)? How they are arrang[ed] [in] hydrogen and chlorine in HCl. What is the valency of hydrogen and chlorine?

(b) The atomic number of Na and Cl are 11 and 17 respectively. Determine the number of electrons in Na^+ and Cl^-.

(a) electrons of ~~the~~ hydrogen atom = +1 (Ans)

electron of chlorine atom = −1 (Ans)

hydrogen arranged : $H \rightarrow 1s^1$

~~chlorine~~

chlorine arranged : $Cl \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^5$

Valency of hydrogen $\rightarrow H^+ \rightarrow 1s^0$ (−1e) valency : 0

valency of chlorine $\rightarrow Cl^- \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$ (+1e)

valency : 6

(b) Atomic number of Na is 11

so electrons of $Na^+ = 11 - 1 = 10$ (Ans)

Atomic number of Cl is 17

so electrons of $Cl^- = 17 + 1 = 18$ (Ans)

Problem 14: (a) Write the electronic configurations of elements with atomic numbers 19, 28 and 29. (b) Calculate the atomic number and name the element that corresponds to each of the following electronic configuration: (i) $1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^1$

(ii) $1s^2, 2s^2 2p^6, 3s^2 3p^6, 3d^5, 4s^1$

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

(a) electronic configuration of 19

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

electronic configuration of 28

$1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^8$

electronic configuration of 29

$\cancel{1s^2 2s^2 2p^6 3p^6 3s^6}$

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

(b) (i) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

atomic number 19 and element name pottasium

(Ans)

(ii) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$

atomic number 24 and element name chromium (Ans)

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

atomic number 29 and element name copper (Ans)

Problem 15 (a) An electron is in 4f orbital. What possible values for the quantum numbers n, l, m and s can it have? (b) What designation is given to an orbital having (i) n=2, l=1 and (ii) n=4, l=0?

(a) . $n = 4$

$l = 0, 1, 2, 3$

$m = -3, -2, -1, 0, 1, 2, 3$

$s = \cancel{7}\left(+\frac{1}{2}, -\frac{1}{2}\right)$

(b) (i) $n = 2, l = 1$

allowable as $l = 0, 1$ value when $n = 2$

(ii) $n = 4, l = 0$

allowable as $l = 0, 1, 2, 3$ value when ~~n=4~~.

$n = 4$

Problem 16: 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 elements.

2K, $n=1$ number of electrons 2

8L, $n=2$ " " 8

5M, $n=3$ " " 5

Total = 15

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

(a) Atomic number 15

(b) s electron 6

(c) p electron 9

(d) Protons 15

(e) $1s^2 2s^2 2p^6 3s^2 3p^3$ valency = 3

Problem 17: State which of the following sets of quantum number is permissible for an electron in an atom. If a set is not permissible, explain why.

(a) $n=1, l=1, m=0, s=+1/2$

not permissible as l cannot have value equal to 1 when $n=1$.

(b) $n=3, l=1, m=-2, s=-1/2$

permissible.

(c) $n=2, l=1, m=0, s=+1/2$

permissible

(d) $n=2, l=0, m=0, s=1$

not permissible as s cannot have value equal to 1.

(e) $n=3, l=2, m=3, s=+1/2$

not permissible as m cannot have value equal to 3 when $n=3$

(f) $n=3, l=2, m=-2, s=0$

not permissible as cannot have value equal to 0.