CHAPTER 2

Structure of Atom

NCERT FOCUS

ANSWERS

Topic 1

1. (i) Mass of an electron is 9.109×10^{-31} kg.

$$1 \text{ g or } 10^{-3} \text{ kg} = \frac{1}{9.109\times10^{-31}}\times10^{-3} \text{ electrons}$$
$$= 1.098 \times 10^{27} \text{ electrons}$$

(ii) Mass of one electron = 9.109×10^{-31} kg

Mass of 1 mole of electrons

$= 9.109 \times 10^{-31} \times 6.022 \times 10^{23} = 5.485 \times 10^{-7}$ kg

Charge of 1 electron = 1.602×10^{-19} C

Charge of 1 mole of electrons

$= 1.602 \times 10^{-19} \times 6.022 \times 10^{23}$ C $= 9.647 \times 10^{4}$ C

2. (i) Total number of electrons present in one mole of CH_4

$= 6 \times 6.022 \times 10^{23} + 4 \times 6.022 \times 10^{23}$

$= 10(6.022 \times 10^{23})$

$= 6.022 \times 10^{24}$ electrons

(ii) (a) We know that, $p + n = A$

$6 + n = 14$ $\quad [\because e = p = Z]$

$n = 14 - 6 = 8$

Now, 1 mole of ^{14}C = 14 g of C

$= 6.022 \times 10^{23}$ atoms of ^{14}C

$= 6.022 \times 10^{23} \times 8$ neutrons

$= 4.8176 \times 10^{24}$ neutrons

(b) 14 g of ^{14}C contains $= 4.8176 \times 10^{24}$ neutrons

7 mg (7×10^{-3} g) of ^{14}C contains

$$= \frac{4.8176\times10^{24}\times7\times10^{-3}}{14} \text{ neutrons}$$

$= 2.4088 \times 10^{21}$ neutrons

Mass of a neutron = 1.675×10^{-27} kg

Mass of 2.4088×10^{21} neutrons

$= 1.675 \times 10^{-27} \times 2.4088 \times 10^{21} = 4.0347 \times 10^{-6}$ kg

(iii) (a) 17 g of NH_3 has $10 \times 6.022 \times 10^{23}$ electrons or protons $= 6.022 \times 10^{24}$

34 mg (34×10^{-3}g) of NH_3 has protons

$$= \frac{6.022\times10^{24}}{17}\times34\times10^{-3} = 1.2044 \times 10^{22} \text{ protons}$$

(b) Mass of a proton = 1.675×10^{-27} kg

Total mass of protons in 34×10^{-3} g of NH_3

$= 1.2044 \times 10^{22} \times 1.675 \times 10^{-27}$ kg $= 2.017 \times 10^{-5}$ kg

The answer will not change if the temperature and pressure are changed.

3. Charge of one electron = 1.602×10^{-19} C

$$\text{Number of electrons present} = \frac{2.5\times10^{-16}}{1.602\times10^{-19}} = 1.56 \times 10^{3}$$

4. Charge of one electron = -1.602×10^{-19} C

$$\text{Number of electrons} = \frac{-1.282\times10^{-18}}{-1.602\times10^{-19}} \approx 8$$

Topic 2

1. $^{13}_{6}C$: We know that, $e = p = Z$

where, e = number of electrons, p = number of protons, Z = atomic number

Here, $Z = p = 6$ and $A = 13$ $\quad [\because A = \text{Mass number}]$

$n = A - p = 13 - 6 \Rightarrow n = 7.$ $\quad [\because A = p + n]$

Number of protons = 6 and number of neutrons = 7.

$^{16}_{8}O$: Here, $p = 8, A = 16$

$n = A - p = 16 - 8 = 8$

Number of neutrons = 8 and number of protons = 8.

$^{24}_{12}Mg$: Here, $A = 24, p = 12$

$n = A - p = 24 - 12 = 12$

Number of neutrons = 12 and number of protons = 12.

$^{56}_{26}Fe$: Here, $p = 26, A = 56$

$n = A - p = 56 - 26 = 30$

Number of neutrons = 30 and number of protons = 26.

$^{88}_{38}Sr$: Here, $A = 88, p = 38$

$n = A - p = 88 - 38 \Rightarrow n = 50$

Number of neutrons = 50 and number of protons = 38.

2. (i) $^{35}_{17}Cl$ (ii) $^{233}_{92}U$ (iii) $^{9}_{4}Be$

3. Wavelength of yellow light = 580 nm

$= 580 \times 10^{-9}$ m $\quad [\because 1 \text{ nm} = 10^{-9} \text{ m}]$

$$\text{Frequency } (\upsilon) = \frac{c}{\lambda}$$

where, c = velocity of light $= 3.0 \times 10^{8}$ m s^{-1},

λ = wavelength of sodium lamp

$$\upsilon = \frac{3.0\times10^{8}}{580\times10^{-9}} = 5.17\times10^{14} \text{ s}^{-1}$$

$$\text{Again, wavenumber } (\bar{\nu}) = \frac{1}{\lambda} = \frac{1}{580\times10^{-9} \text{ m}}$$

$= 1.724 \times 10^6\ m^{-1}$

Therefore, frequency = $5.17 \times 10^{14}\ s^{-1}$ and wavenumber = $1.724 \times 10^6\ m^{-1}$.

4. (i) We know that, $E = h\upsilon$

where, E = energy of photons, h = Planck's constant, υ = frequency of light

$\therefore\ E = h\upsilon = 6.626 \times 10^{-34} \times 3 \times 10^{15} = 1.99 \times 10^{-18}$ J

(ii) $E = \dfrac{hc}{\lambda}$

where, c = velocity of light, h = Planck's constant, λ = wavelength

$$E = \frac{6.626\times10^{-34}\times3\times10^{8}}{0.50\times10^{-10}} = 3.98\times10^{-15}\ \text{J}$$

5. Frequency of a light wave

$$(\upsilon) = \frac{1}{\text{Time period}} = \frac{1}{2.0\times10^{-10}} = 5 \times 10^9\ s^{-1}$$

Wavelength of light wave $(\lambda) = \dfrac{c}{\upsilon} = \dfrac{3\times10^8}{5\times10^9} = 6.0 \times 10^{-2}$ m

Wavenumber of light wave $(\bar{\upsilon}) = \dfrac{1}{\lambda}$

$$= \frac{1}{6.0\times10^{-2}} = 16.6\ m^{-1}$$

Therefore, wavelength, frequency and wave-number of the light wave are 6.0×10^{-2} m, $5 \times 10^9\ s^{-1}$ and $16.6\ m^{-1}$ respectively.

6. Wavelength of light (λ) = 4000 pm

$= 4000 \times 10^{-12}$ m $= 4 \times 10^{-9}$ m [$\because$ 1 pm = 10^{-12} m]

$$E = h\upsilon = h \times \frac{c}{\lambda} = \frac{6.626\times10^{-34}\times3\times10^{8}}{4\times10^{-9}}$$

$= 4.97 \times 10^{-17}$ J

Number of photons providing 1 J of energy

$$= \frac{1}{4.97\times10^{-17}} = 2.012 \times 10^{16}\ \text{photons.}$$

7. (i) Energy of photon $(E) = \dfrac{hc}{\lambda}$

$$= \frac{6.626\times10^{-34}\times3\times10^{8}}{4\times10^{-7}} = 4.9695 \times 10^{-19}\ \text{J}$$

$$= \frac{4.9695\times10^{-19}}{1.6020\times10^{-19}} = 3.102\ \text{eV}$$

(ii) Kinetic energy of the emission

= energy of photon – work function

= (3.102 – 2.13) eV = 0.972 eV

1 eV = 1.602×10^{-19} J

0.972 eV = $1.602 \times 10^{-19} \times 0.972$ J = 1.557×10^{-19} J

(iii) $K.E. = \dfrac{1}{2}mv^2$

Velocity of the photoelectron $(v) = \sqrt{\dfrac{2K.E.}{m}}$

$$v = \sqrt{\frac{2\times1.557\times10^{-19}}{9.1\times10^{-31}}} = 5.85 \times 10^5\ m\ s^{-1}$$

8. Here, λ = 242 nm = 242×10^{-9} m

$$I.E. = \frac{hc}{\lambda} = \frac{6.626\times10^{-34}\times3\times10^{8}}{242\times10^{-9}}$$

$= 8.214 \times 10^{-19}$ J/atom

Ionisation energy of sodium in kJ mol^{-1}

$= 8.214 \times 10^{-19} \times 10^{-3} \times 6.022 \times 10^{23}$

= 494.65 kJ mol^{-1}

9. Power of bulb = 25 watt = 25 J s^{-1}

Energy of photon $(E) = \dfrac{hc}{\lambda}$

$$= \frac{6.626\times10^{-34}\times3\times10^{8}}{0.57\times10^{-6}}$$ [$\because$ 1 μm = 10^{-6} m]

$= 34.87 \times 10^{-20}$ J

Rate of emission of quanta per second

$$= \frac{25}{34.87\times10^{-20}} = 0.7169\times10^{20} = 7.169 \times 10^{19}\ s^{-1}$$

10. Threshold frequency

$$(\upsilon_0) = \frac{c}{\lambda} = \frac{3\times10^8}{6800\times10^{-10}}$$ [1 Å = 10^{-10} m]

$= 4.41 \times 10^{14}\ s^{-1}$

Work function $(W_0) = h\upsilon_0$

$= 6.626 \times 10^{-34} \times 4.41 \times 10^{14} = 2.92 \times 10^{-19}$ J

11. According to Rydberg equation,

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

Here, $n_1 = 2$, $n_2 = 4$ and $R_H = 109677\ cm^{-1}$

$$\frac{1}{\lambda} = 109677\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = 109677\left(\frac{1}{4} - \frac{1}{16}\right)$$

$$= 109677\left(\frac{4-1}{16}\right) = 109677 \times \frac{3}{16}\ cm^{-1}$$

$$\Rightarrow\ \lambda = \frac{16}{109677\times3} = \frac{16}{329031} = 4.86\times10^{-5}\ \text{cm}$$

$= 486 \times 10^{-9}$ m = 486 nm [$\because$ 1 nm = 10^{-9} m]

12. $E_n = \dfrac{13.12 \times 10^5}{n^2}$ J/mole

Energy required to remove the electron completely from $n = 5$ orbital of H-atom is $= \dfrac{13.12 \times 10^5}{5^2}$ J/mole

$= 5.248 \times 10^4$ J/mole $= \dfrac{5.248 \times 10^4}{6.022 \times 10^{23}}$

$= 8.71 \times 10^{-20}$ J/atom

Energy required to remove the electron completely from $n = 1$ orbit in a H-atom is

$= \dfrac{13.12 \times 10^5}{1^2}$ J/mol $= 13.12 \times 10^5$ J/mol

$= \dfrac{13.12 \times 10^5}{6.022 \times 10^{23}} = 2.17 \times 10^{-18}$ J/atom

$\therefore$ Energy required to remove the electron from $n = 1$ orbit is 25 times than that required to remove the electron from $n = 5$.

13. Maximum number of emission lines

$= \dfrac{n\,(n-1)}{2} = \dfrac{6\,(6-1)}{2} = \dfrac{30}{2} = 15$ lines

14. (i) Energy associated with n^{th} orbit in hydrogen atom is

$E_n = \dfrac{-2.18 \times 10^{-18}}{n^2}$ J atom^{-1}

$\therefore$ Energy associated with 5^{th} orbit is

$E_5 = \dfrac{-2.18 \times 10^{-18}}{5^2} = -8.72 \times 10^{-20}$ J atom^{-1}

(ii) Radius of Bohr's fifth orbit for hydrogen atom,

$r_n = 0.529\, n^2$Å

$r_5 = 0.529 \times 5^2$ Å

$r_5 = 13.225$ Å $= 13.225 \times 10^{-10}$ m [$\because$ 1 Å $= 10^{-10}$ m]

$= 1.3225 \times 10^{-9}$ m $= 1.3225$ nm [$\because$ 1 nm $= 10^{-9}$ m]

15. According to Rydberg equation,

$\dfrac{1}{\lambda} = \bar{\upsilon}\,(\text{cm}^{-1}) = R_H\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

$= 109677\left(\dfrac{1}{2^2} - \dfrac{1}{3^2}\right) = 109677\left(\dfrac{1}{4} - \dfrac{1}{9}\right)$

$= 109677 \times \dfrac{5}{36}$ cm^{-1} $= 1.5233 \times 10^4$ cm^{-1}

Wavenumber for the longest wavelength of Balmer series $= 1.523 \times 10^6$ m^{-1}

16. Energy (E) $= 2.18 \times 10^{-18}$ J $\left(\dfrac{1}{n_i^2} - \dfrac{1}{n_f^2}\right)$

where, n_i = initial orbit, n_f = final orbit

$E = 2.18 \times 10^{-18}\left(\dfrac{1}{1^2} - \dfrac{1}{5^2}\right)$

$= 2.18 \times 10^{-18}\left(\dfrac{1}{1} - \dfrac{1}{25}\right) = 2.18 \times 10^{-18} \times \dfrac{24}{25}$

$= 2.09 \times 10^{-18}$ J $= 2.09 \times 10^{-11}$ erg [$\because$ 1 J $= 10^7$ erg]

Wavelength $= \dfrac{hc}{E} = \dfrac{6.626 \times 10^{-27} \times 3 \times 10^{10}}{2.09 \times 10^{-11}}$

9.51×10^{-6} cm $= 951 \times 10^{-8}$ cm $= 951$ Å

17. $E_n = \dfrac{-2.18 \times 10^{-18}}{n^2}$ J

$E_2 = \dfrac{-2.18 \times 10^{-18}}{(2)^2} = \dfrac{-2.18 \times 10^{-18}}{4}$

$= -0.545 \times 10^{-18} = -5.45 \times 10^{-19}$ J

Wavelength of light $(\lambda) = \dfrac{hc}{E}$

$= \dfrac{6.626 \times 10^{-34} \times 3 \times 10^8}{5.45 \times 10^{-19}} = 3.647 \times 10^{-7}$ m

$= 3647 \times 10^{-10}$ m $= 3647$ Å [$\because$ Å $= 10^{-10}$ m]

18.

Species	**Number of electrons**
Na^+	$11 - 1 = 10$
K^+	$19 - 1 = 18$
Mg^{2+}	$12 - 2 = 10$
Ca^{2+}	$20 - 2 = 18$
S^{2-}	$16 + 2 = 18$
Ar	$= 18$

Thus, Na^+ and Mg^{2+}; K^+, Ca^{2+}, S^{2-} and Ar have the same number of electrons.

19.

Species	**Number of electrons**
H_2^+	1 $(1 + 1 - 1 = 1)$
H_2	2 $(1 + 1 = 2)$
O_2^+	15 $(8 + 8 - 1 = 15)$

20. $\dfrac{1}{\lambda} = \bar{v} = 1.097 \times 10^7\, Z^2\left[\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right]$m^{-1}

where, n_1 = number of the lower energy level, n_2 = number of the higher energy level, Z = atomic number, λ = wavelength, $\bar{v}$ = wavenumber

For He^+,

$\dfrac{1}{\lambda} = 1.097 \times 10^7 \times (2)^2\left[\dfrac{1}{(2)^2} - \dfrac{1}{(4)^2}\right]$m^{-1}

$= 1.097 \times 10^7 \times 4\left(\dfrac{3}{16}\right) = 1.097 \times 10^7 \times \dfrac{3}{4}$ ...(i)

For H atom, $\frac{1}{\lambda}=1.097\times10^7\times(1)^2\times\frac{3}{4}$

$$=1.097\times10^7\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right] \quad \ldots\text{(ii)}$$

On comparing (i) and (ii)

$\frac{1}{n_1^2}-\frac{1}{n_2^2}=\frac{3}{4}$. This gives $n_1 = 1, n_2 = 2$

The transition $n_1 = 1$ to $n_2 = 2$ in H-atom would have the same wavelength as Balmer transition $n_2 = 4$ to $n_1 = 2$ of He^+.

21. Energy required $= E_\infty - E_1$

$$=0-\left(-\frac{2.18\times10^{-18}}{n^2}\times Z^2\right)=\frac{2.18\times10^{-18}\times2^2}{(1)^2}$$

$$= 8.72\times10^{-18}\text{ J}$$

22. Lesser number of α-particles will be deflected because nucleus of lighter atoms have smaller positive charge on their nuclei.

23. Atomic number should be a subscript while mass number should be a superscript of the symbol of an element. Thus, $^{35}_{79}Br$ is not acceptable.

The atomic number is fixed, but different isotopes of bromine atoms may have different mass numbers. Therefore, it is essential to mention mass number.

24. We know that $A = p + n \Rightarrow 81 = p + n$

Let number of protons $= x$

According to question,

No. of neutrons $= x+\frac{x\times31.7}{100}=1.317x$

$\therefore\ x + 1.317x = 81$ or $2.317x = 81$

$\therefore\ x=\frac{81}{2.317}=34.96\approx35$

Thus, symbol $= {}^{81}_{35}Br$

25. Let number of electrons $= x$

According to the question, number of neutrons (n)

$$=x+\frac{x\times11.1}{100}=\frac{100x+11.1x}{100}=\frac{111.1x}{100}=1.11x$$

We know that $A = p + n$

But $p = x - 1$

$37 = x - 1 + 1.11x$ or $38 = 2.11x$

$\therefore\ x=\frac{38}{2.11}=18$

So, number of electrons = 18

Hence, number of protons = 18 – 1 = 17

Thus, symbol of ion $= {}^{37}_{17}Cl^-$

26. Let the number of protons(p) $= x$

$\therefore$ Number of electrons (e) $= x - 3$ (because the ion carries 3 units of positive charge, it will have 3 electrons less than the number of protons.)

Number of neutrons(n)

$$=(x-3)+\frac{(x-3)\,30.4}{100}=\frac{100\,(x-3)+(x-3)\,30.4}{100}$$

$$n=\frac{100x-300+30.4x-91.2}{100}=\frac{130.4x-391.2}{100}$$

We know that $A = p + n$

$$56=x+\frac{130.4x-391.2}{100}$$

$$56=\frac{100x+130.4x-391.2}{100}$$

$5600 = 230.4x - 391.2$

$\therefore\ x = 26$

Thus, number of protons (p) = 26, number of electrons (e) = 26 – 3 = 23

Therefore, symbol of the ion $= {}^{56}_{26}Fe^{3+}$

27. The increasing order of frequency is (c) radiation from FM radio < (a) radiation from microwave oven < (b) amber light from traffic signal < (e) X-rays < (d) cosmic rays from outer space.

28. Wavelength of nitrogen = 337.1 nm = 337.1×10^{-9} m

Number of photons = 5.6×10^{24}

Energy of photons (E) $=\frac{nhc}{\lambda}$

$$=\frac{5.6\times10^{24}\times6.626\times10^{-34}\times3\times10^8}{337.1\times10^{-9}}=3.30\times10^6\text{ J}$$

Power of this nitrogen laser is 3.30×10^6 J

29. Wavelength of light (λ) = 616 nm

$= 616\times10^{-9}$ m [$\because$ 1 nm = 10^{-9} m]

(a) Frequency of emission $(\upsilon)=\frac{c}{\lambda}$

$$=\frac{3\times10^8}{616\times10^{-9}}=4.87\times10^{14}\text{ sec}^{-1}$$

(b) Distance travelled in 30 sec

$= 30\times3\times10^8 = 9.0\times10^9$ m

(c) Energy of quanta (E) $= h\nu$

$= 6.626\times10^{-34}\times4.87\times10^{14} = 3.227\times10^{-19}$ J

(d) Number of quanta in 2 J of energy

$$=\frac{2}{3.227\times10^{-19}}=6.2\times10^{18}\text{ photons}$$

30. Energy of photon, $E=\frac{hc}{\lambda}$

Here, $h = 6.626 \times 10^{-34}$ J s, $c = 3 \times 10^8$ m s^{-1}

$\lambda = 600$ nm $= 600 \times 10^{-9}$ m $= 6 \times 10^{-7}$ m

$$\therefore \quad E = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{6 \times 10^{-7}} = 3.31 \times 10^{-19} \text{ J}$$

$\because$ Total energy received $= 3.15 \times 10^{-18}$ J

$$\text{Number of photons received} = \frac{3.15 \times 10^{-18}}{3.31 \times 10^{-19}} = 9.52 \approx 10$$

31. Frequency $(\upsilon) = \dfrac{1}{2 \times 10^{-9}} = 0.5 \times 10^9$ sec^{-1}

Energy of the source $= n \times h\upsilon$

$= 2.5 \times 10^{15} \times 6.626 \times 10^{-34} \times 0.5 \times 10^9 = 8.28 \times 10^{-10}$ J

32. Step I : Wavelength $(\lambda) = 589$ nm $= 589 \times 10^{-9}$ m

$$\text{Frequency } (\upsilon) = \frac{c}{\lambda} = \frac{3 \times 10^8}{589 \times 10^{-9}}$$

$= 5.093 \times 10^{14}$ cycles per sec

Step II : Wavelength $(\lambda) = 589.6$ nm $= 589.6 \times 10^{-9}$ m

$$\therefore \quad \upsilon = \frac{c}{\lambda} = \frac{3 \times 10^8}{589.6 \times 10^{-9}} = 5.088 \times 10^{14} \text{ cycles per sec}$$

Energy difference between two excited states,

$\Delta E = 6.626 \times 10^{-34} (5.093 - 5.088) 10^{14}$

$= 6.626 \times 10^{-34} \times 5 \times 10^{-3} \times 10^{14} = 3.31 \times 10^{-22}$ J

33. (a) Work function $= h\upsilon_0 = 1.9$ eV

$= 1.9 \times 1.602 \times 10^{-19}$ J $= 3.04 \times 10^{-19}$ J

Threshold frequency,

$$(\upsilon_0) = \frac{3.04 \times 10^{-19}}{6.626 \times 10^{-34}} = 4.59 \times 10^{14} \text{ sec}^{-1}$$

(b) Threshold wavelength,

$$(\lambda_0) = \frac{c}{\upsilon_0} = \frac{3 \times 10^8}{4.59 \times 10^{14}} = 6.54 \times 10^{-7} \text{ m}$$

or 654×10^{-9} m or 654 nm

(c) Energy of light,

$$E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{500 \times 10^{-9}} = 3.98 \times 10^{-19} \text{ J}$$

Kinetic energy of ejected electron

$= 3.98 \times 10^{-19} - 3.04 \times 10^{-19} = 9.4 \times 10^{-20}$ J

$$\because \quad K.E. = \frac{1}{2} mv^2$$

$$v = \sqrt{\frac{2\,K.E.}{m}} = \sqrt{\frac{2 \times 9.4 \times 10^{-20}}{9.1 \times 10^{-31}}} = 4.54 \times 10^5 \text{ m s}^{-1}$$

34. Let the threshold wavelength $= \lambda_0$ nm $= \lambda_0 \times 10^{-9}$ m

$$\text{then } hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = \frac{1}{2} mv^2$$

Substituting the given three experiments,

$$\frac{hc}{10^{-9}}\left(\frac{1}{500} - \frac{1}{\lambda_0}\right) = \frac{1}{2} m\,(2.55 \times 10^5)^2 \quad \text{...(i)}$$

$$\frac{hc}{10^{-9}}\left(\frac{1}{450} - \frac{1}{\lambda_0}\right) = \frac{1}{2} m\,(4.35 \times 10^5)^2 \quad \text{...(ii)}$$

$$\frac{hc}{10^{-9}}\left(\frac{1}{400} - \frac{1}{\lambda_0}\right) = \frac{1}{2} m\,(5.20 \times 10^5)^2 \quad \text{...(iii)}$$

Dividing equation (ii) by equation (i) we get,

$$\frac{\lambda_0 - 450}{450\lambda_0} \times \frac{500\lambda_0}{\lambda_0 - 500} = \left(\frac{4.35}{2.55}\right)^2$$

$$\text{or} \quad \frac{\lambda_0 - 450}{\lambda_0 - 500} = \frac{450}{500} \times \left(\frac{4.35}{2.55}\right)^2$$

$$\text{or} \quad \frac{\lambda_0 - 450}{\lambda_0 - 500} = \frac{9}{10} \times \frac{18.92}{6.50} \quad \text{or} \quad \frac{\lambda_0 - 450}{\lambda_0 - 500} = 2.62$$

or $\lambda_0 - 450 = 2.62\lambda_0 - 1310$

$\lambda_0 = 530.86$ nm ≈ 531 nm

Putting this in equation (iii), we get

$$\frac{h \times 3 \times 10^8}{10^{-9}}\left(\frac{1}{400} - \frac{1}{531}\right) = \frac{1}{2}(9.1 \times 10^{-31})(5.20 \times 10^5)^2$$

$$h \times 3 \times 10^{17}\left(\frac{131}{531 \times 400}\right) = \frac{1}{2} \times 27.04 \times 10^{10} \times 9.1 \times 10^{-31}$$

$h = 6.66 \times 10^{-34}$ J s

35. Energy of incident radiation $(E) = \dfrac{hc}{\lambda}$

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{256.7 \times 10^{-9}} = 0.0774 \times 10^{-17}$$

$= 7.74 \times 10^{-19}$ J

$= 4.83$ eV [$\because 1.602 \times 10^{-19}$ J $= 1$ eV]

The potential applied gives the kinetic energy to the electron. Hence, *K.E.* of electron $= 0.35$ eV

$\therefore$ Work function $= (4.83 - 0.35)$ eV $= 4.48$ eV

36. Photon of wavelength $= 150$ pm $= 150 \times 10^{-12}$ m

$$\text{Energy of photon } (E) = \frac{hc}{\lambda}$$

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{150 \times 10^{-12}}$$

$= 0.1325 \times 10^{-14} = 13.25 \times 10^{-16}$ J

Energy of the ejected electron = $\frac{1}{2}mv^2$

$= \frac{1}{2}\times 9.11\times 10^{-31}\times(1.5\times 10^7)^2 = 1.025 \times 10^{-16}$ J

Energy with which the electron is bound to the nucleus

$= (13.25 \times 10^{-16} - 1.025 \times 10^{-16})$ J $= 12.225 \times 10^{-16}$ J

$= \frac{12.225\times 10^{-16}}{1.602\times 10^{-19}} = 7.63 \times 10^3$ eV

[$\because$ 1.602×10^{-19} J = 1 eV]

37. $\because$ λ = 1285 nm = 1285×10^{-9} m [$\because$ 1 nm = 10^{-9} m]

$\therefore \quad \upsilon = \frac{c}{\lambda} = \frac{3\times 10^8}{1285\times 10^{-9}} = 2.33 \times 10^{14}$ sec^{-1}

According to question, $\upsilon = 3.29\times 10^{15}\left(\frac{1}{3^2}-\frac{1}{n^2}\right)$

$\therefore \quad 2.33 \times 10^{14} = 3.29 \times 10^{15}\left(\frac{1}{9}-\frac{1}{n^2}\right)$

$\therefore \quad \frac{2.33\times 10^{14}}{3.29\times 10^{15}} = \frac{1}{9}-\frac{1}{n^2}$ or $0.0708 = \frac{1}{9}-\frac{1}{n^2}$

or $\frac{1}{n^2} = \frac{1}{9} - 0.0708$ or $\frac{1}{n^2} = \frac{1-0.64}{9}$

or $\frac{1}{n^2} = \frac{0.36}{9}$

$\therefore \quad n^2 = \frac{9}{0.36} = \frac{900}{36} = 25 \Rightarrow n = \sqrt{25} = 5$

$\lambda = 1.285 \times 10^{-6}$ m *i.e.*, of order 10^{-6} m which lies in the infrared region.

38. Radius of n^{th} orbit of H-like particles

$= \frac{0.529\times n^2}{Z}$ Å $= \frac{52.9\times n^2}{Z}$ pm

Radius (r_1) = 1.3225 nm = 1322.5 pm = $\frac{52.9\, n_1^2}{Z}$

Radius (r_2) = 211.6 pm = $\frac{52.9\, n_2^2}{Z}$

$\therefore \quad \frac{r_1}{r_2} = \frac{1322.5}{211.6} = \frac{n_1^2}{n_2^2}$

$\Rightarrow \quad 6.25 = \frac{n_1^2}{n_2^2} \Rightarrow \left(\frac{n_1}{n_2}\right)^2 = 6.25 \Rightarrow \frac{n_1}{n_2} = \sqrt{6.25} = 2.5$

$\therefore$ $n_2 = 2, n_1 = 5$ thus, the transition is from 5^{th} orbit to 2^{nd} orbit. It belongs to Balmer series.

$\bar{\upsilon} = 1.097\times 10^7\left(\frac{1}{2^2}-\frac{1}{5^2}\right)$

$= 1.097\times 10^7\left(\frac{1}{4}-\frac{1}{25}\right) = 1.097\times 10^7 \times \frac{21}{100}$

$\lambda = \frac{1}{\bar{\upsilon}} = \frac{100}{1.097\times 21\times 10^7}$ m $= 4.34 \times 10^{-7}$ m

$= 434 \times 10^{-9}$ m = 434 nm

Thus, it lies in the visible region.

Topic 3

1. Wavelength of electron (λ) $= \frac{h}{mv}$

where, $h = 6.626 \times 10^{-34}$ J s (Planck's constant), m = mass of electron, v = velocity of electron

$\therefore \quad \lambda = \frac{6.626\times 10^{-34}}{9.1\times 10^{-31}\times 2.05\times 10^7} = 3.55 \times 10^{-11}$ m

2. $K.E. = \frac{1}{2}mv^2$

$v = \left(\frac{2\times 3\times 10^{-25}}{9.1\times 10^{-31}}\right)^{1/2} = 812$ m s^{-1}

Now, $\lambda = \frac{h}{mv} = \frac{6.626\times 10^{-34}}{9.1\times 10^{-31}\times 812}$

$= 8.967 \times 10^{-7}$ m = 8967 Å

3. According to Bohr's theory, the angular momentum of an electron of mass (m) moving with speed (v) in an orbit of radius (r) is an integral multiple of $\frac{h}{2\pi}$.

$mvr = n\frac{h}{2\pi}$ or $2\pi r = n\frac{h}{mv}$ ...(1)

But according to de Broglie equation,

$\lambda = \frac{h}{mv}$ ...(2)

From equations (1) and (2), we get $2\pi r = n\lambda$, *i.e.*, an integral multiple of the de Broglie wavelength.

4. According to de Broglie equation, $\lambda = \frac{h}{mv}$

where h = Planck's constant = 6.626×10^{-34} J s

m = mass of particles = 9.1×10^{-31} kg,

v = velocity = 1.6×10^6 m/s

$\therefore \quad \lambda = \frac{6.626\times 10^{-34}}{9.1\times 10^{-31}\times 1.6\times 10^6} = 0.455 \times 10^{-9}$ m

$= 455 \times 10^{-12}$ m = 455 pm [$\because$ 1 pm = 10^{-12} m]

5. $v = \frac{h}{m\lambda}$ $\left[\because \lambda = \frac{h}{mv}\right]$

$$= \frac{6.626\times10^{-34}}{1.675\times10^{-27}\times800\times10^{-12}} = 4.94 \times 10^{2}\ \text{m s}^{-1}$$

$$\left[\begin{array}{l} \because\ m = \text{mass of neutron} = 1.675\times10^{-27}\ \text{kg} \\ \lambda = 800\ \text{pm} = 800\times10^{-12}\ \text{m} \end{array}\right]$$

6. We know that, $\lambda = \frac{h}{mv}$

where, $h = 6.626 \times 10^{-34}$ J s,

m = mass of electron = 9.1×10^{-31} kg

$v = 2.19 \times 10^{6}$ m/s

$$\therefore\quad \lambda = \frac{6.626\times10^{-34}}{9.1\times10^{-31}\times2.19\times10^{6}} = 0.332 \times 10^{-9}\ \text{m}$$

$= 332 \times 10^{-12}$ m = 332 pm $\qquad [\because\ 1\ \text{pm} = 10^{-12}\ \text{m}]$

7. We know that $\lambda = \frac{h}{mv}$

where $h = 6.626 \times 10^{-34}$ J s, $m = 0.1$ kg, $v = 4.37 \times 10^{5}$ m s^{-1}

$$\therefore\quad \lambda = \frac{6.626\times10^{-34}}{0.1\times4.37\times10^{5}} = 15.16\times10^{-39}\ \text{m}$$

$$= 1.516 \times 10^{-38}\ \text{m}$$

8. According to uncertainty principle, $\Delta x \times \Delta p = \frac{h}{4\pi}$

where, $\Delta x = \pm\ 0.002$ nm $= \pm\ 0.002 \times 10^{-9}$ m, Δp = ?

$$\therefore\quad \Delta p = \frac{h}{4\pi\Delta x} = \frac{6.626\times10^{-34}}{4\times\frac{22}{7}\times0.002\times10^{-9}}$$

$$= 2.63 \times 10^{-23}\ \text{kg m/sec}$$

Actual momentum = $\frac{h}{4\pi_m}\cdot\frac{1}{0.05}$

$$= \frac{6.626\times10^{-34}}{4\times3.14\times5\times10^{-11}} = 1.05 \times 10^{-24}\ \text{kg m/s}$$

This value cannot be defined as the actual magnitude of the momentum is smaller than the uncertainty in momentum, which is impossible.

9. (i) The respective electronic configurations are :

(a) $H^{-} \longrightarrow 1s^{2}$ (b) $Na^{+} \longrightarrow 1s^{2}2s^{2}2p^{6}$

(c) $O^{2-} \longrightarrow 1s^{2}2s^{2}2p^{6}$ (d) $F^{-} \longrightarrow 1s^{2}2s^{2}2p^{6}$

(ii) (a) $3s^{1} \longrightarrow 1s^{2}2s^{2}2p^{6}3s^{1}$

$\therefore$ The atomic number of element = 11

(b) $2p^{3} \longrightarrow 1s^{2}2s^{2}2p^{3}$

$\therefore$ The atomic number of element = 7

(c) $3p^{5} \longrightarrow 1s^{2}2s^{2}2p^{6}3s^{2}\,3p^{5}$

$\therefore$ The atomic number of element = 17

(iii) (a) [He] $2s^{1} \longrightarrow$ Lithium, Li

(b) [Ne] $3s^{2}3p^{3} \longrightarrow$ Phosphorus, P

(c) [Ar] $4s^{2}3d^{1} \longrightarrow$ Scandium, Sc

10. For g-orbital, l = 4. For a value of n, possible values of l are 0 to n – 1.

Thus, $l = 4 = n - 1 \Rightarrow n = 5$

The lowest value of n that allows g-orbitals to exist is 5.

$$\left[\begin{array}{ll} \because\ l = 0 & 's'\ \text{orbital} \\ l = 1 & 'p'\ \text{orbital} \\ l = 2 & 'd'\ \text{orbital} \\ l = 3 & 'f'\ \text{orbital} \\ l = 4 & 'g'\ \text{orbital} \end{array}\right]$$

11. For $3d$-orbital

$\therefore$ $n = 3$

$l = 2$

$m_l = -l$ to $+l$

$= -2$ to $+2$

$= -2, -1, 0, +1, +2$

12. Number of electrons = 29, number of neutrons = 35

(i) We know that $Z = e = p$

$\because$ $e = 29$ $\qquad \therefore\ p = 29$

(ii) Electronic configuration : $1s^{2}2s^{2}2p^{6}3s^{2}3p^{6}3d^{10}4s^{1}$

13. (i) When $n = 3$, $l = 0, 1, 2$

When $l = 0$, $m_l = 0$. When $l = 1$, $m_l = -1, 0, +1$.

When $l = 2$, $m_l = -2, -1, 0, +1, +2$.

(ii) For $3d$-orbital $l = 2$, $m_l = -2, -1, 0, +1, +2$

(iii) For a particular value of n, the allowed values of l are 0 to n – 1 only. Hence, $2s$ and $2p$ are the only possible orbitals.

14. (a) $1s$ (b) $3p$ (c) $4d$ (d) $4f$

15. (a) Not possible because $n \neq 0$

(c) Not possible because when $n = 1$, $l = 0$

(e) Not possible because when $n = 3$, $l = 0, 1, 2$, and not equal to 3.

16. (a) Total number of electrons in $n = 4$ is $2n^{2} = 2(4)^{2} = 32$

But half of these electrons have $m_s = -1/2$

$\therefore$ Number of electrons = 16

(b) Number of electrons = 2 $\qquad [\because 3s$ subshell]

17. 1. $4d$ ($n + l = 4 + 2 = 6$)

2. $3d$ ($n + l = 3 + 2 = 5$) 3. $4p$ ($n + l = 4 + 1 = 5$)

4. $3d$ ($n + l = 3 + 2 = 5$) 5. $3p$ ($n + l = 3 + 1 = 4$)

6. $4p$ ($n + l = 4 + 1 = 5$)

Greater the value of $n + l$, higher will be the energy of orbital. If two orbitals have same $n + l$ value then the orbital having higher n value will possess higher energy.

Therefore, the required order is :

$5 < 2 = 4 < 6 = 3 < 1$

18. The electron in $4p$ orbital experiences lowest effective nuclear charge because it is farthest from the nucleus.

19. Orbital closer to the nucleus will experience larger effective nuclear charge.

(i) $2s$ (ii) $4d$ (iii) $3p$

20. Si has nuclear charge, Z = 14 while Al has Z = 13. Thus, the electrons of $3p$-orbital of Si will experience more effective nuclear charge from the nucleus.

21. (a) ${}_{15}P \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$

Number of unpaired electrons = 3

(b) ${}_{14}Si \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^2$

Number of unpaired electrons = 2

(c) ${}_{24}Cr \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

Number of unpaired electrons = 6

(d) ${}_{26}Fe \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$

Number of unpaired electrons = 4

(e) ${}_{36}Kr \rightarrow 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6$

Number of unpaired electrons = zero

22. (a) $n = 4, l = 0, 1, 2, 3$ [$\because l = 0$ to $n - 1$]

$\therefore$ Number of sub-shells = 4

(b) Number of electrons having $m_s = -1/2 = \frac{32}{2} = 16$

[$\because$ Maximum number of electrons = $2n^2 = 2 \times 4^2 = 32$]