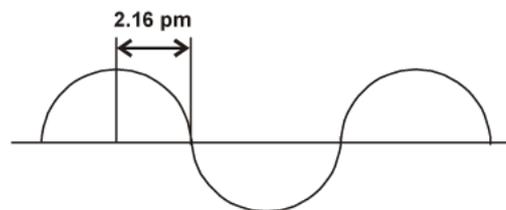
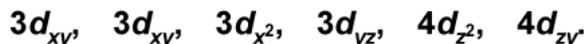


Q18. (a) A hypothetical electromagnetic wave is shown in figure. Find out the wavelength of the radiation.

(b) If the diameter of a carbon atom is 0.15nm, calculate the number of carbon atoms which can be placed side by side in a straight line across the length of scale of length 20 cm long.



(c) Which of the following orbitals are degenerate?



Q19. (a) In a hydrogen atom, electron falls from infinity to stationary state one. What is the wavelength of the radiation emitted? (Rydberg's constant = $1.097 \times 10^7 \text{ m}^{-1}$).

(b) The atomic number of an element M is 26. How many electrons are present in the M -shell of the element in its M^{3+} state?

(c) If value of azimuthal quantum number (l) is 2, then calculate the value of principal quantum number (n).

Q20. Write any three observations of Rutherford scattering experiment. Draw the figure in support of your answer.

Q21. (a) Calculate the frequency and wave number of a radiation having wavelength 600 nm.

(b) What will be the orbital angular momentum of d -electron?

(c) A certain particle carries $2.5 \times 10^{-6} \text{ C}$ of static charge. Calculate the number of electrons present in it.

Q22. (a) Oxygen atom has atomic number 8 and nitrogen has atomic number 7. Calculate the total number of electrons in nitrate ion.

(b) Calculate the mass of photon of sodium light having wavelength 600 nm and velocity $3 \times 10^8 \text{ ms}^{-1}$.

(c) How many radial nodes are present in $4d$ -orbital?

Q23. (a) The exact frequency distribution of the emitted radiation from a black body depends on temperature. Draw the plot of intensity *versus* wavelength of the radiation.

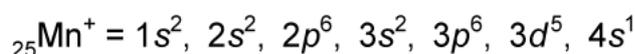
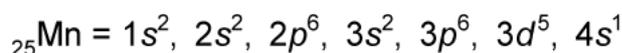
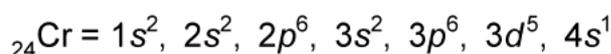
(b) The mass of an electron is $9.1 \times 10^{-31} \text{ kg}$. If its kinetic energy is $3.0 \times 10^{-25} \text{ J}$, what will be its wavelength?

(c) An atom of the element contains 29 electrons and 35 neutrons write the electronic configuration of the element.

- S1.** Here, Atomic number (Z) = Number of protons = 4
Mass number (A) = Number of protons + Number of neutrons = 4 + 5 = 9.

S2. Here, de-Broglie wavelength, $\lambda = \frac{h}{mv} = \frac{6.6 \times 10^{-34} \text{ Js}^{-1}}{60 \times 10^{-3} \text{ kg} \times 11 \text{ ms}^{-1}} = 1 \times 10^{-33} \text{ m}$.

- S3.** Cr and Mn⁺ both show the given electronic configuration



- S4.** (a) Given, $h = 6.626 \times 10^{-34} \text{ Js}$, $m = 9.1 \times 10^{-31} \text{ kg}$ and $\Delta x = 10^{-6} \text{ m}$
According to Heisenberg's uncertainty principle,

$$\Delta x \times mv = \frac{h}{4\pi} \quad \text{or} \quad \Delta v = \frac{h}{4\pi m \Delta x}$$

where,

Δv = uncertainty in velocity

Δx = uncertainty in position

$$\Delta v = \frac{6.626 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1} \times 7}{4 \times 22 \times 9.1 \times 10^{-31} \text{ kg} \times 10^{-8} \text{ m}}$$

$$\Rightarrow \Delta v = 5.791 \times 10^3 \text{ ms}^{-1}.$$

- (b) There can be three subshells having value of $n + l = 5$, which are 5s ($n = 5, l = 0$); 4p ($n = 4, l = 1$) and 3d ($n = 3, l = 2$). Hence, electrons present in these subshells are $2 + 6 + 10 = 18$.

- S5.** (a) Given, Wavelength (λ) = 580 nm

We know that, Frequency, $\nu = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ ms}^{-1}}{580 \times 10^{-7} \text{ cm}}$ [$\because 1 \text{ nm} = 10^{-9} \text{ m}$ and speed of light, $c = 3 \times 10^8 \text{ ms}$]

$$= 5.17 \times 10^{14} \text{ s}^{-1}$$

$$\therefore \text{Wave number, } \bar{\nu} = \frac{1}{\lambda} = \frac{1}{580 \times 10^{-7} \text{ cm}} = 1.724 \times 10^4 \text{ cm}^{-1}$$

- (b) The energy associated with the fifth orbit can be calculated by using the following relation.

$$E_n = \frac{-2.17 \times 10^{-18} \text{ J atom}^{-1}}{n^2}$$

where, n = Number of orbits

Ths, energy associated with fifth orbital ($n = 5$)

$$E_5 = \frac{-2.17 \times 10^{-18} \text{ J atom}^{-1}}{(5)^2}$$

$$= -8.68 \times 10^{-20} \text{ J.}$$

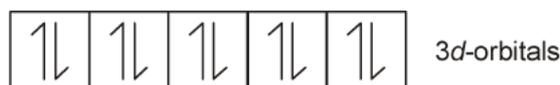
S6. (a) For $n = 3$, $l = 0, 1$ and 2 i.e., 3 subshells, s , p and d are present.

(b) Number of orbitals in 3rd shell = $n^2 = 3^2 = 9$

Each orbital has one electron with $m_s = -\frac{1}{2}$

Hence, there will be 9 electrons with $m_s = -\frac{1}{2}$.

S7. (a) (i) $n = 3$, $l = 2$ means 3d-orbitals which can have 10 electrons because there are five orbitals and each orbital can accommodate 2 electrons



(ii) Total electrons in 4th shell (i.e., $n = 4$) are $2n^2$, i.e., $2 \times 4^2 = 32$

Half of them, i.e., 16 electrons have $m_s = -\frac{1}{2}$.

(b) For H-atom, K.E. of electron in different energy levels is given by = $-\frac{13.6 \times Z^2}{n^2}$ eV

where, n = energy level

$$\text{K.E. of 3rd energy level} = \frac{-13.6 \times 1^2}{3^2} \text{ eV} = \frac{-13.6}{9} \text{ eV}$$

$$\text{K.E. of 4th energy level} = \frac{-13.6 \times 1^2}{4^2} \text{ eV} = \frac{-13.6}{16} \text{ eV}$$

$$\text{Ratio of 3rd and 4th energy level} = \frac{E_3}{E_4} \Rightarrow \frac{\frac{-13.6}{9} \text{ eV}}{\frac{-13.6}{16} \text{ eV}} = \frac{16}{9}$$

S8. (a) According to de-Broglie's equation,

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

Given, $\lambda = 6.62 \times 10^{-35} \text{ m}$

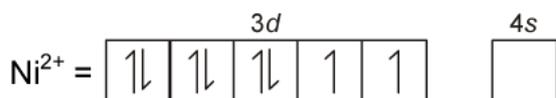
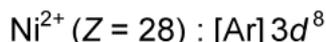
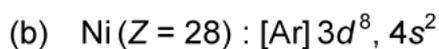
$$v = 100 \text{ ms}^{-1}$$

$$h = 6.63 \times 10^{-34} \text{ Js}$$

and $m = x \text{ kg}$

$$\therefore 6.62 \times 10^{-35} = \frac{6.62 \times 10^{-34} \text{ Js}}{x \text{ kg} \times 100 \text{ ms}^{-1}}$$

$$x = 0.1 \text{ kg}$$



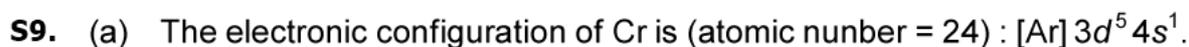
Hence, number of unpaired electrons in Ni^{2+} is two.



Then, $l = 3$ [$\because m$ has value from -3 to $+3$ including zero]

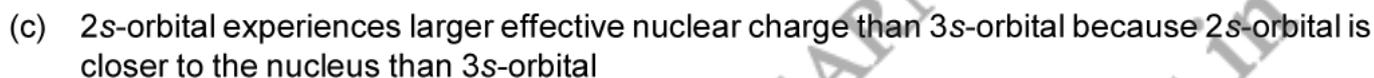
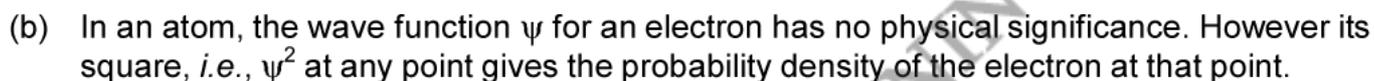
$\therefore n = 4$ [$\because l$ has values from 0 to $n - 1$]

Thus, the principal quantum number (n) = 4 .



This is because half-filled d -orbital is more stable as compared to incompletely filled d -orbital. So, one electron jumps from $4s^2$ -orbital to $3d$ -orbital.

Hence, the free gaseous Cr-atom has six unpaired electrons.



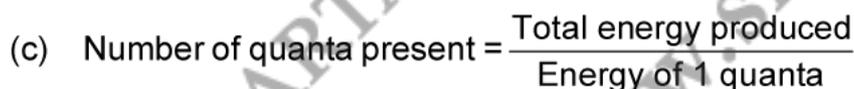
$$v = \frac{c}{\lambda}$$

$$\lambda = 616 \text{ nm} = 616 \times 10^{-9} \text{ m}$$

$$v = \frac{3.0 \times 10^8 \text{ ms}^{-1}}{616 \times 10^{-9} \text{ m}} = 4.870 \times 10^{14} \text{ s}^{-1}$$



$$\begin{aligned} E &= hv = 6.626 \times 10^{-34} \text{ Js} \times 4.870 \times 10^{14} \text{ s}^{-1} \\ &= 32.268 \times 10^{-20} \text{ J} = 32.27 \times 10^{-20} \text{ J} \end{aligned}$$



$$= \frac{2 \text{ J}}{32.27 \times 10^{-20} \text{ J}} = 6.197 \times 10^{18} = 6.2 \times 10^{18} \text{ quanta.}$$



$$r = R_0 A^{1/3}$$

where,

$$R_0 = 1.4 \times 10^{-15} \text{ m,}$$

\therefore

$$r = (1.4 \times 10^{-15} \text{ m}) \times (125)^{1/3} = 7.0 \times 10^{-15} \text{ m}$$

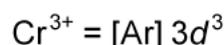
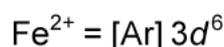
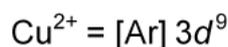
- (b) Electrons will be ejected only if the energy of incident light is greater than the threshold energy.

$$\text{Energy of the incident light} = h\nu = h \frac{c}{\lambda}$$

$$= \frac{6.636 \times 10^{-34} \times 3 \times 10^8}{4000 \times 10^{-10}} = 4.97 \times 10^{-19} \text{ J}$$

This is less than threshold energy, hence electrons will not be ejected.

- (c) Electronic configuration of



Paramagnetism depends on the number of unpaired electrons. From the electronic configuration of these ions, it is clear that Cu^{2+} has one, Fe^{2+} has four and Cr^{3+} has three unpaired electrons.

Hence, Fe^{2+} is the most paramagnetic species.

- S12.** (a) For 3d-electron,

$$n = 3, \quad l = 2$$

$$m = -2, -1, 0, +1, +2 \quad (\text{any one})$$

- (b) (i) $\text{H}^- : 1s^2$ (ii) $\text{Na}^+ : 1s^2, 2s^2, 2p^6$ (iii) $\text{O}^{2-} : 1s^2, 2s^2, 2p^6$ (iv) $\text{F}^- : 1s^2, 2s^2, 2p^6$

- (c) Wavelength, $\lambda = \frac{h}{mv}$

Mass of neutron,

$$m = 1.675 \times 10^{-27} \text{ kg}$$

$$\lambda = 800 \text{ pm} = 800 \times 10^{-12} \text{ m}$$

\therefore

$$\lambda = \frac{6.626 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1}}{1.675 \times 10^{-27} \text{ kg} \times v}$$

$$v = \frac{6.626 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1}}{1.675 \times 10^{-27} \text{ kg} \times 800 \times 10^{-12} \text{ m}}$$

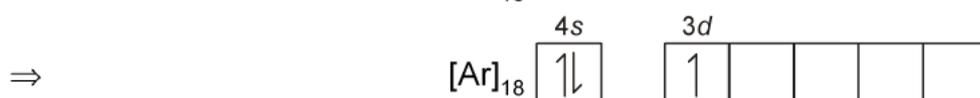
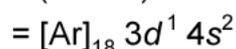
$$= 0.494 \times 10^3 \text{ ms}^{-1} = 4.94 \times 10^2 \text{ ms}^{-1}$$

- S13.** (a) We have the formula for velocity of the electron in n^{th} orbit.

$$v_n = \frac{2.182 \times 10^6}{n}$$

When $n = 3$ then, $v_3 = \frac{2.182 \times 10^6}{3} \text{ ms}^{-1} = 7.273 \times 10^5 \text{ ms}^{-1}$

- (b) Electronic configuration of Sc ($Z = 21$) is



19th electron goes into 4s.

Hence, $n = 4, l = 0, m = 0, m_s = +\frac{1}{2}$.

(c) For H,
$$\bar{\nu} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right)$$

For other atoms/ions,
$$\bar{\nu} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) Z^2$$

\therefore For Li^{2+} , $\bar{\nu} = 15200 \times 3^2 = 136.800 \text{ cm}^{-1}$.

S14. (a)
$$\bar{\nu} = \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) \quad [\text{where, } R_H = \text{Rydber's constant}]$$

For Balmer series, $n_1 = 2$ and for 4th line in Balmer series, $n_2 = 6$

\therefore
$$R_H = 109677 \text{ cm}^{-1} \Rightarrow \bar{\nu} = 109677 \left(\frac{1}{2^2} - \frac{1}{6^2} \right)$$

$$= 109677 \left(\frac{1}{4} - \frac{1}{36} \right) = 24372 \text{ cm}^{-1}$$

(b) Given,
$$h = 6.626 \times 10^{-34} \text{ Js}, \quad m = 9.11 \times 10^{-31} \text{ g}$$

$$\Delta x = 0.1 \text{ \AA}$$

According to Heisenberg's uncertainty principle,

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

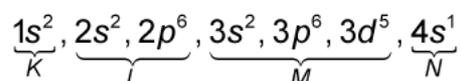
\therefore
$$\Delta v = \frac{6.626 \times 10^{-34}}{4 \times 3.14 \times 9.11 \times 10^{-32} \times 0.1 \times 10^{-10}} \text{ ms}^{-1}$$

$$= 5.79 \times 10^6 \text{ ms}^{-1}$$

- (c) Since, the element contains
 2 electrons in *K*-shell
 8 electrons in *L*-shell
 13 electrons in *M*-shell and 1 electron in *N*-shell
 Total number of electrons = 2 + 8 + 13 + 1 = 24

So, the atomic number of the element is 24.

The element whose atomic number is 24 is chromium (Cr). Its electronic configuration is



S15. (a) The number of radial nodes can be calculated by the expression $(n - l - 1)$

For 3s, Number of nodes = 3 - 0 - 1 = 2

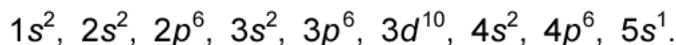
For 2p, Number of nodes = 2 - 1 - 1 = 0

(b) To find out the energy of third Bohr orbit of hydrogen atom

$$E = -313.6 \times \frac{Z^2}{n^2} \text{ k cal mol}^{-1} \quad [\because 1 \text{ cal} = 4.18 \text{ J}]$$

$$E = -313.6 \times \frac{1}{9} \times 4.18 \Rightarrow E = -145 \text{ kJ mol}^{-1}$$

(c) Electronic configuration of Rb ($Z = 37$) is



So, for the valence shell electron ($5s^1$) of Rb,

$$n = 5, \quad l = 0, \quad m = 0, \quad s = +\frac{1}{2}.$$

S16. (a) Configurations with completely filled and half-filled orbitals have extra stability.

In $3d^{10} 4s^1$, d -orbitals are completely filled and s -orbitals is half-filled. Hence, it is a more stable configuration.

(b) We know that,
$$\frac{1}{\lambda} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) Z^2$$

For hydrogen atom,
$$\frac{1}{91.2} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) 1^2 \quad \dots (i)$$

For He^+ ,
$$\frac{1}{\lambda} = R \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right) 2^2 \quad \dots (ii)$$

On dividing Eq. (i) by Eq. (ii), we get

$$\frac{\lambda}{91.2} = \frac{1}{4} \quad \text{or} \quad \lambda = 22.8 \text{ nm}$$

(c) Given, Mass number = 81

$$\therefore p + n = 81$$

If number of protons is equal to x , then neutrons = $\frac{31.7x}{100} = 1.317x$

$$\therefore \text{Mass number} = x + 1.317x = 81$$

$$\text{or} \quad 2.317x = 81$$

$$x = \frac{81}{2.317} = 35$$

Hence, number of protons = 35, therefore atomic number = 35. Thus, the symbol of an element is ${}_{35}^{81}\text{Br}$.

S17. In Lyman series, $n_1 = 1$ and $n_2 = 2$ (corresponding lowest frequency region)

$$\begin{aligned}\frac{1}{\lambda} &= \bar{\nu} = R \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] \\ &= 1.09677 \times 10^7 \text{ m}^{-1} \left[\frac{1}{1^2} - \frac{1}{2^2} \right] \quad (\text{where, } R = \text{Rydberg constant}) \\ &= 1.09677 \times 10^7 \text{ m}^{-1} \left(1 - \frac{1}{4} \right) \\ &= \frac{1.09677 \times 10^7 \times 3}{4} \text{ cm}^{-1}\end{aligned}$$

$$\therefore \text{Wavelength } (\lambda) = \frac{4}{1.09677 \times 10^7 \times 3} \text{ cm}^{-1} = 1.21 \times 10^{-7} \text{ m}$$

$$\text{Frequency } (\nu) = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ ms}^{-1}}{1.215 \times 10^7 \text{ m}} = 2.4677 \times 10^{15} \text{ s}^{-1}$$

$$\begin{aligned}\text{Energy of radiation } (E) &= h\nu = 6.625 \times 10^{-34} \text{ Js} \times 2.4677 \times 10^{15} \text{ s}^{-1} \\ &= 1.6348 \times 10^{-18} \text{ J}\end{aligned}$$

$$\begin{aligned}\text{Energy for corresponding line in the spectrum of } \text{Li}^{2+} &= \text{Energy for hydrogen atom } Z^2 \\ &= 1.6348 \times 10^{-18} \text{ J} \times 32 \\ &= 1.471 \times 10^{-17} \text{ J}.\end{aligned}$$

S18. (a) Wavelength is the distance between two successive peaks (crests) of two successive troughs of a wave.

$$\begin{aligned}\text{Therefore,} \quad \lambda &= 4 \times 2.16 \text{ pm} = 8.64 \text{ pm} \\ &= 6.64 \times 10^{-12} \text{ m} \quad [\because 1 \text{ pm} = 10^{-12} \text{ m}]\end{aligned}$$

(b) Diameter of a carbon atom = $0.15 \text{ nm} = 0.15 \times 10^{-9} \text{ m}$

Length along which atoms are to be placed

$$= 20 \text{ cm} = 0.2 \text{ m}$$

Number of carbon atoms which can be placed in the given length

$$= \frac{0.2}{0.15 \times 10^{-9} \text{ m}} = \frac{0.2 \times 10^9 \text{ m}}{0.15 \text{ m}} = 1.33 \times 10^9 \text{ atoms}.$$

(c) The orbitals which belongs to same subshell and same shell are called degenerate orbitals.

$(3d_{xy}, 3d_{z^2}, 3d_{yz})$ and $(4d_{xy}, 4d_{zy}, 4d_{z^2})$ are two sets of degenerate orbitals.

S19. (a)
$$\frac{1}{\lambda} = \bar{\nu} = R_H \left[\frac{1}{n_1^2} - \frac{1}{n_2^2} \right] = 1.097 \times 10^7 \left[\frac{1}{1^2} - \frac{1}{\infty^2} \right]$$

$$\therefore \lambda = \frac{1}{1.097 \times 10^7} \text{ m} = 9.11 \times 10^{-8} \text{ m}$$

$$= 91.1 \times 10^{-9} \text{ m} = 91.1 \text{ nm} \quad [\because 1 \text{ nm} = 10^{-9} \text{ m}]$$

(b)

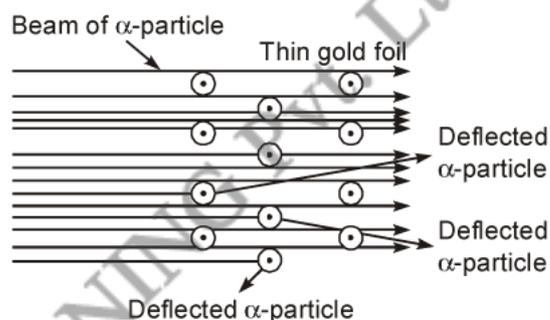
	K	L	M	N
M (26)	$1s^2$	$2s^2 2p^6$	$3s^2 3p^6 3d^6$	$4s^2$
M 3+	$1s^2$	$2s^3 2p^6$	$3s^2 3p^6 3d^5$	$4s^0$

Hence, 13 electrons are present in the M -shell of M^{3+} state.

- (c) Given, azimuthal quantum number (l) = 2
 \therefore Principal quantum number (n) = $l + 1 = 2 + 1 = 3$.

S20. Observations of Rutherford scattering experiment are:

- (a) Most of the α -particles passed through the gold foil undeflected.
 (b) A small fraction of the α -particles was deflected by small angles.
 (c) A very few α -particles (~ 1 in 20000) bounced back, that is, were deflected by nearly 180° .



S21. (a) Given, Wavelength (λ) of the radiation = $600 \text{ nm} = 600 \times 10^{-9} \text{ m} = 6 \times 10^{-7} \text{ m}$

Velocity of light, $c = 3 \times 10^8 \text{ ms}^{-1}$

$$\therefore \text{Frequency, } \nu = \frac{c}{\lambda} = \frac{3 \times 10^8 \text{ ms}^{-1}}{6 \times 10^{-7} \text{ m}} = 5 \times 10^{14} \text{ s}^{-1} \quad [\because c = \nu\lambda]$$

We know that wave number,
$$\bar{\nu} = \frac{1}{\lambda} = \frac{1}{6 \times 10^{-7} \text{ m}} = 1.67 \times 10^6 \text{ m}^{-1}$$

(b) Orbital angular momentum = $\sqrt{l(l+1)} \frac{h}{2\pi}$

For d -orbital, $l = 2$

$$\therefore \text{Orbital angular momentum} = \sqrt{2(2+1)} \frac{h}{2\pi} = \sqrt{6} \frac{h}{2\pi}$$

(c) Charge carried by one electron = $1.6022 \times 10^{-19} \text{ C}$

$$\therefore \text{Electrons present in particle carrying } 2.5 \times 10^{-5} \text{ C charge} = \frac{2.5 \times 10^{-6}}{1.6022 \times 10^{-19}}$$

$$= 1.56 \times 10^{13} \text{ electrons}$$

S22. (a) The nitrate ion is NO_3^- .

$$\begin{aligned} \text{Number of electrons in } \text{NO}_3^- &= \text{Electrons in N} + 3 \times \text{electrons in O} + 1 \text{ (due to negative charge)} \\ &= 7 + 3 \times 8 + 1 = 32 \end{aligned}$$

(b) Wavelength of photon, $\lambda = 600 \times 10^{-9} \text{ m} = 6.0 \times 10^{-7} \text{ m}$

$$\text{Velocity of photon (c)} = 3 \times 10^8 \text{ ms}^{-1}$$

By using formula,
$$m = \frac{h}{c\lambda}$$

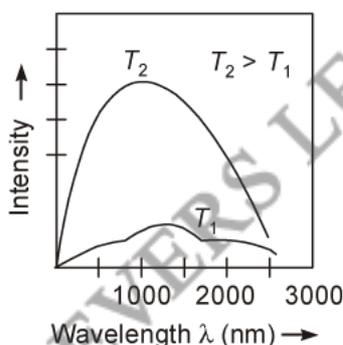
$$\begin{aligned} \text{We get, Mass of photon} &= \frac{6.626 \times 10^{-34} \text{ Js}^{-1}}{3 \times 10^8 \text{ ms}^{-1} \times 6.0 \times 10^{-7} \text{ m}} \\ &= 3.86 \times 10^{-36} \text{ kg} \end{aligned}$$

(c) For a hydrogen atom wave function, there are $n - l - 1$ radial nodes and $(n - 1)$ total nodes.
For $4d$,

$$n = 4 \quad \text{and} \quad l = 2 \quad (\text{for } d\text{-orbital})$$

$$\text{Number of radial nodes} = 4 - 2 - 1 = 1$$

S23. (a) The exact frequency distribution of the emitted radiation from a black body depends on temperature. The variation in the intensity with wavelength at two different temperatures is as shown in figure:



(b)
$$\text{K.E.} = \frac{1}{2} mv^2$$

$$\therefore v = \sqrt{\frac{2\text{K.E.}}{m}} = \frac{2 \times 3.0 \times 10^{-25} \text{ kgm}^2\text{s}^{-2}}{9.1 \times 10^{-31} \text{ kg}} = 812 \text{ ms}^{-1} \quad [\because 1 \text{ J} = 1 \text{ kg m}^2 \text{ s}^{-2}]$$

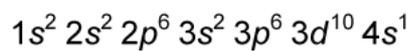
As
$$\lambda = \frac{h}{mv}$$

$$\therefore \lambda = \frac{6.626 \times 10^{-34} \text{ Js}}{9.1 \times 10^{-31} \text{ kg} \times 812 \text{ ms}^{-1}} = 8.967 \times 10^{-7} \text{ m}$$

(c) For a neutral atom, number of electrons = number of protons = atomic number.

\therefore Atomic number of the element = 29

Hence, the element is Cu and its electronic configuration is:



SMARTACHIEVERS LEARNING Pvt. Ltd.
www.smartachievers.in