**1. (i) Calculate the number of electrons which will together weigh one gram.**

**(ii) Calculate the mass and charge of 1 mol of electrons.**

**Ans.** (i) Mass of one electron = $9.11 \times 10^{-31}$ kg,

i.e. $9.11 \times 10^{-31}$ kg = 1 electron

$$\therefore \quad 10^{-3} \text{ kg} = \frac{1}{9.11 \times 10^{-31}} \times 10^{-3} \text{ electrons}$$

i.e. $10^{-3}$ kg = $1.098 \times 10^{27}$ electrons.

(ii) Mass of one electron = $9.11 \times 10^{-31}$ kg

$\therefore$ Mass of 1 mol of electrons

$= (9.11 \times 10^{-31}) \times 6.022 \times 10^{23} = 5.486 \times 10^{-7}$ kg

Charge on one electron = $1.602 \times 10^{-19}$ C

$\therefore$ Charge on 1 mol of electrons

$= (1.602 \times 10^{-19}) \times (6.022 \times 10^{23}) = 9.65 \times 10^{4}$ C.

**2. (i) Calculate the total number of electrons present in 1 mol of methane.**

**(ii) Find (a) the total number and (b) the total mass of neutrons in 7 mg of $^{14}C$ (assume that the mass of neutron = $1.675 \times 10^{-27}$ kg)**

**(iii) Find (a) the total number and (b) the total mass of protons in 34 mg of $NH_3$ at S.T.P. (assume the mass of proton = $1.6726 \times 10^{-27}$ kg). Will the answer change if temperature and pressure are changed?**

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**Ans.** (i) 1 molecule of $CH_4$ contains elctrons = 6 + 4 = 10

$\therefore$ 1 mol i.e. $6.022 \times 10^{23}$ molecules will contain electrons

$= 6.022 \times 10^{24}$

(ii) (a) 1 g atom of $^{14}C$ = 14 g = $6.022 \times 10^{23}$ atoms = $(6.022 \times 10^{23}) \times$ 8 neutrons.

(as each $^{14}C$ atom has 14 – 6 = 8 neutrons)

Thus, 14 g or 14,000 mg have $8 \times 6.22 \times 10^{23}$ neutrons

$\therefore$ 7 mg will have neutrons

$$= \frac{8 \times 6.022 \times 10^{23}}{14,000} \times 7 = 2.4088 \times 10^{21}$$

(b) $\because$ Mass of 1 neutron = $1.675 \times 10^{-27}$ kg

$\therefore$ Mass of $2.4088 \times 10^{21}$ neutrons

$= (2.4088 \times 10^{21})\ (1.675 \times 10^{-27}\ \text{kg})$

$= 4.0347 \times 10^{-6}\ \text{kg}$

(iii) (a) 1 mol of $NH_3$ = 17 g $NH_3$

$= 6.022 \times 10^{23}$ molecules of $NH_3$

$= (6.022 \times 10^{23}) \times (7 + 3)$ protons

$= 6.022 \times 10^{24}$ protons.

$$\therefore\ 34\text{ mg i.e. } 0.034\text{ g } NH_3 = \frac{6.022 \times 10^{24}}{17} \times 0.034\text{ protons}$$

$= 1.2044 \times 10^{22}$ protons.

(b) Mass of one proton $= 1.6726 \times 10^{-27}$ kg

$\therefore$ Mass of $1.2044 \times 10^{22}$ protons

$= (1.6726 \times 10^{-27}) \times (1.2044 \times 10^{22})$ kg

$= 2.0145 \times 10^{-5}$ kg.

There is no effect of T and P.

**3. How many neutrons and protons are there in the following nuclei?**

$^{13}_{6}C$, $^{16}_{8}O$, $^{24}_{12}Mg$, $^{56}_{26}Fe$, $^{88}_{38}Sr$

**Ans.**

| *Nucleus* | *Z* | *A* | *Protons (Z)* | *Neutrons (A–Z)* |
|---|---|---|---|---|
| $^{13}_{6}C$ | 6 | 13 | 6 | 13 – 6 = 7 |
| $^{16}_{8}O$ | 8 | 16 | 8 | 16 – 8 = 8 |
| $^{24}_{12}Mg$ | 12 | 24 | 12 | 24 – 12 = 12 |
| $^{56}_{26}Fe$ | 26 | 56 | 26 | 56 – 26 = 30 |
| $^{88}_{38}Sr$ | 38 | 88 | 38 | 88 – 38 = 50 |

**4. Write the complete symbol for the atom with the given atomic number (*Z*) and atomic mass number (*A*).**

**(i) $Z = 17, A = 35$** **(ii) $Z = 92, A = 233$**

**(iii) $Z = 4, A = 9$**

**Ans.** (i) $^{35}_{17}CI$ (ii) $^{233}_{92}U$ (iii) $^{9}_{4}Be$

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**5. Yellow light emitted from a sodium lamp has a wavelength ($\lambda$) of 580 nm. Calculate the frequency ($v$) and the wave number ($\bar{\nu}$) of the yellow light.**

**Ans.** $\lambda = 580 \text{ nm} = 580 \times 10^{-9} \text{ m}$

$$\text{Frequency, } v = \frac{c}{\lambda} = \frac{3.0 \times 10^{8} \text{ ms}^{-1}}{580 \times 10^{-9} \text{ m}} = 5.17 \times 10^{14} \text{ s}^{-1}$$

$$\text{Wave number, } \bar{\nu} = \frac{1}{\lambda} = \frac{1}{580 \times 10^{-9} \text{ m}} = 1.72 \times 10^{6} \text{ m}^{-1}$$

**6. Find the energy of each of the photons which**

**(i) corresponds to light of frequency $3 \times 10^{15}$ Hz**

**(ii) have wavelength of 0.50 Å.**

**Ans.** (i) $v = 3 \times 10^{15}$ Hz

$E = hv = (6.626 \times 10^{-34} \text{ J s})(3 \times 10^{15} \text{ s}^{-1}) = 1.988 \times 10^{-18} \text{ J}$

(ii) $\lambda = 0.50 \times 10^{-10}$ m,

$$E = hv = h\frac{c}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J s})(3 \times 10^{8} \text{ m s}^{-1})}{0.50 \times 10^{-10} \text{ m}} \text{J}$$

$= 3.98 \times 10^{-15}$ J.

**7. Calculate the wavelength, frequency and wave number of a light wave whose period is $2.0 \times 10^{-10}$ s.**

**Ans.** $$\text{Frequency } (v) = \frac{1}{\text{Period}} = \frac{1}{2.0 \times 10^{-10} \text{ s}} = 5 \times 10^{9} \text{ s}^{-1} \ (v)$$

$$\text{Wavelength, } \lambda = \frac{c}{v} = \frac{3.0 \times 10^{8} \text{ m s}^{-1}}{5 \times 10^{9} \text{ s}^{-1}} = 6.0 \times 10^{-2} \text{ m}$$

$$\text{Wave number, } v = \frac{1}{\lambda} = \frac{1}{6 \times 10^{-2}} = 16.66 \text{ m}^{-1}$$

**8. What is the number of photons of light with a wavelength of 4000 pm that provide 1 J of energy?**

**Ans.** $\lambda = 4000 \text{ pm} = 4000 \times 10^{-12} \text{ m} = 4 \times 10^{-9} \text{ m}$

$$E = N\,hv = N\,h\frac{c}{\lambda}$$

$$\therefore N = \frac{E \times \lambda}{h \times c} = \frac{(1 \text{ J}) \times (4 \times 10^{-9} \text{ m})}{(6.626 \times 10^{-34} \text{ J s})(3.0 \times 10^{8} \text{ m s}^{-1})}$$

$= 2.012 \times 10^{16}$ photons

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**9. A photon of wavelength $4 \times 10^{-7}$ m strikes on a metal surface, the work function of the metal being 2.13 eV. Calculate:**

**(i) the energy of the photon (eV)**

**(ii) the kinetic energy of the emission and**

**(iii) the velocity of the photoelectron ($1 \text{ eV} = 1.602 \times 10^{-19}$ J).**

**Ans.** (i) Energy of the photon ($E$)

$$h\nu = \frac{hc}{\lambda} = \frac{(6.626 \times 10^{-34} \text{ J s}) \times (3 \times 10^{8} \text{ m s}^{-1})}{4 \times 10^{-7} \text{ m}}$$

$$= 4.97 \times 10^{-19} \text{ J} = \frac{4.97 \times 10^{-19}}{1.602 \times 10^{-19}} \text{ eV} = 3.10 \text{ eV}$$

(ii) Kinetic energy of emission $\left(\frac{1}{2}mv^2\right)$

$= h\nu - h\nu_0 = 3.10 - 2.13 = 0.97$ eV

(iii) $\frac{1}{2}mv^2 = 0.97 \text{ eV} = 0.97 \times 1.602 \times 10^{-19}$ J

i.e. $\frac{1}{2} \times (9.11 \times 10^{-31} \text{kg}) \times v^2 = 0.97 \times 1.602 \times 10^{-19}$ J

or $v^2 = 0.341 \times 10^{12} = 34.1 \times 10^{10}$

or $v = 5.84 \times 10^{5}$ m s$^{-1}$

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**10. Electromagnetic radiation of wavelength 242 nm is just sufficient to ionise the sodium atom. Calculate the ionisation energy of sodium in kJ mol$^{-1}$.**

**Ans.** $E = N\,h\nu = Nh\frac{c}{\lambda}$

$$= \frac{(6.02 \times 10^{23} \text{mol}^{-1}) \times (6.626 \times 10^{-34} \text{J s}) \times (3 \times 10^{8} \text{m s}^{-1})}{242 \times 10^{-9} \text{m}}$$

$= 4.945 \times 10^{5}$ J mol$^{-1}$ = 494.5 kJ mol$^{-1}$

**11. A 25 watt bulb emits monochromatic yellow light of wavelength of 0.57 µm. Calculate the rate of emission of quanta per second.**

**Ans.** Energy emitted by the bulb = 25 watt = 25 J s$^{-1}$ ($\because$ 1 W = 1 J s$^{-1}$)

Energy of one photon ($E$) = $h\nu$ = $h\frac{c}{\lambda}$

Here, $\lambda$ = 0.57 µm = $0.57 \times 10^{-6}$ m ($\because$ 1 µm = $10^{-6}$ m )

Putting $c = 3 \times 10^{-8}$ m s$^{-1}$

$h = 6.62 \times 10^{-34}$ J s, we get

$$E = \frac{(6.62 \times 10^{-34}\ \text{J s})(3 \times 10^{8}\ \text{m s}^{-1})}{0.57 \times 10^{-6}\ \text{m}} = 3.48 \times 10^{-19}\ \text{J}$$

$$\because \text{ No. of photons emitted per second } = \frac{25\ \text{J s}^{-1}}{3.48 \times 10^{-19}\ \text{J}} = 7.18 \times 10^{19}\ \text{sec}^{-1}$$

**12. Electrons are emitted with zero velocity from a metal surface when it is exposed to radiation of wavelength 6800 Å. Calculate the threshold frequency and work function ($W_0$) of the metal.**

**Ans.** Threshold wavelength ($\lambda_0$) = 6800 Å = $6800 \times 10^{-10}$ m

$$\text{As } c = \nu\lambda, \ \therefore \ \nu_0 = \frac{c}{\lambda_0} = \frac{3.0 \times 10^{8}\ \text{ms}^{-1}}{6800 \times 10^{-10}\ \text{m}} = 4.41 \times 10^{14}\ \text{s}^{-1}$$

Work function ($W_0$) = $h\nu_0$ = $(6.626 \times 10^{-34}\ \text{J s})(4.41 \times 10^{14}\ \text{s}^{-1})$

$= 2.92 \times 10^{-19}$ J

**13. What is the wavelength of the light emitted when the electron in a hydrogen atom undergoes transition from an energy level with $n = 4$ to an energy level with $n = 2$? What is the colour corresponding to this wavelength? (Rydberg constant = 109,677 cm$^{-1}$)**

**Ans.**
$$\bar{\nu} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) = 109{,}677\left(\frac{1}{2^2} - \frac{1}{4^2}\right)\text{cm}^{-1} = 20{,}564.4\ \text{cm}^{-1}$$

$$\nu = \frac{1}{\lambda} = \frac{1}{20{,}564.4\ \text{cm}^{-1}} = 486 \times 10^{-7}\ \text{cm} = 486 \times 10^{-9}\ \text{m} = 486\ \text{nm}$$

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**14. How much energy is required to ionise a hydrogen atom if the electron occupies fifth orbit? Compare your answer with the ionisation energy of hydrogen atom, i.e., the energy required to remove the electron from first orbit.**

**Ans.**
$$E_n = -\frac{21.8 \times 10^{-19}}{n^2}\ \text{J atom}^{-1}$$

For ionisation from 5th orbit, $n_1 = 5$, $n_2 = \infty$

$$\therefore\ \Delta E = E_2 - E_1 = -21.8 \times 10^{-19}\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) = 21.8 \times 10^{-19}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$= 21.8 \times 10^{-19}\left(\frac{1}{5^2} - \frac{1}{\infty^2}\right) = 8.72 \times 10^{-20}\ \text{J}$$

For ionisation from 1st orbit, $n_1 = 1$, $n_2 = \infty$

$$\Delta E' = 21.8 \times 10^{-19} \left(\frac{1}{1^2} - \frac{1}{\infty}\right) = 21.8 \times 10^{-19}\,\text{J}$$

$$\therefore \quad \frac{\Delta E'}{\Delta E} = \frac{21.8 \times 10^{-19}}{8.72 \times 10^{-20}} = 25$$

Thus, the energy required to remove $e^-$ from 1st orbit is 25 times than that for 5th orbit.

**15. What is the maximum number of lines obtained when the excited electron of a H atom in *n* = 6 drops to the ground state?**

**Ans.** No. of lines produced when electron from *n*th shell drops to ground state

$$= \frac{n(n-1)}{2} = \frac{6(6-1)}{2} = 15$$

These are produced due to following transitions:

| | | | | |
|---|---|---|---|---|
| $6 \longrightarrow 5$ | $5 \longrightarrow 4$ | $4 \longrightarrow 3$ | $3 \longrightarrow 2$ | $2 \longrightarrow 1$ |
| $6 \longrightarrow 4$ | $5 \longrightarrow 3$ | $4 \longrightarrow 2$ | $3 \longrightarrow 1$ | |
| $6 \longrightarrow 3$ | $5 \longrightarrow 2$ | $4 \longrightarrow 1$ | | |
| $6 \longrightarrow 2$ | $5 \longrightarrow 1$ | | | |
| $6 \longrightarrow 1$ | | | | |
| (5 lines) | (4 lines) | (3 lines) | (2 lines) | (1 line) |

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**16. (i) The energy associated with the first orbit in the hydrogen atom is $-2.18 \times 10^{-18}$ J atom$^{-1}$. What is the energy associated with the fifth orbit?**

**(ii) Calculate the radius of Bohr's fifth orbit for hydrogen atom.**

**Ans.** (i) $E_n = -\dfrac{2.18 \times 10^{-18}}{n^2}$ J.

$$\therefore E_5 = -\frac{2.18 \times 10^{-18}}{5^2} = -8.72 \times 10^{-20}\,\text{J}$$

(ii) For H – atom, $r_n = 0.529 \times n^2$ Å

$\therefore r_5 = 0.529 \times 5^2 = 13.225$ Å $= 1.3225$ nm.

**17. Calculate the wave number for the longest wavelength transition in the Balmer series of atomic hydrogen.**

**Ans.** For Balmer series, $n_1 = 2$.

Hence, $\bar{\nu} = R\left(\frac{1}{2^2} - \frac{1}{n_2^2}\right)$

$\bar{\nu} = \frac{1}{\lambda}$, For $\lambda$ to be longest (maximum) $\bar{\nu}$ should be minimum.

This can be so when $n_2$ is minimum, i.e.,

$n_2 = 3$. Hence,

$$\bar{\nu} = (1.097\times10^{7}\ \text{m}^{-1})\left(\frac{1}{2^2} - \frac{1}{3^2}\right) = 1.097\times10^{7} \times \frac{5}{36}\ \text{m}^{-1} = 1.523\times10^{6}\ \text{m}^{-1}$$

**18. What is the energy in joules required to shift the electron of the hydrogen atom from the first Bohr orbit to the fifth Bohr orbit and what is the wavelength of the light emitted when the electron returns to the ground state? The ground state electron energy is $-2.18 \times 10^{-11}$ erg.**

**Ans.** As ground state electronic energy is $-2.18 \times 10^{-11}$ erg, this means that

$E_n = \frac{-2.18\times10^{-11}}{n^2}$ erg. $\Delta E = E_5 - E_1 = 2.18 \times 10^{-11}\left(\frac{1}{1^2} - \frac{1}{5^2}\right)$

$= 2.18\times10^{-11}\left(\frac{24}{25}\right) = 2.09 \times 10^{-11}$ erg. $= 2.09 \times10^{-18}$ J (1 erg = $10^{-7}$ J)

When electron returns to ground state (i.e., to $n = 1$), energy emitted = $2.09 \times10^{-11}$ erg.

As $E = h\nu = h\frac{c}{\lambda}$ or $\lambda = \frac{hc}{E} = \frac{(6.626\times10^{-27}\ \text{erg s})\ (3\times10^{10}\ \text{cm s}^{-1})}{2.09\times10^{-11}\ \text{erg}}$

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

**19. The electron energy in hydrogen atom is given by $E_n = (-2.18 \times 10^{-18})/n^2$ J. Calculate the energy required to remove the electron completely from $n = 2$ orbit. What is the longest wavelength of light in cm that can be used to cause this transition?**

**Ans.** $\Delta E = E_\infty - E_2 = 0 - \left(-\frac{2.18\times10^{-18}\ \text{J atom}^{-1}}{2^2}\right)$

$= 5.45 \times 10^{-19}$ J atom$^{-1}$

$\Delta E = h\nu = h\frac{c}{\lambda}$ or $\lambda = \frac{hc}{\Delta E} = \frac{(6.626\times10^{-34}\ \text{J s})\times(3\times10^{8}\ \text{m s}^{-1})}{5.45\times10^{-19}\ \text{J}}$

$= 3.647 \times 10^{-7}$ m $= 3.647 \times 10^{-5}$ cm.

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**20. Calculate the wavelength of an electron moving with velocity of $2.05 \times 10^7$ m s$^{-1}$.**

**Ans.** By de Broglie equation

$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}\,\text{J s}}{(9.11 \times 10^{-31}\,\text{kg})(2.05 \times 10^{7}\,\text{m s}^{-1})} = 3.55 \times 10^{-11}\,\text{m}$$

$= 3.55 \times 10^{-11}$ m (1 J = 1 kg m$^2$ s$^{-2}$)

**21. The mass of an electron is $9.1 \times 10^{-31}$ kg. If its K.E. is $3.0 \times 10^{-25}$ J, calculate its wavelength.**

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

$$\therefore v = \sqrt{\frac{2\,\text{K.E.}}{m}} = \sqrt{\frac{2 \times 3.0 \times 10^{-25}\,\text{J}}{9.1 \times 10^{-31}\,\text{kg}}} = 812\,\text{m s}^{-1} \quad (1\text{ J} = 1\text{ kg m}^2\text{ s}^{-2})$$

By de Broglie equation,

$$\lambda = \frac{h}{mv} = \frac{6.626 \times 10^{-34}\,\text{J s}}{(9.1 \times 10^{-31}\,\text{kg})\,(812\,\text{m s}^{-1})} = 8.967 \times 10^{-7}\,\text{m} = 8967\,\text{Å}$$

**22. Which of the following are isoelectronic species?**

**$Na^+$, $K^+$, $Mg^{2+}$, $Ca^{2+}$, $S^{2-}$, Ar.**

**Ans.** No. 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.

Hence, isoelectronic species are (i) $Na^+$ and $Mg^{2+}$; (ii) $K^+$, $Ca^2$, $S^{2-}$ and Ar.

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**23. (i) Write the electronic configurations of the following ions:**

**(a) $H^-$** **(b) $Na^+$**

**(c) $O^{2-}$** **(d) $F^-$**

**(ii) What are the atomic numbers of elements whose outermost electrons are represented by**

**(a) $3s^1$** **(b) $2p^3$ and**

**(c) $3d^6$?**

**Ans.** (i) (a) ${}_1H = 1s^1 \therefore H^- = 1s^2$

(b) ${}_{11}Na = 1s^2\,2s^2 2p^6\,3s^1$

$\therefore\ Na^+ = 1s^2\,2s^2\,2p^6$

(c) ${}_8O = 1s^2\,2s^2\,2p^4 \therefore\ O^{2-} = 1s^2\,2s^2\,2p^6$

(d) ${}_9F = 1s^2\,2s^2\,2p^5 \therefore\ F^- = 1s^2\,2s^2\,2p^6$

(ii) (a) $1s^2\ 2s^2\ 2p^6\ 3s^1$ ($Z = 11$)

(b) $1s^2\ 2s^2\ 2p^3$ ($Z = 7$)

(c) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2\ 3d^6$ ($Z = 26$)

**24. What is the lowest value of *n* that allows *g* orbitals to exist?**

**Ans.** For g-subshell, $\ell = 4$, As $\ell = 0$ to $n - 1$, to have $\ell = 4$, minimum value of $n = 5$

**25. An electron is in one of the 3d orbitals. Give the possible values of *n*, $\ell$ and *m* for this electron.**

**Ans.** For 3d orbital, $n = 3$, $\ell = 2$. For $\ell = 2$, $m = -2\ -1, 0, +1 +2$.

**26. An atom of an element contains 29 electrons and 35 neutrons. Deduce (i) the number of protons and (ii) the electronic configuration of the element.**

**Ans.** For neutral atom, number of protons = number of electrons = 29

Thus, atomic number of the element = 29

Electronic configuration of element with $Z = 29$ will be

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$ or $[Ar]^{18}\ 3d^{10}\ 4s^1$, i.e., $_{29}Cu$.

**27. Give the number of electrons in the species $H_2^+$, $H_2$ and $O_2^+$.**

**Ans.** $H_2 = {}_1H + {}_1H = 2$ electrons.

$\therefore H_2^+$ has $= 2 - 1 = 1$ electron.

$O_2 = {}_8O + {}_8O = 16$ electrons.

$\therefore O_2^+$ has $= 16 - 1 = 15$ electrons.

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**28. (i) An atomic orbital has *n* = 3. What are the possible values of *l* and $m_l$ ?**

**(ii) List the quantum numbers (*m* and $\ell$) of electrons for 3d-orbital.**

**(iii) Which of the following orbitals are possible ? 1p, 2s, 2p and 3f.**

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

When $\ell = 0$, $m = 0$. When $\ell = 1$, $m = -1, 0, +1$.

When $\ell = 2$, $m = -2 - 1, 0, +1 + 2$.

(ii) For 3d-orbital, $n = 3$, $\ell = 2$,

For $\ell = 2$, $m = -2, -1, 0, +1, +2$.

(iii) For any value of $n$, $\ell$ varies from 0 to $(n - 1)$. Therefore, p is not possible because when $n = 1, \ell = 0$ only (for p, $\ell = 1$)

2s is possible because when $n = 2$, $\ell = 0$ (for s, $\ell = 0$)

2p is possible because when $n = 2$, $\ell = 0, 1$ (for p, $\ell = 1$)

$3f$ is not possible because when $n = 3$, $\ell = 0, 1, 2$ (for $f$, $\ell = 3$)

**29. Using s, p, d notations, describe the orbital with the following quantum numbers:**

**(a) $n = 1, l = 0$** **(b) $n = 3, l = 1$**

**(c) $n = 4, l = 2$** **(d) $n = 4, l = 3$**

**Ans.** (a) 1s (b) 3p (c) 4d (d) 4f.

**30. Explain, giving reasons, which of the following sets of quantum numbers are not possible**

(a) $n = 0, l = 0, m_l = 0, m_s = + 1/2$

(b) $n = 1, l = 0, m_l = 0, m_s = - 1/2$

(c) $n = 1, l = 1, m_l = -0, m_s = + 1/2$

(d) $n = 2, l = 1, m_l, = 0, m_s = - 1/2$

(e) $n = 3, l = 3, m_l = - 3, m_s = + 1/2$

(f) $n = 3, l = 1, m_l = 0, m_s = + 1/2$

**Ans.** (a) Not possible because $n$ can never be equal to zero.

(b) Possible (c) Not possible

(d) Possible

(e) Not possible because when $n = 3$, $l \neq 3$. (f) Possible.

**31. How many electrons in an atom have the following quantum numbers?**

**(i) $n = 4, m_s = - 1/2$** **(ii) $n = 3, l = 0$**

**Ans.** (i) Total electrons in $n = 4$ are $2n^2$, i.e., $2 \times 4^2 = 32$ Half of them, i.e., 16 electrons have $m_s = -\frac{1}{2}$.

(ii) $n = 3$, $\ell = 0$ means 3s orbital which can have 2 electrons.

**32. Show that the circumference of the Bohr orbit for hydrogen atom is an integral multiple of the de Broglie wavelength associated with the electron moving around the orbit.**

**Ans.** According to Bohr postulate of angular momentum,

$$mvr = n\frac{h}{2\pi} \quad \text{or} \quad 2\pi r = n\frac{h}{mv} \qquad \text{...(i)}$$

According to the de Broglie equation, $\lambda = \frac{h}{mv}$ ...(ii)

Substiuting this value in eq. (i), we get $2\pi r = n\lambda$

Thus, the circumference ($2\pi r$) of the Bohr orbit for hydrogen atom is an integral multiple of de Broglie wavelength.

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**33. What transition in the hydrogen spectrum would have the same wavelength as the Balmer transition, $n = 4$ to $n = 2$ of $He^+$ spectrum?**

**Ans.** He:

$$\bar{v} = RZ^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right) = R\,2^2\left(\frac{1}{2^2}-\frac{1}{4^2}\right)$$

$$\Rightarrow \bar{v} = R\left(\frac{1}{1}-\frac{1}{4}\right) = R\left(\frac{1}{1^2}-\frac{1}{2^2}\right)$$

Comparing with the hydrogen where $Z = 1$

For H:

$$n_1 = 1,\quad n_2 = 2$$

So the transition is from $n = 2$ to $n = 1$

**34. Calculate the energy required for the process**

$$He^+(g) \longrightarrow He^{2+}(g) + e^-$$

**The ionisation energy for the H atom in the ground state is $2.18 \times 10^{-18}$ J atom$^{-1}$.**

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**Ans.** For He:

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

$$n = 1,\ z = 2$$

$$E_1 = -\frac{2.18 \times 10^{-18} \times 2^2}{1^2} = -8.72 \times 10^{-18}\ \text{J atom}^{-1}$$

$$E_\infty = 0$$

$$\therefore \quad \Delta E = E_\infty - E_1 = -(-8.72 \times 10^{-18}) = 8.72 \times 10^{-18}\ \text{J atom}^{-1}$$

**35. If the diameter of a carbon atom is 0.15 nm, 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.**

**Ans.** Diameter of carbon atom = 0.15 nm

$= 0.15 \times 10^{-9}$ m $= 1.5 \times 10^{-10}$ m

Length along which atoms are to be placed

$= 20$ cm $= 20 \times 10^{-2}$ m $= 2 \times 10^{-1}$ m

$$\therefore \text{No. of C-atoms which can be placed along the length} = \frac{2 \times 10^{-1}}{1.5 \times 10^{-10}} = 1.33 \times 10^9$$

**36.** **$2 \times 10^8$ atoms of carbon are arranged side by side. Calculate the radius of carbon atom if the length of this arrangement is 2.4 cm.**

**Ans.** Total length = 2.4 cm.

Total number of atoms along the length = $2 \times 10^8$

$$\therefore \text{ Diameter of each atom} = \frac{3.0 \text{ cm}}{2 \times 10^8} = 1.5 \times 10^{-8}$$

$$= 12 \times 10^{-9} \text{ cm}$$

$$\therefore \text{ Radius of the atom } = \frac{1.5 \times 10^{-8} \text{ cm}}{2}$$

$$= 6 \times 10^{-9} \text{ cm} = .06 \times 10^{-9} \text{ m} = .06 \text{ nm}$$

**37.** **The diameter of zinc atom is 2.6 Å. Calculate (a) radius of zinc atom in pm and (b) number of atoms present in a length of 1.6 cm if the atoms are arranged side by side lengthwise.**

**Ans.** (a) Radius $= \frac{2.6 \text{ Å}}{2} = 1.3 \text{ Å}$

$= 1.3 \times 10^{-10}$ m $= 130 \times 10^{-12}$ m = 130 pm.

Diameter of one atom = 2.6 Å = $2.6 \times 10^{-10}$ m.

$$\therefore \text{ No. of atoms present along the length } = \frac{1.6 \times 10^{-2}}{2.6 \times 10^{-10}} = 6.154 \times 10^7$$

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**38.** **A certain particle carries $2.5 \times 10^{-16}$ C of static electric charge. Calculate the number of electrons present in it.**

**Ans.** Charge carried by one electron = $1.6022 \times 10^{-19}$ C.

Electrons present in particle carrying $2.5 \times 10^{-16}$ C charge

$$= \frac{2.5 \times 10^{-16}}{1.6022 \times 10^{-19}} = 1{,}560$$

**39.** **In Millikan's experiment, static electric charge on the oil drops has been obtained by shining X-rays. If the static electric charge in the oil drop is $-1.282 \times 10^{-18}$ C, calculate the number of electrons present in it.**

**Ans.** As in Q. 38 above, electrons present $= \frac{-1.282 \times 10^{-18} \text{ C}}{-1.6022 \times 10^{-19} \text{ C}} = 8$

**40.** **In Rutherford's experiment, generally thin foils of heavy atoms like gold, platinum etc. have been used to be bombarded by the $\alpha$-particles. If the thin foil of light atoms like aluminium etc. are used, what difference would be observed from the above results?**

**Ans.** Heavy atoms have a heavy nucleus carrying a large amount of positive charge. Hence some $\alpha$-particles are easily deflected back on hitting the nucleus. Also a number of $\alpha$-particles are deflected through small angles because of large positive charge on the nucleus. If light atoms are used, their nuclei will be light and moreover, they will have small positive charge on the nucleus. Hence, the number of particles deflected back and those deflected through some angle will be negligible.

**41. Symbols $^{79}_{35}$Br and $^{79}$Br can be written whereas symbols $^{79}_{35}$Br and 35$^{Br}$ are not acceptable. Answer briefly.**

**Ans.** Atomic number of bromine is fixed i.e. 35. However, different bromine atoms may have different mass numbers (isotopes). Hence, it is essential to indicate mass number.

**42. An element with mass number 81 contains 31.7% more neutrons as compared to protons. Assign the atomic symbol.**

**Ans.** Mass number = 81, i.e., $p + n = 81$

If protons = $x$, then neutrons $= x + \frac{31.7}{100} \times x = 1.317x$

$\therefore \quad x + 1.317\,x = 81$

or $\quad 2.317x = 81 \quad$ or $\; 2.317x = 81$

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

Thus, protons = 35, i.e., atomic no. = 35

Hence, the symbol is $^{81}_{35}$Br.

**43. An ion with mass number 37 possesses one unit of negative charge. If the ion contains 11.1% more neutrons than the electrons, find the symbol of the ion.**

**Ans.** Suppose number of electrons in the ion = $x$

Then number of neutrons $= x + \frac{11.1}{100}x = 1.111x$

No. of electrons in the neutral atom = $x - 1$

$\therefore$ No. of protons = $x - 1$

Mass number = No. of neutrons + No. of protons

$\therefore \quad 37 = 1.111x + x - 1 \quad$ or $\quad 2.111x = 38 \quad$ or $\quad x = 18$

Hence, the symbol of the ion will be $^{37}_{17}\text{Cl}^{-1}$

**44. An ion with mass number 56 contains 3 units of positive charge and 30.4% more neutrons than electrons. Assign the symbol to this ion.**

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**Ans.** Suppose number of electrons in the ion, $M^{3+} = x$

$\therefore$ No. of neutrons $= x + \frac{30.4}{100}x = 1.304x$

No. of electrons in the neutral atom $= x + 3$

$\therefore$ No. of protons $= x + 3$

Mass number = No. of protons + No. of neutrons

$56 = x + 3 + 1.304\,x$ or $2.304\,x = 53$ or $x = 23$

$\therefore$ No. of protons = Atomic number $= x + 3 = 23 + 3 = 26$

Hence, the symbol of the ion will be ${}^{56}_{26}\mathrm{Fe}^{3+}$.

**45. Arrange the following types of radiations in increasing order of frequency:**

**(a) radiation from microwave oven**

**(b) amber light from traffic signal**

**(c) radiation from FM radio**

**(d) cosmic rays from outer space and (e) X-rays.**

**Ans.** Cosmic rays > X-rays > amber colour > microwave > FM

**46. Nitrogen laser produces a radiation at a wavelength of 337.1 nm. If the number of photons emitted is $5.6 \times 10^{24}$, calculate the power of this laser.**

**Ans.** $E = Nh\nu = Nh\frac{c}{\lambda}$

$$= \frac{(5.6\times10^{24})\,(6.626\times10^{-34}\,\mathrm{J\,s})\,(3.0\times10^{8}\,\mathrm{m\,s^{-1}})}{(337.1\times10^{-9}\,\mathrm{m})} = 3.3\times10^{6}\,\mathrm{J}$$

**47. Neon gas is generally used in the sign boards. If it emits strongly at 616 nm, calculate**

**(a) the frequency of the emission.**

**(b) distance travelled by this radiation in 30 s.**

**(c) energy of quantum.**

**(d) number of quanta present if it produces 2 J of energy.**

**Ans.** $\lambda = 616\ \mathrm{nm} = 616 \times 10^{-9}\mathrm{m}$

(a) Frequency, $\nu = \frac{c}{\lambda} = \frac{3.0\times10^{8}\,\mathrm{m\,s^{-1}}}{616\times10^{-9}\,\mathrm{m}} = 4.87\times10^{14}\ \mathrm{s^{-1}}$

(b) Velocity of the radiation $= 3.0 \times 10^{8}\ \mathrm{m\,s^{-1}}$

$\therefore$ Distance travelled in 30 s $= 30 \times 3 \times 10^{8}\ \mathrm{m} = 9.0 \times 10^{9}\ \mathrm{m}$

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(c) $$E = h\nu = h\frac{c}{\lambda} = \frac{(6.626\times10^{-34}\,\text{J s})\times3.0\times10^{8}\,\text{m s}^{-1}}{616\times10^{-9}\,\text{m}}$$

$$= 32.27 \times 10^{-20}\ \text{J photon}^{-1}$$

(d) No. of quanta in 2 J of energy $= \dfrac{2}{32.27\times10^{-20}} = 6.2\times10^{18}$

**48. In astronomical observations, signals observed from the distant stars are generally weak. If the photon detector receives a total of 3.15 × $10^{-18}$ J from the radiations of 600 nm, calculate the number of photons received by the detector.**

**Ans.** Energy of one photon

$$= h\nu = h\,\frac{c}{\lambda} = \frac{(6.626\times10^{-34}\,\text{J s})\,(3\times10^{8}\,\text{m s}^{-1})}{(600\times10^{-9}\,\text{m})} = 3.313\times10^{-19}$$

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

$\therefore$ Number of photons received $= \dfrac{3.15\times10^{-18}}{3.313\times10^{-19}} = 9.51 = 10$

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**49. Life times of the molecules in the excited state are often measured by using pulsed radiation source of duration nearly in the nano second range. If the radiation source has the duration of 2*n*s and the number of photons emitted during the pulse source is 2.5 × $10^{15}$, calculate the energy of the source.**

**Ans.** Frequency $= \dfrac{1}{2\times10^{-9}\,\text{s}} = 0.5\times10^{9}\,\text{s}^{-1}$

Energy = $N h\nu = (2.5 \times 10^{15})\,(6.626 \times 10^{-34})\ (0.5 \times 10^{9}\ \text{s}^{-1})$

$= 8.28 \times 10^{-10}$ J

**50. The longest wavelength doublet absorption transition is observed at 589 and 589.6 nm. Calculate the frequency of each transition and the energy difference between the two excited states.**

**Ans.** $\lambda_1 = 589\ \text{nm} = 589\times10^{-9}\ \text{m}.$

$$\therefore \nu_1 = \frac{c}{\lambda_1} = \frac{3.0\times10^{8}\,\text{m s}^{-1}}{589\times10^{-9}\,\text{m}} = 5.093\times10^{14}\,\text{s}^{-1}$$

$\lambda_2 = 589.6\ \text{nm} = 589.6 \times 10^{-9}\text{m}$

$$\therefore\ \nu_2 = \frac{c}{\lambda_2} = \frac{3.0\times10^{8}\,\text{m s}^{-1}}{589.6\times10^{-9}\,\text{m}} = 5.088 \times 10^{14}\ \text{s}^{-1}$$

$\Delta E = E_2 - E_1 = h\,(v_2 - v_1) = 6.626 \times 10^{-34} \times (5.093 - 5.088) \times 10^{14}\ \text{s}^{-1}$

$= 3.31 \times 10^{-22}\ \text{J}$

**51. The work function for caesium atom is 1.9 eV. Calculate (a) the threshold wavelength and (b) the threshold frequency of the radiation. If the caesium element is irradiated with a wavelength 500 nm, (c) calculate the kinetic energy and the velocity of the ejected photoelectron.**

**Ans.** (a) Work function $(W_0) = h\nu_0$

$$\therefore\ \nu_0 = \frac{W_0}{h} = \frac{1.9 \times 1.602 \times 10^{-19}\ \text{J}}{6.626 \times 10^{-34}\ \text{J s}} = 4.59 \times 10^{14}\ \text{s}^{-1} \qquad (1\text{eV} = 1.602 \times 10^{-19}\ \text{J})$$

(b) $$\lambda_0 = \frac{c}{\nu_0} = \frac{3.0 \times 10^{8}\ \text{m s}^{-1}}{4.59 \times 10^{14}\ \text{s}^{-1}} = 6.54 \times 10^{-7}\ \text{m}$$

$= 654 \times 10^{-9}\ \text{m} = 654\ \text{nm}$

(c) K.E. of ejected electron

$$= \text{h}\,(v - v_0) = hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = (6.626 \times 10^{-34}\ \text{J s})\,(3.0 \times 10^{8}\ \text{m s}^{-1})$$

$$\left(\frac{1}{500 \times 10^{-9}\ \text{m}} - \frac{1}{654 \times 10^{-9}\ \text{m}}\right)$$

$$= \frac{6.626 \times 3.0 \times 10^{-26}}{10^{-9}}\left(\frac{154}{500 \times 654}\right)\text{J} = 9.36 \times 10^{-20}\ \text{J}$$

$$\text{K.E.} = \frac{1}{2}m\nu^2 = 9.36 \times 10^{-20}\ \text{J or kg m}^2\ \text{s}^{-2}$$

$$\therefore\ \frac{1}{2} \times (9.11 \times 10^{-31}\ \text{kg})\nu^2 = 9.36 \times 10^{-20}\ \text{kg m}^2\ \text{s}^{-2}$$

or $v^2 = 2.055 \times 10^{11}\ \text{m}^2\ \text{s}^{-2}$

$= 20.55 \times 10^{10}\ \text{m}^2\ \text{s}^{-2}$ or $v = 4.48 \times 10^{5}\ \text{m s}^{-1}$.

**52. Following results were observed when sodium metal is irradiated with different wavelengths. Calculate (a) threshold wavelength and (b) Planck's constant.**

| **λ (nm)** | **500** | **450** | **400** |
|---|---|---|---|
| **$v \times 10^{-6}$ (m s$^{-1}$)** | **2.55** | **4.35** | **5.20** |

**Ans.** Suppose threshold wavelength $= \lambda_0\ \text{nm} = \lambda_0 \times 10^{-9}\ \text{m}$

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Then $h(\nu - \nu_0) = \frac{1}{2}m\nu^2$ or $hc\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right) = \frac{1}{2}m\nu^2$

Substituting the given results of the three experiments, we get

$$\frac{hc}{10^{-9}}\left(\frac{1}{500} - \frac{1}{\lambda_0}\right) = \frac{1}{2}m(2.55\times10^6)^2 \qquad \ldots\text{(i)}$$

$$\frac{hc}{10^{-9}}\left(\frac{1}{450} - \frac{1}{\lambda_0}\right) = \frac{1}{2}m(4.35\times10^6)^2 \qquad \ldots\text{(ii)}$$

$$\frac{hc}{10^{-9}}\left(\frac{1}{400} - \frac{1}{\lambda_0}\right) = \frac{1}{2}m(5.00\times10^6)^2 \qquad \ldots\text{(iii)}$$

Dividing eq. (ii) by eq. (i), we get

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

or $\frac{\lambda_0 - 450}{\lambda_0 - 500} = \frac{450}{500}\left(\frac{4.35}{2.55}\right)^2 = 2.619$

or $\lambda_0 - 450 = 2.619\lambda_0 - 1309.5$

or $1.619\ \lambda_0 = 859.5$ $\quad\therefore \lambda_0 = 531$ nm

Substituting this value in eq. (iii), we get

$$\frac{h\times(3\times10^8)}{10^{-9}}\left(\frac{1}{400} - \frac{1}{531}\right) = \frac{1}{2}(9.11\times10^{-31})(5.20\times10^6)^2$$

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

**53. The ejection of the photoelectron from the silver metal in the photoelectric effect experiment can be stopped by applying a voltage of 0.35 V when the radiation 256.7 nm is used. Calculate the work function for silver metal.**

**Ans.** Energy of the incident radiation = Work function + Kinetic energy of photoelectron

Energy of incident radiation ($E$)

$$= h\nu = h\frac{c}{\lambda} = \frac{(6.626\times10^{-34}\,\text{J s})(3.0\times10^8\,\text{m s}^{-1})}{(256.7\times10^{-9}\,\text{m})}$$

$= 7.74 \times 10^{-19}$ J $= 4.83$ e V (1eV$= 1.602 \times 10^{-19}$ J)

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The potential applied gives the kinetic energy to the electron.

Hence, kinetic energy of the electron = 0.35 eV

$\therefore$ Work function = 4.83 eV – 0.35 eV = 4.48 eV

**54. If photon of the wavelength 150 pm strikes an atom and one of its inner bound electron is ejected out with a velocity of 1.5 × $10^7$ m $s^{-1}$, calculate the energy with which it is bound to the nucleus.**

**Ans.** Energy of the incident photon

$$= \frac{hc}{\lambda} = \frac{(6.626\times10^{-34}\,\text{J s})(3.0\times10^{8}\,\text{m s}^{-1})}{(150\times10^{-12}\,\text{m})}$$

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

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

$$= \frac{1}{2}(9.11\times10^{-31}\,\text{kg})\,(1.5\times10^{7}\,\text{m s}^{-1})^2$$

$= 1.025 \times 10^{-16}$ J

Energy with which the electron was bound to the nucleus

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

$$= \frac{12.225\times10^{-16}}{1.602\times10^{-19}}\,\text{eV} = 7.63\times10^{3}\,\text{eV}$$

**55. Emission transitions in the Paschen series end at orbit *n* = 3 and start from orbit n and can be represented as $\nu = 3.29 \times 10^{15}$ (Hz) [$1/3^2 - 1/n^2$]. Calculate the value of *n* if the transition is observed at 1285 nm. Find the region of the spectrum.**

**Ans.** $$\nu = \frac{c}{\lambda} = \frac{3.0\times10^{8}\,\text{m s}^{-1}}{1285\times10^{-9}\,\text{m}} = 3.29\times10^{15}\left(\frac{1}{3^2}-\frac{1}{n^2}\right)$$

$$\frac{1}{n^2} = \frac{1}{9} - \frac{3.0\times10^{8}}{1285\times10^{-9}} \times \frac{1}{3.29\times10^{15}} = 0.111 - 0.071 = 0.04 = \frac{1}{25}$$

or $n^2 = 25$ or $n = 5$

The radiation 1,285 nm lie in the infrared region.

**56. Calculate the wavelength for the emission transition if it starts from the orbit having radius 1.3225 nm and ends at 211.6 pm. Name the series to which this transition belongs and the region of the spectrum.**

**Ans.** Radius of *n*th orbit of H-like particles

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

$r_1$ = 1.3225 nm = 1322.5 pm = 52.9

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$$r_2 = 211.6 \text{ pm} = \frac{52.9\, n_2^2}{Z}$$

$$\therefore \frac{r_1}{r_2} = \frac{1322.5}{211.6} = \frac{n_1^2}{n_2^2} = 6.25 \quad \text{or} \quad \frac{n_1}{n_2} = 2.5$$

∴ If $n_2 = 2$, $n_1 = 5$. Thus, the transition is from 5th orbit. It belongs to **Balmer series**.

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

$$\text{or} \qquad \lambda = \frac{1}{\bar{\nu}} = \frac{100}{1.097 \times 21 \times 10^7} \text{ m}$$

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

**57. Dual behaviour of matter proposed by de Broglie led to the discovery of electron microscope often used for the highly magnified images of biological molecules and other types of material. If the velocity of the electron in this microscope is 1.6 × $10^6$ m $s^{-1}$, calculate de Broglie wavelength associated with this electron.**

**Ans.** $$\lambda = \frac{h}{m\nu} = \frac{6.626 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1}}{(9.11 \times 10^{-31} \text{ kg})(1.6 \times 10^6 \text{ m s}^{-1})}$$

$= 4.55 \times 10^{-10}$ m $= 455$ pm

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**58. Similar to electron diffraction, neutron diffraction microscope is also used for the determination of the structure of the molecules. If the wavelength used here is 800 pm, calculate the characteristic velocity associated with the neutron.**

**Ans.** Mass of neutron $= 1.675 \times 10^{-27}$ kg

$$\lambda = \frac{h}{m\nu} \quad \text{or} \quad \nu = \frac{h}{m \times \lambda} = \frac{6.626 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1}}{1.675 \times 10^{-27} \text{ kg} \times (800 \times 10^{-12} \text{ m})}$$

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

**59. If the velocity of the electron in Bohr's first orbit is 2.19 × $10^6$ m $s^{-1}$, calculate the de Broglie wavelength associated with it.**

**Ans.** $$\lambda = \frac{h}{m\nu} = \frac{6.626 \times 10^{-34} \text{ kg m}^2 \text{ s}^{-1}}{(0.1 \text{ kg})(4.37 \times 10^5 \text{ m s}^{-1})}$$

$= 3.32 \times 10^{-10}$ m $= 332$ pm.

**60. The velocity associated with a proton moving in a potential difference of 1000 V is 4.37 × $10^5$ $ms^{-1}$. If the hockey ball of mass 0.1 kg is moving with this velocity, calculate the wavelength associated with this velocity?**

**Ans.** $$\lambda = \frac{h}{m\nu} = \frac{6.626\times10^{-34}\,\text{kg m}^2\ \text{s}^{-1}}{(0.1\,\text{kg})(4.37\times10^{5}\,\text{m s}^{-1})}$$

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

**61. If the position of the electron is measured within an accuracy of ± 0.002 nm, calculate the uncertainty in the momentum of the electron. Suppose the momentum of the electron is ($h/4\pi$) × 0.05 nm, is there any problem in defining this value?**

**Ans.** $\Delta x = 0.002\ \text{nm} = 2\times10^{-3}\ \text{nm} = 2\times10^{-12}\ \text{m}$

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

$$\therefore\ \Delta p = \frac{h}{4\pi\Delta x} = \frac{6.626\times10^{-34}\,\text{kg m}^2\ \text{s}^{-1}}{4\times3.14\times(2\times10^{-12}\,\text{m})} = 2.638\times10^{-23}\ \text{kg ms}^{-1}$$

$$\text{Actual momentum} = \frac{h}{4\pi\times0.05\ \text{nm}} = \frac{h}{4\pi\times5\times10^{-11}\,\text{m}}$$

$$= \frac{6.626\times10^{-34}\,\text{kg m}^2\ \text{s}^{-1}}{4\times3.14\times5\times10^{-11}\ \text{m}} = 1.055\times10^{-24}\ \text{kg m s}^{-1}$$

Cannot be defined as uncertainty is greater than real value.

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**62. The quantum numbers of six electrons are given below. Arrange them in order of increasing energies. List if any of these combinations (*s*) has/have the same energy:**

**(i)** $n = 4,\ \ell = 2,\ m_l = -2,\ m_s = -1/2$

**(ii)** $n = 3,\ \ell = 2,\ m_l = -1,\ m_s = +1/2$

**(iii)** $n = 4,\ \ell = 1,\ m_l = 0,\ m_s = +1/2$

**(iv)** $n = 3,\ \ell = 2,\ m_l = -2,\ m_s = -1/2$

**(v)** $n = 3, \ell = 1,\ m_l = -1,\ m_s = +1/2$

**(vi)** $n = 4,\ \ell = 1,\ m_l = 0,\ m_s = +1/2$

**Ans.** The orbitals occupied by the electrons are (i) 4d (ii) 3d (iii) 4p (iv) 3d (v) 3p (vi) 4p. Their energies will be in the order: (v) < (ii) = (iv) < (vi) = (iii) < (i)

**63. The bromine atom possesses 35 electrons. It contains 6 electrons in 2p orbitals, 6 electrons in 3p orbitals and 5 electrons in 4p orbitals. Which of these electrons experiences the lowest effective nuclear charge?**

**Ans.** 4p electrons being farthest from the nucleus experience the lowest effective nuclear charge.

**64. Among the following pairs of orbitals which orbital will experience the larger effective nuclear charge?**

**(i) 2s and 3s,** **(ii) 4d and 4f,**

**(iii) 3d and 3p**

**Ans.** (i) 2s is closer to the nucleus than 3 s. Hence 2 s will experience larger effective nuclear charge.

(ii) 4d

(iii) 3p (for same reasons)

**65. The unpaired electrons in Al and Si are present in 3p orbital. Which electron will experience more effective charge from the nucleus?**

**Ans.** Silicon has greater nuclear charge (+14) than aluminium (+13). Hence, the unpaired 3p electron of silicon will experience more effective nuclear charge.

**66. Indicate the number of unpaired electrons in**

**(a) P** **(b) Si**

**(c) Cr** **(d) Fe, and**

**(e) Kr**

**Ans.** (a) $_{15}P = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p_{x}^{1} 3p_{y}^{1}\ 3p_{z}^{1}$.

No. of unpaired electron = 3

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

No. of unpaired electron = 2

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

No. of unpaired electron = 6

(d) $_{26}Fe = 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$ number of unpaired electrons = 4 in (3d).

(e) $_{36}Kr$ = Noble gas. All orbitals are filled. Unpaired electrons = 0

**67. (a) How many subshells are associated with $n = 4$?**

**(b) How many electrons will be present in the subshells having $m_s$ value of –1/2 for $n = 4$ ?**

**Ans.** (a) $n = 4$, $l = 0, 1, 2, 3$ (4 subshells, viz., s, p, d and f )

(b) No. of orbitals in 4th shell .

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