5 Atomic Structure

QUICK LOOK

Structure of Atom

- The specific charge (e/m) of proton is $9.58\times10^{7}\ C/kg$.
- Mass of 1 mole proton $= N\times m_p = 6.023\times10^{23}\times1.673\times10^{-27}\ kg\ 1.0076\times10^{-3}\ kg = 1.0076\ g.$
- The radius of proton $=1.53\times10^{-13}\ cm.$
- The volume of proton $=\frac{4}{3}\pi r^3=\frac{4}{3}\times\frac{22}{7}\times\left(1.53\times10^{-13}\right)^3=1.50\times10^{-38}\ cm^3.$
- The charge on positive rays is usually + 1 but it may have + 2, +3 values.
- Number of waves in an orbit $=\frac{\text{circumference of orbit}}{\text{wavelength}}=\frac{2\pi r}{\lambda}=\frac{2\pi r\cdot mu}{h}$ $=\frac{2\pi(mur)}{h}=2\pi\times\frac{n}{2\pi}=n\ \left\{\because mur=\frac{nh}{2\pi}\right\}$
- Number of revolution f an electron per second in the n^{th} orbit $=\frac{\text{speed of electron}}{\text{circumference}}=\frac{u_n}{2\pi r_n}$
- The wavelength of an electron accelerated by a potential difference V can be given by $=\frac{1}{2}mu^2=eV$

$\therefore\quad u=\sqrt{\frac{2eV}{m}}$

$\therefore\quad \lambda=\frac{h}{mu}=\frac{h}{\sqrt{2meV}}.$

- For a gas molecule, $\lambda=\frac{h}{m\cdot u_{rms}}$

$\because$ Average kinetic energy $=\frac{1}{2}mu^2=\frac{3}{2}\frac{RT}{N}$

$k=\frac{R}{N}=1.38\times10^{-23}\ J/K$

Or $\frac{1}{2}mu^2=\frac{3}{2}kT\ \ u=\sqrt{\frac{3kT}{m}}$

$\therefore\quad \lambda=\frac{h}{m\times\sqrt{\frac{3kT}{m}}}=\frac{h}{\sqrt{3mkT}}$

Where, k is Boltzmann's constant.

Bohr Model: (For hydrogen like atoms): The quantum theory to atomic model was first of all applied by Bohr. Bohr quantized angular momentum of electron. The consequence of it was that all the quantities radius, velocity, linear momentum, angular momentum and energy were quantized. Bohr's theory is applicable only to atoms containing one electron only *e.g.,* He, He^+, Li^{++} etc.

Here *e* = elementary charge, r = radius of orbit, m = mass of electron, v = speed of electron, *h* = Planck's constant, *n* = integer = principal quantum number.

- Conditions of circular orbit $\frac{mv^2}{r}=\frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2}{r^2}$
- Condition of quantization: $mvr=n\frac{h}{2\pi}$
- Condition of transition: $hv=E_1\sim E_2$
- Radius of nth orbit: $r_n=\frac{\varepsilon_0h^2n^2}{\pi mZe^2}=0.53\frac{n^2}{Z}\ \text{Å}$

  According to Bohr's theory, radius of nth orbit $r_n\propto n^2$.

  The radius of first Bohr orbit is 0.53Å
- Speed of electron in nth orbit: $v_n=\frac{e}{2\varepsilon_0h}\cdot\frac{Z}{n}=\frac{c}{137}\cdot\frac{Z}{n}$ where c = speed of light.

  The velocity of electron in first Bohr orbit is $\frac{c}{137}=2.2\times10^6\ m/s.$
- Kinetic energy: $E_k=\frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2}{r}$
- Potential energy: $U=-\frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2}{r}$
- Total energy: $E=-\frac{1}{4\pi\varepsilon_0}\cdot\frac{Ze^2}{2r}$
- Total energy of electron $E\propto\frac{1}{n^2}$.

  For hydrogen atom in lowest orbit $(n=1).E=-13.6\,eV$
- The total energy increases as the electron reaches in higher orbits, but kinetic energy decreases.

  In free-state (out of atom), electron can have any energy (continuous state).

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- The energy ΔE is released when electron jumps from higher orbit to lower orbit. The corresponding wavelength of emitted radiation is $\lambda = \frac{12375}{\Delta E}$ Å
- When electron jumps from higher to lower orbit, photon is emitted and the atom recoils. The momentum of recoiled atom is equal to the momentum of photon *i.e.,* $p_N = \frac{h}{\lambda}$
- Summerfield introduced the idea of elliptical orbits. For principal quantum number n, there are n orbits, out of which (n – 1) are elliptical while on is circular.
- Energy Spectrum:
- For nth orbit $E_n = \frac{Z^2 Rhc}{n^2} = -13.6.\frac{Z^2}{n^2}$ eV

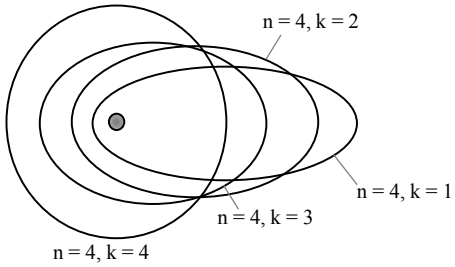


Figure: 5.1

Where $R = \frac{me^2}{8\varepsilon_0^2 ch^3}$ = Rhdberg constant

- Frequency of emitted radiation $V = \frac{E_1 - E_2}{h}$

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

- Wave number $\bar{v}$ or wavelength (λ) of emitted radiation:

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

Series

- Lyman Series $\frac{1}{\lambda} = R\left(\frac{1}{1^2} - \frac{1}{n^2}\right), n = 2,3,4,5,...$
- Balamer Series $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right), n = 3,4,5,...$
- Paschen Series $\frac{1}{\lambda} = R\left(\frac{1}{3^2} - \frac{1}{n^2}\right), n = 4,5,6,...$
- Brackett Series $\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{n^2}\right), n = 5,6,7,...$
- Pfund Series $\frac{1}{\lambda} = R\left(\frac{1}{5^2} - \frac{1}{n^2}\right), n = 6,7,8,...$

The Wave Functions for Hydrogen

According to quantum mechanics, the atom has no sharply defined boundary as suggested by the Bohr Theory. The probability distribution in figure a suggests that the charge of the electron can be modeled as being extended throughout a region of space, commonly referred to as an electron cloud. The darkest portion of the distribution appears at $r = a_0$, corresponding to the most probable value of *r* for the electron.

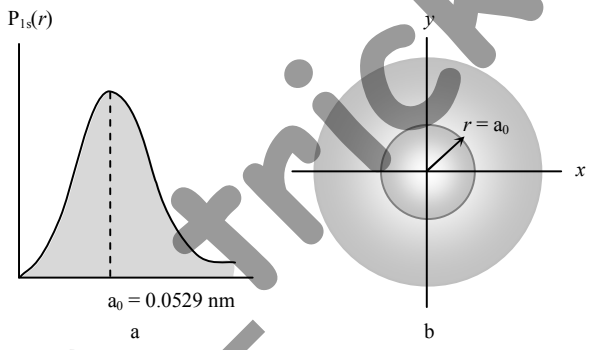


Figure: 5.2

The next-simplest wave function for the hydrogen atom is the one corresponding to the 2s state $(n = 2, l = 0)$. The normalized wave function for this state is

$$\psi_{2s}(r) = \frac{1}{4\sqrt{2}}\left(\frac{1}{a_0}\right)^{3/2}\left(2 - \frac{r}{a_0}\right)e^{-2/2a_0}$$

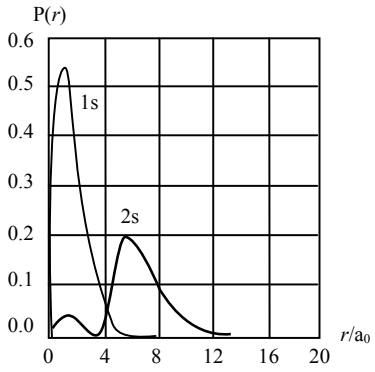


Figure: 5.3

Again notice that ψ_{2s} depends only on *r* and is spherically symmetric. The energy corresponding to this state is $E_2 = -(13.606/4)\text{eV} = -3.401\text{eV}$.

The plot for the 2s states has two peaks. These models were against the Heisenberg uncertainty principle. The principle states that it is impossible to determine momentum and position of a sub-atomic particle precisely and simultaneously.

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$$\Delta p \cdot \Delta x \geq \left[\frac{h}{4\pi}\right];$$

or $m \cdot \Delta u \cdot \Delta x \geq \left[\frac{h}{4\pi}\right]$

or $\Delta u \cdot \Delta x \geq \left[\frac{h}{4\pi m}\right] \geq \frac{\hbar}{2\pi m} \geq \frac{\hbar}{2m}$

$\hbar = \frac{h}{2}$ and $\hbar = \frac{h}{2\pi}$

Δp is uncertainty in momentum;

Δx is uncertainty in position along one axis;

Δu is uncertainty in velocity along same axis.

As the mass of particle increases the uncertainty values decrease and thus, uncertainty principle and de-Broglie concept loses its significance in case of large objects.

Uncertainty principle is also valid for a conjugate pair of variable which are to be measured simultaneously. Some other simultaneous measurements for angular momentum (ω) and angle (θ), for energy (E) and time (t), we can have

$$\Delta\omega \cdot \Delta\theta \geq \frac{h}{4\pi}$$

$$\Delta E \cdot \Delta t \geq \frac{h}{4\pi}$$

Note

- Bohr's model assumes the existence of well defined orbits in which both the position and momentum of the electrons are known exactly. On the other hand, Heisenberg concluded that position and momentum of any sub atomic particle cannot be evaluated precisely and simultaneously.
- The uncertainly principle has negligible effect for macroscopic particles. For example, if the uncertaintities in velocity of an electron and a cricket ball (mass 0.15 kg) are in order of 1 Å, then uncertainty in velocity obtained from Heisenberg principle are $5.8 \times 10^5\ ms^{-1}$ and $3.51 \times 10^{-24}\ ms^{-1}$ respectively. Thus, uncertainty in velocity of cricket ball is definitely negligible.
- Heisenberg uncertainty principle can be best understood with the help of an example. To observe an electron we can illuminate it with light or electromagnetic radiation having wavelength smaller than the dimensions or an electron. But photon of such light having high energy $\left(E \propto \frac{1}{\lambda}\right)$ would change the energy of electron when it strikes on electron. No doubt we can evaluate the position of electron but we would know very little about the velocity of electron after collision.
- If Δu along X-axis and Δx along Y-axis is predicted. Heisenberg uncertainty principle is not valid.
- The wavelength of any particle showing dual nature of wave and particle proposed by de-Broglie as $\lambda = \frac{h}{mu}$ is independent of the nature of charge (*i.e.*, +ve or –ve or neutral).
- A collection of orbitals with the same value of *n* is called an electron shell, *e.g.,* all the orbitals with n = 3 are said to be in 3rd shell. One or more orbitals with same values of *n* and *l* is called a sub-shell. Each sub-shell is designated by a number (the value of *n*) and a letter (*s*, *p*, *d* or *f* corresponding to the values of *l*), e.g., all the orbitals with *n* = 3 and *l* = 1 are collectively referred as 3*p*-orbitals and are said to be in 3*p*-sub-shell.
- An orbital may also be represented as $\psi_{4,2,0}$ which means for $n = 4$, $l = 2$, $m_l = 0$, *i.e.,* 4*d*-orbital.
- The three quantum numbers (n, l, m_l) derived from quantum mechanical concept also have classical analogue but the two quantum mechanical spin states have no classical analogue.
- The plane and point at which zero electron density exists (i.e., $\psi^2 = 0$) is known as nodal plane or nodal point, e.g., the probability of find electron between 1*s* and 2*s*-orbitals or between two lobes of *p*-orbitals is zero.
- An orbital with quantum number *n* and *l* possesses :
  Angular or non-spherical nodes = *l*
  Radial or spherical nodes = n – *l* – 1
  Thus, total nodes in an orbital = n – *l* – 1 + *l* = n – 1
- For one electron systems (an atom or an ion) the energy of orbital depends only on the number of nodes, *i.e.,* on *n* and not on *l* or *m*. It is therefore, in H-atom or He^+ energy levels of orbitals in a shell are same, *i.e.,* energy level of 3*s* = 3*p* = 3*d*.
- As *r* approaches zero, the wave function vanishes for all orbitals except the *s*-orbitals, thus, only an electron in 1*s*-orbital can penetrate the nucleus, *i.e.,* have a finite probability of being found right at the nucleus.
- Actually these rules were framed to explain the experimental facts. For example $_{46}Pd$ was found diamagnetic and thus its configuration was written as $4d^{10}$ and not $4s^2 4p^6 4d^8$, $5s^s$.

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- Write configuration of atoms upto atomic number 57 and note the exceptions. No new rule is needed for them. Some notable exceptions in writing electronic configurations are :

  ${}_{41}Nb : [Kr]\,4d^4, 5s^1$, ${}_{44}Ru : [Kr]\,4d^7, 5s^1$

  ${}_{45}Rh : [Kr]\,4d^8, 5s^1$ ${}_{46}Pd : [Kr]\,4d^{10}$

  ${}_{78}Pt : [Xe]\,4f^{14}, 5d^9, 6s^1$ ${}_{79}Au : [Xe]\,4f^{14}, 5d^{10}, 6s^1$
- The outer shell electrons are often referred to as valence electrons. The electrons in the inner shells are called core electrons.
- The energy of atomic orbitals for H-atom or He^+ is (as the energy depends on the value of n) :

  $1s < 2s = 2p < 3s = 3p = 3d < 4s = 4p = 4d = 4f$
- The energy of orbitals other than H-atom depends upon n + l value and varies as:

  $1s < 2s < 2p < 3s < 3p < 4s < 3d < 4p < 5s$

  $< 4d < 5p < 6s < 4f < 5d < 6p < 7s < 5f < 6d$
- Cu^+ is diamagnetic whereas Cu^{2+} is paramagnetic.
- Alkali metals are paramagnetic but their salts are diamagnetic.
- $Cu^{2+}_{aq.}$ is more stable than $Cu^{+}_{aq.}$ inspite of the fact that Cu^+ has completely filled *d*-orbitals as $Cu^{+}_{aq.}$ undergoes disproportionation in aqueous solutions as:

  $2Cu^{+}_{aq} \longrightarrow Cu^{2+}_{aq.} + Cu$

  However $2Cu_2I_2$ is more stable than CuI_2 because I^- is strongest reducing agent among halides and thus, CuI_2 shows redox change as

  $2CuI_2 \longrightarrow Cu_2I_2 + I_2$

  Whereas $CuCl_2$ is more stable than Cu_2Cl_2.

Compton Effect: Compton allowed the monochromatic *X*-rays to fall on lighter elements such as carbon and noticed that scattered *X*-rays have wavelength larger than incident *X*-rays. In other words:

$\lambda_{\text{Scattered X-rays}} > \lambda_{\text{incident X-rays}}$

or $E_{\text{Scattered X-rays}} > E_{\text{incident X-rays}}$

or $\nu_{\text{Scattered X-rays}} > \nu_{\text{incident X-rays}}$

This phenomenon of increase in wavelength of X-rays after scattering from the surface of light element is known as Compton effect. The scattering of X-rays is due to interaction of photons (X-rays) and electrons and thus, supports quantum theory of light and illustrates uncertainty principle. Further-more X-rays deflected by larger angles show a loss of larger energy.

X-rays

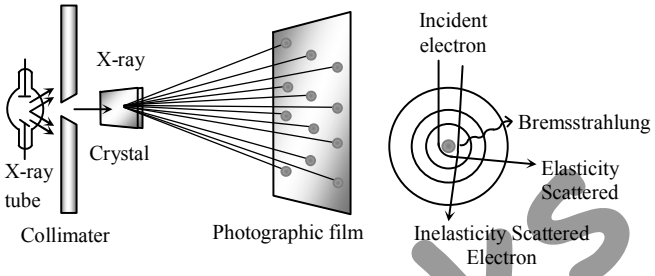


Figure: 5.4

- About X-ray photon

  Energy of X-ray photon $= h\nu = \frac{hc}{\lambda}$

  Momentum of X-ray photon $= \frac{h\nu}{c} = \frac{h}{\lambda}$

  Rest mass X-ray photon = 0

  Dynamic mass of X-ray photon $= \frac{h\nu}{c^2} = \frac{h}{c\lambda}$
- **Duane Hunt Rule:** Minimum wavelength of continuous X-ray spectrum $\lambda_{min} = \frac{hc}{eV}$
- Maximum frequency limit of continuous X-rays spectrum $\nu_{min} = \frac{c}{\lambda_{min}} = \frac{eV}{h}$
- **Mosley Law:** frequency of ν of characteristic X-ray spectrum $\sqrt{\nu} = a(Z - \sigma)$

  Where *a* and σ are constants for given radiation.
- **Bragg's Law:** The directions of maximum of X-ray diffracted form crystal $2d\sin\theta = n\lambda (n = 1, 2, 3, ...)$
- Intensity of X-rays transmitted through a thickness d of the material $I = I_0 e^{-kd}$ (k = a constant for a substance)

  Where $k = Cz^4 dx^4$, wave length, d thickness, C constant, atomic number.

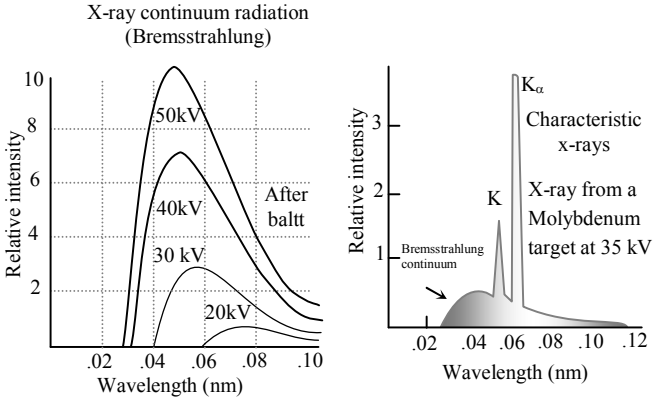


Figure: 5.5

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- X-ray are electromagnetic waves of wavelength $1Å - 100Å$. Wavelength of X-rays is of the same order as spacing between crystal atoms, hence X-rays may be used for study of crystal structure.
- Bremsstrahlung or Continuous X-rays are caused due to deceleration of bombarding electrons in the electric field of heavy nucleus. Continuous spectrum has a short wavelength limit. It extends form $\lambda_{min} = \frac{hc}{eV}$ upto infinity.
- Characteristic X-ray is produced due to jumping of electrons form higher to lower vacant shells in atoms of heavy substances.
- Screening constant $\sigma = 1$ for K_α = radiation of all elements.
- K-electrons: They are very close to nucleus; play an important role in the production of characteristic X-ray spectrum.

Atomic Number: Atomic number and mass number are whole numbers and are never fractional.

- Number of Neutrons = Mass no. – Atomic no.
- Atomic mass = [No. of p × its mass + no. of neutrons × its mass + No. of 'e' × its mass]
- Mass loss due to binding energy.
- Neglecting small masses of 'e' and assuming proton and neutron of nearly 1 amu each, one can have atomic mass = mass number.
- **Relative atomic mass:** The relative atomic mass of an element is the mass of an atom of the element relative to one-twelth the mass of one (C^{12}) carbon atom where mass is taken as 12 amu.
- Atomic mass: The average isotopic mass.

Average atomic mass $\bar{A} = \frac{\sum A_1 X_1}{\sum X_{Total}}$

$$\bar{A} = \frac{\%\text{ of I isotope} \times \text{Relative atomic mass of I isotope} + \%\text{ of II} \times \text{Relative atomic mass of II isotope} + \ldots}{100}$$

Note

- Both atomic mass and molecular mass are just ratios and have no units.
- Accurate determination of atomic masses and their relative abundance of the isotopes were determined using Aston's mass spectrometer.
- Actual masses of atoms are not equal to the sum of the masses of p, n and e present in it.

Aurbau Principles: The electronic configuration is written on the basis of the electrons in a poly electronic atom are filled one by one in order of increasing energy level.

e.g., $_1H$: $1s^1$ is correct

$2s^1$ is wrong

Because energy level of 1s < 2s.

Hund's Rules: In filling a group or orbitals of equal energy (or subshells) it is preferred to assign electrons to empty orbitals rather than pair them in a particular subshell, because the former arrangement leads to lower energy level. Same spin of unpaired electrons in sub-sub shell also gives rise to lower energy level.

e.g., $_7N$: For $2p^3$

↑	↑	↑	is correct
↑↓	↑	↑	is wrong (statement a)
↑	↓	↑	is wrong (statement b)

(n + l) rule: The subshell with lower values of (n + l) possesses lower energy level and should be filled first. *e.g.*, $_{19}K$:

$1s^2, 2s^2, 2p^6, 3s^2 3p^6 3d^1$ is wrong

$1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^1$ is correct

n = l of 4s = 4 + 0 = 4, n = l of 3d = 3 + 2 = 5

Thus, 4s should be filled first.

If (n + l) is same for two sub-shells, the one with lower values of n possess lower energy should be filled first.

e.g., $_{21}Sc$: $1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^2 4p^1$ is wrong

$1s^2, 2s^2 2p^6, 3s^2 3p^6, 3d^1 4s^2$ is correct

n = l of 4p = 4 + 1 = 5, n = l of 3d = 3 + 2 = 5

Thus, 3d should be filled first.

$\because$ n of 3d < n of 4s

A sub-shell having nearly full filled or nearly half filled configuration tends to acquire exactly full filled or exactly half filled nature in order to attain stability *i.e.,* lower energy level.

e.g., $_{24}Cr$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^4, 4s^2$ is wrong

$1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^1$ is correct

$_{29}Cu$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^9, 4s^2$ is wrong

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

$_{46}Pd$: $1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^2 4p^6 4d^8, 5s^2$ is wrong

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

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MULTIPLE CHOICE QUESTIONS

The Wave Functions for Hydrogen

1. Energy of the electron in n^{th} orbit of hydrogen atom is given by $E_n = -\frac{13.6}{n^2}$ eV. The amount of energy needed to transfer electron from first orbit to third orbit is:
a. 13.6 eV **b.** 3.4 eV
c. 12.09 eV **d.** 1.51 eV

2. If the binding energy of the electron in a hydrogen atom is 13.6 eV, the energy required to remove the electron from the first excited state of Li^{++} is:
a. 122.4 eV **b.** 30.6 eV
c. 13.6 eV **d.** 3.4 eV

3. The ratio of the wavelengths for $2 \rightarrow 1$ transition in Li^{++}, He^{+} and H is:
a. 1 : 2 : 3 **b.** 1 : 4 : 9
c. 4 : 9 : 36 **d.** 3 : 2 : 1

4. If scattering particles are 56 for 90º angle then this will be at 60º angle:
a. 224 **b.** 256 **c.** 98 **d.** 108

5. When an electron in hydrogen atom is excited, from its 4^{th} to 5^{th} stationary orbit, the change in angular momentum of electron is? (Planck's constant: $h = 6.6\times10^{-34}$ J–s)
a. 4.16×10^{-34} J–s **b.** 3.32×10^{-34} J–s
c. 1.05×10^{-34} J–s **d.** 2.08×10^{-34} J–s

6. In hydrogen atom, if the difference in the energy of the electron in n=2 and n=3 orbits is E, the ionization energy of hydrogen atom is:
a. 13.2 E **b.** 7.2 E
c. 5.6 E **d.** 3.2 E

7. In Bohr model of hydrogen atom, the ratio of periods of revolution of an electron in n = 2 and n = 1 orbits is:
a. 2 : 1 **b.** 4 : 1
c. 8 : 1 **d.** 16 : 1

8. Hydrogen atom emits blue light when it changes from n = 4 energy level to n = 2 level. Which colour of light would the atom emit when it changes from n = 5 level to n = 2 level?
a. Red **b.** Yellow
c. Green **d.** Violet

9. A single electron orbits a stationary nucleus of charge +Ze, where Z is a constant. It requires 47.2 eV to excited electron from second Bohr orbit to third Bohr orbit. Find the value of Z:
a. 2 **b.** 5 **c.** 3 **d.** 4

10. The first member of the Paschen series in hydrogen spectrum is of wavelength 18,800Å. The short wavelength limit of Paschen series is:
a. 1215 Å **b.** 6560 Å
c. 8225 Å **d.** 12850 Å

11. Hydrogen atom in its ground state is excited by radiation of wavelength 975 Å. How many lines will be there in the emission spectrum?
a. 2 **b.** 4 **c.** 6 **d.** 8

12. A photon of energy 12.4 eV is completely absorbed by a hydrogen atom initially in the ground state so that it is excited. The quantum number of the excited state is:
a. n =1 **b.** n= 3
c. n = 4 **d.** n = ∞

13. The wave number of the energy emitted when electron comes from fourth orbit to second orbit in hydrogen is 20,397 cm^{-1}. The wave number of the energy for the same transition in He^{+} is:
a. 5,099 cm^{-1} **b.** 20,497 cm^{-1}
c. 40,994 cm^{-1} **d.** 81,998 cm^{-1}

X-rays

14. When radiation of wavelength λ is incident on a metallic surface the stopping potential is 4.8 volts. If the same surface is illuminated with radiation of double the wavelength, then the stopping potential becomes 1.6 volts. Then the threshold wavelength for the surface is?
a. 2λ **b.** 4λ **c.** 6λ **d.** 8λ

15. The cut off wavelength of continuous X-ray from two coolidge tubes operating at 30 kV but using different target materials (molybdenum Z=42 and tungsten Z=74) are:
a. 1Å, 3Å **b.** 0.3 Å, 0.2 Å
c. 0.414 Å, 0.8 Å **d.** 0.414 Å, 0.414 Å

16. If the atom $_{100}Fm^{257}$ follows the Bohr model and the radius of $_{100}Fm^{257}$ is n times the Bohr radius, then find n:
a. 100 **b.** 200
c. 4 **d.** 1/4

17. In X-ray tube when the accelerating voltage V is halved, the difference between the wavelength of K_α line and minimum wavelength of continuous X-ray spectrum:
a. Remains constant
b. Becomes more than two times
c. Becomes half
d. Becomes less than two times

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Discovery and Properties of Anode, Cathode Rays Neutron and Nuclear Structure

18. A neutral atom (Atomic no. > 1) consists of:
a. Only protons
b. Neutrons + protons
c. Neutrons + electrons
d. Neutron + proton + electron

19. The ratio of charge and mass would be greater for:
a. Proton **b.** Electron
c. Neutron **d.** Alpha

20. Proton was discovered by?
a. Chadwick **b.** Thomson
c. Goldstein **d.** Bohr

21. One would expect proton to have very large:
a. Ionization potential **b.** Radius
c. Charge **d.** Hydration energy

22. The mass of 1 mole of electrons is:
a. 9.1×10^{-28} g **b.** 1.008 mg
c. 0.55 mg **d.** 9.1×10^{-27} g

23. What is the ratio of mass of an electron to the mass of a proton?
a. 1 : 2 **b.** 1 : 1
c. 1 : 1837 **d.** 1 : 3

Atomic Number, Mass Number, Atomic Species

24. The nucleus of the element having atomic number 25 and atomic weight 55 will contain:
a. 25 protons and 30 neutrons
b. 25 neutrons and 30 protons
c. 55 protons
d. 55 neutrons

25. CO has same electrons as or the ion that is isoelectronic with CO is:
a. N_2^+ **b.** CN^- **c.** O_2^+ **d.** O_2^-

26. The most probable radius (in *pm*) for finding the electron in He^+ is:
a. 0.0 **b.** 52.9
c. 26.5 **d.** 105.8

27. In the nucleus of $_{20}Ca^{40}$ there are:
a. 40 protons and 20 electrons
b. 20 protons and 40 electrons
c. 20 protons and 20 neutrons
d. 20 protons and 40 neutrons

28. Pick out the isoelectronic structures from the following:
$\underset{I}{CH_3^+}$ $\underset{II}{H_3O^+}$ $\underset{III}{NH_3}$ $\underset{IV}{CH_3^-}$
a. I and II **b.** I and IV
c. I and III **d.** II, III and IV

29. Nitrogen atom has an atomic number of 7 and oxygen has an atomic number 8. The total number of electrons in a nitrate ion will be:
a. 8 **b.** 16
c. 32 **d.** 64

30. Which among the following species have the same number of electrons in its outermost as well as penultimate shell?
a. Mg^{2+} **b.** O^{2-}
c. F^- **d.** Ca^{2+}

31. Number of neutrons in heavy hydrogen atom is:
a. 0 **b.** 1
c. 2 **d.** 3

Atomic Models and Planck's Quantum Theory

32. The spectrum of *He* is expected to be similar to:
a. H **b.** Li^+
c. Na **d.** He^+

33. The energy of second Bohr orbit of the hydrogen atom is –328 kJ mol^{-1}, hence the energy of fourth Bohr orbit would be:
a. – 41 $kJ\ mol^{-1}$ **b.** –1312 $kJ\ mol^{-1}$
c. –164 $kJ\ mol^{-1}$ **d.** – 82 $kJ\ mol^{-1}$

34. The specific charge of proton is $9.6\times10^{6}\,C\,kg^{-1}$ then for an α-particle it will be:
a. $38.4\times10^{7}\,C\,kg^{-1}$ **b.** $19.2\times10^{7}\,C\,kg^{-1}$
c. $2.4\times10^{7}\,C\,kg^{-1}$ **d.** $4.8\times10^{7}\,C\,kg^{-1}$

35. If change in energy $(\Delta E) = 3\times10^{-8}$ J, h = 6.64×10^{-34} J-s and c = 3×10^{8} m/s, then wavelength of the light is:
a. 6.36×10^{3} Å **b.** 6.36×10^{5} Å
c. 6.64×10^{-8} Å **d.** 6.36×10^{18} Å

36. The frequency corresponding to transition n = 2 to n = 1 in hydrogen atom is:
a. 15.66×10^{10} Hz **b.** 24.66×10^{14} Hz
c. 30.57×10^{14} Hz **d.** 40.57×10^{24} Hz

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37. The frequency of radiation emitted when the electron falls from n = 4 to n = 1 in a hydrogen atom will be?
(Given ionization energy of $H = 2.18\times10^{-18}$ J atom^{-1} and $h = 6.625\times10^{-34}$ Js)
a. $3.08\times10^{15}\,s^{-1}$ **b.** $2.00\times10^{15}\,s^{-1}$
c. $1.54\times10^{15}\,s^{-1}$ **d.** $1.03\times10^{15}\,s^{-1}$

38. The energy of electron in hydrogen atom in its grounds state is –13.6eV. The energy of the level corresponding to the quantum number equal to 5 is:
a. –0.54 *eV* **b.** – 0.85 *eV*
c. – 0.64 *eV* **d.** – 0.40 *eV*

39. Which of the following transitions have minimum wavelength?
a. $n_4 \rightarrow n_1$ **b.** $n_2 \rightarrow n_1$
c. $n_4 \rightarrow n_2$ **d.** $n_3 \rightarrow n_1$

Dual Nature of Electron

40. An electron has kinetic energy 2.8×10^{-23} J. de-Broglie wavelength will be nearly: ($m_e = 9.1\times10^{-31}$ kg)
a. 9.28×10^{-4} m **b.** 9.28×10^{-7} m
c. 9.28×10^{-8} m **d.** 9.28×10^{-5} m

41. Calculate de-Broglie wavelength of an electron travelling at 1% of the speed of light:
a. 2.73×10^{-24} **b.** 2.42×10^{-10}
c. 242.2×10^{10} **d.** None of these

Uncertainty Principle and Schrodinger Wave Equation

42. The uncertainty in the position of a moving bullet of mass 10 *gm* is 10^{-5} m. Calculate the uncertainty in its velocity:
a. 5.2×10^{-28} m / sec **b.** 3.0×10^{-28} m / sec
c. 5.2×10^{-22} m / sec **d.** 3×10^{-22} m / sec

43. Which quantum number is not related with Schrodinger equation?
a. Principal **b.** Azimuthal
c. Magnetic **d.** Spin

44. According to Heisenberg's uncertainty principle, the product of uncertainties in position and velocities for an electron of mass 9.1×10^{-31} kg is:
a. $2.8\times10^{-3}\,m^2s^{-1}$ **b.** $3.8\times10^{-5}\,m^2s^{-1}$
c. $5.8\times10^{-5}\,m^2s^{-1}$ **d.** $6.8\times10^{-6}\,m^2s^{-1}$

Quantum Number, Electronic Configuration and Shape of Orbital's

45. Correct set of four quantum numbers for valence electron of rubidium ($Z = 37$) is:
a. $5,0,0,+\frac{1}{2}$ **b.** $5,1,0,+\frac{1}{2}$
c. $5,1,1,+\frac{1}{2}$ **d.** $6,0,0,+\frac{1}{2}$

46. The maximum energy is present in any electron at:
a. Nucleus
b. Ground state
c. First excited state
d. Infinite distance from the nucleus

47. The number of radial nodes of 3*s* and 2*p* orbitals are respectively:
a. 2, 0 **b.** 0, 2
c. 1, 2 **d.** 2, 1

48. Which of the following ions is not having the configuration of neon?
a. F^- **b.** Mg^{+2} **c.** Na^+ **d.** Cl^-

49. If the value of azimuthal quantum number is 3, the possible values of magnetic quantum number would be:
a. 0, 1, 2, 3 **b.** 0, – 1, – 2, – 3
c. 0, ± 1, ± 2, ± 3 **d.** ± 1, ± 2, ± 3

50. The set of quantum numbers $n = 3, l = 0, m = 0, s = -1/2$ belongs to the element:
a. Mg **b.** Na **c.** Ne **d.** F

51. For which of the following sets of four quantum numbers, an electron will have the highest energy?

	n	*l*	*m*	*s*
a.	3	2	1	+1/2
b.	4	2	1	+1/2
c.	4	1	0	–1/2
d.	5	0	0	–1/2

52. What is the maximum number of electrons which can be accommodated in an atom in which the highest principal quantum number value is 4?
a. 10 **b.** 18 **c.** 32 **d.** 54

53. The four quantum numbers of the valence electron of potassium are:
a. 4, 1, 0 and $\frac{1}{2}$ **b.** 4, 0, 1 and $\frac{1}{2}$
c. 4, 0, 0 and $+\frac{1}{2}$ **d.** 4, 1, 1 and $\frac{1}{2}$

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54. Orbital angular momentum for a *d*-electron is:

a. $\frac{6h}{2\pi}$ **b.** $\frac{\sqrt{6}\,h}{2\pi}$ **c.** $\frac{12h}{2\pi}$ **d.** $\frac{\sqrt{12}\,h}{2\pi}$

55. The maximum number of electrons present in an orbit $l = 3$, is:

a. 6 **b.** 8

c. 10 **d.** 14

NCERT EXEMPLAR PROBLEMS

More than One Answer

56. When photons of energy 4.25 eV strike the surface of a metal A, the ejected photo electrons have maximum kinetic energy T_A (expressed in eV) and de Broglie wavelength λ_A .The maximum kinetic energy of the photo electrons liberated from another metal 'B' by photons of energy 4.20 eV is $T_B = T_A - 1.5$ (expressed in eV). If the de Broglie wavelength of these photo electrons is $\lambda_B = 2\lambda_A$, then

a. work function of A is 2.25 eV

b. work function of B is 4.20 eV

c. $T_A = 2$ eV

d. $T_B = 2.50$ eV

57. Which of the following pairs have identical values of magnetic moment?

a. Zn^{2+}, Cu^{+} **b.** Co^{2+}, Ni^{2+}

c. Mn^{4+}, Co^{2+} **d.** Mg^{2+}, Sc^{+}

58. If there were three possible values $\left(-\frac{1}{2}, 0, +\frac{1}{2}\right)$ for the spin magnetic quantum number (m_s), which of the following statement (s) is/are correct regarding a hypothetical Periodic Table based on this conditions?

a. The first period would have only 2 vertical columns

b. The second period would have 12 elements

c. The Periodic Table would contain 27 group

d. The third period would have 12 elements

59. Choose the correct statement among the following

a. Radial distribution function $(\psi^2 4\pi r^2)$ gives the probability at a particular distance along one chosen direction:

b. '*xz*' plane acts as a nodal plane for $3p_x$ orbital

c. For 's' orbital's wave function is independent of θ and ϕ

d. '2p' orbital with quantum number $n = 2, l = 1, m = 0$, also shows the angular dependence.

60. Choose the correct statement(s) regarding the photoelectric effect:

a. No electrons are ejected, regardless of the intensity of the radiation, unless the frequency equals or exceeds a threshold value characteristic of the metal

b. The kinetic energy of the ejected electrons varies linearly with the frequency of the incident radiation and its intensity

c. Even at low intensities, electrons are ejected immediately if the frequency is above the threshold value

d. An intense and a weak beam of monochromatic radiations differ in having number of photons and not in the energy of photons

61. Mark out the correct statement (s)

a. Electrons within a subshell for which $l > 0$ mean that the relatively greater electrostatics repulsion between two electrons in the same orbital within a sub shell as compared with occupancy of two orbitals having different m_l values

b. Electrons in singly occupied orbitals tend to have their spins in the same direction so as to maximize the net magnetic moment

c. In the ground state, an atom adopts a configuration with the greatest number of unpaired electrons

d. Electrons in different orbitals with parallel spins show mutual attraction, so the electron-nucleus interaction is improved

62. Which one of the following is/are true for the cathode rays?

a. they have kinetic energy

b. they cause certain substances to fluoresce

c. they travel in straight line

d. they are electromagnetic waves

63. The specific charge of the cathode rays is:

a. a universal constant

b. independent of the place of earth

c. independent of the nature of gas in discharge tube

d. independent of the material of discharge tube

64. The potential difference applied to an X-ray tube is increased. As a result, in the emitted radiation:

a. the intensity increases

b. the minimum wave length increases

c. the intensity remains unchanged

d. the minimum wave length decreases

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65. In Bohr model of hydrogen atom:
a. the radius of n^{th} orbit is proportional to n^2
b. the total energy of electron in n^{th} orbit is proportional to n
c. the angular momentum of the electron in an orbit is an integral multiple of $h/2\pi$
d. the magnitude of the potential energy of an electron in any orbit is greater than its kinetic energy

66. Which of the following are in the ascending order of wavelength?
a. $H_\alpha, H_\beta, H_\gamma$... lines in Balmer series of hydrogen atom
b. Lyman limit, Balmer limit, Paschen limit in the hydrogen spectrum
c. Violet, blue, yellow, red colours in solar spectrum
d. None of these

67. Continuous spectrum is produced by:
a. Incandescent electric bulb **b.** sun
c. Hydrogen molecules **d.** Na-vapour lamp

68. A gas of monoatomic hydrogen is bombarded with a stream of electrons that have been accelerated from rest through a potential difference of 12.75 volt. In emission spectrum one can observe lines of:
a. Lyman series **b.** Balmer series
c. Paschen series **d.** Pfund series

69. If the potential energy of the electron in the first allowed orbit in hydrogen atom is E, its:
a. Ionisation potential is –E/2
b. Kinetic energy is –E/2
c. Total energy is E/2
d. None of these true

70. According to Bohr's theory of the hydrogen atom, for the electron in the n^{th} allowed orbit, the:
a. Linear momentum is proportional to (1/n)
b. the radius is proportional to n
c. The kinetic energy is proportional to $(1/n^2)$
d. The angular momentum is proportional to n

71. In an atom, the two electrons move round the nucleus in circular orbits of radii R and 4R. The ratio of the time taken by them to complete one revolution is:
a. 1/4 **b.** 4/1
c. 8/1 **d.** 1/8

72. An energy of 24.6 eV is required to remove one of the electrons from a neutral helium atom. The energy (in eV) required to remove both the electrons from a neutral helium atom is:
a. 79.0 **b.** 51.8
c. 49.2 **d.** 38.2

Assertion and Reason

Note: Read the Assertion (A) and Reason (R) carefully to mark the correct option out of the options given below:

a. If both assertion and reason are true and the reason is the correct explanation of the assertion.
b. If both assertion and reason are true but reason is not the correct explanation of the assertion.
c. If assertion is true but reason is false.
d. If the assertion and reason both are false.
e. If assertion is false but reason is true.

73. **Assertion:** The cation energy of an electron is largely determined by its principal quantum number.
Reason: The principal quantum number n is a measure of the most probable distance of finding the electron around the nucleus.

74. **Assertion:** Nuclide $^{30}Al_{13}$ is less stable than $^{40}Ca_{20}$
Reason: Nuclides having odd number of protons and neutrons are generally unstable

75. **Assertion:** The atoms of different elements having same mass number but different atomic number are known as isobars
Reason: The sum of protons and neutrons, in the isobars is always different

76. **Assertion:** Two electrons in an atom can have the same values of four quantum numbers.
Reason: Two electrons in an atom can be present in the same shell, sub-shell and orbital and have the same spin

77. **Assertion:** The value of n for a line in Balmer series of hydrogen spectrum having the highest wave length is 4 and 6.
Reason: For Balmer series of hydrogen spectrum, the value $n_1 = 2$ and $n_2 = 3, 4, 5$.

78. **Assertion:** Absorption spectrum conists of some bright lines separated by dark spaces.
Reason: Emission spectrum consists of dark lines.

79. **Assertion:** A resonance hybrid is always more stable than any of its canonical structures.
Reason: This stability is due to delocalization of electrons.

80. **Assertion:** Cathode rays do not travel in straight lines.
Reason: Cathode rays penetrate through thick sheets

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81. **Assertion:** Electrons revolving around the nucleus do not fall into the nucleus because of centrifugal force.
Reason: Revolving electrons are planetary electrons.

82. **Assertion:** The transition of electrons $n_3 \rightarrow n_2$ in H atom will emit greater energy than $n_4 \rightarrow n_3$.
Reason: n_3 and n_2 are closer to nucleus tan n_4.

Comprehension Based

Paragraph –I

The letters n, l, m proposed by Bohr, Sommerfeld and Zeeman respectively for quantization of angular momentum in classical physics were later on obtained as the results of solution of Schrodinger wave equation based on quantum mechanics. The term n, l, m were named as principal quantum number, azimuthal quantum number and magnetic quantum number respectively. The fourth quantum number s was given the name spin quantum number on the basis of two spins of electrons. The first two quantum numbers also decides the nodes of an orbital.

83. The numerical value $\psi_{4,3,0}$ denotes:

a. 3d-orbitals **b.** 4f-orbitals
c. 2s-orbitals **d.** 4d-orbitals

84. The angular momentum of 3*p*-orbitals in terms of $\hbar\left\{\hbar = \frac{h}{2\pi}\right\}$ is:

a. $\sqrt{2}\hbar$ **b.** $2\hbar$
c. $\frac{\hbar}{\sqrt{2}}$ **d.** $\frac{\hbar}{2\pi}$

85. Number of radial and angular nodes in 3p-orbitals respectively are:

a. 1, 1 **b.** 2, 1
c. 1, 2 **d.** 2, 2

86. Which statement about energy level in H-atom is correct?
a. Only n and *l* decide energy level
b. Only '*l*' decides energy level
c. Only n decides energy level
d. n, *l* and m decide energy level

87. The quantum numbers of +½ and –½ for the electron spin represents:
a. rotation of electron in clockwise and anticlockwise direction respectively
b. rotation of electron in anticlockwise and clockwise direction respectively
c. two quantum mechanical states having classical analogue
d. two quantum mechanical states having no classical analogue

88. Δu_x is uncertainty in velocity of electron and Δx_y is uncertainty in position, then:

a. $\Delta u_x \cdot \Delta x_y = \frac{h}{4\pi}$ **b.** $\Delta u_x \cdot \Delta x_y = \frac{h}{4\pi m}$
c. $\Delta u_x \cdot \Delta x_y \geq \frac{h}{4\pi m}$ **d.** None of these

Paragraph –II

The hydrogen-like species Li^{2+} is in a spherically symmetric state S_1 with one radial node. Upon absorbing light the ion undergoes transition to a state S_2. The state S_2 has one radial node and its energy is equal to the ground state energy of the hydrogen atom.

89. The state S_1 is:

a. 1s **b.** 2s
c. 2p **d.** 3s

90. Energy of the state S_1 in units of the hydrogen atom ground state energy is:

a. 0.75 **b.** 1.50
c. 2.25 **d.** 4.50

91. The orbital angular momentum quantum number of the state S_2 is:

a. 0 **b.** 1
c. 2 **d.** 3

Match the Column

92. Match the statement of Column with those in Column II:

Column I	Column II
(A) In the Bohr's hydrogen atom model, the radius of the stationary orbit is directly proportional to (*n* = principle quantum number)	**1.** n^2
(B) The kinetic energy of the electron in an orbit of radius *r* in hydrogen atom is (*e* = electronic charge)	**2.** $\frac{e^2}{2r}$
(C) The angular momentum of electron in nth orbit is given by	**3.** $n^2 \frac{h}{2\pi}$

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(D)	According to Bohr's theory the radius of electron in an orbit described by principal quantum number n and atomic number Z is proportional to	**4.** $\frac{h}{z}$

a. A→ 1; B→ 3,4; C→ 4; D→ 2,3
b. A→ 1; B→ 2,4; C→ 3; D→ 4
c. A→ 2; B→ 1; C→ 4; D→ 3
d. A→ 1; B→ 3,4; C→ 4; D→ 3

93. Match the statement of Column with those in Column II:

Column I	Column II
(A) In any Bohr orbit of the hydrogen atom, the ratio of kinetic energy to potential energy of the electron is	**1.** –1/2
(B) The ratio of the kinetic energy to the total energy of an electron in a Bohr orbit is	**2.** 2
(C) In the lowest energy level of hydrogen atom, the electron has the angular momentum	**3.** $h/2\pi$
(D) Ratio of the wavelengths of first line of Lyman series and first line of Balmer series is	**4.** 5 : 27

a. A→ 1; B→ 3,4; C→ 4; D→ 2,3
b. A→ 1; B→ 3,4; C→ 4; D→ 3
c. A→ 2; B→ 3,4; C→ 1; D→ 3
d. A→ 1; B→ 2,4; C→ 3; D→ 4

94. Match the statement of Column I with those in Column II:

Column I	Column II
(A) Orbits are filled in order of increasing energy	**1.** Hund's rule
(B) Degenerate orbitals are first singly occupied	**2.** Pauli exclusion principle
(C) An orbital can have maximum two electrons	**3.** Aufbau principle
(D) Position and momentum of a small particle cannot be measured simultaneously with absolute accuracy.	**4.** Heisenberg principle

a. A→ 3; B→ 1; C→ 2; D→ 4
b. A→ 2; B→ 4; C→ 3; D→ 1
c. A→ 1; B→ 3; C→ 2; D→ 4
d. A→ 4; B→ 1; C→ 3; D→ 2

95. Match the statement of Column I with those in Column II:

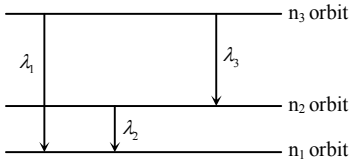
Column I	Column II
(A) Configuration of Cr is	**1.** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$
(B) Configuration of Cu is	**2.** 5
(C) Number of unpaired electrons in Fe^{3+}	**3.** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$
(D) Electronic configuration of Zn^{2+}	**4.** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$
	5. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^9 4s^2$
	6. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^4 4s^2$

a. A→ 3; B→ 4; C→ 2; D→ 1
b. A→ 2; B→ 4; C→ 3; D→ 1
c. A→ 1; B→ 3; C→ 2; D→ 4
d. A→ 4; B→ 1; C→ 3; D→ 2

Integer

96. The angular momentum of electron in 2nd orbit of hydrogen atom is L. The angular momentum of electron in 4th orbit of hydrogen atom is n L where n =?

97. For an atom of an ion having single electron, the wavelength observed $\lambda_1 = 2$ are units and $\lambda_3 = 2$ units figure. The value of missing wavelength λ_2 is



98. How many different wave-length may be observed in the spectrum from a hydrogen sample if the atoms are excited to 3rd excited state?

99. The maximum number of electrons can have principal quantum number n=3 and spin quantum number $m_s = 1/2$ is

100. The work function (ϕ) of some metals is listed below. The number of metals which will show photoelectric effect when light of 300 nm wavelength falls on the metal is

Metal	Li	Na	K	Mg	Cu	Ag	Fe	Pt	W
ϕ (eV)	2.4	2.3	2.2	3.7	4.8	4.3	4.7	6.3	4.75

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ANSWER

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
c	b	c	a	c	b	c	d	b	c
11.	**12.**	**13.**	**14.**	**15.**	**16.**	**17.**	**18.**	**19.**	**20.**
c	c	d	b	d	d	c	d	b	c
21.	**22.**	**23.**	**24.**	**25.**	**26.**	**27.**	**28.**	**29.**	**30.**
d	c	c	a	b	c	c	d	c	d
31.	**32.**	**33.**	**34.**	**35.**	**36.**	**37.**	**38.**	**39.**	**40.**
b	b	d	d	c	b	a	a	a	c
41.	**42.**	**43.**	**44.**	**45.**	**46.**	**47.**	**48.**	**49.**	**50.**
b	a	d	c	a	d	a	d	c	a
51.	**52.**	**53.**	**54.**	**55.**	**56.**	**57.**	**58.**	**59.**	**60.**
b	c	c	b	d	a,c	a,c	b,c,d	c,d	a,c,d
61.	**62.**	**63.**	**64.**	**65.**	**66.**	**67.**	**68.**	**69.**	**70.**
a,b,c	a,b,c	all	c,d	a,c,d	b,c	a,b	a,b,c	a,b,c	a,c,d
71.	**72.**	**73.**	**74.**	**75.**	**76.**	**77.**	**78.**	**79.**	**80.**
d	a	a	a	c	d	e	d	a	e
81.	**82.**	**83.**	**84.**	**85.**	**86.**	**87.**	**88.**	**89.**	**90.**
b	b	b	a	a	c	d	d	b	c
91.	**92.**	**93.**	**94.**	**95.**	**96.**	**97.**	**98.**	**99.**	**100.**
b	b	d	a	a	2	6	6	9	4

SOLUTION

Multiple Choice Questions

1. **(c)** Using $E = -\frac{13.6}{n^2}\text{eV}$

For n = 1, $E_1 = \frac{-13.6}{1^2} = -13.6\,\text{eV}$

and for n = 3 $E_3 = -\frac{13.6}{3^2} = -1.51\,\text{eV}$

So required energy

$= E_3 - E_1 = -1.51 - (-13.6) = 12.09\,\text{eV}$

2. **(b)** Using $E_n = -\frac{13.6 \times Z^2}{n^2}\text{eV}$

For first excited state n = 2 and for Li^{++}, Z = 3

$\therefore \quad E = -\frac{13.6}{2^2} \times 3^2$

$= -\frac{13.6 \times 9}{4} = -30.6\,\text{eV}.$

Hence, remove the electron from the first excited state of Li^{++} be 30.6 eV

3. **(c)** Using $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$\Rightarrow \quad \lambda \propto \frac{1}{Z^2}$

$\Rightarrow \quad \lambda_{Li} : \lambda_{He^+} : \lambda_H = \frac{1}{9} : \frac{1}{4} : \frac{1}{1} = 4 : 9 : 36$

4. **(a)** Using Scattering formula $N \propto \frac{1}{\sin^4(\theta/2)}$

$\Rightarrow \quad \frac{N_2}{N_1} = \left[\frac{\sin\left(\frac{\theta_1}{2}\right)}{\sin\left(\frac{\theta_2}{2}\right)}\right]^4$

$\Rightarrow \quad \frac{N_2}{N_1} = \left[\frac{\sin\left(\frac{90°}{2}\right)}{\sin\left(\frac{60°}{2}\right)}\right]^4 = \left[\frac{\sin 45°}{\sin 30°}\right]^4 = 4$

$\Rightarrow \quad N_2 = 4N_1 = 4 \times 56 = 224$

5. **(c)** Change in angular momentum

$\Delta L = L_2 - L_1$

$= \frac{n_2 h}{2\pi} - \frac{n_1 h}{2\pi}$

$\Rightarrow \quad \Delta L = \frac{h}{2\pi}(n_2 - n_1)$

$= \frac{6.6 \times 10^{-34}}{2 \times 3.14}(5 - 4)$

$= 1.05 \times 10^{-34}\,\text{J-s}$

6. **(b)** Energy difference between n = 2 and n = 3;

$E = K\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

$= K\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5}{36}K \qquad \ldots (i)$

Ionization energy of hydrogen atom $n_1 = 1$ and

$n_2 = \infty$;

$E' = K\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right) = K \qquad \ldots (ii)$

From equation (*i*) and (*ii*) $E' = \frac{36}{5}E = 7.2\,E$

7. **(c)** According to Bohr model time period of electron $T \propto n^3$

$\Rightarrow \quad \frac{T_2}{T_1} = \frac{n_2^3}{n_1^3} = \frac{2^3}{1^3} = \frac{8}{1}$

$\Rightarrow \quad T_2 = 8T_1.$

8. **(d)** In the transition from orbits 5→2 more energy will be liberated as compared to transition from 4→2.
So emitted photon would be of violet light.

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9. **(b)** Excitation energy of hydrogen like atom for $n_2 \rightarrow n_1$

$$\Delta E = 13.6Z^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)eV$$

$$\Rightarrow \quad 47.2 = 13.6Z^2\left(\frac{1}{2^2}-\frac{1}{3^2}\right)$$

$$= 13.6\times\frac{5}{36}Z^2$$

$$\Rightarrow \quad Z^2 = \frac{47.2\times 36}{13.6\times 5} = 24.98 \simeq 25$$

$$\Rightarrow \quad Z = 5$$

10. **(c)** First member of Paschen series mean it's

$$\lambda_{max} = \frac{144}{7R}$$

Short wavelength of Paschen series means

$$\lambda_{min} = \frac{9}{R}$$

Hence $\frac{\lambda_{max}}{\lambda_{min}} = \frac{16}{7}$

$$\Rightarrow \quad \lambda_{min} = \frac{7}{16}\times\lambda_{max}$$

$$= \frac{7}{16}\times 18,800$$

$$= 8225\text{Å}.$$

11. **(c)** Using $\frac{1}{\lambda} = R\left[\frac{1}{n_1^2}-\frac{1}{n_2^2}\right]$

$$\Rightarrow \quad \frac{1}{975\times 10^{-10}}$$

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

$$\Rightarrow \quad n = 4$$

Now number of spectral lines

$$N = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6.$$

12. **(c)** Let electron absorbing the photon energy reaches to the excited state *n*. Then using energy conservation

$$\Rightarrow \quad -\frac{13.6}{n^2} = -13.6 + 12.4$$

$$\Rightarrow \quad -\frac{13.6}{n^2} = -1.2$$

$$\Rightarrow \quad n^2 = \frac{13.6}{1.2} = 12$$

$$\Rightarrow \quad n = 3.46 \simeq 4$$

13. **(d)** Using $\frac{1}{\lambda} = \bar{\nu} = RZ^2\left(\frac{1}{n_1^2}-\frac{1}{n_2^2}\right)$

$$\Rightarrow \quad \bar{\nu} \propto Z^2$$

$$\Rightarrow \quad \frac{\bar{\nu}_2}{\bar{\nu}_1} = \left(\frac{Z_2}{Z_1}\right)^2 = \left(\frac{Z}{1}\right)^2 = 4$$

$$\Rightarrow \quad \bar{\nu}_2 = \bar{\nu}\times 4 = 81588\,cm^{-1}.$$

14. **(b)** By using $V_0 = \frac{hc}{e}\left[\frac{1}{\lambda}-\frac{1}{\lambda_0}\right]$

$$4.8 = \frac{hc}{e}\left[\frac{1}{\lambda}-\frac{1}{\lambda_0}\right] \qquad \ldots (i)$$

$$1.6 = \frac{hc}{e}\left[\frac{1}{2\lambda}-\frac{1}{\lambda_0}\right] \qquad \ldots (ii)$$

From equation (*i*) and (*ii*) $\lambda_0 = 4\lambda$.

15. **(d)** Cut off wavelength of continuous X-rays depends solely on the voltage applied and does not depend on the material of the target. Hence the two tubes will have the same cut off wavelength.

$$Ve = h\nu = \frac{hc}{\lambda}$$

or $$\lambda = \frac{hc}{Ve} = \frac{6.627\times 10^{-34}\times 3\times 10^8}{30\times 10^3\times 1.6\times 10^{-19}}\,m$$

$$= 414\times 10^{-10}\,m = 0.414\,\text{Å}.$$

16. **(d)** $(r_m) = \left(\frac{m^2}{Z}\right)(0.53\text{Å}) = (n\times 0.53\text{Å})$

$$\Rightarrow \quad \frac{m^2}{Z} = n \quad m = 5 \text{ for } {}_{100}Fm^{257} \text{ (the outermost shell) and } z = 100$$

$$\therefore \quad n = \frac{(5)^2}{100} = \frac{1}{4}$$

17. **(c)** $\Delta\lambda = \lambda_{K_\alpha} - \lambda_{min}$ when V is halved λ_{min} becomes two times but λ_{K_a} remains the same.

$$\therefore \quad \Delta\lambda' = \lambda_{K_\alpha} - 2\lambda_{min}$$

$$= 2(\Delta\lambda) - \lambda_{K_a} \quad \Delta\lambda' < 2(\Delta\lambda)$$

18. **(d)** Neutrons and protons in the nucleus and electrons in the extranuclear region.

19. **(b)** Charge/mass for $n = 0, \alpha = \frac{2}{4}, p = \frac{1}{1}$

And $e = \frac{1}{1/1837}$

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20. **(c)** Proton is represented by p having charge +1 discovered in 1988 by Goldstein.

21. **(d)** H^+ (proton) will have very large hydration energy due to its very small ionic size

Hydration energy $\propto \frac{1}{\text{Size}}$

22. **(c)** One mole of electron = 6.023×10^{23} electron
Mass of one electron = 9.1×10^{-28} *gm*
Mass of one mole of electrons
$= 6.023 \times 10^{23} \times 9.1 \times 10^{-28}$ gm
$= 5.48 \times 10^{-4}$ gm
$= 5.48 \times 10^{-4} \times 1000$ mg
$= 0.548$ gm ≈ 0.55 mg .

23. **(c)** Electron $\frac{1}{1837}$ time lighter than proton so their mass ratio will be 1 : 1837

24. **(a)** No. of protons = Atomic no. = 25 and no. of neutron = 55 – 25 = 30.

25. **(b)** CO and CN^- are isoelectronic.
$CO = 6 + 8 = 14$
and $CN^- = 6 + 7 + 1 = 14$.

26. **(c)** Most probable radius = a_0 / Z
Where $a_0 = 52.9$ pm.
For helium ion, $Z = 2$.
$r_{mp} = \frac{52.9}{2} = 26.45\ pm.$

27. **(c)** P = 20, mass no. (a) = 40
N = A–P = 40 – 20 = 20
P = N = 20.

28. **(d)** $CH_3^+ = 6 + 3 - 1 = 8e^-$
$H_3O^+ = 3 + 8 - 1 = 10e^-$
$NH_3 = 7 + 3 = 10e^-$
$CH_3^- = 6 + 3 + 1 = 10e^-$

29. **(c)** Number of electrons in nitrogen = 7 and number of electron is oxygen = 8 we know that formula of nitrate ion is NO_3^- we also know that number of electron
= (1 × Number of electrons in nitrogen)
+ (3 × number of electrons in oxygen) + 1
= (1 × 7) + (3 × 8) + 1 = 32.

30. **(d)** $_{20}Ca = 2, 8, 8, 2$
$Ca^{2+} = 2, 8, 8$
Hence, Ca^{2+} has 8 electrons each in outermost and penultimate shell.

31. **(b)** Heavy hydrogen is $_1^2D$. Number of neutrons = 1

32. **(b)** Both *He* and Li^+ contain 2 electrons each.

33. **(d)** $\frac{E_4}{E_2} = \frac{2^2}{4^2} = \frac{4}{16} = \frac{1}{4}$;
$E_4 = \frac{E_2}{4} = \frac{-328}{4}$
$= -82$ kJ / mol.

34. **(d)** $\left(\frac{q}{m}\right)_\alpha = \frac{1}{2}\left(\frac{q}{m}\right)_p$
$= \frac{1}{2} \times 9.6 \times 10^7$
$= 4.8 \times 10^7\ C\,kg^{-1}$

35. **(c)** $\Delta E = \frac{hc}{\lambda}$ or $\lambda = \frac{hc}{\Delta E}$
$= \frac{6.64 \times 10^{-34} \times 3 \times 10^8}{3 \times 10^{-8}}$
$= 6.64 \times 10^{-8}$ Å

36. **(b)** $v = \frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$
$= 109678\left[\frac{1}{1} - \frac{1}{4}\right] = 82258.5$
$\lambda = 1.21567 \times 10^{-5}$ cm or $\lambda = 12.1567 \times 10^{-6}$ cm
$= 12.1567 \times 10^{-8}$ m
$v = \frac{c}{\lambda} = \frac{3 \times 10^8}{12.567 \times 10^{-8}}$
$= 24.66 \times 10^{14}$ Hz .

37. **(a)** $E_{ionisation} = E_\infty - E_n = \frac{13.6 Z_{eff}^2}{n^2}$ eV
$= \left[\frac{13.6Z^2}{n_2^2} - \frac{13.6Z^2}{n_1^2}\right]$
$E = h\nu = \frac{13.6 \times 1^2}{(1)^2} - \frac{13.6 \times 1^2}{(4)^2}$;
$h\nu = 13.6 - 0.85$
$\because$ $h = 6.625 \times 10^{-34}$
$\nu = \frac{13.6 - 0.85}{6.625 \times 10^{-34}} \times 1.6 \times 10^{-19}$
$= 3.08 \times 10^{15}\ s^{-1}$

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38. **(a)** Energy of ground stage $(E_0) = -13.6\text{eV}$ and energy level = 5

$$E_5 = \frac{-13.6}{n^2}\text{eV} = \frac{-13.6}{5^2}$$

$$= \frac{-13.6}{25} = -0.54\text{eV}.$$

39. **(a)** For $n_4 \to n_1$, greater transition, greater the energy difference, lesser will be the wavelength.

40. **(c)** Formula for de-Broglie wavelength is

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

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

$$\Rightarrow \quad eV = \frac{1}{2}mv^2$$

or $$v = \sqrt{\frac{2eV}{m}}$$

$$\lambda = \frac{h}{\sqrt{2meV}}$$

$$= \frac{6.62\times10^{-34}}{\sqrt{2\times9.1\times10^{-31}\times2.8\times10^{-23}}}$$

$$\lambda = 9.28\times10^{-8}\text{ meter.}$$

41. **(b)** One percent of the speed of light is

$$v = \left(\frac{1}{100}\right)(3.00\times10^8\text{ms}^{-1})$$

$$= 3.00\times10^6\text{ms}^{-1}$$

Momentum of the electron (p) = mv

$$= (9.11\times10^{-31}\text{kg})(3.00\times10^6\text{ms}^{-1})$$

$$= 2.73\times10^{-24}\text{kg ms}^{-1}$$

The de-broglie wavelength of this electron is

$$\lambda = \frac{h}{p} = \frac{6.626\times10^{-34}}{2.73\times10^{-24}\text{kgms}^{-1}}$$

$$\lambda = 2.424\times10^{-10}\text{ m.}$$

42. **(a)** Uncertainty of moving bullet velocity

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

$$= \frac{6.625\times10^{-34}}{4\times3.14\times.01\times10^{-5}}$$

$$= 5.2\times10^{-28}\text{ m/sec.}$$

43. **(d)** Spin quantum number does not related with Schrodinger equation because they always show $+1/2$, $-1/2$ value.

44. **(c)** Given that mass of electron

$$= 9.1\times10^{-31}\text{kg}$$

Planck's constant

$$= 6.63\times10^{-34}\text{kg m}^2\text{s}^{-1}$$

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

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

Where Δx = uncertainity in position

Δv = uncertainity in velocity

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

$$= \frac{6.63\times10^{-34}}{4\times3.14\times9.1\times10^{-31}}$$

$$= 5.8\times10^{-5}\text{m}^2\text{s}^{-1}.$$

45. **(a)** Electronic configuration of $Rb_{(37)}$ is

$1s^2\,2s^2\,2p^6\,3s^2\,3p^6\,3d^{10}\,4s^2\,4p^6\,5s^1$

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

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

46. **(d)** As a result of attraction, some energy is released. So at infinite distance from the nucleus energy of any electron will be maximum. For bringing electrons from ∞ to the orbital of any atom some work has to be done be electrons hence it bill loose its energy for doing that work.

47. **(a)** Number of radial nodes = $(n - l - 1)$

For $3s$: $n = 3, l = 0$ (Number of radial node = 2)

For $2p$: $n = 2, l = 1$ (Number of radial node = 0)

48. **(d)** Configuration of

$Ne = 1s^2\,2s^2\,2p^6$

$F^- = 1s^2\,2s^2\,2p^6$

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

$Mg^{++} = 1s^2\,2s^2\,2p^6$

$Cl^- = 1s^2\,2s^2\,2p^6\,3s^2\,3p^6$.

49. **(c)** When $l = 3$ then

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

$m = -l$ to $+l$ including zero.

50. **(a)** Mg_{12} have $1s^2\,2s^2\,2p^6\,3s^2$ electronic configuration

$$n = 3,\ l = 0,\ m = 0,\ s = -\frac{1}{2}.$$

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51. **(b)** 4*d*-orbital have highest energy in given data.

52. **(c)** Maximum number of electron
$= 2n^2 (\text{where n} = 4) = 2 \times 4^2 = 32.$

53. **(c)** Atomic number of potassium is 19 and hence electronic configuration will be
$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1$
Hence for $4s^1$ electron value of Quantum number are
Principal quantum number $n = 4$
Azimuthal quantum number $l = 0$
Magnetic quantum number $m = 0$
Spin quantum number $s = +1/2$

54. **(b)** We know that for *d*-electron $l = 2$.

$$\mu = \sqrt{l(l+1)}\,\frac{h}{2\pi},$$

$$\mu = \sqrt{2(2+1)}\,\frac{h}{2\pi}$$

$$\mu = \sqrt{2(2+1)}\,\frac{h}{2\pi};$$

$$\mu = \sqrt{6}\,\frac{h}{2\pi}.$$

55. **(d)** Azimuthal quantum number (l) =3 shows the presence of *f* orbit, which contain seven orbitals and each orbital have 2 electrons.
Hence, $7 \times 2 = 14$ electrons.

NCERT Exemplar Problems

More than One Answer

56. **(a, c)** From the date we can write the expression as follows

$$4.25 = W_A + T_A \quad \ldots(i)$$

$$4.20 = W_B + T_B \quad \ldots(ii)$$

$$T_B = T_A - 1.5 \quad \ldots(iii)$$

$$\frac{h}{\sqrt{2mT_B}} = \frac{2h}{\sqrt{2mT_A}}$$

$$\Rightarrow T_A = 4T_B \quad \ldots(iv)$$

So, from above equations
$T_B = 0.5$ eV
$T_A = 2$ eV
$W_A = 2.25$ eV
$W_B = 4.15$ eV

57. **(a, c)** For the same magnetic moment ions (a) atoms should contain same no. of unpaired e^-.

58. **(b, c, d)** The second period would have 12 elements, The Periodic Table would contain 27 group, The third period would have 12 elements

59. **(c, d)** For 's' orbitals wave function is independent of θ and ϕ '2p' orbital with quantum number n = 2, l = 1, m = 0, also shows the angular dependence.

60. **(a, c, d)** No electrons are ejected, regardless of the intensity of the radiation, unless the frequency equals or exceeds a threshold value characteristic of the metal, Even at low intensities, electrons are ejected immediately if the frequency is above the threshold value, An intense and a weak beam of monochromatic radiations differ in having number of photons and not in the energy of photons

61. **(a, b, c)** Electrons within a subshell for which l > 0 mean that the relatively greater electrostatics repulsion between two electrons in the same orbital within a sub shell as compared with occupancy of two orbitals having different m_l values, Electrons in singly occupied orbitals tend to have their spins in the same direction so as to maximize the net magnetic moment, In the ground state, an atom adopts a configuration with the greatest number of unpaired electrons

62. **(a, b, c)** (i) They produce heat when they strike a piece of metal,
(ii) They produce light when they fall on a fluorescent material,
(iii) They cast a sharp shadow of the object placed in their path.

63. **(a, b, c, d)** Specific charge of the cathode rays = e/m, where e is the charge and *m* the mass of an electron. As both the *e* and *m* are universal constants, hence *e/m* will be independent of the place of earth, nature of gas in the tube and material of discharge tube.

64. **(c, d)** Intensity of emitted X-rays is independent of potential difference applied across the tube while minimum wave length of emitted X-rays depends upon the potential difference through the relation:
$\lambda_{min} = (12400/V)$Å.

65. **(a, c, d)** (i) $r_n = \dfrac{n^2h^2}{4\pi^2 m K e^2}$ *i.e* $r_n \propto n^2$,

(ii) Bohr's 2nd postulate: $mvr = \dfrac{nh}{2\pi}$

(iii) $K_n = \dfrac{KZe^2}{2r_n}$, $U_n = -\dfrac{KZe^2}{r_n}$

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66. **(b, c)** (i) Lyman series lies in ultraviolet region, Balmer series in visible region and paschen series in Infrared region.

(ii) $\lambda_R > \lambda_Y$? $\lambda_B > \lambda_V$.

67. **(a, b)** Continuous spectrum is obtained from the bulk state of matter; it has no relation with the atomic or molecular state. It is produced by thermal vibrations of atoms in the macroscopic matter (not by the transitions between the energy states of atoms). Every vibrating atom emits light of frequency of its vibration. In a white hot matter, atoms vibrating with all frequencies within a definite range are present, so this matter emits frequencies of continuous range.

68. **(a, b, c)** $E_n^H = E_1^H + \Delta E$

$= -13.6\,eV + 12.7\,eV = -0.85\,eV$

i.e. hydrogen atoms are excited to n = 4level *i.e.* transitions $4\rightarrow1, 3\rightarrow2, 2\rightarrow1$are possible which correspond to Lyman series, then transitions $4\rightarrow2$ and $3\rightarrow2$ are possible which correspond to Balmer series and then transition $4\rightarrow3$ is also possible which corresponds to Paschen series.

69. **(a, b, c)** (i) $U_1 = E$, then Total energy in 1st orbit

$= (U_1/2) = (E/2)$

(ii) $I.E. = (T.E.)_{n=\infty} - (T.E.)_{n=1}$

$= 0 - (T.E.)_{n=1} = -(E/2)$

(iii) $(K.E.)_{n=1} = -(T.E.)_{n=1} = -(E/2)$.

70. **(a, c, d)** $p_n = mv_n, v_n \propto (1/n), r_n \propto n^2$

and $K_n = \dfrac{Ke^2}{2r_n}$ *i.e* $K_n \propto \dfrac{1}{n^2}$ and $L \alpha n$

71. **(d)** Time period $T \propto \dfrac{n^3}{Z^2}$

For a given atom (Z = constant)

So $T \propto n^3$ . . . (*i*)

and radius $R \propto n^2$ . . . (*ii*)

∴ From equation (*i*) and (*ii*) $T \propto R^{3/2}$

$\Rightarrow \dfrac{T_1}{T_2} = \left(\dfrac{R_1}{R_2}\right)^{3/2} = \left(\dfrac{R}{4R}\right)^{3/2} = \dfrac{1}{8}$.

72. **(a)** After the removal of first electron remaining atom will be hydrogen like atom.

So, energy required to remove second electron from the atom

$E = 13.6 \times \dfrac{2^2}{1} = 54.4\,eV$

∴ Total energy required = 24.6 + 54.4 = 79 eV

The work function of some metals is given below:

Na : 1.92 eV ; K : 2.15 eV ; Mo : 4.17 eV ; Ni : 5.0 eV

Which of these metals will not give photoelectric emission for a radiation of wavelength 3300 Å from a He-Cd laser placed 1m away from the photocell? What happens if the laser is brought nearer and placed 50 cm away.

Assertion and Reason

73. **(a)** We know that principal quantum number represent the main energy level or energy shell. Since each energy level is associated with a definite amount of energy, this quantum number determines to a large extent te energy of an electron. It also determines the average distance of an electron around the nucleus. Therefore both Assertion and Reason are true and the Reason is a correct explanation of the Assertion.

74. **(a)** It is observed that a nucleus which is made up of even number of nucleons (No. of n & p) is more stable than nuclie which consist of odd number of nucleons. If number of neutron or proton is equal to some numbers *i.e.,* 2,8, 20, 50, 82 or 126 (which are called magic numbers), then these passes extra stability.

75. **(c)** The assertion that the isobars are the atoms of different elements having same mass number but different atomic number is correct but reason is false because atomic mass is sum of number of neutron and protons which should be same for isobars.

76. **(d)** We know from the Pauli exclusion principle, that two electrons in the same atom cannot have same value of all four quantum numbers. This means each electron in an atom has only one set of values for n, *l*, m and s. Therefore both the Assertion and Reason are false.

77. **(e)** We know that the line in Balmer series of hydrogen spectrum the highest wavelenght or lowest energy is between n_1 = 2 and n_2 = 3. And for Balmer series of hydrogen spectrum, the value of n_1 = 2 and n_2 = 3,4,5. Therefore the Assertion is false but the Reason is true.

78. **(d)** We know that Absorption spectrum is produced when white light is passed through a substance and transmitted light is analysed by a spectrograph. The dark spaces corresponds to the light radiation absorbed by the substance. And emission spectrum is produced by analysing the radiant energy emitted by an excited substance by a spectrograph. Thus discontinuous spectra consisting of a series of sharp lines and separated by dark bands are obtained. Therefore both the Assertion and Reason are false.

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79. **(a)** We know that a resonance hybrid or the actual molecule is always more stable than any of its canonical structures which is also called hypothetical or imaginary structures. This stability is due to delocalization of electrons and is measured in terms of resonance energy or delocalization energy, it is defined as the difference in internal energy of the resonance hybrid and the most stable canonical structure. Therefore both the Assertion and Reason are true and the Reason is a correct explanation of the Assertion.

80. **(e)** We know that cathode rays cast shadows of solid objects placed in their path. During experiment performed on these rays, fluorescence (flash of light) is observed in the region, outside the shadow. This shows that cathode rays travel in straight lines. We also knew that cathode rays penetrate through a thin sheet of metals but are stopped by thick sheets. Therefore both Assertion and Reason are false.

81. **(b)** We know that electrons are revolving around the nucleus at high speed in circular paths. The centrifugal force (which arises due to rotation of electrons) acting outwards, balances the electrostatic force of attraction (which arises due to attraction between electrons and nucleus). This prevents the electron from falling into the nucleus. We also know that Rutherford's model of atom is comparable to the "solar system". The nucleus represent the sun whereas revolving electrons represent the planets revolving around the sun. Thus revolving electron are also called planetary electrons. Therefore both Assertion and Reason are true but Reason is not a correct explanation of Assertion.

82. **(b)** Both assertion and reason are true but reason is not the correct explanation of assertion. The difference between the energies of adjacent energy levels decreases as we move away from the nucleus. Thus in H atom

$E_2 - E_1 > E_3 - E_2 > E_4 - E_3 .....$

Comprehension Based

83. **(b)** ψ represent an orbital and $\psi_{4,3,0}$ has n = 4, l = 3 *i.e.,* 4*f*-orbital.

84. **(a)** Angular momentum in an orbital

$$= \sqrt{ll+1} \cdot \frac{h}{2\pi}$$

$$= \sqrt{l(l+1)} \cdot \pi = \sqrt{2}\hbar.$$

85. **(a)** Number of radial node = $n - l - 1$

Number of angular node = l.

86. **(c)** Sub-shells of a shell in H-atom possess same energy level, *i.e., l* does not specify for the energy level of an orbital in H-atom.

87. **(d)** The fourth quantum number s has no classical analogue. It was proposed by Uhlenback after Schrodinger quantum concept.

88. **(d)** Heisenberg principle has no significance of Δu is along *X*-axis and Δx along *Y*-axis are given.

For 89 to 91

Energy of state S_2 of $Li^{2+} = E_1$ of $H = 13.6$ eV

Also, E_{s_2} of $Li^{2+} = \frac{E_{1H} \times Z^2}{n^2}$

$$= \frac{-13.6 \times 3^2}{n^2} = -13.6$$

$\therefore$ n = 3

Thus, state S_2 represents 3rd orbit. Also, state S_1 has only one radial node. Thus, it represents 2nd orbit.

Radial node = $n - l - 1$

Because if n = 1, l = 0 (1s) radial node = 0

n = 2, l = 0 (2s) radial node = 1

n = 2, l = 1 (2p) radial node = 0

Thus state, S_1 represents 2s and since transition is possible only when $\Delta l = \pm 1$, therefore state S_3 represents 3p. [radial node = 1 as 3 – 1 – 1 = 1]

89. **(b)** 2s

90. **(c)** $E_{S_1} = \frac{E_{1H} \times 3^2}{2^2} = \frac{9}{4} = 2.25 \times E_{1H}$.

91. **(b)** S_2 is 3p $\therefore$ l = 1.

Match the Column

92. **(b)** A→ 1; B→ 2,4; C→ 3; D→ 4

93. **(d)** A→ 1; B→ 2,4; C→ 3; D→ 4

94. **(a)** $(A \to 3; B \to 1; C \to 2; D \to 4)$

95. **(a)** A→ 3; B→ 4; C→ 2; D→ 1

(A) Cr (atomic number = 24)

$= 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

Half-filled d orbital is more stable due to greater symmetry and exchange energy.

(B) Cu (atomic number = 29)

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

Full-filled d orbital is more stable due to greater symmetry and exchange energy.

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(C) Fe (atomic number = 26)

$-1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6\ 4s^2$

$Fe^{3+}(23) - 1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5$

(D) Electronic configuration of

$Zn^{2+} - 1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10}$

Hence, number of unpaired electrons are 5.

Integer

96. **(2)** $L = 2\left(\frac{h}{2\pi}\right)$

And $L' = 4\left(\frac{h}{2\pi}\right)$

$\therefore$ $L' = 2\ L = n\,L,$

where $n = 2$

97. **(6)** As is clear from figure.

$E_1 = E_2 + E_3$

$\frac{hc}{\lambda_1} = \frac{hc}{\lambda_2} + \frac{hc}{\lambda_3}$

$\therefore$ $\frac{1}{\lambda_2} = \frac{1}{\lambda_1} - \frac{1}{\lambda_3} = \frac{1}{2} - \frac{1}{3} = \frac{1}{6} = 6$ units

98. **(6)** 3rd excited state means n = 4.

No. of different wavelength observed

$N = \frac{n(n-1)}{2} = \frac{4(4-1)}{2} = 6$

99. **(9)** $n = 3 \Rightarrow l = 0, 1, 2$

for $l = 0, m = 0 \Rightarrow m_s = -1/2$ and $+1/2$

for $l = 1, m = -1 \Rightarrow m_s = -1/2$ and $+1/2$

$0 \Rightarrow m_s = -1/2$ and $+1/2$

$-1 \Rightarrow m_s = -1/2$ and $+1/2$

for $l = 2, m = -2 \Rightarrow m_s = -1/2$ and $+1/2$

$-1 \Rightarrow m_s = -1/2$ and $+1/2$

$0 \Rightarrow m_s = -1/2$ and $+1/2$

$1 \Rightarrow m_s = -1/2$ and $+1/2$

$2 \Rightarrow m_s = -1/2$ and $+1/2$

Alternatively n = 3

$\therefore$ Number of electrons

$= 2n^2 = 2 \times 3^2 = 18$

Number of electrons with $m_s = -\frac{1}{2} = \frac{18}{2} = 9$

100. **(4)** Since, the value of hc = 1240 eV nm

Energy corresponding to λ=300nm is

$\frac{1240\,eV}{300\,nm} = 4.134\,eV$

Elements having $\phi < 4.134\,eV$ will show photoelectric effect, are Li, Na, K and Mg $\Rightarrow \boxed{4}$

So, number of metals showing photo-electric will be four, *i.e.*, Li, Na, K and Mg.

* * *

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