ATOMIC STRUCTURE

Contents

Syllabus

Bohr model, spectrum of hydrogen atom, quantum numbers; Wave-particle duality, de-Broglie hypothesis; Uncertainty principle; Qualitative quantum mechanical picture of hydrogen atom, shapes of s, p and d orbitals; Electronic configurations of elements (up to atomic number 36); Aufbau principle; Pauli's exclusion principle and Hund's rule..

Name : ______________________________ **Contact No.** ____________________

ATOMIC STRUCTURE

KEY CONCEPTS

Electromagnetic Wave Radiation :

The oscillating electrical/magnetic field are electromagnetic radiations. Experimentally, the direction of oscillations of electrical and magnetic field are prependicular to each other.

Wavelength (λ) : Wavelength of a wave is defined as the distance between any two consecutive crests or troughs. It is represented by λ (lambda) and is expressed in Å or m or cm or nm (nanometer) or pm (picometer).

1 Å = 10^{-8} cm = 10^{-10} m
1 nm = 10^{-9} m, 1 pm = 10^{-12} m

Frequency (ν) : Frequency of a wave is defined as the number of waves passing through a point in one second. It is represented by ν (nu) and is expressed in Hertz (Hz) or cycles/sec or simply sec^{-1} or s^{-1}.

1 Hz = 1 cycle/sec

$$\boxed{v = \nu \times \lambda}$$

Quantum Theory of Light :

The smallest quantity of energy that can be emitted or absorbed in the form of electromagnetic radiation is called as quantum of light.

h = 6.626 x 10^{-34} J-Sec (h - Planck const.) $E_0 = \frac{hc}{\lambda}$ (c - speed of light) (λ - wavelength)

Order of magnitude of $E_o = \frac{10^{-34} \times 10^{8}}{10^{-10}} = 10^{-16}$ J

One Electron Volt (e.v.) :

Energy gained by an electron when it is accelerated from rest through a potential difference of 1 volt.

$\therefore$ 1eV = 1.6 x 10^{-19}J

For each metal, there is a characteristic minimum frequency, ν_0 (also known as **threshold frequency**) below which photoelectric effect is not observed. At a frequency $\nu > \nu_0$, the ejected electrons come out with certain kinetic energy. The kinetic energies of these electrons increase with the increase of frequency of the light used.

$$h\nu = h\nu_0 + \frac{1}{2}m_e v^2$$

Radius of the Bohr's orbit :

$r = \frac{n^2h^2}{4\pi^2 mKZe^2}$ where ; h = 6.62 × 10^{-27} erg. sec.

$$r_n = 0.529 \times \frac{n^2}{Z} \text{ Å}$$

Velocity of an Electron in Bohr's Orbit :

$$v = \frac{2\pi Ze^2K}{nh}$$

$v_n = 2.18 \times 10^6 \times \frac{Z}{n}$ m/sec ; $v \propto Z$; $v \propto \frac{1}{n}$

Energy of an Electron :

$$\text{T.E.} = -\frac{KZe^2}{2r}$$

$$\text{T.E.} = E_n = -\frac{2\pi^2 me^4 k^2}{h^2}\left(\frac{z^2}{n^2}\right) \qquad \text{... (iv)}$$

$$E_n = -13.6\frac{Z^2}{n^2}\ \text{eV / atom} \quad n\uparrow\ \text{T.E.}\uparrow \quad ; \quad Z\uparrow\ \text{T.E.}\downarrow$$

$$= -2.18 \times 10^{-18}\ \frac{Z^2}{n^2}\ \text{J/atom}$$

Relation Between P. E., K. E. & T. E. :

$$\boxed{\text{T.E.} = \frac{\text{P.E.}}{2} = -\text{K.E.}}$$

Definition Valid for Single Electron System :

(i) Ground state :

Lowest energy state of any atom or ion is called ground state of the atom It is n = 1.
Ground state energy of H–atom = – 13.6 ev
Ground state energy of He^+ Ion = – 54.4 ev

(ii) Excited State :

States of atom other than the ground state are called excited states :

n = 2	first excited state
n = 3	second excited state
n = 4	third excited state
n = n + 1	n^{th} excited state

(iii) Ionisation energy (IE) :

Minimum energy required to move an electron from ground state to n = ∞ is called ionisation energy of the atom or ion.
Ionisation energy of H–atom = 13.6 ev
Ionisation energy of He^+ ion = 54.4 ev
Ionisation energy of Li^{+2} ion = 122.4 ev

Line Spectrum of Hydrogen :

$$\text{Wave number, } \frac{1}{\lambda} = \bar{\nu} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^{\,2}}\right)$$

R = Rydberg constant = $1.09678 \times 10^7 m^{-1}$; R ≃ $1.1 \times 10^7\ m^{-1}$; $R = \frac{13.6eV}{hc}$; R ch = 13.6 eV

Spectra lines of Hydrogen Atom :
Lyman Series

- It is first spectral series of H.
- It was found out in ultraviolet region in 1898 by Lyman.
- It's value of n_1 = 1 and n_2 = 2,3,4 where 'n_1' is ground state and 'n_2' is called excited state of electron present in a H - atom.

Balmer Series :

- It is the second series of H-spectrum.
- It was found out in 1892 in visible region by Balmer.
- It's value of $n_1 = 2$ and $n_2 = 3,4,5,.............$

Paschen Series :

- It is the third series of H - spectrum.
- It was found out in infrared region by Paschen.
- It's value of $n_1 = 3$ and $n_2 = 4,5,6$ ....

Brackett Series :

- It is fourth series of H - spectrum.
- It was found out in infrared region by Brackett.
- It's value of $n_1 = 4$ and $n_2 = 5,6,7$ ....

Pfund Series :

- It is fifth series of H- spectrum.
- It was found out in infrared region by Pfund.
- It's value of $n_1 = 5$ and $n_2 = 6,7,8$ .... where n_1 is ground state and n_2 is excited state.

Humphry Series :

- It is the sixth series of H - spectrum.
- It was found out in infrared region by Humphry.
- It's value of $n_1 = 6$ and $n_2 = 7$, 8 , 9 ....

Wave Mechanical Model of Atom :
Dual nature of electron (de-Broglie Hypothesis):

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

$$\lambda = \frac{h}{\sqrt{2m(K.E.)}} \qquad \Rightarrow \qquad \lambda = \frac{h}{\sqrt{2m(q.V)}}$$

Heisenberg's Uncertainty Principle :

The exact position and momentum of a fast moving particle cannot be calculated precisely at the same moment of time. If Δx is the error in the measurement of position of the particle and if Δp is the error in the measurement of momentum of the particle, then:

$$\Delta x \,.\, \Delta p \geq \frac{h}{4\pi} \text{ or } \qquad \Delta x \,.\, (m\Delta v) \geq \frac{h}{4\pi}$$

Schrodinger wave equation :

$$\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} + \frac{8\pi^2 m}{h^2}(E - V)\psi = 0$$

where x, y and z are three space coordinates
m is the mass of electron
h is planck's constant
E is total energy
V is potential energy of e^-
ψ is the amplitude of wave also called wave function

Quantum Numbers :

The set of four numbers required to define an electron completely in an atom are called quantum numbers. The first three have been derived from Schrodinger wave equation.

(i) Principal quantum number (n) : (Proposed by Bohr)

It describes the size of the electron wave and the total energy of the electron. It has integral values 1, 2, 3, 4 ...., etc., and is denoted by K, L, M, N. ..., etc.

Number of subshell present in n^{th} shell = n

n	**subshell**
1	s
2	s, p
3	s, p, d
4	s, p, d, f

Number of orbitals present in n^{th} shell = n^2 .

The maximum number of electrons which can be present in a principal energy shell is equal to $2n^2$. No energy shell in the atoms of known elements possesses more than 32 electrons.

Angular momentum of any orbit = $\frac{nh}{2\pi}$

(ii) Azimuthal quantum number (ℓ) : (Proposed by Sommerfield)

It describes the shape of electron cloud and the number of subshells in a shell.
It can have values from 0 to (n – 1)

value of ℓ	**subshell**
0	s
1	p
2	d
3	f

Number of orbitals in a subshell = $2\ell + 1$
Maximum number of electrons in particular subshell = $2 \times (2\ell + 1)$

Orbital angular momentum L = $\frac{h}{2\pi}\sqrt{\ell(\ell+1)} = \hbar\sqrt{\ell(\ell+1)}$ $\left[\hbar = \frac{h}{2\pi}\right]$

i.e. Orbital angular momentum of s orbital = 0, Orbital angular momentum of p orbital = $\sqrt{2}\frac{h}{2\pi}$,

Orbital angular momentum of d orbital = $\sqrt{3}\frac{h}{2\pi}$

(iii) Magnetic quantum number (m) : (Proposed by Linde)

It describes the orientations of the subshells. It can have values from $-\ell$ to $+\ell$ including zero, i.e., total $(2\ell + 1)$ values. Each value corresponds to an orbital. s-subshell has one orbital, p-subshell three orbitals (p_x, p_y and p_z), d-subshell five orbitals $(d_{xy}, d_{yz}, d_{zx}, d_{x^2-y^2}, d_{z^2})$ and f-subshell has seven orbitals. The total number of orbitals present in a main energy level is 'n^2'.

(iv) Spin quantum number (s) : (Proposed by Samuel Goldsmit & Uhlenbeck)

It describes the spin of the electron. It has values +1/2 and –1/2. signifies clockwise spinning and anticlockwise spinning.

☞ Spin magnetic moment $\mu_s = \frac{eh}{2\pi mc}\sqrt{s(s+1)}$ or $\mu = \sqrt{n(n+2)}$ B.M. (n = no. of unpaired electrons)

☞ It represents the value of spin angular momentum which is equal to $\frac{h}{2\pi}\sqrt{s(s+1)}$

☞ Maximum spin of atom = $\frac{1}{2}$ x No. of unpaired electron.

EXERCISE # 1

PART - I : OBJECTIVE QUESTIONS

*** Marked Questions are having more than one correct option.**

Section (A) : Nucleus, Plancks Quantum Theory, Photoelectric effect

A-1. The study of cathode rays (i.e. electronic discharge through gases) shows that -
(A) Alpha particles are heavier than protons
(B) All forms of matter contain electrons
(C) All nuclei contain protons
(D) e/m is constant

A-2. Proton is -
(A) Nucleus of deuterium
(B) Ionised hydrogen molecule
(C) Ionised hydrogen atom
(D) An α-particle

A-3. Which is not deflected by magnetic field -
(A) Neutron (B) Positron (C) Proton (D) Electron

A-4. The ratio of the "e/m" (specific charge) values of a electron and an α-particle is -
(A) 2 : 1 (B) 1 : 1 (C) 1 : 2 (D) None of these

A-5. The element having no neutron in the nucleus of its atom is
(A) Hydrogen (B) Nitrogen (C) Helium (D) Boron

A-6. Cathode rays are -
(A) Electromagnetic waves
(B) Radiations
(C) Stream of α-particles
(D) Stream of electrons

A-7.* Which of the following is iso-electronic with neon?
(A) O^{2-} (B) F^- (C) Mg (D) Na

A-8. The approximate size of the nucleus of ${}^{64}_{28}Ni$ is :
(A) 3 fm (B) 4 fm (C) 5 fm (D) 2 fm

A-9. The value of Planck's constant is 6.63×10^{-34} Js. The velocity of light is 3×10^8 m/sec. Which value is closest to the wavelength of a quantum of light with frequency of 8×10^{15} sec^{-1} ?
(A) 5×10^{-18} m (B) 4×10^{-8} m (C) 3×10^7 m (D) 2×10^{-25} m

A-10. According to Dalton's atomic theory, an atom can –
(A) Be created
(B) Be destroyed
(C) Neither be created nor destroyed
(D) None

A-11. Rutherford's experiment on scattering of alpha particles showed for the first time that atom has -
(A) Electrons (B) Protons (C) Nucleus (D) Neutrons

A-12. α - particles are represented by –
(A) Lithium atoms (B) Helium nuclei (C) Hydrogen nucleus (D) None of these

A-13. The MRI (magentic resonance imaging) body scanners used in hospitals operate with 400 MHz radio frequency energy. The wavelength corresponding to this radio frequency is
(A) 0.75 m (B) 0.75 cm (C) 1.5 m (D) 2 cm

A-14. Electromagnetic radiations of wavelength 242 nm is just sufficient to ionise Sodium atom. Then the ionisation energy of Sodium in kJ $mole^{-1}$ is.
(A) 494.65 (B) 400 (C) 247 (D) 600

A-15. Light of wavelength λ falls on metal having work function hc/λ_0. Photoelectric effect will take place only if :
(A) $\lambda \geq \lambda_0$ (B) $\lambda \geq 2\lambda_0$ (C) $\lambda \leq \lambda_0$ (D) $\lambda \leq \lambda_0/2$

A-16. Photon of which light has maximum energy :
(A) red (B) blue (C) violet (D) green

A-17. The ratio of the energy of a photon of 2000 Å wavelength radiation to that of 4000 Å radiation is
(A) 1 / 4 (B) 4 (C) 1 / 2 (D) 2

A-18. A photon of energy $h\nu$ is absorbed by a free electron of a metal having work function $w < h\nu$. Then :
(A) The electron is sure to come out
(B) The electron is sure to come out with a kinetic energy $(h\nu - w)$
(C) Either the electron does not come out or it comes with a kinetic energy $(h\nu - w)$
(D) It may come out with a kinetic energy less than $(h\nu - w)$

A-19. A bulb of 40 W is producing a light of wavelength 620 nm with 80% of efficiency then the number of photons emitted by the bulb in 20 seconds are (1eV = 1.6×10^{-19} J, hc = 12400 eV Å)
(A) 2×10^{18} (B) 10^{18} (C) 10^{21} (D) 2×10^{21}

Section : (B) : Bohr Model

B-1. The shortest wavelength of He atom in Balmer series is x, then longest wavelength in the Paschen series of Li^{+2} is
(A) $\frac{36x}{5}$ (B) $\frac{16x}{7}$ (C) $\frac{9x}{5}$ (D) $\frac{5x}{9}$

B-2. Correct order of radius of the Ist orbit of H, He^+, Li^{2+}, Be^{3+} is :
(A) H > He^+ > Li^{2+} > Be^{3+} (B) Be^{3+} > Li^{2+} > He^+ > H
(C) He^+ > Be^{3+} > Li^{2+} > H (D) He^+ > H > Li^{2+} > Be^{3+}

B-3. Which electronic level would allow the hydrogen atom to absorb a photon but not to emit a photon
(A) 3 (B) 2 (C) 4 (D) 1

B-4. The third line in Balmer series corresponds to an electronic transition between which Bohr's orbits in hydrogen
(A) $5 \rightarrow 3$ (B) $5 \rightarrow 2$ (C) $4 \rightarrow 3$ (D) $4 \rightarrow 2$

B-5. What is likely to be orbit number for a circular orbit of diameter 20 nm of the hydrogen atom if we assume Bohr orbit to be the same as that represented by the principal quantum number ?
(A) 10 (B) 14 (C) 12 (D) 16

B-6. If velocity of an electron in I orbit of H atom is V, what will be the velocity of electron in 3^{rd} orbit of Li^{+2}
(A) V (B) V/3 (C) 3 V (D) 9 V

B-7. The energy of electron in first Bohr's orbit of H-atom is –13.6 eV. What will be its potential energy in n = 4^{th} orbit -
(A) – 13.6 eV (B) –3.4 eV (C) –0.85 eV (D) –1.70 eV

B-8. If the value of E_n = – 78.4 kcal/mole, the order of the orbit in hydrogen atom is :
(A) 4 (B) 3 (C) 2 (D) 1

B-9. The frequency of line spectrum of sodium is 5.09 x 10^{14} sec^{-1}. Its wave length (in nm) will be- [c = 3 × 10^8 m/sec]-
(A) 510 nm (B) 420 nm (C) 589 nm (D) 622 nm

B-10. The species which has its fifth ionisation potential equal to 340 V is
(A) B^+ (B) C^+ (C) B (D) C

B-11. Match the following

(A) Energy of ground state of He^+	(i) + 6.04 eV
(B) Potential energy of I orbit of H-atom	(ii) –27.2 eV
(C) Kinetic energy of II excited state of He^+	(iii) + 54.4 V
(D) Ionisation potential of He^+	(iv) – 54.4 eV

(A) A – (i), B – (ii), C – (iii), D – (iv) (B) A – (iv), B – (iii), C – (ii), D – (i)
(C) A – (iv), B – (ii), C – (i), D – (iii) (D) A – (ii), B – (iii), C – (i), D – (iv)

B-12. In a certain electronic transition in the hydrogen atoms from an initial state (A) to a final state (B), the difference in the orbital radius ($r_1 – r_2$) is 24 times the first Bohr radius. Identify the transition.
(A) 5 → 1 (B) 25 → 1 (C) 8 → 3 (D) 6 → 5

B-13. **S_1 :** Bohr model is applicable for Be^{2+} ion.
S_2 : Total energy coming out of any light source is integral multiple of energy of one photon.
S_3 : Number of waves present in unit length is wave number.
S_4 : e/m ratio in cathode ray experiment is independent of the nature of the gas.
(A) F F T T (B) T T F F (C) F T T T (D) T F F F

B-14. On Bohr's stationary orbits -
(A) Electrons do not move (B) Electrons move emitting radiations
(C) Energy of the electron remains constant (D) Angular momentum of the electron is $h/2\pi$

B-15. The value of Bohr radius of hydrogen atom is -
(A) 0.529x 10^{-7}cm (B) 0.529x 10^{-8}cm (C) 0.529x 10^{-9}cm (D) 0.529x 10^{-10} cm

B-16. On the basis of Bohr's model, the radius of the 3rd orbit is -
(A) Equal to the radius of first orbit (B)Three times the radius of first orbit
(C) Five times the radius of first orbit (D) Nine time the radius of first orbit

B-17. Supposing the energy of fourth shell for hydrogen atom is - 50 a.u. (arbitrary unit). What would be its ionization potential -
(A) 50 (B) 800 (C) 15.4 (D) 20.8

B-18. Supposing the ionization energy of hydrogen atom is 640 eV. Point out the main shell having energy equal to – 40 eV -
(A) n = 2 (B) n = 3 (C) n = 4 (D) n = 5

B-19. Ionization energy for hydrogen atom in ergs, Joules and eV respectively is -
(A) 21.8 x 10^{-12} , 218 x 10^{-20} , 13.6 (B) 13.6 x 218 x 10^{-20}, 21.8 x 10^{-13}
(C) 21.8 x 10^{-20}, 13.6 , 21.8 x 10^{-13} (D) 21.8 x 10^{-13}, 13.6, 21.8 x 10^{-20}

B-20. For ionising an excited hydrogen atom, the energy required in eV will be -
(A) 3.4 or less (B) More than 13.6 (C) Little less than 13.6 (D) 13.6

B-21. A gas absorbs a photon of 300 nm and then re-emitts two photons. One photon has a wavelength 600 nm. The wavelength of second photon is -
(A) 300 nm (B) 400 nm (C) 500 nm (D) 600 nm

B-22. The ratio of difference in wavelengths of 1st and 2nd lines of Lyman series in H–like atom to difference in wavelength for 2nd and 3rd lines of same series is:
(A) 2.5 : 1 (B) 3.5 : 1 (C) 4.5 : 1 (D) 5.5 : 1

B-23. If radius of second stationary orbit (in Bohr's atom) is R. Then radius of third orbit will be
(A) R/3 (B) 9R (C) R/9 (D) 2.25R

B-24. The velocity of an electron in the third orbit of hydrogen atom -
(A) 7.28×10^{7} cm sec^{-1} (B) 7.08×10^{7} cm sec^{-1}
(C) 7.38×10^{7} cm sec^{-1} (D) 7.48×10^{7} cm sec^{-1}

B-25. The ionization energy of a hydrogen atom is 13.6eV. The energy of the third-lowest electronic level in doubly ionized lithium (Z = 3) is -
(A) –28.7 eV (B) –54.4 eV (C) –122.4 eV (D) –13.6 eV

B-26. The momentum of a photon with energy 20 eV is -
(A) 10.66×10^{-27} Kg m sec^{-1} (B) 10.55×10^{-27} Kg m sec^{-1}
(C) 10.60×10^{-27} Kg m sec^{-1} (D) 10.80×10^{-27} Kg m sec^{-1}

B-27. The energy of hydrogen atom in its ground state is –13.6 eV. The energy of the level corresponding to n = 5 is:
(A) –0.54 eV (B) –5.40 eV (C) –0.85 eV (D) –2.72 eV

B-28. Three energy levels P, Q, R of a certain atom are such that $E_P < E_Q < E_R$. If λ_1, λ_2 and λ_3 are the wave length of radiation corresponding to transition R $\rightarrow$ Q ; Q $\rightarrow$ P and R$\rightarrow$ P respectively. The correct relationship between λ_1, λ_2 and λ_3 is
(A) $\lambda_1 + \lambda_2 = \lambda_3$ (B) $\frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$ (C) $\lambda_3 = \sqrt{\lambda_1\lambda_2}$ (D) $\frac{2}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$

Section : (C) : Spectrum/Spectral lines

C-1. The wavelength of a spectral line for an electronic transition is inversely proportional to :
(A) number of electrons undergoing transition
(B) the nuclear charge of the atom
(C) the velocity of an electron undergoing transition
(D) the difference in the energy involved in the transition

C-2. No. of visible lines when an electron returns from 5th orbit to ground state in H spectrum :
(A) 5 (B) 4 (C) 3 (D) 10

C-3. Number of possible spectral lines which may be emitted in bracket series in H atom, if electrons present in 9th excited level returns to ground level, are
(A) 21 (B) 6 (C) 45 (D) 5

C-4. The ratio of wave length of photon corresponding to the α-line of Lyman series in H-atom and β-line of Balmer series in He^+ is
(A) 1 : 1 (B) 1 : 2 (C) 1 : 4 (D) 3 : 16

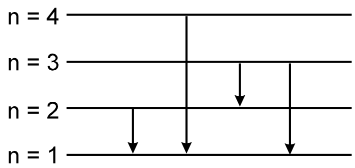
C-5. Total no. of lines in Lyman series of H spectrum will be (where n = no. of orbits)
(A) n (B) n – 1 (C) n – 2 (D) n (n + 1)

C-6. The difference between the wave number of 1st line of Balmer series and last line of paschen series for Li^{2+} ion is :
(A) $\frac{R}{36}$ (B) $\frac{5R}{36}$ (C) 4R (D) $\frac{R}{4}$

C-7. The wave number of the first line of Balmer series of hydrogen is 15200 cm^{-1}. The wave number of the first Balmer line of Li^{2+} ion is-

(A) 15200 cm^{-1} (B) 60800 cm^{-1} (C) 76000 cm^{-1} (D) 136800 cm^{-1}

C-8. Suppose that a hypothetical atom gives a red, green, blue and violet line spectrum . Which jump according to figure would give off the red spectral line.



(A) $3 \rightarrow 1$ (B) $2 \rightarrow 1$ (C) $4 \rightarrow 1$ (D) $3 \rightarrow 2$

C-9. The wavelength of the third line of the Balmer series for a hydrogen atom is -

(A) $\frac{21}{100R_H}$ (B) $\frac{100}{21\ R_H}$ (C) $\frac{21R_H}{100}$ (D) $\frac{100R_H}{21}$

C-10. Wave number of a spectral line for a given transition is x cm^{-1} for He^+, then its value for Be^{3+} for the same transition is -

(A) 4x cm^{-1} (B) x cm^{-1} (C) x/4 cm^{-1} (D) 2x cm^{-1}

C-11. What is the change in the orbit radius when the electron in the hydrogen atom (Bohr model) undergoes the first Paschen transition -

(A) 4.23×10^{-10} m (B) 0.35×10^{-10} m (C) 3.7×10^{-10} m (D) 1.587×10^{-10} m

C-12. Wave-length of the first line of Paschen Series hydrogen spectrum is - (R = 109700 cm^{-1}) -

(A) 18750 (Å) (B) 2854 (Å) (C) 3452 (Å) (D) 6243 (Å)

C-13. The longest wavelength of He^+ in Paschen series is "m", then shortest wavelength of Be^{+3} in Paschen series is (in terms of m) :

(A) $\frac{5}{36}$ m (B) $\frac{64}{7}$ m (C) $\frac{53}{8}$ m (D) $\frac{7}{64}$ m

C-14. If the shortest wavelength of H atom in Lyman series is x, then longest wavelength in Balmer series of He^+ is -

(A) $\frac{9x}{5}$ (B) $\frac{36x}{5}$ (C) $\frac{x}{4}$ (D) $\frac{5x}{9}$

C-15. A photon was absorbed by a hydrogen atom in its ground state and the electron was promoted to the fifth orbit. When the excited atom returned to its ground state, visible and other quanta were emitted. Other quanta are -

(A) $2 \rightarrow 1$ (B) $5 \rightarrow 2$ (C) $3 \rightarrow 1$ (D) $4 \rightarrow 1$

C-16. In a sample of H-atom electrons make transition from 5^{th} excited state to ground state, producing all possible types of photons, then number of lines in infrared region are

(A) 4 (B) 5 (C) 6 (D) 3

Section : (D) Debroglies hypothesis and Heisenbergs Uncertainty principle

D-1. An α-particle is accelerated through a potential difference of V volts from rest. The de-Broglie's wavelength associated with it is

(A) $\sqrt{\frac{150}{V}}$ Å (B) $\frac{0.286}{\sqrt{V}}$ Å (C) $\frac{0.101}{\sqrt{V}}$ Å (D) $\frac{0.983}{\sqrt{V}}$ Å

D-2. de-Broglie wavelength of electron in second orbit of Li^{2+} ion will be equal to de-Broglie of wavelength of electron in

(A) n = 3 of H-atom (B) n = 4 of C^{5+} ion (C) n = 6 of Be^{3+} ion (D) n = 3 of He^{+} ion

D-3. A ball has a mass of 0.1 kg its velocity is 40 m/s, find out de Broglie wave length -

(A) 1.66×10^{-34}m (B) 2×10^{-34} m (C) 3×10^{-34} m (D) 4×10^{-34} m

D-4. If the uncertainty of position for an electron is zero, what is the uncertainty of the momentum-

(A) Zero (B) $\hbar$ (C) h (D) Infinite

D-5. In an electron microscope, electron are accelerated to great velocities. Calculate the wavelength of an electron travelling with a velocity of 7.0 megameters per second . The mass of an electron is 9.1×10^{-28} g -

(A) 1.0×10^{-13}m (B) 1.0×10^{-7}m (C) 1.0 m (D) 1.0×10^{-10}m

D-6. What possibly can be the ratio of the de Broglie wavelengths for two electrons each having zero initial energy and accelerated through 50 volts and 200 volts ?

(A) 3 : 10 (B) 10 : 3 (C) 1 : 2 (D) 2 : 1

D-7. In H-atom, if 'x' is the radius of the first Bohr orbit, de Broglie wavelength of an electron in 3rd orbit is:

(A) $3\pi x$ (B) $6\pi x$ (C) $\frac{9x}{2}$ (D) $\frac{x}{2}$

D-8. Which of the following is the most correct expression for Heisenberg's uncertainty principle

(A) $\Delta x.\Delta p = \frac{h}{4\pi}$ (B) $\Delta x.\Delta p \geq \frac{h}{4\pi}$ (C) $\Delta x.\Delta p \leq \frac{h}{4\pi}$ (D) $\Delta x \cdot \Delta v = \frac{h}{4\pi}$

D-9. A 200g cricket ball is thrown with a speed of 3.0×10^{3} cm sec^{-1}. What will be its de Broglie's wavelength - [$h = 6.6 \times 10^{-27}$g cm^{2} sec^{-1}]

(A) 1.1×10^{-32} cm (B) 2.2×10^{-32} cm (C) 0.55×10^{-32} cm (D) 11.0×10^{-32} cm

D-10. Which is the de-Broglie equation -

(A) $h = p\lambda$ (B) $h = p\lambda^{-1}$ (C) $h = \lambda p^{-1}$ (D) $h = p + \lambda$

D-11. Velocity of helium atom at 300 K is 2.40×10^{2} meter per sec. What is its wave length - (mass number of helium is 4)

(A) 0.416 nm (B) 0.83 nm (C) 803 Å (D) 8000Å

Section (E). Quantum theory

E-1. An electron has a spin quantum number + 1/2 and a magnetic quantum number –1. It cannot be present in -

(A) d-Orbital (B) f-Orbital (C) s-Orbital (D) p-Orbital

E-2. If the electronic structure of oxygen atom is written as $1s^2, 2s^2$ 2p [↑↓][↑↓][ ] it would violate -

(A) Hund's rule (B) Paulis exclusion principle
(C) Both Hund's and Pauli's principles (D) None of these

E-3. The d-subshell is -

(A) 5 - Fold degenerate (B) 3-Fold degenerate (C) 7-Fold degenerate (D) Non- degenerate

E-4. The energy of an electron of $2p_y$ orbital is -

(A) Greater than $2p_x$ orbital (B) Less than $2p_z$ orbital
(C) Equal to 2s orbital (D) Same as that of $2p_x$ and $2p_z$ orbitals

E-5. In which of the following pairs is the probability of finding the electron in xy-plane zero for both orbitals ?

(A) $3d_{yz}, 4d_{x^2-y^2}$ (B) $2p_z, dz^2$ (C) $4d_{zx}, 3p_z$ (D) All of these

E-6. The number of unpaired electrons in carbon atom is -

(A) 2 (B) 4 (C) 1 (D) 3

E-7. When 4 d orbital is complete, the newly entering electrons goes in to -

(A) 5f (B) 5s (C) 5p (D) 6d Orbital

E-8. Which electronic level would allow the hydrogen atom to absorb a photon but not to emit a photon

(A) 3s (B) 2p (C) 2s (D) 1s

E-9. The orbital diagram in which 'Aufbau principle' is violated is -

2s ← 2p →

(A) [↑↓] [↑↓][↑][ ] (B) [↑] [↑↓][↑][↑]
(C) [↑↓] [↑][↑][↑] (D) [↑↓] [↑↓][↑↓][↑]

E-10. s [↑↑] p [↑↓][↑][↓] d [ ][ ][ ][ ][ ]

The above configuration is not correct as it violates -

(A) Only Hund's rule (B) Only Pauli's exclusion principle
(C) (n + ℓ) rule (D) (Hund + Pauli) rule

E-11. d^6 configuration will result in total spin of -

(A) 3/2 (B) 1/2 (C) 2 (D) 1

PART - II : MISCELLANEOUS QUESTIONS

Comprehensions Type

Comprehension # 1

The only electron in the hydrogen atom resides under ordinary conditions on the first orbit. When energy is supplied, the electron moves to higher energy shells depending on the amount of energy absorbed. When this electron returns to any of the lower energy shells, it emits energy. Lyman series is formed when the electron returns to the lowest energy state while Balmer series is formed wen the electron returns to second energy shell. Similarly, Paschen, Brackett and pfund series are formed when electron returns to the third, fourth and fifth energy shells from higher energy shells respectively. Thus, the different spectral lines in the spectra of atoms correspond to different transitions of electrons from higher energy levels to lower energy levels.

1. If the shortest wavelength of H atom in Lyman series is x, then longest wavelength in Balmer series of He^+ is :

(A) $\frac{9x}{5}$ (B) $\frac{36x}{5}$ (C) $\frac{x}{4}$ (D) $\frac{5x}{9}$

2. The ratio of the number of spectral lines obtained when an electron jumps from 7th level to ground state to 6th level to 3rd level.

(A) 7 (B) 3.5 (C) 2.5 (D) 10

3. In hydrogen atom which of the following transitions should be associated with highest absorption of energy?

(A) n = 1 to n = 4 (B) n = 2 to n = 3 (C) n = 4 to n = 1 (D) n = 3 to n = 2

Comprehension # 2

The French physicist Louis de Broglie in 1924 postulated that matter, like radiation, should exhibit a dual behaviour. He proposed the following relationship between the wavelength λ of a material particle, its linear momentum p and planck constant h

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

The de-Broglie relation implies that th wavelength of a particle should decreases as its velocity increase. It also implies that for a given velocity heavier particles should have shorter wavelength than lighter particles. The waves associated with particles in motion are called matter waves or de Broglie waves. These waves differ from the electromagnetic waves as they

(i) have lower velocities

(ii) have no electrical and magnetic fields and

(iii) are not emitted by the particle under consideration.

The experimental confirmation of the de Broglie relation was obtained when Devisson and Gerner, in 1927, observed that a beam of electron is diffracted by a nickel crystal. As diffraction is a characteristic property of waves, hence the beam of electron behaves as a wave, as proposed by de Broglie.

Warner Heisenberg considered the limits of how precisely we can measure properties of an electron or other microscopic particle like electron. He determined that there is a fundamental limit of how closely we can measure both positon and momentum. The more accurately we measure the momentum of a particle, the les accurately we can determine its position. The converse is also true. This is summed up in what we now call the 'Heisenberg uncertainty principle. It is impossible to determine simultaneously and precisely both the momentum and position of a particle. The product of uncertainty in the position, Δx and the uncetainty in the momentum Δ(mv) must be greater than or equal to $\frac{h}{4\pi}$ i.e.

$$\Delta x\, \Delta(mv) \geq \frac{h}{4\pi}$$

4. If the uncertainty in velocity and position is same, then the uncertainity in momentum will be:

(A) $\sqrt{\frac{hm}{4\pi}}$ (B) $m\sqrt{\frac{h}{4\pi}}$ (C) $\sqrt{\frac{h}{4\pi m}}$ (D) $\frac{1}{m}\sqrt{\frac{h}{4\pi}}$

5. Two particles A and B are in motion. If the wavelength associated with the particle A is 5.0×10^{-8} m, the wavelength of particles B having momentum half of A is-

(A) 2.5×10^{-8} m (B) 1.25×10^{-8} m (C) 1.0×10^{-7} m (D) 1.0×10^{-8} m

6. The uncertainty in the position of an electron (mass = 9.1×10^{-28} g) moving with a velocity of 3.0×10^{4} cm s^{-1} accurate upto 0.011% will be

(A) 1.92 cm (B) 0.768 cm (C) 0.175 cm (D) 3.84cm

Comprehension # 3

de Broglie proposed dual nature for electron by putting his famous equation $\lambda = \frac{h}{mu}$. Later on Heisenburg proposed uncertainty principle as $\Delta p.\Delta x \geq \frac{n}{2}\left(n = \frac{h}{2\pi}\right)$. On the contrary particle nature of electron was established on the basis of photoelectric effect. When a photon strikes the metal surface, it gives up its energy to the electron. Part of this energy (saw W) is used by the electrons to escape from the metal and the remaining imparts the kinetic energy $(\frac{1}{2}mu^2)$ to the photoelectron. The potential applied on the surface to reduce the velocity of photoelectron to zero is known as stopping potential.

7. The wavelength of helium atom whose speed is equal to its rms speed at 27°C :

(A) $7.29\times10^{-11}m$ (B) $4.28\times10^{-10}m$ (C) $5.31\times10^{-11}m$ (D) $6.28\times10^{-11}m$

8. With what potential should a beam of electron be accelerated so that its wavelength becomes equal to 1.54 A°:

(A) 63.3V (B) 6.33V (C) 633V (D) None of these

9. The wavelength of a golf ball weighing 200g and moving at a speed of 5m/hr is of the order

(A) $10^{-10}m$ (B) $10^{-20}m$ (C) $10^{-30}m$ (D) $10^{-40}m$

Comprehension # 4

The behaviour of an electron in an atom is described mathematically by a wave function, or orbital. It turns out that each wave function contains three variables, called quantum numbers, which are represented as n, l and m. These quantum numbers describe the energy level of an orbital and define the shape and orientation of the region in space where the electron will be found.

10. Which quantum number determines orientation of the electron ?

(A) Principal (B) Secondary (C) Magnetic (D) Spin

11. Radial nodes are maximum in

(A) 4s (B) 4p (C) 3d (D) 5f

12. Consider following statements.

A. Splitting of spectral line occurs when placed in a magnetic field or in an electric field

B. In case of 1s-orbital, the density of the charge cloud is the greatest at the nucleus and falls off with the distance. The density (at a particular distance) is uniform

C. Electron-density is concentrated along a particular direction in case of 2p-orbital.

D. A p-orbital can take maximum of six electrons.

Select the correct option

(A) A, B, D (B) A, B, C (C) B, C, D (D) A, C, D

Match the column

13.

Column I	**Column II**
(i) Aufbau principle	(a) Line spectrum in visible region
(ii) de broglie	(b) Maximum multiplicity of electron
(iii) Angular momentum	(c) Photon
(iv) Hund's rule	(d) $\lambda = h/(mv)$
(v) Balmer series	(e) Electronic configuration
(vi) Planck's law	(f) mvr

14.

Column I	**Column II**
(i) Cathode rays	(a) Helium nuclei
(ii) Dumb-bell	(b) Uncertainty principle
(iii) Alpha particles	(c) Electromagnetic radiation
(iv) Moseley	(d) p-orbital
(v) Heisenberg	(e) Atomic number
(vi) X-rays	(f) Electrons

15. Frequency = f, Time period = T, Energy of n^{th} orbit = E_n , radius of n^{th} orbit = r_n , Atomic number = Z, Orbit number = n

Column I	**Column II**
(i) f	(a) n^3
(ii) T	(b) Z^2
(iii) E_n	(c) $\frac{1}{n^2}$
(iv) $\frac{1}{r_n}$	(d) Z

16.

Column I	**Column II**
(i) Lyman series	(a) maximum number of spectral line observed = 6
(ii) Balmer series	(b) maximum number of spectral line observed = 2
(iii) In a sample of H-atom for $5 \rightarrow 2$ transition	(c) 2^{nd} line has wave number $\frac{8R}{9}$
(iv) In a single isolated H-atom for $3 \rightarrow 1$ transition	(d) 2^{nd} line has wave number $\frac{3R}{16}$
	(e) Total number of spectral line is 10.

PART - I : MIXED OBJECTIVE

* ***Marked Questions are having more than one correct option.***

Single Choice type

1. Multiple of fine structure of spectral lines is due to -
(A) Presence of main energy levels (B) Presence of sub- levels
(C) Presence of electronic configuration (D) Is not a characteristics of the atom.

2. The quantum number not obtained from the Schrodinger's wave equation is -
(A) n (B) l (C) m (D) s

3. Wave mechanical model of the atom depends upon -
(A) de-Broglie concept of dual nature of electron (B) Heisenberg uncertainty principle
(C) Schrodinger uncertainty principle (D) All

4. Which orbital is dumb-bell shaped -
(A) s-Orbital (B) p-Orbital (C) d-Orbital (D) f-Orbital

5. Which of the following subshell can accommodate as many as 10 electrons -
(A) 2d (B) 3d (C) 3dxy (D) $3dz^2$

6. "No two electrons in an atom can have the same set of four quantum numbers. "This principle was enunciated by -
(A) Heisenberg (B) Pauli (C) Maxwell (D) de Broglie.

7. How many spherical nodes are present in a 4s orbital in hydrogen atom -
(A) 0 (B) 1 (C) 2 (D) 3

8. Minimum core charge is shown by the atom -
(A) O (B) Na (C) N (D) Mg

9. Which one of the statement of quantum numbers is false -
(A) Quantum number were proposed out of necessity in Bohr model of the atom.
(B) Knowing n and ℓ it possible to designated a subshell .
(C) The principal quantum number alone can give the complete energy of an electron in any atom.
(D) Azimuthal quantum number refers to the subshell to which an electron belongs and describes the motion of the electron.

10. I.P. of hydrogen atom is equal to 13.6 eV. What is the energy required for the process :
$He^+ + \text{energy} \longrightarrow He^{+2} + e^-$
(A) 2 × 13.6 eV (B) 1 × 13.6 eV (C) 4 × 13.6 eV (D) None of these

11. If elements with principal quantum number n > 4 is not allowed in nature, the number of possible elements would be -
(A) 60 (B) 32 (C) 64 (D) 50

12. The correct statement(s) about Bohr's orbits of hydrogen atom is/are -
(A) $r = \left[\frac{n^2h^2}{4\pi^2me^2}\right]$ (B) K.E. of the electron = –1/2 (P. E. of the electron)
(C) Angular momentum (L) = $n\left(\frac{h}{2\pi}\right)$ (D) All the above

13. In centre-symmetrical system, the orbital angular momentum, a measure of the momentum of a particle travelling around the nucleus, is quantised. Its magnitude is -

(A) $\sqrt{\ell(\ell+1)}\ \frac{h}{2\pi}$ (B) $\sqrt{\ell(\ell-1)}\ \frac{h}{2\pi}$ (C) $\sqrt{s(s+1)}\ \frac{h}{2\pi}$ (D) $\sqrt{s(s-1)}\ \frac{h}{2\pi}$

14. If the values of $(n + \ell)$ is not > 3, then the maximum number of electron in all the orbital would be -
(A) 12 (B) 10 (C) 2 (D) 6

15. It is not possible to explain the pauli's exclusion principle with the help of this atom -
(A) B (B) Be (C) C (D) H

16. Each orbital has a nodal plane. Which of the following statements about nodal planes are not true -
(A) A plane on which there is zero probability that the electron will be found
(B) A plane on which there is maximum probability that the electron will be found
(C) Both
(D) None

17. One energy difference between the states n = 2 and n = 3 is E eV, in hydrogen atom. The ionisation potential of H atom is -
(A) 3.2 E (B) 5. 6E (C) 7.2 E (D) 13.2 E

18. Magnetic moments of V(Z = 23), Cr(Z = 24), Mn(Z = 25) are x, y, z. Hence -
(A) x = y = z (B) x < y < z (C) x < z < y (D) z < y < x

19. An electron, a proton and an alpha particle have kinetic energies of 16E, 4E and E respectively. What is the qualitative order of their de Broglie wavelengths -
(A) $\lambda_e > \lambda_p = \lambda_\alpha$ (B) $\lambda_p = \lambda_a > \lambda_e$ (C) $\lambda_p < \lambda_e > \lambda_a$ (D) $\lambda_a < \lambda_e \gg \lambda_p$

20. Consider the following ions -
1. Ni^{2+} 2. Co^{2+} 3. Cr^{2+} 4. Fe^{3+}
(Atomic numbers : Cr = 24, Fe = 26, Co = 27, Ni = 28)
The correct sequence of the increasing order of the number of unpaired electrons in these ions is -
(A) 1, 2, 3, 4 (B) 4, 2, 3, 1 (C) 1, 3, 2, 4 (D) 3, 4, 2, 1

21. What are the values of the orbital angular momentum of an electron in the orbitals 1s, 3s, 3d and 2p-

(A) 0, 0, $\sqrt{6}\,\hbar$, $\sqrt{2}\,\hbar$ (B) 1, 1, $\sqrt{4\hbar}$, $\sqrt{2\hbar}$ (C) 0, 1, $\sqrt{6\hbar}$, $\sqrt{3\hbar}$ (D) 0, 0, $\sqrt{20\hbar}$, $\sqrt{6\hbar}$

22. In an atom two electron move around the nucleus in circular orbits of radii R and 4R. The ratio of the time taken by them to complete one revolution -
(A) 1 : 4 (B) 4 : 1 (C) 1 : 8 (D) 8 : 7

23. A beam of electrons is accelerated by a potential difference of 10000 volts. The wavelength of the wave associated with it will be -
(A) 0.0123 Å (B) 1.23 Å (C) 0.123 Å (D) None of these

24. If the number of electrons in p-orbital are two, then which one of the following is in accordance with Hund's rule -

(A) $p_x^2\ p_y^0\ p_z^0$ (B) $p_x^0\ p_y^2\ p_z^0$ (C) $p_x^0\ p_y^0\ p_z^2$ (D) $p_x^1\ p_y^1\ p_z^0$

25. If there are six energy levels in H–atom then the number of lines its emission spectrum in ultra voilet region will be -
(A) 6 (B) 5 (C) 4 (D) 3

26. Magnetic moment of X^{3+} ion of 3d series is $\sqrt{35}$ BM. What is atomic number of X^{3+} ?

(A) 25 (B) 26 (C) 27 (D) 28

27. An electron is moving with the velocity equal to 10% of the velocity of light. Its de-Broglie wave length will be-
(A) 2.4×10^{-12}cm (B) 2.4×10^{-18}cm (C) 2.4×10^{-9}Cm (D) None of these

28. Correct set of four quantum numbers for the valence (outer most) 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) 5,0,0, $-\frac{3}{2}$

29. Ratio of time period of electron in first and second orbit of H-atom would be -
(A) 1 : 18 (B) 1 : 8 (C) 1 : 2 (D) 2 : 1

30. If x is the velocity of an electron in first Bohr's orbit. What would be the velocity of the electron in third Bhor's orbit -
(A) $\frac{x}{9}$ (B) $\frac{x}{3}$ (C) 3x (D) 9 x

31. The total energy associated per quanta with light of wavelength 600 nm -
(A) 3.3×10^{-12} erg (B) 3.3×10^{-6} erg (C) 6.6×10^{-12} erg (D) 6.6×10^{-6} erg

32. The number of revolution/sec. made by electron in 3rd orbit of hydrogen atom -
(A) 4.88×10^{14} (B) 2.44×10^{14} (C) 9.9×10^{14} (D) 2.44×10^{12}

33. Angular and spherical nodes in 3s -
(A) 1, 1 (B) 1, 0 (C) 2, 0 (D) 0, 2

34. The magnetic moment of V^{4+} ion -
(A) 1.73 (B) 1.41 (C) 3.46 (D) 2

35. Which orbital represents the following set of quantum numbers n = 3, ℓ = 0, m = 0, s = +1/2 -
(A) 3p (B) 2s (C) 3s (D) 2p

36. The number of unpaired electrons in Zn^{+2} -
(A) 0 (B) 1 (C) 2 (D) 3

37. The uncertainly in velocity of electron having uncertainty in its position of 1Å -
(A) 5.8×10^{5} m/s (B) 5.8×10^{6} m/s (C) 5.8×10^{7} m/s (D) 5.8×10^{8} m/s

38. If ionisation energy of hydrogen atom is 13.6 eV. I.E. of Li^{+2} will be -
(A) 13.6 eV (B) 10.4 eV (C) 40.8 eV (D) 122.4 eV

39. The wavelength of third lyman series of hydrogen atom is approximately -
(A) 1×10^{-7} m (B) 1×10^{-8} m (C) 1×10^{-6} m (D) 1×10^{-5} m

40. The number of waves made by a Bohr electron in one complete revolution in its 3rd orbit -
(A) 1 (B) 2 (C) 3 (D) 4

41. If potential energy of an electron in hydrogen atom is –x eV, then its kinetic energy will be -
(A) x eV (B) –x eV (C) 2x eV (D) x/2 eV

42. The number of orbitals in n = 3 are -
(A) 1 (B) 3 (C) 5 (D) 9

43. Maximum value (n + l + m) for unpaired electrons in second excited state of chlorine ^{17}Cl is:
(A) 28 (B) 25 (C) 20 (D) none of these

44. If there are three possible values (–1/2, 0, +1/2) for the spin quantum, then electronic configuration of K(19) will be:
(A) $1s^3, 2s^3 2p^9, 3s^3 3p^1$ (B) $1s^2, 2s^2 2p^6, 3s^2 3p^6, 4s^1$
(C) $1s^2, 2s^2 2p^9, 3s^2 3p^4$ (D) none of these

45. The fourth electron of Beryllium has the following four quantum numbers in the order $n, l, m \& s$

(A) $1,0,1,+\frac{1}{2}$ (B) $1,1,1,\frac{1}{2}$ (C) $2,0,0,-\frac{1}{2}$ (D) $2,1,0,\frac{1}{2}$

46. A proton and an α-particle are accelerated through the same potential difference from rest. Then the ratio of their de Broglie wavelength is :

(A) $\sqrt{2}$ (B) $\frac{1}{\sqrt{2}}$ (C) $2\sqrt{2}$ (D) $1/2\sqrt{2}$

More than one choice type

47. The spectrum of He^+ is expected to be similar to that of :
(A) Li^{2+} (B) He (C) H (D) Na

48. Select the correct relations on the basis of Bohr's theory:

(A) velocity of electron $\propto \frac{1}{n}$ (B) frequency of revolution $\propto \frac{1}{n^3}$

(C) radius of orbit $\propto n^2z$ (D) force on electron $\propto \frac{1}{n^4}$

49. The ratio of $(E_2 - E_1)$ to $(E_4 - E_3)$ for the hydrogen atom is not approximately equal to:
(A) 10 (B) 15 (C) 17 (D) 12

50. Which of the following statement is not correct -
(A) Number of angular nodes = $n - \ell - 1$ (B) Number of radial nodes = ℓ
(C) Total number of nodes = $n - 1$ (D) All

51. If Hund's rule is followed, magnetic moment of Fe^{2+}, Mn^+ and Cr all having 24 electrons will not be in order -
(A) $Fe^{2+} < Mn^+ < Cr$ (B) $Fe^{2+} < Cr = Mn^+$ (C) $Fe^{2+} = Mn^+ < Cr$ (D) $Mn^{2+} = Cr < Fe^{2+}$

52. Which of the following are not correct about the e/m ratio for cathode rays -
(A) Is constant
(B) Varies as the atomic number of the element forming cathode in the discharge tube changes
(C) Varies as atomic number of the gas in the discharge tube varies
(D) Has the smallest value when the discharge tube is filled with hydrogen

53. Which are the incorrect relationship :
(A) E_1 of H = 1/2 E_2 of He^+ = 1/3 E_3 of Li^{2+} = 1/4 E_4 of Be^{3+}
(B) $E_1(H) = E_2(He^+) = E_3(Li^{2+}) = E_4(Be^{3+})$
(C) $E_1(H) = 2E_2(He^+) = 3E_3(Li^{2+}) = 4E_4(Be^{3+})$
(D) No relation

54. Which of the followings are not correct about the maximum probability of finding electron in the d_{xy} orbital ?
(A) Along the x axis (B) Along the y axis
(C) At an angle of 45º from the x and y axis (D) At an angle of 90º from the x and y axis

PART - II : SUBJECTIVE QUESTIONS

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

2. A photon of wavelength 4×10^{-7} m strikes on 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 eV = 1.6020 10^{-19} J).

3. Ionization energy of a hydrogen-like ion A is greater than that of another hydrogen like ion B. Let r, u, E and L represent the radius of the orbit, speed of the electron, total energy of the electron and angular momentum of the electron respectively (for the same n). In ground state

4. There are two samples of H and He atom. Both are in some excited state. In hydrogen atom total number of lines observed in Balmer series is 4 and in He^+ atom total number of lines observed in paschen series is 1. Electron in hydrogen sample make transitions to lower states from its excited state, then the photon corresponding to the line of maximum energy line of Balmer series of H sample is used to further excite the already excited He^+ sample. Then maximum excitation level of He^+ sample will be :

5. Photon having energy equivalent to the binding energy of 4th state of He^+ ion is used to eject an electron from the metal with K.E. 2eV. If electron is further accelerated through the potential difference of 4V then the minimum value of de–Broglie wavelength associated with the electron is :
($h = 6.6 \times 10^{-34}$ J-s, $m_e = 9.1 \times 10^{-31}$ kg, 1 eV = 1.6×10^{-19}J)

6. In Balmer series of lines of hydrogen spectrum, the first line from the red end corresponds to which one of the following inter-orbit jumps of the electron for Bohr orbits in an atom of hydrogen ?

7. Which transition in Li^{2+} would have the same wavelength as the $2 \rightarrow 4$ transition in He^+ ion ?

8. Photons of equal energy were incident on two different gas samples. One sample containing H-atoms in the ground state and the other sample containing H-atoms in some excited state with a principal quantum number 'n'. The photonic beams totally ionise the H-atoms. If the difference in the kinetic energy of the ejected electrons in the two different cases is 12.75 eV. Then find the principal quantum number 'n' of the excited state.

9. The speed of a proton is one hundredth of the speed of light in vacuum. What is its de-Broglie wavelength? Assume that one mole of protons has a mass equal to one gram [$h = 6.626 \times 10^{-27}$ erg sec] -

10. Iodine molecule dissociates into atom after absorbing light of 4500 Å. The K.E. of iodine atoms if B.E. of I_2 is 240 kJ mol^{-1} -

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

12. Explain, giving reasons, which of the following sets of quantum numbers are not possible.
(a) $n = 0$, $l = 0$, $m_l = 0$, $m_s = +$
(b) $n = 1$, $l = 0$, $m_l = 0$, $m_s = -$
(c) $n = 1$, $l = 1$, $m_l = 0$, $m_s = +$
(d) $n = 2$, $l = 1$, $m_l = 0$, $m_s = -$
(e) $n = 3$, $l = 3$, $m_l = -3$, $m_s = +$
(f) $n = 3$, $l = 1$, $m_l = 0$, $m_s = +$

EXERCISE # 3

PART-I IIT-JEE (PREVIOUS YEARS PROBLEMS)

1. The wavelength associated with a golf ball weighing 200g and moving at a speed of 5 m/h is of the order **[IIT-2001]**

(A) 10^{-10}m (B) 10^{-20}m (C) 10^{-30} m (D) 10^{-40}m

2. The quantum numbers +1/2 and –1/2 for the electron spin represent **[IIT-2001]**

(A) rotation of the electron in clockwise and anticlockwise direction respectively
(B) rotation of the electron in anticlockwise and clockwise direction respectively
(C) magnetic moment of the electron pointing up and down respectively
(D) two quantum mechanical spin states which have no classical analogue

3. Rutherford's experiment, which estabilished the nuclear model of the atom, used a beam of - **[IIT-2002]**

(A) β–particles, which impinged on a metal foil and got absorbed
(B) γ–rays, which impinged on a metal foil and ejected electrons
(C) helium atoms, which impinged on a metal foil and got scattered
(D) helium nuclei, which impinged on a metal foil and got scattered

4. If the nitrogen atom had electronic configuration 1s, it would have energy lower than that of the normal ground state configuration $1s^2\ 2s^2\ 2p^3$, because the electrons would be closer to the nucleus. Yet, $1s^7$ is not observed because it violates. **[IIT-2002]**

(A) Heisenberg uncertainty principle (B) Hund's rule
(C) Pauli's exclusion principle (D) Bohr postulates of stationary orbits.

5. Calculate the energy required to excite one litre Hydrogen gas at 1 atm and 298 K to first excited state of atomic hydrogen. The energy for the dissociation of H-H bond is 436 kJ mol^{-1}.

6. The orbit having Bohr radius equal to 1^{st} Bohr orbit of H–atom is **[JEE 2004, 3/144]**

(A) n = 2 of He^{+} (B) n = 2 of B^{+4} (C) n = 3 of Li^{+2} (D) n = 2 of Be^{+3}

7. Find wavelength for 100 g particle moving with velocity 100 m/s. **[JEE 2004, 1.5/144]**

8. (A) Using Bohr's model for hydrogen atom, find the speed of electron in the first orbit if the Bohr's radius is $a_0 = 0.529 \times 10^{-10}$ m. Find deBroglie wavelength of the electron also.

(B) Find the orbital angular momentum of electron if it is in 2p orbital of H in terms of $\frac{h}{2\pi}$. **[JEE 2005 ,4/144]**

9. According to Bohr's theory,
E_n = Total energy
K_n = Kinetic energy
V_n = Potential energy
r_n = Radius of n^{th} orbit **[JEE 2006 ,6/184]**

Match the following:

Column I	Column II
(A) $V_n / K_n = ?$	(p) 0
(B) If radius of n^{th} orbit $\propto E_n^{x}$, x = ?	(q) – 1
(C) Angular momentum in lowest orbital	(r) – 2
(D) $\frac{1}{r_n} \propto Z^{y}$, y = ?	(s) 1

Paragraph for Question Nos. 10 to 12

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.

10. The state S_1 is : **[JEE 2010, 3/163]**
(A) 1s (B) 2s (C) 2p (D) 3s

11. Energy of the state S_1 in units of the hydrogen atom ground state energy is : **[JEE 2010, 3/163]**
(A) 0.75 (B) 1.50 (C) 2.25 (D) 4.50

12. The orbital angular momentum quantum number of the state S_2 is : **[JEE 2010, 3/163]**
(A) 0 (B) 1 (C) 2 (D) 3

13. The maximum number of electrons that can have principal quantum number, n = 3 and spin quantum number, $m_s = -½$, is **[IIT-JEE - 2011]**

14. 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 metals is **[IIT-JEE - 2011]**

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

15. The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is [a_0 is Bohr radius] **[IIT-JEE- 2012]**

(A) $\frac{h^2}{4\pi^2 m a_0^2}$ (B) $\frac{h^2}{16\pi^2 m a_0^2}$ (C) $\frac{h^2}{32\pi^2 m a_0^2}$ (D) $\frac{h^2}{64\pi^2 m a_0^2}$

PART - II : AIEEE (PREVIOUS YEARS PROBLEMS)

1. Which of the following ions has the maximum magnetic moment? **[AIEEE - 2002]**
(1) Mn^{+2} (2) Fe^{+2} (3) Ti^{+2} (4) Cr^{+2}.

2. Energy of H-atom in the ground state is –13.6 eV, hence energy in the second excited state is : **[AIEEE 02]**
(1) – 6.8 eV (2) – 3.4 eV (3) – 1.51 eV (4) – 4.53 eV

3. Uncertainity in position of a particle of 25 g in space is 10^{-15} m. Hence, Uncertainity in velocity ($m.sec^{-1}$) is : (plank's constant, h = 6.6×10^{-34} Js) **[AIEEE 02]**
(1) 2.1×10^{-18} (2) 2.1×10^{-34} (3) 0.5×10^{-34} (4) 5.0×10^{-24}

4. The de-Broglie wavelength of a tennis ball of mass 60 g moving with a velocity of 10 m/s is approximately (planck's constant, h = 6.63×10^{-34} J-s) **[AIEEE 03]**
(1) 10^{-33} m (2) 10^{-31} m (3) 10^{-16} m (4) 10^{-25} m

5. In Bohr series of lines of hydrogen spectrum, the third line from the red end corresponds to which one of the following inner-orbit jumps of the electron for Bohr orbits in an atom of hydrogen ? **[AIEEE 03]**
(1) $3 \rightarrow 2$ (2) $5 \rightarrow 2$ (3) $4 \rightarrow 1$ (4) $2 \rightarrow 5$

6. The numbers of d-electrons retained in Fe^{2+} (atomic number Fe = 26) ion is **[AIEEE 03]**

(1) 3 (2) 4 (3) 5 (4) 6

7. The orbital angular momentum for an electron revolving in an orbit is given by $\sqrt{\ell(l+1)}\ \frac{h}{2\pi}$. This momentum for an s-electron will be given by : **[AIEEE 03]**

(1) $+\frac{1}{2}\cdot\frac{h}{2\pi}$ (2) Zero (3) $\frac{h}{2\pi}$ (4) $\sqrt{2}\cdot\frac{h}{2\pi}$

8. The wavelength of the radiation emitted, when in a hydrogen atom electron falls from infinity to stationary state 1, would be (Rydberg constant = $1.097 \times 10^{7}\ m^{-1}$) **[AIEEE 04]**

(1) 91 nm (2) 192 nm (3) 406 (4) 9.1×10^{-6} nm

9. Which of the following set a of quantum numbers is correct for an electron in 4f orbital ? **[AIEEE 04]**

(1) n = 4, l =3, m = +4, s = +1/2 (2) n = 4, l = 4, m = –4, s = –1/2
(3) n = 4, l = 3, m = +1, s = +1/2 (4) n = 3, l=2, m =–2, s = +1/2

10. Consider the ground state of Cr atom (Z = 24). The numbers of electrons with the azimuthal quantum numbers, ℓ = 1 and 2 are, respectively **[AIEEE 04]**

(1) 12 and 4 (2) 12 and 5 (3) 16 and 4 (4) 16 and 5

11. Which of the following statements in relation to the hydrogen atom is correct ? **[AIEEE 05]**

(1) 3s, 3p and 3d orbitals all have the same energy
(2) 3s and 3p orbitals are of lower energy than 3d orbital
(3) 3p orbital is lower in energy than 3d orbital
(4) 3s orbital is lower in energy than 3p orbital

12. In a multi-electron atom, which of the following orbitals described by the three quantum numbers will have the same energy in the absence of magnetic and electric field ? **[AIEEE 05]**

(i) n = 1, l = 0, m = 0 (ii) n =2, l = 0, m = 0 (iii) n = 2, l = 1, m = 1 (iv) n = 3, l = 2, m =1
(v) n = 3, l = 2, m = 0

(1) (iv) and (v) (2) (iii) and (iv) (3) (ii) and (iii) (4) (i) and (ii)

13. Uncertainity in the position of an electron (mass = 9.1×10^{-31} Kg) moving with a velocity 300 $m.sec^{-1}$, Accurate upto 0.001%, will be : (h = 6.63×10^{-34} J-s) **[AIEEE 06]**

(1) 19.2×10^{-2} m (2) 5.76×10^{-2} m (3) 1.92×10^{-2} m (4) 3.84×10^{-2} m

14. According to Bohr's theory, the angular momentum of an electron in 5^{th} orbit is : **[AIEEE 06]**

(1) $25\ \frac{h}{\pi}$ (2) $1.0\ \frac{h}{\pi}$ (3) $10\ \frac{h}{\pi}$ (4) $2.5\ \frac{h}{\pi}$

15. The 'spin-only' magnetic moment [in units of Bohr magneton (μ_β)] of Ni^{2+} in aqueous solution would be (Atomic number : Ni = 28) **[AIEEE 06]**

(1) 2.84 (2) 4.90 (3) 0 (4) 1.73

16. Which of the following nuclear reactions will generate an isotope ? **[AIEEE 07, 3/120]**

(1) Neutron particle emission (2) Positron emission
(3) α-particle emission (4) β-particle emission

17. The ionisation enthalpy of hydrogen atom is 1.312×10^6 J mol^{-1}. The energy required to excite the electron in the atom from $n_1 = 1$ to $n = 2$ is **[AIEEE 08, 3/105]**

(1) 8.51×10^5 J mol^{-1} (2) 6.56×10^5 J mol^{-1} (3) 7.56×10^5 J mol^{-1} (4) 9.84×10^5 J mol^{-1}

18. Which of the following set of quantum numbers represents the highest energy of an atom ? **[AIEEE 08,3/105]**

(1) $n = 3, l = 0, m = 0, s = +\frac{1}{2}$ (2) $n = 3, l = 1, m = 1, s = +\frac{1}{2}$

(3) $n = 3, l = 2, m = 1, s = +\frac{1}{2}$ (4) $n = 4, l = 0, m = 0, s = +\frac{1}{2}$

19. Calculate the wavelength (in nanometer) associated with a proton moving at 1.0×10^3 m s^{-1} (Mass of proton = 1.67×10^{-27} kg and h = 6.63×10^{-34} J-s) : **[AIEEE 2009, 4/144]**

(1) 0.40 nm (2) 2.5 nm (4) 14.0 nm (4) 0.032 nm

20. In an atom, an electron is moving with a speed of 600 m/s with an accuracy of 0.005%. Certainity with which the position of the electron can be located is (h = 6.6×10^{-34} kg m^2 s^{-1}, mass of electron, $e_m = 9.1 \times 10^{-31}$ kg): **[AIEEE 2009, 4/144]**

(1) 5.10×10^{-3} m (2) 1.92×10^{-3} m (3) 3.83×10^{-3} m (4) 1.52×10^{-4} m

21. The energy required to break one mole of Cl – Cl bonds in Cl_2 is 242 kJ mol^{-1}. The longest wavelength of light capable of breaking a single Cl – Cl bond is (c = 3×10^8 m s^{-1} and $N_A = 6.02 \times 10^{23}$ mol^{-1}) **[AIEEE 2010, 4/144]**

(1) 594 nm (2) 640 nm (3) 700 nm (4) 494 nm

22. Ionisation energy of He^+ is **[AIEEE 2010, 4/144]**

19.6×10^{-18} J atom^{-1}. The energy of the first stationary state (n = 1) of Li^{2+} is :

(1) 0.40 nm (2) 2.5 nm (3) 14.0 nm (4) 0.032 nm

23. The electrons identified by quantum numbers n and l : **[AIEEE-2012]**

(A) n = 4, l = 1 (B) n = 4, l = 0 (C) n = 3, l = 2 (D) n = 3, l = 1

can be placed in order of increasing energy as :

(1) (C) < (D) < (B) < (A) (2) (D) < (B) < (C) < (A)

(3) (B) < (D) < (A) < (C) (4) (A) < (C) < (B) < (D)

24. Energy of an electron is given by $E = -2.178 \times 10^{-18}\ J \left(\frac{Z^2}{n^2}\right)$. Wavelength of light required to excit an electron in an hydrogen atom from level n = 1 to n = 2 will be :

(h = 6.62×10^{-34} Js and c = 3.0×10^8 ms^{-1}) **[JEE Mains - 2013]**

(1) 1.214×10^{-7} m (2) 2.816×10^{-7} m (3) 6.500×10^{-7} m (4) 8.500×10^{-7} m

EXERCISE # 4

BOARD PATTERN QUESTIONS

1. (i) Calculate the number of electrons which will together weigh one gram.
(ii) Calculate the mass and charge of one mole of electrons.

2. (i) Calculate the total number of electrons present in one mole of methane.
(ii) Find (a) the total number and (b) the total mass of neutrons in 7 mg of ^{14}C.
(Assume that mass of a neutron = 1.675 × 10.27 kg).
(iii) Find (a) the total number and (b) the total mass of protons in 34 mg of NH_3 at STP.
Will the answer change if the temperature and pressure are changed ?

3. How many neutrons and protons are there in the following nuclei ?
$^{13}_{6}C$, $^{16}_{8}O$, $^{24}_{12}Mg$, $^{56}_{26}Fe$, $^{88}_{38}Sr$

4. Write the complete symbol for the atom with the given atomic number (Z) and atomic mass (A)
(i) Z = 17, A = 35.
(ii) Z = 92, A = 233.
(iii) Z = 4, A = 9.

5. Yellow light emitted from a sodium lamp has a wavelength (λ) of 580 nm. Calculate the frequency (ν) and wavenumber ($\bar{\nu}$) of the yellow light.

6. Find energy of each of the photons which
(i) correspond to light of frequency 310^{15} Hz.
(ii) have wavelength of 0.50 Å.

7. Calculate the wavelength, frequency and wavenumber of a light wave whose period is 2.0 10^{-10} s.

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

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

10. Electrons are emitted with zero velocity from a metal surface when it is exposed to radiation of wavelength 6800 Å. Calculate threshold frequency (ν_0) and work function (W_0) of the metal.

11. What is the wavelength of 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?

12. How much energy is required to ionise a H atom if the electron occupies n = 5 orbit? Compare your answer with the ionization enthalpy of H atom (energy required to remove the electron from n =1 orbit).

13. (i) The energy associated with the first orbit in the hydrogen atom is –2.18 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.

14. Calculate the wavenumber for the longest wavelength transition in the Balmer series of atomic hydrogen.

15. 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 × 10^{-11} ergs.

16. 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 an electron completely from the n = 2 orbit. What is the longest wavelength of light in cm that can be used to cause this transition?

17. Calculate the wavelength of an electron moving with a velocity of 2.05×10^7 m s^{-1}.

18. The mass of an electron is 9.1×10^{-31} kg. If its K.E. is 3.0×10^{-25} J, calculate its wavelength.

19. Which of the following are isoelectronic species i.e., those having the same number of electrons?
Na^+, K^+, Mg^{2+}, Ca^{2+}, S^{2-}, Ar.

20. (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) $3p^5$?
(iii) Which atoms are indicated by the following configurations ?
(a) [He] $2s^1$ (b) [Ne] $3s^2$ $3p^3$ (c) [Ar] $4s^2$ $3d^1$.

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

22. An electron is in one of the 3*d* orbitals. Give the possible values of n, ℓ and m_l for this electron.

23. 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.

24. Give the number of electrons in the species H_2^+, H_2 and O_2^+

25. (i) An atomic orbital has n = 3. What are the possible values of ℓ and $2m_l$?
(ii) List the quantum numbers (m_l and ℓ) of electrons for 3d orbital.
(iii) Which of the following orbitals are possible?
1*p*, 2*s*, 2*p* and 3*f*

26. 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) $n = 4$; $l = 3$.

27. How many electrons in an atom may have the following quantum numbers?
(a) $n = 4$, $ms = -$ (b) $n = 3$, $l = 0$

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

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

30. Calculate the energy required for the process
$He^+ (g) \rightarrow He^{2+} (g) + e^-$
The ionization energy for the H atom in the ground state is 2.18×10^{-18} J $atom^{-1}$

31. 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 length of scale of length 20 cm long.

32. 2 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.

33. 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 zinc atoms are arranged side by side lengthwise.

34. A certain particle carries 2.5×10^{-16}C of static electric charge. Calculate the number of electrons present in it.

35. In Milikan's experiment, static electric charge on the oil drops has been obtained by shining X-rays. If the static electric charge on the oil drop is -1.282×10^{-18}C, calculate the number of electrons present on it.

36. In Rutherford's experiment, generally the thin foil of heavy atoms, like gold, platinum etc. have been used to be bombarded by the α-particles. If the thin foil of light atoms like aluminium etc. is used, what difference would be observed from the above results ?

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

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

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

40. 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.

41. Arrange the following type 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.

42. Nitrogen laser produces a radiation at a wavelength of 337.1 nm. If the number of photons emitted is 5.6×10^{24}, calculate the power of this laser.

43. Neon gas is generally used in the sign boards. If it emits strongly at 616 nm, calculate (a) the frequency of emission, (b) distance traveled by this radiation in 30 s (c) energy of quantum and (d) number of quanta present if it produces 2 J of energy.

44. 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.

45. Lifetimes of the molecules in the excited states 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 ns and the number of photons emitted during the pulse source is 2.5×10^{15}, calculate the energy of the source.

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

47. 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, calculate the kinetic energy and the velocity of the ejected photoelectron.

48. Following results are observed when sodium metal is irradiated with different wavelengths. Calculate (a) threshold wavelength and, (b) Planck’s constant.

λ (nm)	500	450	400
$v \times 10^{-5}$ (cm s^{-1})	2.55	4.35	5.35

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

50. If the photon of the wavelength 150 pm strikes an atom and one of tis inner bound electrons 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.

51. Emission transitions in the Paschen series end at orbit n = 3 and start from orbit n and can be represeted as
v = 3.29 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.

52. 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.

53. 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 type of material. If the velocity of the electron in this microscope is 1.6 106 ms^{-1}, calculate de Broglie wavelength associated with this electron.

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

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

56. 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, calcualte the wavelength associated with this velocity.

57. If the position of the electron is measured within an accuracy of $\pm$ 0.002 nm, calculate the uncertainty in the momentum of the electron. Suppose the momentum of the electron is $h/4\pi_m$ 0.05 nm, is there any problem in defining this value.

58. The quantum numbers of six electrons are given below. Arrange them in order of increasing energies. If any of these combination(s) has/have the same energy lists :

1. $n = 4$, $l = 2$, $m_l = -2$, $m_s = -1/2$
2. $n = 3$, $l = 2$, $m_l = 1$, $m_s = +1/2$
3. $n = 4$, $l = 1$, $m_l = 0$, $m_s = +1/2$
4. $n = 3$, $l = 2$, $m_l = -2$, $m_s = -1/2$
5. $n = 3$, $l = 1$, $m_l = -1$, $m_s = +1/2$
6. $n = 4$, $l = 1$, $m_l = 0$, $m_s = +1/2$

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

60. Among the following pairs of orbitals which orbital will experience the larger effective nuclear charge ? (i) 2*s* and 3*s*, (ii) 4*d* and 4*f*, (iii) 3*d* and 3*p*.

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

62. Indicate the number of unpaired electrons in : (a) P, (b) Si, (c) Cr, (d) Fe and (e) Kr.

63. (a) How many sub-shells are associated with $n = 4$? (b) How many electrons will be present in the sub-shells having ms value of –1/2 for $n = 4$?

ANSWERS

Exercise # 1

PART - I

A-1.	(D)	**A-2.**	(C)	**A-3.**	(A)	**A-4.**	(D)	**A-5.**	(A)	**A-6.**	(D)	**A-7.***	(AB)
A-8.	(C)	**A-9.**	(B)	**A-10.**	(C)	**A-11.**	(C)	**A-12.**	(B)	**A-13.**	(A)	**A-14.**	(A)
A-15.	(C)	**A-16.**	(C)	**A-17.**	(D)	**A-18.**	(D)	**A-19.**	(D)	**B-1.**	(B)	**B-2.**	(A)
B-3.	(D)	**B-4.**	(B)	**B-5.**	(B)	**B-6.**	(A)	**B-7.**	(D)	**B-8.**	(C)	**B-9.**	(C)
B-10.	(C)	**B-11.**	(C)	**B-12.**	(A)	**B-13.**	(C)	**B-14.**	(C)	**B-15.**	(B)	**B-16.**	(D)
B-17.	(B)	**B-18.**	(C)	**B-19.**	(A)	**B-20.**	(A)	**B-21.**	(D)	**B-22.**	(B)	**B-23.**	(D)
B-24.	(A)	**B-25.**	(D)	**B-26.**	(A)	**B-27.**	(A)	**B-28.**	(B)	**C-1.**	(D)	**C-2.**	(C)
C-3.	(B)	**C-4.**	(A)	**C-5.**	(B)	**C-6.**	(D)	**C-7.**	(D)	**C-8.**	(D)	**C-9.**	(B)
C-10.	(D)	**C-11.**	(C)	**C-12.**	(A)	**C-13.**	(D)	**C-14.**	(A)	**C-15.**	(A)	**C-16.**	(C)
D-1.	(C)	**D-2.**	(B)	**D-3.**	(A)	**D-4.**	(C)	**D-5.**	(B)	**D-6.**	(D)	**D-7.**	(B)
D-8.	(D)	**D-9.**	(A)	**D-10.**	(C)	**D-11.**	(A)	**E-1.**	(C)	**E-2.**	(A)	**E-3.**	(A)
E-4.	(D)	**E-5.**	(C)	**E-6.**	(A)	**E-7.**	(C)	**E-8.**	(D)	**E-9.**	(B)	**E-10.**	(B)
E-11.	(C)												

PART - II

1.	(A)	**2.**	(B)	**3.**	(A)	**4.**	(A)	**5.**	(C)	**6.**	(C)	**7.**	(A)
8.	(A)	**9.**	(C)	**10.**	(C)	**11.**	(A)	**12.**	(B)				

13. (i – e) ; (ii – d) ; (iii – f) ; (iv – b) ; (v – a) ; (vi – c)

14. (i – f) ; (ii – d) ; (iii – a) ; (iv – e) ; (v – b) ; (vi – c)

15. (i – b) , (ii – a), (iii – b, c) , (iv – c, d).

16. (i – c) , (ii – d), (iii – a), (iv – b).

Exercise # 2

PART - I

1.	(B)	**2.**	(D)	**3.**	(D)	**4.**	(B)	**5.**	(B)	**6.**	(B)	**7.**	(D)
8.	(B)	**9.**	(C)	**10.**	(C)	**11.**	(A)	**12.**	(D)	**13.**	(A)	**14.**	(A)
15.	(D)	**16.**	(B)	**17.**	(C)	**18.**	(C)	**19.**	(A)	**20.**	(A)	**21.**	(A)
22.	(C)	**23.**	(C)	**24.**	(D)	**25.**	(B)	**26.**	(B)	**27.**	(C)	**28.**	(A)
29.	(B)	**30.**	(B)	**31.**	(A)	**32.**	(B)	**33.**	(D)	**34.**	(A)	**35.**	(C)
36.	(A)	**37.**	(A)	**38.**	(D)	**39.**	(A)	**40.**	(C)	**41.**	(D)	**42.**	(D)
43.	(B)	**44.**	(A)	**45.**	(C)	**46.**	(C)	**47.**	(AC)	**48.**	(ABC)	**49.**	(ACD)
50.	(AB)	**51.**	(ACD)	**52.**	(BCD)	**53.**	(ACD)	**54.**	(ABD)				

PART - II

3.	$u_A > u_B$	**4.**	n = 12	**5.**	**5 Å**	**6.**	**$3 \rightarrow 2$**	**7.**	$3 \rightarrow 6$	**8.**	**4**
9.	1.33×10^{-3} Å	**10.**	0.216×10^{-19} J	**11.**	15						

Exercise # 3

PART - I

1. (C) **2.** (D) **3.** (B) **4.** (C) **5.** 98.17 kJ **6.** (D)

7. 6.6×10^{-35} m. **8.** (A) 2.18×10^{6} m/s, 3.32×10^{-10} m (B) $\sqrt{2}\cdot\left(\frac{h}{2\pi}\right)$

9. **(A) r ; (B) q ; (C) p ; (D) s.** **10.** (B) **11.** (C) **12.** (B) **13.** **9**

14. **4** **15.** (C)

PART - II

1. (1) **2.** (3) **3.** (1) **4.** (1) **5.** (2) **6.** (4) **7.** (2)

8. (1) **9.** (3) **10.** (2) **11.** (1) **12.** (1) **13.** (3) **14.** (4)

15. (1) **16.** (1) **17.** (4) **18.** (3) **19.** (1) **20.** (2) **21.** (4)

22. (1) **23.** (2) **24.** (1)

Exercise # 4

4. (i) $^{35}_{17}Cl$ (ii) $^{233}_{92}U$ (iii) $^{9}_{4}Be$ **5.** 1.72×10^{-6} m^{-1} **6.** (i) E = 1.988×10^{-18} J (ii) E = 3.98×10^{-15} J

7. 16.66 **8.** 494 kJ mol^{-1} **9.** 7.169×10^{19} s^{-1} **10.** 2.922×10^{-19} J **11.** 486 nm

12. 2.18×10^{-18} J **13.** (i) $E_5 = -8.72 \times 10^{-20}$ J (ii) $r_5 = 1.3225$ nm **14.** 1.5236 × 106 m^{-1}

15. 9.498×10^{-8} m **16.** $\lambda = 3647 \times 10^{-10}$ m = 3647 Å **17.** 3.548×10^{-11} m

18. 8.9625×10^{-7} m.

19. 1) Na^{+} and Mg^{2+} (10 electrons each) 2) K^{+}, Ca^{2+}, S^{2-} and Ar (18 electrons each)

31. **1.33×10^{9}** **34.** **1560 C** **35.** **8.0**