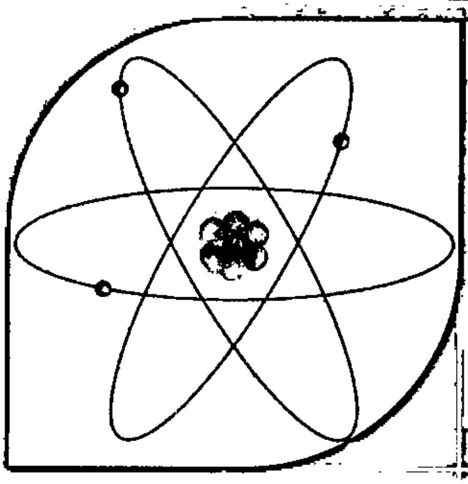


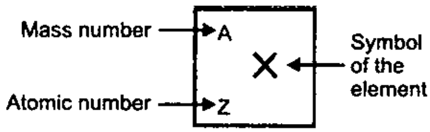
2

ATOMIC STRUCTURE

Atomic Number of an Element

Total number of protons present in the nucleus = Total number of electrons present in the atom

Mass number of an element = Number of protons + Number of neutrons.



e.g., $^{23}_{11}Na$, $^{35}_{17}Cl$ and so on.

Terms associated with elements

- Isotopes : Atoms having same number of protons.
- Isobars : Elements having same mass number.
- Isotones : Elements having same number of neutrons $(A - Z)$.
- Isoelectronic : Species/elements having same number of electrons.
- Isosters : Species having same number of atoms and electrons
- Isodiaphers : Elements having same number of $|N - Z|$ or $|A - 2Z|$
- Paramagnetic : Species having non-zero unpaired electron.
- Diamagnetic : Species having zero unpaired electron.

Rutherford's Model

- Electrons, protons & neutrons are the most important fundamental particles of atoms of all elements (Except hydrogen)
- $^{A}_{Z}X$, Mass number (A) = Atomic number (Z) + number of neutrons (n)
- $R_N = R_0(A)^{1/3}$, $R_0 = 1.33 \times 10^{-13}$ cm A = mass number, R_N = Radius of nucleus

- $\frac{1}{2}m_\alpha v_\alpha^2 = K\frac{q_1 \times q_2}{r}$; r = distance of closest approach, v_α = Velocity of a α-particle

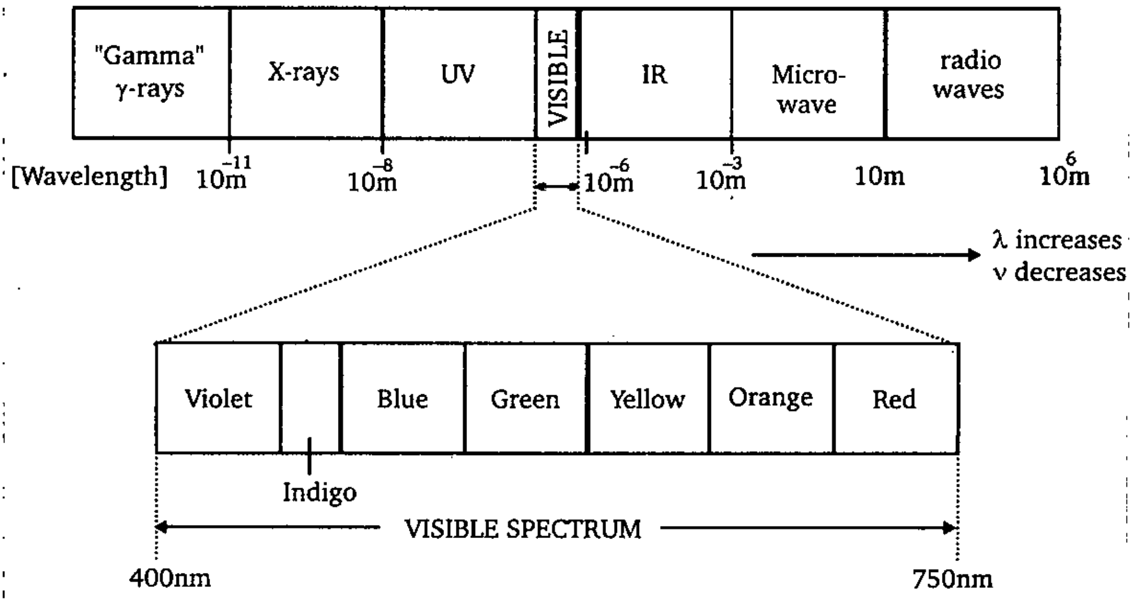
  m_α = mass of α-particle
  q_1 = charge on α-particle
  q_2 = charge on metal foil.

Size of the Nucleus

The volume of the nucleus is very small and is only a minute fraction of the total volume of the atom. Nucleus has a diameter of the order of 10^{-12} to 10^{-13} cm and the atom has a diameter of the order of 10^{-8} cm.

Thus, diameter (size) of the atom is 1,00,000 times the diameter of the nucleus.

Electromagnetic Spectrum



Light

- Photon is considered as massless bundle of energy.
- Energy of light $E = mc^2$, where m = mass of light particle, c = speed of light
- $E_{\text{Photon}} = h\nu = hc/\lambda = hc\bar{\nu} \cong \frac{1240\,\text{eV. nm}}{\lambda(\text{nm})}$

  where h = Planck constant, λ = wavelength of photon, $\bar{\nu}$ = wave number.
- Quantum efficiency or Quantum Yield = $\frac{\text{no. of molecules reacting}}{\text{no. of quanta absorbed}}$

Bohr's Model

- Electrostatic force = $\frac{Kq_1q_2}{r^2}$ where $K = \frac{1}{4\pi\varepsilon_0} = 9\times10^9\,\text{N - m}^2/\text{C}^2$

- Potential energy due to electrostatic force $= \frac{Kq_1q_2}{r}$

  q_1 = charge of electron, q_2 = charge of nucleus

- Potential due to a charge (Q) particle at a distance (r) $= \frac{KQ}{r}$
- Bohr quantization rule $mvr = n \cdot \frac{h}{2\pi} = n.\hbar$
- According to newtons' second law, in a uniform circular motion resultant of all the forces towards centre must be equal to $\frac{mv^2}{r}$.
- $\frac{Kq_1q_2}{r^2} = \frac{mv^2}{r}$,

  where q_1 = charge of electron, q_2 = charge of nucleus, m = mass of electron,
  r = radius of Bohr's orbit
- Total energy of electron in n^{th} Bohr orbit

  $E_n = \frac{E_1}{n^2} Z^2 = -\frac{2\pi^2 me^4 K^2}{n^2h^2} Z^2$; $E_1 = \frac{-2\pi^2 me^4 K^2 Z^2}{h^2}$

  $E_n = -13.6 \times \frac{z^2}{n^2}$ eV/atom, where z = atomic number of single electron atoms/ion,

  n = principle quantum number of shell, E_1 = total energy of electron in Ist Bohr orbit.
- Radius of n^{th} Bohr orbit, $r_n = \frac{h^2}{4\pi^2 e^2 mK} \times \frac{n^2}{Z} = 0.529 \times \frac{n^2}{Z}$ Å $= r_1\left(\frac{n^2}{Z}\right)$Å,

  where r_1 = radius of Ist Bohr orbit.
- Velocity of electron in n^{th} Bohr orbit, $v_n = \frac{2\pi e^2 K}{h} \times \frac{Z}{n} = 2.18 \times 10^6 \times \frac{Z}{n}$ m/s $= v_1\left(\frac{Z}{n}\right)$m/s

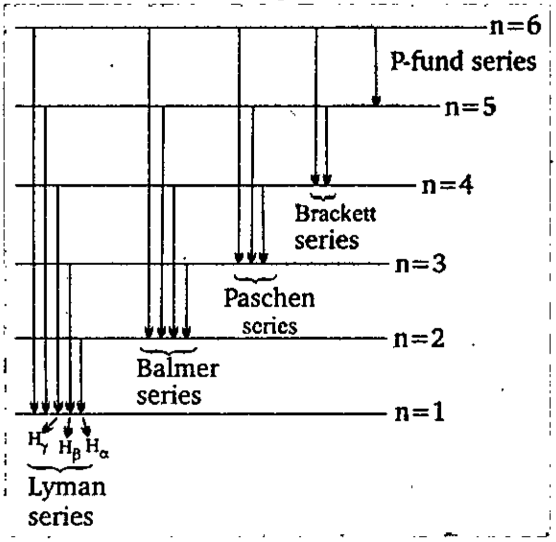
  where v_1 = velocity of electron in Ist Bohr orbit.
- Revolutions per sec $= v/2\pi r = 0.657 \times 10^{16}\left(\frac{Z^2}{n^3}\right)$
- Time for one revolution $= 2\pi r/v = 1.52 \times 10^{-16}\left(\frac{n^3}{Z^2}\right)$
- Energy difference between n_1 and n_2 energy level.

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

  where IE = ionization energy of single electron species.
- Ionization energy $= E_\infty - E_{G.S} = E_{G.S}$; $E_{G.S}$ = Energy of electron in ground state
- Total energy of electron in terms of kinetic energy (KE) and potential energy (PE)

$$E_n = KE + PE = -KE = \frac{PE}{2}$$

Spectral Lines

- Rydberg's Equation $\frac{1}{\lambda} = \bar{\nu} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \times Z^2; R_H \cong 109700\,\text{cm}^{-1}$ = Rydberg constant
- For First line of a series $n_2 = n_1 + 1$
- Limiting spectral line (series limit) means $n_2 = \infty$
- H_α line means $n_2 = n_1 + 1$; also known as line of longest λ, shortest ν, least E
- Similarly H_β line means $n_2 = n_1 + 2$
- When electrons de-excite from higher energy level (n) to ground state in atomic sample, then number of spectral lines observed in the spectrum $= \frac{n(n-1)}{2}$
- When electrons de-excite from higher energy level (n_2) to lower energy level (n_1) in atomic sample, then number of spectral line observed in the spectrum $= \frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$
- When electron de-excites from higher energy level (n_2) to lower energy level (n_1) in isolated atom, then number of spectral line observed in the spectrum $= (n_2 - n_1)$
- 

Photoelectric Effect

- When radiation with certain minimum frequency (ν_0 called threshold frequency), strikes the surface of a metal, electrons (called photoelectrons) are ejected from the surface.
- Kinetic energy of photoelectron $= h\nu - w = h\nu - h\nu_0$
  where w = work function
  ν_0 = Threshold frequency
- If $\nu \geq \nu_0$, then photoelectric effect takes place.
- Accelerating potential $= eV = KE = \frac{1}{2}mv^2$

De-broglie Hypothesis

- All material particles possess wave character as well as particle character.
- $\lambda = h/mv = h/p$
- The circumference of the n^{th} orbit is equal to n times of wavelength of electron *i.e.*, $2\pi r_n = n\lambda$

  Number of waves $= n =$ principal quantum number
- Wavelength of electron $(\lambda) \cong \sqrt{\frac{150}{V(\text{volts})}}$ Å
- Wave nature of electron has been confirmed by Davisson and Germer experiment.

Heisenberg Uncertainty Principle

- According to this principle, "it is impossible to measure simultaneously the position and momentum of a microscopic particle with absolute accuracy".

  If one of them is measured with greater accuracy, the other becomes less accurate.
- $\Delta x \cdot \Delta p \geq h/4\pi$ or $(\Delta x)(\Delta v) \geq \frac{h}{4\pi m}$ or $(\Delta x)(\Delta\lambda) \geq \frac{\lambda^2}{4\pi}$

  where $\Delta x =$ Uncertainty in position, $\Delta p =$ Uncertainty in momentum.

  $\Delta v =$ Uncertainty in velocity, $\Delta\lambda =$ Uncertainty in wavelength.

  $m =$ mass of microscopic particle, $\lambda =$ Wavelength of microscopic particle
- Heisenberg replaced the concept of orbit by that of orbital.

Schrodinger Equation

- Schrodinger equation is central equation of wave mechanics according to following equation.

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

  $\psi =$ Wave function $= f(x, y, z)$

  $E =$ Total energy of particle

  $V =$ Potential energy of particle.
- A solution to schrodinger equation leads to infinite solution.
- Most of the solution are not realistic (or acceptable). Only few solution can be accepted.
- Each solution - $\psi(x, y, z)$ correspond to a definite energy state depends on quantum number n, l & m.

  By proper mathematical manipulation the main equation is broken in two parts and solved separately.

  (i) Radial part contain only 'r', depends on quantum number n & l.

  (ii) Angular part contain θ and ϕ, depends on quantum number l & m.

  Each ψ contain all the information about that particular quantum state.
- **Atomic Orbital :** This is a three dimensional space around the nucleus within which the probability of finding the electron is maximum.
- **Degenerate Orbital :** Orbitals with same value of n and of same sub shell are degenerate orbitals.

  For Ex. $2p_x, 2p_y, 2p_z$ etc.

- **Radial Probability Density** = $4\pi r^2 R^2(r)$

  It is the probability of finding electron in the region between r and $r + dr$
- **Radial Node :** It is zero electron density region. $R^2(r) = 0$ or $R(r) = 0$
- **Nodal Point :** It is a point $(r = 0)$ where electron density is zero.
- **Nodal Planes :** It is plane by which two lobes are separated and electron density is zero here.

Quantum Number

Four types of quantum number which are following :

- **Principal quantum number (n) :** It determine the size of an orbital. Each value of n represents a shell of orbital. Possible values of $n = 1, 2, 3, 4, \ldots\ldots\ldots\ldots$
- **Azimuthal quantum number (l) :** It determine shape of an orbital. Each value of l represents a subshell of an orbital. Possible values of $l = 0, 1, 2, \ldots\ldots\ (n-1)$
- **Magnetic quantum number (m) :** It decides orientation of orbital in space.

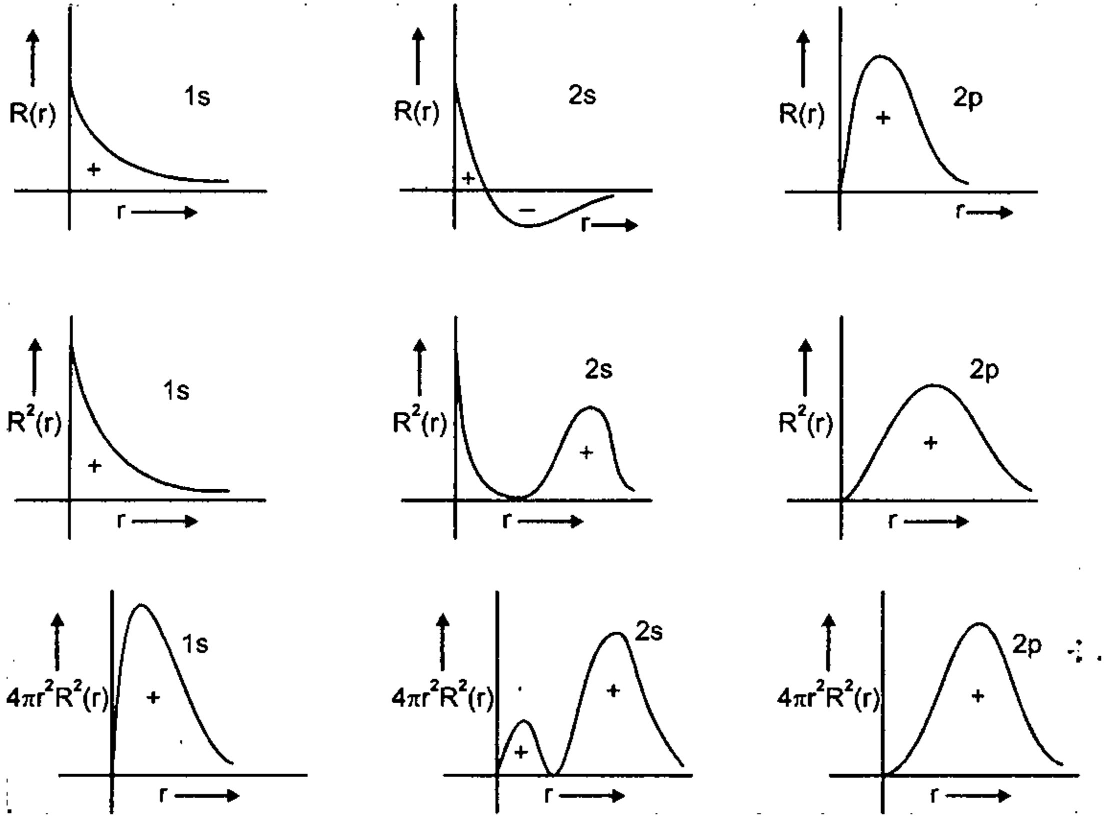
  Possible values of $m = -l, -l+1, \ldots\ldots\ 0, 1, 2, l$

  Total $(2l + 1)$ value.
- **Spin quantum number (s) :** It is intrinsic property of an electron. The electron has two spin states. Possible values of $s = +\frac{1}{2}, -\frac{1}{2}$

Shell, sub-shells and orbitals present

Shell (n)	Sub-shells (l)	Orbitals (m)
1	0	0
2	0	0
	1	±1, 0
3.	0	0
	1	±1, 0
	2	±2, ± 1, 0

Various Curves



Important Points on Quantum Number

- Orbital angular momentum $= \dfrac{h}{2\pi}\sqrt{l(l+1)}$
- Spin angular momentum $= \dfrac{h}{2\pi}\sqrt{S(S+1)}$
- Spin Magnetic moment $(\mu) = \sqrt{n(n+2)}$ B.M. ; n = number of unpaired electron
- Maximum number of electrons in a shell $= 2n^2$
- Maximum number of electrons in a subshell $= 2(2l+1)$
- Maximum number of electrons in an orbital = 2
- Total number of orbitals in a subshell $= 2l+1$
- Number of subshells in a shell $= n$
- Number of orbitals in a shell $= n^2$
- Radial Nodes $= (n-l-1)$
- Angular nodes $= l$
- Total nodes $= (n-1)$
- Azimuthal quantum number and name of sub-shell:

Azimuthal quantum number	0	1	2	3	4
Name of sub-shell	*s*	*p*	*d*	*f*	*g*

Pauli's Exclusion Principle

No two electrons in an atom can have the same set of all the four quantum numbers, *i.e.*, an orbital cannot have more than 2 electrons because three quantum numbers (principal, azimuthal and magnetic) at the most may be same but the fourth must be different, *i.e.*, spins must be in opposite directions.

Aufbau Principle

Electrons are filled in various orbitals in order of their increasing energies. An orbital of lowest energy is filled first. The sequence of orbitals in order of their increasing energy is :

$$1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s, 5f, 6d, \ldots\ldots$$

The energy of the orbitals is governed by $(n + l)$ rule.

Hund's Rule

No electron pairing takes place in the orbitals in a sub energy shell until each orbital is occupied by an electron with parallel spin. Exactly half filled and fully filled orbitals make the atoms more stable, *i.e.*, $p^3, p^6, d^5, d^{10} f^7$ and f^{14} configurations are more stable.

Level 1

1. Which of the following pair is isodiaphers?
(a) ${}^{14}_{6}C$ and ${}^{23}_{11}Na$
(b) ${}^{24}_{12}Mg$ and ${}^{23}_{11}Na$
(c) ${}^{4}_{2}He$ and ${}^{16}_{8}O$
(d) ${}^{12}_{6}C$ and ${}^{15}_{7}N$

2. Which of the following does not characterise X-rays?
(a) The radiation can ionise the gas
(b) It causes fluorescence effect on ZnS
(c) Deflected by electric and magnetic fields
(d) Have wavelength shorter than ultraviolet rays

3. The ratio of specific charge of a proton and an α-particle is
(a) 2 : 1 (b) 1 : 2 (c) 1 : 4 (d) 1 : 1

4. The increasing order for the values of e/m (charge/mass) is :
(a) e, p, n, α (b) n, p, e, α (c) n, p, α, e (d) n, α, p, e

5. The mass to charge ratio (m/e) for a cation is 1.5×10^{-8} kg/C. What is the mass of this atom?
(a) 2.4×10^{-19} g (b) 2.4×10^{-27} g (c) 2.4×10^{-24} g (d) None of these

6. Rutherford's experiment on scattering of alpha particles showed for the first time that atom has :
(a) Electrons (b) Protons (c) Nucleus (d) Neutrons

7. α-particles are represented by
(a) Lithium atoms (b) Helium nuclei (c) Hydrogen nuclei (d) None of these

8. In 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 $h/2\pi$

9. 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 times the radius of first orbit

10. The correct expression derived for the energy of an electron in the nth energy level is for H-atom
(a) $E_n = \frac{2\pi^2 me^4}{n^2h^2}$ (b) $E_n = -\frac{\pi^2 me^4}{2n^2h^2}$ (c) $E_n = -\frac{2\pi^2 me^2}{n^2h^2}$ (d) $E_n = -\frac{2\pi^2 me^4}{n^2h^2}$

11. Ionization energy for hydrogen atom in ergs, Joules and eV respectively is
(a) $21.8 \times 10^{-12}, 218 \times 10^{-20}, 13.6$
(b) $13.6 \times 218 \times 10^{-20}, 21.8 \times 10^{-13}$
(c) $21.8 \times 10^{-20}, 13.6, 21.8 \times 10^{-13}$
(d) $21.8 \times 10^{-13}, 13.6, 21.8 \times 10^{-20}$

12. For any H like system, the ratio of velocities of I, II & III orbit *i.e.*, $V_1 : V_2 : V_3$ will be
(a) 1 : 2 : 3 (b) 1 : 1/2 : 1/3 (c) 3 : 2 : 1 (d) 1 : 1 : 1

13. The volume of nucleus is about :
(a) 10^{-4} times to that of an atom (b) 10^{-15} times to that of an atom
(c) 10^{-5} times to that of an atom (d) 10^{-10} times to that of an atom

14. An electron in an atom jumps in such a way that its kinetic energy changes from x to $\frac{x}{4}$. The change in potential energy will be :
(a) $+\frac{3}{2}x$ (b) $-\frac{3}{8}x$ (c) $+\frac{3}{4}x$ (d) $-\frac{3}{4}x$

15. The potential energy of an electron in the hydrogen atom is –6.8 eV. Indicate in which excited state, the electron is present?
(a) first (b) second (c) third (d) fourth

16. What is the potential energy of an electron present in *N*-shell of the Be^{3+} ion?
(a) –3.4 eV (b) –6.8 eV (c) –13.6 eV (d) –27.2 eV

17. The kinetic and potential energy (in eV) of electron present in third Bohr's orbit of hydrogen atom are respectively :
(a) –1.51, –3.02 (b) 1.51, –3.02 (c) –3.02, 1.51 (d) 1.51, –1.51

18. The distance between 4th and 3rd Bohr orbits of He^+ is :
(a) 2.645×10^{-10} m (b) 1.322×10^{-10} m (c) 1.851×10^{-10} m (d) None

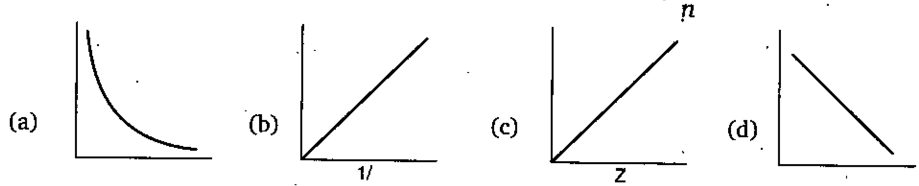
19. What atomic number of an element "*X*" would have to become so that the 4th orbit around *X* would fit inside the 1st Bohr orbit of H atom ?
(a) 3 (b) 4 (c) 16 (d) 25

20. The ratio of velocity of the electron in the third and fifth orbit of Li^{2+} would be :
(a) 3 : 5 (b) 5 : 3 (c) 25 : 9 (d) 9 : 25

21. If radius of second stationary orbit (in Bohr's atom) is *R*. Then radius of third orbit will be :
(a) *R*/3 (b) 9*R* (c) *R*/9 (d) 2.25 *R*

22. Which state of Be^{3+} has the same orbit radius as that of the ground state of hydrogen atom?
(a) 3 (b) 2 (c) 4 (d) 5

23. Select the incorrect graph for velocity of e^- in an orbit *vs.* Z, $\frac{1}{n}$ and n :



24. What is the frequency of revolution of electron present in 2nd Bohr's orbit of H-atom?
(a) 1.016×10^{16} s^{-1} (b) 4.065×10^{16} s^{-1}
(c) 1.626×10^{15} s^{-1} (d) 8.2×10^{14} s^{-1}

25. An electron travels with a velocity of x ms^{-1}. For a proton to have the same de-Broglie wavelength, the velocity will be approximately :
(a) $\frac{1840}{x}$ (b) $\frac{x}{1840}$ (c) 1840 x (d) x

26. According to Bohr's atomic theory, which of the following is correct ?

(a) Potential energy of electron $\propto \frac{Z^2}{n^2}$

(b) The product of velocity of electron and principle quantum number $(n) \propto Z^2$

(c) Frequency of revolution of electron in an orbit $\propto \frac{Z^2}{n^3}$

(d) Coulombic force of attraction on the electron $\propto \frac{Z^2}{n^2}$

27. Number of waves produced by an electron in one complete revolution in n^{th} orbit is :

(a) n (b) n^2 (c) $(n+1)$ (d) $(2n+1)$

28. Electronic transition in He^+ ion takes from n_2 to n_1 shell such that :

$2n_2 + 3n_1 = 18$

$2n_2 - 3n_1 = 6$

What will be the total number of photons emitted when electrons transit to n_1 shell ?

(a) 21 (b) 15 (c) 20 (d) 10

29. Which of the following expressions represents the spectrum of Balmer series (If n is the principal quantum number of higher energy level) in Hydrogen atom ?

(a) $\bar{v} = \frac{R(n-1)(n+1)}{n^2} \text{cm}^{-1}$ (b) $\bar{v} = \frac{R(n-2)(n+2)}{4n^2} \text{cm}^{-1}$

(c) $\bar{v} = \frac{R(n-2)(n+2)}{n^2} \text{cm}^{-1}$ (d) $\bar{v} = \frac{R(n-1)(n+1)}{4n^2} \text{cm}^{-1}$

30. 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

31. Which of the following statement does not form part of Bohr's model of the hydrogen atom ?

(a) Energy of the electrons in the orbit is quantized

(b) The electron in the orbit nearest the nucleus has the lowest energy

(c) Electrons revolve in different orbits around the nucleus

(d) The position and velocity of the electrons in the orbit cannot be determined simultaneously

32. With increasing principle quantum number, the energy difference between adjacent energy levels in H-atom:

(a) decreases

(b) increases

(c) remains constant

(d) decreases for low value of Z and increases for higher value of Z.

33. What is the separation energy (in eV) for Be^{3+} in the first excited state in eV?

(a) 13.6 eV (b) 27.2 eV (c) 40.8 eV (d) 54.5 eV

34. If in Bohr's model, for unielectronic atom, time period of revolution is represented as $T_{n,Z}$ where n represents shell no. and Z represents atomic number then the value of $T_{1,2} : T_{2,1}$ will be :

(a) 8 : 1 (b) 1 : 8 (c) 1 : 1 (d) 1 : 32

35. Which of the following is discreted in Bohr's theory?
(a) Potential energy (b) Kinetic energy
(c) Velocity (d) Angular momentum

36. What is the ratio of time periods (T_1/T_2) in second orbit of hydrogen atom to third orbit of He^+ ion?
(a) 8/27 (b) 32/27 (c) 27/32 (d) None of these

37. Be^{3+} and a proton are accelerated by the same potential, their de-Broglie wavelengths have the ratio (assume mass of proton = mass of neutron) :
(a) 1 : 2 (b) 1 : 4 (c) 1 : 1 (d) $1 : 3\sqrt{3}$

38. The mass of an electron is m, charge is e and it is accelerated from rest through a potential difference of V volts. The velocity acquired by electron will be :
(a) $\sqrt{\frac{V}{m}}$ (b) $\sqrt{\frac{eV}{m}}$ (c) $\sqrt{\frac{2eV}{m}}$ (d) zero

39. The spectrum produced from an element is :
(a) atomic spectrum (b) line spectrum
(c) absorption spectrum (d) any one of the above

40. Line spectra is characteristic of :
(a) molecules (b) atoms (c) radicals (d) none of these

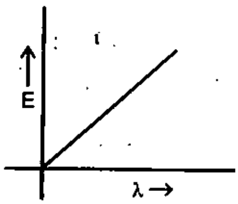
41. If the ionization energy of He^+ is 19.6×10^{-18} J per atom then the energy of Be^{3+} ion in the second stationary state is :
(a) -4.9×10^{-18} J (b) -44.1×10^{-18} J (c) -11.025×10^{-18} J (d) None of these

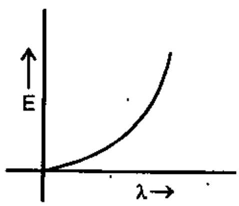
42. Find the value of wave number $(\bar{\nu})$ in terms of Rydberg's constant, when transition of electron takes place between two levels of He^+ ion whose sum is 4 and difference is 2.
(a) $\frac{8R}{9}$ (b) $\frac{32R}{9}$ (c) $\frac{3R}{4}$ (d) none of these

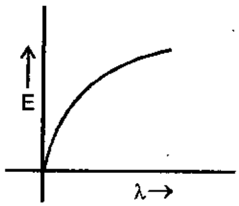
43. A H-atom moving at a speed (v) absorbs a photon of $\lambda = 122$ nm and stops. What was the speed of H-atom? $(h = 6.63 \times 10^{-34}$ J - s)
(a) 0.325 m/s (b) 1 m/s (c) 2.5 m/s (d) 3.25 m/s

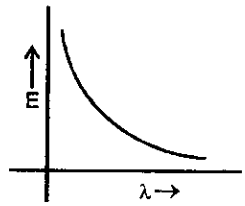
44. Assume that 2×10^{-17} J of light energy is needed by the interior of the human eye to see an object. How many photons of yellow light with $\lambda = 595.2$ nm are needed to generate this minimum energy?
(a) 6 (b) 30 (c) 45 (d) 60

45. Which graph shows how the energy E of a photon of light is related to its wavelengths (l)?

(a) 

(b) 

(c) 

(d) 

46. The mass of a particle is 10^{-10} g and its radius is 2×10^{-4} cm. If its velocity is 10^{-6} cm sec^{-1} with 0.0001% uncertainty in measurement, the uncertainty in its position is :
(a) 5.2×10^{-8} m (b) 5.2×10^{-7} m (c) 5.2×10^{-6} m (d) 5.2×10^{-9}

47. If an electron is travelling at 200 m/s within 1 m/s uncertainty, what is the theoretical uncertainty in its position in μm (micrometer)?
(a) 14.5 (b) 29 (c) 58 (d) 114

48. The energy of the second Bohr orbit in the hydrogen atom is –3.41 eV. The energy of the second Bohr orbit of He^+ ion would be :
(a) –0.85 eV (b) –13.64 eV (c) –1.70 eV (d) –6.82 eV

49. Which of the following statement(s) is/are consistent with the Bohr theory of the atom (and no others)?
(1) An electron can remain in a particular orbit as long as it continuously absorbs radiation of a definite frequency.
(2) The lowest energy orbits are those closest to the nucleus.
(3) All electrons can jump from the *K* shell to the *M* shell by emitting radiation of a definite frequency.
(a) 1, 2, 3 (b) 2 only (c) 3 only (d) 1, 2

50. Wavelength for high energy EMR transition in H-atom is 91 nm. What energy is needed for this transition?
(a) 1.36 eV (b) 1240 eV (c) 13 eV (d) 13.6 eV

51. The ionization potential for the electron in the ground state of the hydrogen atom is 13.6 eV atom^{-1}. What would be the ionization potential for the electron in the first excited state of Li^{2+}?
(a) 3.4 eV (b) 10.2 eV (c) 30.6 eV (d) 6.8 eV

52. What is the energy content per photon (J) for light of frequency 4.2×10^{14}?
(a) 2.8×10^{-21} (b) 2.5×10^{-19} (c) 2.8×10^{-19} (d) 2.5×10^{-18}

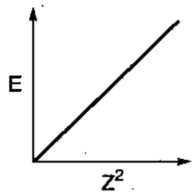
53. What is the wavelength in nm of the spectral line associated with a transition from $n = 3$ to $n = 2$ for the Li^{2+} ion?
(a) 219 (b) 656 (c) 73.0 (d) 486

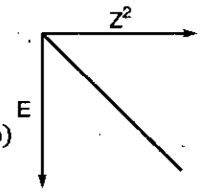
54. What is the energy (kJ/mol) associated with the de-excitation of an electron from $n = 6$ to $n = 2$ in He^+ ion?
(a) 1.36×10^6 (b) 1.36×10^3 (c) 1.16×10^3 (d) 1.78×10^3

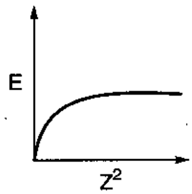
55. The momentum (in kg-m/s) of photon having 6 MeV energy is :
(a) 3.2×10^{-21} (b) 2.0 (c) 1.6×10^{-21} (d) none of these

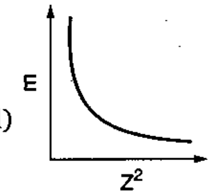
56. The H-spectrum show:
(a) Heisenberg's uncertainty principle (b) Diffraction
(c) Polarization (d) Presence of quantized energy level

57. The energy of an electron moving in n^{th} Bohr's orbit of an element is given by $E_n = \frac{-13.6}{n^2} Z^2$ eV/atom (Z = atomic number). The graph of E vs. Z^2 (keeping "n" constant) will be :

(a) 

(b) 

(c) 

(d) 

58. If ε_0 be the permittivity of vacuum and r be the radius of orbit of H -atom in which electron is revolving then velocity of electron is given by :
(a) $v = \frac{e}{\sqrt{4\pi\varepsilon_0 rm}}$ (b) $v = e \times \sqrt{4\pi\varepsilon_0 rm}$ (c) $v = \frac{4\pi\varepsilon_0 rm}{e}$ (d) $v = \frac{4\pi\varepsilon_0 rm}{e^2}$

59. What is the shortest wavelength line in the Paschen series of Li^{2+} ion?
(a) $\frac{R}{9}$ (b) $\frac{9}{R}$ (c) $\frac{1}{R}$ (d) $\frac{9R}{4}$

60. What is the maximum wavelength line in the Lyman series of He^+ ion?
(a) $3R$ (b) $\frac{1}{3R}$ (c) $\frac{4}{4R}$ (d) None of these

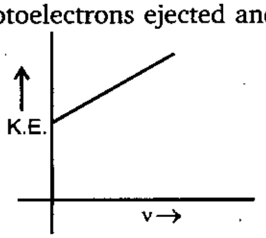
61. Splitting of spectral lines under the influence of magnetic field is called
(a) Zeeman effect (b) Stark effect
(c) Photoelectric effect (d) None of these

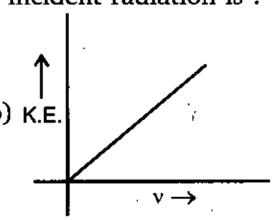
62. The colour of sky is due to
(a) Absorption of light by atmospheric gases (b) Transmission of light
(c) Wavelength of scattered light (d) All of the above

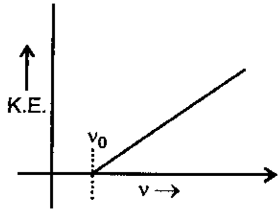
63. In photoelectric effect, the kinetic energy of photoelectrons increases linearly with the
(a) Wavelength of incident light (b) Frequency of incident light
(c) Velocity of incident light (d) Atomic mass of an element

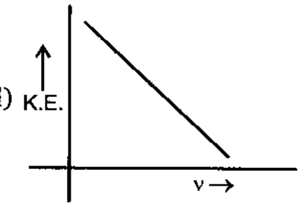
64. Slope of V_0 vs ν curve is (where V_0 = Stopping potential, ν = subjected frequency)
(a) e (b) $\frac{h}{e}$ (c) ϕ (d) h

65. According to Einstein's photoelectric equation, the graph between kinetic energy of photoelectrons ejected and the frequency of the incident radiation is :

(a) 

(b) 

(c) 

(d) 

66. The photoelectric emission from a surface starts only when the light incident upon the surface has certain minimum :
(a) intensity (b) wavelength (c) frequency (d) velocity

67. If λ_0 and λ be the threshold wavelength and the wavelength of incident light, the velocity of photo-electrons ejected from the metal surface is :
(a) $\sqrt{\frac{2h}{m}(\lambda_0 - \lambda)}$ (b) $\sqrt{\frac{2hc}{m}(\lambda_0 - \lambda)}$ (c) $\sqrt{\frac{2hc}{m}\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)}$ (d) $\sqrt{\frac{2h}{m}\left(\frac{1}{\lambda_0} - \frac{1}{\lambda}\right)}$

68. A light source of wavelength λ illuminates a metal and ejects photo-electrons with $(\text{K.E.})_{max} = 1$ eV

Another light source of wavelength $\frac{\lambda}{3}$, ejects photo-electrons from same metal with $(\text{K.E.})_{max} = 4$ eV

Find the value of work function?
(a) 1 eV (b) 2 eV (c) 0.5 eV (d) None of these

69. Electromagnetic radiation having $\lambda = 310$ Å is subjected to a metal sheet having work function $= 12.8$ eV. What will be the velocity of photo-electrons having maximum kinetic energy.
(a) 0, no emission will occur (b) 4.352×10^6 m/s
(c) 3.09×10^6 m/s (d) 8.72×10^6 m/s

70. The ratio of slopes of K_{max} *vs.* ν and V_0 *vs.* ν curves in the photoelectric effect gives (ν = frequency, K_{max} = maximum kinetic energy, V_0 = stopping potential) :
(a) charge of electron
(b) Planck's constant
(c) work function
(d) the ratio of Planck's constant of electronic charge

71. Radiation corresponding to the transition $n = 4$ to $n = 2$ in hydrogen atoms falls on a certain metal (work function = 2.5 eV). The maximum kinetic energy of the photo-electrons will be :
(a) 0.55 eV (b) 2.55 eV (c) 4.45 eV (d) None of these

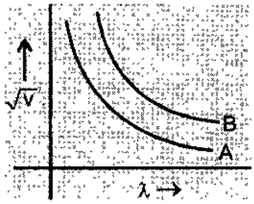
72. Select the incorrect statement :
(a) K.E. of photo-electron does not depend upon the wavelength of incident radiation
(b) Photoelectric current depends on intensity of incident radiation and not on frequency
(c) Stopping potential depends on frequency of radiation and not on intensity
(d) None of these

73. The de-Broglie wavelength of an electron accelerated by an electric field of V volts is given by :
(a) $\lambda = \frac{1.23}{\sqrt{m}}$ (b) $\lambda = \frac{1.23}{\sqrt{h}} m$ (c) $\lambda = \frac{1.23}{\sqrt{V}}$ nm (d) $\lambda = \frac{1.23}{V}$

74. Which is the de-Broglie equation:
(a) $h = p\lambda$ (b) $h = p\lambda^{-1}$ (c) $h = \lambda p^{-1}$ (d) $h = p + \lambda$

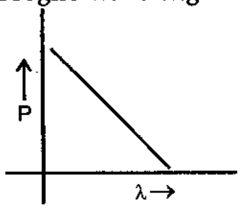
75. Which of the following has the largest de Broglie wavelength (all have equal velocity)
(a) CO_2 molecule (b) NH_3 molecule (c) Electron (d) Proton

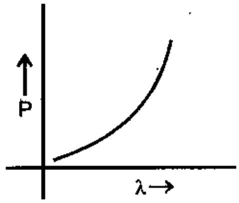
76. $\sqrt{V}$ on two particles A and B are plotted against de-Broglie wavelengths. Where V is the potential on the particles. Which of the following relation is correct about the mass of particles?

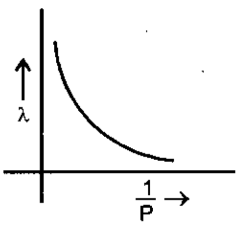


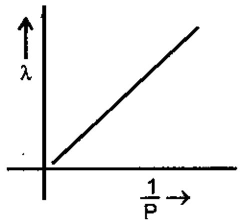
(a) $m_A = m_B$ (b) $m_A > m_B$ (c) $m_A < m_B$ (d) $m_A \le m_B$

77. Which of following graphs correctly represents the variation of particles momentum with de-Broglie wavelength ?

(a)


(b)


(c)


(d)


78. An excited state of H atom emits a photon of wavelength λ and returns in the ground state, the principal quantum number of excited state is given by :
(a) $\sqrt{\lambda R(\lambda R - 1)}$ (b) $\sqrt{\dfrac{\lambda R}{(\lambda R - 1)}}$ (c) $\sqrt{\lambda R(\lambda R - 1)}$ (d) $\sqrt{\dfrac{(\lambda R - 1)}{\lambda R}}$

79. A dye absorbs a photon of wavelength λ and re-emits the same energy into two photons of wavelengths λ_1 and λ_2 respectively. The wavelength λ is related with λ_1 and λ_2 as :
(a) $\lambda = \dfrac{\lambda_1 + \lambda_2}{\lambda_1 \lambda_2}$ (b) $\lambda = \dfrac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$ (c) $\lambda = \dfrac{\lambda_1^2 \lambda_2^2}{\lambda_1 + \lambda_2}$ (d) $\lambda = \dfrac{\lambda_1 \lambda_2}{(\lambda_1 + \lambda_2)^2}$

80. Which of the following electron transitions in a hydrogen atom will require the largest amount of energy?
(a) from $n = 1$ to $n = 2$ (b) from $n = 2$ to $n = 4$
(c) from $n = 5$ to $n = 1$ (d) from $n = 3$ to $n = 5$

81. If a_0 be the radius of first Bohr's orbit of H-atom, the de-Broglie's wavelength of an electron revolving in the second Bohr's orbit will be :
(a) $6\pi a_0$ (b) $4\pi a_0$ (c) $2\pi a_0$ (d) None of these

82. Which electronic transition in a hydrogen atom, starting from the orbit $n = 7$, will produce infrared light of wavelength 2170 nm? (Given : $R_H = 1.09677 \times 10^7\ m^{-1}$)
(a) $n = 7$ to $n = 6$ (b) $n = 7$ to $n = 5$ (c) $n = 7$ to $n = 4$ (d) $n = 7$ to $n = 3$

83. A hydrogen atom in the ground state is excited by monochromatic radiation of wavelength λ Å. The resulting spectrum consists of maximum 15 different lines. What is the wavelength λ? ($R_H = 109737\ cm^{-1}$)
(a) 937.3 Å (b) 1025 Å (c) 1236 Å (d) None of these

84. In any subshell, the maximum number of electrons having same value of spin quantum number is :
(a) $\sqrt{l(l+1)}$ (b) $l + 2$ (c) $2l + 1$ (d) $4l + 2$

85. The number of photons of light having wave number 'x' in 10 J of energy source is :
(a) $10hcx$ (b) $\frac{hc}{10x}$ (c) $\frac{10}{hcx}$ (d) None of these

86. Which of the following relates to photons both as wave motion and as a stream of particles?
(a) Interference (b) $E = mc^2$ (c) Diffraction (d) $E = h\nu$

87. Electromagnetic radiation (photon) with highest wavelength results when an electron in the hydrogen atom falls from $n = 6$ to :
(a) $n = 1$ (b) $n = 2$ (c) $n = 3$ (d) $n = 5$

88. Energy required to ionise 2 mole of gaseous He^+ ion present in its ground state is :
(a) 54.4 eV (b) $108.8\,N_A$ eV (c) $54.4\,N_A$ eV (d) 108.8 eV

89. 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) $\Delta x.\Delta v = \frac{h}{4\pi}$

90. The Heisenberg uncertainty principle can be applied to
(a) A cricket ball (b) A foot ball (c) A jet aeroplane (d) An electron

91. The wave character of electron was experimentally verified by
(a) De-Broglie (b) A. Einstein (c) Germer (d) Schrodinger

92. "The exact path of electron in 2p-orbital cannot be determined." The above statement is based upon
(a) Hund's Rule (b) Bohr's Rule
(c) Uncertainty principle (d) Aufbau principle

93. Which series of subshells is arranged in the order of increasing energy for multi-electron atoms?
(a) $6s, 4f, 5d, 6p$ (b) $4f, 6s, 5d, 6p$ (c) $5d, 4f, 6s, 6p$ (d) $4f, 5d, 6s, 6p$

94. The correct Schrodinger's wave equation for a electron with total energy E and potential energy V is given by
(a) $\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} + \frac{8\pi^2}{mh^2}(E - V)\psi = 0$ (b) $\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} + \frac{8\pi m}{h^2}(E - V)\psi = 0$

(c) $\frac{\partial^2\psi}{\partial x^2}+\frac{\partial^2\psi}{\partial y^2}+\frac{\partial^2\psi}{\partial z^2}+\frac{8\pi^2 m}{h^2}(E-V)\psi=0$ (d) None of the above

95. 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

96. $\psi^2(r,\theta,\phi)$ represents: (for schrodinger wave mechanical model)
(a) Amplitude of electron wave
(b) Probability density of electron
(c) Total probability of finding electron around nucleus
(d) Orbit

97. Radial amplitude of electron wave can be represented by
(a) $R(r)$ (b) $R^2(r)$ (c) $4\pi r^2$ (d) $4\pi r^2R^2(r)$

98. Arrange the orbitals of H-atom in the increasing order of their energy
$3p_x, 2s, 4d_{xy}, 3s, 4p_z, 3p_y, 4s$
(a) $2s < 3s = 3p_x = 3p_y < 4s = 4p_z = 4d_{xy}$
(b) $2s < 3s < 3p_x = 3p_y < 4s = 4p_z = 4d_{xy}$
(c) $2s < 3s < 3p_x = 3p_y < 4s = 4p_z = 4d_{xy}$
(d) $2s < 3s < 3p_x = 3p_y < 4s < 4p_z < 4d_{xy}$

99. Which of the following orbitals in hydrogen atom is closer to the nucleus?
(a) $5f$ (b) $6d$ (c) $7s$ (d) $7p$

100. The radii of maximum probability for $3s$, $3p$ and $3d$ electrons are in the order :
(a) $(r_{max})_{3d} > (r_{max})_{3p} > (r_{max})_{3s}$ (b) $(r_{max})_{3d} > (r_{max})_{3s} > (r_{max})_{3p}$
(c) $(r_{max})_{3s} > (r_{max})_{3p} > (r_{max})_{3d}$ (d) None of these

101. The correct order of penetrating power of $3s$, $3p$, $3d$ electrons is :
(a) $3d > 3p > 3s$ (b) $3s > 3p > 3d$ (c) $3s > 3d > 3p$ (d) $3d > 3s > 3p$

102. The correct order of total number of node of atomic orbitals is:
(a) $4f > 6s > 5d$ (b) $6s > 5d > 4f$
(c) $4f > 5d > 6s$ (d) $5d > 4f > 6s$

103. If the subsidiary quantum number of a subenergy level is 4, the maximum and minimum values of the spin multiplicities are :
(a) 9, 1 (b) 10, 1 (c) 10, 2 (d) 4, –4

104. Which two orbitals are located along the axis, and not between the axis?
(a) d_{xy}, d_{z^2} (b) d_{xy}, p_z (c) d_{yz}, p_x (d) $p_z, d_{x^2-y^2}$

105. In a set of degenerate orbitals the electrons distribute themselves to retain similar spins as far as possible. This statement is attributed to
(a) Pauli's exclusion principle
(b)Aufbau principle
(c) Hund's Rule
(d) Slater rule

106. Which of the following rules could explain the presence of three unpaired electrons in N-atom?
(a) Hund's rule (b) Aufbau's principle
(c) Heisenberg's uncertainty principle (d) Pauli's exclusion principle

107. Pauli's exclusion principle states that:
(a) Nucleus of an atom contains no negative charge
(b) Electrons move in circular orbits around the nucleus
(c) Electrons occupy orbitals of lowest energy
(d) All the four quantum numbers of two electrons in an atom cannot be equal.

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

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

109. Which of the following statements concerning the four quantum numbers is false ?
(a) n gives idea of the size of an orbital
(b) l gives the shape of an orbital
(c) m gives the energy of the electron in the orbital
(d) s gives the direction of spin of the electron in an orbital

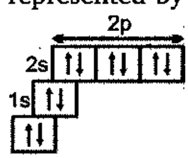
110. Maximum number of electrons in a subshell is given by
(a) $(2l+1)$ (b) $2(2l+1)$ (c) $(2l+1)^2$ (d) $2(2l+1)^2$

111. The orbital angular momentum of 3p electron is :
(a) $\sqrt{3}\,h$ (b) $\sqrt{6}\,h$ (c) zero (d) $\sqrt{2}\,\frac{h}{2\pi}$

112. The atomic orbitals are progressively filled in order of increasing energy. The principle is called as:
(a) Hund's rule (b) Aufbau principle
(c) Exclusion principle (d) de-Broglie rule

113. The orbital diagram in which both the Pauli's exclusion principle and Hund's rule are violated, is :
(a) [↑↓] [↓|↓|↓] (b) [↑↓] [↑↓|↑↓|↑] (c) [↑↓] [↑↓|↑↓|] (d) [↑↓] [↑↑|↑↓|]

114. Which of the following elements is represented by the electronic configuration ?



(a) Nitrogen (b) Fluorine (c) Oxygen (d) Neon

115. The ratio of magnetic moments of Fe (III) and Co (II) is :
(a) $\sqrt{5}:\sqrt{7}$ (b) $\sqrt{35}:\sqrt{15}$ (c) 7 : 3 (d) $\sqrt{24}:\sqrt{15}$

116. 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

117. A compound of vanadium has a magnetic moment (μ) of 1.73 BM. If the vanadium ion in the compound is present as V^{x+}, then, the value of x is?

(a) 1 (b) 2 (c) 3 (d) 4

118. d^6 configuration will result in total spin of:

(a) $\frac{3}{2}$ (b) $\frac{1}{2}$ (c) 2 (d) 1

119. The probability of finding electrons in d_{xy} orbital is :

(a) along *X*- and *Y*-axis (b) along *X*- and *Z*-axis
(c) along *Y*- and *Z*-axis (d) at an angle of 45° with *X*-axis

120. The correct order of screening effects of *s, p, d, f* sub-shells is :

(a) $s > p > d > f$ (b) $s < p < d < f$ (c) $d > p > s > f$ (d) $s > f > d > p$

121. Read the following statements and choose the correct option:

(I) If the radius of the first Bohr orbit of hydrogen atom is *r*, then radius of 2nd orbit of Li^{2+} would be 4*r*

(II) For *s*-orbital electron, the orbital angular momentum is zero

(a) only I is correct (b) only II is correct (c) both are correct (d) both are incorrect

122. The quantum numbers of four electrons (*e*1 to *e*4) are given below :

	n	*l*	*m*	*s*		*n*	*l*	*m*	*s*
*e*1	3	0	0	+1/2	*e*2	4	0	0	1/2
*e*3	3	2	2	–1/2	*e*4	3	1	–1	1/2

The correct order of decreasing energy of these electrons is :

(a) $e4 > e3 > e2 > e1$ (b) $e2 > e3 > e4 > e1$ (c) $e3 > e2 > e4 > e1$ (d) $e1 > e4 > e2 > e3$

123. 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 $2p_z$ orbital

124. How do the energy gaps between successive electron energy levels in an atom vary from low to high *n* values?

(a) All energy gaps are the same
(b) The energy gap decreases as *n* increases
(c) The energy gap increases as *n* increases
(d) The energy gap changes unpredictably as *n* increases

125. When an electron jumps from L to K shell -

(a) Energy is absorbed
(b) Energy is released
(c) Energy is neither absorbed nor released
(d) Energy is sometimes absorbed and some times released

126. The number of unpaired valence electrons in an atom of phosphorus is :

(a) 0 (b) 2 (c) 3 (d) 4

127. Which quantum number defines the orientation of orbital in the space around the nucleus?

(a) Principal quantum number (*n*) (b) Angular momentum quantum number
(c) Magnetic quantum number (m_l) (d) Spin quantum number (m_s)

128. What is the maximum number of electrons in an atom that can have the quantum numbers $n = 3$ and $l = 2$?

(a) 2 (b) 5 (c) 6 (d) 10

129. Which of the following statements about an electron with $m_l = +2$ is incorrect?
(a) The electron could be in the third shell
(b) The electron is in a non-spherical orbital
(c) The electron may have $m_s = \frac{1}{2}$
(d) The electron is not in a d-orbital

130. Which of the following set of quantum numbers is impossible for an electron?
(a) $n = 1, l = 0, m_l = 0, m_s = +\frac{1}{2}$
(b) $n = 9, l = 7, m_l = -6, m_s = -\frac{1}{2}$
(c) $n = 2, l = 1, m_l = 0, m_s = +\frac{1}{2}$
(d) $n = 3, l = 2, m_l = -3, m_s = +\frac{1}{2}$

131. In a $3d$ subshell, all the five orbitals are degenerate. What does it mean?
(a) All the orbitals have the same orientation.
(b) All the orbitals have the same shape.
(c) All the orbitals have the same energy.
(d) All the orbitals are unoccupied.

132. Which of the following subshell can accommodate as many as 10 electrons?
(a) $2d$ (b) $3d$ (c) $3d_{xy}$ (d) $3d_{z^2}$

133. Which of the following statements is correct for an electron having azimuthal quantum number $l = 2$?
(a) The electron may be in the lowest energy shell.
(b) The electron is in a spherical orbital.
(c) The electron must have spin $m_s = +\frac{1}{2}$
(d) The electron may have a magnetic quantum number $= -1$

134. Which of the following statements is incorrect?
(a) The concepts of "penetration" and "shielding" are important in deciding the energetic ordering of orbitals in multi-electron atoms
(b) A wave-function can have positive and negative values
(c) "Radial nodes" can appear in radial probability distribution functions
(d) The absolute size of an orbital is given by the principal quantum number.

135. For $4p_y$ orbital: There are
nodal plane =....and azimuthal quantum number l =
(a) 1,0 (b) 0,1 (c) 1,1 (d) 2,1

136. Which of the following statement is correct?
(a) Number of angular nodes $= n - l - 1$
(b) Number of radial nodes $= l$
(c) Total number of nodes $= n - 1$
(d) All

137. Give the correct order of initials **T** (True) or **F** (False) for following statements.
(I) If electron has zero magnetic number, then it must be present in s-orbital.
(II) In [↑↓] [↑↓][ ][↑↓] orbital diagram, Pauli's exclusion principle is violated.
(III) Bohr's model can explain spectrum of the hydrogen atom.
(IV) A d-orbital can accommodate maximum 10 electrons only.
(a) TTFF (b) FFTF (c) TFTT (d) FFTT

138. "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

139. The orbital diagraram in which both the Pauli's exclusion principle and Hund's rule are violated is :

(a) [↑↓] [↑↑ | ↑ |] (b) [↑↓] [↑↓ | | ↑↓]

(c) [↑↑] [↑ | ↑ | ↑] (d) [↑↓] [↑↓ | ↑↓ | ↑]

140. 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

141. The subshell that arises after *f* subshell is called *g* subshell. What is the total number of orbitals in the shell in which the *g* subshell first occur?

(a) 9 (b) 16 (c) 25 (d) 36

142. If hydrogen atom in ground state is passed through an inhomogeneous magnetic field, the beam splits in two parts. This interaction with magnetic field shows :

(a) existence of *ortho* and *para* hydrogen
(b) existence of magnetic moment associated with orbital motion of electron
(c) existence of spin magnetic moment of electron
(d) existence of magnetic moment of proton

143. In iron atom, how many electrons atom have $n = 3$ and $l = 2$?

(a) 2 (b) 4 (c) 6 (d) 8

144. For similar orbitals having different values of n :

(a) the most probable distance increases with increase in n
(b) the most probable distance decreases with increase in n
(c) the most probable distance remains constant with increase in n
(d) none of these

145. If n and l are principal and azimuthal quantum numbers respectively, then the expression for calculating the total number of electrons in any energy level is :

(a) $\sum_{l=0}^{l=n} 2(2l+1)$ (b) $\sum_{l=1}^{l=n} 2(2l+1)$ (c) $\sum_{l=0}^{l=n} (2l+1)$ (d) $\sum_{l=0}^{l=n-1} 2(2l+1)$

146. Maximum number of total nodes is present in :

(a) 5*s* (b) 5*p*
(c) 5*d* (d) All have same number of nodes

147. The possible correct set of quantum numbers for the unpaired electron of Cl atom is :

(a) $2, 0, 0, +\frac{1}{2}$ (b) $2, 1, -1, +\frac{1}{2}$
(c) $3, 1, 1, \pm\frac{1}{2}$ (d) $3, 0, \pm\frac{1}{2}$

148. The aufbau principle implies that a new electron will enter an orbital for which :

(a) n has a lower value (b) l has a lower value
(c) $(n + l)$ value is maximum (d) $(n + l)$ value is minimum

149. The orbital diagram in which aufbau principle is violated, is :

(a) [↑↓] [↑↑ | ↑ | ↑] (b) [↑] [↑↓ | ↑ | ↑] (c) [↑↓] [↑ | ↑ | ↑] (d) [↑↓] [↑↓ | ↑↓ | ↑]

150. Consider the following six electronic configurations (remaining inner orbitals are completely filled) and mark the incorrect option.

I. 3s [↑] 3p [↑|↑|↑] II. 3s [↑↓] 3p [↑|↑|] III. 3s [↑↓] 3d [↑|↑|↑|↑|]

IV. 4s [↑] 3d [↑|↑|↑|↑|↑] V. 4s [↑] 4p [↑|↑|↑↑] VI. 4s [↑↓] 3d [↑|↑| | |]

(a) Stability order : II > I > IV > III

(b) Order of spin multiplicity : IV > III = I > II

(c) V does not violate all the three rules of electronic configuration

(d) If VI represents A and A^+ when kept near a magnet, acts as diamagnetic substance.

151. Which of the following set of quantum numbers belong to highest energy?

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

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

152. A subshell $n = 5, l = 3$ can accommodate :

(a) 10 electrons (b) 14 electrons (c) 18 electrons (d) None of these

153. In H-atom energy of electron is determined by :

(a) only n (b) n, l

(c) n, l, m (d) all the four quantum numbers.

154. How many electron(s) in an atom can have $n = 3, l = 2$?

(a) 1 (b) 2 (c) 5 (d) 10

155. How many electrons in an atom can have $n = 4, l = 2, m = -2$ and $s = +\frac{1}{2}$?

(a) 1 (b) 2 (c) 5 (d) 10

156. Threshold frequency of a metal is f_0. When light of frequency $\nu = 2f_0$ is incident on the metal plate, maximum velocity of e^- emitted is v_1. When frequency of incident radiation is $5f_0$, maximum velocity of emitted e^- is v_2. Find ratio of $\frac{v_1}{v_2}$:

(a) 1 : 4 (b) 1 : 2 (c) 2 : 1 (d) none of these

157. Which orbital has only positive values of wave function at all distances from the nucleus :

(a) 1s (b) 2s (c) 2p (d) 3d

158. Four electrons in an atom have the sets of quantum numbers as given below. Which electron in at the highest energy level?

(a) $n = 4, l = 0, m_l = 0, m_s = +1/2$ (b) $n = 3, l = 0, m_l = 0, m_s = -1/2$

(c) $n = 3, l = 2, m_l = 0, m_s = +1/2$ (d) $n = 4, l = 1, m_l = -1, m_s = -1/2$

159. The set of quantum numbers, $n = 3, l = 2, m_l = 0$

(a) describes an electron in a 2s orbital

(b) is not allowed

(c) describes an electron in a 3p orbital

(d) describes one of the five orbitals of same energy

160. The set of quantum numbers, $n=2,\ l=2,\ m_l=0$:
(a) describes an electron in a $2s$ orbital
(b) describes one of the five orbitals of a similar type
(c) describes an electron in a $2p$ orbital
(d) is not allowed

161. Consider the argon atom. For how many electrons does this atom have $m_l=1$?
(a) 1 (b) 6 (c) 4 (d) 2

162. An orbital is occupied by an electron with the quantum numbers $n=4,\ l=1$. How many orbitals of this type are found in a multi-electron atom?
(a) $4p$, 3 (b) $4s$, 1 (c) $4d$, 5 (d) $4p$, 6

163. Which of the following sets of quantum numbers describes the electron which is removed most easily from a potassium atom in its ground state?
(a) $n=3,\ l=1,\ m_l=1,\ m_s=-\frac{1}{2}$ (b) $n=2,\ l=1,\ m_l=0,\ m_s=-\frac{1}{2}$
(c) $n=4,\ l=0,\ m_l=1,\ m_s=+\frac{1}{2}$ (d) $n=4,\ l=0,\ m_l=0,\ m_s=+\frac{1}{2}$

164. The subshell that arises after f is called the g subshell. How many electrons may occupy the g subshell?
(a) 9 (b) 7 (c) 5 (d) 18

165. Which of the following electron configurations is correct for iron, (atomic number 26)?
(a) [Kr] $4s^1 3d^6$ (b) [Kr] $4s^1 3d^7$ (c) [Ar] $4s^2 3d^6$ (d) [Kr] $4s^2 3d^6$

166. Which of the following electron configurations is correct for copper, (atomic number 29)?
(a) [Ar] $3d^{10} 4s^1$ (b) [Kr] $3d^9 4s^1$ (c) [Ar] $3d^9 4s^2$ (d) [Kr] $3d^{10} 4s^1$

167. The electronic configurations of $_{24}Cr$ and $_{29}Cu$ are abnormal
(a) Due to extra stability of exactly half filled and exactly fully filled sub shells
(b) Because they belong to d-block
(c) Both the above
(d) None of the above

168. Which of the following representation of excited states of atoms is impossible?
(a) $1s^1 2s^1$ (b) [Ne] $3s^2 3p^3 4s^1$ (c) [Ne] $3s^2 3p^6 4s^1 3d^6$ (d) $1s^2 2s^2 2p^7 3s^2$

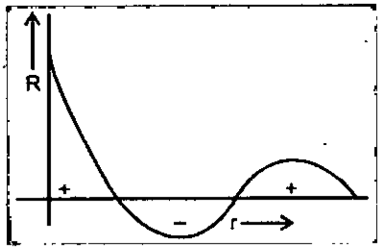
169. Among the following representations of excited states of atoms which is impossible?
(a) $1s^1 2s^1$ (b) [Ne] $3s^2 3p^3 4s^1$
(c) $1s^2 2s^2 2p^4 3s^2$ (d) [Ne] $3s^2 3p^6 4s^3 3d^2$

170. Among the following series of transition metal ions, the one where all metal ions have same $3d$ electronic configuration is:
(a) $Ti^{2+}, V^{3+}, Cr^{4+}, Mn^{5+}$ (b) $Ti^{3+}, V^{2+}, Cr^{3+}, Mn^{4+}$
(c) $Ti^{+}, V^{4+}, Cr^{6+}, Mn^{7+}$ (d) $Ti^{4+}, V^{3+}, Cr^{2+}, Mn^{3+}$

171. Which of the following has the maximum number of unpaired electrons?
(a) Mn (b) Ti (c) V (d) Al

172. Which of the following orbitals has two spherical nodes?
(a) $2s$ (b) $4s$ (c) $3d$ (d) $6f$

173. Wave function of an orbital is plotted against the distance from nucleus. The graphical representation is of:



(a) 1*s* (b) 2*s* (c) 3*s* (d) 2*p*

174. The Schrodinger wave equation for hydrogen atom is

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

where a_0 is Bohr's radius. If the radial node in 2*s* be at r_0, then r_0 would be equal to :

(a) $\frac{a_0}{2}$ (b) $2a_0$ (c) $\sqrt{2}\,a_0$ (d) $\frac{a_0}{\sqrt{2}}$

175. The Schrodinger wave equation for hydrogen atom is

$$\Psi\text{ (radial)} = \frac{1}{16\sqrt{4}}\left(\frac{Z}{a_0}\right)^{3/2}[(\sigma-1)(\sigma^2-8\sigma+12)]\,e^{-\sigma/2}$$

where a_0 and Z are the constant in which answer can be expressed and $\sigma = \frac{2Zr}{a_0}$

minimum and maximum position of radial nodes from nucleus are ......respectively.

(a) $\frac{a_0}{Z}, \frac{3a_0}{Z}$ (b) $\frac{a_0}{2Z}, \frac{a_0}{Z}$ (c) $\frac{a_0}{2Z}, \frac{3a_0}{Z}$ (d) $\frac{a_0}{2Z}, \frac{4a_0}{Z}$

Level 2

1. Potential energy of electron present in He^+ is :

(a) $\frac{e^2}{2\pi\varepsilon_0 r}$ (b) $\frac{3e^2}{4\pi\varepsilon_0 r}$ (c) $\frac{-2e^2}{4\pi\varepsilon_0 r}$ (d) $\frac{-e^2}{4\pi\varepsilon_0 r^2}$

2. A single electron in an ion has ionization energy equal to 217.6 eV. What is the total number of neutrons present in one ion of it?

(a) 2 (b) 4 (c) 5 (d) 9

3. For a hypothetical hydrogen like atom, the potential energy of the system is given by $U(r) = \frac{-Ke^2}{r^3}$, where r is the distance between the two particles. If Bohr's model of quantization of angular momentum is applicable then velocity of particle is given by :

(a) $v = \frac{n^2h^3}{Ke^2 8\pi^3 m^2}$ (b) $v = \frac{n^3h^3}{8Ke^2\pi^3 m^2}$ (c) $v = \frac{n^3h^3}{24Ke^2\pi^3 m^2}$ (d) $v = \frac{n^2h^3}{24Ke^2\pi^3 m^2}$

4. A small particle of mass m moves in such a way that P. E. $= -\frac{1}{2}mkr^2$, where k is a constant and r is the distance of the particle from origin. Assuming Bohr's model of quantization of angular momentum and circular orbit, r is directly proportional to :

(a) n^2 (b) n (c) $\sqrt{n}$ (d) none of these

5. A beam of specific kind of particles of velocity 2.1×10^7 m/s is scattered by a gold ($Z = 79$) nuclei. Find out specific charge (charge/mass) of this particle if the distance of closest approach is 2.5×10^{-14} m.

(a) 4.84×10^7 C/kg (b) 4.84×10^{-7} C/kg (c) 2.42×10^7 C/kg (d) 3×10^{-12} C/kg

6. What is the angular velocity (ω) of an electron occupying second orbit of Li^{2+} ion?

(a) $\frac{8\pi^3me^4}{h^3}K^2$ (b) $\frac{8\pi^3me^4}{9h^3}K^2$ (c) $\frac{64}{9} \times \frac{\pi^3me^4}{h^3}K^2$ (d) $\frac{9\pi^3me^4}{h^3}K^2$

7. The ratio of the radius difference between 4^{th} and 3^{rd} orbit of H-atom and that of Li^{2+} ion is :

(a) 1 : 1 (b) 3 : 1 (c) 3 : 4 (d) 9 : 1

8. The velocity of an electron in excited state of H-atom is 1.093×10^6 m/s. What is the circumference of this orbit?

(a) 3.32×10^{-10} m (b) 6.64×10^{-10} m (c) 13.30×10^{-10} m (d) 13.28×10^{-8} m

9. The angular momentum of an electron in a Bohr's orbit of He^+ is 3.1652×10^{-34} kg-m^2/sec. What is the wave number in terms of Rydberg constant (R) of the spectral line emitted when an electron falls from this level to the first excited state. [Use $h = 6.626 \times 10^{-34}$ J·s]

(a) $3R$ (b) $\frac{5R}{9}$ (c) $\frac{3R}{4}$ (d) $\frac{8R}{9}$

10. If radiation corresponding to second line of "Balmer series" of Li^{2+} ion, knocked out electron from first excited state of H-atom, then kinetic energy of ejected electron would be:

(a) 2.55 eV (b) 4.25 eV (c) 11.25 eV (d) 19.55 eV

11. When an electron makes a transition from $(n+1)$ state to nth state, the frequency of emitted radiations is related to n according to $(n >> 1)$:

(a) $\nu = \frac{2cRZ^2}{n^3}$ (b) $\nu = \frac{cRZ^2}{n^4}$

(c) $\nu = \frac{cRZ^2}{n^2}$ (d) $\nu = \frac{2cRZ^2}{n^2}$

12. In a collection of H-atoms, all the electrons jump from $n = 5$ to ground level finally (directly or indirectly), without emitting any line in Balmer series. The number of possible different radiations is :

(a) 10 (b) 8 (c) 7 (d) 6

13. An electron is allowed to move freely in a closed cubic box of length of side 10 cm. The uncertainty in its velocity will be :

(a) 3.35×10^{-3} m sec^{-1} (b) 5.8×10^{-4} m sec^{-1}

(c) 4×10^{-5} m sec^{-1} (d) 4×10^{-6} m sec^{-1}

14. An element undergoes a reaction as shown :

$X + 2e^- \longrightarrow X^{2-}$, energy released = 30.87 eV/atom. If the energy released, is used to dissociate 4 gms of H_2 molecules, equally into H^+ and H^*, where H^* is excited state of H atoms where the electron travels in orbit whose circumference equal to four times its de Broglie's wavelength. Determine the least moles of X that would be required :

Given : I.E. of H = 13.6 eV/atom, bond energy of H_2 = 4.526 eV/molecule.

(a) 1 (b) 2 (c) 3 (d) 4

15. If the energy of H-atom in the ground state is $-E$, the velocity of photo-electron emitted when a photon having energy E_p strikes a stationary Li^{2+} ion in ground state, is given by :

(a) $v = \sqrt{\frac{2(E_p - E)}{m}}$ (b) $v = \sqrt{\frac{2(E_p + 9E)}{m}}$

(c) $v = \sqrt{\frac{2(E_p - 9E)}{m}}$ (d) $v = \sqrt{\frac{2(E_p - 3E)}{m}}$

16. At which temperature will the translational kinetic energy of H-atom equal to that for H-atom of first line Lyman transition? (Given $N_A = 6 \times 10^{23}$)

(a) 780 K (b) 1.32×10^5 K

(c) 7.84×10^4 K (d) 1000 K

17. For a 3s-orbital

$$\Psi(3s) = \frac{1}{9\sqrt{3}}\left(\frac{1}{a_0}\right)^{3/2}(6 - 6\sigma + \sigma^2)\, e^{-\sigma/2}; \quad \text{where } \sigma = \frac{2r\cdot Z}{3a_0}$$

What is the maximum radial distance of node from nucleus?

(a) $\frac{(3+\sqrt{3})\,a_0}{Z}$ (b) $\frac{a_0}{Z}$

(c) $\frac{3}{2}\frac{(3+\sqrt{3})\,a_0}{Z}$ (d) $\frac{2a_0}{Z}$

18. Monochromatic radiation of specific wavelength is incident on H-atoms in ground state. H-atoms absorb energy and emit subsequently radiations of six different wavelength. Find wavelength of incident radiations:

(a) 9.75 nm (b) 50 nm
(c) 85.8 nm (d) 97.25 nm

19. The energy of a I, II and III energy levels of a certain atom are E, $\frac{4E}{3}$ and $2E$ respectively. A photon of wavelength λ is emitted during a transition from III to I. What will be the wavelength of emission for transition II to I?

(a) $\frac{\lambda}{2}$ (b) λ (c) 2λ (d) 3λ

20. Calculate the minimum and maximum number of electrons which may have magnetic quantum number, $m = +1$ and spin quantum number, $s = -\frac{1}{2}$ in chromium (Cr) :

(a) 0, 1 (b) 1, 2 (c) 4, 6 (d) 2, 3

21. An electron in a hydrogen atom in its ground state absorbs 1.5 times as much energy as the minimum required for it to escape from the atom. What is the velocity of the emitted electron?

(a) 1.54×10^6 m/s (b) 1.54×10^8 m/s
(c) 1.54×10^3 m/s (d) 1.54×10^4 m/s

22. In a measurement of quantum efficiency of photosynthesis in green plants, it was found that 10 quanta of red light of wavelength 6850 Å were needed to release one molecule of O_2. The average energy storage in this process is 112 kcal/mol O_2 evolved.
What is the energy conversion efficiency in this experiment?
Given : 1 cal = 4.18 J; $N_A = 6 \times 10^{23}$; $h = 6.63 \times 10^{-34}$ J.s

(a) 23.5 (b) 26.9
(c) 66.34 (d) 73.1

23. A hydrogen like species (atomic number Z) is present in a higher excited state of quantum number n. This excited atom can make a transition to the first excited state by successive emission of two photons of energies 10.20 eV and 17.0 eV respectively. Alternatively, the atom from the same excited state can make a transition to the second excited state by successive emission of two photons of energy 4.25 eV and 5.95 eV respectively. Determine the value of Z.

(a) 1 (b) 2 (c) 3 (d) 4

24. H-atom is exposed to electromagnetic radiation of $\lambda = 1025.6$ Å and excited atom gives out induced radiations. What is the minimum wavelength of these induced radiations?

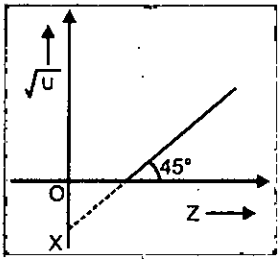
(a) 102.6 nm (b) 12.09 nm
(c) 121.6 nm (d) 810.8 nm

25. If the lowest energy X-rays have $\lambda = 3.055 \times 10^{-8}$ m, estimate the minimum difference in energy between two Bohr's orbits such that an electronic transition would correspond to the emission of an X-ray. Assuming that the electrons in other shells exert no influence, at what Z (minimum) would a transition from the second energy level to the first result in the emission of an X-ray?

(a) 1 (b) 2
(c) 3 (d) 4

26. An α-particle having kinetic energy 5 MeV falls on a Cu-foil. The shortest distance from the nucleus of Cu to which α-particle reaches is (Atomic no. of Cu = 29, $K = 9 \times 10^9 Nm^2/C^2$)
(a) 2.35×10^{-13} m
(b) 1.67×10^{-14} m
(c) 5.98×10^{-15} m
(d) None of these

27. In the graph between $\sqrt{v}$ and Z for the Mosley's equation $\sqrt{v} = a(Z - b)$, the intercept OX is −1 on $\sqrt{v}$ axis.



What is the frequency when atomic number (Z) is 51 ?
(a) 50 s^{-1}
(b) 100 s^{-1}
(c) 2500 s^{-1}
(d) None of these

28. Balmer gave an equation for wavelength of visible region of H-spectrum as $\lambda = \frac{Kn^2}{n^2 - 4}$.
Where n = principal quantum number of energy level, K = constant in terms of R (Rydberg constant). The value of K in terms of R is:
(a) R
(b) $\frac{R}{2}$
(c) $\frac{4}{R}$
(d) $\frac{5}{R}$

29. The energy of separation of an electron in a Hydrogen like atom in excited state is 3.4 eV. The de-Broglie wave length (in Å) associated with the electron is:
(Given radius of first orbit of H-atom is 0.53Å)
(a) 3.33
(b) 6.66
(c) 13.31
(d) None of these

30. If I^{st} excitation energy for the H-like (hypothetical) sample is 24 eV, then binding energy in III^{rd} excited state is:
(a) 2 eV
(b) 3 eV
(c) 4 eV
(d) 5 eV

Level 3

PASSAGE 1

Werner Heisenberg considered the limits of how precisely we can measure the properties of an electron or other microscopic particle. He determined that there is a fundamental limit to how closely we can measure both position and momentum. The more accurately we measure the momentum of a particle, the less accurately we can determine its position. The converse is also true. This is summed up in what we now call the Heisenberg uncertainty principle.

The equation is $\Delta x \cdot \Delta (mv) \geq \frac{h}{4\pi}$

The uncertainty in the position or in the momentum of a macroscopic object like a baseball is too small to observe. However, the mass of microscopic object such as an electron is small enough for the uncertainty to be relatively large and significant.

1. If the uncertainties in position and momentum are equal, the uncertainty in the velocity is :

(a) $\sqrt{\frac{h}{\pi}}$ (b) $\sqrt{\frac{h}{2\pi}}$ (c) $\frac{1}{2m}\sqrt{\frac{h}{\pi}}$ (d) none of these

2. If the uncertainty in velocity and position is same, then the uncertainty 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) $\frac{1}{m}\sqrt{\frac{h}{4\pi}}$

3. What would be the minimum uncertainty in de-Broglie wavelength of a moving electron accelerated by potential difference of 6 volt and whose uncertainty in position is $\frac{7}{22}$ nm?

(a) 6.25 Å (b) 6 Å (c) 0.625 Å (d) 0.3125 Å

PASSAGE 2

One of the fundamental laws of physics is that matter is most stable with the lowest possible energy. Thus, the electron in a hydrogen atom usually moves in the $n = 1$ orbit, the orbit in which it has the lowest energy. When the electron is in this lowest energy orbit, the atom is said to be in its ground electronic state. If the atom receives energy from an outside source, it is possible for the electron to move to an orbit with a higher n value, in which case the atoms is in an excited with a higher energy.

The law of conservation of energy says that we cannot create or destroy energy. Thus, if a certain amount of external energy is required to excite an electron from one energy level to another, then that same amount of energy will be liberated when the electron returns to its initial state.

Lyman series is formed when the electron returns to the lowest orbit while Balmer series is formed when the electron returns to second orbit. Similarly, Paschen, Brackett and Pfund series are formed when electrons returns to the third, fourth and fifth orbits from higher energy orbits respectively.

When electrons return from n_2 to n_1 state, the number of lines in the spectrum will equal to

$$\frac{(n_2 - n_1)(n_2 - n_1 + 1)}{2}$$

If the electron comes back from energy level having energy E_2 to energy level having energy E_1, then the difference may be expressed in terms of energy of photon as :

$$E_2 - E_1 = \Delta E, \ \ \Delta E \Rightarrow \frac{hc}{\lambda}$$

Since, h and c are constants, ΔE corresponds to definite energy; thus, each transition from one energy level to another will produce a radiation of definite wavelength. This is actually observed as a line in the spectrum of hydrogen atom.

Wave number of a spectral line is given by the formula

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

where R is a Rydberg's constant ($R = 1.1 \times 10^7 \text{ m}^{-1}$)

1. If the wavelength of series limit of Lyman series for He^+ ion is x Å, then what will be the wavelength of series limit of Balmer series for Li^{2+} ion?

(a) $\frac{9x}{4}$ Å (b) $\frac{16x}{9}$ Å (c) $\frac{5x}{4}$ Å (d) $\frac{4x}{7}$ Å

2. The emission spectra is observed by the consequence of transition of electron from higher energy state to ground state of He^+ ion. Six different photons are observed during the emission spectra, then what will be the minimum wavelength during the transition?

(a) $\frac{4}{27R_H}$ (b) $\frac{4}{15R_H}$ (c) $\lambda = \frac{15}{16R_H}$ (d) $\frac{16}{15R_H}$

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

(a) $n = 3$ to $n = 1$ (b) $n = 3$ to $n = 2$ (c) $n = 4$ to $n = 1$ (d) $n = 2$ to $n = 1$

4. An electron in H-atom in M-shell on de-excitation to ground state gives .... spectrum lines.

(a) 10 (b) 6 (c) 3 (d) 1

PASSAGE 3

If hydrogen atoms (in the ground state) are passed through an homogeneous magnetic field, the beam is split into two parts. This interaction with the magnetic field shows that the atoms must have magnetic moment. However, the moment cannot be due to the orbital angular momentum since $l = 0$. Hence one must assume existence of intrinsic angular momentum, which as the experiment shows, has only two permitted orientations.

Spin of the electron produce angular momentum equal to $S = \sqrt{s(s+1)}\frac{h}{2\pi}$ where $S = +\frac{1}{2}$.

Total spin of an atom $= +\frac{n}{2}$ or $-\frac{n}{2}$

where n is the number of unpaired electron.

The substance which contain species with unpaired electrons in their orbitals behave as paramagnetic substances. The paramagnetism is expressed in terms of magnetic moment.

The magnetic moment of an atom

$$\mu_s \sqrt{s(s+1)}\frac{eh}{2\pi mc} = \sqrt{\frac{n}{2}\left(\frac{n}{2}+1\right)}\frac{eh}{2\pi mc} \qquad s = \frac{n}{2}$$

$\Rightarrow \quad \mu_s = \sqrt{n(n+2)}$ B.M.

n = number of unpaired electrons

1. B.M. (Bohr magneton) $= \frac{eh}{4\pi mc}$

If magnetic moment is zero the substances is di-magnetic.

1. Which of the following ion has lowest magnetic moment.
(a) Fe^{2+} (b) Mn^{2+} (c) Cr^{3+} (d) V^{3+}

2. If an ion of $_{25}Mn$ has a magnetic moment of 3.873 B.M. Then Mn is in which state.
(a) +2 (b) +3 (c) +4 (d) +5

PASSAGE 4

Ozone in the upper atmosphere absorbs ultraviolet radiation which induces the following chemical reaction

$$O_3(g) \longrightarrow O_2(g) + O(g)$$

O_2produced in the above photochemical dissociation undergoes further dissociation into one normal oxygen atom (O) and more energetic oxygen atom O*.

$$O_2(g) \longrightarrow O + O^*$$

If (O*) has 1 eV more energy than (O) and normal dissociation energy of O_2 is 480 kJ mol^{-1}.

[1 eV/ Photon = 96 kJ mol^{-1}]

1. What is the maximum wavelength effective for the photochemical dissociation of O_2 molecule

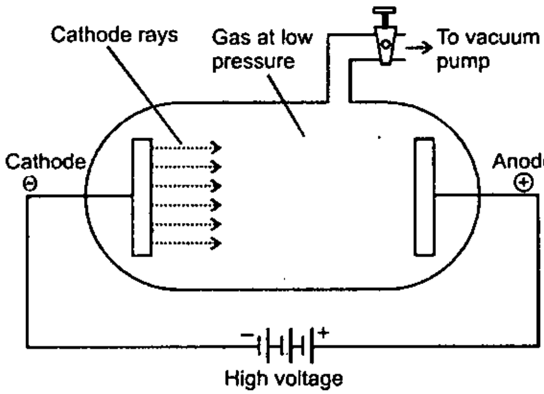
(a) 2440 Å (b) 2066.67 Å (c) 1000 Å (d) 155 Å

2. If dissociation of O_3 into O_2 and O requires 400kJ mol^{-1} and O_2 produced in this reaction is further dissociated to O and O* then the total energy required to for the dissociation of O_3 into O and O* is:

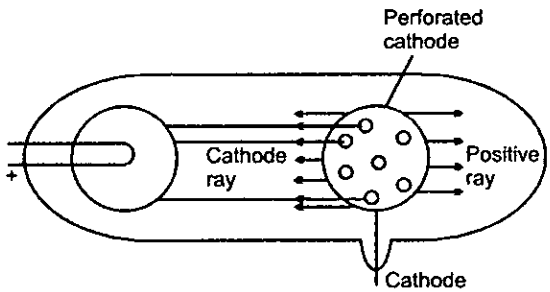
(a) 1168kJ/mol (b) 976kJ/mol (c) 880kJ/mol (d) None of these

PASSAGE 5

The existence of negatively charged particle in an atom was shown by J.J. Thomson as a result of the studies of the passage of electricity through gases at extremely low pressures known as discharge tube experiments. When a high voltage of the order of 10,000 volts or more was impressed across the electrodes, some sort of invisible rays moved from the negative electrode to the positive electrodes these rays are called as cathode rays.



Cathode rays experiment



Anode rays experiment

Properties of Cathode rays :

Cathode rays travels in straight path and produce mechanical effect. Cathode rays consist of material part and charged particles. Cathode rays produce X-rays and light is emitted when they strike on ZnS screen. Cathode rays penetrate through thin sheets of aluminium and other metals. They affect the photographic plate and passes heating effect when they strike on metal foil. The ratio of charge to mass *i.e.* charge/mass is same for all the cathode rays irrespective of the gas used in the tube.

The existence of positively charged particles in an atom was shown by E. Goldstein. He repeated the same discharge tube experiments by using a perforated cathode. It was observed that when a high potential difference was applied between the electrodes, not only cathode rays were produced but also a new type of rays were produced simultaneously from anode moving towards cathode and passed through the holes or canal of the cathode. These termed as canal ray or cathode ray.

Properties of Anode Rays are as follow :

These rays travel in straight lines and consist of positively charged particle. These rays have kinetic energy and produces heating effect also. The e/m ratio of for these rays is smaller than that of electrons. Unlike cathode rays, their e/m value is is dependent upon the nature of the gas taken in the tube. These rays produce flashes of light on Zn-S screen and can pass throughs thin metal foils. They can produce physical and chemical changes and are capable to produce ionisation in gases.

1. For cathode rays the value of e/m:
   (a) Is independent of the nature of the cathode and the gas filled in the discharge tube
   (b) Is constant
   (c) Is -1.7588×10^8 coulombs/g
   (d) All of the above are correct
2. Which is not true with respect to cathode rays ?
   (a) A stream of electrons (b) Charged particles
   (c) Move with same speed as that of light (d) Can be deflected by the electric field
3. Select the incorrect statement :
   (a) Cathode rays has charge only and no mass
   (b) Anode rays are deflected by electrical and magnetic field
   (c) Canal rays is named for beam of positive charged particle
   (d) Anode rays do not originate from the anode

ONE OR MORE ANSWERS IS/ARE CORRECT

1. Select the correct statement(s) :
   (a) The phenomena of diffraction of light can only be explained by assuming that light behaves as waves
   (b) de-Broglie postulate the dual character existed with matter
   (c) In his atomic model Bohr considered electron as a particle
   (d) Wave nature of electrons was obtained when diffraction rings were observed photographically when a stream of protons was passed through a metal foil
2. The angular momentum of electron can have the value(s) :
   (a) $0.5\frac{h}{\pi}$ (b) $\frac{h}{\pi}$ (c) $\frac{h}{0.5\,\pi}$ (d) $2.5\frac{h}{2\pi}$
3. Select incorrect statement(s) :
   (a) Only three quantum numbers n, l and m are needed to define an orbital
   (b) Four quantum numbers are needed for complete description of an electron
   (c) Two quantum numbers n and l are needed to identify subshell and shape of orbital
   (d) Splitting of spectrum lines in presence of electric field is known as Zeeman effect
4. Select the correct statement(s):
   (a) An electron near the nucleus is attracted by the nucleus and has a low potential energy
   (b) According to Bohr's theory, an electron continuously radiate energy if it stayed in one orbit
   (c) Bohr's model could not explain the spectra of multielectron atoms
   (d) Bohr's model was the first atomic model based on quantisation of energy
5. Choose the correct statement(s) :
   (a) The shape of an atomic orbital depends upon azimuthal quantum number
   (b) The orientation of an atomic orbital depends upon the magnetic quantum number
   (c) The energy of an electron in an atomic orbital of multi-electron atom depends upon principal quantum number only

(d) The number of degenerate atomic orbitals of one type depends upon the value of azimuthal quantum number

6. For radial probability curves, which of the following is/are correct?
(a) The number of maxima in 2s orbital are two
(b) The number of spherical or radial nodes is equal to $n - l - 1$
(c) The number of angular nodes are 'l'
(d) $3d_z^2$ has 3 angular nodes

7. Select the correct statement(s):
(a) Radial distribution function indicates that there is a higher probability of finding the 3s electron close to the nucleus than in case of 3p and 3d electrons
(b) Energy of 3s orbital is less than for the 3p and 3d orbitals
(c) At the node, the value of the radial function changes from positive to negative
(d) The radial function depends upon the quantum numbers n and l

8. Choose the incorrect statement(s):
(a) For a particular orbital in hydrogen atom, the wave function may have negative value
(b) Radial probability distribution function may have zero value but can never have negative value
(c) $3d_{x^2-y^2}$ orbital has two angular nodes and one radial node
(d) yz and xz planes are nodal planes for d_{xy} orbital

9. Select the correct statement(s) :
(a) Heisenberg's principle is applicable to stationary e^-
(b) Pauli's exclusion principle is not applicable to photons
(c) For an e^-, the product of velocity and principal quantum number will be independent of principal quantum number
(d) Quantum numbers l and m determine the value of angular wave function

10. Choose the correct statements among the following :
(a) A node is a point in space where the wave-function Ψ has zero amplitude
(b) The number of maxima (peaks) in radial distribution is $n - l$
(c) Radial probability density is $4\pi r^2 R_{n,l}^2(r)$
(d) Ψ^2 represents probability of finding electron

11. Select the correct statement(s) regarding $3P_y$ orbital :
(a) Total no. of nodes are 2
(b) Number of maxima in the curve $4\pi r^2 R^2$ vs r are two
(c) Quantum no. n, l and m for orbital may be 3, 1, –1 respectively
(d) The magnetic quantum number may have a positive value

12. Select the correct statement(s) :
(a) In wave mechanical model the energy of e^- in the orbital remains the same
(b) d_{xy} orbital is lies in yz plane
(c) Nodal planes are yz and xy in $d_{x^2-y^2}$ orbital
(d) Rest mass of photon is zero and increases with it's velocity

13. Hydrogen has :
(a) half filled subshell
(b) half filled shell
(c) one electron in valence shell
(d) half filled orbital

14. Select incorrect statement(s) :

(a) If the value of $l = 0$, the electrons distribution is spherical
(b) the shape of the orbital is given by magnetic quantum number
(c) Angular momentum of $1s$, $2s$, $3s$ orbit electrons are equal
(d) In an atom, all the electrons travel with the same velocity

15. The radial distribution functions $[P(r)]$ is used to determine the most probable radius, which is used to find the electron in a given orbital $\frac{dP(r)}{dr}$ for $1s$-orbital of hydrogen like atom having atomic number Z, is $\frac{dP}{dr} = \frac{4Z^3}{a_0^3}\left(2r - \frac{2Zr^2}{a_0}\right)e^{-2Zr/a_0}$:

Then which of the following statements is/are correct?

(a) At the point of maximum value of radial distribution function $\frac{dP(r)}{dr} = 0$; one antinode is present
(b) Most probable radius of Li^{2+} is $\frac{a_0}{3}$ pm
(c) Most probable radius of He^+ is $\frac{a_0}{2}$ pm
(d) Most probable radius of hydrogen atom is a_0 pm

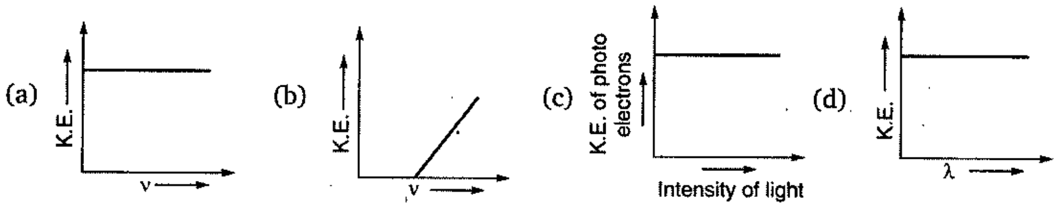
16. Select the correct statement(s) :

(a) An orbital with $l = 0$ is symmetrical about the nucleus
(b) An orbital with $l = 1$ is spherically symmetrical about the nucleus
(c) $3d_{z^2}$ is spherically symmetrical about the z-axis
(d) All are correct

17. Select the correct statement(s) :

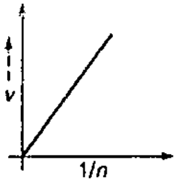
(a) Radial function $[R(r)]$ a part of wave function is dependent on quantum number n only
(b) Angular function depends only on the direction, and is independent to the distance from the nucleus
(c) $\Psi^2(r, \theta, \phi)$ is the probability density of finding the electron at a particular point in space
(d) Radial distribution function $(4\pi r^2 R^2)$ gives the probability of the electron being present at a distance r from the nucleus

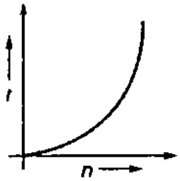
18. Which is/are correct graph?

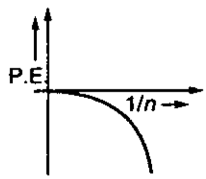


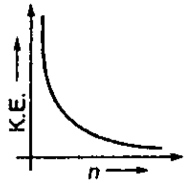
19. Select the correct curve(s) :

If v = Velocity of electron in Bohr's orbit
r = Radius of electron in Bohr's orbit
P.E. = Potential energy of electron in Bohr's orbit
K.E. = Kinetic energy of electron in Bohr's orbit

(a) 

(b) 

(c) 

(d) 

20. Select the correct set (s) of quantum number

(a) $n = 3, l = 0, m_l = -1$ (b) $n = 3, l = 3, m_l = -2$

(c) $n = 3, l = 2, m_l = -2$ (d) $n = 3, l = 1, m_l = 0$

21. Which is/are correct statement?

(a) Number of subshell present in M-shell = 3

(b) Number of orbitals present in N-shell = 16

(c) Cu^+ (z = 29) is paramagnetic

(d) Zeeman effect explains splitting of spectral lines in magnetic field.

22. In H-atom sample electrons are de-excited from 4^{th} excited state to ground state. Which is/are correct statement?

(a) No line observed in P-fund series.

(b) Total ten lines observed in spectrum.

(c) 4 line in UV-region and 3 line in visible region observed.

(d) One line observed in Brackett series.

MATCH THE COLUMN

Column-I and Column-II contains four entries each. Entries of Column-I are to be matched with some entries of Column-II. One or more than one entries of Column-I may have the matching with the same entries of Column-II.

1.

Column-I	Column-II
(A) Electron	(P) Negative charge
(B) Proton	(Q) Positive charge
(C) Neutron	(R) 1.6×10^{-19} C
(D) Positron	(S) Chargeless

2.

Column-I	Column-II
(A) Thomson model of atom	(P) Electrons are present in extra nuclear region
(B) Rutherford model of atom	(Q) Electron in the atom is described as wave
(C) Bohr model of atom	(R) Positive charge is accumulated in the nucleus
(D) Schrodinger model of hydrogen atom	(S) Uniform sphere of positive charge with embedded electrons

3.

Column-I	Column-II
(A) Atomic theory of matter	(P) Rutherford scattering experiment
(B) Quantization of charge	(Q) Muliken's oil drop experiment
(C) Quantization of electronic energy level	(R) Atomic spectra
(D) Size of nucleus	(S) Law of multiple proportions

4.

Column-I	Column-II
(A) $\frac{\text{K.E.}}{\text{P.E.}}$	(P) 2
(B) P.E. + 2 K.E.	(Q) $-\frac{1}{2}$
(C) $\frac{\text{P.E.}}{\text{T.E.}}$	(R) –1
(D) $\frac{\text{K.E.}}{\text{T.E.}}$	(S) 0

5.

Column-I	Column-II
(A) Lyman series	(P) Visible region
(B) Humphery series	(Q) Ultraviolet region
(C) Paschen series	(R) Infrared region
(D) Balmer series	(S) Far infrared region

6. In case of hydrogen spectrum wave number is given by

$$\bar{\nu} = R_H \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \quad \text{where} \quad n_1 < n_2$$

Column-I	Column-II
(A) Lyman series	(P) $n_2 = 2$
(B) Balmer series	(Q) $n_2 = 3$
(C) Pfund series	(R) $n_2 = 6$
(D) Brackett series	(S) $n_2 = 5$

7.

Column-I (Shell)	Column-II (Value of l)
(A) 2nd	(P) 1
(B) 3rd	(Q) 2
(C) 4th	(R) 3
(D) 1st	(S) 0

8. If in Bohr's model, for unielectronic atom following symbols are used

$r_{n,z} \rightarrow$ Radius of n^{th} orbit with atomic number Z;

$U_{n,z} \rightarrow$ Potential energy of e^-; $K_{n,z} \rightarrow$ Kinetic energy of e^-;

$V_{n,z} \rightarrow$ Velocity of e^-; $T_{n,z} \rightarrow$ Time period of revolution

Column-I	Column-II
(A) $U_{1,2} : K_{1,1}$	(P) 1 : 8
(B) $r_{2,1} : r_{1,2}$	(Q) –8 : 1
(C) $V_{1,3} : V_{3,1}$	(R) 1 : 9
(D) $T_{1,2} : T_{2,2}$	(S) 8 : 1

9.

Column-I	Column-II
(A) The radial node of 5*s* atomic orbital is	(P) 1
(B) The angular node of $3d_{yz}$ atomic orbital is	(Q) 4
(C) The sum of angular node and radial node of $4d_{xy}$ atomic orbital	(R) 2
(D) The angular node of 3*p* atomic orbital is	(S) 3

10.

Column-I	Column-II
(A) The *d*-orbital which has two angular nodes	(P) $3d_{x^2-y^2}$
(B) The *d*-orbital with two nodal surfaces formed cones	(Q) $3d_{z^2}$
(C) The orbital without angular node	(R) 4*f*
(D) The orbital which has three angular nodes	(S) 3*s*

11.

Column-I	Column-II
(A) Orbital angular momentum of an electron	(P) $\sqrt{s(s+1)}\,\dfrac{h}{2\pi}$
(B) Angular momentum of an electron in an orbit	(Q) $\sqrt{n(n+2)}$
(C) Spin angular momentum of an electron	(R) $\dfrac{nh}{2\pi}$
(D) Magnetic moment of atom	(S) $\sqrt{l(l+1)}\,\dfrac{h}{2\pi}$

12.

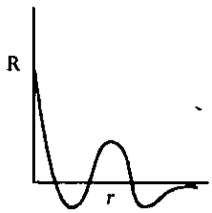
Column-I	Column-II
(A) No. of orbitals in the n^{th} shell	(P) $2(2l + 1)$
(B) Max. no. of electrons in a subshell	(Q) n
(C) No. of subshells in n^{th} shell	(R) $2l + 1$
(D) No. of orbitals in a subshell	(S) n^2

13.

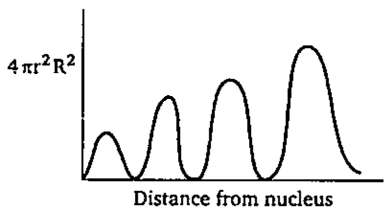
Column-I	Column-II
(A) 2s	(P) $n = 4, l = 2, m = 0$
(B) $2p_z$	(Q) $n = 4, l = 2, m = -2$ or $+2$
(C) $4d_{x^2-y^2}$	(R) $n = 2, l = 1, m = 0$
(D) $4d_{z^2}$	(S) $n = 2, l = 0, m = 0$

14.

Column-I | **Column-II**

(A) 

(P) 4s

(B) 

(Q) $5p_y$

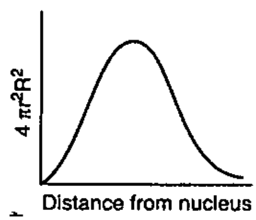
(C) Angular probability is dependent of θ and ϕ — (R) 3s

(D) Atleast one angular node is present — (S) $6d_{xy}$

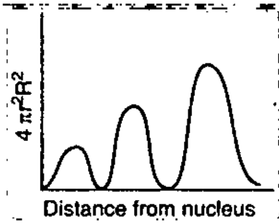
15.

Column-I | **Column-II**

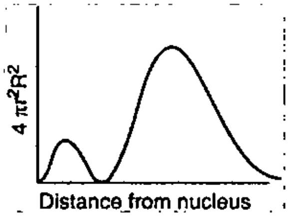
(A) 3s

(P) 

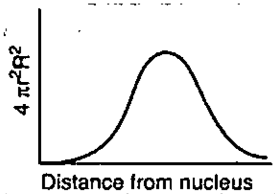
(B) $3p$ (Q)



(C) $3d$ (R)



(D) $2p$ (S)



ASSERTION-REASON TYPE QUESTIONS

Each question contains STATEMENT-1 (Assertion) and STATEMENT-2 (Reason).
Examine the statements carefully and mark the correct answer according to the instructions given below :

(A) If both the statement are TRUE and STATEMENT-2 is the correct explanation of STATEMENT-1

(B) If both the statements are TRUE but STATEMENT-2 is NOT the correct explanation of STATEMENT-1

(C) If STATEMENT-1 is TRUE and STATEMENT-2 is FALSE

(D) If STATEMENT-1 is FALSE and STATEMENT-2 is TRUE

1. **STATEMENT-1 :** The angular momentum of d-orbitals is $\sqrt{6}\,\frac{h}{2\pi}$.

   STATEMENT-2 : Angular momentum of electron in orbit is $mvr = \frac{nh}{2\pi}$.

2. **STATEMENT-1 :** Angular momentum of the electron in the orbit which has four subshell is $\frac{2h}{\pi}$.

   STATEMENT-2 : Angular momentum of electron is quantized.

3. **STATEMENT-1 :** Line emission spectra useful in the study of electronic structure.

   STATEMENT-2 : Each element has a unique line emission spectrum.

4. **STATEMENT-1 :** Emitted radiation will fall in visible range when an electron jump from $n = 4$ to $n = 2$ in H-atom.

   STATEMENT-2 : Balmer series radiations belong to visible range for hydrogen atom only.

5. **STATEMENT-1 :** Half-filled and fully-filled degenerate orbitals are more stable.
STATEMENT-2 : Extra stability is due to the symmetrical distribution of electrons and exchange energy.

6. **STATEMENT-1 :** The ground state of configuration of Cr is $3d^5 4s^1$.
STATEMENT-2 : A set of half-filled orbitals containing one electrons each with their spin parallel provides extra stability.

7. **STATEMENT-1 :** The ground state electronic configuration of nitrogen is

$$\boxed{\uparrow\downarrow} \quad \boxed{\uparrow\downarrow} \quad \boxed{\uparrow \mid \uparrow \mid \uparrow}$$

STATEMENT-2 : Electrons are filled in orbitals as per aufbau principle, Hund's rule of maximum spin multiplicity and Pauli's principle.

8. **STATEMENT-1 :** An orbital cannot have more than two electrons and they must have opposite spins.
STATEMENT-2 : No two electrons in an atom can have same set of all the four quantum numbers as per Pauli's exclusion principle.

9. **STATEMENT-1 :** Orbital having xz plane as node may be $3d_{xy}$.
STATEMENT-2 : $3d_{xy}$ has zero radial node.

10. **STATEMENT-1 :** The kinetic energy of photo-electrons increases with increase in frequency of incident light where $\nu > \nu_0$.
STATEMENT-2 : Whenever intensity of light is increased the number of photo-electron ejected always increases.

11. **STATEMENT-1 :** Cu^{2+} is a coloured ion.
STATEMENT-2 : Every ion with unpaired electron is coloured.

12. **STATEMENT-1 :** For $n = 3$, l may be 0,1 and 2 and m may be 0; 0 ± 1 ; 0 ± 1 and ± 2
STATEMENT-2 : For each value of n, there are 0 to $(n-1)$ possible values of l; and for each value of l, there are 0 to ± 1 values of m.

SUBJECTIVE PROBLEMS

1. Given $r_{n+1} - r_{n-1} = 2r_n$, where r_n, r_{n-1}, r_{n+1} are Bohr radius for hydrogen atom in n^{th}, $(n-1)^{th}$ and $(n+1)^{th}$ shell respectively. Calculate the value of n.
2. The energy of separation of an electron is 30.6 eV moving in an orbit of Li^{+2}. Find out the number of waves made by the electron in one complete revolution in the orbit.
3. Calculate the number of waves made by a Bohr electron in one complete revolution in n^{th} orbit of H-atom. If ratio of de-Broglie wavelength associated with electron moving in n^{th} orbit and 2^{nd} orbit is 1.5.
4. A certain dye absorbs lights of $\lambda = 400$ nm and then fluorescence light of wavelength 500 nm. Assuming that under given condition 40% of the absorbed energy is re-emitted as fluorescence. Calculate the ratio of quanta absorbed to number of quanta emitted out.
5. A photon of energy 4.5 eV strikes on a metal surface of work function 3.0 eV. If uncertainty in position is $\frac{25}{4\pi}$ Å. Find uncertainty in measurement of de-Broglie wavelength (in Å).

6. Find out the difference in number of angular nodes and number of radial nodes in the orbital to which last electron of chromium present.

7. What is the total number of radial and angular nodes present in $5f$ orbital ?

8. Infrared lamps are used in restaurants to keep the food warm. The infrared radiation is strongly absorbed by water, raising its temperature and that of the food. If the wavelength of infrared radiation is assumed to be 1500 nm, then the number of photons per second of infrared radiation produced by an infrared lamp that consumes energy at the rate of 100 W and is 12% efficient only is $(x \times 10^{19})$. The value of x is;

(Given : $h = 6.625 \times 10^{-34}$ J-s)

9. When an electron makes transition from $(n+1)$ state to n state the wavelength of emitted radiations is related to $n\,(n >>> 1)$ according to $\lambda \propto n^x$.

What is the value of x ?

10. For 3s orbital of hydrogen atom, the normalised wave function is

$$\psi_{3s} = \frac{1}{81\sqrt{3\pi}}\left(\frac{1}{a_0}\right)^{3/2}\left[27 - \frac{18r}{a_0} + \frac{2r^2}{a_0^2}\right]e^{\frac{-r}{3a_0}}$$

If distance between the radial nodes is d. Calculate the value of $\frac{d}{1.73a_0}$.

11. Find the separation between two electrons (in Å) in vacuum, if electrostatic potential energy between these electrons is 7.67×10^{-19}J.

[Given: $e = 1.6 \times 10^{-19}$C ; $\epsilon_0 = 8.85 \times 10^{-12}$ J^{-1} C^{2}m^{-1}, $\pi = 3.14$]

12. An α- particle moving with velocity $\frac{1}{30}$ th times of velocity of light. If uncertainty in position is $\frac{3.31}{\pi}$ pm, then minimum uncertainty in kinetic energy is $y \times 10^{-16}$J. Calculate the value of y.

13. In a sample of excited hydrogen atoms electrons make transition from $n = 2$ to $n = 1$. Emitted photons strike on a metal of work function (ϕ) 4.2eV.

Calculate the wavelength (in Å) associated with ejected electrons having maximum kinetic energy.

14. For 1s orbital of Hydrogen atom radial wave function is given as:

$$R(r) = \frac{1}{\sqrt{\pi}}\left(\frac{1}{a_0}\right)^{3/2} e^{-r/a_0} \qquad \text{(where } a_0 = 0.529\text{Å)}$$

The ratio of radial probability density of finding electron at $r = a_0$ to the radial probability density of finding electron at the nucleus is given as $(x \cdot e^{-y})$. Calculate the value of $(x + y)$.

15. Calculate the value of A.

$A = \frac{E_{1,2}}{2E_{2,1}}$ where $E_{n,z}$: Energy of electron in n^{th} orbit; Z= atomic number of hydrogen like specie.

ANSWERS

Level 1

1. (c)	2. (c)	3. (a)	4. (d)	5. (c)	6. (c)	7. (b)	8. (c)	9. (d)	10. (d)
11. (a)	12. (b)	13. (b)	14. (a)	15. (a)	16. (d)	17. (b)	18. (c)	19. (c)	20. (b)
21. (d)	22. (b)	23. (d)	24. (d)	25. (b)	26. (c)	27. (a)	28. (d)	29. (b)	30. (b)
31. (d)	32. (a)	33. (d)	34. (d)	35. (d)	36. (b)	37. (d)	38. (c)	39. (d)	40. (b)
41. (d)	42. (b)	43. (d)	44. (d)	45. (d)	46. (a)	47. (c)	48. (b)	49. (b)	50. (d)
51. (c)	52. (c)	53. (c)	54. (c)	55. (a)	56. (d)	57. (b)	58. (a)	59. (c)	60. (b)
61. (a)	62. (c)	63. (b)	64. (b)	65. (c)	66. (c)	67. (c)	68. (c)	69. (c)	70. (a)
71. (d)	72. (a)	73. (c)	74. (a)	75. (c)	76. (b)	77. (d)	78. (b)	79. (b)	80. (a)
81. (b)	82. (c)	83. (a)	84. (c)	85. (c)	86. (d)	87. (d)	88. (b)	89. (b)	90. (d)
91. (c)	92. (c)	93. (a)	94. (c)	95. (d)	96. (b)	97. (a)	98. (a)	99. (c)	100. (c)
101. (b)	102. (b)	103. (c)	104. (d)	105. (c)	106. (a)	107. (d)	108. (b)	109. (c)	110. (b)
111. (d)	112. (b)	113. (d)	114. (d)	115. (b)	116. (a)	117. (d)	118. (c)	119. (d)	120. (a)
121. (b)	122. (c)	123. (d)	124. (b)	125. (b)	126. (c)	127. (c)	128. (d)	129. (d)	130. (d)
131. (c)	132. (b)	133. (d)	134. (d)	135. (c)	136. (c)	137. (b)	138. (b)	139. (a)	140. (d)
141. (c)	142. (c)	143. (c)	144. (a)	145. (d)	146. (d)	147. (c)	148. (d)	149. (b)	150. (d)
151. (d)	152. (b)	153. (a)	154. (d)	155. (a)	156. (b)	157. (a)	158. (d)	159. (d)	160. (d)
161. (c)	162. (a)	163. (d)	164. (d)	165. (c)	166. (a)	167. (a)	168. (d)	169. (d)	170. (a)
171. (a)	172. (d)	173. (c)	174. (b)	175. (c)					

Level 2

1. (c)	2. (c)	3. (c)	4. (c)	5. (a)	6. (d)	7. (b)	8. (c)	9. (b)	10. (d)
11. (a)	12. (d)	13. (a)	14. (b)	15. (c)	16. (c)	17. (c)	18. (d)	19. (d)	20. (d)
21. (a)	22. (b)	23. (c)	24. (a)	25. (b)	26. (b)	27. (c)	28. (c)	29. (b)	30. (a)

Level 3

Passage–1	**1.** (c)	**2.** (a)	**3.** (c)	
Passage–2	**1.** (b)	**2.** (b)	**3.** (d)	**4.** (c)
Passage–3	**1.** (d)	**2.** (c)		
Passage–4	**1.** (b)	**2.** (b)		
Passage–5	**1.** (d)	**2.** (c)	**3.** (a)	

One or More Answers is/are Correct

1. (a,b,c)	**2.** (a,b,c)	**3.** (d)	**4.** (a,c,d)	**5.** (a,b,d)	**6.** (a,b,c)
7. (a,b,c,d)	**8.** (c)	**9.** (b,c,d)	**10.** (a,b,c,d)	**11.** (a,b,c,d)	**12.** (a,d)
13. (a,b,c,d)	**14.** (b,c,d)	**15.** (a,b,c,d)	**16.** (a,c)	**17.** (b,c,d)	**18.** (b,c)
19. (a,b,c,d)	**20.** (c,d)	**21.** (a,b,d)	**22.** (a,b,c,d)		

Match the Column

1.	$A \to P, R$;	$B \to Q, R$;	$C \to S$;	$D \to Q, R$
2.	$A \to S$;	$B \to P, R$;	$C \to P, R$;	$D \to P, Q, R$
3.	$A \to S$;	$B \to Q$;	$C \to R$;	$D \to P$
4.	$A \to Q$;	$B \to S$;	$C \to P$;	$D \to R$
5.	$A \to Q$;	$B \to S$;	$C \to R$;	$D \to P$
6.	$A \to P, Q, R, S$;	$B \to Q, R, S$;	$C \to R$;	$D \to R, S$
7.	$A \to P, S$;	$B \to P, Q, S$;	$C \to P, Q, R, S$;	$D \to S$
8.	$A \to Q$;	$B \to S$;	$C \to R$;	$D \to P$
9.	$A \to Q$;	$B \to R$;	$C \to S$;	$D \to P$
10.	$A \to P; Q$	$B \to Q$;	$C \to S$;	$D \to R$
11.	$A \to S$;	$B \to R$;	$C \to P$;	$D \to Q$
12.	$A \to S$;	$B \to P$;	$C \to Q$;	$D \to R$
13.	$A \to S$;	$B \to R$;	$C \to Q$;	$D \to P$
14.	$A \to P$;	$B \to P, Q, S$;	$C \to Q, S$;	$D \to Q, S$
15.	$A \to Q$;	$B \to R$;	$C \to S$;	$D \to P$

Assertion-Reason Type Questions

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

Subjective Problems

1. 2	2. 2	3. 3	4. 2	5. 4	6. 2	7. 4	8. 9	9. 3	10. 3
11. 3	12. 5	13. 5	14. 3	15. 8					

Hints and Solutions

Level 1

4. (d) Charge/mass for $n = 0$, for $\alpha = \frac{2}{4}$,

for $p = \frac{1}{1}$, for $e^- = \frac{1}{1/1837}$

14. (a) Change in P.E. $= -\frac{2x}{4} + (2x) \Rightarrow \frac{3}{2}x$

15. (a) $E_n = \frac{1}{2}$ P.E. $= -\frac{6.8}{2} = -3.4$ eV

$\because E_n \Rightarrow \frac{-13.6}{n^2} = -3.4$

$n = 2$ or first excited state

16. (d) Energy of N-shell $= \frac{-13.6 \times (4)^2}{(4)^2} = -13.6$ eV

$\therefore$ P. E. $= 2 \times E \Rightarrow 2 \times -13.6 = -27.2$ eV

17. (b) Total energy of third shell $= \frac{-13.6}{3^2}$

$= -1.51$ eV

K. E. $= -$ Total energy $\Rightarrow$ 1.51 eV

P. E. $= 2 \times$ T. E. $= -3.02$ eV

18. (c) $r = 0.529 \frac{n^2}{Z}$ Å;

$r_4 - r_3 = 0.529\left(\frac{16}{2} - \frac{9}{2}\right)$ Å $= 1.851 \times 10^{-10}$ m

19. (c) $r_1 = 0.529$ Å; $r_{4(X)} = r_1 \times \frac{n^2}{Z}$;

$r_{4(X)} \Rightarrow \frac{0.529 \times (4)^2}{Z}$; $Z = 16$

22. (b) r_1 of H-atom = 0.529 Å r_n

(n like atom) $= \frac{n^2}{Z} \times r_1$ (H-atom)

r_n of $Be^{3+} \Rightarrow \frac{n^2}{Z} \times r_1$ (H-atom)

$= 0.529$ Å ($Z = 4$ for Be^{3+})

$\Rightarrow \frac{n^2}{Z} \times 0.529 = 0.529 = n^2 = Z$

$\Rightarrow \quad n^2 = 4 = n = 2$

24. (d) Frequency of revolution

$= \frac{\text{velocity in second orbit } (V_2)}{2\pi r_2}$

$= \frac{1.082 \times 10^6 \text{ ms}^{-1}}{2 \times \pi \times (2.12 \times 10^{-10}) \text{ m}} = 8.2 \times 10^{14} \text{ s}^{-1}$

25. (b) $\lambda = \frac{h}{m_e x} = \frac{h}{m_p V} = \frac{h}{1840\, m_e V}$ $[m_p = 1840\, m_e]$

Hence, $V = \frac{x}{1840}$

26. (c) $v \propto \frac{Z}{n}$; $r \propto \frac{n^2}{Z}$;

frequency of revolution $= \frac{v_n}{2\pi r_n}$;

Coulombic force of attraction $= \frac{Ze^2}{(4\pi\varepsilon_0)\, r^2}$

33. (d) For Be^{3+} $E_\infty - E_2 = +13.6 \frac{z^2}{n^2}$

$= 13.6 \times \frac{4^2}{2^2} = 54.4$ eV

34. (d) $T \propto \frac{n^3}{Z^2}$; $\frac{T_{1,2}}{T_{2,1}} = \frac{1}{4} \times \frac{1}{8} = \frac{1}{32}$

36. (b) $T \propto \frac{n^3}{Z^2}$; $\frac{T_1}{T_2} = \frac{n_1^3}{Z_1^2} \times \frac{Z_2^2}{n_2^3}$

$= \frac{Z^3}{1} \times \frac{2^2}{3^3} = \frac{32}{27}$

37. (d) $\lambda_p = \frac{h}{\sqrt{2 eV m_p}}$

$\lambda_{Be^{3+}} = \frac{h}{\sqrt{2 \times 3\, eV\, m_{Be^{3+}}}} = \frac{h}{\sqrt{2 \times 3\, eV \times 9 m_p}}$

Hence, $\frac{\lambda_{Be^{3+}}}{\lambda_p} = \sqrt{\frac{2\, eV\, m_p}{2 \times 3\, eV \times 9 m_p}} = \frac{1}{3\sqrt{3}}$

38. (c) When an electron of charge e and mass m is accelerated with a potential difference of V volts K.E. $= eV$

$$\Rightarrow \frac{1}{2}mv^2 = eV \text{ or } v^2 = \frac{2eV}{m}$$

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

41. (d) E_H in first orbit $= \frac{-19.6 \times 10^{-18}}{4}$ J

$E_{Be^{3+}}$ in second orbit

$$= -\left(\frac{19.4 \times 10^{-18}}{4}\right) \times \frac{16}{4}$$

$$= -19.4 \times 10^{-18} \text{ J}$$

42. (b) $n_1 + n_2 = 4$; $n_2 - n_1 = 2$; $\therefore n_1 = 1$, $n_2 = 3$

$$\bar{\nu} = R(2)^2\left[\frac{1}{1^2} - \frac{1}{3^2}\right] = \frac{32R}{9}$$

43. (d) $E = (mC)C$ or momentum of photon $P = \frac{E}{C}$

$$\Rightarrow \frac{h}{\lambda} \Rightarrow \frac{6.63 \times 10^{-34}}{122 \times 10^{-9}}$$

$$P = 5.43 \times 10^{-27} \text{ kg ms}^{-1}$$

As photon is absorbed and atom stops so final momentum is zero as per law of conservation of linear momentum.

$1.67 \times 10^{-27} \times v = 5.43 \times 10^{-27}$; $v = 3.25$ m/s

44. (d) $E = n\frac{hc}{\lambda}$

$$\Rightarrow \frac{2 \times 10^{-17}}{1.6 \times 10^{-19}} \text{ eV} = n \times \frac{1240}{595.2} \times \frac{\text{eV. nm}}{\text{nm}}$$

$$\Rightarrow n = 60$$

46. (a) $m = 10^{-10}$ g $\Rightarrow 10^{-13}$ kg;

$$\Delta v = \frac{0.0001}{100} \times 10^{-6} \times 10^{-2} = 10^{-14} \text{ m sec}^{-1}$$

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

$$\Rightarrow \Delta x = \frac{h}{4\pi\Delta p} = \frac{h}{4\pi \cdot m\Delta v};$$

$$\Delta x = \frac{6.62 \times 10^{-34}}{4 \times 3.14 \times 10^{-13} \times 10^{-14}}$$

$$\Delta x = \frac{6.62}{12.56} \times \frac{10^{-34}}{10^{-27}}; \ \Delta x = 5.2 \times 10^{-8} \text{ m}$$

47. (c) $\Delta x \approx \frac{h}{4\pi\Delta p} \approx \frac{h}{4\pi \times m\Delta v}$

$$\approx \frac{6.63 \times 10^{-14}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 1}$$

$(\because \Delta v = 1 \text{ m/s})$

$$\therefore \Delta x = 58 \ \mu\text{m}$$

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

For the ionization of Li^{2+} ($Z = 3$) from first excited state, $n_1 = 2$ and $n_2 = \infty$.

Hence, IP $= \Delta E = 13.6 \times 3^2 \times \left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$

$$= 30.6 \text{ eV}$$

55. (a) $E = (mC) \cdot C$ or $P = \frac{E}{C}$

$$= \frac{6 \times 10^6 \times 1.6 \times 10^{-19}}{3 \times 10^8}$$

$$= 3.2 \times 10^{-21} \text{ kg-m/s}$$

57. (b) $\because E_n \propto -\frac{Z^2}{n^2} \Rightarrow E_n \propto -Z^2$

58. (a) $\because \frac{mv^2}{r} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Ze \cdot e}{r^2}$

$$\therefore v^2 = \frac{e^2}{4\pi\varepsilon_0 rm} \quad \text{(Hydrogen } Z = 1)$$

$$v^2 = \frac{e^2}{4\pi\varepsilon_0 rm} \Rightarrow v = \frac{e}{\sqrt{4\pi\varepsilon_0 rm}}$$

59. (c) $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R \times 3^2\left[\frac{1}{3^2} - \frac{1}{\infty^2}\right]$

$$\Rightarrow R \text{ or } \lambda = \frac{1}{R}$$

60. (b) $\frac{1}{\lambda} = RZ^2\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] = R \times 2^2\left[\frac{1}{1^2} - \frac{1}{2^2}\right]$

$$\Rightarrow 3R; \ \lambda = \frac{1}{3R}$$

67. (c) As per Einstein's equation of photoelectric effect $h\nu = h\nu_0 + \text{K.E.}$

$$\therefore \frac{1}{2}mv^2 = h\nu - h\nu_0 = \frac{hc}{\lambda} - \frac{hc}{\lambda_0}$$

$$v^2 = \frac{2hc}{m}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right);$$

$$v = \left[\frac{2hc}{m}\left(\frac{1}{\lambda} - \frac{1}{\lambda_0}\right)\right]^{1/2}$$

$$\Rightarrow \left[\frac{2hc}{m}\left(\frac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)\right]^{1/2}$$

68. (c) $\frac{hc}{\lambda} = 1 + \phi$ ...(1)

$3 \times \frac{hc}{\lambda} = 4 + \phi$ ...(2)

from, eq. (1) and (2) $\phi = 0.5$ eV

69. (c) $\frac{1}{2}mv^2 = \frac{1240 \text{ eV nm}}{31 \text{ nm}} = 12.8 \text{ eV} = 27.2 \text{ eV}$

$= \frac{1}{2} \times 9.1 \times 10^{-31} \times v^2 = 27.2 \times 1.6 \times 10^{-19}$

$v = 3.09 \times 10^6$ m/s

70. (a) $h\nu = h\nu_0 + eV_0$; $eV_0 = h\nu - h\nu_0$ or

$V_0 = \frac{h}{e}\nu - \frac{h}{e}\nu_0$; slope$_1 = \frac{h}{e}$

Similarly, $h\nu = h\nu_0 + K_{max}$

or $K_{max} = h\nu - h\nu_0$;

slope$_2 = h$, $\frac{\text{slope}_2}{\text{slope}_1} = \frac{h}{h/e} = e$

71. (d) $E_n = -\frac{13.6}{n^2}$ eV; $E_2 = -\frac{13.6}{2^2}$;

$E_4 = -\frac{13.6}{4^2}$ eV/atom

$\Delta E = E_4 - E_2 = 2.55$ eV

Absorbed energy = work function of metal + K.E.

2.55 = 2.5 + K.E.; K.E. = 0.05 eV

73. (c) $\lambda = \frac{h}{\sqrt{2eVm}} = \frac{1.23}{\sqrt{V}}$ nm

78. (b) $\because$ $\frac{1}{\lambda} = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$; $n_1 = 1$, $n_2 = ?$;

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

$\Rightarrow n_2 = \sqrt{\frac{\lambda R}{\lambda R - 1}}$

79. (b) $E = E_1 + E_2$; $\frac{hc}{\lambda} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$

$\Rightarrow \frac{hc}{\lambda} = hc\left(\frac{\lambda_2 + \lambda_1}{\lambda_1\lambda_2}\right)$; $\lambda = \frac{\lambda_1\lambda_2}{\lambda_1 + \lambda_2}$

80. (a) For the transition $n = 1$ to $n = 2$, the energy change, ΔE is positive, *i.e.*, energy is absorbed. For the transition $n = 5$ to $n = 1$, ΔE is negative, *i.e.*, energy is released.

81. (b) $\because$ $mvr_n = \frac{nh}{2\pi}$ and $p = \frac{h}{\lambda}$

$= pr_2 = \frac{2 \times h}{2 \times \pi} \Rightarrow \frac{h}{\pi}$

or $\frac{h}{\lambda} \cdot r_2 = \frac{h}{\pi} \Rightarrow \lambda = \pi r_2$,

$\therefore$ $r_2 = 4a_0$;

$\therefore$ $\lambda = 4a_0\pi$

82. (c) For hydrogen atom

$\frac{1}{\lambda} = R_H\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$;

$\lambda = 2170 \text{ nm} = 2170 \times 10^{-9}$ m;

$R_H = 1.09677 \times 10^7 \text{ m}^{-1}$

$\therefore$ $\frac{10^9}{2170} = 1.09677 \times 10^7\left[\frac{1}{n_1^2} - \frac{1}{7^2}\right]$; $n_1 = 4$

So, electron transition from $n = 7$ to $n = 4$ will produce infrared light of wavelength 2170 nm.

83. (a) Total number of spectral lines given by

$\frac{1}{2}[n-1] \times n = 15$; $\therefore$ $n = 6$

Thus, electron is excited upto 6[th] energy level from ground state. Therefore,

$\frac{1}{\lambda} = R_H\left[\frac{1}{1^2} - \frac{1}{n^2}\right] = 109737 \times \frac{35}{36}$;

$\lambda = 9.373 \times 10^{-6} \text{ cm} = 937.3$ Å

84. (c) Maximum number of electrons with same spin is equal to maximum number of orbitals, *i.e.*, $(2l + 1)$.

85. (c) $E = \frac{nhc}{\lambda} = nhc\bar{\nu}$ $\left(\because \bar{\nu} = \frac{1}{\lambda}\right)$

$\therefore$ $10 = nhc\bar{\nu}$ or $n = \frac{10}{hc\bar{\nu}} = \frac{10}{hcx}$

88. (b) I. E. $= +13.6 \times \frac{Z^2}{n^2}$ eV $= 13.6 \times 4 = 54.4$ eV

for 2 mole $= 54.4 \times 2 \times N_A$ eV $= 108.8\, N_A$ eV

93. (a) Use $(n + l)$ rule.

99. (c) 7s orbital, with low value of $(n + l)$.

103. (c) $l = 4$;

number of degenerate orbitals $= 2l + 1 = 9$;

maximum total spins $= 9 \times \frac{1}{2}$

maximum multiplicity $= 2S + 1$

$= 2 \times \frac{9}{2} + 1 = 10$

minimum total spins $= \frac{1}{2}$

minimum multiplicity $= 2 \times \frac{1}{2} + 1 = 2$

108. (b) $4f$ has the highest energy among $3d$, $4f$, $4p$, $5s$ orbitals.

111. (d) Orbital angular momentum $= \sqrt{l(l+1)}\,\frac{h}{2\pi}$; $l = 1$ for p-orbital.

115. (b) Fe(III)—[Ar] $3d^5$; unpaired electrons = 5;

magnetic moment $= \sqrt{5(5+2)}$ BM

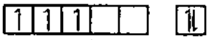
Co(II)—[Ar] $3d^7$; unpaired electrons = 3;

magnetic moment $= \sqrt{3 \times (3+2)}$ BM

117. (d) Given $\mu = \sqrt{n(n+2)} = 1.73$ BM

(where n is number of unpaired electrons)

$\therefore n = 1$; $_{23}V = 1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^3$



$3d^3$ $4s^2$

for $n = 1$ it must release 4 electrons, first two from 4s-orbital and then next two electrons from 3d-orbital. So, $x = 4$.

120. (a) The order of screening effects of sub-shells is $s > p > d > f$.

141. (c) For f subshell $l = 3$; $\therefore$ g subshell $l = 4$

for principal shell, $l = 4, n = 5$

total no. of orbital in shell $= n^2 = 5^2 = 25$

147. (c) Unpaired electron of Cl atom is $3p^1$ for which $n = 3$,

$l = 1, m = -1, 0$ or $+1$ and $s = \pm\frac{1}{2}$

150. (d) A : excitation possible only in d-orbitals

B : Spin multiplicity $= 2|S| + 1$; $|S|$ = total spin

C : V violated Hund's rule

D : A^+ is paramagnetic due to unpaired e^-

$\therefore$ A, B, C are correct.

151. (d) Orbitals are $4s$, $2s$, $3p$ and $3d$. Out of these $3d$ has highest energy.

172. (d) No. of spherical nodes $= n - l - 1$;

for s, p, d, f values of $l = 0, 1, 2, 3$ respectively.

175. (c) Probability of finding e^- is zero implies that $\Psi^2 = 0$ or $\Psi = 0$

$\Rightarrow \quad (\sigma - 1) = 0 \Rightarrow \sigma = 1$

or $\quad r_1 = \frac{a_0}{2z}$ or $(\sigma^2 - 8\sigma + 12) = 0$

and $\quad (\sigma - 6)(\sigma - 2) = 0$

$\sigma = 6,\ r = \frac{3a_0}{z}$

and $\quad \sigma = 2,\ r = \frac{a_0}{z}$

$r_2 = \frac{3a_0}{z}$

Level 2

1. (c) $\quad$ P.E. $= \frac{1}{4\pi\varepsilon_0}\frac{(+Ze)(-e)}{r}$

$= \frac{1}{4\pi\varepsilon_0}\frac{(+2e)(-e)}{r} = -\frac{e^2}{2\pi\varepsilon_0 r}$

2. (c) Ionization energy :

$-217.6 = -13.6 \times \frac{Z^2}{1^2}$; $\quad Z = 4$ m

So, it is $^9_4Be^{3+}$; no. of neutrons $9 - 4 = 5$

3. (c) $\frac{d[U(r)]}{dr} = \frac{3Ke^2}{r^4} \Rightarrow$ Magnitude of the force

$\therefore \quad \frac{3Ke^2}{r^4} = \frac{mv^2}{r}$

and we know $mvr = \frac{nh}{2\pi}$ or $r = \frac{nh}{2\pi m \cdot v}$,

$3Ke^2 \times \frac{8\pi^3 m^3 v^3}{n^3 h^3} = mv^2, \quad v = \frac{n^3 h^3}{24Ke^2\pi^3 m^2}$

4. (c) $\quad -\frac{1}{2} \times$ P.E. = K.E

$= -\frac{1}{2}\left(-\frac{1}{2}mkr^2\right) = \frac{1}{2}mv^2, \quad mvr = \frac{nh}{2\pi}$,

$v^2 = \frac{n^2h^2}{4\pi^2 m^2 r^2}$; $\quad r^4 = \frac{n^2h^2}{2\pi^2 m^2 k^2}$

or $\quad r \propto \sqrt{n}$

5. (a) $\frac{1}{2}mv^2 = \frac{k(q_1)q_2}{r} \Rightarrow \frac{q_2}{m} = \frac{r.v^2}{2k.q_1.Z}$

$\frac{q_2}{m} = \frac{2.5 \times 10^{-14} \times (2.1 \times 10^7)^2}{2 \times 9 \times 10^9 \times 79 \times 1.6 \times 10^{-19}}$

$\Rightarrow \quad 4.84 \times 10^7$ coulomb/kg

6. (d) $\quad v = r\omega$ where $r_n = \frac{n^2h^2}{4\pi^2 me^2 Z \cdot K}$

and $\quad v_n = \frac{2\pi \cdot Z \cdot e^2 \cdot K}{n \cdot h}$

$\therefore \frac{2\pi Ze^2 \cdot K}{n \cdot h} = \frac{n^2h^2}{4\pi^2 me^4 Z \cdot K} \times \omega$;

$$\omega = \frac{8\pi^3 me^4 \cdot Z^2 \cdot K^2}{n^3 \cdot h^3}$$

$$= \frac{9\pi^3 me^4 \cdot K^2}{h^2} \quad (\because n = 2 \text{ and } Z = 3)$$

7. (b) $r_n \propto \frac{v^2}{Z}$; for H, $r_4 - r_3 = 0.529(16 - 9)$

$\Rightarrow 0.529 \times 9$ Å

$r_4 - r_3$ for Li^{2+} $\Rightarrow 0.529\left(\frac{16}{3} - \frac{9}{3}\right)$

$\Rightarrow 0.529 \times \frac{7}{3}$ so ratio $\frac{7}{7/3} = 3:1$

8. (c) $v_n = 2.186 \times 10^6 \frac{Z}{n}$

$\Rightarrow 1.093 \times 10^6 = 2.186 \times 10^6 \times \frac{1}{n}; n = 2$

from Bohr theory we know $2\pi r = n\lambda$

$\Rightarrow 2\lambda$, where $\lambda = \frac{h}{mv}$

or $r = 0.529 \frac{n^2}{Z} \Rightarrow 0.529 \times 4$ Å

$\therefore$ Circumference of the orbit

$\Rightarrow 2 \times \frac{22}{7} \times 0.529 \times 4 \times 10^{-10}$

$\Rightarrow 13.30 \times 10^{-10}$ m

9. (b) Angular momentum $= \frac{nh}{2\pi}$

$3.1652 \times 10^{-34} = \frac{n \times 6.626 \times 10^{-34}}{2\pi}$;

$n = 3$

$\therefore \quad \bar{v} = R \cdot Z^2 \cdot \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$;

$\bar{v} = R \cdot 2^2 \left(\frac{1}{2^2} - \frac{1}{3^2}\right) \Rightarrow \frac{5R}{9}$

10. (d) Energy of photon corresponding to second line of Balmer series for Li^{2+} ion

$= (13.6) \times (3)^2 \left[\frac{1}{2^2} - \frac{1}{4^2}\right]$

$= 13.6 \times \frac{27}{16}$

Energy needed to eject electron from $n = 2$ level in H-atom;

$= 13.6 \times 1^2 \times \left[\frac{1}{2^2} - \frac{1}{\infty^2}\right] \Rightarrow \frac{13.6}{4}$

K.E. of ejected electron

$= 13.6 \times \frac{9 \times 3}{16} - \frac{13.6}{4} = 13.6 \times \left(\frac{27 - 4}{16}\right)$

$\Rightarrow$ 19.55 eV

11. (a) $\frac{1}{\lambda} = RZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$, where $n_1 = n$,

$n_2 = n + 1$

$\therefore \quad \frac{1}{\lambda} = RZ^2\left(\frac{1}{n^2} - \frac{1}{(n+1)^2}\right)$

$\Rightarrow \quad \frac{1}{\lambda} = \left(\frac{2n+1}{n^2(n+1)^2}\right) RZ^2$

Since, $n >> 1$;

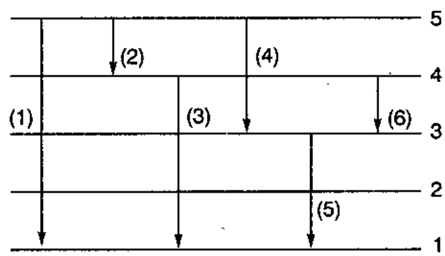
Therefore, $2n + 1 \approx 2n$

and $(n+1)^2 \approx n^2$

$\therefore \quad \frac{1}{\lambda} = RZ^2\left(\frac{2n}{n^2 \cdot n^2}\right)$

$\Rightarrow \quad \frac{v}{c} = \frac{2RZ^2}{n^3}$ or $v = \frac{2cRZ^2}{n^3}$

12. (d)



Total radiations are = 6

13. (a) If a is side of cube, then $\Delta x = a\sqrt{3}$

$\therefore \quad \Delta x = 10\sqrt{3}$ cm $= 10\sqrt{3} \times 10^{-3}$m

$\Delta x \cdot \Delta p = \frac{h}{4\pi}$; $\quad \Delta x \cdot m \cdot \Delta v = \frac{h}{4\pi}$

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

$= \frac{6.63 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 10 \times \sqrt{3} \times 10^{-3}}$

$\therefore \Delta v \approx 3.34 \times 10^{-3}$ ms^{-1}

14. (b) $2\pi r = 4\lambda$; $\quad n = 4$

Total energy required + total energy released = 0

$2 \times 4.526 \text{ eV} \times N_A + 2 \times 13.6 \times N_A + 2 \times 13.6 \times \left(1 - \frac{1}{16}\right) \times N_A - 30.87 \times x \times N_A = 0$

$x = 2 \quad \therefore$ moles of X required = 2

15. (c) Work function for $Li^{2+} = 9E$.

$E_p = w + \frac{1}{2}mv^2$; $\quad E_p = 9E + \frac{1}{2}mv^2$

$$v = \sqrt{\frac{2(E_p - 9E)}{m}}$$

16. (c) $E = hc\bar{\nu} \Rightarrow 1.63 \times 10^{-18}$ J

where $\bar{\nu} = R(1)^2 \left(\frac{1}{1^2} - \frac{1}{2^2}\right) \Rightarrow \frac{3}{4}R$

Translational K.E. of H-atom $= \frac{3}{2} \times \frac{R}{N_A} \times T$

$$\frac{3}{2} \times \frac{8.314}{6 \times 10^{23}} \times T = 1.63 \times 10^{-18}$$

$$T = 7.84 \times 10^4 \text{ K}$$

17. (c) Radial node occurs where probability of finding e^- is zero.

$\therefore \ \psi^2 = 0$ or $\psi = 0$

$\therefore \ 6 - 6\sigma + \sigma^2 = 0; \quad \sigma = 3 \pm \sqrt{3}$

For max. distance $r = \frac{3}{2} \frac{(3 + \sqrt{3})a_0}{Z}$

18. (d) $\frac{n(n-1)}{2} = 6; n = 4,$

$n = 4 \qquad E_4 = -0.85$ eV

$n = 1 \qquad E_1 = -13.6$ eV

$\therefore \quad \Delta E = 12.75$ eV

$$12.75 \text{ eV} = \frac{1240 \text{ eV-nm}}{\lambda}$$

$$\lambda = 97.25 \text{ nm}$$

19. (d) For II to I transition

$\Delta E = \frac{4E}{3} - E = \frac{hc}{\lambda_{II \to I}}; \quad \boxed{\frac{E}{3} = \frac{hc}{\lambda_{II-I}}}$

For III to I transition

$\Delta E = 2E - E = \frac{hc}{\lambda}$ or $E = \frac{hc}{\lambda}$

$\therefore \quad \frac{hc}{3 \times \lambda} = \frac{hc}{\lambda_{II-I}} \quad \lambda_{II-I} = 3\lambda$

20. (d)

1s	2s	2p	3s	3p	4s
↑↓	↑↓	↑↓ ↓↑ ↑↓	↓↑	↓↑ ↑↓ ↓↑	↑

3d
↑ ↑ ↑ ↑ ↑

Out of 6 electrons in 2p and 3p must have on electron with $m = +1$ and $s = -\frac{1}{2}$ but in 3d-subshell an orbital having $m = +1$ may have spin quantum no. $-\frac{1}{2}$ or $+\frac{1}{2}$.

Therefore, minimum and maximum possible values are 2 and 3 respectively.

21. (a) Energy absorbed $= 13.6 \times 1.5 = 20.4$ eV of this 6.8 eV is converted to K.E.

6.8 eV $\Rightarrow 6.8 \times 1.6 \times 10^{-19}$ J;

$6.8 \times 1.6 \times 10^{-19} = \text{K.E.} \Rightarrow \left(\frac{1}{2}\right) mv^2$

$$v = \sqrt{\frac{2KE}{m}} = \sqrt{\frac{2 \times 1.088 \times 10^{-18}}{9.1 \times 10^{-31}}}$$

$$= 1.54 \times 10^6 \text{ m/s}$$

22. (b) $E = \frac{hc}{\lambda} = 2.9 \times 10^{-19}$ J

Total energy of 10 quanta

$\Rightarrow 10 \times 2.9 \times 10^{-19} \Rightarrow 29 \times 10^{-19}$ J

Energy stored for process

$$= \frac{112 \times 4.18 \times 10^3}{6 \times 10^{23}} = 7.80 \times 10^{-19} \text{ J}$$

% efficiency $= \frac{7.8 \times 10^{-19}}{29 \times 10^{-19}} \times 100 \Rightarrow 26.9\%$

23. (c) Total energy emitted by photo-electron

$= 10.2 + 17 = 27.20$ eV

Since, E_1 = Photon of energy emitted through the transition

$n = n$ to $n = 2 \Rightarrow \frac{hc}{\lambda_1} = 27.20$ eV

We have $\frac{1}{\lambda_1} = R_H \cdot Z^2 \left(\frac{1}{2^2} - \frac{1}{n^2}\right)$

or $\quad \frac{hc}{\lambda_1} = (hc)R_H \cdot Z^2 \left(\frac{1}{2^2} - \frac{1}{n^2}\right)$

$\therefore \ 27.20 = (hc)\, R_H\, Z^2 \left(\frac{1}{4} - \frac{1}{n^2}\right) \quad \ldots(1)$

Similarly, total energy liberated during transition of electron from $n = n$ to $n = 3$ is

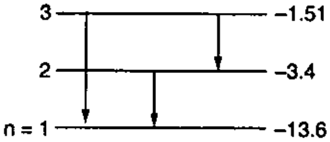
$E_2 = \frac{hc}{\lambda_2} = (4.25 + 5.95) = 10.20$ eV

$\therefore \quad 10.20 = (hc)\, R_H\, Z^2 \left(\frac{1}{9} - \frac{1}{n^2}\right) \quad \ldots(2)$

Dividing Eq. (1) by (2), we get $n = 6$ and putting $n = 6$ in Eq. (1) or (2), we get, $Z = 3$.

24. (a) $\Delta E = \frac{hc}{\lambda} \Rightarrow \frac{1240 \text{ eV-nm}}{1025.6 \times 10^{-10} \times 10^9}$

$\Delta E = 12.09$ eV



ΔE = 12.09 ; ∴ n = 3

In three different radiations, minimum wavelength for 3 → 2 transition

$$\lambda_{3-1} = \frac{hc}{\Delta E} \Rightarrow \frac{1240 \text{ eV-nm}}{12.09 \text{ eV}} \approx 102.6 \text{ nm}$$

25. (b) $\Delta E = \frac{hc}{\lambda} = \frac{(6.63 \times 10^{-34} \text{J-s})(3.00 \times 10^8 \text{ m/s})}{3.055 \times 10^{-8} \text{ m}}$

$= 6.52 \times 10^{-18}$ J

$\Delta E_H = \frac{3}{4}(2.176 \times 10^{-18} \text{ J})$

$= 1.63 \times 10^{-18}$ J; $\Delta E = \Delta E_H(Z^2)$

$Z^2 = \frac{\Delta E}{\Delta E_H} = \frac{(6.52 \times 10^{-18})}{(1.63 \times 10^{-18})} = 4;$

$Z = 2$ (helium)

26. (b) K.E. $= \frac{K.Ze.2e}{r}$

$r = \frac{9 \times 10^9 \times 29 \times 2 \times (1.6 \times 10^{-19})^2}{5 \times 1.6 \times 10^{-19} \times 10^6}$

$r = \frac{9 \times 10^9 \times 29 \times 2 \times 1.6 \times 10^{-19}}{5 \times 10^6}$

$= 1.67 \times 10^{-14}$ m

27. (c) $\sqrt{v} = aZ - ab$

$ab = 1,\ a = \tan 45° = 1$

$\sqrt{v} = 51 - 1 = 50$

$v = 50^2 = 2500\, s^{-1}$

28. (c) $\frac{1}{\lambda} = R\left[\frac{1}{2^2} - \frac{1}{n^2}\right] = R\left[\frac{n^2-4}{4n^2}\right]$

$\lambda = \frac{4}{R} \times \frac{n^2}{n^2-4}$ ...(1)

Given: $\lambda = k \times \frac{n^2}{n^2-4}$ ...(2)

Comparing equation (1) and (2) we have

$K = \frac{4}{R}$

29. (b) $2\pi r_n = n\lambda \Rightarrow 2\pi \times 0.53\frac{n^2}{z} = n\lambda$

$\lambda = 2\pi \times 0.53 \times \frac{n}{z}$ ...(1)

$E_{sep} = 3.4 = 13.6\frac{z^2}{n^2} \Rightarrow \frac{n}{z} = 2$

$\lambda = 2p \times 0.53 \times 2 = 6.66$ Å

Level 3

Passage-1

1. (c) $\Delta x\, \Delta p = \frac{h}{4\pi} \Rightarrow \Delta p^2 = \frac{h}{4\pi}$

$\Rightarrow m^2 \Delta v^2 = \frac{h}{4\pi} \Rightarrow \Delta v = \frac{1}{2m}\sqrt{\frac{h}{\pi}}$

2. (a) $\Delta x = \sqrt{\frac{h}{4\pi m}}$; $\Delta x\, \Delta p = \frac{h}{4\pi}$

$\sqrt{\frac{h}{4\pi m}}\, \Delta p = \frac{h}{4\pi}$, $\Delta p = \sqrt{\frac{mh}{4\pi}}$

3. (c) $\lambda_{D.B.} = \sqrt{\frac{150}{6}}$ Å $= 5$ Å

and $\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$; $p = \frac{h}{\lambda}$ or $\Delta p = \frac{h}{\lambda^2}\Delta\lambda$

$\Rightarrow \Delta x \cdot \frac{h}{\lambda^2} \times \Delta\lambda \geq \frac{h}{4\pi}$

$\Rightarrow \frac{1}{\pi} \times \frac{10^{-9}}{\lambda^2} \times \Delta\lambda > \frac{1}{4\pi} \Rightarrow \Delta\lambda \geq \frac{2.5}{4} \times 10^{-10}$

$\Delta\lambda \geq 0.625$ Å

Passage-2

1. (b) ∵ $\frac{1}{\lambda} = R_H \times Z^2\left[1 - \frac{1}{n^2}\right]$ for Lyman's series

For He^+ ion series limit $n = \infty$;

$\frac{1}{\lambda_1} = R_H \times 2^2\left[1 - \frac{1}{\infty^2}\right] \Rightarrow \frac{1}{\lambda_1} = R_H \times 4$

Similarly, Balmer series limit for Li^{2+} ion

$\frac{1}{\lambda_2} = R_H \times 3^2 = 9R_H \Rightarrow 9 \times \frac{1}{4\lambda} \Rightarrow \lambda_2 = \frac{4x}{9}$

2. (b) $6 = (n_2 - n_1)\frac{(n_2 - n_1 + 1)}{2}$; $n_2 = 4,\ n_1 = 1$

$\therefore \frac{1}{\lambda} = R_H \times 2^2\left[1 - \frac{1}{16}\right]$

$\Rightarrow R \times \frac{15}{4}$; $\lambda = \frac{4}{15R_H}$

3. (d) $\frac{1}{\lambda} = R_{H \cdot z^2}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$$\frac{1}{\lambda_{He^+}} = R_H \times 2^2\left(\frac{1}{2^2}-\frac{1}{4^2}\right)$$
$$= R_H\left(\frac{1}{1^2}-\frac{1}{2^2}\right) = \frac{1}{\lambda_H}$$

for $n_2 = 2$ to $n_1 = 1$

Passage-4

1. (b) Total energy required for dissociation of O_2 molecule and then assigning (O^*) 1eV more energy than (O)$\Rightarrow$ (480+96)$\Rightarrow$ 576 kJ/mol

Maximum wavelength $E = \frac{hc}{\lambda}$;

$$\lambda_{maximum} = \frac{hc}{E_{min}};\ \lambda_{max}(\text{Å}) = \frac{12400}{E_{min}(eV)}$$
$$= \frac{12400}{6} = 2066.67\text{Å}$$

2. (b) $O_3(g) \longrightarrow O_2(g) + O$ ....(i)

$O_2(g) \longrightarrow O + O^*$ ...(ii)

Energy required for (i) reaction is = 400 kJ/mol

Normal dissociation of O_2 required = 480 kJ/mol (given)

each (O^*) has 1 eV more energy than (0) and given 1 eV/photon = 96 kJ/mol

So total energy required for the dissociation of O_3 into O and O^* is 400 + 480 + 96 = 976 kJ/mol

One or More Answers is/are Correct

15. (a,b,c,d) At the point of maximum value of RDF

$$\frac{dP}{dr} = 0$$
$$\left(2r - \frac{2Zr^2}{a_0}\right) = 0;\quad r = \frac{a_0}{Z}$$

where $Z = 3$ for Li^{2+} and $Z = 2$ for the He^+;

$Z = 1$ for hydrogen.

19. (a, b, c, d)

(a) $v \propto \frac{Z}{n}$ (b) $r \propto \frac{n^2}{Z}$

(c) P.E. $\propto -\frac{Z^2}{n^2}$ (d) K.E. $\propto \frac{Z^2}{n^2}$

Match the Column

13. (a) s-orbital $\because r = 0,\ \psi \neq 0$ and 3 radial nodes $\Rightarrow 4s$

(b) 3 radial nodes (s, p, d) $\Rightarrow$ $4s$, $5p_x$ $6d_{xy}$

(c) Angular probability is dependent of θ and ϕ for $5p_y$, $6d_{xy}$

(d) Atleast one angular node$\Rightarrow$ $5p_x(1); 6d_{xy}(2)$

Subjective Problems

11. $$7.67\times10^{-19} = \frac{(1.6\times10^{-19})^2}{4\times3.14\times8.85\times10^{-12}\times r}$$

$\Rightarrow\ r = 3.00\times10^{-10}$ m = 3Å

12. $$d(KE) = mv\,dv = mv\frac{h}{4\pi m\Delta x}$$
$$= \frac{3\times10^8}{3}\times\frac{6.62\times10^{-34}}{4\times\pi\times\frac{3.31}{\pi}\times10^{-12}}$$
$$= 5\times10^{-16}\text{J}$$

13. $E_{in} = 10.2$ eV

$\phi = 4.2$eV

$KE_{max} = 10.2 - 4.2 = 6$ eV

$\therefore\ \lambda e^- = \sqrt{\frac{150}{6}}\text{Å} = 5\text{Å}$

14. $$\frac{\text{Radial probability density at } r = a_0}{\text{Radial probability density at } r = 0} = \frac{R^2(a_0)}{R^2(0)}$$

For 1s orbital: $R_{(r)} = \frac{1}{\sqrt{\pi}}\left(\frac{1}{a_0}\right)^{3/2} e^{\frac{r}{a_0}}$

$$\Rightarrow \frac{R^2(a_0)}{R^2(0)} = \frac{(1/\pi a_0^3)e^{-2r/a_0}}{(1/\pi a_0^3)e^0} = e^{-2}$$

15. $$A = \frac{E_{1,2}}{2E_{2,1}} = \frac{-13.6\times2^2\times2^2}{2\times1^2\times(-13.6)\times1^2} = \frac{16}{2} = 8$$