2

Structure of Atom

TOPIC 1 Atomic Models and Dual Nature of Electromagnetic Radiation

1. The difference between the radii of 3rd and 4th orbits of Li^{2+} is ΔR_1. The difference between the radii of 3rd and 4th orbits of He^+ is ΔR_2. Ratio $\Delta R_1 : \Delta R_2$ is : **[Sep. 05, 2020 (I)]**

(a) 8 : 3 (b) 3 : 8 (c) 2 : 3 (d) 3 : 2

2. Among the following, the energy of 2*s* orbital is lowest in: **[April 12, 2019 (II)]**

(a) K (b) H (c) Li (d) Na

3. What is the work function of the metal if the light of wavelength 4000Å generates photoelectrons of velocity 6×10^5 ms^{-1} from it ? **[Jan. 12, 2019 (I)]**

(Mass of electron $= 9 \times 10^{-31}$ kg
Velocity of light $= 3 \times 10^8$ ms^{-1}
Planck's constant $= 6.626 \times 10^{-34}$ Js
Charge of electron $= 1.6 \times 10^{-19}$ JeV^{-1})

(a) 0.9 eV (b) 3.1 eV (c) 2.1 eV (d) 4.0 eV

4. A stream of electrons from a heated filaments was passed two charged plates kept at a potential difference V esu. If 'e' and *m* are charge and mass of an electron, respectively, then the value of h/λ (where λ is wavelength associated with electron wave) is given by: **[2016]**

(a) $\sqrt{meV}$ (b) $\sqrt{2meV}$ (c) meV (d) $2meV$

5. If λ_0 and λ be threshold wavelength and wavelength of incident light, the velocity of photoelectron ejected from the metal surface is: **[Online April 11, 2014]**

(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) $\sqrt{\frac{2h}{m}\left(\frac{1}{\lambda_0} - \frac{1}{\lambda}\right)}$

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

(a) 594 nm (b) 640 nm (c) 700 nm (d) 494 nm

7. Calculate the wavelength (in nanometer) associated with a proton moving at 1.0×10^3 ms^{-1}. (Mass of proton $= 1.67 \times 10^{-27}$ kg and $h = 6.63 \times 10^{-34}$ Js) **[2009]**

(a) 0.40 nm (b) 2.5 nm (c) 14.0 nm (d) 0.32 nm

8. The orbital angular momentum for an electron revolving in an orbit is given by $\sqrt{l(l+1)} \cdot \frac{h}{2\pi}$. This momentum for an *s*-electron will be given by **[2003]**

(a) zero (b) $\frac{h}{2\pi}$ (c) $\sqrt{2} \cdot \frac{h}{2\pi}$ (d) $+\frac{1}{2} \cdot \frac{h}{2\pi}$

TOPIC 2 Bohr's Model for Hydrogen Atom (Emission and Absorption Spectra)

9. The region in the electromagnetic spectrum where the Balmer series lines appear is : **[Sep. 04, 2020 (I)]**

(a) Visible (b) Microwave
(c) Infrared (d) Ultraviolet

10. The shortest wavelength of H atom in the Lyman series is λ_1. The longest wavelength in the Balmer series is He^+ is : **[Sep. 04, 2020 (II)]**

(a) $\frac{36\lambda_1}{5}$ (b) $\frac{5\lambda_1}{9}$ (c) $\frac{9\lambda_1}{5}$ (d) $\frac{27\lambda_1}{5}$

11. For the Balmer series in the spectrum of H atom, $\bar{v} = R_H \left\{\frac{1}{n_1^2} - \frac{1}{n_2^2}\right\}$, the correct statements among (I) to (IV) are: **[Jan. 08, 2020 (I)]**

(I) As wavelength decreases, the lines in the series converge
(II) The integer n_1 is equal to 2
(III) The lines of longest wavelength corresponds to $n_2 = 3$
(IV) The ionization energy of hydrogen can be calculated from wave number of these lines

(a) (I), (III), (IV) (b) (I), (II), (III)
(c) (I), (II), (IV) (d) (II), (III), (IV)

12. The radius of the second Bohr orbit, in terms of the Bohr radius, a_0, in Li^{2+} is: **[Jan. 08, 2020 (II)]**

(a) $\frac{2a_0}{3}$ (b) $\frac{4a_0}{9}$ (c) $\frac{4a_0}{3}$ (d) $\frac{2a_0}{9}$

13. The ratio of the shortest wavelength of two spectral series of hydrogen spectrum is found to be about 9. The spectral series are : **[April 10, 2019 (II)]**

(a) Lyman and Paschen (b) Balmer and Brackett
(c) Brackett and Pfund (d) Paschen and Pfund

14. For any given series of spectral lines of atomic hydrogen, let $\Delta\bar{v} = \bar{v}_{max} - \bar{v}_{min}$ be the difference in maximum and minimum frequencies in cm^{-1}. The ratio $\Delta\bar{v}_{Lyman}/\Delta\bar{v}_{Balmer}$ is : **[April 9, 2019 (I)]**

(a) 4 : 1 (b) 9 : 4 (c) 5 : 4 (d) 27 : 5

15. Which one of the following about an electron occupying the 1*s* orbital in a hydrogen atom is incorrect? (The Bohr radius is represented by a_0). **[April 9, 2019 (II)]**

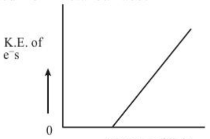
(a) The probability density of finding the electron is maximum at the nucleus.
(b) The electron can be found at a distance $2a_0$ from the nucleus.
(c) The magnitude of the potential energy is double that of its kinetic energy on an average.
(d) The total energy of the electron is maximum when it is at a distance a_0 from the nucleus.

16. Heat treatment of muscular pain involves radiation of wavelength of about 900 nm. Which spectral line of H-atom is suitable for this purpose? **[Jan. 11, 2019 (I)]**
$[R_H = 1 \times 10^5\ cm^{-1}.\ h = 6.6 \times 10^{-34}\ Js,\ c = 3 \times 10^8\ ms^{-1}]$

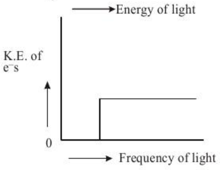
(a) Paschen, $\infty \to 3$ (b) Paschen, $5 \to 3$
(c) Balmer, $\infty \to 2$ (d) Lyman, $\infty \to 1$

17. Which of the graphs shown below does not represent the relationship between incident light and the electron ejected from metal surface? **[Jan. 10, 2019 (I)]**

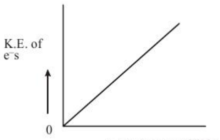
(a)



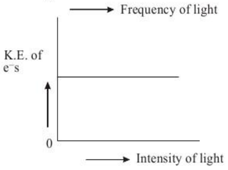
(b)



(c)



(d)



18. The ground state energy of hydrogen atom is –13.6 eV. The energy of second excited state of He^+ ion in eV is: **[Jan. 10, 2019 (II)]**

(a) – 54.4 (b) – 3.4 (c) – 6.04 (d) – 27.2

19. For emission line of atomic hydrogen from $n_i = 8$ to $n_f = n$, the plot of wave number ($\bar{v}$) against $\left(\frac{1}{n^2}\right)$ will be (The Rydberg constant, R_H is in wave number unit) **[Jan. 9, 2019 (I)]**

(a) Linear with intercept – R_H
(b) Non linear
(c) Linear with slope R_H
(d) Linear with slope – R_H

20. Which of the following statements is false? **[Online April 16, 2018]**

(a) Splitting of spectral lines in electrical field is called Stark effect
(b) Frequency of emitted radiation from a black body goes from a lower wavelength to higher wavelength as the temperature increases
(c) Photon has momentum as well as wavelength
(d) Rydberg constant has unit of energy

21. Ejection of the photoelectron from metal in the photoelectric effect experiment can be stopped by applying 0.5V when the radiation of 250 nm is used. The work function of the metal is : **[Online April 15, 2018 (I)]**

(a) 4 eV (b) 5.5 eV (c) 4.5 eV (d) 5 eV

22. The radius of the second Bohr orbit for hydrogen atom is : (Plank's const. $h = 6.6262 \times 10^{-34}$ Js ; mass of electron $= 9.1091 \times 10^{-31}$ kg ; charge of electron $e = 1.60210 \times 10^{-19}$ C ; permittivity of vaccum $\epsilon_0 = 8.854185 \times 10^{-12}\ kg^{-1}\ m^{-3}\ A^2$) **[2017]**

(a) 1.65Å (b) 4.76Å (c) 0.529Å (d) 2.12Å

23. If the shortest wavelength in Lyman series of hydrogen atom is A, then the longest wavelength in Paschen series of He^+ is : **[Online April 8, 2017]**

(a) $\frac{5A}{9}$ (b) $\frac{9A}{5}$ (c) $\frac{36A}{5}$ (d) $\frac{36A}{7}$

24. The electron in the hydrogen atom undergoes transition from higher orbitals to orbital of radius 211.6 pm. This transition is associated with : **[Online April 9, 2017]**
(a) Lyman series (b) Balmer series
(c) Paschen series (d) Brackett series

25. Which of the following is the energy of a possible excited state of hydrogen ? **[2015]**
(a) –3.4 eV (b) +6.8 eV (c) +13.6 eV (d) –6.8 eV

26. The energy of an electron in first Bohr orbit of H-atom is – 13.6 eV. The energy value of electron in the excited state of Li^{2+} is: **[Online April 9, 2014]**
(a) – 27.2 eV (b) 30.6 eV (c) – 30.6 eV (d) 27.2 eV

27. Based on the equation: **[Online April 11, 2014]**

$$\Delta E = -2.0\times10^{-18}\,J\left(\frac{1}{n_2^2}-\frac{1}{n_1^2}\right)$$

the wavelength of the light that must be absorbed to excite hydrogen electron from level $n = 1$ to level $n = 2$ will be:
($h = 6.625 \times 10^{-34}$ Js, $C = 3 \times 10^8$ ms^{-1})
(a) 1.325×10^{-7} m (b) 1.325×10^{-10} m
(c) 2.650×10^{-7} m (d) 5.300×10^{-10} m

28. If m and e are the mass and charge of the revolving electron in the orbit of radius r for hydrogen atom, the total energy of the revolving electron will be: **[Online April 12, 2014]**
(a) $\frac{1}{2}\frac{e^2}{r}$ (b) $-\frac{e^2}{r}$ (c) $\frac{me^2}{r}$ (d) $-\frac{1}{2}\frac{e^2}{r}$

29. Excited hydrogen atom emits light in the ultraviolet region at 2.47×10^{15} Hz. With this frequency, the energy of a single photon is: **[Online April 12, 2014]**
($h = 6.63 \times 10^{-34}$ Js)
(a) 8.041×10^{-40} J (b) 2.680×10^{-19} J
(c) 1.640×10^{-18} J (d) 6.111×10^{-17} J

30. Ionization energy of gaseous Na atoms is 495.5 kJ mol^{-1}. The lowest possible frequency of light that ionizes a sodium atom is
($h = 6.626 \times 10^{-34}$ Js, $N_A = 6.022 \times 10^{23}$ mol^{-1})
[Online April 19, 2014]
(a) 7.50×10^4 s^{-1} (b) 4.76×10^{14} s^{-1}
(c) 3.15×10^{15} s^{-1} (d) 1.24×10^{15} s^{-1}

31. Energy of an electron is given by $E = -2.178 \times 10^{-18}\,J\left(\frac{Z^2}{n^2}\right)$.
Wavelength of light required to excite an electron in an hydrogen atom from level $n = 1$ to $n = 2$ will be : **[2013]**
($h = 6.62 \times 10^{-34}$ Js and $c = 3.0 \times 10^8$ ms^{-1})
(a) 1.214×10^{-7} m (b) $2.816 \times 10.^{-7}$ m
(c) 6.500×10^{-7} m (d) 8.500×10^{-7} m

32. The wave number of the first emission line in the Balmer series of H-Spectrum is : **[Online April 22, 2013]**
(R = Rydberg constant) :
(a) $\frac{5}{36}R$ (b) $\frac{9}{400}R$ (c) $\frac{7}{6}R$ (d) $\frac{3}{4}R$

33. The limiting line in Balmer series will have a frequency of **[Online May 7, 2012]**
(Rydberg constant, $R_\infty = 3.29 \times 10^{15}$ cycles/s)
(a) 8.22×10^{14} s^{-1} (b) 3.29×10^{15} s^{-1}
(c) 3.65×10^{14} s^{-1} (d) 5.26×10^{13} s^{-1}

34. The frequency of light emitted for the transition n = 4 to n = 2 of the He^+ is equal to the transition in H atom corresponding to which of the following ? **[2011 RS]**
(a) n = 2 to n = 1 (b) n = 3 to n = 2
(c) n = 4 to n = 3 (d) n = 3 to n = 1

35. Ionisation energy of He^+ is 19.6×10^{-18} J atom^{-1}. The energy of the first stationary state ($n = 1$) of Li^{2+} is **[2010]**
(a) 4.41×10^{-16} J atom^{-1} (b) -4.41×10^{-17} J atom^{-1}
(c) -2.2×10^{-15} J atom^{-1} (d) 8.82×10^{-17} J atom^{-1}

36. The ionization enthalpy of hydrogen atom is 1.312×10^6 J mol^{-1}. The energy required to excite the electron in the atom from $n = 1$ to $n = 2$ is **[2008]**
(a) 8.51×10^5 J mol^{-1} (b) 6.56×10^5 J mol^{-1}
(c) 7.56×10^5 J mol^{-1} (d) 9.84×10^5 J mol^{-1}

37. According to Bohr's theory, the angular momentum of an electron in 5th orbit is **[2006]**
(a) 10 h / π (b) 2.5 h / π
(c) 25 h / π (d) 1.0 h / π

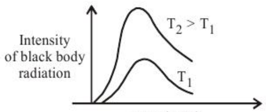
38. The wavelength of the radiation emitted, when in a hydrogen atom electron falls from infinity to stationary state 1, would be (Rydberg constant = 1.097×10^7 m^{-1}) **[2004]**
(a) 406 nm (b) 192 nm
(c) 91 nm (d) 9.1×10^{-8} nm

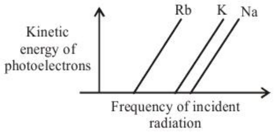
39. In Bohr series of lines of hydrogen spectrum, the third line from the red end corresponds to which one of the following inter-orbit jumps of the electron for Bohr orbits in an atom of hydrogen **[2003]**
(a) 5 → 2 (b) 4 → 1 (c) 2 → 5 (d) 3 → 2

40. In a hydrogen atom, if energy of an electron in ground state is 13.6. eV, then that in the 2nd excited state is **[2002]**
(a) 1.51 eV (b) 3.4 eV (c) 6.04 eV (d) 13.6 eV.

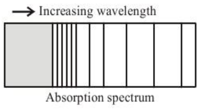
TOPIC 3 Dual Behaviour of Matter and Heisenberg Uncertainty Principle

41. The figure that is **not** a direct manifestation of the quantum nature of atoms is : **[Sep. 02, 2020 (I)]**

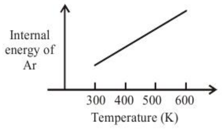
(a)


(b)


(c)



(d)



42. The work function of sodium metal is 4.41×10^{-19} J. If photons of wavelength 300 nm are incident on the metal, the kinetic energy of the ejected electrons will be ($h = 6.63 \times 10^{-34}$ J s; $c = 3 \times 10^8$ m/s) _______ $\times 10^{-21}$ J. **[NV, Sep. 02, 2020 (II)]**

43. The de Broglie wavelength of an electron in the 4th Bohr orbit is: **[Jan. 09, 2020 (I)]**
(a) $2\pi a_0$ (b) $4\pi a_0$ (c) $6\pi a_0$ (d) $8\pi a_0$

44. If p is the momentum of the fastest electron ejected from a metal surface after the irradiation of light having wavelength », then for $1.5p$ momentum of the photoelectron, the wavelength of the light should be: (Assume kinetic energy of ejected photoelectron to be very high in comparison to work function): **[April 8, 2019 (II)]**
(a) $\frac{3}{4}\lambda$ (b) $\frac{1}{2}\lambda$ (c) $\frac{2}{3}\lambda$ (d) $\frac{4}{9}\lambda$

45. If the de Broglie wavelength of the electron in nth Bohr orbit in a hydrogenic atom is equal to $1.5\ \pi a_0$ (a_0 is Bohr radius), then the value of n/z is : **[Jan. 12, 2019 (II)]**
(a) 0.40 (b) 1.50 (c) 1.0 (d) 0.75

46. The de Broglie wavelength (λ) associated with a photoelectron varies with the frequency (v) of the incident radiation as, [v_0 is threshold frequency]: **[Jan. 11, 2019 (II)]**
(a) $\lambda \propto \frac{1}{(\nu - \nu_0)}$ (b) $\lambda \propto \frac{1}{(\nu - \nu_0)^{\frac{1}{4}}}$
(c) $\lambda \propto \frac{1}{(\nu - \nu_0)^{\frac{3}{2}}}$ (d) $\lambda \propto \frac{1}{(\nu - \nu_0)^{\frac{1}{2}}}$

47. The de-Broglie's wavelength of electron present in first Bohr orbit of 'H' atom is: **[Online April 15, 2018 (II)]**
(a) 4×0.529Å (b) $2\pi \times 0.529$Å
(c) $\frac{0.529}{2\pi}$Å (d) 0.529Å

48. At temperature T, the average kinetic energy of any particle is $\frac{3}{2}$kT . The de Broglie wavelength follows the order : **[Online April 11, 2015]**
(a) Visible photon > Thermal neutron > Thermal electron
(b) Thermal proton > Thermal electron > Visible photon
(c) Thermal proton > Visible photon > Thermal electron
(d) Visible photon > Thermal electron > Thermal neutron

49. The de-Broglie wavelength of a particle of mass 6.63 g moving with a velocity of 100 ms^{-1} is: **[Online April 12, 2014]**
(a) 10^{-33} m (b) 10^{-35} m (c) 10^{-31} m (d) 10^{-25} m

50. The de Broglie wavelength of a car of mass 1000 kg and velocity 36 km/hr is : **[Online April 23, 2013]**
(a) 6.626×10^{-34} m (b) 6.626×10^{-38} m
(c) 6.626×10^{-31} m (d) 6.626×10^{-30} m

51. If the radius of first orbit of H atom is a_0, the de-Broglie wavelength of an electron in the third orbit is **[Online May 12, 2012]**
(a) $4\pi a_0$ (b) $8\pi a_0$ (c) $6\pi a_0$ (d) $2\pi a_0$

52. If the kinetic energy of an electron is increased four times, the wavelength of the de-Broglie wave associated with it would become **[Online May 19, 2012]**
(a) one fourth (b) half
(c) four times (d) two times

53. In an atom, an electron is moving with a speed of 600 m/s with an accuracy of 0.005%. Certainity with which the position of the electron can be located is ($h = 6.6 \times 10^{-34}$ kg m^2s^{-1}, mass of electron, $e_m = 9.1 \times 10^{-31}$ kg) : **[2009]**
(a) 5.10×10^{-3} m (b) 1.92×10^{-3} m
(c) 3.84×10^{-3} m (d) 1.52×10^{-4} m

54. Uncertainty in the position of an electron (mass $= 9.1 \times 10^{-31}$ kg) moving with a velocity 300 ms^{-1}, accurate upto 0.001% will be **[2006]**
(a) 1.92×10^{-2} m (b) 3.84×10^{-2} m
(c) 19.2×10^{-2} m (d) 5.76×10^{-2} m
($h = 6.63 \times 10^{-34}$ Js)

55. The de Broglie wavelength of a tennis ball of mass 60 g moving with a velocity of 10 metres per second is approximately **[2003]**
(a) 10^{-31} metres (b) 10^{-16} metres
(c) 10^{-25} metres (d) 10^{-33} metres
Planck's constant, $h = 6.63 \times 10^{-34}$ Js

56. Uncertainty in position of a minute particle of mass 25 g in space is 10^{-5} m. What is the uncertainty in its velocity (in ms^{-1})? ($h = 6.6 \times 10^{-34}$ Js) **[2002]**
(a) 2.1×10^{-34} (b) 0.5×10^{-34}
(c) 2.1×10^{-28} (d) 0.5×10^{-23}.

TOPIC 4 Quantum Mechanical Model of Atom

57. In the sixth period, the orbitals that are filled are : **[Sep. 05, 2020 (I)]**
(a) 6*s*, 4*f*, 5*d*, 6*p* (b) 6*s*, 5*d*, 5*f*, 6*p*
(c) 6*s*, 5*f*, 6*d*, 6*p* (d) 6*s*, 6*p*, 6*d*, 6*f*

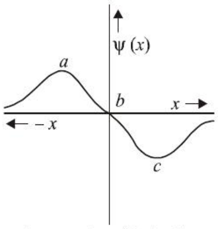
58. The correct statement about probability density (except at infinite distance from nucleus) is : **[Sep. 05, 2020 (II)]**
(a) It can be zero for 1*s* orbital
(b) It can be negative for 2*p* orbital
(c) It can be zero for 3*p* orbital
(d) It can never be zero for 2*s* orbital

59. Consider the hypothetical situation where the azimuthal quantum number, *l*, takes values 0, 1, 2, ... $n+1$, where *n* is the principal quantum number. Then, the element with atomic number : **[Sep. 03, 2020 (II)]**
(a) 9 is the first alkali metal
(b) 13 has a half-filled valence subshell
(c) 8 is the first noble gas
(d) 6 has a 2*p*-valence subshell

60. The number of subshells associated with $n = 4$ and $m = -2$ quantum numbers is : **[Sep. 02, 2020 (II)]**
(a) 8 (b) 2 (c) 16 (d) 4

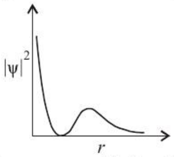
61. The number of orbitals associated with quantum numbers $n = 5, m_s = +\frac{1}{2}$ is: **[NV, Jan. 07, 2020 (I)]**
(a) 11 (b) 25 (c) 50 (d) 15

62. The electrons are more likely to be found : **[April 12, 2019 (I)]**



(a) in the region *a* and *c* (b) in the region *a* and *b*
(c) only in the region *a* (d) only in the region *c*

63. The graph between $|\psi|^2$ and r (radial distance) is shown below. This represents : **[April 10, 2019 (I)]**



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

64. The isoelectronic set of ions is **[April 10, 2019 (I)]**
(a) N^{3-}, O^{2-}, F^- and Na^+ (b) N^{3-}, Li^+, Mg^{2+} and O^{2-}
(c) F^-, Li^+, Na^+ and Mg^{2+} (d) Li^+, Na^+, O^{2-} and F^-

65. The quantum number of four electrons are given below :
I. $n = 4, l = 2, m_l = -2, m_s = -1/2$
II. $n = 3, l = 2, m_l = 1, m_s = +1/2$
III. $n = 4, l = 1, m_l = 0, m_s = +1/2$
IV. $n = 3, l = 1, m_l = 1, m_s = -1/2$

The correct order of their increasing energies will be : **[April 8, 2019 (I)]**
(a) IV < III < II < I (b) I < II < III < IV
(c) IV < II < III < I (d) I < III < II < IV

66. The size of the iso-electronic species Cl^-, Ar and Ca^{2+} is affected by : **[April 8, 2019 (I)]**
(a) azimuthal quantum number of valence shell
(b) electron-electron interaction in the outer orbitals
(c) principal quantum number of valence shell
(d) nuclear charge

67. Which of the following combination of statements is true regarding the interpretation of the atomic orbitals? **[Jan. 9, 2019 (II)]**
(a) An electron in an orbital of high angular momentum stays away from the nucleus than an electron in the orbital of lower angular momentum.
(b) For a given value of the principal quantum number, the size of the orbit is inversely proportional to the azimuthal quantum number.
(c) According to wave mechanics, the ground state angular momentum is equal to $\frac{h}{2\pi}$
(d) The plot of ψ vs r for various azimuthal quantum numbers, shows peak shifting towards higher r value.
(a) (a), (d) (b) (a), (b)
(c) (a), (c) (d) (b), (c)

68. The total number of orbitals associated with the principal quantum number 5 is : **[Online April 9, 2016]**
(a) 20 (b) 25 (c) 10 (d) 5

69. If the principal quantum number $n = 6$, the correct sequence of filling of electrons will be : **[Online April 10, 2015]**
(a) $ns \rightarrow (n-2)f \rightarrow np \rightarrow (n-1)d$
(b) $ns \rightarrow (n-2)f \rightarrow (n-1)d \rightarrow np$
(c) $ns \rightarrow np \rightarrow (n-1)d \rightarrow (n-2)f$
(d) $ns \rightarrow (n-1)d \rightarrow (n-2)f \rightarrow np$

70. The correct set of four quantum numbers for the valence electrons of rubidium atom ($Z = 37$) is: **[2014]**
(a) $5, 0, 0, +\frac{1}{2}$ (b) $5, 1, 0, +\frac{1}{2}$
(c) $5, 1, 1, +\frac{1}{2}$ (d) $5, 0, 1, +\frac{1}{2}$

71. In an atom how many orbital(s) will have the quantum numbers; $n = 3, l = 2$ and $m_l = +2$? **[Online April 9, 2013]**
(a) 5 (b) 3 (c) 1 (d) 7

72. Given
(A) $n = 5, m_\ell = +1$
(B) $n = 2, \ell = 1, m_\ell = -1, m_s = -1/2$
The maximum number of electron(s) in an atom that can have the quantum numbers as given in (A) and (B) are respectively: **[Online April 25, 2013]**
(a) 25 and 1 (b) 8 and 1
(c) 2 and 4 (d) 4 and 1

73. The electrons identified by quantum numbers n and ℓ :

(A) $n = 4, l = 1$ (B) $n = 4, l = 0$ **[2012]**

(C) $n = 3, l = 2$ (D) $n = 3, l = 1$

can be placed in order of increasing energy as :

(a) (C) < (D) < (B) < (A) (b) (D) < (B) < (C) < (A)

(c) (B) < (D) < (A) < (C) (d) (A) < (C) < (B) < (D)

74. The increasing order of the ionic radii of the given isoelectronic species is : **[2012]**

(a) $Cl^-, Ca^{2+}, K^+, S^{2-}$ (b) $S^{2-}, Cl^-, Ca^{2+}, K^+$

(c) $Ca^{2+}, K^+, Cl^-, S^{2-}$ (d) $K^+, S^{2-}, Ca^{2+}, Cl^-$

75. The following sets of quantum numbers represent four electrons in an atom. **[Online May 26, 2012]**

(i) $n = 4, l = 1$ (ii) $n = 4, l = 0$

(iii) $n = 3, l = 2$ (iv) $n = 3, l = 1$

The sequence representing increasing order of energy, is

(a) (iii) < (i) < (iv) < (ii) (b) (iv) < (ii) < (iii) < (i)

(c) (i) < (iii) < (ii) < (iv) (d) (ii) < (iv) < (i) < (iii)

76. Which one of the following constitutes a group of the isoelectronic species? **[2008]**

(a) C_2^{2-}, O_2^-, CO, NO (b) $NO^+, C_2^{2-}, CN^-, N_2$

(c) $CN^-, N_2, O_2^{2-}, C_2^{2-}$ (d) N_2, O_2^-, NO^+, CO

77. Which of the following sets of quantum numbers represents the highest energy of an atom? **[2007]**

(a) $n = 3, l = 0, m = 0, s = +1/2$

(b) $n = 3, l = 1, m = 1, s = +1/2$

(c) $n = 3, l = 2, m = 1, s = +1/2$

(d) $n = 4, l = 0, m = 0, s = +1/2$.

78. Which one of the following sets of ions represents a collection of isoelectronic species? **[2006]**

(a) $N^{3-}, O^{2-}, F^-, S^{2-}$ (b) $Li^+, Na^+, Mg^{2+}, Ca^{2+}$

(c) $K^+, Cl^-, Ca^{2+}, Sc^{3+}$ (d) $Ba^{2+}, Sr^{2+}, K^+, Ca^{2+}$

79. Of the following sets which one does NOT contain isoelectronic species? **[2005]**

(a) $BO_3^{3-}, CO_3^{2-}, NO_3^-$ (b) $SO_3^{2-}, CO_3^{2-}, NO_3^-$

(c) CN^-, N_2, C_2^{2-} (d) $PO_4^{3-}, SO_4^{2-}, ClO_4^-$

80. In a multi-electron atom, which of the following orbitals described by the three quantum members will have the same energy in the absence of magnetic and electric fields? **[2005]**

(A) $n = 1, l = 0, m = 0$ (B) $n = 2, l = 0, m = 0$

(C) $n = 2, l = 1, m = 1$ (D) $n = 3, l = 2, m = 1$

(E) $n = 3, l = 2, m = 0$

(a) (D) and (E) (b) (C) and (D)

(c) (B) and (C) (d) (A) and (B)

81. Which of the following sets of quantum numbers is correct for an electron in 4*f* orbital ? **[2004]**

(a) $n = 4, l = 3, m = +1, s = +½$

(b) $n = 4, l = 4, m = -4, s = -½$

(c) $n = 4, l = 3, m = +4, s = +½$

(d) $n = 3, l = 2, m = -2, s = +½$

82. Consider the ground state of Cr atom (X = 24). The number of electrons with the azimuthal quantum numbers, $l = 1$ and 2 are, respectively **[2004]**

(a) 16 and 4 (b) 12 and 5

(c) 12 and 4 (d) 16 and 5

83. Which one of the following sets of ions represents the collection of isoelectronic species? **[2004]**

(a) $K^+, Cl^-, Mg^{2+}, Sc^{3+}$ (b) $Na^+, Ca^{2+}, Sc^{3+}, F^-$

(c) $K^+, Ca^{2+}, Sc^{3+}, Cl^-$ (d) $Na^+, Mg^{2+}, Al^{3+}, Cl^-$

(Atomic nos. : F = 9, Cl = 17, Na = 11, Mg = 12, Al = 13, K = 19, Ca = 20, Sc = 21)

84. The number of *d*-electrons retained in Fe^{2+} (At. no. of Fe = 26) ion is **[2003]**

(a) 4 (b) 5 (c) 6 (d) 3

85. Which one of the following groupings represents a collection of isoelectronic species ?(At. nos. : Cs : 55, Br : 35) **[2003]**

(a) N^{3-}, F^-, Na^+ (b) Be, Al^{3+}, Cl^-

(c) Ca^{2+}, Cs^+, Br (d) Na^+, Ca^{2+}, Mg^{2+}

Hints & Solutions

1. **(c)** $r = 0.529\dfrac{n^2}{Z}\text{Å}$

For Li^{2+},

$$(r_{Li^{2+}})_{n=4} - (r_{Li^{2+}})_{n=3} = \frac{0.529}{3}[4^2 - 3^2] = \Delta R_1$$

For He^+,

$$(r_{He^+})_{n=4} - (r_{He^+})_{n=3} = \frac{0.529}{2}[4^2 - 3^2] = \Delta R_2$$

$$\frac{\Delta R_1}{\Delta R_2} = \frac{2}{3}$$

2. **(a)** As the value of Z (atomic number) increases, energy of orbitals decreases (becomes more –ve value)

$\therefore$ Order of energy of 2*s* orbital is $H > Li > Na > K$.

3. **(c)** $E = h\nu = \dfrac{hc}{\lambda}$

$$E = \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{4000 \times 10^{-10}} = 4.97 \times 10^{-19}\,\text{J}$$

$$= \frac{4.97 \times 10^{-19}\,\text{J}}{1.6 \times 10^{-10}\,\text{J eV}^{-1}} = 3.1\,\text{eV}$$

$$\text{KE} = \frac{1}{2}m\nu^2 = \frac{1}{2} \times 9 \times 10^{-31}\,\text{kg} \times (6 \times 10^5\,\text{ms}^{-1})^2$$

$$= 1.62 \times 10^{-19}\,\text{J}\,[1\text{J} = \text{kg.m}^2\text{s}^{-2}]$$

$$= 1\,\text{eV}$$

According to photoelectric effect,

$$\text{K.E.} = h\nu - hv_0$$

$$hv_0 = h\nu - \text{K.E.}$$

Work function $(W_0) = E - \text{K.E.}$

$$= 3.1 - 1 = 2.1\,\text{eV}$$

4. **(b)** As electron of charge 'e' is passed through 'V' volt, kinetic energy of electron will be eV

Wavelength of electron wave $(\lambda) = \dfrac{h}{\sqrt{2m.\text{K.E}}}$

$$\lambda = \frac{h}{\sqrt{2m\text{eV}}} \quad \therefore \quad \frac{h}{\lambda} = \sqrt{2m\text{eV}}$$

5. **(c)** The kinetic energy of the ejected electron is given by the equation

$$h\nu = h\nu_0 + \frac{1}{2}mv^2 \quad \because \nu = \frac{c}{\lambda}$$

or $\dfrac{hc}{\lambda} = \dfrac{hc}{\lambda_0} + \dfrac{1}{2}mv^2$

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

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

or $v = \sqrt{\dfrac{2hc}{m}\left(\dfrac{\lambda_0 - \lambda}{\lambda\lambda_0}\right)}$

6. **(d)** Energy required to break single Cl – Cl bond

$$= \frac{242 \times 10^3}{6.023 \times 10^{23}} = \frac{hc}{\lambda}$$

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^8}{\lambda}$$

$$\therefore \lambda = \frac{6.626 \times 10^{-34} \times 3 \times 10^8 \times 6.023 \times 10^{23}}{242 \times 10^3}$$

$$= 0.4947 \times 10^{-6}\,\text{m} = 494.7\,\text{nm}$$

7. **(a)** $\lambda = \dfrac{h}{mv} = \dfrac{6.63 \times 10^{-34}}{1.67 \times 10^{-27} \times 1 \times 10^3}$

$$= 3.97 \times 10^{-10}\,\text{m} = 0.397\,\text{nm}.$$

8. **(a)** For *s*-electron, $l = 0$

$\therefore$ Orbital angular momentum $= \sqrt{0(0+1)}\dfrac{h}{2\pi} = 0$

9. **(a)** In hydrogen spectrum maximum lines of Balmer series lies in visible region.

10. **(c)** Shortest wavelength → Max. energy $(\infty \to 1)$

For Lyman series of H atom,

$$\frac{1}{\lambda_1} = R_H(1)^2\left[\frac{1}{1} - 0\right]$$

$$\Rightarrow \frac{1}{\lambda_1} = R_H \Rightarrow R_H = \frac{1}{\lambda_1}$$

For Balmer series of He^+,

$$\frac{1}{\lambda} = R_H(2)^2\left[\frac{1}{2^2} - \frac{1}{3^2}\right] \Rightarrow \frac{1}{\lambda} = R_H(4)\left(\frac{9-4}{36}\right)$$

$$\Rightarrow \frac{1}{\lambda} = \frac{5R_H}{9} \Rightarrow \lambda = \frac{9}{5R_H} = \frac{9\lambda_1}{5}$$

11. **(b)** In the Balmer series of H–atom the transition takes place from the higher oribtal to n = 2. Therefore the longest wave length corresponds to $n_1 = 2$ and $n_2 = 3$. As the wave length decreases, the lines in the series converges. Hence, statement I, II, III are the correct statements among the given options.

12. **(c)** $r = \dfrac{a_0 n^2}{Z}$

For Li^{2+}, $r = \dfrac{a_0(2)^2}{3} = \dfrac{4a_0}{3}$

13. **(a)** For determined shortest wavelength, $n_2 = \infty$

Lyman series $\bar{v}_L = \dfrac{1}{\lambda_L} = R\left[\dfrac{1}{(1)^2} - \dfrac{1}{\infty^2}\right]$

Paschen series $\bar{v}_P = \dfrac{1}{\lambda_P} = R\left[\dfrac{1}{(3)^2} - \dfrac{1}{\infty^2}\right]$

$\dfrac{\bar{v}_L}{\bar{v}_P} = \dfrac{\lambda_P}{\lambda_L} = 9$

14. **(b)** $\bar{v} \propto \Delta E$

For H-atom

$$\bar{v} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

For Lyman series,

$$\bar{v}\,(\max) = 13.6\left(1 - \frac{1}{\infty}\right)$$

$$\bar{v}\,(\min) = 13.6\left(1 - \frac{1}{4}\right)$$

$$\therefore \quad \bar{v}_{\max} - \bar{v}_{\min} = 13.6\left(\frac{1}{4}\right)$$

For Balmer series,

$$\bar{v}\,(\max) = 13.6\left(\frac{1}{4} - \frac{1}{\infty}\right)$$

$$\bar{v}\,(\min) = 13.6\left(\frac{1}{4} - \frac{1}{9}\right)$$

$$\therefore \quad \bar{v}_{\max} - \bar{v}_{\min} = 13.6\left(\frac{1}{9}\right)$$

So, $\dfrac{\Delta \bar{v}_{\text{Lyman}}}{\Delta \bar{v}_{\text{Balmer}}} = \dfrac{9}{4}$

15. **(d)** The total energy of the electron is minimum at a distance of a_0 from the nucleus for 1 *s* orbital.

16. **(a)** $\dfrac{1}{\lambda} = R\left(\dfrac{1}{n_1^2} - \dfrac{1}{n_2^2}\right)$

$n_1 = 3,\ n_2 = \infty$

$$\frac{1}{\lambda} = R\left(\frac{1}{9}\right) \Rightarrow \lambda = \frac{9}{R} = \frac{9}{10^5} = 9 \times 10^{-5}\,\text{cm} = 900\,\text{nm}$$

17. **(c)** K.E. = $h\nu - h\nu_0$

where, ν = Frequency of incident radiation

ν_0 = Threshold frequency

KE is independent of intensity but it depends on frequency of light. Intensity is directly proportional to the no. of electrons emitted.

18. **(c)** According to Bohr's model energy in n^{th} state

$$= -13.6 \times \frac{Z^2}{n^2}\ \text{eV}$$

For second excited state, of He$^+$, $n = 3$

$$\therefore\ E_3(\text{He}^+) = -13.6 \times \frac{2^2}{3^2}\ \text{eV} = -6.04\ \text{eV}$$

19. **(d)** As we know,

$$\bar{v} = -R_H\left(\frac{1}{n_2^2} - \frac{1}{n_1^2}\right) Z^2 \ (\text{where, } Z = 1)$$

After putting the values, we get

$$\bar{v} = -R_H\left(\frac{1}{n^2} - \frac{1}{8^2}\right)$$

$$\Rightarrow \quad \bar{v} = \frac{R_H}{64} - \frac{R_H}{n^2}$$

Comparing to $y = mx + c$, we get

$x = \dfrac{1}{n^2}$ and $m = -R_H$ (slope)

20. **(b)** When temperature is increased, black body emits high energy radiation from higher wavelength to lower wavelength.

21. **(c)** $\lambda = 250\,\text{nm}$

$$E = \frac{hc}{\lambda} = \frac{1240\ \text{eV.nm}}{250\ \text{nm}} = 4.96\ \text{eV}$$

KE = stopping potential = 0.5 eV

$E = W_0 + \text{K.E.}$

$4.96 = W_0 + 0.5$

$W_0 = 4.46 \approx 4.5\ \text{eV}$

22. **(d)** Radius of n^{th} Bohr orbit in H-atom = $0.53\, n^2$ Å

Radius of II Bohr orbit = $0.53 \times (2)^2 = 2.12$ Å

23. **(d)** For Lyman series (shortest wavelength)

$n_1 = 1,\ n_2 = \infty$

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

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

Longest wavelength = 1st line

$n_1 = 3, n_2 = 4$

$$\frac{1}{\lambda} = RZ^2\left(\frac{1}{3^2} - \frac{1}{4^2}\right) \Rightarrow \frac{1}{\lambda} = \frac{R7}{36}$$

$$R = \frac{1}{A}$$

$$\frac{1}{\lambda} = \frac{\frac{1}{A}\times 7}{36} \Rightarrow \frac{1}{\lambda} = \frac{7}{36A} \Rightarrow \lambda = \frac{36A}{7}$$

24. **(b)** $r = 0.529 \times \frac{n^2}{Z}$ Å

r = 211.6 pm = 2.11 Å

$$\Rightarrow 0.529 \times \frac{n^2}{Z} = 2.11\text{Å}$$

$n = 2$ (Balmer series)

25. **(a)** Total energy $= -\frac{13.6}{n^2}Z^2\text{eV}$

where $n = 2, 3, 4 ....$

Putting $n = 2$

$$E_T = -\frac{13.6}{4} = -3.4 \text{ eV}$$

26. **(c)** For Li^{2+} ion

$$E = -13.6 \times \frac{Z^2}{n^2}\text{ eV} = -13.6 \times \frac{(3)^2}{(2)^2}$$

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

27. **(a)** $\Delta E = -2.0 \times 10^{-18} \times \left(\frac{1}{2^2} - \frac{1}{1^2}\right)$

$$= -2.0 \times 10^{-18} \times \frac{-3}{4}$$

$$= 1.5 \times 10^{-18}\text{ J}$$

$$\Delta E = \frac{hc}{\lambda}$$

$$\lambda = \frac{hc}{\Delta E} = \frac{6.625 \times 10^{-34}\ js \times 3 \times 10^8\ \text{ms}^{-1}}{1.5 \times 10^{-18}\ J}$$

$= 1.325 \times 10^{-7}$ m

28. **(d)** Total energy of a revolving electron is the sum of its kinetic and potential energy.

Total energy = K.E. + P. E.

$$= \frac{e^2}{2r} + \left(-\frac{e^2}{r}\right); = -\frac{e^2}{2r}$$

29. **(c)** $E = h\nu$

$$= 6.63 \times 10^{-34} \times 2.47 \times 10^{15}$$

$$= 1.640 \times 10^{-18}\text{ J}$$

30. **(d)** Energy $= N_A h\nu$

$$495.5 = 6.023 \times 10^{23} \times 6.6 \times 10^{-34} \times \nu$$

$$\nu = \frac{495.5 \times 10^3\text{ J}}{6.023 \times 10^{23} \times 6.6 \times 10^{-34}} = 12.4 \times 10^{14}$$

$$= 1.24 \times 10^{15}\ \text{s}^{-1}.$$

31. **(a)** $\Delta E = 2.178 \times 10^{-18}\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{hc}{\lambda}$

$$\Rightarrow 2.178 \times 10^{-18} \times \frac{3}{4} = \frac{hc}{\lambda}$$

$$= \frac{6.62 \times 10^{-34} \times 3 \times 10^8}{\lambda}$$

$$\lambda = \frac{6.62 \times 10^{-34} \times 3 \times 10^8 \times 4}{2.178 \times 10^{-18} \times 3}$$

$= 1.214 \times 10^{-7}$m

32. **(a)** $\overline{v} = RZ^2\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$

$$= R\left(\frac{1}{4} - \frac{1}{9}\right) = \frac{5R}{36}$$

33. **(a)** $\nu = R\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$Hz

$$\nu = 3.29 \times 10^{15}\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right)$$

$$= 8.22 \times 10^{14}\text{s}^{-1}$$

34. **(a)** For He^+,

$$v = RZ^2\left(\frac{1}{2^2} - \frac{1}{4^2}\right)\text{Hz}$$

For H,

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

For same frequency,

$$Z^2\left(\frac{1}{2^2} - \frac{1}{4^2}\right) = \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

Since, $Z = 2$

$$\therefore\ \frac{1}{n_1^2} - \frac{1}{n_2^2} = \frac{1}{1^2} - \frac{1}{2^2}$$

$\therefore\ n_1 = 1\ \&\ n_2 = 2$

35. **(b)** $\text{I.E} = \frac{Z^2}{n^2} \times 13.6\,\text{eV}$ ...(i)

or $\frac{I_1}{I_2} = \frac{Z_1^{\;2}}{n_1^{\;2}} \times \frac{n_2^{\;2}}{Z_2^2}$ ...(ii)

Given $I_1 = -19.6 \times 10^{-18}$ J/atom, $Z_1 = 2$,
$n_1 = 1$, $Z_2 = 3$ and $n_2 = 1$

Substituting these values in equation (ii).

$$-\frac{19.6 \times 10^{-18}}{I_2} = \frac{4}{1} \times \frac{1}{9}$$

or $I_2 = -19.6 \times 10^{-18} \times \frac{9}{4}$

$= -4.41 \times 10^{-17}$ J/atom

36. **(d)** (ΔE), The energy required to excite an electron in an atom of hydrogen from $n = 1$ to $n = 2$ is ΔE (difference in energy E_2 and E_1)

Values of E_2 and E_1 are,

$$E_2 = \frac{-1.312 \times 10^6 \times (1)^2}{(2)^2} = -3.28 \times 10^5\ \text{J mol}^{-1}$$

ΔE is given by the relation,

$E_1 = -1.312 \times 10^6\ \text{J mol}^{-1}$

$\therefore \Delta E = E_2 - E_1 = [-3.28 \times 10^5] - [-1.312 \times 10^6]\ \text{J mol}^{-1}$

$= (-3.28 \times 10^5 + 1.312 \times 10^6)\ \text{J mol}^{-1}$

$= 9.84 \times 10^5\ \text{J mol}^{-1}$

37. **(b)** Angular momentum of an electron in n^{th} orbital is given by, $mvr = \frac{nh}{2\pi}$

For $n = 5$, we have

Angular momentum of electron $= \frac{5h}{2\pi} = \frac{2.5h}{\pi}$

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

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

$\lambda = 91.15 \times 10^{-9}\ \text{m} \approx 91\ \text{nm}$

39. **(a)** The lines falling in the visible region comprise Balmer series. Hence the third line from red would be $n_1 = 2$, $n_2 = 5$ i.e. $5 \rightarrow 2$.

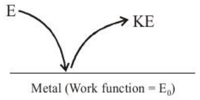
40. **(a)** 2nd excited state will be the 3rd energy level

$$E_n = \frac{13.6}{n^2}\,\text{eV}$$

or $E_3 = \frac{13.6}{9}\,\text{eV} = 1.51\,\text{eV}$.

41. **(d)** (a), (b) and (c) are according to quantum theory but (d) is statement of kinetic theory of gases.

42. **(222)**



$$E = E_0 + (\text{KE})_{\text{max}}$$

$$\frac{hc}{\lambda} = 4.41 \times 10^{-19} + \text{KE}$$

$$\frac{6.63 \times 10^{-34} \times 3 \times 10^8}{300 \times 10^{-9}} = 4.41 \times 10^{-19} + \text{KE}$$

So, $(\text{KE})_{\text{max}} = 6.63 \times 10^{-19} - 4.41 \times 10^{-19}$

$= 2.22 \times 10^{-19}\ \text{J} = 222 \times 10^{-21}\ \text{J}$

43. **(d)** $2\pi r = n\lambda$

$$r = \frac{n^2 a_0}{Z}$$

$$2\pi \times \frac{4^2}{1} a_0 = 4\lambda$$

$$\lambda = 2\pi \times \frac{4}{1} a_0$$

$$\lambda = 8\pi a_0$$

44. **(d)** In photoelectric effect,

$\frac{hc}{\lambda} = w + \text{KE of electron}$

Given that KE of ejected photoelectron is very high in comparison to work function w.

$$\frac{hc}{\lambda} = \text{KE}$$

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

$$\frac{hc}{\lambda} = \frac{1}{2} \cdot \frac{m^2 v^2}{m}$$

$$\frac{hc}{\lambda} = \frac{P^2}{2m}$$

New wavelength

$$\frac{hc}{\lambda_1} = \frac{(1.5P)^2}{2m} \Rightarrow \lambda_1 = \frac{4}{9}\lambda$$

45. **(d)** Given $\lambda = 1.5\pi a_0$

$$n\lambda = 2\pi r \qquad \text{...(i)}$$

Radii of stationary states (r) is expressed as:

$$r = a_0 \frac{n^2}{z} \qquad \text{...(ii)}$$

From eqn (i) and (ii)

$$n\lambda = \frac{2\pi a_0 n^2}{z} \; ; \lambda = \frac{2\pi a_0 n}{z}$$

$$1.5\pi a_0 = 2\pi a_0 \frac{n}{z}$$

$$\frac{n}{z} = \frac{1.5}{2} = 0.75$$

46. **(d)** According to de-Broglie wavelength equation,

$$\lambda = \frac{h}{m\nu} \Rightarrow \quad \lambda \propto \frac{1}{\nu}$$

According to photoelectric effect,

$$h\nu - h\nu_0 = \frac{1}{2}mv^2; \nu - \nu_0 = \frac{1}{2} = \frac{mv^2}{h}$$

$$\nu - \nu_0 \propto v^2$$

$$v \propto (\nu - \nu_0)^{1/2}$$

$$\therefore \quad \lambda \propto \frac{1}{(\nu - \nu_0)^{1/2}}$$

47. **(b)** First Bohr orbit of H atom has radius r = 0.529 Å
Also, the angular momentum is quantised.

$$mvr = \frac{h}{2\pi}$$

$$2\pi r = \frac{h}{mv} = \lambda$$

$$\therefore \quad \lambda = 2\pi \times 0.529 \text{ Å}$$

48. **(d)** Kinetic energy of any particle $= \frac{3}{2}kT$

Also K.E. $= \frac{1}{2}mv^2$

$$\frac{1}{2}mv^2 = \frac{3}{2}kT \Rightarrow v^2 = \frac{3kT}{m}$$

$$v = \sqrt{\frac{3kT}{m}}$$

de-broglie wavelength $= \lambda = \frac{h}{mv} = \frac{h}{m\sqrt{\frac{3kT}{m}}}$

$$\lambda = \frac{h}{\sqrt{3kTm}}; \; \lambda \propto \frac{1}{\sqrt{m}}$$

Mass of electron < mass of neutron
λ (electron) > λ (neutron)

49. **(a)** de Broglie wavelength $(\lambda) = \frac{h}{mv}$

$$= \frac{6.63\times10^{-34}\text{ Js}}{6.63\times10^{-3}\text{ kg}\times100\text{ m/s}} = 10^{-33}\text{ m}$$

50. **(b)** $\lambda = \frac{h}{mv}$

$h = 6.6 \times 10^{-34}$ Js
$m = 1000$ kg

$$v = 36\text{ km/hr} = \frac{36\times10^3}{60\times60}\text{ m/sec} = 10\text{ m/sec}$$

$$\therefore \quad \lambda = \frac{6.6\times10^{-34}}{10^3\times10} = 6.6\times10^{-38}\text{ m}$$

51. **(c)** $r_n = a_0 n^2$
$r = a_0 \times (3)^2 = 9a_0$

$$mvr = \frac{nh}{2\pi}; \quad mv = \frac{nh}{2\pi r} = \frac{3h}{2\pi\times9a_0} = \frac{h}{6\pi\, a_0}$$

$$\lambda = \frac{h}{mv} = \frac{n}{h}\times6\pi a_0 = 6\pi a_0$$

52. **(b)** de – Broglie wavelength is given by :

$$\lambda = \frac{h}{mv} \qquad \text{... (i)}$$

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

$$v^2 = \frac{2K.E}{m}$$

$$v = \sqrt{\frac{2K.E}{m}}$$

Substituting this in equation (i)

$$\lambda = \frac{h}{m}\sqrt{\frac{m}{2K.E}}$$

$$\lambda = h\sqrt{\frac{1}{2m(K.E)}}$$

i.e. $\quad \lambda \propto \frac{1}{\sqrt{K.E}}$

$\therefore$ when *KE* become 4 times wavelength become 1/2.

53. **(b)** According to Heisenberg uncertainty principle.

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

Here $\Delta v = \frac{600\times0.005}{100} = 0.03$ m/s

So, $\Delta x = \dfrac{6.6 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 0.03}$

$= 1.92 \times 10^{-3}\,\text{m}$

54. **(a)** Given $m = 9.1 \times 10^{-31}\,\text{kg}$

$h = 6.6 \times 10^{-34}\,\text{Js}$

$\Delta v = \dfrac{300 \times .001}{100} = 0.003\,\text{ms}^{-1}$

From Heisenberg's uncertainity principle

$\Delta x = \dfrac{6.62 \times 10^{-34}}{4 \times 3.14 \times 0.003 \times 9.1 \times 10^{-31}}$

$= 1.92 \times 10^{-2}\,\text{m}$

55. **(d)** $\lambda = \dfrac{h}{mv} = \dfrac{6.63 \times 10^{-34}}{60 \times 10^{-3} \times 10}$

$= 1.105 \times 10^{-33} \approx 10^{-33}\,\text{m}$

56. **(c)** $\Delta x.\Delta p = \dfrac{h}{4\pi}$; or $\Delta x.m.\Delta v = \dfrac{h}{4\pi}$

$\therefore \Delta v = \dfrac{6.62 \times 10^{-34}}{4 \times 3.14 \times 0.025 \times 10^{-5}} = 2.1 \times 10^{-28}\,\text{ms}^{-1}$

57. **(a)**

$$\begin{array}{ccccc} & 6s & 4f & 5d & 6p \\ n+l & 6+0 & 4+3 & 5+2 & 6+1 \\ & \Downarrow & \Downarrow & \Downarrow & \Downarrow \\ & 6 & 7 & 7 & 7 \end{array}$$

Thus, order of orbitals filled are
$6s < 4f < 5d < 6p$.

58. **(c)** Radial node $= n - l - 1$

$\therefore 1s \Rightarrow 0(\psi^2 \neq 0)$

$2s \Rightarrow 1(\psi^2 = 0)$

$2p \Rightarrow 0(\psi^2 \neq 0)$

$3p \Rightarrow 1(\psi^2 = 0)$

Probability density (ψ^2) can be zero for $3p$ orbital other than infinite distance. It has one radial node.
Thus, statement (c) is correct.

59. **(b)** Under the given situation for
$n = 1, l = 0, 1, 2$
$n = 2, l = 0, 1, 2, 3$
$n = 3, l = 0, 1, 2, 3, 4$
According to $(n + l)$ rule of order of filling of subshells will be :
$1s\ 1p\ 1d\ 2s\ 2p\ 3s\ 2d\ 3f$

Atomic number 6	$1s^2\ 1p^4$
Atomic number 9	$1s^2\ 1p^6\ 1d^1$
Atomic number 8	$1s^2\ 1p^6$
Atomic number 13	$1s^2\ 1p^6\ 1d^5$

Therefore option (b) is correct. Atomic number of first noble gas will be 18 ($1s^2\ 1p^6\ 1d^{10}$).

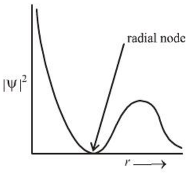
60. **(b)** For $n = 4$ possible values of $l = 0, 1, 2, 3$; only $l = 2$ and $l = 3$ can have $m = -2$. So possible subshells are 2.

61. **(b)** The possible number of orbitals in a shell in term of 'n' is n^2

$\therefore n = 5$; $n^2 = 25$

62. **(a)** Probability of finding an electron will have maximum value at both 'a' and 'c'. There is zero probability of finding an electron at 'b'.

63. **(b)** The given probability density curve is for $2s$ orbital due to the presence of only one radial node. $1s$ and $2p$ orbital do not have any radial node and $3s$ orbital has two radial nodes. Hence, option (b) is correct.



64. **(a)** Atomic numbers of N, O, F and Na are 7, 8, 9 and 11 respectively. Therefore, total number of electrons in each of N^{3-}, O^{2-}, F^-, and Na^+ are 10 and hence they are isoelectronic.

65. **(c)**

				$n+\ell$
(I)	$n = 4$	$\ell = 2$	$4d$	6
(II)	$n = 3$	$\ell = 2$	$3d$	5
(III)	$n = 4$	$\ell = 1$	$4p$	5
(IV)	$n = 3$	$\ell = 1$	$3p$	4

The energy of an atomic orbital increases with increasing $n + \ell$. For identical values of $n + \ell$, energy increases with increasing value of n. Therefore the correct order of energy is:

$$\underset{\text{IV}}{3p} < \underset{\text{II}}{3d} < \underset{\text{III}}{4p} < \underset{\text{I}}{4d}$$

66. **(d)** Iso-electronic species differ in size due to different effective nuclear charge.

67. **(a)**

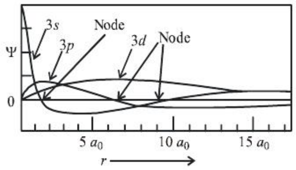
(a) Angular momentum $(L) = \dfrac{nh}{2\pi}$

Therefore, as n increases, L also increases.

(b) $r \propto \dfrac{n^2}{z}$

(c) For $n = 1, L = \dfrac{h}{2\pi}$

(d) As l increases, the peak of ψ vs r shifts towards higher 'r' value.



68. **(b)** Number of orbitals in a shell $= n^2 = (5)^2 = 25$.

69. **(b)** According to Aufbau principle, the sequence of filling electrons in sixth period is

$6s - 4f - 5d - 6p$ i.e., $(ns) \rightarrow (n-2)f \rightarrow (n-1)d \rightarrow np$

70. **(a)** The electronic configuration of Rubidium (Rb = 37) is

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

Since last electron enters in 5s orbital

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

71. **(c)** $n = 3, l = 2$ means 3d orbital

+2	+1	0	−1	−2

i.e. in an atom only one orbital can have the value $m_l = +2$

72. **(b)** (i) $n = 5$ means $l = 0, 1, 2, 3, 4$

since $m = +1$

hence total no. of electrons will be

$= 0(\text{from } s) + 2(\text{from } p) + 2(\text{from } d) + 2(\text{from } f) + 2(\text{from } g)$

$= 0 + 2 + 2 + 2 + 2 = 8$

(ii) $n = 2, l = 1, m_l = -1, m_s = -1/2$ represent 2p orbital with one electron.

73. **(b)** (A) 4p (B) 4s (C) 3d (D) 3p

Accroding to Bohr Bury's $(n + l)$ rule, increasing order of energy $(D) < (B) < (C) < (A)$.

Note: If the two orbitals have same value of $(n + l)$ then the orbital with lower value of n will be filled first.

74. **(c)** Among isoelectronic species ionic radii increases as the negatives charge increases.

Order of ionic radii $Ca^{2+} < K^+ < Cl^- < S^{2-}$

The number of electrons remains the same but nuclear charge increases with increase in the atomic number causing decrease in size.

75. **(b)** (i) 4p (ii) 4s (iii) 3d (iv) 3p

According to Bohr Bury's $(n + l)$ rule, increasing order of energy will be (iv) < (ii) < (iii) < (i).

Note: If the two orbitals have same value of $(n + l)$ then the orbital with lower value of n will be filled first.

76. **(b)** Species having same number of electrons are isoelectronic. On calculating the number of electrons in each species given here, we get.

$CN^- (6 + 7 + 1 = 14); N_2 (7 + 7 = 14)$

$O_2^{2-} (8 + 8 + 2 = 18); C_2^{2-} (6 + 6 + 2 = 14)$

$O_2^- (8 + 8 + 1 = 17); NO^+ (7 + 8 - 1 = 14)$

$CO (6 + 8 = 14); NO (7 + 8 = 15)$

From the above calculation we find that all the species listed in choice (b) have 14 electrons each so it is the correct answer.

77. **(c)** (a) $n = 3, l = 0$ means 3s-orbital and $n + l = 3$

(b) $n = 3, l = 1$ means 3p-orbital $n + l = 4$

(c) $n = 3, l = 2$ means 3d-orbital $n + l = 5$

(d) $n = 4, l = 0$ means 4s-orbital $n + l = 4$

Increasing order of energy among these orbitals is

$3s < 3p < 4s < 3d$

$\therefore$ 3d has highest energy.

78. **(c)** (a) $N^{3-} = 7 + 3 = 10e^-$, $O^{2-} \longrightarrow 8 + 2 = 10e^-$

$F^- = 9 + 1 = 10e^-$, $S^{2-} \longrightarrow 16 + 2 = 18e^-$

(not isoelectronic)

(b) $Li^+ = 3 - 1 = 2e^-$, $Na^+ = 11 - 1 = 10e^-$,

$Mg^{2+} = 12 - 2 = 10e^-$

$Ca^{2+} = 20 - 2 = 18e^-$ (not isoelectronic)

(c) $K^+ = 19 - 1 = 18e^-$, $Cl^- = 17 + 1 = 18e^-$,

$Ca^{2+} = 20 - 2 = 18e^-$, $Sc^{3+} = 21 - 3 = 18e^-$

(isoelectronic)

(d) $Ba^{2+} = 56 - 2 = 54e^-$, $Sr^{2+} = 38 - 2 = 36e^-$

$K^+ = 19 - 1 = 18e^-$, $Ca^{2+} = 20 - 2 = 18e^-$

(not isoelectronic)

79. **(b)** Calculating number of electrons

a. $$\left.\begin{array}{l} BO_3^{3-} \longrightarrow 5 + 8 \times 3 + 3 = 32 \\ CO_3^{2-} \longrightarrow 6 + 8 \times 3 + 2 = 32 \\ NO_3^- \longrightarrow 7 + 8 \times 3 + 1 = 32 \end{array}\right\} \text{isoelectronic species}$$

b. $$\left.\begin{array}{l} SO_3^{2-} \longrightarrow 16 + 8 \times 3 + 2 = 42 \\ CO_3^{2-} \longrightarrow 32 \\ NO_3^- \longrightarrow 32 \end{array}\right\} \text{not isoelectronic species}$$

c. $$\left.\begin{array}{l} CN^- \longrightarrow 6 + 7 + 1 = 14 \\ N_2 \longrightarrow 7 \times 2 = 14 \\ C_2^{2-} \longrightarrow 6 \times 2 + 2 = 14 = 14 \end{array}\right\} \text{isoelectronic species}$$

$$\text{d.}\quad \left.\begin{array}{l} PO_4^{3-} \longrightarrow 15+8\times 4+3=50 \\ SO_4^{2-} \longrightarrow 16+8+2=50 \\ ClO_4^{-} \longrightarrow 17+8\times 4+1=50 \end{array}\right\} \begin{array}{c}\text{isoelectronic}\\ \text{species}\end{array}$$

Hence the species in option (b) are not iso-electronic.

80. **(a)** The energy of an orbital is given by $(n + l)$ rule. $(n + l)$ value for option (E) and (D) is $(3 + 2) = 5$ hence they will have same energy, since their n values are also same.

81. **(a)** The possible quantum numbers for $4f$ electron are

$n = 4, l = 3, m = -3, -2 -1, 0, 1, 2, 3$ and $s = \pm\frac{1}{2}$

Of various possiblities only option (a) is possible.

82. **(b)** Electronic configuration of Cr atom (Z = 24)

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

when $l = 1$, p-subshell,

Numbers of electrons = 12

when $l = 2$, d-subshell,

Numbers of electrons = 5

83. **(c)** $_{19}K^+, _{20}Ca^{2+}, _{21}Sc^{3+}, _{17}Cl^-$

each contains 18 electrons.

84. **(c)** $Fe^{++}(26 - 2 = 24) = 1s^2 2s^2 2p^6 3s^2 3p^6 4s^0 3d^6$ hence no. of d electrons retained is 6.

[Two $4s$ electron are removed]

85. **(a)** N^{3-}, F^- and Na^+ contain 10 electrons each.