EXERCISE II (JEE ADVANCED)

Section A (Only one Correct)

1. The e/m ratio of cathode rays is x unit, when hydrogen is filled in the discharge tube. What will be its value, when deuterium (D_2) is filled in it?

(a) x unit (b) $x/2$ unit
(c) $2x$ unit (d) $x/4$ unit

2. Specific charges of two particles A and B are in the ratio 2:3. If the mass ratio, $m_A:m_B$ is 2:3, then the ratio of their charges, $e_A:e_B$, is

(a) 1:1 (b) 4:9
(c) 9:4 (d) 2:3

3. An electron at rest is accelerated through a potential difference of 200 V. If the specific charge of electron is 1.76×10^{11} C/kg, the speed acquired by the electron is about

(a) 8.4×10^6 cm/s
(b) 8.4×10^6 m/s
(c) 4.2×10^6 m/s
(d) 4.2×10^6 cm/s

4. The mass of a negative meson is 208 time the mass of electron. If e/m ratio of α-particle is x unit, the e/m ratio of this meson will be

(a) $\frac{x}{208}$ unit (b) $\frac{x}{52}$ unit
(c) $17.65\ x$ unit (d) $104\ x$ unit

5. An electron and a proton are accelerated through a potential V. If P_e and P_p are their momentum, then $P_p:P_e$ ratio is approximately equal to

(a) 1:1836 (b) 1:1
(c) 1836:1 (d) 43:1

6. The frequency of an electromagnetic radiation which makes 2×10^6 waves per 50 cm is

(a) 1.2×10^{15} Hz
(b) 150 Hz
(c) 6×10^{14} Hz
(d) 1.2×10^{13} Hz

7. A certain laser transition emits 6.0×10^{15} quanta per sec per square metre of $\lambda = 662.6$ nm. What is the power output in joule per sec per square metre?

(a) 1.8×10^{-3}
(b) 6.626×10^{-4}
(c) 1.8×10^{3}
(d) 6.626×10^{-12}

8. A bulb emits light of wavelength $\frac{1987.8}{7}$ nm. The bulb is rated as 200 W and 14% of the energy is emitted as light. How many photons are emitted by the bulb per second?

(a) 1.2×10^{21}
(b) 4×10^{10}
(c) 1.33×10^{11}
(d) 4×10^{19}

9. An amount of 1.75×10^{-4} mole of HI decomposes by the absorption of photons of wavelength 2500 Å. If one molecule is decomposed per absorbed photon, the total energy absorbed is ($N_A \times hc = 0.12$)

(a) 42.0 J (b) 4.2 J
(c) 8.4 J (d) 84 J

10. The dye acriflavine when dissolved in water has its maximum light absorption at 4530 Å and has maximum florescence emission at 5080 Å. The number of fluorescence quanta is about 53% of the number of quanta absorbed. What percentage of absorbed light energy is emitted as fluorescence?

(a) 41% (b) 47%
(c) 74% (d) 63%

11. The vapours of Hg absorb some electron accelerated by a potential difference of 5.0 V as a result of which light is emitted. If the full energy of single incident electron is supposed to be converted into light emitted by single Hg-atom, the wavelength of the emitted light is

(a) 2480 nm (b) 248 nm
(c) 6200 nm (d) 620 nm

12. At one time the meter was defined as 1650763.73 wavelength of the orange light emitted by a light source containing Kr^{86} atoms. What is the corresponding photon energy of this radiation?

(a) 3.28×10^{-19} J/quanta
(b) 1.2×10^{-31} J/quanta
(c) 1.09×10^{-27} J/quanta
(d) 2.048 J/quanta

13. A ruby laser produces radiations of wavelength 662.6 nm in pulses whose duration are 1.0×10^{-9} s. If the laser produces 0.36 J of energy per pulse, how many photons are produced in each pulse?

(a) 1.2×10^{9} (b) 1.2×10^{27}
(c) 1.2×10^{18} (d) 1.2×10^{15}

14. O_2 undergoes photochemical dissociation into one normal oxygen atom and one oxygen atom, 1.2 eV more energetic than normal. The dissociation of O_2 into two normal atoms of oxygen requires 482.5 kJ/mol. The maximum wavelength effective for photochemical dissociation of O_2 is (1 eV = 96.5 kJ/mol)

(a) 248 nm (b) 1033.3 nm
(c) 1236.2 nm (d) 200 nm

15. Photo-dissociation of water $H_2O(l) + h\nu \rightarrow H_2(g) + \frac{1}{2}O_2(g)$ has been suggested as a source of hydrogen. The heat absorbed in this reaction is 289.5 kJ/mole of water decomposed. The maximum wavelength that would provide the necessary energy assuming that one photon causes the dissociation of one water molecule is (1 eV = 96.5 kJ/mol)

(a) 413.33 nm (b) 826.67 nm
(c) 206.67 nm (d) 4.3 nm

16. The dissociation energy of H_2 is 429.0 kJ/mol. If H_2 is dissociated by illumination with radiation of wavelength 270.0 nm, what percentage of radiant energy will be converted into kinetic energy? ($h = 6.6 \times 10^{-34}$ J·s, $N_A = 6 \times 10^{23}$)

(a) 1.25% (b) 2.5%
(c) 5.0% (d) 7.5%

17. In a measurement of the quantum efficiency of photosynthesis in green plants, it was found that 9 quanta of red light at 6900 Å were needed to evolve 1 molecule of O_2. The average energy storage in the photosynthesis process is 111.6 kcal/mol of O_2 evolved. What is the energy conversion efficiency in this experiment? ($\frac{h \cdot c}{e} = 1.24 \times 10^{-7}$ nm.eV, 1 eV = 23 kcal/mol)

(a) 70% (b) 50%
(c) 40% (d) 30%

18. For a photochemical reaction, A $\rightarrow$ B, 1×10^{-5} moles of 'B' were formed on absorption of 6.626×10^{7} erg at 360 nm. The quantum efficiency (molecules of 'B' formed per photon) is

(a) 1.0 (b) 0.25
(c) 0.5 (d) 2.0

19. Light of wavelength, λ, falls on a metal having work function hc/λ_0. Photoelectric effect will take place only if

(a) $\lambda \geq \lambda_0$ (b) $\lambda \geq 2\lambda_0$
(c) $\lambda \leq \lambda_0$ (d) $\lambda \leq \lambda_0/2$

20. Light of wavelength, λ, strikes a metal surface with intensity X and the metal emits Y electrons per second of maximum kinetic energy Z. What will happen to Y and Z if X is halved?

(a) Y will be halved and Z will be doubled
(b) Y will be doubled and Z will be halved

(c) Y will be halved and Z will remain the same
(d) Y will remain same and Z will be halved

21. Photoelectric emission is observed from a metal surface for frequencies v_1 and v_2 of the incident radiation ($v_1 > v_2$). If maximum kinetic energies of the photoelectrons in the two cases are in the ratio 1:K, then the threshold frequency for the metal is given by

(a) $\dfrac{\nu_2 - \nu_1}{K-1}$ (b) $\dfrac{K\nu_2 - \nu_1}{K-1}$

(c) $\dfrac{K\nu_1 - \nu_2}{K}$ (d) $\dfrac{K\nu_1 - \nu_2}{K-1}$

22. Photons of frequency, ν, fall on metal surface for which the threshold of frequency is v_0. Then
(a) All ejected electrons have the same kinetic energy, $h(v - v_0)$.
(b) The ejected electrons have a distribution of kinetic energy from zero to $h(v - v_0)$.
(c) The most energetic electron has kinetic energy hv.
(d) The average kinetic energy of ejected electrons is $h(v - v_0)$.

23. If λ_0 is the threshold wavelength for photoelectric emission from a metal surface, λ is the wavelength of light falling on the surface of metal and m is the mass of electron, then the maximum speed of ejected electrons is given by

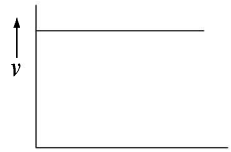
(a) $\left[\dfrac{2h}{m}(\lambda_0 - \lambda)\right]^{1/2}$

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

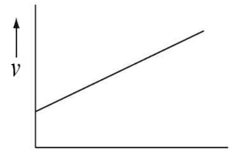
(c) $\left[\dfrac{2hc}{m}\left(\dfrac{\lambda_0 - \lambda}{\lambda_0\lambda}\right)\right]^{1/2}$

(d) $\left[\dfrac{2h}{m}\left(\dfrac{1}{\lambda_0} - \dfrac{1}{\lambda}\right)\right]^{1/2}$

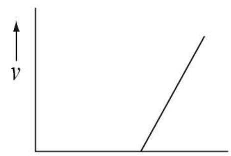
24. Which of the following graphs is correct for the photoelectric effect?

(a)


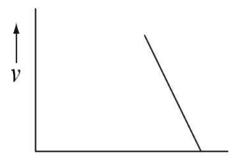
K.E. of Emitted → Electrons

(b)


K.E. of Emitted → Electrons

(c)


K.E. of Emitted → Electrons

(d)


K.E. of Emitted → Electrons

25. The wavelength of K_α-characteristic X-rays produced is λ, when cathode rays strike on a metal of atomic number Z. What should be the atomic number of metal such that it can produce the K_α-characteristic X-rays of wavelength 4λ?

(a) $\dfrac{Z}{16}$ (b) $\dfrac{Z}{2}$

(c) $\dfrac{Z+1}{2}$ (d) $2Z - 1$

26. Two carbon discs, 1.0 g each, are 1.0 cm apart have equal and opposite charges. If force of attraction between them is 10^{-5} N, the ratio of excess electrons to the total atoms on the negatively charged disc is ($N_A = 6 \times 10^{23}$)

(a) $2.4 \times 10^{-12}:1$ (b) $10^{-12}:2.4$
(c) $10^{12}:2.4$ (d) $2.4:10^{12}$

27. The radius of the hydrogen atom in its ground state is 5.3×10^{-11} m. After collision with an electron it is found to have a radius of 21.2×10^{-11}m. The principal quantum number of final state of the atom is

(a) 2 (b) 3
(c) 4 (d) 16

28. For which orbit in He^+ ion, the circumference is 26.5 Å?

(a) 2 (b) 3
(c) 4 (d) 16

29. The radius of the second orbit of H-atom is equal to the radius of

(a) second orbit of He^+ ion
(b) third orbit of Li^{2+} ion
(c) fourth orbit of He^+ ion
(d) fourth orbit of Be^{3+} ion

30. As the orbit number increases, the distance between two consecutive orbits (r_1 = radius of first orbit)

(a) increases by $2r_1$
(b) increases by $(2n - 1)r_1$, where n is lower orbit number
(c) increases by $(2n - 1)r_1$, where n is higher orbit number
(d) remains constant

31. The ratio of the areas within the electron orbits for the first excited state to the ground state for the hydrogen atom is

(a) 2:1 (b) 4:1
(c) 8:1 (d) 16:1

32. When an electron jumps from the second orbit to fourth orbit, its distance from nucleus increases by 2.116 Å. The atom or ion should be

(a) H atom (b) He^+ ion
(c) Li^{2+} ion (d) Be^{3+} ion

33. What is the distance travelled by an electron revolving in the second orbit of Be^{3+} ion, in 100 revolutions?

(a) 3.32×10^{-8} m (b) 5.29×10^{-8} m
(c) 6.64×10^{-8} m (d) 1.16×10^{-8} m

34. Which of the following cannot be circumference of an orbit in H-atom? (r_0 = radius of the first orbit)

(a) $2\pi r_0$ (b) $4\pi r_0$
(c) $8\pi r_0$ (d) $18\pi r_0$

35. The speed of electron revolving round H-nucleus is 0.547×10^6 m/s. The distance of electron from nucleus is

(a) 2.116 Å (b) 4.761 Å
(c) 8.464 Å (d) 0.529 Å

36. The speed of electron in H-atom is directly proportional to

(a) r (b) $\sqrt{r}$
(c) $1/r$ (d) $1/\sqrt{r}$

37. The ratio of the speed of the electron in the first Bohr orbit of hydrogen and the speed of light is equal to (where e, h and c have their usual meanings)

(a) $2\pi hc/e^2$ (b) $e^2c/2\pi h$
(c) $e^2h/2\pi c$ (d) $e^2/2\in_0 hc$

38. In the Bohr's atomic model, the electrostatic force of attraction between nuclear charge (Z_e) and electron of charge e is balanced by the centripetal force acting towards the centre of atom. If $\in_0$ be the permittivity of vacuum and r be the radius of orbit in which electron is revolving, the speed of electron is

(a) $\sqrt{\dfrac{Ze^2}{(4\pi\varepsilon_o)mr}}$

(b) $\sqrt{\dfrac{(4\pi\varepsilon_o)mr}{Ze^2}}$

(c) $\sqrt{(4\pi\varepsilon_o)mrZe^2}$

(d) $\dfrac{e}{\sqrt{(4\pi\varepsilon_o)mr}}$

39. If an electron is revolving round the nucleus of He^+ ion at a distance of 4.0 Å, the magnitude of centripetal force on electron by the nucleus is

(a) 2.88×10^{-9} N
(b) 2.88×10^{-7} N
(c) 1.152×10^{-18} N
(d) 1.44×10^{-9} N

40. The time period of revolution in the third orbit of Li^{2+} ion is x second. The time period of revolution in the second orbit of He^+ ion, should be

(a) x s (b) $\frac{3}{2} x$ s
(c) $\frac{2}{3} x$ s (d) $\frac{8}{27} x$ s

41. In two hydrogen atoms A and B, the electrons are revolving round the nucleus in circular orbits of radius r and $4r$, respectively. The ratio of times taken by them to complete one revolution is

(a) 1:2 (b) 1:4
(c) 1:8 (d) 1:64

42. The time period of revolution of electron in H-atom is directly proportional to

(a) r (b) $r^{1/2}$
(c) $r^{3/2}$ (d) r^2

43. The average life time of an electron in an excited state of hydrogen atom is about 10^{-8} s. How many revolutions does an electron in the $n = 2$ state make before dropping to the $n = 1$ state?

(a) 10^8 (b) 8.33×10^6
(c) 6.67×10^7 (d) 1.04×10^6

44. According to Maxwell's theory of electrodynamics, an electron going in a circle should emit radiation of frequency equal to its frequency of revolution. What should be the wavelength of the radiation emitted by a hydrogen atom in the ground state if this rule is followed?

(a) 4500 nm (b) 450 nm
(c) 45 nm (d) 4.5 nm

45. The angular momentum of electron in Bohr's orbit is J. What will be the K.E. of electron in that Bohr's orbit?

(a) $\frac{1}{2}\frac{Jv}{r}$ (b) $\frac{Jv}{r}$
(c) $\frac{J^2}{2m}$ (d) $\frac{J^2}{2r}$

46. The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is (a_o is the Bohr radius)

(a) $\frac{h^2}{4\pi^2 m a_o^2}$ (b) $\frac{h^2}{16\pi^2 m a_o^2}$
(c) $\frac{h^2}{32\pi^2 m a_o^2}$ (d) $\frac{h^2}{64\pi^2 m a_o^2}$

47. The ionization energy of a hydrogen-like atom is 14.4 eV. The amount of energy released when electron jumps from the fourth orbit to the first orbit in this atom, is

(a) 13.5 eV (b) 10.8 eV
(c) 0.9 eV (d) 12.75 eV

48. The radius of first orbit of H-atoms is 0.529 Å. The radius of first orbit of D-atoms should be

(a) exactly 0.529 Å
(b) slightly less than 0.529 Å
(c) slightly greater than 0.529 Å
(d) 1.058 Å

49. The ionization energy of H–atoms is 13.6 eV. The ionization energy of deuterium atom should be

(a) exactly 13.6 eV
(b) slightly less than 13.6 eV
(c) slightly greater than 13.6 eV
(d) 27.2 eV

50. An antiproton has the mass of a proton but a charge of $-e$. If a proton and an antiproton orbited each other, how far apart would they be in ground state of such a system? Mass of a proton is 1836 times the mass of an electron.

(a) 0.058 pm
(b) 0.029 pm
(c) 0.014 pm
(d) 194.25 nm

51. A lithium atom has three electrons. Assume the following simple picture of the atom. Two electrons move close to the nucleus making up a spherical cloud around it and the third moves outside this cloud in a circular orbit. Bohr's model can be used for the motion of this third electron but $n = 1$ state is not available to it. The ionization energy of lithium in ground state, using the above picture, is

(a) 13.6 eV (b) 10.2 eV
(c) 3.4 eV (d) 1.51 eV

52. 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 speed of the emitted electron?

(a) 1.55×10^6 m/s
(b) 2.68×10^6 m/s
(c) 2.19×10^6 m/s
(d) 1.02×10^6 m/s

53. Sodium atoms emit a spectral line with a wavelength in the yellow, 589.6 nm. What is the approximate difference in energy between the two energy levels involved in the emission of this spectral line?

(a) 3.37×10^{-19} J
(b) 2.1 eV
(c) 48.35 kcal/mol
(d) all of these

54. A certain molecule has an energy level diagram for its vibrational energy in which two levels are 0.0141 eV apart. The wavelength of the emitted line for the molecule as it falls from one of these levels to the other, is about

(a) 88 μm
(b) 88 mm
(c) 174.84 m
(d) 88 nm

55. In a discharge tube, there are only two hydrogen atoms. If the electrons in both atoms are de-exciting from 4^{th} orbit, the minimum and maximum number of spectral lines should, respectively, be

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

56. Electrons are de-exciting from the fifth orbit in hydrogen atoms but the first orbit is not available for them. The maximum number of spectral lines should be

(a) 10 (b) 6
(c) 15 (d) 3

57. From a hydrogen discharge tube, only three photons are picked up. The energies of these three photons were 10.2, 12.1 and 1.9 eV. These photons are coming from

(a) only one atoms
(b) two atoms
(c) three atoms
(d) two or more atoms

58. When electron jumps from the fourth orbit to the second orbit in He^+ ion, the radiation emitted out will fall in

(a) ultraviolet region
(b) visible region
(c) infrared region
(d) radio wave region

59. When electrons are de-exciting to the ground state from n^{th} orbit of hydrogen atoms, 15 spectral lines are formed. The shortest wavelength among these will be

(a) $\frac{11}{900}R$ (b) $\frac{900}{11R}$
(c) $\frac{35}{36}R$ (d) $\frac{35}{36R}$

60. Rydberg given the equation for all visible radiation in the hydrogen spectrum as $\lambda = \frac{kn^2}{n^2 - 4}$. The value of k in terms of Rydberg constant is

(a) $4R$ (b) $\frac{R}{4}$
(c) $\frac{4}{R}$ (d) R

61. The wavelengths of the first Lyman lines of hydrogen, He^+ and Li^{2+} ions are λ_1, λ_2, λ_3. The ratio of these wavelengths is
(a) 1:4:9 (b) 9:4:1
(c) 36:9:4 (d) 6:3:2

62. An excited hydrogen atom emits a photon of wavelength λ in returning to the ground state. If R is the Rydberg constant, then the quantum number n of the excited state is
(a) $\sqrt{\lambda R}$
(b) $\sqrt{\lambda R - 1}$
(c) $\sqrt{\frac{\lambda R}{\lambda R - 1}}$
(d) $\sqrt{\lambda R(\lambda R - 1)}$

63. Suppose that in any Bohr atom or ion, orbits are only in even numbers like 2, 4, 6, …. The maximum wavelength of radiation emitted in the visible region of H-spectrum should be
(a) $\frac{4}{R}$ (b) $\frac{R}{4}$
(c) $\frac{36}{5R}$ (d) $\frac{16}{3R}$

64. The wavelength of first line of Lyman series of H-atom is 1216 Å. What will be the wavelength of first line of Lyman series in 10 time ionized sodium atom $(Z = 11)$
(a) 1216 Å (b) 12.16 Å
(c) 10 Å (d) 110 Å

65. In a sample of hydrogen atoms, all the atoms are in a particular excited state. If the emission spectrum of this sample has only 4 spectral lines in the visible region, then the total number of spectral lines in IR region possible from that state is
(a) 6 (b) 5
(c) 7 (d) 15

66. Imagine an atom made up of a stationary proton and a hypothetical particle of double the mass of electron but having the same charge as the electron. Apply Bohr atomic model and consider all possible transitions of this hypothetical particle directly to the first excited state. The longest wavelength photon that will be emitted has wavelength (given in terms of Rydberg constant R for the hydrogen atom) equal to
(a) $\frac{9}{5R}$ (b) $\frac{36}{5R}$
(c) $\frac{18}{5R}$ (d) $\frac{4}{R}$

67. Which of the following expression represent the wave number of spectral lines in Balmer series (if n is the principal quantum number of higher energy level)?
(a) $\frac{R(n^2 - 4)}{n^2}$
(b) $\frac{R(n-2)(n+2)}{n^2}$
(c) $\frac{R(n-2)(n+2)}{4n^2}$
(d) $\frac{R(n-1)(n+1)}{4n^2}$

68. The energy emitted when electron of 1.0 g atom of hydrogen undergo transition giving the spectral lines of lowest energy in visible region of its atomic spectra is
(a) 301.22 kJ (b) 328 kJ
(c) 984 kJ (d) 182.22 kJ

69. A series of lines in the spectrum of atomic hydrogen lines at wavelength 656.46, 486.27, 434.17, 410.29 nm. What is the wavelength of next line in this series?
(a) 397.12 nm (b) 407.83 nm
(c) 389.01 nm (d) 360.54 nm

70. To what series does the spectral line of atomic hydrogen belong if its wave number is equal to the difference between the wave numbers of the following two lines of the Balmer series: 486.1 and 410.2 nm?
(a) Lyman series
(b) Balmer series
(c) Paschen series
(d) Brackett series

71. The value of Rydberg constant R, if He^+ ions are known to have the wavelength difference between the first (of the longest wavelength) lines of the Balmer and Lyman series equal to 132 nm, is
(a) $2.07 \times 10^{16}\ m^{-1}$
(b) $1.11 \times 10^{7}\ m^{-1}$
(c) $9 \times 10^{-8}\ m^{-1}$
(d) $1.936 \times 10^{7}\ m^{-1}$

72. The wavelength of the first line of the He^+ ion spectral series whose interval between the extreme lines is $2.725 \times 10^6\ m^{-1}$ is ($R = 1.09 \times 10^7\ m^{-1}$)
(a) 471.82 nm
(b) 4718.2 nm
(c) 1019.37 nm
(d) 165.14 nm

73. The binding energy of an electron in the ground state of hydrogen-like ions in whose spectrum, the third line the Balmer series is equal to 108.5 nm, is
(a) 13.6 eV (b) 54.4 eV
(c) 122.4 eV (d) 14.4 eV

74. A stationary He^+ ion emitted a photon corresponding to the first line of the Lyman series. That photon liberated a photoelectron from a stationary hydrogen atom in the ground state. The velocity of the photoelectron is
(a) 3.1×10^6 m/s
(b) 3.1×10^5 m/s
(c) 9.56×10^{12} m/s
(d) 9.56×10^6 m/s

75. A single electron species in energy level (orbit number n) with energy X was provided with excess of energy so that it jumps to higher energy level with energy Y. If it can emit radiations of six different wavelengths on de-excitement between these two energy levels, then the correct relation is
(a) $\frac{X}{Y} = (n-1)^2$
(b) $\frac{X}{Y} = 1 + \frac{3}{n}$
(c) $\sqrt{\frac{X}{Y}} = 1 + \frac{3}{n}$
(d) $\frac{X}{Y} = 1 + \frac{n}{3}$

76. When an electron de-excites from higher orbit in H-atom, two radiations are emitted out in Paschen and Lyman series. The wavelength of radiation emitted out in Lyman series is
(a) $\frac{8R}{9}$ (b) $\frac{3R}{4}$
(c) $\frac{4}{3R}$ (d) $\frac{9}{8R}$

77. If the radius of first Bohr orbit is x unit, then de-Broglie wavelength of electron in the third orbit is
(a) $2\pi x$ unit (b) $6\pi x$ unit
(c) $9x$ unit (d) $18\pi x$ unit

78. If E_1, E_2 and E_3 are the kinetic energies of an electron, an α-particle and a proton, with same de-Broglie wavelength, then
(a) $E_1 > E_3 > E_2$ (b) $E_2 > E_3 > E_1$
(c) $E_1 > E_2 > E_3$ (d) $E_1 = E_2 = E_3$

79. A proton and an α-particle are accelerated through the same potential difference. The ratio of their de-Broglie wavelengths is
(a) 1:1 (b) 2:1
(c) $\sqrt{2}:1$ (d) $2\sqrt{2}:1$

80. The de-Broglie wavelength of a vehicle moving with velocity v is λ. Its load is changed so that the velocity as well as kinetic energy is doubled. What will be the new de-Broglie wavelength?

(a) λ (b) 2λ
(c) 4λ (d) $\lambda/2$

81. When accelerated electrons are directed against an anticathode in an X-ray tube, the radiation obtained has a continuous spectrum with a wavelength minimum, $\lambda_{min} = \dfrac{1.24\times10^{-6}}{V}$ m, where V is the voltage used for accelerating the electrons. λ_{min} for $V = 5 \times 10^4$ V is

(a) 0.124 nm (b) 0.248 nm
(c) 2.48 nm (d) 1.24 nm

82. The dynamic mass (in kg) of the photon with a wavelength corresponding to the series limit of the Balmer transitions of the He^+ ion is

(a) 4.22×10^{-36}
(b) 2.24×10^{-34}
(c) 2.42×10^{-35}
(d) 4.22×10^{-35}

83. An electron is continuously accelerated in a vacuum tube by the application of a potential difference. If its de-Broglie wavelength decreases by 1% over a path length of l cm, its kinetic energy

(a) increases by 1%
(b) increases by 2%
(c) decreases by 2%
(d) increases by 0.5%

84. Assume that the uncertainty in the position of a particle is equal to its de-Broglie wavelength. The minimum uncertainly in its velocity is equal to

(a) 0.25 times its velocity
(b) $\dfrac{\pi}{4}$ times its velocity
(c) π times its velocity
(d) $\dfrac{4}{\pi}$ times its velocity

85. What should be the increase in kinetic energy, of electron in order to decrease its de-Broglie wavelength from 100 nm to 50 nm?

(a) 0.451 keV
(b) 4.51×10^{-4} eV
(c) 4.51×10^{-3} eV
(d) 0.0451 eV

86. An α–particle is accelerated from rest through a potential difference of 6.0V. Its de-Broglie wavelength is

(a) 5 Å (b) 4.15 pm
(c) 414.6 Å (d) 5 nm

87. The de-Broglie wavelength of electron of He^+ ion is 3.329 Å. If the photon emitted upon de-excitation of this He^+ ion is made to hit H-atom in its ground state so as to liberate electron from it, what will be the de-Broglie wavelength of photoelectron?

(a) 2.348 Å (b) 1.917 Å
(c) 3.329 Å (d) 1.66 Å

88. Photoelectrons are liberated by ultraviolet light of wavelength 3000 Å from a metallic surface for which the photoelectric threshold is 4000 Å. The de-Broglie wavelength of electrons emitted with maximum kinetic energy is

(a) 1000 Å (b) 42.43 Å
(c) 12.05 Å (d) 3.54 Å

89. The minimum uncertainty in de-Broglie wavelength of an electron accelerated from rest by a potential difference of 6.0V, if the uncertainty in measuring the position is $\dfrac{1}{\pi}$ nm, is

(a) 6.25 Å (b) 6.0 Å
(c) 0.625 Å (d) 0.3125 Å

90. A photon of 2.55 eV is emitted out by an electronic transition in hydrogen atom. The change in de-Broglie wavelength of the electron is

(a) 3.32 Å (b) 4.98 Å
(c) 6.64 Å (d) 9.96 Å

91. The orbital angular momentum of 2p- and 3p-orbitals
(a) are same
(b) are different, more for 2p-orbital
(c) are different, more for 3p-orbital
(d) depends on the type of atom or ion

92. Which of the following energy level may bring absorption of photon but never emission of photon?
(a) 3d (b) 2p
(c) 1s (d) 2s

93. An electron that has the quantum numbers $n = 3$ and $m = 2$
(a) must have spin quantum number value, +1/2
(b) must have $l = 2$, 3 or 4
(c) must have $l = 0$, 1 or 2
(d) must have $l = 2$

94. If an electron has spin quantum number of + ½ and magnetic quantum number of –1, it cannot be present in
(a) s-orbital (b) p-orbital
(c) d-orbital (d) f-orbital

95. In which of the following orbital, electron will be closer to the nucleus?
(a) 6s (b) 4f
(c) 5d (d) 6p

96. In the absence of external magnetic field, d-orbital is
(a) 3-fold degenerate
(b) 5-fold degenerate
(c) 7-fold degenerate
(d) non-degenerate

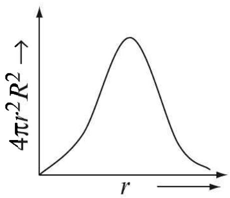
97. The following electronic transitions occur when Lithium atoms are sprayed into a hot flame;

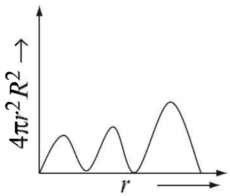
$$2s \xrightarrow{\text{I}} 2p \xrightarrow{\text{II}} 3d \xrightarrow{\text{III}} 3p \xrightarrow{\text{IV}} 4s \xrightarrow{\text{V}} 3p,$$

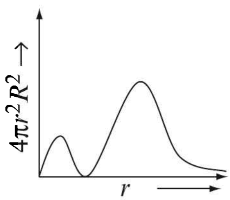
which of these transition would result in the emission of light?
(a) I, II and IV
(b) III and V
(c) III, IV and V
(d) all of these steps

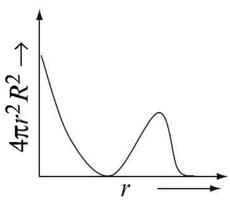
98. Possible set of quantum numbers for which: $n = 4$, $l = 3$ and $s = +\frac{1}{2}$ is
(a) 14 (b) 7
(c) 5 (d) 10

99. Which of the following graph represents the radial probability function of 3d electron?

(a)


(b)


(c)


(d)


100. The wave function of 1s orbital of H-atom is: $\psi = \frac{1}{\sqrt{\pi}}\left(\frac{1}{a_0}\right)^{3/2} e^{-r/a_0}$, where a_o = Bohr radius. The probability of finding the electrons at a distance 'r' from the nucleus is given by

(a) $\psi = \psi^2\, dr$
(b) $\int \psi^2 4\pi r^2 dr$
(c) $\psi^2 4\pi r^2 dr$
(d) $\psi \cdot dV$

101. For an electron in a hydrogen atom, the wave function is given by $\psi_{1s} = (\pi/\sqrt{2})\, e^{-r/a_0}$, where a_o is the radius of first Bohr's orbit and r is the distance from the nucleus with which probability of finding electron varies. What will be the ratio of probabilities of finding electrons at the nucleus to first Bohr's orbit a_o?

(a) 0 (b) e
(c) e^2 (d) $\frac{1}{e^2}$

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

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

103. Which of the following element will have same number of electrons in s-as well as p-type of orbitals?

(a) Fe ($Z = 26$)
(b) Mg ($Z = 12$)
(c) Ne ($Z = 10$)
(d) Ar ($Z = 18$)

104. Electronic configuration of an element is $1s^2, 2s^1, 2p^2$. It is

(a) ground state configuration of B ($Z = 5$)
(b) excited state configuration of B
(c) ground state configuration of C^+ ion ($Z = 6$)
(d) impossible configuration

105. Number of electrons having $m = 0$ for sodium atom is

(a) 2 (b) 5
(c) 7 (d) 3

106. The magnitude of the orbital angular momentum of an electron is given by $L = \sqrt{5}\, h/\pi$. How many orbitals of this kind are possible, belonging to an orbit?

(a) 4 (b) 5
(c) 11 (d) 9

107. What is the most probable distance of a 1s electron in a He^+ ion. The wave function for 1s orbital is given by $\psi = \sqrt{\left(\frac{Z^3}{\pi a_o^3}\right) e^{-Zr/a_o}}$, where a_o = radius of first Bohr's orbit in H-atom = 52.9 pm.

(a) 52.9 pm (b) 13.25 pm
(c) 6.61 pm (d) 26.45 pm

108. The average and the most probable distance from the nucleus for 1s electron in hydrogen atom are, respectively (a_o is the first Bohr radius.),

(a) a_o, a_o
(b) a_o, $1.5a_o$
(c) $1.5a_o$, a_o
(d) $1.5a_o$, $1.5a_o$

109. For an atom or ion having single electron, compare the energies of the following orbitals:

S_1 = a spherically symmetrical orbital having two spherical nodes.

S_2 = an orbital which is double dumb-bell and has no radial node.

S_3 = an orbital with orbital angular momentum zero and three radial nodes.

S_4 = an orbital having one planar and one radial node.

(a) $S_1 = S_2 = S_3 = S_4$
(b) $S_1 = S_2 = S_4 < S_3$
(c) $S_1 > S_2 > S_3 > S_4$
(d) $S_1 < S_4 < S_3 < S_2$

110. The orbital angular momentum of an electron is $\sqrt{3}\,\frac{h}{\pi}$. Which of the following may be the permissible value of angular momentum of this electron revolving in unknown Bohr orbit?

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

Section B (One or More than one Correct)

1. An α-particle having kinetic energy 4.0 MeV is projected towards tin nucleus ($Z = 50$). Select the correct information(s) regarding the α-particle.

(a) Its distance of closest approach towards the nucleus is 3.6×10^{-14} m.
(b) Its potential energy at a distance of 9.0×10^{-14} m from the nucleus is 1.6 MeV.
(c) Its kinetic energy at a distance of 4.5×10^{-14} m from the nucleus is 0.8 MeV.
(d) At a moment, the distance between α-particle and the nucleus becomes 2.0×10^{-16} m.

2. The energy of an electron in the first Bohr orbit of H^- atom is –13.6 eV. The possible energy value(s) of the excited state(s) for electrons in Bohr orbits to hydrogen is

(a) –3.4 eV
(b) –10.2 eV
(c) –1.51 eV
(d) –0.85 eV

3. According to Bohr's atomic theory, which of the following relations is/are correct?

(a) Kinetic energy of electron α $\frac{z^2}{n^2}$
(b) The product of speed of electron and the principal quantum number α z^2
(c) Frequency of revolution of the electron in an orbit α $\frac{z^2}{n^3}$
(d) Coloumbic force of attraction on the electron α $\frac{z^3}{n^4}$

4. As an electron jumps from the fourth orbit to the second orbit in Be^{3+} ion, its

(a) K.E. increases
(b) speed increases
(c) frequency of revolution increases
(d) P.E. decreases

5. Which of the following statement(s) is/are correct about the Bohr model of hydrogen atom?

(a) The acceleration of the electron in the $n = 2$ orbit is more than that in the $n = 1$ orbit.
(b) The angular momentum of the electron in then $n = 2$ orbit is more than that in the $n = 1$ orbit.
(c) The kinetic energy of electron in the $n = 2$ orbit is less than in the $n = 1$ orbit.
(d) The centripetal force on electron in $n = 2$ orbit is more than that in the $n = 1$ orbit.

6. The frequency of certain line of the Lyman series ($n_2 = 4$ to $n_1 = 1$) of the atomic spectrum of hydrogen can satisfy the following conditions:

(a) It is the sum of the frequencies of a Lyman line and a Balmer line.
(b) It is the sum of the frequencies of a certain Lyman line, a Balmer line and a Brackett line.
(c) It is the sum of the frequencies of a Lyman line, a Balmer line and a Paschen line.
(d) It is the sum of the frequencies of a Lyman and a Paschen line.

7. A sample of hydrogen atoms in ground state is exposed to electromagnetic radiations of 1028 Å. The wavelengths of the induced radiation(s) is/are

(a) 1028 Å (b) 1218.4 Å
(c) 6579.2 Å (d) 190.4 Å

8. Some hydrogen-like atoms in ground state absorbs 'n' photons having same energy and on de-excitement, it emits exactly 'n' photons. The energy of absorbed photon may be

(a) 91.8 eV (b) 40.8 eV
(c) 48.4 eV (d) 54.4 eV

9. Which of the following statement(s) is/are correct?

(a) The ratio of the radii of the first three Bohr orbits of hydrogen atom is 1:8:27.
(b) The ratio of magnitude of total energy:kinetic energy:potential energy for electron in any orbit of hydrogen atom is 1:1:2.
(c) The frequency of a green light is 6×10^{14} Hz, then its wavelength is 500 nm.
(d) The ratio of de-Broglie wavelength of a H-atom, He-atom and CH_4-molecule moving with equal kinetic energy is 4:2:1.

10. When photons of energy 4.25 eV strike the surface of a metal 'A', the ejected photoelectrons have maximum kinetic energy, T_A (in eV) and de-Broglie wavelength, λ_A. The maximum kinetic energy of photoelectrons liberated from another metal 'B' by photons of energy 4.20 eV is T_B (= T_A – 1.50 eV). If the de-Broglie wave length of these photoelectrons is λ_B (= $2\lambda_A$), then

(a) the work function of 'A' is 2.25 eV
(b) the work function of 'B' is 3.70 eV
(c) $T_A = 2.00$ eV
(d) $T_B = 2.75$ eV

11. Which of the following suggested de-Broglie wavelengths is not possible for the electron in a Bohr orbit of the hydrogen atom?

(a) 3.20 Å (b) 4.98 Å
(c) 9.96 Å (d) 6.64 Å

12. The magnitude of spin angular momentum of an electron is given by

(a) $\left\{\sqrt{s(s+1)}\right\}\dfrac{h}{2\pi}$
(b) $\dfrac{sh}{2\pi}$
(c) $\dfrac{\sqrt{3}}{2}\dfrac{h}{2\pi}$
(d) $\dfrac{h}{4\pi}$

13. Which of the following is/are true information(s)?

(a) 3s orbital is spherically symmetrical with two nodes.
(b) $d_{x^2-y^2}$ orbitals has lobes of electron density in XY-plane along X- and Y-axis.
(c) The radial probability curve of 1s, 3p and 5d have one, two and three regions of maximum probability.
(d) $3d_{z^2}$ has zero electron density in XY-plane.

14. Correct statement(s) regarding $3p_y$ orbital is/are

(a) Angular part of wave function is independent of angles θ and φ.
(b) Number of maxima in $4\pi r^2 R^2(r)$ vs. r curve is 2.
(c) XZ plane is the nodal plane.
(d) Magnetic quantum number must be −1.

15. The angular part of the wave function depends on the quantum numbers

(a) n (b) ℓ
(c) m (d) s

16. The electronic configuration of carbon atom in the excited state is $1s^2\ 2s^1\ 2p^3$. Which of the following is/are incorrect statement(s) about it?

(a) The number of unpaired electron is 4.
(b) There are five electrons in the same spin.
(c) There are only two unpaired electrons.
(d) The spin of all p-electrons are similar.

17. Which of the following statement(s) is (are) correct?

(a) The electronic configuration of Cr is [Ar] $3d^5 4s^1$ (Atomic Number of Cr = 24).
(b) The magnetic quantum number may have a negative value.
(c) In silver atom, 23 electrons have a spin of one type and 24 of the opposite type.
(d) The oxidation state of nitrogen in HN_3 is –3.

18. Which is/are correct for sodium atom, in the ground state?

(a) There is only one unpaired electrons.
(b) There are five pairs of electrons.
(c) 6 electrons are in one spin and other 5 in opposite spin.
(d) There are ten electrons in the same spin

19. Select the correct statement(s) among the following

(a) Outside any orbital, the probability of finding electron is zero.
(b) For single electronic atom or ion, the most probable distance of electron in an orbital having no radial node is $\frac{n^2 a_o}{Z}$ from the nucleus, where a_o is the first Bohr radius.
(c) The average distance of electron (belonging from the same orbit) from the nucleus decreases with the increase in the value of angular momentum quantum number for the orbital.
(d) The angular wave function of any s-orbital is independent from θ and ϕ.

20. Among the following, select the correct information(s)

(a) The opposite lobes in any d-orbital have the same sign of wave function.
(b) 1s orbital is the only orbital for which the sign of wave function does not have radial as well as angular dependency.
(c) The number of radial nodes is always greater than that of angular nodes.
(d) All the orbitals belonging from an orbit have the same number of total nodes.

Section C (Comprehensions)

Comprehension I

Three laser guns labelled as I, II and III have power 2, 3 and 5 W (not necessary in the same order) are used to produce photocurrent from metal plate. Number of photons emitted by laser guns are 4×10^{18}, 5×10^{18} and 9×10^{18} per second. Metal plate have threshold energy 4.5×10^{-19} J. Neither the power nor the number of photons emitted by a particular laser gun is known and it is known that all capable photons emit a photoelectron.

1. Minimum possible wavelength of emitted photoelectron is

(a) $\sqrt{680}$ Å (b) $\sqrt{30}$ Å
(c) $\sqrt{480}$ Å (d) $\sqrt{120}$ Å

2. Minimum photocurrent which must be passed through the circuit is
(a) 2.88 A (b) 1.44 A
(c) 2.08 A (d) 0.64 A

3. Ratio of maximum to minimum photocurrent which can be passed through the circuit is
(a) 5:4 (b) 9:5
(c) 9:4 (d) 9:2

Comprehension II

Let us assume a different atomic model in which electron revolves around the nucleus (proton) at a separation *r* under the action of force which is different form electrostatic force of attraction. The potential energy between an electron and the proton due to this force is given by $U = -k/r^4$, where *k* is a constant. This hypothetical atom is obeying Bohr's quantization condition.

4. The radius of n^{th} Bohr's orbit is
(a) $r = \dfrac{\pi}{nh}\sqrt{km}$
(b) $r = \dfrac{2\pi}{nh}\sqrt{km}$
(c) $r = \dfrac{4\pi}{nh}\sqrt{km}$
(d) $r = \dfrac{8\pi}{nh}\sqrt{km}$

5. The speed of electron in the n^{th} orbit is
(a) $V = \dfrac{nh}{8\pi^2 m\sqrt{km}}$
(b) $V = \dfrac{n^2 h}{8\pi^2 m\sqrt{km}}$
(c) $V = \dfrac{nh^2}{4\pi^2 m\sqrt{km}}$
(d) $V = \dfrac{n^2 h^2}{8\pi^2 m\sqrt{km}}$

6. The total energy of the electron in the n^{th} orbit is
(a) $\text{T.E.} = \dfrac{-n^4 h^4}{128\pi^4 m^2 k}$
(b) $\text{T.E.} = \dfrac{n^4 h^4}{128\pi^4 m^2 k}$
(c) $\text{T.E.} = \dfrac{n^4 h^4}{256 k\pi^4 m^2}$
(d) $\text{T.E.} = \dfrac{-n^4 h^4}{256\pi^4 m^2}$

Comprehension III

A hydrogen-like atom (atomic number *Z*) is in a higher excited state of quantum number *n*. This excited atom can make a transition to the first excited state by successively emitting two photons of energies 10.20 and 17.00 eV, respectively. Alternatively, the atom from the same excited state can make a transition to the second excited state by successively emitting two photons of energies 4.25 and 5.9 eV, respectively.

7. The value of '*n*' is
(a) 4 (b) 5
(c) 6 (d) 7

8. The value of *Z* is
(a) 2 (b) 3
(c) 4 (d) 5

9. How much energy will be emitted when an electron in this atom moves from $(n + 1)$ to ground state?
(a) 114.75 eV
(b) 117.5 eV
(c) 119.9 eV
(d) 122.74 eV

Comprehension IV

A certain gas of identical hydrogen-like atoms has all its atoms in a particular upper energy level. The atoms make transition to a higher level when a monochromatic radiation, having wavelength 1654 Å, is incident on it. Subsequently, the atoms emit radiation of only three different photon energies.

10. The initial energy level of atoms was

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

11. The final energy level of atoms is

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

12. The atom/ion is

(a) H (b) D
(c) He^{+} (d) Li^{+2}

13. The energy of photon required to remove electron from higher energy level is

(a) 6.04 eV (b) 13.6 eV
(c) 27.2 eV (d) 36.8 eV

Comprehension V

A gas of identical H-like atom has some atoms in the lowest (ground) energy level 'A' and some atoms in a particular upper (excited) energy level 'B' and there are no atoms in any other energy level. The atoms of the gas make transition to a higher energy level by absorbing monochromatic light of photon energy 2.7 eV. Subsequently, the atoms emit radiation of only six different photons energies. Some of the emitted photons have energy 2.7 eV. Some have more and some have less than 2.7 eV.

14. The principal quantum number of initially excited level 'B' is

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

15. The ionization energy for gas atoms is

(a) 3.4 eV (b) 12.8 eV
(c) 14.4 eV (d) 13.6 eV

16. The minimum energy of emitted photon is

(a) 0.2 eV
(b) 13.5 eV
(c) 6.7 eV
(d) 0.7 eV

Comprehension VI

A muon is an unstable elementary particle whose mass is $207m_e$ and whose charge is either $+e$ or $-e$. A negative muon (μ^-) can be captured by a proton to form a muonic atom. This atom follows Bohr's quantization condition. Answer the following, neglecting reduced mass effect.

17. What is the radius of the first Bohr orbit of this atom?

(a) 52.9 pm (b) 0.256 pm
(c) 0.256 nm (d) 10.9 nm

18. What is the ionization energy of the atom?

(a) 13.6 eV (b) 0.066 eV
(c) 0.583 MeV (d) 2.82 keV

19. What is the wavelength of the photon emitted when muon drops from second orbit to the ground state in this atom?

(a) 2.53×10^{-5} m
(b) 1.22×10^{-7} m
(c) 5.91×10^{-10} m
(d) 2.85×10^{-12} m

Comprehension VII

A sample of H-atoms contains all atoms in ground state. If the atoms are irradiated by photons of x Å, the atoms get excited to a particular energy level. When these atoms de-excites, they emit the radiations of six different photon energies.

20. What is the value of x?
(a) 978.6 (b) 0.098
(c) 1032 (d) 1223

21. What is the orbit number for the excited state?
(a) 6 (b) 3
(c) 4 (d) 2

22. What is the maximum wavelength among emitted radiations?
(a) 978.6 Å
(b) 1223 Å
(c) 18,872.87 nm
(d) 18,872.87 Å

23. What is the maximum frequency among emitted radiations?
(a) 2.453×10^{15} Hz
(b) 3.066×10^{15} Hz
(c) 5.912×10^{16} Hz
(d) 1.081×10^{18} Hz

24. What are the wavelengths of all infrared radiations coming out?
(a) 1887.3 nm, 4077.5 nm
(b) 1887.3 nm
(c) 122.3 nm, 103.2 nm, 97.9 nm
(d) 122.3 nm, 103.2 nm

25. What are the wavelengths of all visible radiations coming out?
(a) 660.5 nm, 489.3 nm
(b) 660.5 nm, 489.3 nm, 436.9 nm
(c) 660.5 nm, 489.3 nm, 436.9 nm, 412.8 nm
(d) 660.5 nm, 436.9 nm

Comprehension VIII

When a sample of hydrogen atoms is irradiated by electromagnetic radiations of suitable wave length, all the electrons jump from the ground state to the fifth orbit. As the electrons cannot remain permanently in the fifth orbit, they de-excites to the ground state making one or more than one transitions. Each transition results the emission of an electromagnetic radiation of a particular wave length. When these radiations pass through a prism, they deviate with different angles resulting in the spectral lines.

26. What is the maximum number of spectral lines, if the sample is containing only one atom?
(a) 5 (b) 4
(c) 6 (d) 10

27. What is the maximum number of spectral lines, if the sample is containing only two atoms?
(a) 5 (b) 6
(c) 7 (d) 10

28. What is the maximum number of spectral lines, if the sample is containing only three atoms?
(a) 5 (b) 6
(c) 7 (d) 10

29. What is the maximum number of spectral lines, if the sample contains infinite number of atoms?
(a) 5 (b) 6
(c) 7 (d) 10

30. What should be the minimum number of hydrogen atoms in the sample to get a maximum of 10 spectral lines?
(a) 1 (b) 6
(c) 8 (d) 10

Comprehension IX

A hydrogen-like atom of atomic number Z is in an excited state of quantum number $2n$. It can emit a maximum energy photon of 204 eV. If it makes a transition to quantum state n, a photon of energy 40.8 eV is emitted.

31. What is the initial excited state of the atom?

(a) 4 (b) 8
(c) 16 (d) 2

32. What is the value of Z?

(a) 2 (b) 4
(c) 8 (d) 16

33. What is the energy of ground state of this atom?

(a) −13.6 eV
(b) −54.4 eV
(c) −217.6 eV
(d) −870.4 eV

34. What is the minimum energy of the photons emitted by this atom during de-excitation?

(a) 204 eV (b) 4.16 eV
(c) 42.3 eV (d) 13.6 eV

Comprehension X

In stars, the Pickering series is found in the He^+ spectrum. It is emitted when the electron in He^+ jumps from higher levels to the level with $n = 4$.

35. The wavelengths of the lines in this series are given by $\lambda = \dfrac{Cn^2}{n^2 - 16}$, in which $n = 5, 6, 7\ldots$ and C is a constant. What is the value of C, in nm?

(a) 366.97 (b) 91.74
(c) 22.93 (d) 1467.89

36. What is the wavelength of the series limit?

(a) 22.93 nm (b) 366.97 nm
(c) 1019.36 nm (d) 63.71 nm

37. In what region(s) of the spectrum does this series occur? Visible region is from 360 to 780 nm.

(a) Visible only
(b) Infrared only
(c) Visible and infrared
(c) Visible and ultraviolet

Comprehension XI

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

38. The state S_1 is

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

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

(a) 0.75 (b) 1.50
(c) 2.25 (d) 4.50

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

(a) 0
(b) 1
(c) 2
(d) 3

Comprehension XII

Suppose a particle has four quantum numbers such that the permitted values are

$n = 1, 2, 3......$

$l = (n-1), (n-3), (n-5), ...,$ but no negative value

$j = \left(l + \frac{1}{2}\right)$ or $\left(l - \frac{1}{2}\right)$, the latter is not negative

$m = -j$ in integer step to $+j$.

41. The other permitted values for $n = 2$ is/are

(a) $l = 1, j = \frac{3}{2}, m = -\frac{3}{2}$

(b) $l = 0, j = \frac{1}{2}; m = -\frac{1}{2}$

(c) $l = 1, j = \frac{1}{2}; m = -\frac{3}{2}$

(d) all of these

42. For $n = 3$, the possible sets of (n, l, j, m) is

(a) 10 (b) 8

(c) 12 (d) 6

Comprehension XIII

The wave function for an atomic orbital of single electron atom or ion is

$$\psi(r, \theta, \phi) = \frac{2}{3}\left(\frac{Z}{3a_o}\right)^{3/2}(\sigma - 1)(12 - 8\sigma + \sigma^2)\cdot\sigma\cdot e^{-\sigma/2}\cdot\cos\theta$$

where $\sigma = \frac{2Zr}{a_o}$ and $a_o = 0.529$ Å. All other parameters have their usual meaning.

43. The number of radial and angular nodes for the orbital is, respectively,

(a) 3, 1 (b) 2, 1

(c) 3, 2 (d) 2, 2

44. The atomic orbital should be

(a) 4p (b) 5p

(c) 5d (d) 5f

45. If θ is the angle measured from Z-axis, then the orbital should be

(a) p_x (b) p_y

(c) p_z (d) d_{z^2}

46. The maximum distance of radial node from the nucleus is

(a) $\frac{a_o}{Z}$ (b) $\frac{2a_o}{Z}$

(c) $\frac{6a_o}{Z}$ (d) $\frac{3a_o}{Z}$

Section D (Assertion – Reason)

The following questions consist of two statements. Mark

(a) If both statements are CORRECT, and **Statement II** is the CORRECT explanation of **Statement I**.

(b) If both statements are CORRECT, and **Statement II** is NOT the CORRECT explanation of **Statement I**.

(c) If **Statement I** is CORRECT, but **Statement II** is INCORRECT.

(d) If **Statement I** is INCORRECT, but **Statement II** is CORRECT.

1. **Statement I:** The orbital angular momentum of an electron in any s-atomic orbital is zero.

   Statement II: For any s-electron, $l = 0$.

2. **Statement I:** The kinetic energy of the photoelectron ejected increases with the increase in frequency of incident light.

   Statement II: Increase in intensity of incident light increases the photoelectric current.

3. **Statement I:** Threshold frequency is the maximum frequency required for the ejection of electron from the metal surface.

   Statement II: Threshold frequency is characteristic of a metal.

4. **Statement I:** Spin quantum number can have two values $+\frac{1}{2}$ and $-\frac{1}{2}$.

   Statement II: +ve and –ve signs signify the positive and negative wave functions.

5. **Statement I:** For He^+ ion, the energy of electron in 3p-orbital is greater than that in 3s-orbital.

   Statement II: Energy of an electron in single electron system depends only on principal quantum number.

6. **Statement I:** Helium and beryllium have similar outer electronic configuration ns^2.

   Statement II: Both are chemically inert.

7. **Statement I:** Sum of the radial and angular nodes of all the occupied orbitals in ground state of oxygen atom is 4.

   Statement II: Electronic configuration of oxygen atom is $1s^2\,2s^2\,2p^4$. The number of radial and angular nodes for an orbital is $(n - l - 1)$ and l, respectively.

8. **Statement I:** The XY-plane is nodal plane for d_{z^2} orbital.

   Statement II: For a d-orbital, the number of angular nodes is 2.

9. **Statement I:** The radial wave functions for $3p_x$ and $3p_y$ orbitals are different.

   Statement II: The radial function depends on n and l while the angular function depends on l and m.

10. **Statement I:** In multi-electron system (atom or ion), 4s orbital if filled first then 3d orbital is filled.

    Statement II: 4s orbital is closer to the nucleus than 3d orbital.

Section E (Column Match)

1. Match the following

Column I (Orbitals)	Column II (Nodal Properties)
(A) 2s	(P) Angular node = 1
(B) 1s	(Q) Radial node = 0
(C) 2p	(R) Radial node = 1
(D) 3p	(S) Angular node = 0

2. Match Column I with Column II in hydrogen atom spectrum.

Column I	Column II
(A) Lyman series	(P) Visible region
(B) Balmer series	(Q) Infrared region
(C) Paschen series	(R) Absorption spectrum
(D) Brackett series	(S) Ultraviolet region

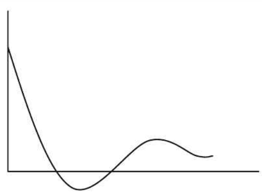
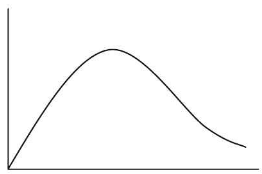
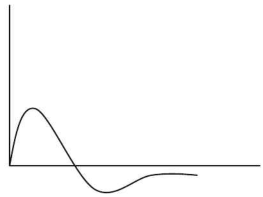
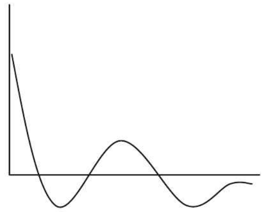
3. According to Bohr's theory, E_n = Total energy, K_n = Kinetic energy, V_n = Potential energy, r_n = Radius of nth orbit. Match the following:

Column I	**Column II**
(A) V_n/K_n =?	(P) 0
(B) If radius of nth orbit $\propto E_n^x$; x = ?	(Q) –1
(C) Orbital angular momentum in lowest energy	(R) –2
(D) $\frac{1}{r^n} \propto Z^y$; y = ?	(S) 1

4. Match list I with list II

List I	**List II**
(A) Number of values of l for an energy level	(P) 0, 1, 2, ……, $(n-1)$
(B) Actual values of l for and energy level	(Q) $+l$, ……, 0,……., $-l$
(C) Number of m values for a particular type of orbital	(R) $2l + 1$
(D) Actual value of 'm' for a particular type of orbital	(S) n

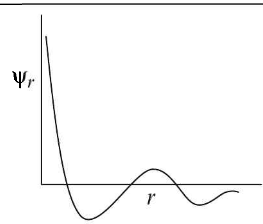
5. Match the column:

Column I (Orbital)	**Column II (R vs. r Graph)**
(A) 3s	(P) 
(B) 4s	(Q) 
(C) 2p	(R) 
(D) 3p	(S) 

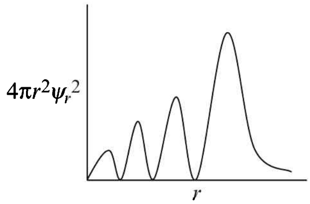
6. Match the column:

Column I (Parameters for H-like atoms)	**Column II (Dependence on n and Z)**
(A) Radius of orbit	(P) n^2
(B) Speed of electron	(Q) $1/n$
(C) Centripetal force between electron and nucleus	(R) $1/n^3$
(D) Frequency of revolution of electron	(S) $1/n^4$
	(T) Z
	(U) 1/Z
	(V) Z^2
	(W) Z^3

7. Match the column:

Column I	**Column II**
(A) 	(P) 4s

(*Continued*)

Column I	Column II
(B) 	(Q) any of the 5p orbital
(C) Angular wave function independent from θ and ϕ	(R) 3s
(D) At least one angular node	(S) any of the 6d orbital

8. Match the entries in Column I with the correctly related quantum number(s) in Column II.

Column I	Column II
(A) Orbital angular momentum of the electron in a hydrogen-like atomic orbital	(P) Principle quantum number
(B) A hydrogen-like one-electron wave function obeying Pauli principle	(Q) Azimuthal quantum number
(C) Shape, size and orientation of hydrogen-like atomic orbital	(R) Magnetic quantum number
(D) Probability density of electron at the nucleus in hydrogen-like atom	(S) Electron spin quantum number

9. Match the column:

Column I	Column II
(A) Orbital with equal number of radial and angular nodes	(P) $3d_{x^2-y^2}$
(B) Orbitals with number of radial nodes less than the number of angular nodes	(Q) $2p_z$
(C) Orbitals with zero radial nodes but two angular nodes	(R) $3p_x$
	(S) $5d_{xy}$

10. Match the following:

Column I	Column II
(A) Ratio of speed of electron in the fifth and third excited state of H-atom	(P) $\frac{4}{1}$
(B) Ratio of wavelength of series limit of Balmer and Lyman series of H-spectrum	(Q) $\frac{2}{3}$
(C) Ratio of wavelength of photon corresponding to β-line of Lyman series and γ-line of Paschen series of H-spectrum	(R) $\frac{1}{4}$
(D) Ratio of energy difference between 3rd and 1st orbits of H-atom and He^+ ion	(S) $\frac{3}{32}$

Section F (Subjective)

Single-digit Integer Type

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

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

2. The average life time for then $n = 3$ excited state of a hydrogen-like atom is 4.8×10^{-8} s and that for the $n = 2$ state is 1.28×10^{-7} s. Ratio of the average number of revolutions made in the $n = 3$ state to the average number of revolutions made in the $n = 2$ state before any transitions can take place from these states is $1{:}x$. The value of x is

3. The quantum number n corresponding to the excited state of He^+ ion if on transition to the ground state that ion emits two photons in succession with wavelengths 108.5 and 30.4 nm, is

4. The atomic number of hydrogen-like ion has the wavelength difference between the first line of Balmer and Lyman series equal to 59.3 nm?

5. A sample of hydrogen atoms containing all the atoms in a particular excited state, absorb radiations of a particular wavelength by which the atoms get excited to another excited state. When the atoms finally de-excite to the ground state, they emit the radiations of 10 different wavelengths. Out of these 10 radiations, 7 have wavelengths shorter than the absorbed radiation and 2 have wavelength longer than the absorbed radiation. The orbit number for the initial excited state of atoms is

6. Photons of same energy were allowed to strike on two different samples of hydrogen atoms, one having each atom in ground state and other, in a particular excited state of orbit number n. The photonic beams ionize the hydrogen atoms in both the samples. If the difference in maximum kinetic energy of emitted photoelectron from both the samples is 12.75 eV, the value of n is

7. The diameter of a dust particle of mass 10^{-3} g, is 2 Å. The speed of this dust particle is measured with the uncertainty of $\frac{3.313}{\pi} \times 10^{-3}$ m/s. The minimum uncertainty in measuring the position of the duct particle (in order of 10^{-26} m) is

8. The uncertainty in position and velocity of a particle are 10^{-11} m and 5.27×10^{-24} m·s^{-1}, respectively. The mass of the particle (in kg) is

9. The circumference of the second orbit of an atom or ion having single electron, is 4 nm. The de-Broglie wavelength of electron (in nm) revolving in this orbit is

10. The Schrodinger wave equation for hydrogen atom is: $\Psi_{2s} = \frac{1}{4\sqrt{2\pi}}\left(\frac{1}{a_0}\right)^{3/2}\left(2 - \frac{r_0}{a_0}\right)e^{-\frac{r_0}{a_0}}$, where a_0 is Bohr's radius. If the radial node is 2s be at r_0, then the value of $\frac{r_o}{a_o}$ is

Four-digit Integer Type

1. An α-particle of momentum 3.2×10^{-20} kg ms^{-1} is projected towards the nucleus of an atom of an element. If the distance of closest approach of α-particle is 1.5×10^{-13} m, the atomic number of element is (Mass of α-particle = 4 amu, charge on electron = 1.6×10^{-19} coulomb, $N_A = 6 \times 10^{23}$)

2. Suppose a satellite is in geostationary orbit at an average distance of 12600 km from earth surface. This satellite is telecasting a cricket match between Indian and Pakistan. The radiowaves from stadium are first received by the satellite and then from satellite to our TV sets. If a batsman hits a ball, after what time (approximate, in milliseconds), we will see this action in our TV sets?

3. A cobalt target is bombarded with electrons and the wavelength of its characteristic spectrum is measured. A second fainter characteristic spectrum is also found, due to an impurity in the target. The wavelengths of the K_α lines are 180.0 pm (cobalt, $Z = 27$) and 144.0 pm (impurity). The atomic number of impurity is

4. How many moles of photon would contain sufficient energy to raise the temperature of 245 g of water from 19.5°C to 99.5°C? Specific heat of water is 4.2 J/°C-g and frequency of light radiation used is 2.45×10^{10} per second. ($6.626 \times 0.15 = 1.0$, $N_A = 6 \times 10^{23}$)

5. A quantity of 1.0 g hydrogen atoms are excited to radiations. The study of spectra indicates that 45% of the atoms are in third energy level and 20% of atoms in second energy level and the rest, in ground state. The total energy (in kJ) evolved, when all the atoms return to ground state, is (Ionization energy of hydrogen atom is 1312 kJ/mol)

6. A proton and an electron, both at rest initially, combine to form a hydrogen atom in the ground state. A single photon is emitted in this process. The wavelength (in nm) of emitted photon is

7. The energy (in kJ) required to excite 1 l of hydrogen gas at 1 atm and 300 K to the first excited state of atomic hydrogen is (The energy for the dissociation of H–H bond is 436 kJ mol^{-1} and the ionization energy of hydrogen is 1312 kJ mol^{-1}.)

8. In the hydrogen spectrum, the longest wavelength in the Lyman series is 120 nm and the shortest wavelength in the Balmer series is 360 nm. From this data, the longest wavelength (in nm) of light that could ionize hydrogen atom is

9. An electron beam can undergo diffraction by crystals. Through what potential (in Volt) should a beam of electron be accelerated so that its wavelength becomes equal to 0.25 nm?

10. The atomic masses of He and Ne are 4 and 20 amu, respectively. The value of the de-Broglie wavelength of He gas at −73°C is M times that of the de-Broglie wavelength of Ne at 727°C. M is

Answer Keys – Exercise II

Section A (Only one Correct)

1. (a)	2. (b)	3. (b)	4. (c)	5. (d)	6. (a)	7. (a)	8. (d)	9. (d)	10. (b)
11. (b)	12. (a)	13. (c)	14. (d)	15. (a)	16. (b)	17. (d)	18. (c)	19. (c)	20. (c)
21. (d)	22. (b)	23. (c)	24. (b)	25. (c)	26. (b)	27. (a)	28. (c)	29. (d)	30. (c)
31. (d)	32. (c)	33. (a)	34. (b)	35. (c)	36. (d)	37. (d)	38. (a)	39. (a)	40. (c)
41. (c)	42. (c)	43. (b)	44. (c)	45. (a)	46. (c)	47. (a)	48. (b)	49. (c)	50. (a)
51. (c)	52. (a)	53. (d)	54. (a)	55. (a)	56. (b)	57. (d)	58. (a)	59. (d)	60. (c)
61. (c)	62. (c)	63. (d)	64. (c)	65. (a)	66. (c)	67. (c)	68. (d)	69. (a)	70. (d)

71. (b) 72. (a) 73. (b) 74. (a) 75. (c) 76. (d) 77. (b) 78. (a) 79. (d) 80. (a)
81. (c) 82. (c) 83. (b) 84. (b) 85. (b) 86. (b) 87. (a) 88. (c) 89. (c) 90. (c)
91. (a) 92. (c) 93. (d) 94. (a) 95. (b) 96. (b) 97. (b) 98. (b) 99. (a) 100. (a)
101. (a) 102. (d) 103. (b) 104. (b) 105. (c) 106. (d) 107. (d) 108. (c) 109. (b) 110. (d)

Section B (One or More than one Correct)

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

Section C

Comprehension I

1. (b) 2. (d) 3. (d)

Comprehension II

4. (c) 5. (d) 6. (c)

Comprehension III

7. (c) 8. (b) 9. (c)

Comprehension IV

10. (b) 11. (c) 12. (c) 13. (a)

Comprehension V

14. (b) 15. (c) 16. (d)

Comprehension VI

17. (b) 18. (d) 19. (c)

Comprehension VII

20. (a) 21. (c) 22. (d) 23. (a)
24. (b) 25. (a)

Comprehension VIII

26. (b) 27. (b) 28. (c)
29. (d) 30 (b)

Comprehension IX

31. (b) 32. (c) 33. (d) 34. (b)

Comprehension X

35. (a) 36. (b) 37. (c)

Comprehension XI

38. (b) 39. (c) 40. (b)

Comprehension XII

41. (a) 42. (c)

Comprehension XIII

43. (a) 44. (b) 45. (c) 46. (d)

Section D (Assertion – Reason)

1. (a) 2. (b) 3. (d) 4. (c) 5. (d) 6. (c) 7. (a) 8. (d) 9. (d) 10. (c)

Section E (Column Match)

1. A → R, S; B → Q, S; C → P, Q; D → P, R
2. A → R, S; B → P, S; C → Q; D → Q
3. A → R; B → Q; C → P; D → S
4. A → S; B → P; C → R; D → Q
5. A → P; B → S; C → Q; D → R

6. A → P, U; B → Q, T; C → S, W; D → R, V
7. A → P; B → P, Q, S; C → P, R; D → Q, S
8. A → Q, R; B → P, Q, R, S; C → P, Q, R; D → P, Q
9. A → R, S; B → Q, P; C → P
10. A → Q; B → P; C → S; D → R

Section F (Subjective)

Single-digit Integer Type

1. (4)	2. (9)	3. (5)	4. (3)	5. (3)
6. (4)	7. (5)	8. (1)	9. (2)	10. (2)

Four-digit Integer Type

1. (0025)	2. (0840)	3. (0030)	4. (8400)	5. (0774)
6. (0091)	7. (0100)	8. (0090)	9. (0024)	10. (0005)