Topic 1 Preliminary Developments and Bohr's Model

Objective Questions I (Only one correct option)

- Which one of the following about an electron occupying the 1s-orbital in a hydrogen atom is incorrect? (The Bohr radius is represented by a₀)
 (2019 Main, 9 April II)
 - (a) The electron can be found at a distance $2a_0$ from the nucleus.
 - (b) The magnitude of the potential energy is double that of its kinetic energy on an average.
 - (c) The probability density of finding the electron is maximum at the nucleus.
 - (d) The total energy of the electron is maximum when it is at a distance a_0 from the nucleus.
- **2.** If p is the momentum of the fastest electron ejected from a metal surface after the irradiation of light having wavelength , then for 1.5 p 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) (2019 Main, 8 April II)

(a) $\frac{4}{9}$	(b) $\frac{3}{4}$
(c) $\frac{2}{3}$	(d) $\frac{1}{2}$

3. What is the work function of the metal, if the light of wavelength 4000 Å generates photoelectron of velocity $6 \quad 10^5 \text{ ms}^{-1}$ from it?

(Mass of electron 9 10^{31} kg Velocity of light 3 10^8 ms⁻¹

velocity of light 5 10 lis

Planck's constant 6.626×10^{-34} Js

Charge of electron	1.6	10^{10} JeV $($	(2019 Main, 12 Jan I)
(a) 4.0 eV		(b) 2.1 eV	
(c) 0.9 eV		(d) 3.1 eV	

 The ground state energy of hydrogen atom is 13.6 eV. The energy of second excited state of He ion in eV is (2019 Main, 10 Jan II)

				(====	
(a)	54.4	(b)	3.4		

(c) 6.04	(d)	27.2
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Which of the graphs shown below does not represent the relationship between incident light and the electron ejected from metal surface? (2019 Main, 10 Jan I)



6. A stream of electrons from a heated filament was passed between 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/ (where, is wavelength associated with electron wave) is given by (2016 Main)

(a) 2 <i>meV</i>	(b) \sqrt{meV}
(c) $\sqrt{2meV}$	(d) <i>meV</i>

- Rutherford's experiment, which established the nuclear model of the atom, used a beam of (2002, 3M)
 - (a) -particles, which impinged on a metal foil and got absorbed
 - (b) -rays, which impinged on a metal foil and got scattered
 - (c) helium atoms, which impinged on a metal foil and got scattered
 - (d) helium nuclei, which impinged on a metal foil and got scattered

- **8.** Rutherford's alpha particle scattering experiment eventually led to the conclusion that (1986, 1M)
 - (a) mass and energy are related
 - (b) electrons occupy space around the nucleus
 - (c) neutrons are burried deep in the nucleus
 - (d) the point of impact with matter can be precisely determined
- 9. The radius of an atomic nucleus is of the order of (1985, 1M)
 - (a) 10^{10} cm (b) 10^{13} cm
 - (c) 10^{15} cm (d) 10^{8} cm
- **10.** Bohr's model can explain (1985, 1M) (a) the spectrum of hydrogen atom only
 - (b) spectrum of an atom or ion containing one electron only(c) the spectrum of hydrogen molecule
 - (d) the solar spectrum
- **11.** The increasing order (lowest first) for the values of *e/m* (charge/mass) for electron (*e*), proton (*p*), neutron (*n*) and
 - alpha particle (is
 (1984, 1M)

 (a) e, p, n,
 (b) n, p, e,
 - (c) n, p, , e (d) n, p, e
- 12. Rutherford's scattering experiment is related to the size of the (1983, 1M) (a) nucleus (b) atom (c) electron (d) neutron
- Rutherford's experiment on scattering of for the first time that the atom has (1981, 1M)
 (a) electrons (b) protons
 (c) nucleus (d) neutrons

Objective Questions II

(One or more than one correct option)

- 14. 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 of hydrogen is (are) (1988)
 (a) 3.4 eV (b) 4.2 eV (c) 6.8 eV (d) 6.8 eV
- **15.** The atomic nucleus contains
 (1988, 1M)

 (a) protons
 (b) neutrons

 (c) electrons
 (d) photons
- 16. The sum of the number of neutrons and proton in the isotope of hydrogen is (1986, 1M)
 (a) 6 (b) 5 (c) 4 (d) 3

- 17. When alpha particles are sent through a thin metal foil, most of them go straight through the foil, because (1984, 1M) (a) alpha particles are much heavier than electrons
 - (b) alpha particles are positively charged
 - (c) most part of the atom is empty space
 - (d) alpha particles move with high velocity
- 18. Many elements have non-integral atomic masses, because(a) they have isotopes (1984, 1M)
 - (b) their isotopes have non-integral masses
 - (c) their isotopes have different masses
 - (d) the constituents, neutrons, protons and electrons, combine to give fractional masses

Match the Columns

- **19.** According to Bohr's theory,
 - E_n Total energy K_n Kinetic energy V_n Potential energy r^n Radius of *n*th orbitMatch the following :(2006, 6M)

	Column I		Column II
А.	$V_n/K_n = ?$	p.	0
В.	If radius of <i>n</i> th orbit E_n^x , <i>x</i> ?	q.	- 1
C.	Angular momentum in lowest orbital	r.	-2
D.	$\frac{1}{r^n}$ Z^y, y ?	s.	1

Fill in the Blanks

- **21.** The mass of a hydrogen is kg. (1982, 1M)
- **22.** Isotopes of an element differ in the number of in their nuclei. (1982, 1M)

Subjective Questions

24. With what velocity should an -particle travel towards the nucleus of a copper atom so as to arrive at a distance 10⁻¹³ m from the nucleus of the copper atom ? (1997 (C), 3M)

(a) K

Topic 2 Advanced Concept (Quantum Mechanical Theory) Electronic Configuration and Quantum Number

Objective Questions I (Only one correct option)

1. Among the following, the energy of 2*s*-orbital is lowest in (2019 Main, 12 April II)

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

2. The electrons are more likely to be found



(2019 Main, 12 April I) (b) in the region a and b

- (a) in the region *a* and *c*(c) only in the region *a*
 - a (d) only in the region c
- The ratio of the shortest wavelength of two spectral series of hydrogen spectrum is found to be about 9. The spectral series are (2019 Main, 10 April II)
 - (a) Lyman and Paschen(c) Paschen and Pfund

(b) Brackett and Pfund(d) Balmer and Brackett

4. The graph between $| |^2$ and *r* (radial distance) is shown below. This represents (2019 Main, 10 April I)



- (a) *ls*-orbital(c) *3s*-orbital
- (c) 3s-orbital
 (d) 2s-orbital
 5. For any given series of spectral lines of atomic hydrogen, let _____min be the difference in maximum and

minimum frequencies in cm 1 . The ratio

$$L_{yman}$$
 / B_{almer} is (2019 Main, 9 April I)
(a) 27:5 (b) 5:4 (c) 9:4 (d) 4:1

6. The quantum number of four electrons are given below:

I.
$$n \quad 4, l \quad 2, m_l \quad 2, m_s \quad \frac{1}{2}$$

II. $n \quad 3, l \quad 2, m_l \quad 1, m_s \quad \frac{1}{2}$
III. $n \quad 4, l \quad 1, m_l \quad 0, m_s \quad \frac{1}{2}$
IV. $n \quad 3, l \quad 1, m_l \quad 1, m_s \quad \frac{1}{2}$

The correct order of their increasing energies will be

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	(2019 Main, 8 April I)
(a) $IV < III < II < I$	(b) $I < II < III < IV$
(c) $IV < II < III < I$	(d) $I < III < II < IV$

- 7. If the de-Broglie wavelength of the electron in nth Bohr orbit in a hydrogenic atom is equal to 1.5 a₀ (a₀ is Bohr radius), then the value of n/Z is (2019 Main, 12 Jan II)
 (a) 1.0 (b) 0.75 (c) 0.40 (d) 1.50
- 8. The de-Broglie wavelength () associated with a photoelectron varies with the frequency () of the incident radiation as, [0 is threshold frequency]
 (2019 Main, 11 Jan II)

(a)
$$\frac{1}{(0,0)^{\frac{1}{4}}}$$
 (b) $\frac{1}{(0,0)^{\frac{3}{2}}}$
(c) $\frac{1}{(0,0)^{\frac{1}{4}}}$ (d) $\frac{1}{(0,0)^{\frac{1}{2}}}$

9. Which of the following combination of statements is true regarding the interpretation of the atomic orbitals?

(2019 Main, 9 Jan II)

- I. An electron in an orbital of high angular momentum stays away from the nucleus than an electron in the orbital of lower angular momentum.
- II. For a given value of the principal quantum number, the size of the orbit is inversely proportional to the azimuthal quantum number.
- III. According to wave mechanics, the ground state angular momentum is equal to $\frac{h}{2}$.
- IV. The plot of vs r for various azimuthal quantum numbers, shows peak shifting towards higher r value.

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

10. Heat treatment of muscular pain involves radiation of wavelength of about 900 nm. Which spectral line of H-atom is suitable for this purpose? $[R_{\rm H} \ 1 \ 10^5 \ {\rm cm}^{-1},$

11. For emission line of atomic hydrogen from $n_i = 8 \text{ to } n_f = n$, the plot of wave number () against $\frac{1}{n^2}$ will be (The Rydberg constant, R_{H} is in wave number unit) (2019 Main, 9 Jan I)

- (a) non linear
- (b) linear with slope $R_{\rm H}$
- (c) linear with slope $R_{\rm H}$
- (d) linear with intercept $R_{\rm H}$

- **12.** The radius of the second Bohr orbit for hydrogen atom is (Planck's constant (h) 6.6262 10 ³⁴ Js; mass of electron 9.1091 10 ³¹ kg ; charge of electron (e) 1.60210 10 ¹⁹ C; permitivity of vacuum
 - $(_{0})$ 8.854185 10 12 kg 1 m 3 A 2) (2017 Main)

13. *P* is the probability of finding the 1*s* electron of hydrogen atom in a spherical shell of infinitesimal thickness, *dr*, at a distance *r* from the nucleus. The volume of this shell is 4 $r^2 dr$. The qualitative sketch of the dependence of *P* on *r* is (2016 Adv.)



- 14. Which of the following is the energy of a possible excited state of hydrogen? (2015 Main)
 (a) + 13.6 eV (b) 6.8 eV
 (c) -3.4 eV (d) + 6.8 eV
- **15.** The correct set of four quantum numbers for the valence electrons of rubidium atom $(Z \quad 37)$ is (2013 Main)

(a)
$$5, 0, 0, \frac{1}{2}$$
(b) $5, 1, 0, \frac{1}{2}$ (c) $5, 1, 1, \frac{1}{2}$ (d) $5, 0, 1, \frac{1}{2}$

16. Energy of an electron is given by

$$E = 2.178 \quad 10^{-18} \text{ J} \quad \frac{Z^2}{n^2}$$
 (2013 Main)

Wavelength of light required to excite an electron in an hydrogen atom from level n + 1 to n + 2 will be

- **17.** The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is $[a_0$ is Bohr radius] (2012)

(a)
$$\frac{h^2}{4\ ^2ma_0^2}$$
 (b) $\frac{h^2}{16\ ^2ma_0^2}$ (c) $\frac{h^2}{32\ ma_0^2}$ (d) $\frac{h^2}{64\ ^2ma_0^2}$

- **18.** The number of radial nodes in 3*s* and 2*p* respectively are (a) 2 and 0 (b) 0 and 2 (2005, 1M) (c) 1 and 2 (d) 2 and 1
- **19.** Which hydrogen like species will have same radius as that of Bohr orbit of hydrogen atom? (2004, 1M) (a) n = 2, Li² (b) n = 2, Be³ (c) n = 2, He (d) n = 3, Li²
- **20.** If the nitrogen atom had electronic configuration $1s^7$, it would have energy lower than that of the normal ground state configuration $1s^2 2s^2 2p^3$, because the electrons would be closer to the nucleus, yet $1s^7$ is not observed, because it violates
 - (a) Heisenberg uncertainty principle (2002, 3M)
 - (b) Hund's rule
 - (c) Pauli exclusion principle
 - (d) Bohr postulate of stationary orbits
- **21.** The quantum numbers $\frac{1}{2}$ and $\frac{1}{2}$ for the electron spin represent (2001, 1M)
 - (a) rotation of the electron in clockwise and anti-clockwise direction respectively
 - (b) rotation of the electron in anti-clockwise and clockwise direction respectively
 - (c) magnetic moment of the electron pointing up and down respectively
 - (d) two quantum mechanical spin states which have no classical analogue
- **22.** The wavelength associated with a golf ball weighing 200 g and moving at a speed of 5 m/h is of the order (2001, 1M) (a) 10^{-10} m (b) 10^{-20} m
 - (c) 10 30 m (d) 10 40 m
- **23.** The number of nodal planes in a p_x orbital is (a) one (b) two (c) three (d) zero
 (2001, 1M)
- **24.** The electronic configuration of an element is $1s^2$, $2s^2 2p^6$, $3s^2 3p^6 3d^5$, $4s^1$. This represents its (2000, 1M) (a) excited state (b) ground state (c) cationic form (d) anionic form
- 25. The electrons, identified by quantum numbers n and l,
 (i) n 4, l 1, (ii) n 4, l 0, (iii) n 3, l 2, (iv) n 3, l 1
 can be placed in order of increasing energy, from the lowest to highest, as (1999, 2M)
 (a) (iv) < (ii) < (iii) < (i) (b) (ii) < (iv) < (i) < (iii)
 (b) (ii) < (iv) < (i) < (iii)
 (c) (i) < (iii) < (iv) (d) (iii) < (iv) < (ii)
- 26. 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 of hydrogen is (are) (1998, 2M) (a) -3.4 eV (b) 4.2 eV (c) 6.8 eV (d) + 6.8 eV
- 27. For a *d*-electron, the orbital angular momentum is (1997, 1M) (a) $\sqrt{6} \quad \frac{h}{2}$ (b) $\sqrt{2} \quad \frac{h}{2}$ (c) $\frac{h}{2}$ (d) $2 \quad \frac{h}{2}$

- 28. The first use of quantum theory to explain the structure of atom was made by (1997, 1M)
 (a) Heisenberg (b) Bohr
 (c) Planck (d) Einstein
- **29.** Which of the following has the maximum number of unpaired electrons ? (1996, 1M) (a) Mg^{2+} (b) Ti^{3+} (c) V^{3+} (d) Fe^{2+}
- **30.** The orbital angular momentum of an electron in 2*s*-orbital is (1996, 1M)

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

- **31.** Which of the following relates to photons both as wave motion and as a stream of particles ? (1992, 1M) (a) Interference (b) $E mc^2$ (c) Diffraction (d) E h
- 32. Which of the following does not characterise X-rays ?
 (a) The radiation can ionise gases (1992, 1M)
 (b) It causes ZnS to fluoresce
 (c) Deflected by electric and magnetic fields
 - (d) Have wavelengths shorter than ultraviolet rays
- **33.** The correct set of quantum numbers for the unpaired electron of chlorine atom is (1989, 1M)

	n	l	т		n	l	m
(a)	2	1	0	(b) 1	2	1	1
(c)	3	1	1	(d)	3	0	0

- **34.** The correct ground state electronic configuration of chromium atom is (1989, 1M) (a) $[Ar] 3d^5 4s^1$ (b) $[Ar] 3d^4 4s^2$ (c) $[Ar] 3d^6 4s^0$ (d) $[Ar] 4d^5 4s^1$
- **35.** The outermost electronic configuration of the most electronegative element is (1988, 90, 1M) (a) $ns^2 np^3$ (b) $ns^2 np^4$ (c) $ns^2 np^5$ (d) $ns^2 np^6$
- **36.** The orbital diagram in which the Aufbau principle is violated (1988, 1M)



- **37.** The wavelength of a spectral line for an electronic transition is inversely related to (1988, 1M)
 - (a) the number of electrons undergoing the transition
 - (b) the nuclear charge of the atom $% \left(b\right) =\left(b\right) \left(b$
 - (c) the difference in the energy of the energy levels involved in the transition
 - (d) the velocity of the electron undergoing the transition

38. The ratio of the energy of a photon of 200 Å wavelength radiation to that of 4000 Å radiation is (1986, 1M)

(a)
$$\frac{1}{4}$$
 (b) 4
(c) $\frac{1}{2}$ (d) 2.

39. Which one of the following sets of quantum numbers represents an impossible arrangement? (1986, 1M)

	n	l	т	S
(a)	3	2	-2	$\frac{1}{2}$
(b)	4	0	0	$\frac{1}{2}$
(c)	3	2	-3	$\frac{1}{2}$
(d)	5	3	0	$\frac{1}{2}$

- 40. Electromagnetic radiation with maximum wavelength is
 (a) ultraviolet
 (b) radio wave
 (1985, 1M)
 (c) X-ray
 (d) infrared
- 41. Which electronic level would allow the hydrogen atom to absorb a photon but not to emit a photon? (1984, 1M)
 (a) 3s (b) 2p
 (c) 2s (d) 1s

42. Correct set of four quantum numbers for the valence (outermost) electron of rubidium (Z 37) is (1984, 1M) (a) 5, 0, 0, $\frac{1}{2}$ (b) 5, 1, 0, $\frac{1}{2}$

(c) 5, 1, 1,
$$\frac{1}{2}$$
 (d) 6, 0, 0, $\frac{1}{2}$

- 43. The principal quantum number of an atom is related to the (a) size of the orbital (1983, 1M)
 (b) spin angular momentum
 (c) orientation of the orbital in space
 (d) orbital angular momentum
 - (d) orbital angular momentum
- **44.** Any *p*-orbital can accommodate upto (1983, 1M)
 - (a) four electrons
 - (b) six electrons
 - (c) two electrons with parallel spins
 - (d) two electrons with opposite spins

Objective Questions II

(One or more than one correct option)

45. The ground state electronic configuration of nitrogen atom can be represented by (1999, 3M)



- **46.** Which of the following statement (s) is (are) correct ? (1998, 2M)
 - (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. (atomic number of Ag = 47)
 - (d) The oxidation state of nitrogen in HN_3 is -3

47.	An isotone of $^{76}_{32}$ Ge is		(1984, 1M)
	(a) $^{77}_{32}$ Ge	(b) $^{77}_{33}$ As	
	(c) $^{77}_{34}$ Se	(d) $^{78}_{34}$ Se	

Assertion and Reason

- 76

Read the following questions and answer as per the direction given below :

- (a) Both Statement I and Statement II are correct; Statement II is the correct explanation of Statement I
- (b) Both Statement I and Statement II are correct; Statement II is not the correct explanation of Statement I
- (c) Statement I is correct; Statement II is incorrect
- (d) Statement I is incorrect; Statement II is correct
- **48.** Statement I The first ionisation energy of Be is greater than that of B.

Statement II 2*p*-orbital is lower in energy than 2*s*. (2000)

Passage Based Questions

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.

49.	The state S	S_1 is		(2	010)
	(a) 1 <i>s</i>	(b) 2 <i>s</i>	(c) 2 <i>p</i>	(d) 3 <i>s</i>	
50.	Energy of state energy	the state S_1 in by is	units of the hyd	lrogen atom gro (2	und 010)
	(a) 0.75	(b) 1.50	(c) 2.25	(d) 4.50	
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51. The orbital angular momentum quantum number of the state S_2 is (2010)(a) 0 (b) 1 (c) 2 (d) 3

Match the Columns

Answer Q. 52, Q. 53 and Q. 54 by appropriately matching the information given in the three columns of the following table.

The wave function, n, l, m_l is a mathematical function whose value depends upon spherical polar coordinates (r, ,) of the electron and characterised by the quantum number n, l and m_l . Here r is distance from nucleus, is colatitude and is azimuth. In the mathematical functions given in the Table, Z is atomic number and a_0 is Bohr radius. (2017 Adv.)

Column 1	Column 2	Column 3
(I) ls-orbital	(i) $\frac{Z}{a_0} = \frac{Z}{a_0} = \frac{Z}{a_0} = \frac{Zr}{a_0}$	(P) (\mathbf{P}) (\mathbf{P}) (\mathbf{P})
(II) 2s-orbital	(ii) One radial node	(Q) Probability density at nucleus $\frac{1}{a_0^3}$
(III) $2p_z$ -orbital	(iii) $_{n, l m_l} = \frac{Z}{a_0} \frac{\frac{5}{2}}{re} \frac{Zr}{a_0} \cos \frac{Zr}{2}$	(R) Probability density is maximum at nucleus
(IV) 3 d_z^2 -orbital	(iv) xy-plane is a nodal plane	(S) Energy needed to excite electron from $n = 2$ state to $n = 4$ state (S) $is \frac{27}{32}$ times the energy needed to excite electron from $n = 2$ state to $n = 6$ state

52.	For He ion, the only INC	ORRECT combination is					
	(a) (I) (i) (S)	(b) (II) (ii) (Q)	(c) (I) (iii) (R)	(d) (I) (i) (R)			
53.	. For the given orbital in Column 1, the Only CORRECT combination for any hydrogen-like species is						
	(a) (II) (ii) (P)	(b) (I) (ii) (S)	(c) (IV) (iv) (R)	(d) (III) (iii) (P)			
54.	4. For hydrogen atom, the only CORRECT combination is						
	(a) (I) (i) (P)	(b) (I) (iv) (R)	(c) (II) (i) (Q)	(d) (I) (i) (S)			

55. Match the entries in Column I with the correctly related quantum number(s) in Column II. (2008, 6M)

	Column I		Column II
А.	Orbital angular momentum of the electron in a hydrogen-like atomic orbital.	p.	Principal quantum number
В.	A hydrogen-like one-electron wave function obeying Pauli's principle.	q.	Azimuthal quantum number
C.	Shape, size and orientation of hydrogen-like atomic orbitals.	r.	Magnetic quantum number
D.	Probability density of electron at the nucleus in hydrogen-like atom.	s.	Electron spin quantum number

Fill in the Blanks

- The uncertainty principle and the concept of wave nature of matter were proposed by andrespectively. (1988, 1M)

- **61.** When there are two electrons in the same orbital, they have spins. (1983, 1M)

True/False

- **62.** In a given electric field, -particles are deflected more than -particles in spite of -particles having larger charge.
- (1993, 1M) 63. The electron density in the XY-plane in $3d_{x^2} = \frac{1}{y^2}$ orbital is
- zero. (1986, 1M)
- **64.** The energy of the electron in the 3d-orbital is less than that in the 4s-orbital in the hydrogen atom. (1983, 1M)
- **65.** Gamma rays are electromagnetic radiations of wavelengths of 10 6 to 10 5 cm. (1983, 1M)
- **66.** The outer electronic configuration of the ground state chromium atom is $3d^44s^2$. (1982, 1M)

Integer Answer Type Questions

67. Not considering the electronic spin, the degeneracy of the second excited state $(n \ 3)$ of H-atom is 9, while the degeneracy of the second excited state of H is (2015 Adv.)

68. In an atom, the total number of electrons having quantum numbers (2014 Adv.)

$$n \quad 4, |m_l| \quad 1 \text{ and } m_s \quad \frac{1}{2} \text{ is}$$

- 69. 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 (2013 Adv.)
- **70.** The work function () 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 (2011)

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

71. The maximum number of electrons that can have principal quantum number, n = 3 and spin quantum number, $m_s = 1/2$, is (2011)

Subjective Questions

- **72.** (a) Calculate velocity of electron in first Bohr orbit of hydrogen atom (Given, $r = a_0$).
 - (b) Find de-Broglie wavelength of the electron in first Bohr orbit.
 - (c) Find the orbital angular momentum of 2p-orbital in terms of h/2 units. (2005, 2M)
- **73.** (a) The Schrodinger wave equation for hydrogen atom is

$$2s \quad \frac{1}{4(2)^{1/2}} \quad \frac{1}{a_0} \quad 2 \quad \frac{r}{a_0} \quad e^{r/2a_0}$$

where, a_0 is Bohr's radius. Let the radial node in 2s be at r_0 . Then, find r in terms of a_0 .

(b) A base ball having mass 100 g moves with velocity 100 m/s. Find out the value of wavelength of base ball.

(2004, 2M)

- 74. The wavelength corresponding to maximum energy for hydrogen is 91.2 nm. Find the corresponding wavelength for He⁺ ion. (2003, 2M)
- 75. Calculate the energy required to excite 1 L of hydrogen gas at 1 atm and 298 K to the first excited state of atomic hydrogen. The energy for the dissociation of H—H bond is 436 kJ mol⁻¹.
- 76. An electron beam can undergo diffraction by crystals. Through what potential should a beam of electrons be accelerated so that its wavelength becomes equal to 1.54 Å. (1997 (C), 2M)
- **77.** Consider the hydrogen atom to be proton embedded in a cavity of radius a_0 (Bohr's radius) whose charge is neutralised by the addition of an electron to the cavity in vacuum, infinitely slowly. Estimate the average total energy of an electron in its ground state in a hydrogen atom as the work done in the above neutralisation process. Also, if the magnitude of the average kinetic energy is half the magnitude of the average potential energy, find the average potential energy. (1996, 2M)

- **78.** Calculate the wave number for the shortest wavelength transition in the Balmer series of atomic hydroger(1996, 1M)
- **79.** Iodine molecule dissociates into atoms after absorbing light to 4500Å. If one quantum of radiation is absorbed by each molecule, calculate the kinetic energy of iodine atoms. (Bond energy of $I_2 = 240 \text{ kJ mol}^{-1}$) (1995, 2M)
- Find out the number of waves made by a Bohr's electron in one complete revolution in its 3rd orbit. (1994, 3M)
- **81.** What transition in the hydrogen spectrum would have the same wavelength as the Balmer transition n = 4 to n = 2 of He⁺ spectrum? (1993, 3M)
- **82.** Estimate the difference in energy between 1st and 2nd Bohr's orbit for a hydrogen atom. At what minimum atomic number, a transition from n = 2 to n = 1 energy level would result in the emission of X-rays with $l = 3.0 \ 10^{-8} \text{ m}$? Which hydrogen atom-like species does this atomic number correspond to? (1993, 5M)
- **83.** According to Bohr's theory, the electronic energy of hydrogen atom in the *n*th Bohr's orbit is given by :

$$E_n = \frac{21.7 \cdot 10^{-19}}{n^2} \,\mathrm{J}$$

Calculate the longest wavelength of electron from the third Bohr's orbit of the He^+ ion. (1990, 3M)

- **84.** What is the maximum number of electrons that may be present in all the atomic orbitals with principal quantum number 3 and azimuthal quantum number 2? (1985, 2M)
- 85. Give reason why the ground state outermost electronic configuration of silicon is (1985, 2M)



- **86.** The electron energy in hydrogen atom is given by $E_n = \frac{21.7 \quad 10^{-12}}{n^2}$ erg. Calculate the energy required to remove an electron completely from the n = 2 orbit. What is the longest wavelength (in cm) of light that can be used to cause this transition? (1984, 3M)
- **87.** Calculate the wavelength in Angstroms of the photon that is emitted when an electron in the Bohr's orbit, n = 2 returns to the orbit, n = 1 in the hydrogen atom. The ionisation potential of the ground state hydrogen atom is 2.17 10⁻¹¹ erg per atom. (1982, 4M)
- **88.** The energy of the electron in the second and third Bohr's orbits of the hydrogen atom is $5.42 \ 10^{12}$ erg and $2.41 \ 10^{12}$ erg respectively. Calculate the wavelength of the emitted light when the electron drops from the third to the second orbit. (1981, 3M)

Answers

Тор	ic 1					33. (c)	34. (a)	35. (c)	36. (b)
1.	(d)	2.	(a)	3. (b)	4. (c)	37. (c)	38. (d)	39. (c)	40. (b)
5.	(d)	6.	(c)	7. (d)	8. (b)	41. (d)	42. (a)	43. (a)	44. (d)
9.	(b)	10.	(b)	11. (d)	12. (a)	45. (a,d)	46. (a,b,c)	47. (b,d)	48. (c)
13.	(c)	14.	(a)	15. (a,b)	16. (d)	49. (b)	50. (c)	51. (b)	52. (c)
17.	(a,c)	18.	(a,c)	19. A r;	Bq; Cp, Ds	53. (a)	54. (d)		
20.	(photon	is) 21.	(1.66	10^{-27} kg)	22. (neutrons)	55. A q;	B p, q, r, s C	p,q,r D	p, q, r
	23.	(isobars)	24.	$6.3 10^6$		56. Cr [Ar]	$3d^5, 4s^1$	57. 1 : 16	
Тор	ic 2					58. Heisenber	rg, de-Broglie.	59. orbital	
1.	(a)	2.	(a)	3. (a)	4. (d)	60. Orientatio	on in space	61. opposite	
5.	(c)	6.	(c)	7. (b)	8. (d)	62. True	63. False	64. True	65. False
9.	(d)	10.	(b)	11. (c)	12. (d)	66. False	67. (3)	68. (6)	69. (5)
13.	(c)	14.	(c)	15. (a)	16. (a)	70. (4.14 eV)	71. (9)	74. (22.8 nm)	75. (98.44 kJ)
17.	(c)	18.	(a)	19. (b)	20. (c)	76. (63.56 V)	78. (2.725 10 ⁶	⁵ M ⁻¹)	
21.	(d)	22.	(c)	23. (a)	24. (b)	79. (2.16 10 ²	⁰ J/atom)	83. (471 nm)	84. (10)
25.	(a)	26.	(a)	27. (a)	28. (b)	86. (3.66 10	⁵ cm) 87. (1220 Å)	88. (660 nm)	
29.	(d)	30.	(b)	31. (a)	32. (c)		, (1220 11)		

Hints & Solutions

Topic 1 Preliminary Developments and Bohr's Model

1. Statement (d) is incorrect. For 1s-orbital radial probability density (R^2) against *r* is given as:



For *ls*-orbital, probability density decreases sharply as we move away from the nucleus.

The radial distribution curves obtained by plotting radial probability functions vs r for 1*s*-orbital is



The graph initially increases and then decreases. It reaches a maximum at a distance very close to the nucleus and then decreases. The maximum in the curve corresponds to the distance at which the probability of finding the electron in maximum.

2. The expression of kinetic energy of photo electrons,

$$\text{KE} \quad \frac{1}{2} m v^2 \quad E \quad E_0$$

When, KE E_0 , the equation becomes,

$$KE \quad \frac{1}{2}mv^2 \quad E$$

$$\frac{1}{2}mv^2 \quad \frac{hc}{2} \quad \frac{p^2}{2m^2} \quad \frac{hc}{p}$$

$$hc \quad 2m^2 \quad \frac{1}{p^2} \qquad \frac{1}{p^2}$$

 $E \stackrel{hc}{-}$ energy of incident light.

 E_0 threshold energy or work functions,

$$\frac{1}{2}mv^2 \quad \frac{1}{2} \quad \frac{(mv)^2}{m^2} \quad \frac{1}{2} \quad \frac{p^2}{m^2}$$

2

 $\therefore p$ momentum mv

As per the given condition,

$$\begin{array}{c} \underline{p}_1 \\ \underline{p}_2 \\ 1 \end{array} \begin{array}{c} \underline{p}_1 \\ p_2 \end{array}$$

3. Work function of metal () h_0 where, 0 threshold frequency

Also,
$$\frac{1}{2}m_e v^2 \quad h \quad h_0$$
or
$$\frac{1}{2}m_e v^2 \quad h \qquad \dots(i)$$

$$\frac{1}{2}m_e v^2 \quad \frac{hc}{dt} \qquad \dots(ii)$$

Given : 4000 Å 4000 10 ¹⁰m

$$v = 6 = 10^5 \,\mathrm{ms}^{-1}$$
,

$$m_e$$
 9 10 ³¹kg, c 3 10⁸ ms ¹

Thus, on substituting all the given values in Eq. (i), we get

$$\frac{1}{2} \quad 9 \quad 10^{31} \text{ kg} \quad (6 \quad 10^5 \text{ ms}^{-1})^2$$

$$\frac{6.626 \quad 10^{-34} \text{ J s} \quad 3 \quad 10^8 \text{ ms}^{-1}}{4000 \quad 10^{-10} \text{ m}}$$

$$1.62 \quad 10^{-21} \text{ kgm}^2 \text{s}^{-2} \quad 4.96 \quad 10^{-19} \text{ J}$$

$$3.36 \quad 10^{-19} \text{ J} \qquad \qquad [1 \text{ kgm}^2 \text{s}^{-2} \quad 1\text{ J}]$$

$$2.1 \text{ eV}$$

4. The ground state energy of H-atom is 13.6 eV.

For second excited state, n = 2 = 1 = 3

$$E_3$$
(He) 13.6 $\frac{Z^2}{n^2}$ eV [:: for He, Z 2]
13.6 $\frac{2^2}{3^2}$ eV 6.04 eV

5. For photoelectric effect,

KE
$$E E_0$$

| |²

where,

(i)

- KE Kinetic energy of ejected electrons.
- E Energy of incident light h
- E_0 Threshold energy h_0 Frequency of incident light
 - 0 Threshold frequency



Slope 1, intercept E_0

So, option (a) is correct.

(ii) KE of ejected electrons does not depend on the intensity of incident light.



So, option (b) is correct.

(iii) When, number of ejected electrons is plotted with frequency of light, we get



So, option (c) is also correct.



Slope h, intercept h_{0} . So, option (d) is not correct.

6. Plan As you can see in options, energy term is mentioned hence, we have to find out relation between h/ and energy. For this, we shall use de-Broglie wavelength and kinetic energy term in eV.

de-Broglie wavelength for an electron () $\frac{h}{p}$

Kinetic energy of an electron eV

As we know that, KE
$$\frac{p^2}{2m}$$

eV $\frac{p^2}{2m}$ or $p \sqrt{2meV}$...(ii)

From equations (i) and (ii), we get $\frac{n}{2} \sqrt{2meV}$

7. Rutherford used -particle (He² nuclei) in his experiment.

- **8.** According to Rutherford's model, there is a heavily positively charged nucleus and negatively charged electrons occupies space around it in order to maintain electro-neutrality.
- **9.** Radius of a nucleus is in the order of 10^{-13} cm, a fact.
- **10.** Bohr's model is applicable to one-electron system only.
- **11.** Neutron has no charge, hence e/m is zero for neutron. Next, -particle (He²⁺) has very high mass compared to proton and electron, therefore very small e/m ratio. Proton and electron have same charge (magnitude) but former is heavier, hence has smaller value of e/m.

$$\frac{e}{m}$$
: n p ϵ

- **12.** The negligibly small size of nucleus compared to the size of atom was first established in Rutherford's experiment.
- **13.** The most important findings of Rutherford's experiment is discovery of nucleus.
- **14.** Energy of electron in H-atom is determined by the expression:

$$E_{n} = \frac{13.6}{n^{2}} \text{ eV} \quad \text{where,} \quad n = 1, 2, 3,$$

In excited states, $E_{2} = \frac{13.6}{4} = 3.4 \text{ eV}$
 $E_{3} = \frac{13.6}{9} = 1.51 \text{ eV}$ etc.

...

- 15. Nucleus is composed of neutrons and protons.
- **16.** The isotopes of hydrogen are ${}_{1}H^{2}$ and ${}_{1}H^{3}$.
- **17.** Alpha particles passes mostly undeflected when sent through thin metal foil mainly, because
 - (i) it is much heavier than electrons.

(ii) most part of atom is empty space.

18. Many elements have several isotopes. For such elements, atomic mass is average of the atomic masses of different isotopes, which is usually non-integral.

19. A.
$$V_n = \frac{1}{4} \frac{Ze^2}{0} \frac{Ze^2}{r}$$

 $K_n = \frac{1}{8} \frac{Ze^2}{0} \frac{Ze^2}{r}$
 $\frac{V_n}{K_n} = 2$ (r)
B. $E_n = \frac{Ze^2}{8} r^{-1}$
 $x = 1$ (q)
C. Angular momentum $\sqrt{l(l-1)} \frac{h}{r}$

...(i)

C. Angular momentum $\sqrt{l(l-1)} \frac{h}{2} = 0$ in 1*s*-orbital (*p*).

D.
$$r_n = \frac{a_0 n^2}{Z} = \frac{1}{r_n} = Z$$
 (s)

- **20.** Photons have quantised energy.
- **21.** Mass of one H-atom $\frac{10^{3}}{6.023 \times 10^{23}}$ kg = 1.66 10^{27} kg

- 22. Isotopes have different number of neutrons.
- 23. Isobars have same mass number but different atomic numbers.
- **24.** When -particle stop at 10 13 m from nucleus, kinetic energy is zero, i.e. whole of its kinetic energy at the starting point is now converted into potential energy.

Potential energy of this -particle can be determined as

$$PE = \frac{Z_1 - Z_2 e^2}{(4 - 0) r}$$

$$(Z_1 - 2, Z_2 - 29, -0) = 8.85 - 10^{-12} J^{-1} C^2 m^{-1}, r - 10^{-13} m)$$

$$|PE| = \frac{2 - 29 - (1.6 - 10^{-19})^2}{4 - 3.14 - 8.85 - 10^{-12} - 10^{-13}} J$$

$$I.33 - 10^{-13} J$$

$$= \text{kinetic energy of -particle at } t = 0$$

$$KE = \frac{1}{2} mv^2 - 1.33 - 10^{-13}$$

$$v = \sqrt{\frac{2 - 1.33 - 10^{-13}}{4 - 1.66 - 10^{-27}}} = 6.3 - 10^6 \text{ ms}^{-1}$$

Topic 2 Advanced Concept (Quantum Mechanical Theory) Electronic Configuration and **Quantum Number**

1. The energy of 2s-orbital is lowest in K(potassium). An orbital gets larger as the principal quantum number n increases. Correspondingly, the energy of the electron in such an orbital becomes less negative, meaning that the electron is less strongly bound and has less energy. The graph of principal quantum number with atomic number is



2. The electrons are more likely to be found in the region *a* and *c*. At b, wave function becomes zero and is called radial nodal surface or simply node.



The graph between wavefunction () and distance (r) from the nucleus helps in determining the shape of orbital.

3. According to Rydberg's equation,

1

$$\frac{1}{1} \quad \frac{R_{\rm H}}{hc} \quad \frac{1}{n_1^2} \quad \frac{1}{n_2^2} \quad \text{or} \quad \frac{1}{-1} \quad \frac{1}{n_1^2} \quad \frac{1}{n_2^2}$$

For shortest wavelength, i.e. highest energy spectral line, n_2 will be ().

For the given spectral series, ratio of the shortest wavelength of two spectral series can be calculated as follows :

(a)
$$\frac{L}{P}$$
 $\frac{\frac{1}{3^2}}{\frac{1}{1^2}}$ $\frac{1}{2}$ $\frac{\frac{1}{9}}{1}$ $\frac{0}{1}$ $\frac{1}{9}$
(b) $\frac{Bk}{Pf}$ $\frac{\frac{1}{5^2}}{\frac{1}{4^2}}$ $\frac{1}{2}$ $\frac{1}{25}$ $\frac{16}{1}$ $\frac{16}{25}$
(c) $\frac{P}{Pf}$ $\frac{\frac{1}{5^2}}{\frac{1}{3^2}}$ $\frac{1}{2}$ $\frac{1}{25}$ $\frac{9}{1}$ $\frac{9}{25}$
(d) $\frac{B}{Bk}$ $\frac{\frac{1}{4^2}}{\frac{1}{2^2}}$ $\frac{1}{2}$ $\frac{1}{16}$ $\frac{4}{1}$ $\frac{1}{4}$
Note Lyman L (n₁ 1), Balmer B (n₁)

2) Paschen P $(n_1 \quad 3)$, Brackett Bk $(n_1 \quad 3)$ 4) Pfund Pf (n_1) 5)

4. The graphs between $| |^2$ and *r* are radial density plots having $(n \ l \ 1)$ number of radial nodes. For 1s, 2s, 3s and 2 *p*-orbitals these are respectively.



Thus, the given graph between $| |^2$ and *r* represents 2*s*-orbital.

5. For any given series of spectral lines of atomic hydrogen.
 Let - - - max min be the difference in maximum and minimum frequencies in cm⁻¹.
 For Lyman series,

General formula:

109677
$$\frac{1}{n_i^2}$$
 $\frac{1}{n_f^2}$

max

min

For Lyman
$$n_1$$
 1, n_2 2, 3, ...
 $-_{max}$ 109,677 $\frac{1}{1}$ $\frac{1}{-}$ 109,677 $\frac{1}{1}$ 0
109,677
 $-_{min}$ 109,677 $\frac{1}{1}$ $\frac{1}{(2)^2}$

Lyman
$$\max_{109,677} \min_{109,677} \frac{109,677}{4} \frac{109,677}{4}$$

For Balmer series,

6. Smaller the value of $(n \ l)$, smaller the energy. If two or more sub-orbits have same values of $(n \ l)$, sub-orbits with lower values of *n* has lower energy. The $(n \ l)$ values of the given options are as follows :

I. n 4, l 2; n lII. n 3, l 2; n lIII. n 4, l 1, n lIV. n 3, l 1, n l

7.

Among II and III, n = 3 has lower value of energy. Thus, the correct order of their increasing energies will be

Number of waves
$$\frac{\text{Circumference}}{\text{Wavelength}} \qquad n \quad \frac{2 r}{2}$$

Also, we know that radius (r) of an atom is given by

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

Thus, Eq. (i) becomes

$$2 \ a_0 \frac{n^2}{Z} \ n \qquad \dots (ii)$$

$$2 \ a_0 \frac{n^2}{Z} \ n (1.5 \ a_0) \ [Given, \qquad 1.5 \ a_0]$$

$$\frac{n}{Z} \ \frac{1.5 \ a_0}{2 \ a_0} \ \frac{1.5}{2} \ 0.75$$

8. de-Broglie wavelength () for electron is given by

$$\frac{h}{\sqrt{2 m \text{ K.E}}} \qquad \dots (i)$$

Also, according to photoelectric effect KE $h h_0$

On substituting the value of KE in Eq (i), we get

$$\frac{h}{\sqrt{2m} (h h_0)}$$
$$\frac{1}{(1)^{1/2}}$$

9. (I) Angular momentum, $mvr = \frac{nh}{2}$

distance from the nucleus

(II) This statement is incorrect as size of an orbit

Azimuthal quantum number (l)

(:: n constant)

(III) This statement is incorrect as at ground state, n = 1, l = 0

Orbital angular momentum (wave mechanics)

$$\sqrt{l(l-1)} \frac{h}{2} \quad 0 \qquad [\because l \quad 0]$$

(IV) The given plot is



10.
$$E \quad hc \quad \frac{1}{-} \quad hc \quad R_{\rm H} \quad \frac{1}{n_1^2} \quad \frac{1}{n_2^2} \quad Z^2$$

$$\frac{1}{n_1^2} \quad \frac{1}{n_2^2} \quad \frac{hc}{R_{\rm H}} \qquad [\text{for H, atom } Z \quad 1]$$

$$\frac{1}{R_{\rm H}} \quad \frac{1}{(1 \quad 10^7 \text{ m}^{-1})} \quad \frac{1}{(900 \quad 10^{-9} \text{ m})}$$

$$\frac{1}{n_1^2} \quad \frac{1}{n_2^2} \quad \frac{1}{9}$$
So, in option (b) $\frac{1}{3^2} \quad \frac{1}{-2} \quad \frac{1}{9} \quad 0 \quad \frac{1}{9} \qquad n_1 \quad 3,$

11. According to Rydberg's formula,

wave number ($-R_{\rm H}Z^2 \frac{1}{n_i^2} - \frac{1}{n_i^2}$ Given, n_i , n_f 8 [: it is the case of emission] $-R_{\rm H}$ $(1)^2 \frac{1}{n^2} \frac{1}{8^2}$ $-R_{\rm H} = \frac{1}{n^2} \frac{1}{64} = \frac{R_{\rm H}}{n^2} \frac{R_{\rm H}}{64}$

On comparing with equation of straight line, y mx c, we get Slope $R_{\rm H}$, intercept $\frac{R_{\rm H}}{64}$.

Thus, plot of wave number (against $\frac{1}{n^2}$ will be linear with slope $(R_{\rm H})$.

12. Bohr radius $(r_n) = {}_0 n^2 h^2$

$$r_n = \frac{n^2 h^2}{4 2 m e^2 kZ}$$

$$k = \frac{1}{4 0}$$

$$r_n = \frac{n^2 h^2}{m e^2 Z} n^2 \frac{a_0}{Z}$$

where, *m* mass of electron

- e charge of electron
- h Planck's constant
- k Coulomb constant

$$r_n = \frac{n^2 - 0.53}{Z} \text{\AA}$$

Radius of n^{th} Bohr orbit for H-atom

$$0.53 n^2 \text{ Å}$$
 [Z 1 for H-atom]

Radius of 2nd Bohr orbit for H-atom

$$0.53 (2)^2 2.12 \text{ Å}$$

13. This graph shows the probability of finding the electron within shell at various distances from the nucleus (radial probability). The curve shows the maximum, which means that the radial probability is greatest for a given distance from the nucleus. This distance is equal to Bohr's radius a_0



- (a) It is for 2*s*-orbital.
- (b) It is radial wave function for 1s.
- (c) Correct
- (d) Probability cannot be zero at a certain distance from nucleus.

$$\frac{13.6}{n^2} \text{ eV} \qquad \text{where, } n \quad 1, 2, 3 \dots$$

$$\frac{13.6}{n^2} \quad 3.4 \text{ eV}$$

In excited states,
$$E_2 = \frac{13.6}{4}$$
 3.4 eV

 E_{n}

15. Given, atomic number of Rb, Z = 37

Thus, its electronic configuration is $[Kr]5s^1$. Since, the last electron or valence electron enter in 5s subshell. So, the quantum numbers are n = 5, l = 0, (for s-orbital) m = 0(:: $m \ l \text{ to } l$), $s \ 1/2 \text{ or } 1/2$.

 E_2 2.178 10⁻¹⁸ J $\frac{1}{2^2}$

16. Given, in the question E 2.178 10⁻¹⁸ J $\frac{Z^2}{r^2}$ For hydrogen Z 1, E_1 2.178 10 ¹⁸ J $\frac{1}{1^2}$ So,

Now, $E_1 = E_2$

i.e.
$$E = 2.178 = 10^{-18} \frac{1}{1^2} \frac{1}{2^2} = \frac{h}{2}$$

2.178 = 10⁻¹⁸ $\frac{1}{1^2} \frac{1}{2^2} = \frac{1}{2^2} = \frac{6.62 = 10^{-34} - 3.0 = 10^8}{1.21 = 10^{-7} \text{ m}}$

17. According to Bohr's model,

$$mvr \quad \frac{nh}{2} \qquad (mv)^2 \quad \frac{n^2h^2}{4 \ ^2r^2}$$

KE
$$\frac{1}{2}mv^2 \quad \frac{n^2h^2}{8 \ ^2r^2m} \qquad \dots(i)$$

hc

Also, Bohr's radius for H-atom is, $r = n^2 a_0$

Substituting 'r' in Eq. (i) gives

KE
$$\frac{h^2}{8 \, {}^2n^2a_0^2m}$$
 when $n = 2$, KE $\frac{h^2}{32 \, {}^2a_0^2m}$

- **18.** The number of radial nodes is given by expression $(n \ l \ 1)$. For 3s, number of nodes 3 0 1 2 For 2*p*, number of nodes 2 1 1 0
- **19.** Expression for Bohr's orbit is, $r_n = \frac{a_0 n^2}{7} = a_0$ when n = 2, Z = 4.
- **20.** $1s^7$ violate Pauli exclusion principle, according to which an orbital cannot have more than two electrons.
- $\frac{1}{2}$ and $\frac{1}{2}$ just represents two quantum mechanical spin states **21**. which have no classical analogue.
- **22.** Using the de-Broglie's relationship :

$$\frac{h}{nv} = \frac{6.625 \times 10^{-34}}{0.2 \times \frac{5}{60 \times 60}} = 2.3 \times 10^{-30} \text{ m}$$

23. Nodal plane is an imaginary plane on which probability of finding an electron is minimum. Every p-orbital has one nodal plane :



- **24.** $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$ is ground state electronic configuration of Cr.
- **25.** (i) n + 4, l + 1 4 *p*-orbital (ii) n + 4, l + 0 4 *s*-orbital
 - (iii) n = 3, l = 2 3*d*-orbital
 - (iv) n = 3, l = 1 3*d*-orbital

According to Aufbau principle, energies of above mentioned orbitals are in the order of

(iv)
$$3p < (ii) 4s < (iii) 3d < (i) 4p$$

26. The energy of an electron in a Bohr atom is expressed as

$$E_n \quad \frac{kZ^2}{n^2} \qquad \text{where, } k \quad \text{Constant,} \\ Z \quad \text{Atomic number,} \\ n \quad \text{Orbit number} \\ 13.6 \text{ eV for H} (n \quad 1) \\ \text{when } n \quad 2 \,, E_2 \quad \frac{13.6}{2^2} \text{ eV} = \quad 3.40 \text{ eV}$$

(*n* can have only integral value 1, 2, 3,.....)

The orbital angular momentum (L)
$$\sqrt{l(l-1)} \frac{h}{2}$$

 $\sqrt{6} \frac{h}{2} (l-2 \text{ for } d\text{ - orbital})$

- atom and proposed that energy of electron in an atom is quantised.
- **29.** $Mg^2 = 1s^2 2s^2 2p^6$ no unpaired electron
 - Ti^{3+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$ one unpaired electron
 - V^{3+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^2$ two unpaired electrons
 - Fe^{2+} $1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ four unpaired electrons
- **30.** Expression for orbital angular momentum (*L*) is

$$L \quad \sqrt{l(l-1)} \frac{h}{2} \quad 0 \quad \text{for } 2s\text{-electrons}$$

 \therefore For *s*-orbital, l = 0.

27.

- **31.** Diffraction is property of wave, $E mc^2$ determine energy of particle and E h determine energy of photon. Interference phenomena is exhibited by both matter and waves.
- **32.** X-rays is electrically neutral, not deflected in electric or magnetic fields.
- **33.** Cl (17) $1s^2 2s^2 2p^6 3s^2 3p^5$

The last, unpaired electron has, n = 3, l = 1(p) and m can have any of the three value (1, 0, 1).

34. Cr (24)
$$\underbrace{1s^2 2s^2 2p^6 3s^2 3p^6}_{\text{Ar}}$$
 3d⁵ 4s

The above configuration is exception to Aufbau's principle.

35. Fluorine, a halogen, is the most electronegative atom, has the electronic configuration $2s^2 2p^5$ (valence shell).

- **36.** Option (b) is wrong representation according to aufbau principle. A high energy atomic orbital (2p) cannot be filled unless the low energy orbital (2s) is completely occupied.
- **37.** Transition energy (E) $kZ^2 \frac{1}{n_1^2} \frac{1}{n_2^2} \frac{hc}{m_1^2}$ i.e. E $\frac{1}{n_1^2}$

 E_1

38.
$$E \frac{hc}{-}$$

$$\frac{1}{E_2} = \frac{1}{1} = 2$$
39. *n l m s*

$$3 = 2 = 3 = \frac{1}{2}$$

This is the wrong set of quantum number because |m| cannot be greater than *l*.

40. The wavelength order is

- **41.** When electron jumps to lower orbit photons are emitted while photons are absorbed when electron jumps to higher orbit. *ls*-orbital is the lower most, electron in this orbital can absorb photons but cannot emit.
- **42.** The valence shell configuration of Rubidium (Rb) is

[Kr]
$$5s^1$$
 n $5, l$ $0, m$ $0, s$ $\frac{1}{2}$ or $\frac{1}{2}$

- **43.** The principal quantum number '*n*' represents orbit number hence, determine the size of orbitals.
- **44.** According to Pauli exclusion principle, an atomic orbital can accommodate at the most, two electrons, with opposite spins.
- **45.** Both (a) and (d) are correct. The three electrons in the 2*p*-orbitals must have same spin, no matter up spin or down spin.
- **46.** (a) $\operatorname{Cr} = [\operatorname{Ar}] 3d^5 4s^1$, an exception to aufbau principle. (b) For a given value of *l*, *m* can have any value from (*l* to *l*), so can have negative value.
 - (c) Ag is in copper group with d¹⁰s¹ configuration,
 i.e. 46 electrons are spin paired.
- **47.** Isotones have same number of neutrons.

 $_{32}$ Ge⁷⁶, $_{33}$ As⁷⁷ and $_{34}$ Se⁷⁸ have same number (44) of neutrons, hence they are isotones.

- **48.** Assertion is correct $Be(1s^2, 2s^2)$ has stable electronic configuration, removing an electron require more energy than the same for $B(2p^1)$. Reason is incorrect (Aufbau principle).
- **49.** S_1 is spherically symmetrical state, i.e. it correspond to a *s*-orbital. Also, it has one radial node. Number of radial nodes $n \ l \ l$

r of radial nodes
$$n \ l \ l$$

 $n \ 0 \ 1 \ 1$

 $n \quad 2 \text{ i.e. } S_1 \quad 2s \text{-orbital.}$

50. Ground state energy of electron in H-atom $(E_{\rm H})$

$$E_{\rm H} \quad \frac{kZ^2}{n^2} \quad k \ (Z \quad 1, n \quad 1)$$

For S_1 state of Li^2 ,

$$E \quad \frac{k(3)^2}{2^2} \quad \frac{9}{4} k \quad 2.25 \ k$$

51. In S_2 state, $E(\text{Li}^2)$ K (given)

$$\begin{array}{ccc} K & \frac{q\kappa}{n^2} \\ n & 3 \end{array}$$

Since, S_2 has one radial node.

K

3 1 1 1 1 1

- **52.** In the wave function () expression for 1s-orbital of He , there should be no angular part. Hence (iii) can't be true for 1, of Не
- **53.** Correct : 2*s* orbital has one radial node.

No of radial node n l 1 2 0 1 1

Also, when radial part of wave function () is plotted against "r", wave function changes its sign at node.

- 54. *i* is the correct expression of wave function for 1s-orbital of hydrogenic system.
- **55.** A. Orbital angular momentum

(L)
$$\sqrt{l(l-1)} \frac{h}{2}$$

i.e. L depends on azimuthal quantum number only.

- B. To describe a one electron wave function, three quantum numbers n, l and m are needed. Further to abide by Pauli exclusion principle, spin quantum number(s) is also needed.
- C. For shape, size and orientation, only n, l and m are needed.
- D. Probability density $(^{2})$ can be determined if *n*, *l* and *m* are known.
- **56.** Cr [Ar] $3d^54s^1$
- **57.** 1 : 16
- 58. Heisenberg proposed uncertainty principle and de-Broglie proposed wave nature of electron.
- **59.** orbital
- **60.** $2p_x, 2p_y$ and $2p_z$ have different orientation in space.
- 61. Two electrons in same orbital must have opposite spin.
- 62. Very large mass of alpha particles than beta particles is responsible for less deflection in former case.
- **63.** $3d_{x^2} = \sqrt{2}$ orbital lies in *XY*-plane.
- 64. Aufbau principle.
- **65.** This is the wavelength of infrared radiation.

66. Cr $3d^54s^1$.

67. In an one electron (hydrogenic) system, all orbitals of a shell remains degenerate, hence in second excited state, the degeneracy of H-atom is nine



In case of many electrons system, different orbitals of a shell are non-degenerate. Hence,



68. **PLAN** This problem is based on concept of quantum number. Follow the following steps to solve this problem. Write all possible orbitals having combination of same principal, azimuthal, magnetic and spin quantum number.

Then count the all possible electrons having given set of quantum numbers.

For n = 4, the total number of possible orbitals are

According to question $|m_l| = 1$, i.e. there are two possible values of m_l , i.e. +1 and -1 and one orbital can contain $\frac{1}{2}$ and other having maximum two electrons one having s

1/2.

S

So, total number of orbitals having $\{|m_1| = 1\} = 6$

Total number of electrons having

$$\{\mid m_l \mid 1 \text{ and } m_s = \frac{1}{2}\}$$

69. PLAN KE
$$\frac{1}{2}mv^2$$
 $\frac{3}{2}RT$
 m^2v^2 2mKE mv $\sqrt{2mKE}$
(wavelength) $\frac{h}{mv}$ $\frac{h}{\sqrt{2mKE}}$ $\frac{h}{\sqrt{2m(T)}}$
where, T Temperature in Kelvin
(He at 73 C 200 K) $\frac{h}{\sqrt{2m}}$

le at 73 C 200 K)
$$\frac{1}{\sqrt{2} + 200}$$

М - 5

1000 K)
$$\frac{n}{\sqrt{2 \ 20 \ 1000}}$$

 $\frac{(\text{He})}{(\text{Ne})} M \sqrt{\frac{2 \ 20 \ 1000}{2 \ 4 \ 200}} 5$

h

Thus,

70. Energy of photon

(Ne at 727°C

$$\frac{hc}{e} J = \frac{hc}{e} eV - \frac{6.625 \ 10^{-34} \ 3 \ 10^8}{300 \ 10^{-9} \ 1.602 \ 10^{-19}} - 4.14 \ eV$$

For photoelectric effect to occur, energy of incident photons must be greater than work function of metal. Hence, only Li, Na, K and Mg have work functions less than 4.14 V.

71. When n = 3, l = 0, 1, 2 i.e. there are 3s, 3p and 3d-orbitals. If all these orbitals are completely occupied as



Alternatively In any *n*th orbit, there can be a maximum of $2n^2$ electrons. Hence, when n = 3, number of maximum electrons = 18. Out of these 18 electrons, 9 can have spin $-\frac{1}{2}$ and remaining nine with spin $\frac{1}{2}$.

72. (a)
$$mvr \quad \frac{nh}{2}$$

 $v \quad \frac{nh}{2 mr} \quad \frac{6.625 \quad 10^{-34}}{2 \quad 3.14 \quad 9.1 \quad 10^{-31} \quad 0.529 \quad 10^{-10}}$
2.18 $\quad 10^6 \text{ ms}^{-1}$
(b) $\quad \frac{h}{mv} \quad \frac{6.625 \quad 10^{-34}}{9.1 \quad 10^{-31} \quad 2.18 \quad 10^6} \quad 0.33 \quad 10^{-9} \text{ m}$

(c) Orbital angular momentum

(L)
$$\sqrt{l(l-1)} \frac{h}{2} \sqrt{2} \frac{h}{2}$$

[:: For *p*-orbital, l = 1]

73. (a) At radial node, 2 must vanishes, i.e.

74. The general Rydberg's equation is

$$-\frac{1}{R(Z)^{2}} \frac{1}{n_{1}^{2}} \frac{1}{n_{2}^{2}}$$

$$\frac{1}{R(Z)^{2}} \frac{1}{n_{1}^{2}} \frac{1}{n_{2}^{2}}$$

$$\frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}}$$

$$\frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}}$$

$$\frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}}$$

$$\frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}}$$

$$\frac{1}{R(Z)^{2}} \frac{1}{R(Z)^{2}} \frac{$$

75. Moles of H₂
$$\frac{pV}{RT}$$
 $\frac{1}{0.082}$ $\frac{1}{298}$ 0.0409
Bond energy 0.0409 436 17.84 kJ

Number of H-atoms produced after dissociation $2 \quad 0.0409 \quad 6.023 \quad 10^{23} \quad 4.93 \quad 10^{22}$ Transition energy/atom 2.18 10¹⁸ 1 $\frac{1}{4}$ J $\frac{3}{4}$ 2.18 10¹⁸ J Total transition energy

$$\frac{3}{4} 2.18 \ 10^{18} \ 4.93 \ 10^{22} \text{ J}$$

80.60 $10^3 \text{ J} = 80.60 \text{ kJ}$

Therefore, total energy required

(17.84 + 80.60) kJ = 98.44 kJ

76. If accelerated by potential difference of V volt, then

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

$$\frac{p^2}{2m} = eV, \text{ here } p \text{ momentum } (mv)$$

Using de-Broglie equation,

g de-Broglie equation,
$$\frac{h}{p} \frac{h}{\sqrt{2meV}}$$

1.54 10 ¹⁰ $\frac{6.625 \ 10^{34}}{(2 \ 9.1 \ 10^{31} \ 1.6 \ 10^{19} \ V)^{1/2}}$

Solving for V gives : V 63.56 V.

77. The work done in the given neutralisation process is

$$W = \frac{e^2}{a_0} F \, dr \text{ and } F = \frac{e^2}{4 - 0r^2}$$
$$W = \frac{e^2}{4 - 0} \frac{1}{r} \frac{e^2}{a_0} = \frac{e^2}{4 - 0r} \text{ Total energy } (E)$$

Now, if 'V' is magnitude of potential energy, then according to given information, kinetic energy (E_k) is V/2. Therefore,

$$E \qquad V \qquad \frac{V}{2} \qquad (PE \text{ is always negative})$$
$$\frac{V}{2}$$
$$V \qquad 2E \qquad \frac{e^2}{2 \qquad _0r}$$

78. The Rydberg's equation for H-atom is

$$\frac{1}{2}$$
 - (wave number) $R_{\rm H} = \frac{1}{n_1^2} = \frac{1}{n_2^2}$

For Balmer series, n_1 2 and n_2 3, 4, 5, ...,

For shortest , n_2 has to be maximum, i.e. infinity. Then

$$-R_{\rm H} \frac{1}{4} \frac{1}{4} - \frac{R_{\rm H}}{4} \frac{1.09 \cdot 10^7}{4} 2.725 \cdot 10^6 \,{\rm m}^{-1}$$

79. After breaking of the bond of I_2 molecule, the remaining energy would be distributed uniformly to iodine atoms as their kinetic energy, i.e.

E (energy of photon) Bond energy 2 kinetic energy

$$\frac{6.625 \quad 10^{34} \quad 3 \quad 10^8}{4500 \quad 10^{10}} \quad \frac{240 \quad 10^3}{6.023 \quad 10^{23}} \quad 2 \quad E_k$$
$$E_k \quad 2.16 \quad 10^{20} \text{ J/atom}$$

80. The Bohr de-Broglie relationship is

2 r n circumference of Bohr's orbit.

i.e. number of complete waves formed in one complete revolution of electron in any Bohr orbit is equal to orbit number, hence three.

81. The expression for transition wavelength is given by Rydberg's equation :

$$\frac{1}{r_{\rm H}^2} R_{\rm H} Z^2 \frac{1}{n_1^2} \frac{1}{n_2^2}$$

Equating the transition wavelengths of H-atom and He^+ ion,

$$R_{\rm H} = \frac{1}{n_1^2} = \frac{1}{n_2^2} = R_{\rm H} = \frac{4}{2^2} = \frac{4}{4^2}$$

Equating termwise on left to right of the above equation gives $n_1 = 1$ and $n_2 = 2$

82. For H-atom, the energy of a stationary orbit is determined as

$$E_n = \frac{k}{n^2}$$
 where, k constant (2.18 10⁻¹⁸ J)
 $E(n \ 2 \text{ to } n \ 1) \quad k \ 1 \quad \frac{1}{4} = \frac{3}{4} k$

 $= 1.635 \quad 10^{-18} \text{ J}$

For a H-like species, energy of stationary orbit is determined as

$$E_n = \frac{kZ^2}{n^2}$$

where, Z atomic number

$$E \quad kZ^{2} \quad \frac{1}{n_{1}^{2}} \quad \frac{1}{n_{2}^{2}}$$

$$\frac{1}{-\frac{E}{hc}} \quad \frac{k}{hc} Z^{2} \quad \frac{1}{1} \quad \frac{1}{4} \qquad R_{\rm H} Z^{2} \quad \frac{3}{4}$$

$$Z^{2} \quad \frac{4}{3R_{\rm H}} \quad \frac{4}{3 \ 1.097 \ 10^{7} \ 3 \ 10^{8}} \quad 4.05$$

$$Z \quad 2 \ ({\rm He^{+}})$$

83. For H-like species, the energy of stationary orbit is expressed as $E(X) = Z^2 = E(H)$

For $\operatorname{He}^+(Z = 2)$

$$E \qquad \frac{4 \quad 21.7 \quad 10^{-19}}{n^2} \text{ J}$$

For longest wavelength transition from 3rd orbit, electron must jump to 4th orbit and the transition energy can be determined as

$$E \quad 4 \quad 21.7 \quad 10^{-19} \quad \frac{1}{9} \quad \frac{1}{16} \quad J \quad 4.22 \quad 10^{-19} \quad J$$

$$\therefore \qquad E \quad \frac{hc}{2}$$

Also, 🙄

$$\frac{hc}{E} = \frac{6.625 \ 10^{-34} \ 3 \ 10^8}{4.22 \ 10^{-19}} \text{ m}$$

$$471 \ 10^{-9} \text{ m} = 471 \text{ nm}$$

- **84.** Ten, the given value of *n* and *l* correspond to 3*d*-orbital which has five fold degeneracy level.
- **85.** The 2nd configuration is against Hund's rule of maximum multiplicity which states that the singly occupied degenerate atomic orbitals must have electrons of like spins.
- **86.** The required transition is $n_1 ext{ 2 to } n_2$ and corresponding transition energy is

21.7 10¹²
$$\frac{1}{n_1^2}$$
 $\frac{1}{n_2^2}$ erg
 $\frac{21.7}{10}$ 10¹² erg 5.425 10¹² erg

4 The longest wavelength that can cause above transition can be determined as :

$$\frac{hc}{E} = \frac{6.625 \times 10^{-34} \times 3 \times 10^8}{5.425 \times 10^{-12} \times 10^{-7}}$$

3.66 \quad 10^{-7} m = 3.66 \quad 10^{-5} cm

87. Ionisation potential of H-like species $E_1 = 2.17 = 10^{-11} \text{ erg}$

Ε

$$E = 2.17 \quad 10^{-11} \quad 1 \quad \frac{1}{2^2} = 10^{-7} \text{ J}$$

$$1.6275 \quad 10^{-18} \text{ J} \qquad \frac{hc}{E}$$

$$\frac{6.625 \quad 10^{-34} \quad 3 \quad 10^8}{1.6275 \quad 10^{-18}} \text{ m}$$

$$122 \quad 10^{-9} \text{ m} = 1220 \text{ Å}$$

88. Transition energy $[2.41 (5.42)] 10^{12} \text{ erg}$

hc

3.01 10 ¹² erg
3.01 10 ¹⁹ J [
$$:: 1 \text{ erg} = 10^{-7} \text{ J}$$
]

Also, E

$$\frac{6.625 \quad 10^{-34} \quad 3 \quad 10^8}{3.01 \quad 10^{-19}} \text{ m}$$

660 10⁹ m 660 nm