Unit

2

STRUCTURE OF ATOM

I. Multiple Choice Questions (Type-I)

1. Which of the following conclusions could not be derived from Rutherford's α -particle scattering experiement?

(i) Most of the space in the atom is empty.

(ii) The radius of the atom is about 10^{-10} m while that of nucleus is 10^{-15} m.

(iii) Electrons move in a circular path of fixed energy called orbits.

(iv) Electrons and the nucleus are held together by electrostatic forces of attraction.

2. Which of the following options does not represent ground state electronic configuration of an atom?

(i) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8\ 4s^2$

(ii) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9\ 4s^2$

(iii) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$

(iv) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5\ 4s^1$

3. The probability density plots of 1s and 2s orbitals are given in Fig. 2.1:

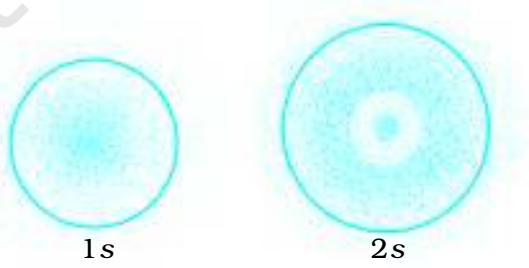

***Fig.** 2.1*

The density of dots in a region represents the probability density of finding electrons in the region.

On the basis of above diagram which of the following statements is incorrect?

(i) 1*s* and 2*s* orbitals are spherical in shape.

(ii) The probability of finding the electron is maximum near the nucleus.

(iii) The probability of finding the electron at a given distance is equal in all directions.

(iv) The probability density of electrons for 2*s* orbital decreases uniformly as distance from the nucleus increases.

4. Which of the following statement is **not** correct about the characteristics of cathode rays?

(i) They start from the cathode and move towards the anode.

(ii) They travel in straight line in the absence of an external electrical or magnetic field.

(iii) Characteristics of cathode rays do not depend upon the material of electrodes in cathode ray tube.

(iv) Characteristics of cathode rays depend upon the nature of gas present in the cathode ray tube.

5. Which of the following statements about the electron is incorrect?

(i) It is a negatively charged particle.

(ii) The mass of electron is equal to the mass of neutron.

(iii) It is a basic constituent of all atoms.

(iv) It is a constituent of cathode rays.

6. Which of the following properties of atom could be explained correctly by Thomson Model of atom?

(i) Overall neutrality of atom.

(ii) Spectra of hydrogen atom.

(iii) Position of electrons, protons and neutrons in atom.

(iv) Stability of atom.

7. Two atoms are said to be isobars if.

(i) they have same atomic number but different mass number.

(ii) they have same number of electrons but different number of neutrons.

(iii) they have same number of neutrons but different number of electrons.

(iv) sum of the number of protons and neutrons is same but the number of protons is different.

8. The number of radial nodes for 3*p* orbital is _____.

(i) 3

(ii) 4

(iii) 2

(iv) 1

9. Number of angular nodes for 4*d* orbital is _____.

(i) 4

(ii) 3

(iii) 2

(iv) 1

10. Which of the following is responsible to rule out the existence of definite paths or trajectories of electrons?

(i) Pauli's exclusion principle.

(ii) Heisenberg's uncertainty principle.

(iii) Hund's rule of maximum multiplicity.

(iv) Aufbau principle.

11. Total number of orbitals associated with third shell will be _____.

(i) 2

(ii) 4

(iii) 9

(iv) 3

12. Orbital angular momentum depends on _____.

(i) *l*

(ii) *n* and *l*

(iii) *n* and *m*

(iv) *m* and *s*

13. Chlorine exists in two isotopic forms, Cl-37 and Cl-35 but its atomic mass is 35.5. This indicates the ratio of Cl-37 and Cl-35 is approximately

(i) 1:2

(ii) 1:1

(iii) 1:3

(iv) 3:1

14. The pair of ions having same electronic configuration is _____.

(i) Cr^{3+}, Fe^{3+}

(ii) Fe^{3+}, Mn^{2+}

(iii) Fe^{3+}, Co^{3+}

(iv) Sc^{3+}, Cr^{3+}

15. For the electrons of oxygen atom, which of the following statements is correct?

(i) Z_{eff} for an electron in a 2*s* orbital is the same as Z_{eff} for an electron in a 2*p* orbital.

(ii) An electron in the 2*s* orbital has the same energy as an electron in the 2*p* orbital.

(iii) Z_{eff} for an electron in 1*s* orbital is the same as Z_{eff} for an electron in a 2*s* orbital.

(iv) The two electrons present in the 2*s* orbital have spin quantum numbers m_s but of opposite sign.

16. If travelling at same speeds, which of the following matter waves have the shortest wavelength?

(i) Electron

(ii) Alpha particle (He^{2+})

(iii) Neutron

(iv) Proton

II. Multiple Choice Questions (Type-II)

In the following questions two or more options may be correct.

17. Identify the pairs which are **not** of isotopes?

(i) ${}^{12}_{6}X$, ${}^{13}_{6}Y$

(ii) ${}^{35}_{17}X$, ${}^{37}_{17}Y$

(iii) ${}^{14}_{6}X$, ${}^{14}_{7}Y$

(iv) ${}^{8}_{4}X$, ${}^{8}_{5}Y$

18. Out of the following pairs of electrons, identify the pairs of electrons present in degenerate orbitals :

(i) (a) $n = 3,\ l = 2,\ m_l = -2,\ m_s = -\frac{1}{2}$

(b) $n = 3,\ l = 2,\ m_l = -1,\ m_s = -\frac{1}{2}$

(ii) (a) $n = 3,\ l = 1,\ m_l = 1,\ m_s = +\frac{1}{2}$

(b) $n = 3,\ l = 2,\ m_l = 1,\ m_s = +\frac{1}{2}$

(iii) (a) $n = 4,\ l = 1,\ m_l = 1,\ m_s = +\frac{1}{2}$

(b) $n = 3,\ l = 2,\ m_l = 1,\ m_s = +\frac{1}{2}$

(iv) (a) $n = 3,\ l = 2,\ m_l = +2,\ m_s = -\frac{1}{2}$

(b) $n = 3,\ l = 2,\ m_l = +2,\ m_s = +\frac{1}{2}$

19. Which of the following sets of quantum numbers are correct?

	n	l	m_l
(i)	1	1	+2
(ii)	2	1	+1
(iii)	3	2	–2
(iv)	3	4	–2

20. In which of the following pairs, the ions are iso-electronic?

(i) Na^+, Mg^{2+}

(ii) Al^{3+}, O^-

(iii) Na^+, O^{2-}

(iv) N^{3-}, Cl^-

21. Which of the following statements concerning the quantum numbers are correct?

(i) Angular quantum number determines the three dimensional shape of the orbital.

(ii) The principal quantum number determines the orientation and energy of the orbital.

(iii) Magnetic quantum number determines the size of the orbital.

(iv) Spin quantum number of an electron determines the orientation of the spin of electron relative to the chosen axis.

III. Short Answer Type

22. Arrange *s*, *p* and *d* sub-shells of a shell in the increasing order of effective nuclear charge (Z_{eff}) experienced by the electron present in them.

23. Show the distribution of electrons in oxygen atom (atomic number 8) using orbital diagram.

24. Nickel atom can lose two electrons to form Ni^{2+} ion. The atomic number of nickel is 28. From which orbital will nickel lose two electrons.

25. Which of the following orbitals are degenerate?

$3d_{xy}, 4d_{xy}\ 3d_{z^2}, 3d_{yz}, 4d_{yz}, 4d_{z^2}$

26. Calculate the total number of angular nodes and radial nodes present in 3*p* orbital.

27. The arrangement of orbitals on the basis of energy is based upon their $(n+l)$ value. Lower the value of $(n+l)$, lower is the energy. For orbitals having same values of $(n+l)$, the orbital with lower value of n will have lower energy.

I. Based upon the above information, arrange the following orbitals in the increasing order of energy.

(a) 1*s*, 2*s*, 3*s*, 2*p*

(b) 4*s*, 3*s*, 3*p*, 4*d*

(c) 5*p*, 4*d*, 5*d*, 4*f*, 6*s*

(d) 5*f*, 6*d*, 7*s*, 7*p*

II. Based upon the above information, solve the questions given below :

(a) Which of the following orbitals has the lowest energy?

4*d*, 4*f*, 5*s*, 5*p*

(b) Which of the following orbitals has the highest energy?

5*p*, 5*d*, 5*f*, 6*s*, 6*p*

28. Which of the following will not show deflection from the path on passing through an electric field?

Proton, cathode rays, electron, neutron.

29. An atom having atomic mass number 13 has 7 neutrons. What is the atomic number of the atom?

30. Wavelengths of different radiations are given below :

λ(A) = 300 nm λ(B) = 300 μm λ(C) = 3 nm λ(D) = 30 A^0

Arrange these radiations in the increasing order of their energies.

31. The electronic configuration of valence shell of Cu is $3d^{10}4s^1$ and not $3d^9 4s^2$. How is this configuration explained?

32. The Balmer series in the hydrogen spectrum corresponds to the transition from $n_1 = 2$ to $n_2 = 3, 4, \ldots\ldots$. This series lies in the visible region. Calculate the wave number of line associated with the transition in Balmer series when the electron moves to $n = 4$ orbit.

(R_H = 109677 cm^{-1})

33. According to de Broglie, matter should exhibit dual behaviour, that is both particle and wave like properties. However, a cricket ball of mass 100 g does not move like a wave when it is thrown by a bowler at a speed of 100 km/h. Calculate the wavelength of the ball and explain why it does not show wave nature.

34. What is the experimental evidence in support of the idea that electronic energies in an atom are quantized?

35. Out of electron and proton which one will have, a higher velocity to produce matter waves of the same wavelength? Explain it.

36. A hypothetical electromagnetic wave is shown in Fig. 2.2. Find out the wavelength of the radiation.

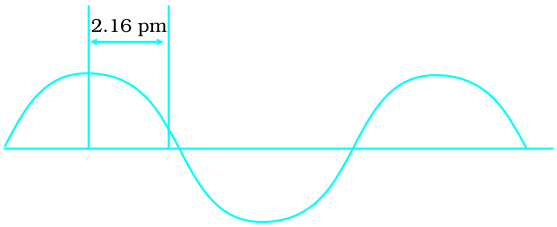

Fig. *2.2*

37. Chlorophyll present in green leaves of plants absorbs light at 4.620×10^{14} Hz. Calculate the wavelength of radiation in nanometer. Which part of the electromagnetic spectrum does it belong to?

38. What is the difference between the terms orbit and orbital?

39. Table-tennis ball has a mass 10 g and a speed of 90 m/s. If speed can be measured within an accuracy of 4% what will be the uncertainty in speed and position?

40. The effect of uncertainty principle is significant only for motion of microscopic particles and is negligible for the macroscopic particles. Justify the statement with the help of a suitable example.

41. Hydrogen atom has only one electron, so mutual repulsion between electrons is absent. However, in multielectron atoms mutual repulsion between the electrons is significant. How does this affect the energy of an electron in the orbitals of the same principal quantum number in multielectron atoms?

IV. Matching Type

In some of the following questions, one option of left column may be correlated to more than one option in the right column.

42. Match the following species with their corresponding ground state electronic configuration.

	Atom / Ion		**Electronic configuration**
(i)	Cu	(a)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}$
(ii)	Cu^{2+}	(b)	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2$

(iii) Zn^{2+} (c) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^1$

(iv) Cr^{3+} (d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9$

(e) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^3$

43. Match the quantum numbers with the information provided by these.

Quantum number	**Information provided**
(i) Principal quantum number	(a) orientation of the orbital
(ii) Azimuthal quantum number	(b) energy and size of orbital
(iii) Magnetic quantum number	(c) spin of electron
(iv) Spin quantum number	(d) shape of the orbital

44. Match the following rules with their statements :

Rules	**Statements**
(i) Hund's Rule	(a) No two electrons in an atom can have the same set of four quantum numbers.
(ii) Aufbau Principle	(b) Half-filled and completely filled orbitals have extra stablity.
(iii) Pauli Exclusion Principle	(c) Pairing of electrons in the orbitals belonging to the same subshell does not take place until each orbital is singly occupied.
(iv) Heisenberg's Uncertainty Principle	(d) It is impossible to determine the exact position and exact momentum of a subatomic particle simultaneously.
	(e) In the ground state of atoms, orbitals are filled in the order of their increasing energies.

45. Match the following

(i) X-rays (a) $\nu = 10^0 - 10^4\ Hz$

(ii) UV (b) $\nu = 10^{10}\ Hz$

(iii) Long radio waves (c) $\nu = 10^{16}\ Hz$

(iv) Microwave (d) $\nu = 10^{18}\ Hz$

46. Match the following

(i)	Photon	(a)	Value is 4 for N shell
(ii)	Electron	(b)	Probability density
(iii)	ψ^2	(c)	Always positive value
(iv)	Principal quantum number n	(d)	Exhibits both momentum and wavelength

47. Match species given in Column I with the electronic configuration given in Column II.

Column I		**Column II**	
(i)	Cr	(a)	$[Ar]3d^8 4s^0$
(ii)	Fe^{2+}	(b)	$[Ar]3d^{10} 4s^1$
(iii)	Ni^{2+}	(c)	$[Ar]3d^6 4s^0$
(iv)	Cu	(d)	$[Ar]\ 3d^5 4s^1$
		(e)	$[Ar]3d^6 4s^2$

V. Assertion and Reason Type

In the following questions a statement of Assertion (A) followed by a statement of Reason (R) is given. Choose the correct option out of the choices given below each question.

48. ***Assertion (A) :*** All isotopes of a given element show the same type of chemical behaviour.

Reason (R) : The chemical properties of an atom are controlled by the number of electrons in the atom.

(i) Both A and R are true and R is the correct explanation of A.

(ii) Both A and R are true but R is not the correct explanation of A.

(iii) A is true but R is false.

(iv) Both A and R are false.

49. ***Assertion (A) :*** Black body is an ideal body that emits and absorbs radiations of all frequencies.

Reason (R) : The frequency of radiation emitted by a body goes from a lower frequency to higher frequency with an increase in temperature.

(i) Both A and R are true and R is the correct explanation of A.

(ii) Both A and R are true but R is not the explanation of A.

(iii) A is true and R is false.

(iv) Both A and R are false.

50. ***Assertion (A) :*** It is impossible to determine the exact position and exact momentum of an electron simultaneously.

Reason (R) : The path of an electron in an atom is clearly defined.

(i) Both A and R are true and R is the correct explanation of A.

(ii) Both A and R are true and R is not the correct explanation of A.

(iii) A is true and R is false.

(iv) Both A and R are false.

VI. Long Answer Type

51. What is photoelectric effect? State the result of photoelectric effect experiment that could not be explained on the basis of laws of classical physics. Explain this effect on the basis of quantum theory of electromagnetic radiations.

52. Threshold frequency, ν_0 is the minimum frequency which a photon must possess to eject an electron from a metal. It is different for different metals. When a photon of frequency 1.0×10^{15} s^{-1} was allowed to hit a metal surface, an electron having 1.988×10^{-19} J of kinetic energy was emitted. Calculate the threshold frequency of this metal. Show that an electron will not be emitted if a photon with a wavelength equal to 600 nm hits the metal surface.

53. When an electric discharge is passed through hydrogen gas, the hydrogen molecules dissociate to produce excited hydrogen atoms. These excited atoms emit electromagnetic radiation of discrete frequencies which can be given by the general formula

$$\bar{\nu} = 109677\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]$$

What points of Bohr's model of an atom can be used to arrive at this formula? Based on these points derive the above formula giving description of each step and each term.

54. Calculate the energy and frequency of the radiation emitted when an electron jumps from $n = 3$ to $n = 2$ in a hydrogen atom.

55. Why was a change in the Bohr Model of atom required? Due to which important development (s), concept of movement of an electron in an orbit was replaced by, the concept of probability of finding electron in an orbital? What is the name given to the changed model of atom?

ANSWERS

I. Multiple Choice Questions (Type-I)

1. (iii) 2. (ii) 3. (iv) 4. (iv) 5. (ii) 6. (i)

7. (iv) 8. (iv) 9. (iii) 10. (ii) 11. (iii) 12. (i)

13. (iii) 14. (ii) 15. (iv) 16. (ii)

II. Multiple Choice Questions (Type-II)

17. (iii), (iv) 18. (i), (iv) 19. (ii), (iii)

20. (i), (iii) 21. (i), (iv)

III. Short Answer Type

22. $d < p < s$

23. 

24. $4s$

25. $3d_{xy}$, $3d_{z^2}$, $3d_{yz}$ and $4d_{xy}$, $4d_{yz}$, $4d_{z^2}$

26. For $3p$ orbital $n = 3$, $l = 1$
Number of angular nodes = $l = 1$
Number of radial nodes = $n - l - 1 = 3-1-1=1$

27. I. (a) $1s < 2s < 2p < 3s$ II. (a) $5s$ (b) $5f$
(b) $3s < 3p < 4s < 4d$
(c) $4d < 5p < 6s < 4f < 5d$
(d) $7s < 5f < 6d < 7p$

28. neutron

29. $A = 13$, $A - Z = 7$ $\therefore Z = 6$
atomic number = 6

30. $B < A < C = D$
$\left(\textbf{Hint : } E \ \alpha \frac{1}{\lambda}\right)$

31. Completely filled and half filled orbitals have extra stability. In $3d^{10}4s^1$, d orbital is completely filled and s is half filled. So it is more stable configuration.

32. $\bar{\nu} = 109677\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right] \text{cm}^{-1}$

For $n_i = 2$ to $n_f = 4$ transition in Balmer series.

$\therefore \quad \bar{\nu} = 109677\left(\frac{1}{2^2} - \frac{1}{4^2}\right) \text{cm}^{-1}$

$= 109677\left(\frac{1}{4} - \frac{1}{16}\right) \text{cm}^{-1} = 20564.44 \text{ cm}^{-1}$

33. $\lambda = \frac{h}{mv}$

m = 100 g = 0.1 kg.

v = 100 km/hr $= \frac{100 \times 1000 \text{ m}}{60 \times 60 \text{ s}} = \frac{1000}{36} \text{ms}^{-1}$

$h = 6.626 \times 10^{-34}$ Js

$\lambda = \frac{6.626 \times 10^{-34} \text{ Js}}{0.1 \text{ kg} \times \frac{1000}{36} \text{ ms}^{-1}} = 6.626 \times 10^{-36} \times 36 \text{ m}^{-1} = 238.5 \times 10^{-36} \text{m}^{-1}$

Since the wavelength is very small, the wave nature cannot be detected.

35. Being lighter particles, electrons will have higher velocity.

Hint : $\left(\lambda = \frac{h}{mv}\right)$

36. Wavelength is the distance between two successive peaks or two successive troughs of a wave. So $\lambda = 4 \times 2.16 \text{ pm} = 8.64 \text{ pm}$

37. $\lambda = \frac{c}{\nu} = \frac{3.0 \times 10^8 \text{ ms}^{-1}}{4.620 \times 10^{14} \text{ Hz}} = 0.6494 \times 10^{-6} \text{ m} = 649.4 \text{ nm}$; Visible light.

39. Uncertainty in the speed of ball = $\frac{90 \times 4}{100} = \frac{360}{100} = 3.6 \text{ ms}^{-1}$

Uncertainty in position = $\frac{h}{4\pi m \Delta v}$

$$= \frac{6.626 \times 10^{-34}\ \text{Js}}{4 \times 3.14 \times 10 \times 10^{-3}\ \text{kg g}^{-1} \times 3.6\ \text{ms}^{-1}}$$

$$= 1.46 \times 10^{-33}\ \text{m}$$

41. The energy of electron is determined by the value of n in hydrogen atom and by $n + l$ in multielectron atom. So for a given principal quantum number electrons of s, p, d and f orbitals have different energy.

IV. Matching Type

42.	(i) → (c)	(ii) → (d)	(iii) → (a)	(iv) → (e)
43.	(i) → (b)	(ii) → (d)	(iii) → (a)	(iv) → (c)
44.	(i) → (c)	(ii) → (e)	(iii) → (a)	(iv) → (d)
45.	(i) → (d)	(ii) → (c)	(iii) → (a)	(iv) → (b)
46.	(i) → (d)	(ii) → (d)	(iii) → (b), (c)	(iv) → (a), (c)
47.	(i) → (d)	(ii) → (c)	(iii) → (a)	(iv) → (b)

V. Assertion and Reason Type

48. (i) 49. (ii) 50. (iii)

VI. Long Answer Type

52. $\left(\textbf{Hint :}\ h\nu = h\nu_0 + \frac{1}{2}\text{mv}^2\right)$

54. $\Delta E = -3.052 \times 10^{-19}\ \text{J},\ \nu = 4.606 \times 10^{16}\ \text{Hz}$