CHAPTER › 02

Structure of Atom

KEY NOTES

- The first atomic theory proposed by Dalton in 1808, regarded the atom as the ultimate indivisible particle of matter.
- A large number of subatomic particles have been discovered but only electron, proton and neutron are of great importance among them and hence are called **fundamental particles.**

Discovery of Subatomic Particles

- **Cathode rays or electrons** were discovered by J.J. Thomson in 1897, by utilising Faraday's study of electrical discharge in partially evacuated tube known as **cathode rays tubes.**
- The specific charge is the ratio of **charge to mass of an electron,** i.e. e/m_e ratio.
- By carrying out accurate measurements, Thomson was able to determine the value of e/m_e as 1.758820×10^{11} C kg^{-1}.
- Millikan devised a method known as **oil drop experiment** to determine the charge on the electron to be -1.6×10^{-19}C.
- The mass of electron was determined by combining Millikan's and Thomson's value of e/m_e ratio which comes out to be 9.1094×10^{-31} kg.
- **Canal rays (or anode rays or positive rays)** were discovered by Goldstein. These rays consist of positively charged particles called **protons.**
- Unlike cathode rays, the e/m_e value of canal rays depends upon the nature of gas taken in the tube.
- **Neutrons** are neutral particles and discovered by Chadwick. These are the heaviest particles of the atom.
- The discovery of sub-atomic particles led to the proposal of various atomic models to explain the structure of atom.

Atomic Models

Thomson's Model of Atom

- **Thomson** in 1898 assumed that an atom is a sphere of positive charged uniformly distributed with the electrons scattered as points throughout the sphere. This was also known as **plum pudding, raisin pudding** or **watermelon model.** An important feature of this model is that the mass of atom is assumed to be uniformly distributed over the atom.
- Henri Becqueral observed that there are certain elements which emit radiation on their own. These elements were named as radioactive elements and the phenomenon is called **radioactivity.**
- **Rutherford's nuclear model of atom** Rutherford bombarded very thin gold foil with α-particle.
- **Thomson's model of atom** was proved wrong by Rutherford's alpha-particles scattering experiment carried in 1909.
- The main features of this model are :
  - Most of the particles passed the foil undeflected, which indicated that most of the space in atom is empty.
  - Some of them were deflected, but only at small angles. This shows that there is something positively charged at the centre.
  - Few particles were deflected at large angles. It means that in the atom, mass and positive charge is centrally located in extremely small region called nucleus. The nucleus is surrounded by electrons that move around the nucleus with a very high speed in circular paths called **orbits.**
  - Electrons and the nucleus are held together by electrostatic force of attraction.

Atomic and Mass Number

- Atomic number (Z) = number of protons in the nucleus of an atom = number of electrons in a neutral atom
- The protons and neutrons present in the nucleus are collectively known as **nucleons.** The total number of nucleons is termed as mass number of the atom.

  Mass number (A) = number of protons (Z) + number of neutrons (n).

Isobars and Isotopes

- **Isobars** are the atoms with same mass number, but different atomic number for, e.g. $^{14}_{6}C$ and $^{14}_{7}N$.
- The species with same atomic number but different mass number are called **isotopes**, e.g. $_6C^{12}$ and $_6C^{14}$.
- Hydrogen has three isotopes protium (^1_1H, only one proton), deuterium (^2_1D, one proton and one neutron) and tritium (^3_1T, one proton and two neutrons).

Drawbacks of Rutherford's Model

Rutherford's model was failed to account for the stability of the atom. Also, it did not explain about the electronic structure of atoms.

Development Leading to the Bohr's Model of Atom

- Nature of electromagnetic radiation and experimental results regarding atomic spectra play an important role in the development of Bohr's model.
- Light, X-rays and γ-rays are the examples of radiant energy.
- Maxwell in 1856 showed that radiant energy has wave properties and called them **electromagnetic waves** or **electromagnetic radiations.**
- There are many types of electromagnetic radiations which differ from one another in wavelength or frequency. These constitute **electromagnetic spectrum.**
- The small portion in the electromagnetic spectrum around 10^{15} Hz is called **visible light.**
- All these radiations travel with the speed of light and do not require any medium for their propagation or transmission.
- The frequency (ν), wavelength (λ) and velocity of light (c) are related by the equation,

$$c = \nu\lambda$$

- **Wave number** is defined as the number of wavelengths per unit length. Its commonly used unit is cm^{-1}.

Particle Nature of Electromagnetic Radiation : Planck's Quantum Theory

- The ideal body, which emits and absorbs radiations of all frequencies is called a black body and the radiation emitted by such a body is called **black body radiation.**
- According to **Planck's quantum theory,** the radiant energy which is emitted or absorbed in the atom of small discrete packets of energy known as **quantum** and in case of light, the quantum of energy is called **photons.**

$$E = h\nu \text{ or } E = h\frac{c}{\lambda}$$

where, h = Planck's constant = 6.63×10^{-34} Js

E = Energy of photon or quantum

- If n is the number of quanta of a particular frequency and E_T be the total energy, then

$$E_T = nh\nu$$

Photoelectric Effect

- The phenomenon of ejection of electrons from a metal surface when a light of certain frequency strikes on its surface is called **photoelectric effect.**
- For each metal, there is a characteristic minimum frequency, known as **threshold frequency** (ν_0) below, which photoelectric effect is not observed.
- When a photon of sufficient energy strikes an electron in the atom of the metal, it transfers its energy instantaneously to the electron during the collision and the electron is ejected.
- The number of electrons ejected is proportional to the intensity or brightness of light.
- Following the conservation of energy principle, the **kinetic energy** of **ejected electron** is given by the equation,

$$h\nu = h\nu_0 + \frac{1}{2}m_e v^2$$

- **Dual nature of electromagnetic radiation** Light possesses both particle and wave like properties. Whenever radiation interacts with matter, it displays particles, like properties in contrast to the wave like properties.

Atomic Spectra

- The pictorial representation of arrangement of various types of EMR in their increasing order of wavelength (or decreasing order of frequency) is known as spectrum.
- The spectrum of white light ranges from violet at 7.50×10^{14} Hz to red at 4×10^{14} Hz, such a spectrum is called **continuous spectrum.**
- The spectrum of radiation emitted by a substance that has absorbed energy in increasing order of wavelengths or decreasing frequencies is called as an **emission spectrum.** Atoms, molecules or ions that have absorbed radiation are said to be 'excited'.

- An **absorption spectrum** is like the photographic negative of an emission spectrum.
- The study of emission or absorption spectra is referred to as **spectroscopy.**
- The emission spectra of gas phase do not show a continuous spread of wavelength from red to violet, rather they emit light only at specific wavelengths with dark spaces between them. Such spectra are called **line spectra or atomic spectra.**
- **Line emission spectra** are of great interest in the study of electronic structure and also used in chemical analysis to identify unknown atoms.
- When an electric discharge is passed through gaseous hydrogen, the H_2 molecules dissociate and the energetically excited hydrogen atoms produced emit electromagnetic radiation of discrete frequencies.
- The **line spectra of hydrogen** lies in three regions of electromagnetic spectrum, i.e. infrared, visible and UV-region.
- The set of lines in the visible region is known as **Balmer series**.
- The Swedish spectroscopist, Johannes Rydberg noted that all series of lines in the hydrogen spectrum could be described by the following formula.

$$\bar{\nu} = 109677 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \text{cm}^{-1}$$

where, $n_1 = 1, 2 \ldots$

$n_2 = n_1 + 1, n_1 + 2 \ldots$

- The value $109677\ \text{cm}^{-1}$ is called the Rydberg constant.
- The first five series of lines that correspond to $n_1 = 1, 2, 3, 4, 5$ are known Lyman, Balmer, Paschen, Bracket and Pfund series respectively.

Series	n_1	n_2	Spectral Regions
Lyman	1	2, 3, 4…	Ultraviolet
Balmer	2	3, 4, 5…	Visible
Paschen	3	4, 5, 6…	Infrared
Brackett	4	5, 6, 7…	Infrared
Pfund	5	6, 7…	Infrared

Bohr's Model for Hydrogen Atom

- The main postulates for Bohr's model are :
  - The electron in the hydrogen atom can move around the nucleus in a circular path of fixed radius and energy. These paths are called orbits, stationary states or allowed energy states.
  - Energy is emitted when an electron jumps from higher energy level to lower energy level.
  - The frequency of radiation absorbed or emitted when transition occurs between two stationary states that differ in energy by ΔE is given by :

$$\upsilon = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h}$$

where, E_1 and E_2 are the energies of the lower and higher allowed energy states respectively. This expression is commonly known as **Bohr's frequency rule.**

  - The **angular momentum of an electron** is quantised. In a given stationary state, it can be expressed as,

$$m_e vr = n \cdot \frac{h}{2\pi}, \quad n = 1, 2, 3 \ldots$$

  - The stationary states for electron are numbered, $n = 1, 2, 3...$. These integral numbers are known as **principle quantum number.**
  - The **radii of the stationary states** are expressed as :

$$r_n = n^2 a_0$$

where, $a_0 = 52.9$ pm.

Thus, the radius of the first stationary state called the Bohr orbit is 52.9 pm.

  - **Energy of an electron** in nth state is given as,

$$E_n = -R_{\text{H}}\left(\frac{1}{n^2}\right)$$

$$n = 1, 2, 3 \ldots$$

where, R_{H} is called **Rydberg constant** and its value is equal to 2.18×10^{-18} J.

- **Bohr's theory** can also be applied to the ions containing only one electron, for example He^+, Li^{2+}, Be^{3+} and so on.
- The energy of the stationary states associated with these hydrogen like species is given by,

$$E_n = -2.18 \times 10^{-18}\left(\frac{Z^2}{n^2}\right) \text{J}$$

and radii by the expression,

$$r_n = 52.9\,\frac{n^2}{Z}\ \text{pm}$$

Line Spectrum of Hydrogen

- The energy gap between the two orbits (higher and lower orbits) is given by equation,

$$\Delta E = 2.18 \times 10^{-18}\text{J}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

- The frequency associated with the absorption and emission of the photon can be evaluated by using equation,

$$\nu = \frac{\Delta E}{h} = \frac{R_{\text{H}}}{h}\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$$

- In case of absorption spectrum, $n_f > n_i$ and in case of emission spectrum $n_i > n_f$.

Limitations of Bohr's Model

Bohr's model did not explain the fine structure of atom, spectrum of multielectron system, Zeeman effect and Stark effect (splitting of spectral lines under the influence of magnetic and electric field respectively) and ability of atoms to form molecules by chemical bonds.

Towards Quantum Mechanical Model of Atom

- In view of shortcoming of the Bohr's model, two important developments, i.e. dual behaviour of matter and Heisenberg uncertainty principle came into existence.
- **de-Broglie** explains the dual nature of electron (i.e., wave nature as well as particle nature)

$$\lambda = \frac{h}{mv} = \frac{h}{p}$$

where, λ = wavelength, v = velocity of particle, m = mass of particle, p = momentum

- **Heisenberg's uncertainty principle** states ''that it is impossible to determine at any given instant, both the momentum and the position of subatomic particles like electron simultaneously''.

$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi} \text{ or } \Delta x \cdot \Delta v_x \geq \frac{h}{4\pi m}$$

- Heisenberg uncertainty principle rules out the existence of definite paths or trajectories of electrons and other similar particles.
- The effect of Heisenberg uncertainty principle is significant only for motion of microscopic objects and is negligible for that of macroscopic objects. This is because in dealing with milligram sized or heavier objects, the associated uncertainties are hardly of real consequence.
- In case of microscopic object like an electron, $\Delta v \cdot \Delta x$ obtained is much larger and such uncertainties are of real consequence.
- The precise statement of the position and momentum of electrons have to be replaced by the statements of probability that the electron has at a given position and momentum.
- In Bohr model, an electron is regarded as a charged particle moving in well defined orbits about the nucleus. Thus, Bohr model not only ignores the dual behaviour of matter but also contradicts Heisenberg uncertainty principle.

Quantum Mechanical Model of Atom

- The branch of science that takes into account this dual behaviour of matter is called **quantum mechanics.**
- **Schrodinger** derived an equation for an electron which describes the wave motion of an electron along any three axes. For a system (such as an atom or molecule whose energy does not change with time), the Schrodinger equation is written as $\hat{H}\psi = E\psi$,

where $\hat{H}$ is a mathematical operator called **Hamiltonian.**

- The important features of quantum mechanical model of atom are :
  - The energy of electron in atoms is quantised.
  - Both the exact position and exact velocity of an electron in an atom cannot be determined simultaneously.
  - An atomic orbital is the wave function ψ for an electron in an atom.
  - The probability of finding an electron at a point within an atom is proportional to the square of the orbital wave function $|\psi|^2$ at that point, which is known as probability density and is always positive.
- From the value of $|\psi|^2$ at different points within an atom, it is possible to predict the region around the nucleus, where electron will most probably be found.

Orbitals and Quantum Numbers

- Atomic orbitals are precisely distinguished by **quantum number.**
- **Principal quantum number** (n) determines the size and the energy of orbital. It also identifies the shell.
- **Azimuthal quantum number** (l) is also known as orbital angular momentum or subsidiary quantum number. It gives information about the three dimensional shape of the orbital.
- Every shell consists of one or more subshell or sublevels. The number of sublevels in a principal shell is equal to the value of 'n'.
- **Magnetic orbital quantum number** (m_l) gives information about the spatial orientation of the orbital with respect to standard set of coordinate axis.
- **Spin quantum number** (m_s) refers to orientation of the spin of the electron, i.e. clockwise or anti-clockwise. These two orientations are distinguished by the spin quantum number m_s, which can take values $+\frac{1}{2}$ or $-\frac{1}{2}$.

Shapes of Atomic Orbitals

- The region inside an atom, where this probability density function reduces to zero is called **nodal surface** or **simply nodes.** With increase in principal quantum number n, number of nodes increases.
- Shapes of s, p, d and f-orbitals are :

  s-orbital - spherical

  p-orbital - dumble

  d-orbital - double dumble

  f-orbital - complicated
- Besides the radial nodes, the probability density function are zero at the planes passing through the nucleus regions. These are called angular nodes and the number of angular node are given by 'l'.
- The total number of nodes are given by $(n-1)$, i.e. sum of angular nodes and $(n-l-1)$ radial nodes.

Energies of Orbitals

- For hydrogen and hydrogen like species, all the orbitals within a given shell have same energy, i.e.

  $1s < 2s = 2p < 3s = 3p = 3d < 4s = 4p = 4d = 4f < \ldots$
- The orbitals having same energy are called **degenerate orbitals**.
- In an multielectron atoms, energy of orbitals depends upon the values of n and l. The lower the value of $(n + l)$ for an orbital, the lower its energy.
- If two orbitals have the same $(n + l)$ value, the orbital with lower value of n has the lower energy.
- The shielding of the outer shell electrons from the nucleus by the inner shell electrons and as a result the net positive charge experienced by the outer electrons is known as effective nuclear charge.
- Energies of the orbitals in the same subshell decreases with increase in the atomic number (Z_{eff}).
- When a set of equivalent orbitals is either fully-filled or half-filled, i.e. each containing one or a pair of electrons, the atom gain more stability. This effect is more dominant in d-and f-subshells.
- Presence of two or more electrons having the same spin in the degenerate orbitals of a subshell also contributes towards stability. These electrons tends to exchange their positions and the energy released because of this exchange is called exchange energy.

Rules for Filling of Electrons in Orbitals

Filling of electrons into the orbitals of different atoms takes place according to the following discussed rules :

- **Aufbau principle** In the ground state of the atoms, the orbitals are filled in order of their increasing energies. $1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p, 5s, 4d, 5p, 6s, 4f, 5d, 6p, 7s$.
- **Pauli's exclusion principle** No two electrons in an atom can have the same set of four quantum numbers.
  It can also be stated as, "only two electrons may exist in the same orbital and these electrons must have opposite spin".
  The maximum number of electrons in the shell with principal quantum number in is equal to $2n^2$.
- **Hund's rule** of maximum multiplicity states that ''pairing of electrons in the orbitals belonging to the same subshell (p, d or f) does not take place until each orbital belonging to that subshell has got one electron each, i.e. it is singly occupied.''

Mastering NCERT

MULTIPLE CHOICE QUESTIONS

TOPIC 1 ~ *Subatomic Particles*

1 Michael Faraday showed that, if electricity is passed through a solution of an electrolyte, chemical reactions occurred at the electrodes which resulted in
(a) liberation of matter at the electrodes
(b) deposition of matter at the electrodes
(c) emission of energy at the electrodes
(d) Both (a) and (b)

2 In cathode ray discharge tube experiment, when sufficiently high voltage is applied across the electrodes, current starts flowing through a stream of particles from negative electrode to positive electrodes. These particles are called
(a) anode rays
(b) cathode rays
(c) cathode ray particles
(d) Both (b) or (c)

3 The electrical discharge through the gases could be observed only at
(a) very low pressure and very low voltage
(b) very high pressure and very high voltage
(c) very high pressure and very low voltage
(d) very low pressure and very high voltage

4 Which of the following substances, shows the properties of phosphorescent?
(a) Zinc sulphide (b) Zinc sulphate
(c) Zinc nitrate (d) Zinc chloride

5 According to Thomson, the amount of deviation of the particles from their path in the presence of electrical or magnetic field depends upon
(a) the magnitude of the negative charge on the particle
(b) the mass of the particle
(c) the strength of the electrical or magnetic field
(d) All of the above

6 Which of the following phenomenon is responsible for the television pictures ?
(a) Chemiluminescence (b) Fluorescence
(c) Luminescence (d) Phosphorescence

7 Which of the following options is correct regarding characteristics of cathode ray?
(a) It does not depend upon the material of electrodes
(b) It does not depend upon the nature of the gas present in the cathode ray tube
(c) Both (a) and (b)
(d) None of the above

8 Thomson determined the value of e/m_e as

(a) 1.758820×10^{10} C kg^{-1}
(b) 17.58820×10^{12} C kg^{-1}
(c) 1.758820×10^{9} C kg^{-1}
(d) 1.758820×10^{11} C kg^{-1}

9 Formula for calculating the mass of the electron (m_e) is

(a) $m_e = e \cdot (e/m_e)$
(b) $m_e = \dfrac{e}{(e/m_e)}$
(c) $m_e = e + \left(\dfrac{e}{m_e}\right)$
(d) $m_e = e - \left(\dfrac{e}{m_e}\right)$

TOPIC 2 ~ *Atomic Models*

10 To account for the stability of atom was one of the major problem for the scientists after the discovery of sub-atomic particles. The other problems for scientists were

(a) to compare the behaviour of elements in terms of both physical and chemical properties
(b) to explain the formation of different kind of molecules by the combination of different atoms
(c) to understand the origin and nature of the characteristics of electromagnetic radiation absorbed or emitted by atoms
(d) All of the above

11 Consider the following table.

Name	*B*	Relative charge	*D*	Mass/u	Approx. mass/u
Electron	-1.6022×10^{-19}	-1	9.10939×10^{-31}	*E*	*F*
A	$+ 1.6022 \times 10^{-19}$	$+1$	1.67262×10^{-27}	1.00727	1
Neutron	*C*	0	1.67493×10^{-27}	1.00867	1

In the above table, missing terms *A, B, C, D, E* and *F* are respectively

(a) $A \rightarrow$ Positron; $B \rightarrow$ Absolute charge/C; $C \rightarrow 0$; $D \rightarrow$ Mass-kg; $E \rightarrow 0.00054$; and $F \rightarrow 1$
(b) $A \rightarrow$ Proton; $B \rightarrow$ Absolute charge/C; $C \rightarrow 0$; $D \rightarrow$ Mass/kg; $E \rightarrow 0.00054$; and $F \rightarrow 0$
(c) $A \rightarrow$ Proton; $B \rightarrow$ Mass/kg; $C \rightarrow 1$; $D \rightarrow$ Absolute charge/C; $E \rightarrow 1.00054$; and $F \rightarrow 1$
(d) $A \rightarrow$ Positron; $B \rightarrow$ Mass/kg; $C \rightarrow 1$; $D \rightarrow$ Absolute charge/C; $E \rightarrow 1.00854$; and $F \rightarrow 0$

12 According to the Thomson model of an atom, mass of the atom is assumed to be

(a) uniformly distributed over the atom
(b) randomly distributed over the atom
(c) partially distributed over the atom
(d) None of the above

13 Cathode rays have same charge to mass ratio as

(a) β-rays
(b) α-rays
(c) anode rays
(d) None of the above

14 Increasing order (lowest first) for the values of e/m_e for electron (e), proton (p), neutron (n) and α-particles is

(a) e, p, n, α (b) n, α, p, e (c) n, p, e, α (d) n, p, α, e

15 On bombarding a beam of α-particles on the atom of the gold sheet, few particles get deflected, whereas most of them go straight and remains undeflected. This is due to

(a) the nucleus occupy much smaller volume as compared to the volume of atom
(b) the force of repulsion on fast moving α-particles is very small
(c) the neutrons in the nucleus do not have any effect on α-particles
(d) the force of attraction on α-particles by the oppositely charged electron is not sufficient

16 Electrons and nucleus are held together by

(a) Coulombic forces
(b) electrostatic forces of attraction
(c) hydrogen bonding
(d) None of the above

17 For $^{19}F^{-1}$, $^{16}O^{-2}$ ^{20}Ne, choose the correct statement.

(a) Both O^{-2} and F^- are isoelectronic
(b) All the given species have equal number of e^-
(c) F^- and Ne have equal number of e^-
(d) All of the above

18 An element *E* loses one α and two β-particles in three successive stages. The resulting element will be

(a) an isobar of *E*
(b) an isotope of *E*
(c) an isotone of *E*
(d) *E* itself

19 Mass number of an atom (A) is equal to

(a) total number of nucleons
(b) total number of neutrons
(c) total number of protons and electrons
(d) total number of protons, electrons and neutrons

20 The chemical properties of atom are controlled by the

(a) number of electrons present in the nucleus
(b) number of protons present in the nucleus
(c) number of neutrons present in the nucleus
(d) Both (a) and (b)

21 ${}^{14}_{6}C$ and ${}^{14}_{7}N$ are the examples of

(a) isobars (b) isotopes
(c) isotones (d) None of these

22 99.985% of hydrogen atoms contain only one proton. This isotope is called

(a) protium
(b) deuterium
(c) tritium
(d) Both (a) and (b)

23 Calculate the number of protons, neutrons and electrons in ${}^{80}_{35}Br$.

(a) Protons = 80, electrons = 80, neutrons = 35
(b) Protons = 35, electrons = 55, neutrons = 80
(c) Protons = 35, electrons = 35, neutrons = 80
(d) Protons = 35, electrons = 35, neutrons = 45

24 Rutherford's nuclear model of an atom is like a small scale solar system. Further coulombic force between electron and the nucleus is mathematically similar to the

(a) gravity $\left(\frac{Gr^2}{m_1 m_2}\right)$ (b) gravity $\left(\frac{G\, m_1 \cdot m_2}{r}\right)$
(c) gravitational force $\left(\frac{Gm_1 \cdot m_2}{r^2}\right)$
(d) gravitational force $\left(\frac{r^2}{G \cdot m_1 \cdot m_2}\right)$

25 Rutherford model could not explain the

(a) electronic structure of an atom
(b) stability of an atom
(c) Both (a) and (b)
(d) None of the above

TOPIC 3 ~ *Development Leading to the Bohr's Model of Atom*

26 Major development(s) responsible for the formulation of Bohr's model of atom were

(a) dual character of the electromagnetic radiation
(b) experimental results regarding atomic spectra
(c) Both (a) and (b)
(d) None of the above

27 Maxwell suggested that when electrically charged particle moves under acceleration, alternating electrical and magnetic fields are produced and transmitted.

These fields are transmitted in the form of waves called

(a) electromagnetic waves
(b) electronic radiations
(c) Both (a) and (b)
(d) None of the above

28 Maxwell revealed that light waves are associated with

(a) oscillating electric character
(b) oscillating magnetic character
(c) Both (a) and (b)
(d) None of the above

29 Many types of electromagnetic radiations, differ from one another in wavelength (or frequency) constitute a spectrum known as

(a) electromagnetic spectrum (b) line spectrum
(c) Both (a) and (b) (d) None of these

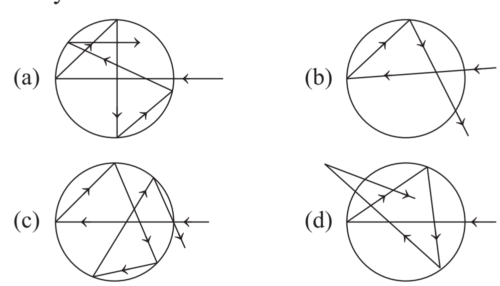
30 Classical physics is failed to explain

(a) black-body radiation
(b) photoelectric effect
(c) variation of heat capacity of solids as a function of temperature
(d) All of the above

31 Which of the given statements correctly represents the effect of rise in temperature on the emitted radiations of a hot body?

(a) The radiations move towards shorter wavelengths
(b) The radiations move towards shorter frequency
(c) The radiations move towards lower energy
(d) The frequency of radiations does not change

32 Which of the following figure represents a black body?



33 The energies E_1 and E_2 of two radiations are 25 eV, and 50eV, respectively. The relation between their wavelengths, i.e. λ_1 and λ_2 will be ***CBSE AIPMT 2012***

(a) $\lambda_1 = \frac{1}{2}\lambda_2$ (b) $\lambda_1 = \lambda_2$
(c) $\lambda_1 = 2\lambda_2$ (d) $\lambda_1 = 4\lambda_2$

34 The value of Planck's constant is 6.63×10^{-34} Js. The speed of light is 3×10^{17} nm s^{-1}. Which value is closest to the wavelength (in nm) of a quantum of light with frequency of $6 \times 10^{15} s^{-1}$?

(a) 10 (b) 25 (c) 50 (d) 75

35 Number of photons emitted by a 100 W (Js^{-1}) yellow lamp in 1.0 s is (λ of yellow light is 560 nm) ***JIPMER 2018***

(a) 1.6×10^{18} (b) 1.4×10^{18}
(c) 2.8×10^{20} (d) 2.1×10^{20}

36 The energy required to break one mole of Cl—Cl bonds in Cl_2 is 242 kJ mol^{-1}. The largest wavelength of light capable of breaking a single Cl—Cl bond is

(a) 700 nm (b) 494 nm
(c) 596 nm (d) 640 nm

37 The work function of a metal is 4.2 eV. If radiation of 2000Å fall on the metal then the kinetic energy of the fastest photoelectron is ***AIIMS 2018***

(a) 1.6×10^{-19} J (b) 16×10^{-10} J
(c) 3.2×10^{-19} J (d) 6.4×10^{-10} J

38 Calculate the energy in joule corresponding to light of wavelength 45 nm (Planck's constant, $h=6.63\times10^{-34}$ Js; speed of light, $c=3\times10^{8}$ nm s^{-1}).

(a) 6.67×10^{15} b) 6.67×10^{11}
(c) 4.42×10^{15} (d) 4.42×10^{-18}

39 The number of electron ejected in the photoelectric experiment is proportional to the

(a) intensity of light
(b) brightness of light
(c) Both (a) and (b)
(d) None of the above

40 Kinetic energy of the ejected electron is

(a) equal to the frequency of the electromagnetic radiation
(b) proportional to the frequency of the electromagnetic radiation
(c) more than the frequency of the electromagnetic radiation
(d) inversely proportional to the frequency of the electromagnetic radiation

41 What is the work function of the metal, *n* the light of wavelength 4000 Å generates photoelectron of velocity 6×10^{5} ms^{-1} from it? ***JEE Main 2019***

(Mass of electron $=9\times10^{-31}$ kg

Velocity of light $=3\times10^{8}$ ms^{-1}

Planck's constant $=6.626\times10^{-34}$ Js

Charge of electron $=1.6\times10^{-19}$ JeV^{-1})

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

42 The spectrum of white light ranges from violet (at 7.50×10^{14} Hz) to red (at 4×10^{14} Hz) is called

(a) emission spectra (b) line spectra
(c) continuous spectra (d) Both (a) and (c)

43 The emission spectra of atoms in the gaseous phase do not show a continuous spread of wavelength from red to violet, rather they emit light only at specific wavelengths with dark spaces between them. Such spectra is/are called

(a) line spectra (b) atomic spectra
(c) Both (a) and (b) (d) None of these

44 Uses of emission spectra is

(a) the study of electronic structure
(b) chemical analysis to identify unknown atoms
(c) Both (a) and (b)
(d) None of the above

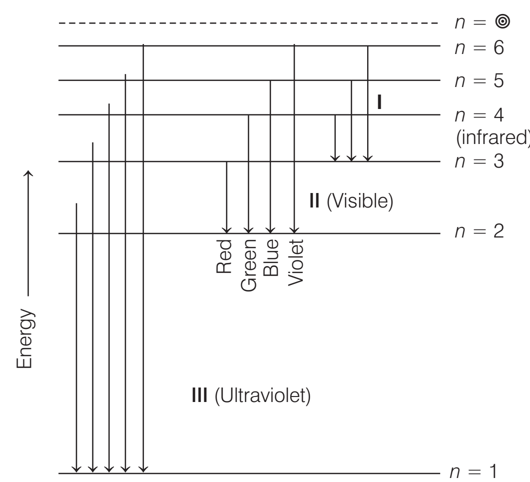
45 The ratio of the shortest wavelength of two spectral series of hydrogen spectrum is found to be about 9. The spectral series are ***JEE Main 2019***

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

46 Which of the following series of transitions in the spectrum of hydrogen atom fall in visible region? ***NEET (National) 2019***

(a) Balmer series (b) Paschen series
(c) Brackett series (d) Lyman series

47 Transition of the electron in the hydrogen atom is shown in the given figure.



Identify I, II, III in the above figure.

(a) I → Lyman series; II → Paschen series; III → Balmer series
(b) I → Paschen series; II → Lyman series; III → Balmer series
(c) I → Paschen series; II → Balmer series; III → Lyman series
(d) I → Balmer series; II → Lyman series; III → Paschen series

48 Which of the following relation correctly described all the lines in the hydrogen spectrum?

(a) $\bar{\nu} = \frac{1}{109677}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \text{cm}^{-1}$

(b) $\bar{\nu} = 109677\left[\frac{1}{n_2^2} - \frac{1}{n_1^2}\right] \text{cm}^{-1}$

(c) $\bar{\nu} = 109677\,[n_1^2 - n_2^2]\ \text{cm}^{-1}$

(d) $\bar{\nu} = 109677\,[n_2^2 - n_1^2]\ \text{cm}^{-1}$

49 The value 109677 cm^{-1} is called

(a) Pfund constant
(b) Balmer constant
(c) Rydberg constant
(d) Lyman constant

50 The electronic transition from $n = 2$ to $n = 1$ will produce the shortest wavelength in
(where, $n =$ principal quantum number)

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

TOPIC 4 ~ *Bohr's Model for Hydrogen Atom*

51 Angular momentum is the

(a) sum of moment of inertia (I) and angular velocity (ω)
(b) difference of moment of inertia (I) and angular velocity (ω)
(c) product of moment of inertia (I) and angular velocity (ω)
(d) ratio of moment of inertia (I) and angular velocity (ω)

52 The expression for Bohr's frequency rule is

(a) $v = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h}$

(b) $v = \Delta E \cdot h = E_2 - E_1 \cdot h$

(c) $\frac{v}{h} = \Delta E + h = (E_2 - E_1) + h$

(d) $v = \frac{\Delta E}{h} = \frac{E_1 - E_2}{2}$

53 An electron can move only in those orbits for which its angular momentum is integral multiple of

(a) $\frac{h}{4\pi}$ (b) $\frac{h}{2\pi}$ (c) $\frac{h}{\sqrt{2\pi}}$ (d) $h \cdot 2\pi$

54 The radius of the second Bohr orbit in terms of the Bohr radius, a_0, in Li^{2+} is ***JEE Main 2019***

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

55 Energy of an electron is given by

$$E = -2.178 \times 10^{-18}\,\text{J}\left(\frac{Z^2}{n^2}\right)$$

Wavelength of light required to excite an electron in an hydrogen atom from level $n = 1$ to $n = 2$ will be ($h = 6.62 \times 10^{-34}$ Js and $c = 3.0 \times 10^8\ \text{ms}^{-1}$)

(a) 1.214×10^{-7} m (b) 2.816×10^{-7} m
(c) 6.500×10^{-7} m (d) 8.500×10^{-7} m

56 The ionisation enthalpy of hydrogen atom is $1.312 \times 10^6\ \text{J mol}^{-1}$. The energy required to excite the electron in the atoms from $n_1 = 1$ to $n_2 = 2$ is

(a) $6.56 \times 10^5\ \text{J mol}^{-1}$ (b) $9.84 \times 10^5\ \text{J mol}^{-1}$
(c) $7.56 \times 10^5\ \text{J mol}^{-1}$ (d) $8.51 \times 10^5\ \text{J mol}^{-1}$

57 The kinetic energy of an electron in the second Bohr orbit of a hydrogen atom is [a_0 is Bohr radius]

(a) $\frac{h^2}{4\pi^2 m a_0^2}$ (b) $\frac{h^2}{16\pi^2 m a_0^2}$ (c) $\frac{h^2}{32\pi^2 m a_0^2}$ (d) $\frac{h^2}{64\pi^2 m a_0^2}$

58 The energy of the electron in a hydrogen atom has a negative sign for hydrogen atom because

(a) the energy of the electron in the atom is lower than the energy of a free electron at rest
(b) a free electron at rest is an electron that is infinitely far away from the nucleus
(c) the energy value assigned to free electron at rest is zero
(d) All of the above

59 The radius of the second Bohr orbit for hydrogen atom is (Planck's constant $(h) = 6.6262 \times 10^{-34}$ Js; mass of electron $= 9.1091 \times 10^{-31}$ kg; charge of electron $(e) = 1.60210 \times 10^{-19}$ C; permitivity of vacuum $(\epsilon_0) = 8.854185 \times 10^{-12}\ \text{kg}^{-1}\,\text{m}^{-3}\,\text{A}^2$) ***JEE Main 2017***

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

60 The energy of an electron in first Bohr orbit of H-atom is –13.6 eV. Which of the following energy value(s) of excited state(s) for electrons in Bohr orbits of hydrogen is correct? ***JEE Main 2015***

(a) – 3.4 eV (b) – 4.2 eV (c) – 6.8 eV (d) + 6.8 eV

61 The frequency (ν) associated with the absorption and emission of the photon can be evaluated by equation

(a) $v = \frac{\Delta E}{h} = \frac{R_H}{h}(n_i^2 - n_f^2)$

(b) $v = \frac{\Delta E}{h} = R_H \cdot h\left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$

(c) $v = \frac{\Delta E}{h} = \frac{R_H}{h} \cdot \left(\frac{1}{n_i^2} - \frac{1}{n_f^2}\right)$

(d) $v = \frac{\Delta E}{h} = R_H \cdot h\,(n_i^2 - n_f^2)$

62 Bohr's atomic model suggests that
(a) electrons have a particle as well as wave character
(b) atomic spectrum of atom should contain only five lines
(c) electron on hydrogen atom can have only certain values of angular momentum
(d) All of the above

63 The first line in the Balmer series in the H-atom will have the frequency
(a) $3.29\times 10^{15}\ s^{-1}$ (b) $4.57\times 10^{14}\ s^{-1}$
(c) $8.22\times 10^{15}\ s^{-1}$ (d) $8.02\times 10^{14}\ s^{-1}$

64 For emission line of atomic hydrogen from $n_i = 8$ to $n_f = n$, the plot of wave number ($\bar{\nu}$) against $\left(\frac{1}{n^2}\right)$ will be (The Rydberg constant, R_H is in wave number unit) ***JEE Main 2019***
(a) non linear (b) linear with slope $-R_H$
(c) linear with slope R_H (d) linear with intercept $-R_H$

65 The brightness or intensity of spectral lines depends upon the
(a) number of photons of same wavelength emitted
(b) number of photons of same frequency absorbed
(c) number of photons of same frequency emitted
(d) All of the above

66 The phenomenon of splitting of spectral lines under the influence of the electric field is called
(a) Stark effect (b) photoelectric effect
(c) Zeeman effect (d) electromagnetic effect

67 Zeeman effect is due to
(a) splitting up the lines in an emission spectrum in the presence of an external electrostatic field
(b) random scattering of light by colloidal particles
(c) splitting up of the lines in an emission spectrum in a magnetic field
(d) emission of electrons from metals when light falls upon them

68 Limitations of Bohr's model is/are
(a) it fails to account for the finer details of the hydrogen atom spectrum observed by using sophisticated spectroscopic techniques
(b) it is unable to explain the spectrum of atoms other than hydrogen
(c) it is unable to explain the ability of atoms to form molecules by chemical bonds
(d) All of the above

TOPIC 5 ~ *Towards Quantum Mechanical Model of Atom*

69 Electron microscope is based on the principle of
(a) wave like behaviour of electrons
(b) wave nature of light
(c) particle behaviour of electrons
(d) None of the above

70 Calculate the mass of a photon with wavelength 3.6 Å.
(a) 6.135×10^{-27} kg (b) 6.135×10^{-28} kg
(c) 6.135×10^{-33} kg (d) 6.135×10^{-30} kg

71 The de-Broglie wavelength of an electron in the 4th Bohr orbit is ***JEE Main 2020***
(a) $6\pi a_0$ (b) $2\mu a_0$ (c) $8\pi a_0$ (d) $4\pi a_0$

72 In hydrogen atom, the de-Broglie wavelength of an electron in the second Bohr orbit is
[Given that, Bohr radius, $a_0 = 52.9$ pm] ***NEET (Odisha) 2019***
(a) 211.6 pm (b) 211.6 π pm (c) 52.9 π pm (d) 105.8 pm

73 The effect of Heisenberg uncertainty principle is significant
(a) only for motion of microscopic objects
(b) negligible for that of macroscopic objects
(c) Both (a) and (b)
(d) None of the above

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

75 The uncertainties in the velocities of two particles A and B are 0.05 and 0.02 ms^{-1} respectively. The mass of B is five times to that of mass A. What is the ratio of uncertainties ($\Delta x_A / \Delta x_B$) in their positions?
(a) 2 (b) 0.25
(c) 4 (d) 1

76 Uncertainty in the position of an electron (mass $= 9.1\times 10^{-31}$ kg) moving with a velocity 300 ms^{-1}, accurate upon 0.001% will be ($h = 6.63\times 10^{-34}$ J-s)
(a) 19.2×10^{-2} m (b) 5.76×10^{-2} m
(c) 1.93×10^{-2} m (d) 3.84×10^{-2} m

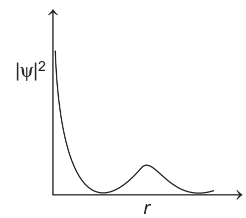
77 The trajectory of an object is determined by
(a) its location
(b) its velocity at various moments
(c) Both (a) and (b)
(d) None of the above

78 If E_A, E_B and E_C represent kinetic energies of an electron, alpha particle and proton respectively and each moving with same de-Broglie wavelength, then choose the correct increasing representation,
(a) $E_A = E_B = E_C$ (b) $E_A > E_B > E_C$
(c) $E_B > E_C > E_A$ (d) $E_A < E_C < E_B$

TOPIC 6 ~ *Quantum Mechanical Model of Atom*

79 In the Schrodinger equation, $\hat{H}$ is
(a) a mathematical operator called Hamiltonian operator
(b) introduced by Schrodinger from the expression for the total energy of the system
(c) Both (a) and (b)
(d) None of the above

80 The graph between $|\psi|^2$ and r (radial distance) is shown below. This represents ***JEE Main 2019***



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

81 The total number of nodes are given by
(a) $(n+1)$ (b) $(n-l-1)$ (c) $(n-1)$ (d) $(n-l+1)$

82 Orbital having 3 angular nodes and 3 total nodes is ***NEET (Odisha) 2019***
(a) $5p$ (b) $3d$ (c) $4f$ (d) $6d$

83 Identify the correct order of increase in the energy of the orbitals for hydrogen atom
(a) $1s < 2s = 2p < 3s = 3p = 3d < 4s = 4p = 4d = 4f$
(b) $1s > 2s = 2p > 3s = 3p = 3d > 4s = 4p = 4d = 4f$
(c) $1s = 2s = 3s = 4s > 2p = 3p = 4p > 3d = 4d > 4f$
(d) $1s = 2s = 3s = 4s < 2p = 3p = 4p < 3d = 4d < 4f$

84 The stability of an electron in multielectron atom is due to
(a) total attractive interactions > repulsive interactions
(b) total attractive interactions = repulsive interactions
(c) total attractive interactions < repulsive interactions
(d) total of attractive and repulsive interactions only

85 Out of the following pairs of electrons, identify the pairs of electrons present in degenerate orbitals.
(a) (i) $n=3,\ l=1,\ m_l=-1,\ m_s=-\frac{1}{2}$
(ii) $n=3,\ l=2,\ m_l=-1,\ m_s=-\frac{1}{2}$
(b) (i) $n=3,\ l=1,\ m_l=1,\ m_s=+\frac{1}{2}$
(ii) $n=3,\ l=2,\ m_l=1,\ m_s=+\frac{1}{2}$
(c) (i) $n=4,\ l=1,\ m_l=1,\ m_s=+\frac{1}{2}$
(ii) $n=3,\ l=2,\ m_l=1,\ m_s=+\frac{1}{2}$
(d) (i) $n=3,\ l=2,\ m_l=+2,\ m_s=-\frac{1}{2}$
(ii) $n=3,\ l=2,\ m_l=+2,\ m_s=+\frac{1}{2}$

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

87 $4d, 5p, 5f$ and $6p$-orbitals are arranged in the order of decreasing energy. ***NEET (National) 2019***
The correct option is
(a) $6p > 5f > 5p > 4d$ (b) $5p > 5f > 4d > 5p$
(c) $5f > 6p > 4d > 5p$ (d) $5f > 6p > 5p > 4d$

88 Which of the following does not represent ground state electronic configuration of an atom?
(a) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8 4s^2$
(b) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^9 4s^2$
(c) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10} 4s^1$
(d) $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^5 4s^1$

89 With the saturation of $3d$ orbitals, the filling of the $4p$ orbitals starts at A and is completed at B. Here, A and B refer to
(a) $A \rightarrow$ Ga; $B \rightarrow$ Kr (b) $A \rightarrow$ Ga; $B \rightarrow$ Xe
(c) $A \rightarrow$ Zn; $B \rightarrow$ Br (d) $A \rightarrow$ Zn; $B \rightarrow$ Kr

90 The atomic numbers of elements X, Y and Z are 19, 21 and 25 respectively. The number of electrons present in the M-shell of these elements follow the order
(a) $Z > X > Y$ (b) $X > Y > Z$
(c) $Z > Y > X$ (d) $Y > Z > X$

91 The number of d-electrons in Fe^{2+} $(Z-26)$ is not equal to the number of electrons in which one of the following?
(a) s-electrons in Mg $(Z=12)$
(b) p-electrons in Cl $(Z=17)$
(c) d-electrons in Fe $(Z=26)$
(d) p-electrons in Ne $(Z=10)$

92 The number of orbitals associated with quantum numbers $n=5,\ m_s=+\frac{1}{2}$ is ***JEE Main 2020***
(a) 25 (b) 50 (c) 15 (d) 11

93 Aufbau principle does not give the correct arrangement of filling up of the atomic orbitals in
(a) Cu and Zn (b) Co and Zn
(c) Mn and Cr (d) Cu and Cr

SPECIAL TYPES QUESTIONS

I. Statement Based Questions

94 Which of the following statement regarding the characteristics of positively charged canal rays is incorrect?

(a) Unlike cathode rays, mass of positively charged particles depends upon the nature of gas present in the cathode ray tube

(b) The charge to mass ratio of these particles depends on the gas from which these originate

(c) The behaviour of these particles in electric or magnetic field is same as that observed for electron or cathode rays

(d) Some of the positively charged particles carry a multiple of the fundamental unit of fundamental charge

95 Which of the following statement is correct?

(a) The energy of a quantum of radiation is proportional to its frequency (ν) is expressed by equation, $E = h\nu$

(b) With the help of quantum theory, Plank explained the distribution of intensity in the radiation from black body as a function of frequency or wavelength at different temperatures

(c) In photoelectric effect, there is no time lag between the striking of light beam and the ejection of electrons from metal surface

(d) All of the above

96 Which of the following statement is incorrect regarding the oil droplets experiment?

(a) Oil droplets in the form of mist, produced by the atomiser were allowed to enter through tiny hole in the upper plate of electrical condenser

(b) The air inside the chamber was ionised by passing a beam of X-ray through it

(c) The fall of these charged oil droplets can be retarted accetered or made stationary

(d) Magnitude of electric charge, 'q' on the droplets is always fractional multiple of the electrical charge (e)

97 Which of the following statement is/are correct about Hertz (Hz)?

(a) It is the SI unit of frequency (ν)

(b) It is named after Heinrich Hertz

(c) It is the number of waves that pass a given point in one second

(d) All of the above

98 According to the electromagnetic theory of Maxwell, which one is correct?

(a) Charged particles when accelerated should emit electromagnetic radiation

(b) Charged particles when accelerated should absorb electromagnetic radiation

(c) Charged particles when retarted should emit EMR

(d) None of the above

99 Which of the following statement is incorrect regarding Bohr's model of hydrogen atom?

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

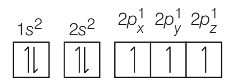
(b) The electron in the orbit nearest to the nucleus has the lowest energy

(c) Electrons revolve in different orbits around the nucleus

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

100 Which one is a incorrect statement? ***NEET 2018***

(a) The electronic configuration of N-atom is



(b) An orbital is designated by three quantum numbers while an electron in an atom is designated by four quantum numbers

(c) Total orbital angular momentum of electron in 's' orbital is equal to zero

(d) The value of m for d_{z^2} is zero

101 Which one is the incorrect statement? ***NEET 2017***

(a) de-Broglie's wavelength is given by $\lambda = h/mv$

where m = mass of the particle,

v = group velocity of the particle

(b) The uncertainty principle is $\Delta E \times \Delta t \geq h/4\pi$

(c) Half-filled and fully-filled orbitals have greater stability due to greater exchange energy, greater symmetry and more balanced arrangement

(d) The energy of $2s$-orbital is less than the energy of $2p$-orbital in case of hydrogen like atoms

102 Consider the following statements about cathode rays.

I. These moves from cathode to anode.

II. These are visible rays.

III. Television picture tubes are cathode rays tubes.

IV. In the absence of electrical or magnetic field, these rays travel in a straight line.

Choose the correct statement from the above and mark the correct option.

(a) I, II and III (b) II, III and IV

(c) I, III and IV (d) All of these

103 Consider the following statements :

I. Canal rays are simply the charged gaseous ions.

II. Charge to mass ratio of these particles is found to depend on the gas from which these originate.

III. Some of the positively charged particles carry a multiple of the fundamental unit of electrical charge.

IV. Behaviour of canal rays in the electrical or magnetic field is opposite to that observed for cathode rays or electron.

Which of the above mentioned statements are correct?

(a) I, II and III (b) II, III and IV
(c) I, III and IV (d) All of these

104 Consider the following statements regarding the Thomson's model of atom.

I. The electrons are embedded in the nucleus, so as to give the most stable electrostatic arrangement.

II. The model was able to explain the overall neutrality of the atom.

III. The different name of this model are plum pudding model, raisin pudding model or watermelon models.

Choose the option with all the correct statements.

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

105 Wilhelm Roentgen showed that when electrons strike a material in the cathode ray tubes, some rays are produced.

Consider the following statements regarding these rays.

I. These can cause fluorescence in the fluoroscent materials placed outside the cathode ray tubes.

II. These rays are named as X-rays.

III. These rays are deflected by both, electric and magnetic fields.

IV. These are used to study interior of the objects.

Choose the option containing all the incorrect statement(s).

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

106 Consider the following statements :

I. The presence of positive charge on the nucleus is due to the presence of protons and neutrons in the nucleus.

II. The number of protons present in the nucleus is equal to the atomic number.

III. In order to keep the electrical neutrality, the number of electrons in an atom is equal to the number of proton in an atom.

IV. Protons, neutrons and electrons present in the atom are collectively called nucleons.

Choose the option with all incorrect statements.

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

107 The oscillating electric and magnetic fields produced by oscillating charged particles are

I. perpendicular to each other.

II. parallel to each other.

III. both are perpendicular to the direction of propagation of the wave.

IV. both are parallel to the direction of the waves.

Choose the correct option.

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

108 Consider the following statements :

I. The speed of light does not depends upon the nature of the medium through which it passes.

II. The beam of light is deviated or refracted from its original path as it passes from one medium to another.

III. When a ray of white light is passed through a prism, the wave with shorter wavelength bends more than the one with a longer wavelength.

Choose the correct statements and select the correct option.

(a) I and II (b) II and III (c) I and III (d) None of these

109 Consider the following statements :

I. Qualitatively, the magnitude of velocity of electron increases with increase of positive charge on the nucleus.

II. Magnitude of velocity of electron decreases with increase of principal quantum number.

The correct statement(s) is/are

(a) Only I (b) Only II
(c) Neither I nor II (d) Both I and II

110 Consider the following statements :

I. The energy of radiation increases with decrease in wavelength.

II. The spectrum of H atom is exactly same as that of He^+ ion.

III. Energy of radiation increases with increase in $\overline{\nu}$.

The correct statements are

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

111 Consider the following statements :

I. Bohr's theory can also be applied to species He^+, Li^{2+}, Be^{3+} and energy of stationary states associated with these kind of ions is given as,

$E_n = 2.18 \times 10^{-18} (Z^2/n^2)$ J

II. In case of absorption spectrum, $n_i > n_f$ and in case of emission spectrum $n_f > n_i$.

III. de-Broglie suggested that like mater, radiation should also exhibit dual behaviour.

IV. Heisenberg uncertainty principle rules out existence of definite path or trajectories of electrons.

Choose the incorrect statement(s) :

(a) I and II (b) II and III (c) Only IV (d) Only II

112 Consider the following statements obtained after solving the Schrodinger equation for hydrogen atom,

I. we get the possible energy levels that the electron can occupy.

II. the atomic orbital is the wave function (ψ) for an electron in an atom.

The correct statement(s) is/are

(a) Only I (b) Only II
(c) Both I and II (d) Neither I nor II

113 Consider the following statements about wave function?

I. When an electron is in energy state, the wave function corresponds to that energy state, which contains all information about the electron.

II. It is a mathematical function whose value depends upon the coordinates of the electron in the atom and does not carry any physical meaning.

III. Wave functions of hydrogen or hydrogen like species with one electron are called atomic orbitals.

IV. Wave functions pertaining to one-electron species are called one-electron systems.

The correct statements are

(a) I, II and III (b) III and IV (c) I and II (d) All of these

114 Consider the following statements :

I. The energy of electrons in atoms is quantised.

II. The existence of quantised electronic energy levels is a direct result of the wave like properties of electrons.

III. The path of an electron in an atom can never be determined accurately.

The correct statements are

(a) I and II (b) II and III (c) I and III (d) All of these

115 Consider the following statements regarding probability density,

I. It is denoted by $|\psi|^2$.

II. It is the probability of finding an electron at a point within an atom is proportional to the square of the orbital wave function.

III. From the value of $|\psi|^2$ at different points, within an atom, it is possible to predict the region around the nucleus where electron will most probably be found.

Choose the correct option.

(a) I and II (b) II and III (c) I and III (d) All of these

116 If probability density $|\psi|^2$ is constant on a given surface,

I. ψ is constant over the surface.

II. the boundary surface for $|\psi|^2$ and $|\psi|$ are different.

The correct statements is/are

(a) Only I (b) Only II
(c) Both I and II (d) None of these

117 Consider the following statements :

I. The attractive interactions of an electron increases with increase of positive charge (Z_e) on the nucleus.

II. Due to the presence of electrons in the inner shells, the electrons in the outer shell will not experience the full positive charge of the nucleus (Z_e).

III. The effect will be lowered due to the partial screening of positive charge on the nucleus by the inner shell electrons.

IV. The net positive charge experienced by the other electrons is known as effective nuclear charge (Z_{eff}).

The correct statements are

(a) I, II and III
(b) II, III and IV
(c) I, III and IV
(d) All of the above

118 Consider the following statements concerning the quantum numbers,

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.

The correct set of statements are

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

119 Consider the following statements :

I. The shape of the orbitals is given by magnetic quantum number.

II. In an atom, all electrons travel with the same velocity.

III. If the value of $l = 0$, the electron distribution is spherical.

IV. Angular momentum of 1*s*, 2*s*, 3*s* electrons are equal.

Choose the correct statements and select the correct option.

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

II. Assertion and Reason

■ **Directions** (Q. Nos. 120-131) *In the following questions, a statement of Assertion* (A) *is followed by a corresponding statement of Reason* (R). *Of the following statements, choose the correct one.*

(a) Both A and R are correct; R is the correct explanation of A.
(b) Both A and R are correct; R is not the correct explanation of A.
(c) A is correct; R is incorrect.
(d) A is incorrect; R is correct.

120 **Assertion** (A) X-rays are used to study the interior of the objects.

Reason (R) They are not deflected by the electric and magnetic fields and have very high penetrating power through the matter.

121 **Assertion** (A) Most of the space in the atoms is empty.

Reason (R) Most of the α-particles passed through the foil remain undeflected.

122 **Assertion** (A) Electromagnetic waves can move in vacuum.

Reason (R) They do not require medium to propagate.

123 **Assertion** (A) Iron rod is heated in furnace, it first turns to dull red, intense red, white and then become blue as the temperature becomes high.

Reason (R) The frequency of emitted radiation goes from a higher frequency to a lower frequency as the temperature increases.

124 **Assertion** (A) Classical mechanics fails to explain the behaviour of microscopic particles.

Reason (R) It ignores the concept of dual behaviour of matter.

125 **Assertion** (A) Red light of any brightness may shine on a piece of potassium-metal but no photoelectrons are ejected but as soon as even a very weak yellow light shines on the potassium-metal, the photoelectric effect is observed.

Reason (R) The number of electrons ejected does depend upon the brightness of light and not on the kinetic energy of the ejected electrons.

126 **Assertion** (A) Greater the energy possessed by the photon, lesser will be transfer of energy to the electron and the kinetic energy of the ejected electron.

Reason (R) The kinetic energy of the ejected electron is proportional to the frequency of the electromagnetic radiation.

127 **Assertion** (A) Energies of the orbitals in hydrogen or hydrogen like species depend only on the quantum number '*n*'.

Reason (R) Energies of the orbitals in multielectron atoms depend on quantum numbers '*n*' and '*l*'.

128 **Assertion** (A) Energy of the orbital increases with increase of principal quantum number.

Reason (R) Energy is required in shifting away the negatively charged electron from the positively charged nucleus.

129 **Assertion** (A) For a given principal quantum number, *s, p, d, f* ..., subshells, all have different energies.

Reason (R) Mutual repulsion exists among the electrons in a multielectron atoms.

130 **Assertion** (A) *s*-orbital electron will be more tightly bound to the nucleus than *p*-orbital electron.

Reason (R) Z_{eff} experienced by the electron decreases with increase of azimuthal quantum number (l).

131 **Assertion** (A) Half-filled and fully filled degenerate set of orbitals acquire extra stability.

Reason (R) The reason for the above fact is the symmetry of such orbitals.

III. Matching Type Questions

132 Match the following type of rays given in Column I with their characteristics given in Column II. Select an appropriate answer from the codes given below.

Column I (Type of rays)	Column II (Characteristics)
A. α - ray	1. Negatively charged particles similar to electrons.
B. β - ray	2. X-ray, neutral in nature.
C. γ - ray	3. Two units of positive charge and four units of atomic mass.

Codes

	A	B	C		A	B	C
(a)	3	2	1	(b)	1	2	3
(c)	3	2	1	(d)	3	1	2

133 Match the Column I with Column II and III and select an appropriate option from the codes given below.

Column I (Region)	Column II (Frequency (Hz))	Column III (Application)
A. Radiofrequency	1. 10^{10}	(i) Heating
B. Microwave	2. 10^{13}	(ii) Radar
C. Infrared	3. 10^{16}	(iii) Broadcasting
D. Ultraviolet	4. 10^{6}	(iv) Solar radiations

Codes

	A	B	C	D
(a)	3(i)	1(ii)	4(iii)	2(iv)
(b)	1(iv)	2(iii)	3(i)	4(ii)
(c)	4(iii)	1(ii)	2(i)	3(iv)
(d)	2(i)	4(ii)	3(iv)	1(iii)

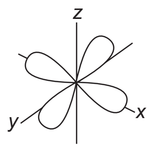
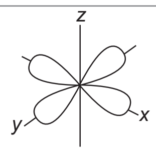
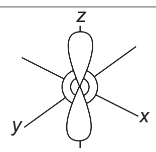
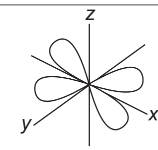
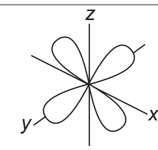
134 Match the Column. Select an appropriate code from the given options.

Column I n	Column II l	Column III (Subshell notation)
A. 1	I. 0	(i) 4*f*
B. 2	II. 0	(ii) 4*s*
C. 3	III. 0	(iii) 3*p*
D. 3	IV. 3	(iv) 3*d*
E. 4	V. 2	(v) 1*s*
F. 4	VI 1	(vi) 2*s*

Codes

	A	B	C	D	E	F
(a)	II(v)	I(vi)	VI(iii)	V(iv)	IV(i)	III(ii)
(b)	I(vi)	II(v)	III(iv)	IV(iii)	V(ii)	VI(i)
(c)	VI(i)	V(ii)	IV(iii)	III(iv)	II(v)	I(vi)
(d)	III(iii)	VI(vi)	IV(iv)	II(ii)	I(i)	V(v)

135 Match the Column I with Column II and choose the correct options from the codes given below :

Column I (Boundary surface diagram)		**Column II** (d-orbital)
A.		1. d_{z^2}
B.		2. d_{xy}
C.		3. d_{xz}
D.		4. $d_{x^2-y^2}$
E.		5. d_{yz}

Codes

	A	B	C	D	E
(a)	4	5	2	1	3
(b)	3	4	5	2	1
(c)	5	3	1	4	2
(d)	5	4	1	2	3

NCERT & NCERT Exemplar

MULTIPLE CHOICE QUESTIONS

NCERT

136 Yellow light emitted from a sodium lamp has a wave length(λ) of 580 nm. Calculate wave number ($\bar{\nu}$) of the yellow light.

(a) $1.927\times10^{5}cm^{-1}$ (b) $1.724\times10^{4}cm^{-1}$
(c) $1.0021\times10^{-5}cm^{-1}$ (d) $2.147\times10^{-4}cm^{-1}$

137 What is the number of photons of light with a wavelength of 4000 pm that provide 1 J of energy?

(a) 2.145×10^{14} photons
(b) 2.0122×10^{16} photons
(c) 2.0012×10^{10} photons
(d) 2.0233×10^{8} photons

138 What is the maximum number of emission lines when the excited electron of a H-atom in $n=6$ drops to the ground state?

(a) 10 (b) 20 (c) 15 (d) 18

139 Calculate the energy required for the process Z_{eff} $He^{+}(g)\rightarrow He^{2+}(g)+e^{-}$. The ionisation energy for the H-atom in the ground state is 2.18×10^{-18} J atom^{-1}.

(a) 8.72×10^{-18} atoms^{-1}
(b) 10.75×10^{-20} atoms^{-1}
(c) 12.77×10^{-22}atoms^{-1}
(d) 15.22×10^{-15} atoms^{-1}

NCERT Exemplar

140 Which of the following statements about the electron is incorrect?

(a) It is a negatively charged particle
(b) The mass of electron is equal to the mass of neutron
(c) It is a basic constituent of all atoms
(d) It is a constituent of cathode rays

141 Which of the following statement is incorrect about the characteristics of cathode rays?

(a) They start from the cathode and move towards the anode
(b) They travel in a straight line in the absence of an external electrical or magnetic field
(c) Characteristics of cathode rays do not depend upon the material of electrodes in cathode ray tube
(d) Characteristics of cathode rays depend upon the nature of gas present in the cathode ray tube

142 Which of the following conclusions could not be derived from Rutherford's α-particle scattering experiment?

(a) Most of the space in the atom is empty
(b) The radius of the atom is about 10^{-10} m while that of nucleus is 10^{-15} m
(c) Electrons move in a circular path of fixed energy called orbits
(d) Electrons and the nucleus are held together by electrostatic forces of attraction

143 Which of the following properties of an atom could be explained correctly by Thomson's model of atom?
(a) Overall neutrality of atom
(b) Spectra of hydrogen atom
(c) Position of electrons, protons and neutrons in atom
(d) Stability of atom

144 Two atoms are said to be isobars, if
(a) they have same atomic number but different mass number
(b) they have same number of electrons but different number of neutrons
(c) they have same number of neutrons but different number of electrons
(d) sum of the number of protons and neutrons is same but the number of protons is different

145 Which of the following is responsible to rule out the existence of definite paths or trajectories of electrons?
(a) Pauli's exclusion principle
(b) Heisenberg's uncertainty principle
(c) Hund's rule of maximum multiplicity
(d) Aufbau principle

146 If travelling at same speeds, which of the following matter waves have the shortest wavelength?
(a) Electron
(b) Alpha particle (He^{2+})
(c) Neutron
(d) Proton

147 Which of the following sets of quantum numbers are correct?

	n	l	m_l		n	l	m_l
I.	1	1	+2	II.	2	1	+1
III.	3	2	–2	IV.	3	4	–2

The correct option is
(a) II and III (b) I and II
(c) I and III (d) III and IV

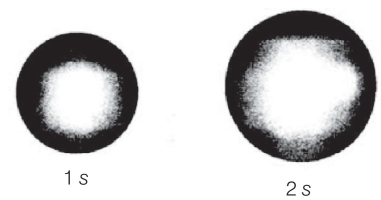
148 The pair of ions having same electronic configuration is
(a) Cr^{3+}, Fe^{3+}
(b) Fe^{3+}, Mn^{2+}
(c) Fe^{3+}, Co^{3+}
(d) Sc^{3+}, Cr^{3+}

149 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
(a) 1 : 2 (b) 1 : 1 (c) 1 : 3 (d) 3 : 1

150 Total number of orbitals associated with third shell will be ......
(a) 2 (b) 4 (c) 9 (d) 3

151 Orbital angular momentum depends on......... .
(a) l (b) n and l (c) n and m (d) m and s

152 The probability density plots of 1*s* and 2*s*-orbitals are given in figure.



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?
(a) 1*s* and 2*s*-orbitals are spherical in shape
(b) The probability of finding the electron is maximum near the nucleus
(c) The probability of finding the electron at a given distance is equal in all directions
(d) The probability density of electrons for 2*s*-orbital decreases uniformly as distance from the nucleus increases

153 The number of radial nodes for 3*p*-orbital is........... .
(a) 3 (b) 4
(c) 2 (d) 1

154 For the electrons of oxygen atom, which of the following statements is correct?
(a) Z_{eff} for an electron in a 2*s*-orbital is ths same is Z_{eff} for an electron in a 2*p*-orbital
(b) An electron in the 2*s*-orbital has the same energy as an electron in the 2*p*-orbital
(c) Z_{eff} for an electron in 1*s*-orbital is the same as Z_{eff} for an electron in a 2*s*-orbital
(d) The two electrons present in the 2*s*-orbital have spin quantum numbers, m_s but of opposite sign

Answers

Mastering NCERT with MCQs

1 (b)	2 (d)	3 (d)	4 (a)	5 (d)	6 (b)	7 (c)	8 (d)	9 (b)	10 (d)
11 (b)	12 (a)	13 (a)	14 (b)	15 (a)	16 (b)	17 (d)	18 (b)	19 (a)	20 (d)
21 (a)	22 (a)	23 (d)	24 (c)	25 (c)	26 (c)	27 (c)	28 (c)	29 (a)	30 (d)
31 (a)	32 (a)	33 (c)	34 (c)	35 (c)	36 (b)	37 (c)	38 (d)	39 (c)	40 (b)
41 (b)	42 (c)	43 (c)	44 (c)	45 (a)	46 (a)	47 (c)	48 (a)	49 (c)	50 (d)
51 (c)	52 (a)	53 (b)	54 (c)	55 (a)	56 (b)	57 (c)	58 (a)	59 (d)	60 (a)
61 (c)	62 (c)	63 (b)	64 (c)	65 (d)	66 (a)	67 (c)	68 (d)	69 (a)	70 (c)
71 (b)	72 (b)	73 (c)	74 (c)	75 (a)	76 (c)	77 (c)	78 (d)	79 (c)	80 (d)
81 (c)	82 (c)	83 (a)	84 (a)	85 (d)	86 (a)	87 (d)	88 (b)	89 (a)	90 (c)
91 (b)	92 (a)	93 (d)							

Special Types Questions

94 (c)	95 (d)	96 (d)	97 (d)	98 (a)	99 (d)	100 (a)	101 (d)	102 (c)	103 (d)
104 (c)	105 (b)	106 (c)	107 (a)	108 (b)	109 (d)	110 (c)	111 (d)	112 (c)	113 (d)
114 (d)	115 (d)	116 (a)	117 (d)	118 (b)	119 (d)	120 (a)	121 (a)	122 (a)	123 (c)
124 (a)	125 (a)	126 (d)	127 (b)	128 (b)	129 (a)	130 (b)	131 (a)	132 (d)	133 (c)
134 (a)	135 (d)								

NCERT & NCERT Exemplar Questions

136 (b)	137 (b)	138 (c)	139 (a)	140 (b)	141 (d)	142 (c)	143 (a)	144 (d)	145 (b)
146 (b)	147 (a)	148 (b)	149 (c)	150 (c)	151 (a)	152 (d)	153 (d)	154 (d)	

5 (*d*) According to Thomson, the amount of deviation of the particles from their path in the presence of electrical or magnetic field depends upon

(a) the magnitude of the negative charge on the particle-greater the magnitude of the charge on particle, greater is the interaction with electrical or magnetic field and thus, greater is the deflection.

(b) the mass of the particle-lighter the particle, greater the deflection.

(c) the strength of the electrical or magnetic field-the deflection of electrons from its original path increases with increase in the voltage across the electrodes or the strength of the magnetic field.

6 (*b*) The phenomenon is responsible for television pictures is fluorescence. Fluorescence is the phenomenon in which molecules of a substance when bombarded with energetic electrons emit electromagnetic radiation.

8 (*d*) Thomson was able to determine the charge to the mass ratio of electron by carrying out accurate measurements on the amount of deflections observed by the electrons on the electric field strength or magnetic field strength as,

$$e/m_e = 1.758820 \times 10^{11} \text{ C kg}^{-1}$$

where, m_e is the mass of electron in kg and e is the magnitude of the charge on the electron in Coulomb (C).

9 (*b*) Formula for calculating mass of electron (m_e) is

$$m_e = \frac{e}{(e/m_e)}.$$

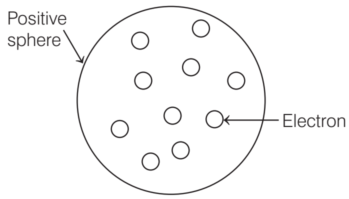
where, m_e = mass of electron in kg.
e = magnitude of the charge on the electron in Coulomb (C).

Since, electrons are negatively charged, the charge on electron is $-e$.

11 (*b*)

Name	Symbol	Absolute charge/C (*B*)	Relative charge	Mass/kg (*D*)	Mass/u	Approx. mass/u
Electron	*e*	-1.6022×10^{-19}	-1	9.10939×10^{-31}	**0.00054 (*E*)**	**0 (*F*)**
Proton (*A*)	*p*	$+1.6022 \times 10^{-19}$	$+1$	1.67262×10^{-27}	1.00727	1
Neutron	*n*	**0 (C)**	0	1.67493×10^{-27}	1.00867	1

12 (*a*) According to Thomson's model of atom, an atom possesses a spherical shape (radius approx. 10^{-10}m) in which the positive charge is uniformly distributed and the mass of the atom is assumed to be uniformly distributed over the atom.



Thomson model of atom

13 (*a*) Cathode rays have same charge to mass ratio as β -rays. β-rays are negatively charged particles similar to electrons.

14 (*b*) Electrons (e) and protons (p) have the same charge $(1.602 \times 10^{-19}$ C) but protons are 1840 times heavier than electrons.

e/m_e of any particle decreases, if the mass is increased. So, the e/m_e of electron is higher than the proton.

Alpha particle (α) is a helium nucleus which consists of two protons and two electrons. It has +2 charge and the mass of 4 protons. So, the α-particle has the least e/m because of its large mass.

Neutron (n) has no charge thus its e/m_e is zero.

Thus, the increasing order of e/m_e values is

$$n < \alpha < p < e$$

18 (*b*) ${}_{Z}^{A}E \xrightarrow{-\alpha} {}_{Z-2}^{A-4}X \xrightarrow{-\beta} {}_{Z-1}^{A-4}Y \xrightarrow{-\beta} {}_{Z}^{A-4}W$

Both elements E and W have same atomic number but different mass numbers. Hence, both are isotopes. So, the resulting element will be an isotope of E.

19 (*a*) Mass number of an atom (A) is total number of nucleons,

i.e. A = number of protons + number of neutrons.

20 (*d*) The chemical properties of atoms are controlled by the number of electrons which are determined by the number of protons present in the nucleus. Number of neutrons present in the nucleus have very little effect on the chemical properties of an element.

Therefore, all the isotopes of a given element show same chemical behaviour.

21 (*a*) ${}_{6}^{14}C$ and ${}_{7}^{14}C$ are the examples of isobars having same mass number but different atomic numbers.

23 (*d*) In ${}_{35}^{80}Br$

Number of protons = Number of electrons = 35 = Atomic number

Number of neutrons = Mass number (A) − Number of proton = $(80 - 35) = 45$

24 (*c*) Rutherford model of an atom is like small scale solar system with the nucleus acts as massive sun and the electrons similar to the lighter planets.

It is mathematically similar to the gravitational force $\left(\frac{G \cdot m_1 m_2}{r^2}\right)$.

where, m_1 and m_2 are the masses, r is the distance of separation of the masses and G is the gravitational constant.

26 (*c*) Major developments responsible for the formulation of Bohr's model of atom were dual character of the electromagnetic radiation which means that radiations possess both wave like and particle like properties. Experimental results regarding atomic spectra which can be explained only by assuming quantised electronic energy levels in atoms.

31 (*a*) The intensities of radiations emitted by hot body depends on temperature. As the temperature is raised, the emitted radiations move towards shorter wavelengths.

It shows that, as the temperature is raised, the maxima of the curve shifts towards shorter wavelengths.

32 (*a*) A cavity with a tiny hole, that has no other opening, can be considered as a black body. A ray of light entering the hole would be reflected by the walls of the cavity and ultimately absorbed by it.

Therefore, option (a) is correct.

33 (*c*) $$\frac{E_1}{E_2} = \frac{\lambda_2}{\lambda_1}$$

$$\Rightarrow \quad \frac{25\,\text{eV}}{50\,\text{eV}} = \frac{\lambda_2}{\lambda_1} \quad \text{or} \quad \lambda_1 = 2\lambda_2$$

34 (*c*) Given, Planck's constant, $h = 6.63 \times 10^{-34}$ Js

Speed of light, $(c) = 3 \times 10^{17}\,\text{nm s}^{-1}$

Frequency of quantam $(\nu) = 6 \times 10^{15}\text{s}^{-1}$

Wavelength $(\lambda) = ?$

We know that, $\nu = \frac{c}{\lambda}, \lambda = \frac{c}{\nu}$

$$= \frac{3 \times 10^{17}}{6 \times 10^{15}} = 0.5 \times 10^2 \text{ nm} = 50 \text{ nm}$$

35 (*c*) As we know that,

$$E = Nh\nu = N\frac{hc}{\lambda} \Rightarrow N = \frac{E\lambda}{hc} \quad \ldots\text{(i)}$$

$$E = 100\,\text{W (Js}^{-1}) \times 1\,\text{s} = 100\,\text{J}$$

Putting the value in eq. (i) we get

$$N = \frac{100\,\text{J} \times 560 \times 10^{-9}\text{ m}}{6.626 \times 10^{-34}\,\text{Js} \times 3 \times 10^{8}\text{ ms}^{-1}} = 2.82 \times 10^{20}$$

36 (*b*) Energy required for one Cl_2 molecule $= \dfrac{242 \times 10^3}{N_A}$ J

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

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

$$= \frac{6.626 \times 10^{-34} \times 3 \times 10^8 \times 6.02 \times 10^{23}}{242 \times 10^3}$$

$$= 494 \times 10^{-9} \text{ m}$$

$$= 494 \text{ nm}$$

37 (*c*) Given, $E_0 = 4.2$ eV

$$= 4.2 \times 1.60 \times 10^{-19} \text{ J} = 6.72 \times 10^{-19} \text{ J}$$

we know that, $(c) = 3 \times 10^8$ m/s [1 Å = 10^{-10} m]

$\because$ $$E = h\nu = \frac{hc}{\lambda}$$

$\therefore$ $$E = \frac{6.63 \times 10^{-34} \text{ Js} \times 3 \times 10^8 \text{ ms}^{-1}}{2000 \times 10^{-10} \text{ m}}$$

$$= 9.94 \times 10^{-19} \text{ J}$$

$\therefore$ Kinetic energy of electron emitted

$$= (9.94 - 6.72) \times 10^{-19} \text{ J}$$

$$= 3.22 \times 10^{-19} \text{ J}$$

38 (*d*) Given, $\lambda = 45 \text{ nm} = 45 \times 10^{-9}$ m [$\because$ 1 nm = 10^{-9} m]

The wavelength of light is related to its energy by the equation,

$$E = h\nu \qquad [\because \text{ where, } \nu = c/\lambda]$$

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

Hence, $$E = \frac{6.63 \times 10^{-34} \text{ Js} \times 3 \times 10^8 \text{ ms}^{-1}}{45 \times 10^{-9} \text{ m}}$$

$$= 4.42 \times 10^{-18} \text{ J}$$

Hence, the energy corresponds to the light of wavelength 45 nm is 4.42×10^{-18} J.

41 (*b*) Work function of metal $(\phi) = h\nu_0$

where, ν_0 = threshold frequency

Also, $$\frac{1}{2} m_e v^2 = h\nu - h\nu_0$$

or $$\frac{1}{2} m_e v^2 = h\nu - \phi \qquad \ldots\text{(i)}$$

$$\frac{1}{2} m_e v^2 = \frac{hc}{\lambda} - \phi \qquad \ldots\text{(ii)}$$

Given : $\lambda = 4000$ Å $= 4000 \times 10^{-10}$ m

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

$m_e = 9 \times 10^{-31}$ kg,

$c = 3 \times 10^8 \text{ ms}^{-1}$

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

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

$$\frac{1}{2} \times 9 \times 10^{-31} \text{ kg} \times (6 \times 10^5 \text{ ms}^{-1})^2 = \frac{6.626 \times 10^{-34} \text{ J s} \times 3 \times 10^8 \text{ ms}^{-1}}{4000 \times 10^{-10} \text{ m}} - \phi$$

$\therefore$ $$\phi = 1.62 \times 10^{-21} \text{ kgm}^2\text{s}^{-2} - 4.96 \times 10^{-19} \text{ J}$$

$$= 3.36 \times 10^{-19} \text{ J} \qquad [1 \text{ kg m}^2\text{s}^{-2} = 1\text{J}]$$

$$= 2.1 \text{ eV}$$

45 (*a*) According to Rydberg's equation,

$$\frac{1}{\lambda} = \frac{R_H}{hc}\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right) \quad \text{or} \quad \frac{1}{\lambda} \propto \left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

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) $$\frac{\lambda_L}{\lambda_P} = \frac{\frac{1}{3^2} - \frac{1}{\infty^2}}{\frac{1}{1^2} - \frac{1}{\infty^2}} = \frac{\frac{1}{9} - 0}{1 - 0} = \frac{1}{9}$$

(b) $$\frac{\lambda_{Bk}}{\lambda_{Pf}} = \frac{\frac{1}{5^2} - \frac{1}{\infty^2}}{\frac{1}{4^2} - \frac{1}{\infty^2}} = \frac{1}{25} \times \frac{16}{1} = \frac{16}{25}$$

(c) $$\frac{\lambda_P}{\lambda_{Pf}} = \frac{\frac{1}{5^2} - \frac{1}{\infty^2}}{\frac{1}{3^2} - \frac{1}{\infty^2}} = \frac{1}{25} \times \frac{9}{1} = \frac{9}{25}$$

(d) $$\frac{\lambda_B}{\lambda_{Bk}} = \frac{\frac{1}{4^2} - \frac{1}{\infty^2}}{\frac{1}{2^2} - \frac{1}{\infty^2}} = \frac{1}{16} \times \frac{4}{1} = \frac{1}{4}$$

Note Lyman = L $(n_1 = 1)$, Balmer = B $(n_1 = 2)$

Paschen = P $(n_1 = 3)$, Brackett = Bk $(n_1 = 4)$

Pfund = Pf $(n_1 = 5)$

46 (*a*) Balmer series of transitions in the spectrum of hydrogen atom fall in visible region. Lyman series fall in ultraviolet while Paschen, Brackett and Pfund fall in infrared region.

47 (*c*) I. Paschen series,

II. Balmer series and III. Lyman series

48 (*a*) Rydberg noted that all series of lines in the hydrogen spectrum could be described by the following expression :

$$\bar{\nu} = 109{,}677 \left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right] \text{cm}^{-1}$$

where, $n_1 = 1, 2 \ldots$

$n_2 = n_1 + 1, n_2 + 2 \ldots$

50 (*d*) The electronic transition from $n = 2$ to $n = 1$ will produce the shortest wavelength in Li^{2+}. The exact value can be calculated *via* Rydberg formula $\left(\because\ Z \propto \frac{1}{\lambda}\right)$

Formula to be used : For E_1, $n = 2$,
For E_2, $n = 1$

$$E = -2.178 \times 10^{18}\,\text{J}\left(\frac{Z^2}{n^2}\right)$$

$$E_1 - E_2 = \frac{hc}{\lambda}$$

$$\Rightarrow \quad \lambda = \frac{hc}{E_1 - E_2}$$

51 (*c*) Linear momentum is the product of mass (m) and linear velocity (v), similary angular momentum is the product of moment of inertia (I) and angular velocity (ω).

52 (*a*) The frequency of radiation is absorbed or emitted when transition occurs between two stationary states that differ in energy by ΔE, is given by

$$v = \frac{\Delta E}{h} = \frac{E_2 - E_1}{h}$$

where, E_1 and E_2 are the energies of the lower and higher allowed energy states respectively.

This expression is commonly known as Bohr's frequency rule.

53 (*b*) An electron can move only in those orbits for which its angular momentum is integral multiple of $h/2\pi$.

This means angular momentum is quantised.

54 (*b*) According to Bohr model, radius of orbit

$r_n = \frac{a_0 \times n^2}{Z}$, where a_0 = Bohr radius

(Radius of 1st orbit of H-atom)

For, Li^{2+}, $Z = 3$ and $n = 2$

$$\therefore \quad r = \frac{2^2 \times a_0}{3} = \frac{4a_0}{3}$$

55 (*a*) Given, $E = -2.178 \times 10^{18}\,\text{J}\left[\frac{Z^2}{n^2}\right]$

For hydrogen, $Z = 1$

So, $$E_1 = -2.178 \times 10^{-18}\,\text{J}\left[\frac{1}{1^2}\right]$$

$$E_2 = -2.178 \times 10^{-18}\,\text{J}\left[\frac{1}{2^2}\right]$$

Now, $E_1 - E_2$

i.e., $$\Delta E = 2.178 \times 10^{-18}\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{hc}{\lambda}$$

$$2.178 \times 10^{-18}\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = \frac{6.62 \times 10^{-34} \times 3.0 \times 10^8}{\lambda}$$

$$\therefore \quad \lambda \approx 1.21 \times 10^{-7}\,\text{m}$$

56 (*b*) Ionisation enthalpy of hydrogen atom is 1.312×10^6 J mol^{-1}. It suggests that the energy of electron in the ground state (first orbit) is -1.312×10^6 J mol^{-1}.

$$\Delta E = E_2 - E_1$$

$$= \left(\frac{-1.312 \times 10^6}{2^2}\right) - \left(\frac{-1.312 \times 10^6}{1}\right)$$

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

57 (*c*) According to Bohr's model, $mvr = \frac{nh}{2\pi}$

$$\Rightarrow \quad (mv)^2 = \frac{n^2h^2}{4\pi^2r^2}$$

$$\Rightarrow \quad \text{KE} = \frac{1}{2}mv^2 = \frac{n^2h^2}{8\pi^2r^2m} \quad \text{...(i)}$$

Also, Bohr's radius for H-atom is,

$$r = n^2a_0$$

On substituting 'r' in Eq. (i), we get

$$\text{KE} = \frac{h^2}{8\pi^2n^2a_0^2m}$$

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

58 (*a*) (a) The energy of the electron in a hydrogen atom has a negative sign for hydrogen atom because the energy of the electron in the atom is lower than the energy of a free electron at rest.

(b) A free electron at rest is an electron that is infinitely far away from the nucleus.

(c) The energy value assigned to free electron at rest is zero.

59 (*d*) Bohr radius $(r_n) = \in_0 n^2h^2$

$$r_n = \frac{n^2h^2}{4\pi^2me^2kZ}$$

$$\Rightarrow \quad k = \frac{1}{4\pi\in_0}$$

$$\therefore \quad r_n = \frac{n^2h^2\in_0}{\pi me^2Z} = n^2\frac{a_0}{Z}$$

where, m = mass of electron, e = charge of electron

h = Planck's constant,
k = Coulomb constant

$$r_n = \frac{n^2 \times 0.53}{Z}\ \text{Å}$$

Radius of nth Bohr orbit for H-atom = $0.53\,n^2$ Å

[$Z = 1$ for H-atom]

$\therefore$ Radius of 2nd Bohr orbit for H-atom

$$= 0.53 \times (2)^2$$

$$= 2.12\ \text{Å}$$

60 (*a*) Energy of electron in H-atom is determined by the expression :

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

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

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

63 (*b*) Frequency of first line in Balmer series can be calculated as

$$\nu = 3.29 \times 10^{15}\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]\text{s}^{-1}$$

$$= 3.29 \times 10^{15}\left[\frac{1}{(2)^2} - \frac{1}{(3)^2}\right]$$

$$= 3.29 \times 10^{15}\left[\frac{1}{4} - \frac{1}{9}\right]$$

$$= 3.29 \times 10^{15} \times \frac{5}{36}$$

$$= 4.57 \times 10^{14}\ \text{s}^{-1}.$$

64 (*c*) According to Rydberg's formula,

wave number $(\bar{\nu})$

$$= R_\text{H} Z^2 \left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]$$

Given, $n_i = n, n_f = 8$ [$\because$ it is the case of emission]

$$\bar{\nu} = R_\text{H} \times (1)^2 \left[\frac{1}{n^2} - \frac{1}{8^2}\right]$$

$$\bar{\nu} = R_\text{H}\left[\frac{1}{n^2} - \frac{1}{64}\right] = \frac{R_\text{H}}{n^2} - \frac{R_\text{H}}{64}$$

On comparing with equation of straight line,

$y = mx + C$, we get

Slope $= R_\text{H}$, intercept $= \frac{-R_\text{H}}{64}$

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

68 (*d*) Limitations of Bohr's model are :

(i) It fails to account for the finer details of the hydrogen atom spectrum observed by using sophisticated spectroscopic techniques.

(ii) It is unable to explain the spectrum of atoms other than hydrogen.

(iii) It is unable to explain the ability of atoms to form molecules by chemical bonds.

69 (*a*) Electron microscope is based on the principle of wave like behaviour of electrons. It is the powerful tool in research because it achieves a magnification of about 15 million times.

70 (*c*) $\lambda = 3.6\text{Å} = 3.6 \times 10^{-10}$ m

We know that,

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

Velocity of photon = Velocity of light

$$m = \frac{h}{\lambda v} = \frac{6.626 \times 10^{-34}\ \text{Js}}{(3.6 \times 10^{-10}\ \text{m})(3 \times 10^8\ \text{ms}^{-1})}$$

$$= 6.135 \times 10^{-33}\ \text{kg}$$

71 (*c*) The de-Broglie wavelength of an electron,

$$\lambda = \frac{h}{p}, \text{ or } \frac{h}{mv}$$

But, from the Bohr's postulate of quantisation of angular momentum of electrons, $l = mvr = \frac{nh}{2\pi}$,

$$\therefore \quad mv = \frac{nh}{2\pi r}$$

Upon substitution, $\lambda = \frac{h}{\left(\frac{nh}{2\pi r}\right)} = \frac{2\pi r}{n}$,

where, r is the radius of orbits in Bohr model $= \frac{n^2 a_0}{Z}$

$$\therefore \quad \lambda = \frac{2\pi \times n^2 \times a_0}{n \times Z} = \frac{2\pi n a_0}{Z} = 8\pi a_0$$

$$\begin{Bmatrix} Z = 1 \text{ for hydrogen} \\ n = 4 \text{ (given)} \end{Bmatrix}$$

72 (*b*) According to Bohr,

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

$$2\pi r = \frac{nh}{mv} = n\lambda \qquad \ldots\text{(i)} \qquad \left[\because \lambda = \frac{h}{mv}\right]$$

where, r = radius, λ = wavelength

n = number of orbit

Also, $$r = \frac{a_0 n^2}{Z} \qquad \ldots\text{(ii)}$$

where, a_0 = Bohr radius = 52.9 pm

Z = atomic number

On substituting the value of 'r' from Eq. (ii) to Eq. (i), we get

$$n\lambda = \frac{2\pi n^2 a_0}{Z} \Rightarrow \lambda = \frac{2\pi n a_0}{Z}$$

$$\lambda = 2\pi \times 2 \times 52.9 \qquad [\because n = 2, Z = 1]$$

$$= 211.6\ \pi\ \text{pm}$$

73 (*c*) The effect of Heisenberg uncertainty principle is significant only for motion of microscopic objects and negligible for the motion of macroscopic objects.

74 (*c*) By Heisenberg's uncertainty principle,

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

$$\Delta v = 0.005\% \text{ of } 600 \text{ m/s } = \frac{600 \times 0.005}{100} = 0.03$$

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

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

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

75 (*a*) According to Heisenberg,

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

where, Δx = uncertainty in position

m = mass of particle

Δv = uncertainty in velocity

According to question,

$$\Delta x_A \times m \times 0.05 = \frac{h}{4\pi}$$

$$\Delta x_B \times 5m \times 0.02 = \frac{h}{4\pi}$$

Divide Eq. (i) by Eq. (ii), then

$$\frac{\Delta x_A \times m \times 0.05}{\Delta x_B \times 5m \times 0.02} = 1$$

$\Rightarrow$ $\dfrac{\Delta x_A}{\Delta x_B} = \dfrac{5m \times 0.02}{m \times 0.05} = 2$

or $\dfrac{\Delta x_A}{\Delta x_B} = 2$

76 (*c*) $\Delta x \cdot \Delta v \geq \dfrac{h}{4\pi m}$

$$\Delta x = \frac{6.63 \times 10^{-34}}{4 \times 3.14 \times 9.1 \times 10^{-31} \times 300 \times 0.001 \times 10^{-2}}$$

$$= 0.01933 = 1.93 \times 10^{-2} \text{ m}$$

78 (*d*) As we know that,

$$\lambda = \frac{h}{mv} = \frac{h}{\sqrt{2m\text{KE}}}$$

$\because$ $\lambda \propto \dfrac{1}{\sqrt{m}}$

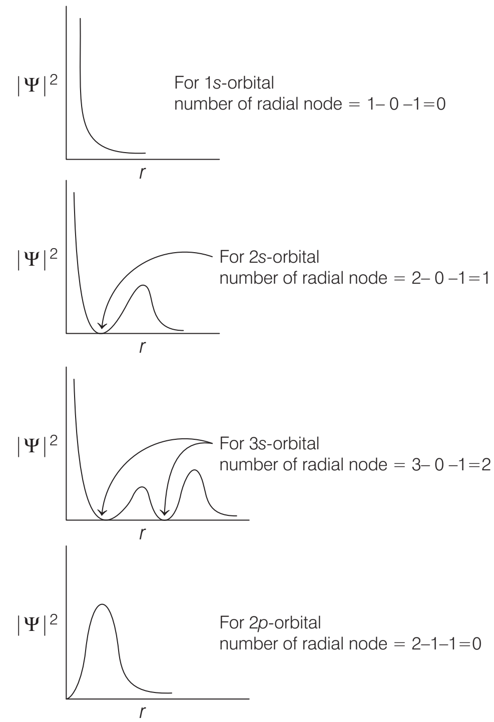
Mass of e, α and p are $m_e < m_p < m_\alpha$.

The correct order is $E_A < E_C < E_B$.

79 (*c*) Schrodinger equation is written as, $\hat{\mathbf{H}}\psi = E\psi$

In this equation, $\hat{\mathbf{H}}$ is a mathematical **operator called** Hamiltonian. It was introduced by Schrödinger from the expression for the total energy of the system.

80 (*d*) The graphs between $|\psi|^2$ 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 $|\psi|^2$ and r represents 2s-orbital.

81 (*c*) The total number of nodes are given by $(n - 1)$, i.e. sum of l angular nodes and radial nodes $(n - l - 1)$.

82 (*c*) Angular node $(l) = 3$

Total nodes = radial nodes + angular nodes

$$3 = (n - l - 1) + l$$

$$3 = n - 1 \Rightarrow n = 4$$

$\therefore$ Orbital having 3 angular nodes and 3 total nodes is $= nl = 4f$ [$\because l = 3$ for f- orbital]

84 (*a*) The stability of an electron in multielectron system is because total attractive interactions are more than the total repulsive interactions.

85 (*d*) Degenerate orbitals means the orbitals of the same subshell of the same main shell, i.e. their n and l values should be same for both the given sets:

(a) (i) $3p_y$ (ii) $3d_{yz}$

(b) (i) $3p_x$ (ii) $3d_{xy}$

(c) (i) $4s$ (ii) $3d_{xy}$

(d) (i) $3d_{x^2-y^2}$ (ii) $3d_{x^2-y^2}$

Thus, $3d_{x^2-y^2}$ and $3d_{x^2-y^2}$ represents pair of degenerate orbitals.

86 (*a*) Given, atomic number of Rb, $Z = 37$

Thus, its electronic configuration is $[\text{Kr}]5s^1$. Since, the last electron or valence electron enter in 5s subshell.

So, the quantum numbers are $n = 5, l = 0$, (for s-orbital) $m = 0 (\because m = +l \text{ to } -l), s = +1/2 \text{ or } -1/2$.

87 (d) The order of energy of orbitals can be calculated from $(n + l)$ rule. The lower the value of $(n + l)$ for an orbital, lower is its energy. If two orbitals have same $(n + l)$ value, the orbital with lower value of n has the lower energy.

(a) $6p = 6 + 1 = 7$ (b) $5f = 5 + 3 = 8$

(c) $4d = 4 + 2 = 6$ (d) $5p = 5 + 1 = 6$

$\therefore$ The order of decreasing energy will be

$$5f > 6p > 5p > 4d.$$

88 (b) The correct representation should be $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ for the copper which has atomic number 29. Due to extra stability of fully-filled orbital of d-subshell, the last electron enter into d-orbital instead of s-orbital.

89 (a) With the saturation of $3d$ orbitals, the filling up of the $4p$ orbitals starts at Ga and is completed at Kr.

90 (c)

Symbols	=	K	L	M	N
$_{19}X$	=	2	8	8	1
$_{21}Y$	=	2	8	9	2
$_{25}Z$	=	2	8	13	2

Hence, the order of number of electrons in M-shell is $Z > Y > X$.

91 (b) Electronic configuration of Fe^{2+} is $[Ar]\ 3d^6 4s^0$

$\therefore$ Number of d-electrons = 6

$$Mg = 1s^2 2s^2 2p^6 3s^2 \text{ (6}s\text{-electrons)}$$

It matches with the the $6d$-electrons of Fe^{2+}

$$Cl = 1s^2 2s^2 2p^6 3s^2 3p^5 \text{ (11}p\text{-electrons)}$$

It does not match with the $6d$-electrons of Fe^{2+}.

$$Cr = [Ar] 3d^6 4s^2 \text{ (6}d\text{-electrons)}$$

It matches with the $6d$-electrons of Fe^{2+}.

$$Ne = 1s^2 2s^2 2p^6 \text{ (6}p\text{-electrons)}$$

It matches with the $6d$-electrons of Fe^{2+}.

Hence, Cl has $11p$-electrons which does not matches in number with $6d$-electrons of Fe^{2+}.

92 (a) According to quantum mechanical atom model, for each value of n (principal quantum number), there are 'n' different values of l (azimuthal quantum number), i.e. $l = 0, 1, 2, \ldots, (n - 1)$. And, for each value of l, there are $2l + 1$ different values of m_l (magnetic quantum number), i.e. $m_l = 0, \pm 1, \pm 2 \ldots \pm l$.

$\therefore$ Total number of possible combinations of n, l and m_l, for a given value of n is n^2, and each such combination is associated with an orbital. Each orbital can occupy a maximum of two electrons, having a different value of spin quantum number (m_s), which are $+\frac{1}{2}$ or $-\frac{1}{2}$.

$\therefore$ Number of orbitals associated with $n = 5$ is $n^2 = 25$.

Each of those orbitals can be associated with $m_s = +\frac{1}{2}$ as well as $m_s = -\frac{1}{2}$.

$\therefore$ Answer = 25

93 (d) Aufbau principle does not give the correct arrangement of filling up of atomic orbitals in copper and chromium because half-filled and completely filled electronic configuration of Cr and Cu have lower energy and therefore, more stable.

$$Cr(Z = 24) = 1s^2, 2s^2 2p^6, 3s^2 3p^6 3d^5, 4s^1$$

$$Cu(Z = 29) = 1s^2, 1s^2 2p^6, 3s^2 3p^6 3d^{10}, 4s^1$$

94 (c) Statement (c) is incorrect.

It's correct form is as follows :

The behaviour of these particles in the magnetic or electric field is opposite to that observed for electron or cathode rays.

Rest other statements are correct.

96 (d) Statement (d) is incorrect.

It's correct form is as follows :

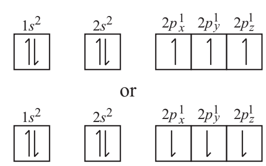
Millikan concluded that the magnitude of electrical charge, q, on the droplets is always an integral multiple of the electrical charge, e, that is, $q = ne$, where $n = 1,2,3$.

Rest other statements are correct.

100 (a) Statement (a) is incorrect.

It's correct form is as follows :

According to Hund's rule "the pairing of electrons in the orbitals of a particular subshell does not takes place until all the orbitals of a subshell are singly occupied. Moreover, the singly orbitals must have the electrons with parallel spin, i.e.



Rest other statements are correct.

101 (d) Statement (d) is incorrect.

It's correct form is as follows :

Both $2s$ and $2p$ will have equal energy as their $n = 2$.

Rest other statements are correct.

102 (c) Statements I, III and IV are correct, while statement II is incorrect. It's correct form is as follows :

These rays themselves are not visible but their behaviour can be observed with the help of certain kind of materials (fluorescent or phosphorescent) which glow when hit by them.

105 (*b*) Statement III is incorrect.
It's correct form is as follows :

X-rays are not deflected by electric and magnetic fields and have a very high penetrating power through the matter and that is the reason that these rays are used to study the interior of the objects.

Rest other statements are correct.

106 (*c*) Statements I and IV are incorrect.
It's correct form are as follows :

I The presence of positive charge on the nucleus is due to the presence of protons in the nucleus.

IV Protons and neutrons present in the nucleus is collectively known as nucleons.

Rest other statements are correct.

107 (*a*) The oscillating electric and magnetic fields produced by oscillating charged particles are perpendicular to each other and also perpendicular to the direction of propagation of the wave.

Thus, statements I and III are correct.

108 (*b*) Statements II and III are correct, while the statement I is incorrect. It's correct form is as follows :

The speed of light depends upon the nature of the medium through which it passes.

110 (*c*) Statements I and III are correct, while statement II is incorrect. It's correct form is as follows :

The spectrum of H atom and He^+ ion differ in wavelength and energies of lines emitted.

111 (*d*) Statement II is incorrect.
It's correct form is as follows :

In case of absorption spectrum, $n_f > n_i$ and in case of emission spectrum $n_i > n_f$.

Rest other statements are correct.

118 (*b*) Statements I and IV are correct, while the other statements are incorrect.

Corrected form are as follows :

II. The principal quantum number determines the size and to large extent the energy of the orbital.

III. The magnetic quantum number gives information about the spatial orientation of the orbital with respect to standard set of coordinate axis.

119 (*d*) Statements III and IV are correct, while the other statements are incorrect.

Corrected form are as follows :

I. The shape of the orbitals is given by azimuthal quantum number.

II. In an atom, all electrons travel with the different velocity.

120 (*a*) X-rays are not deflected by the electric and magnetic fields and have a very high penetrating power through the matter and it is the reason that these rays are used to study the interior of the objects.

Thus, both A and R are correct and R is the correct explanation of A.

121 (*a*) Most of the α-particles passed through the foil remain undeflected as most of the space in the atoms is empty.

Thus, both A and R are correct and R is the correct explanation of A.

122 (*a*) Electromagnetic waves can move in vacuum because these do not require medium to propagate.

Thus, both A and R are correct and R is the correct explanation of A.

123 (*c*) When an iron rod is heated in a furnace, it first turns to dull red and become more red as the temperature increases. it becomes white and then blue as the temperature become very high.

Frequency of emitted radiation goes from lower frequency to higher frequency as the temperature increases.

The red colour lies in the lower frequency while blue colour belongs to the higher frequency region of electromagnetic spectrum.

Thus, A is correct but R is incorrect.

124 (*a*) Classical mechanics fails to explain the behaviour of microscopic particles because it ignores the concept of dual behaviour of matter. It is explained in quantum mechanics.

Thus, both A and R are correct and R is the correct explanation of A.

125 (*a*) Red light of any brightness may shine on a piece of potassium metal for hours but no photoelectrons are ejected. But as soon as even a very weak yellow light shines on the potassium metal, photoelectric effect is observed. This is because, the number of electrons ejected does depend upon the brightness of light, the kinetic energy of the ejected electron does not.

Thus, both A and R are correct and R is the correct explanation of A.

126 (*d*) Kinetic energy of the ejected electron is proportional to the frequency of the electromagnetic radiation.

∴ Greater the energy possessed by the photon, greater will be transfer of energy to the electron and greater the kinetic energy of the ejected electron.

Thus, A is incorrect but R is correct.

127 (*b*) Energies of the orbitals in hydrogen or hydrogen like species depend only on the quantum number '*n*'. Energies of the orbitals in multielectron atoms depend on quantum numbers '*n*' and '*l*', i.e. more than 1 quantum number.

Thus, both A and R are correct but R is not the correct explanation of A.

129 (*a*) For a given principal quantum number, *s, p, d, f, …* subshells, all have different energies because mutual repulsion exists among the electrons in a multielectron atoms.

Thus, both A and R are correct and R is the correct explanation of A.

130 (*b*) *s*-orbital electron will be more tightly bound to the nucleus than *p*-orbital electron.

Z_{eff} experienced by the electron decreases with increase of azimuthal quantum number (l).

Thus, both A and R are correct but R is not the correct explanation of A.

131 (*a*) Half-filled and fully-filled degenerate set of orbitals acquire extra stability because of the symmetry.

Thus, both A and R are correct and R is the correct explanation of A.

132 (*d*) Rutherford found that α-rays consist of high energy particles carrying two units of positive charge and four units of atomic mass. α-particles are helium nuclei. β-rays are negatively charged particle similar to electrons. γ-rays are high energy radiations like X-rays, are neutral in nature and do not consist of particles.

Thus, the correct match is

$$A \rightarrow 3, B \rightarrow 1, C \rightarrow 2$$

133 (*c*)

(A) Radio frequency region (around 10^6 Hz) used for broadcasting.

(B) Microwave region (around 10^{10} Hz) used for radar.

(C) Infrared region (around 10^{13} Hz) used for heating.

(D) Ultraviolet region (around 10^{16} Hz) used for solar radiations.

Thus, the correct match is

$A \rightarrow 4$ (iii), $B \rightarrow 1$(ii), $C \rightarrow 2$(i), $D \rightarrow 3$(iv)

134 (*a*)

Value of '*n*'	Value of '*l*'	Subshell notation
1	0	1*s*
2	0	2*s*
3	1	3*p*
3	2	3*d*
4	3	4*f*
4	0	4*s*

Thus, the correct match is

$A \rightarrow$ II(v), $B \rightarrow$ I(vi), $C \rightarrow$ VI(iii), $D \rightarrow$ V(iv),

$E \rightarrow$ IV(i), $F \rightarrow$ III(iv)

136 (*b*) Frequency, $\nu = c/\lambda$

$$1 \text{ nm} = 10^{-9} \text{ m}$$

$$580 \text{ nm} = 580 \times 10^{-9} \text{ m}$$

$$= 580 \times 10^{-7} \text{ cm}$$

$$\text{Wave number, } \bar{\nu} = \frac{1}{\lambda} = \frac{1}{580 \times 10^{-7} \text{ cm}}$$

$$= 1.724 \times 10^4 \text{ cm}^{-1}$$

137 (*b*) Energy,

$$E = \frac{hc}{\lambda} = \frac{6.626 \times 10^{-34} \text{ Js} \times 3.0 \times 10^8 \text{ ms}^{-1}}{4000 \times 10^{-12} \text{ m}}$$

(1 pm $= 10^{-12}$ m)

$$= 4.9695 \times 10^{-17} \text{ J}$$

$$\text{Number of photons, } N = \frac{1 \text{ J}}{4.9695 \times 10^{-17} \text{ J}}$$

$$= 2.0122 \times 10^{16} \text{ photons}$$

138 (*c*) Number of lines produced when electron from *n*th shell drops to ground state $= n\,(n-1)/2$

When $n = 6$,

$$\text{number of lines produced} = \frac{6\,(6-1)}{2} = \frac{6 \times 5}{2} = 15$$

139 (*a*) Energy of electron in uni-electron atomic system,

$$E_n = \frac{-2\pi^2 mZ^2 e^4}{n^2 h^2}$$

For H-atom, ionisation energy (IE) $= E_\infty - E_1$

$$\text{IE} = 0 - \left(-\frac{2\pi^2 me^4 1^2}{1^2 h^2}\right) \text{(where, } Z = 1 \text{ and } n = 1 \text{ for H-atom)}$$

$$\text{IE} = 2.18 \times 10^{-18} \text{ J atom}^{-1}$$

For He^+, IE $= E_\infty - E_1$

$$= 0 - \left(\frac{-2\pi^2 me^4 2^2}{1^2 h^2}\right) = 4 \times \frac{2\pi^2\, me^4}{h^2}$$

$$= 4 \times 2.18 \times 10^{-18}$$

$$= 8.72 \times 10^{-18} \text{ J atom}^{-1}$$

$\therefore$ The energy required for the process

$$He^+ \longrightarrow He^{2+} + e^- \text{ is } 8.72 \times 10^{-18} \text{ atoms}^{-1}.$$

140 (*b*) Statement (b) is incorrect. It's correct form is as follows :

The mass of electron is not equal to the mass of neutron. It is much less than that of neutrons.

Rest other statements are correct.

141 (*d*) Statement (d) is incorrect. It's correct form is as follows :

Cathode rays do not depend upon the nature of gas present in the cathode rays tube.

Rest other statements are correct.

142 (*c*) Rutherford's model does not provide any idea about the movement of electrons in a circular path of fixed energy called orbits.

146 (*b*) Alpha particle (He^{2+}) has the shortest wavelength.

It can be calculated through de-Broglie's wavelength (λ).

148 (b) $_{24}Cr = [Ar]3d^5, 4s^1$ $_{24}Cr^{3+} = [Ar]3d^3$

$_{26}Fe = [Ar]3d^6, 4s^2$ $_{26}Fe^{3+} = [Ar]3d^5$

$_{25}Mn = [Ar]3d^5, 4s^2$ $_{25}Mn^{2+} = [Ar]3d^5$

$_{27}Co = [Ar]3d^7, 4s^2$ $_{27}Co^{3+} = [Ar]3d^6$

$_{21}Sc = [Ar]3d^1, 4s^2$ $_{21}Sc^{3+} = [Ar]$

Thus, Fe^{3+} and Mn^{2+} have the same electronic configuration.

150 (c) Total number of orbitals associated with n^{th} shell $= n^2$

$\therefore$ Total number of orbitals associated with third shell $= (3)^2 = 9$

151 (a) Orbital angular momentum,

$$mvr = \frac{h}{2\pi}\sqrt{l(l+1)}.$$

Hence, it depends only on 'l'. l can have values ranging from 0 to $(n-1)$.

152 (d) Statement (d) is incorrect. It's correct form is as follows :

The probability density of electrons in 2s-orbital first increases then decreases and after that it begins to increases again as distance increases from nucleus.

Rest other statements are correct.

153 (d) For an atom there are $n-l-1$ radial nodes and $(n-1)$ total nodes.

Number of radial nodes for $3p$-orbital $= n - l - 1$

$= 3 - 1 - 1 = 1$

154 (d) Statement (d) is correct, while the statements (a), (b) and (c) are incorrect.

Corrected form are as follows :

(a) Electrons in 2s and 2p-orbitals have different screening effect.

Hence, their Z_{eff} is different.
Z_{eff} of $2s$-orbital $> Z_{eff}$ of $2p$-orbital
Thus, it is not correct.

(b) Energy of $2s$-orbital < energy of $2p$-orbital
Thus, it is not correct.

(c) Z_{eff} of $1s$-orbital $\neq Z_{eff}$ of $2s$-orbital
Thus, it is incorrect.