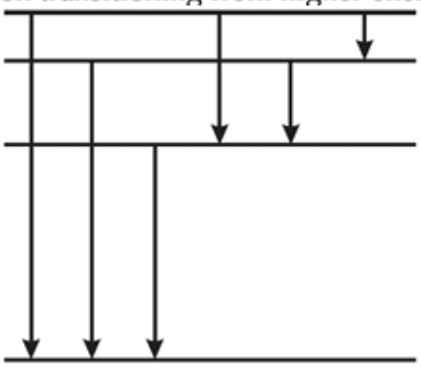
UNIT 12

ATOMS

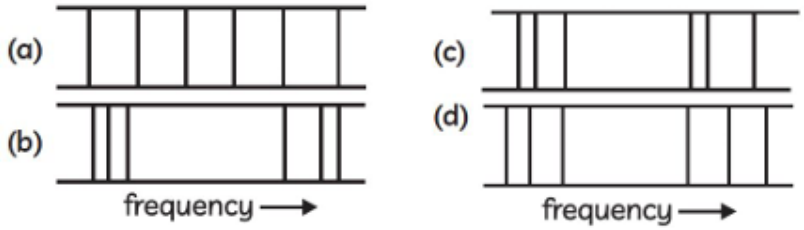
SECTION – A

Questions 1 to 10 carry 1 mark each.

1. The emission spectrum of an element is the spectrum of frequencies of EM radiations emitted due to electrons making a transition from a higher energy state to a lower energy state.
The given diagram shows electron transitioning from higher energy states to lower energy states.



Which of the following spectrums most closely corresponds to the above transitions?



2. In Balmer series of hydrogen atom, as the wavelength of spectral lines decreases, they appear:
(a) equally spaced and equally intense. (b) further apart and stronger in intensity.
(c) closer together and stronger in intensity. (d) closer together and weaker in intensity.

3. The radius (rn) of nth orbit in Bohr model of hydrogen atom varies with n as:
(a) $r_n \propto n$ (b) $r_n \propto 1/n$ (c) $r_n \propto n^2$ (d) $r_n \propto 1/n^2$

4. Specify the transition of electron in the wavelength of the line in the Bohr model of hydrogen atom which gives rise to the spectral line of highest wavelength.
(a) n = 3 to n = 1 (b) n = 3 to n = 2 (c) n = 4 to n = 1 (d) n = 4 to n = 2

5. When alpha particles are sent through a thin gold foil, most of them go straight through the foil, because:
(a) alpha particles are positively charged
(b) the mass of an alpha particle is more than the mass of an electron
(c) most of the part of an atom is empty space

(d) alpha particles move with high velocity

6. An electron with angular momentum L moving around the nucleus has a magnetic moment given by:
(a) eL/2m (b) eL/3m (c) eL/4m (d) eL/m

7. The energy of an electron in nth orbit of hydrogen atom is, $E_n = -13.6/n^2$ eV. The negative sign of energy indicates that:
(a) electron is free to move.
(b) electron is bound to the nucleus.
(c) kinetic energy of electron is equal to potential energy of electron.
(d) atom is radiating energy.

8. Which of the following statements is NOT correct according to Rutherford model?
(a) Most of the space inside an atom is empty.
(b) The electrons revolve around the nucleus under the influence of Coulomb force acting on them.
(c) Most part of the mass of the atom and its positive charge are concentrated at its centre.
(d) The stability of atom was established by this model.

In the following questions 9 and 10, a statement of assertion (A) is followed by a statement of reason (R). Mark the correct choice as:
(a) Both assertion (A) and reason (R) are true and reason (R) is the correct explanation of assertion (A).
(b) Both assertion (A) and reason (R) are true but reason (R) is not the correct explanation of assertion (A).
(c) Assertion (A) is true but reason (R) is false.
(d) Assertion (A) is false but reason (R) is true.

9. **Assertion (A):** Bohr postulated that the electrons in stationary orbits around the nucleus do not radiate energy.
Reason (R): According to classical Physics, all accelerated electrons radiate energy.

10. **Assertion (A):** According to Bohr's atomic model the ratio of angular momenta of an electron in first excited state to that in ground state is 2 : 1.
Reason (R): According to Bohr's theory the angular momentum of the electron is directly proportional to the principal quantum number.

SECTION – B

Questions 11 to 14 carry 2 marks each.

11. What is meant by ionisation energy? Write its value for hydrogen atom?

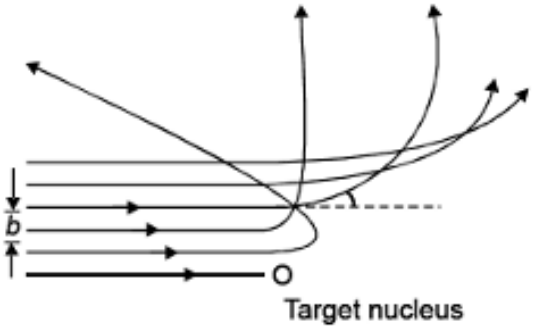
OR

The ground state energy of hydrogen atom is –13.6 eV. What is the potential energy and kinetic energy of an electron in the third excited state?

12. A hydrogen atom is in its third excited state.
(a) How many spectral lines can he emitted by it before coming to the ground state? Show these transitions in the energy level diagram.
(b) In which of the above transitions will the spectral line of shortest, wavelength be emitted?

OR

The trajectories, traced by different α-particles, in Geiger-Marsden experiment were observed as shown in the figure.



(a) What names are given to the symbols 'b' and 'θ' shown here?
(b) What can we say about the values of b for (i) $\theta = 0°$ (ii) $\theta = \pi$ radians?

13. The ground state energy of hydrogen atom is –13·6 eV. If an electron makes a transition from an energy level –1·51 eV to –3·4 eV, calculate the wavelength of the spectral line emitted and name the series of hydrogen spectrum to which it belongs.

OR

Write shortcomings of Rutherford atomic model. Explain how these were overcome by the postulates of Bohr's atomic model.

14. Name the spectral series for a hydrogen atom which lies in the visible region. Find the ratio of the maximum to the minimum wavelengths of this series.

OR

An electron in a hydrogen atom makes transitions from orbits of higher energies to orbits of lower energies.
(a) When will such transitions result (i) Lyman, (ii) Balmer series?
(b) Find the ratio of the longest wavelength in Lyman series to the shortest wavelength in Balmer series.

SECTION – C

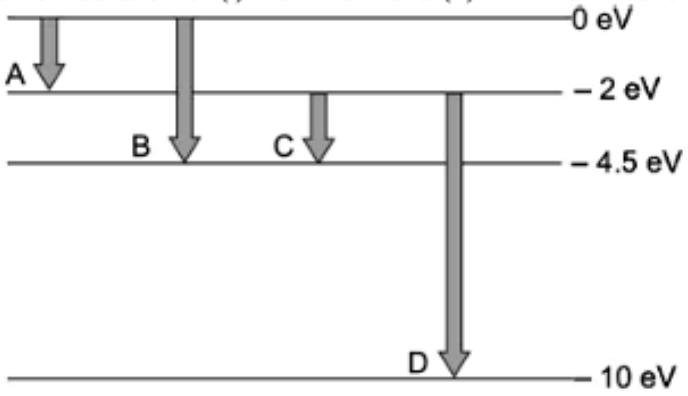
Questions 15 to 17 carry 3 marks each.

15. Calculate the de-Broglie wavelength associated with the electron revolving in the first excited state of hydrogen atom. The ground state energy of the hydrogen atom is –13.6 eV.

OR

(i) State Bohr postulate of hydrogen atom that gives the relationship for the frequency of emitted photon in a transition.
(ii) An electron jumps from fourth to first orbit in an atom. How many maximum number of spectral lines can be emitted by the atom? To which series these lines correspond?

16. The energy levels of a hypothetical atom are shown alongside. Which of the shown transitions will result in the emission of a photon of wavelength 275 nm? Which of these transitions correspond to emission of radiation of (i) maximum and (ii) minimum wavelength?



OR

Determine the distance of closest approach when an alpha particle of kinetic energy 4.5 MeV strikes a nucleus of Z = 80, stops and reverses its direction.

17. Draw the graph showing variation of scattered particles detected (N) with the scattering angle (θ) in Geiger-Marsden experiment. Write two conclusions that you can draw from this graph. Obtain the expression for the distance of closest approach in this experiment.

OR

Derive an expression for the frequency of radiation emitted when a hydrogen atom de-excites from level n to level $(n - 1)$. Also show that for large values of n, this frequency equals to classical frequency of revolution of an electron.

SECTION – D

Questions 18 carry 5 marks.

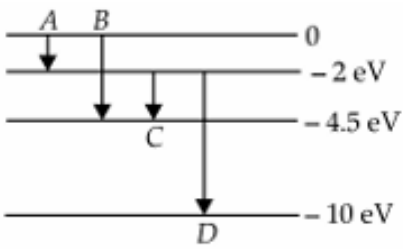
18. Draw a schematic arrangement of the Geiger-Marsden experiment. How did the scattering of α-particles of a thin foil of gold provide an important way to determine an upper limit on the size of the nucleus? Explain briefly.

OR

(a) State Bohr's postulate to define stable orbits in hydrogen atom. How does de Broglie's hypothesis explain the stability of these orbits?

(b) A hydrogen atom initially in the ground state absorbs a photon which excites it to the n = 4 level. Estimate the frequency of the photon.

(c) The energy levels of a hypothetical atom are given below. Which of the shown transitions will result in the emission of photon of wavelength 275 nm?

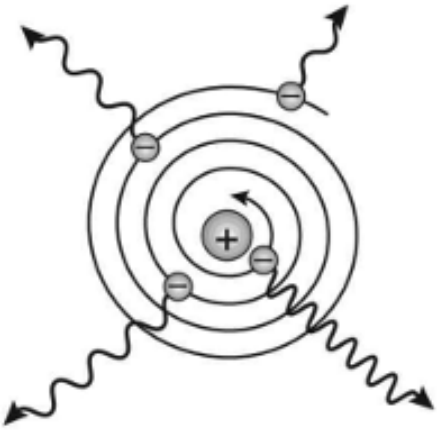


SECTION – E (Case Study Based Questions)

Questions 19 to 20 carry 4 marks each.

19. Case-Study 1: Read the following paragraph and answer the questions.

The Bohr Atom: Rutherford's model of the atom, although strongly supported by evidence for the nucleus, is inconsistent with classical physics. An electron moving ina circular orbit round a nucleus is accelerating and according to electromagnetic theory it should emit radiation continuously and so lose energy. If this happened the radius of the orbit would decrease and the electron would spiral into the nucleus. Evidently either this model of the atom or the classical theory of radiation requires modification.



In 1913, in an effort to overcome this paradox, Bohr, drawing inspiration from the success of the quantum theory in solving other problems involving radiation and atoms, made two revolutionary suggestions.

Electrons can revolve round the nucleus only in certain 'allowed orbits' and while they are in these orbits they do not emit radiation. An electron in an orbit has a definite amount of energy. It possesses kinetic energy because of its motion and potential energy on account of the attraction of the nucleus. Each allowed orbit is therefore associated with a certain quantity of energy, called the 'energy of the orbit', which equals the total energy of an electron in it.
An electron can 'jump' from one orbit of energy E_2 to another of lower energy E_1 and the energy difference is emitted as one quantum of radiation of frequency f given by Planck's equation
$E_2 - E_1 = hf$.

(*i*) According to Bohr's model of hydrogen atom, an electron can revolve round a proton indefinitely, if its path is
(*a*) a perfect circle of any radius (*b*) a circle of constantly decreasing radius
(*c*) a circle of an allowed radius (*d*) an ellipse

(*ii*) In Bohr model of hydrogen atom, which of the following is quantised?
(*a*) Linear velocity of electron (*b*) Angular velocity of electron
(*c*) Linear momentum of electron (*d*) Angular momentum of electron

(*iii*) For an electron in the second orbit of hydrogen, what is the moment of momentum as per the Bohr's model?
(*a*) 2p*h* (*b*) p*h* (*c*) *h*/p (*d*) 2*h*/p

OR

An electron orbiting in H atom has energy level –3.4 eV. Its angular momentum will be
(*a*) 2.1×10^{-34} Js (*b*) 2.1×10^{-20} Js (*c*) 4×10^{-20} Js (*d*) 4×10^{-34} Js
(*iv*) The Bohr's model is applicable to which kind of atoms?
(*a*) Having one electron only (*b*) Having two electrons
(*c*) Having eight electrons (*d*) Having more than eight electrons

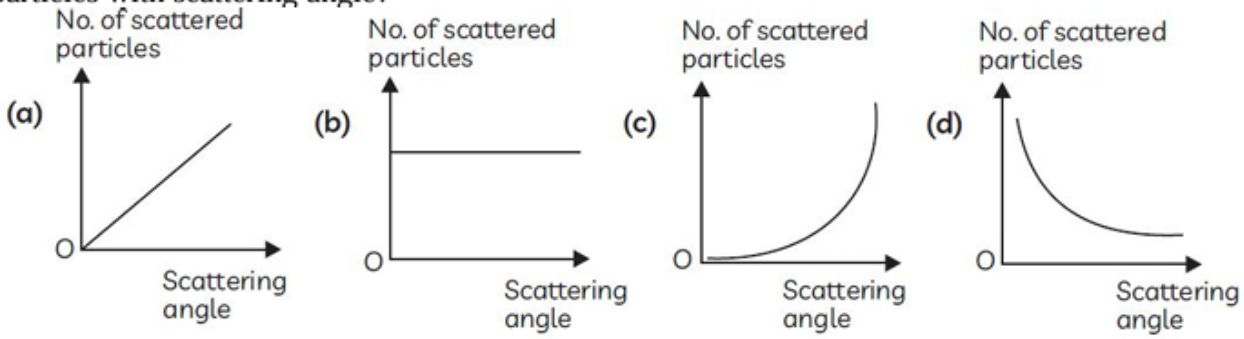
20. J. J. Thomson's "plum pudding" model was unable to account for some scientific findings about the atomic structure of elements. As a result, British scientist Ernest Rutherford conducted an experiment in 1909 and, based on the results, developed the Rutherford atomic model and the atomic structure of the elements. At the time, there was still no clear model that defined atoms. He conducts an experiment in which he bombards a thin sheet of gold with alpha particles, observing the interactions between the particles and the foil as well as their route.
First, he noticed that the majority of α-particles that are fired at the gold sheet pass through the foil without being deflected, indicating that the majority of the space is vacant.

The fact that some of the α-particles were partially deflected through the gold sheet at extremely small angles indicates that the positive charge in an atom is not spread uniformly. In an atom, the positive charge is confined to a relatively small volume. Only a very small percentage of the

alpha particles (1–2%) were redirected, meaning that only a very small fraction of α-particles deflected nearly 180 degrees. This demonstrates that, in comparison to the entire volume of an atom, the positively charged particles' volume is extremely small.

(i) Which of the following was not a conclusion drawn by Rutherford?
(a) Most of the mass of atoms is concentrated at their center and it is known as the nucleus.
(b) Nucleus consists of protons and neutrons (only the particles with significant mass).
(c) Electrons revolve around the positively charged nucleus in parabolic orbits.
(d) Coulomb's force provides the necessary centripetal acceleration for the electron.

(ii) Which of the following graph correctly represents the variation of number of scattered particles with scattering angle?



(iii) Which of the following is a limitation of Rutherford's model?
(a) It cannot explain the charge distribution of the atom.
(b) It cannot explain the stability of atoms.
(c) It cannot explain the presence of electronic orbits.
(d) It cannot explain the existence of a nucleus.

(iv) According to the Bohr's model of hydrogen atom, which of the following orbit will not be available for electron to revolve in?
(a) Orbit A in which electrons have an angular momentum of $2h/\pi$.
(b) Orbit B in which electrons have an angular momentum of $h/3\pi$
(c) Orbit C in which electrons have an angular momentum of $3h/\pi$
(d) Orbit D in which electrons have an angular momentum of $h/2\pi$