UNIT VIII ATOMS AND NUCLEI

CHAPTER 12-ATOMS

Gist

- Early atomic models and their limitations. Thomson's model of atom

-Rutherford's alpha ray scattering experiment

-Rutherford's model of atom .

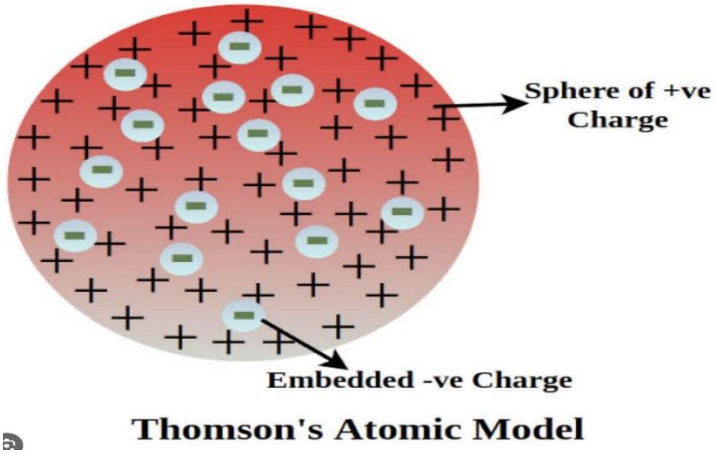
- Bohr's model of the atom and its postulates.

- Hydrogen atom spectrum and energy level transitions.

1. **Introduction to Atomic Models**

- Dalton's Atomic Theory: Early concept of the atom as an indivisible particle.

- Discovery of Electrons and Nucleus : Introduction to the electron discovered by J.J. Thomson and the nucleus discovered by Rutherford through the gold foil experiment.

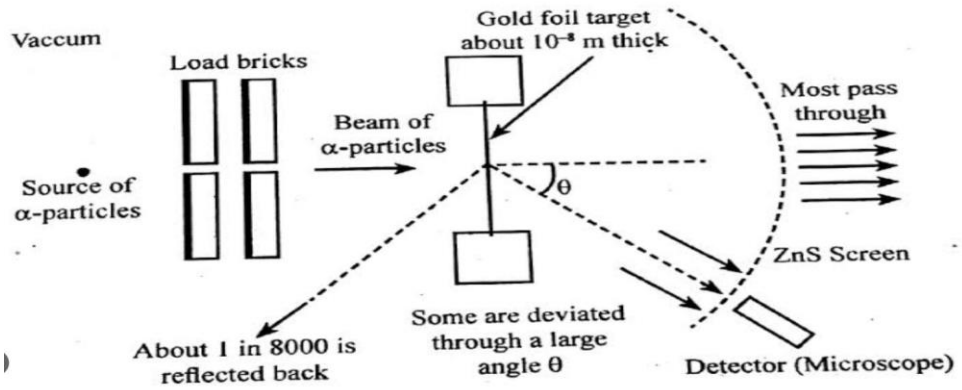


Thomson's Atomic Model

2. **Rutherford's Model of the Atom**

- Description of the gold foil experiment.

Setup of the Gold Foil Experiment



Apparatus - A source of alpha particles (helium nuclei), a thin sheet of gold foil, a fluorescent screen, and a detector.

Alpha Particles : High-energy particles emitted from a radioactive source, typically radium or polonium.

Gold Foil : Extremely thin sheet of gold, only a few atoms thick.

- Detection Screen : Circular screen coated with zinc sulfide that fluoresces when struck by alpha particles.

Procedure

1. Alpha Particle Emission: The alpha particles were directed at the thin gold foil.

2. Observation: The particles that passed through or were deflected by the foil struck the fluorescent screen, producing tiny flashes of light (scintillations).

3. Detection: A microscope was used to observe and count the scintillations at various angles relative to the incident beam.

Observations

1. Most Particles Passed Through:The majority of the alpha particles went straight through the gold foil with little to no deflection, suggesting that most of the atom is empty space.

2. Some Particles Deflected : A small number of alpha particles were deflected at small angles, indicating the presence of a positive charge within the atom that repelled the positively charged alpha particles.

3. Very Few Particles Reflected : A very small fraction of the particles (about 1 in 8000) bounced back at angles greater than 90 degrees, indicating a very dense, positively charged core within the atom.

Conclusions

1. Existence of Nucleus : The large deflections and reflections of alpha particles could only be explained if the positive charge and most of the mass of the atom were concentrated in a small, dense region at the center of the atom. This region was named the nucleus.

2. Atomic Model : Rutherford proposed a new model of the atom, where the atom consists of a small, dense nucleus containing protons (and later, neutrons) surrounded by electrons that orbit the nucleus, much like planets orbit the sun.

3. Empty Spacen: The fact that most alpha particles passed through the foil without deflection indicated that the majority of the atom’s volume is empty space.

Significance

- Disproval of Thomson’s Model : The experiment disproved J.J. Thomson’s plum pudding model, which suggested that electrons were uniformly distributed within a positively charged “soup.”

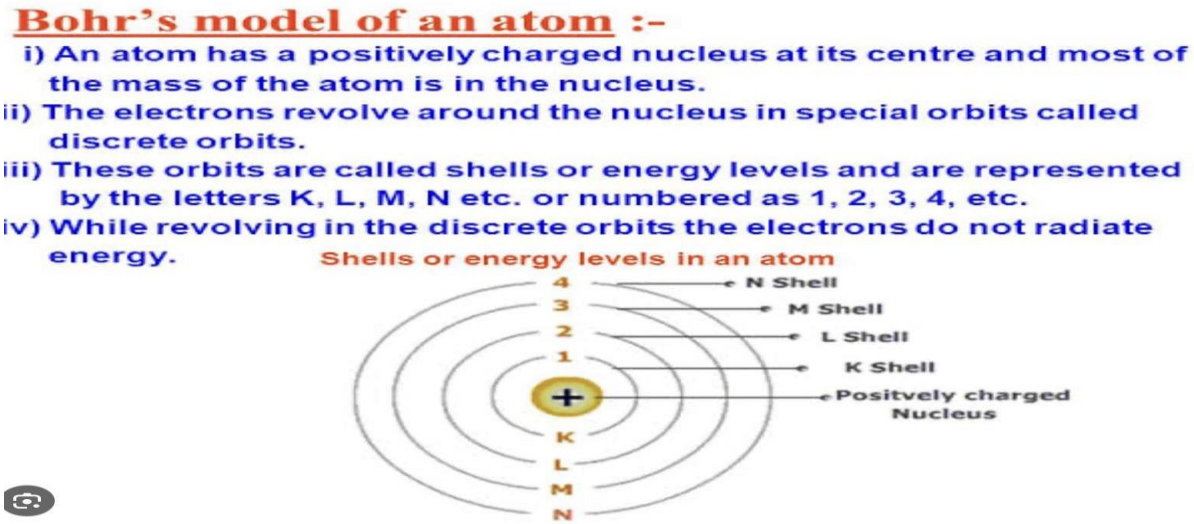
- Foundation for Modern Atomic Theory : The discovery of the nucleus paved the way for the development of the Bohr model and subsequent quantum mechanical models of the atom.

The gold foil experiment was crucial in advancing our understanding of atomic structure, leading to the realization that atoms have a tiny, dense nucleus surrounded by electrons, fundamentally changing the way we understand matter at a microscopic level.

- Rutherford's nuclear model: Electrons orbit a dense, positively charged nucleus.

- Limitations: Stability of atoms and spectrum of hydrogen couldn't be explained.

3. Bohr's Model of the Atom



- Postulates of Bohr's theory: Quantized electron orbits, stationary states, and energy levels.

- Energy quantization: Electrons can only occupy certain discrete orbits.

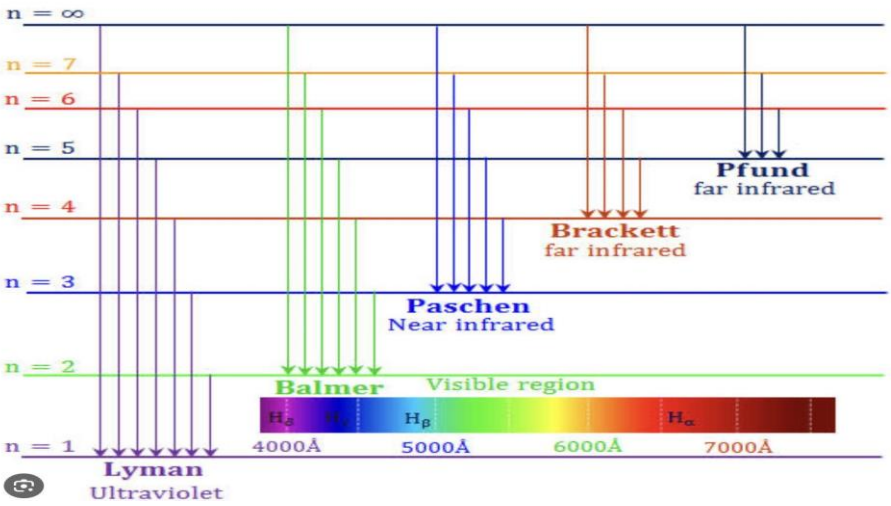
- Explanation of hydrogen spectrum: Emission and absorption spectra explained using the concept of electronic transitions between quantized orbits.

4. Spectral Series

- Lyman Series: Transitions to n=1 (ultraviolet region).

- Balmer Series: Transitions to n=2 (visible region).

- Paschen, Brackett, and Pfund Series : Transitions to n=3, 4, and 5 (infrared region).



5. Success and Limitations of Bohr's Model

- Success in explaining the hydrogen atom spectrum and its limitations.

- Failure to explain spectra of multi-electron atoms and finer spectral details (Zeeman effect and Stark effect).

Formulae :

1.Magnitude of force of α particle: $F = \frac{1}{4\pi\varepsilon_0}\frac{(2e)(Ze)}{r^2}$

2.Total energy of the electron $E = K + U = \frac{e^2}{8\pi\varepsilon_0 r} - \frac{e^2}{4\pi\varepsilon_0 r}$

$= -\frac{e^2}{8\pi\varepsilon_0 r}$

3.Angular Momentum

$L = nh/2\pi$

4.Frequency of emitted photon $h\nu = E_i - E_f$

5.Radius of nth possible orbit

$r_n = \frac{n^2}{m}\left(\frac{h}{2\pi}\right)^2 \frac{4\pi\varepsilon_0}{e^2}$

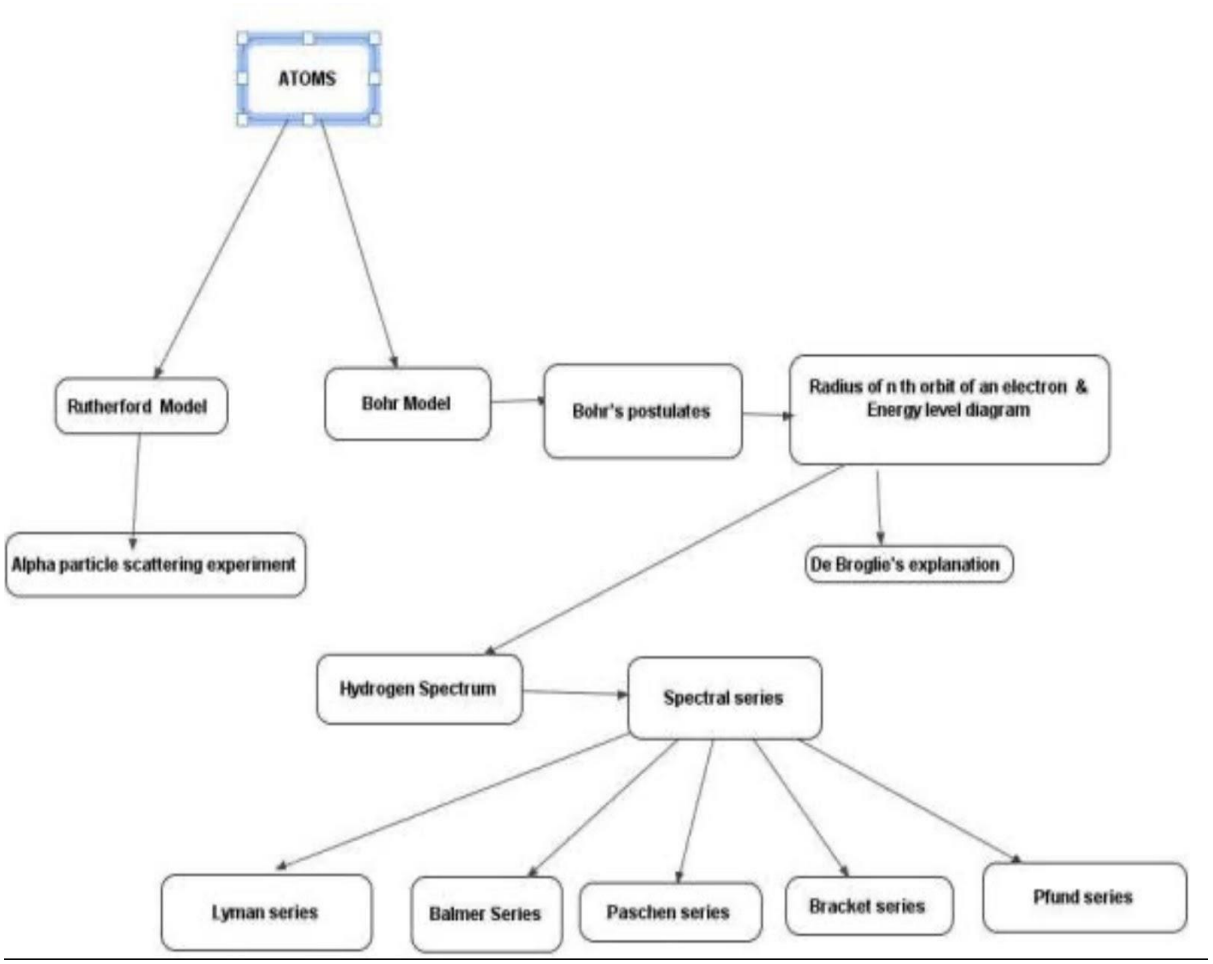
6.Energy of an electron $E = -\frac{13.6}{n^2}$ eV

7.Difference in energy levels $h\omega_{if} = E_{ni} - E_{nf}$

8.The energy of an electron in Bohr's orbit of hydrogen atom is given by the expression

$E_n = -\frac{2\pi^2 me^4 Z^2}{n^2 h^2 (4\pi\varepsilon_0)^2} = -13.6\frac{Z^2}{n^2} eV$ Since Z = 1 for hydrogen $E_n = -13.6/n^2$ eV

MIND MAP /CONCEPT MAP



Level 1

1. Who proposed the plum pudding model of the atom?
   - A) Rutherford B) Thomson C) Bohr D) Dalton

2. What did Rutherford's gold foil experiment demonstrate?
   - A) Electrons are in fixed orbits.
   - B) Atoms have a nucleus.
   - C) Atoms are indivisible.
   - D) Atoms are electrically neutral.

3. What particles are found in the nucleus of an atom?
   - A) Electrons and protons
   - B) Electrons and neutrons
   - C) Protons and neutrons
   - D) Only protons

4. What is the charge of an electron?
   - A) Positive B) Negative C) Neutral D) Depends on the atom

5. Bohr's model states that electrons revolve around the nucleus in:
   - A) Elliptical orbits B) Fixed orbits C) Random paths D) Parabolic paths

6. When an electron jumps from a higher orbit to a lower orbit, it:
   - A) Absorbs energy B) Emits energy C) Remains stationary D) Loses mass

7. Which series of hydrogen spectrum lies in the visible region?
   - A) Lyman series B) Balmer series C) Paschen series D) Brackett series

8. The energy of an electron in a Bohr orbit is:
   - A) Positive B) Negative C) Zero D) Depends on the orbit

9. In Bohr’s model, the angular momentum of an electron is:
   - A) Quantized B) Continuous C) Always zero D) Infinite

10. What is the principal quantum number \(n \) of the ground state of a hydrogen atom?
    - A) 0 B) 1 C) 2 D) 3

11. The spectral lines of hydrogen were explained using:
    - A) Thomson’s model B) Rutherford’s model C) Bohr’s model D) Dalton’s model

12. What does the Rydberg constant represent?
    - A) Speed of light
    - B) Planck's constant
    - C) The constant used in calculating the wavelengths of spectral lines
    - D) Mass of an electron

13. In the hydrogen atom, the transition from (n = 3) to (n = 2)emits a photon in which series?
    - A) Lyman series B) Balmer series C) Paschen series D) Pfund series

14. Who discovered the nucleus of the atom?
- A) Bohr B) Thomson C) Rutherford D) Einstein

15. Which particle has the least mass?
- A) Proton B) Neutron C) Electron D) Nucleus

16. The energy levels in an atom are:
- A) Continuous B) Quantized C) Infinite D) Non-existent

17. What is the charge of a neutron?
- A) Positive B) Negative C) Neutral D) Double positive

18. In Bohr's model, which orbit has the lowest energy?
- A) First orbit B) Second orbit C) Third orbit D) Fourth orbit

19. What is the main limitation of Rutherford's model?
- A) Could not explain atomic spectra
- B) Could not explain the charge of the nucleus
- C) Could not explain the mass of the atom
- D) Could not explain the behavior of neutrons

20. In which region of the electromagnetic spectrum does the Lyman series lie?
- A) Visible B) Infrared C) Ultraviolet D) X-ray

Level 2

1. According to Bohr's model of the atom, which of the following statements is true about the orbits of electrons?
- A) Electrons in higher orbits have higher energy.
- B) Electrons in lower orbits have higher energy.
- C) Electrons in all orbits have the same energy.
- D) Electrons have no defined energy in Bohr's model.

2. Which series of hydrogen spectrum lies in the ultraviolet region?
- A) Lyman series B) Balmer series C) Paschen series D) Brackett series

3. In Bohr's model, what does the quantum number \(n \) represent?
- A) Energy level of the electron
- B) Angular momentum of the electron
- C) Spin of the electron
- D) Magnetic quantum number of the electron

4. What is the fundamental assumption in Bohr's model that leads to quantization of electron orbits?
- A) Electrons emit radiation continuously.
- B) Electrons do not radiate energy while moving in orbits.
- C) Electrons move in random paths around the nucleus.
- D) Electrons have no specific mass.

5.The energy difference between two energy levels in an atom corresponds to:
- A) The wavelength of light emitted or absorbed
- B) The number of electrons in the atom

- C) The speed of electrons in the atom
- D) The mass of the nucleus

6.The ionisation potential of hydrogen is 13.6 V. The energy of the atom in n = 2 state will be
A) -10.2 eV B) -6.4eV C) – 3.4 eV D)– 4.4 eV

7.In Bohr's model of the hydrogen atom, the ratio between the period of revolution of an electron in the orbit n = 1 to the period of revolution of electron in the orbit n = 2 is
A) ½ B) ¼ C)1/8 D) 2

8.To explain fine structure of spectrum of hydrogen atom, we must consider.
A) a finite size of nucleus.
B) the presence of neutrons in the nucleus.
C) spin angular momentum.
D) orbital angular momentum.

9.When an electron jumps from some outer orb it to the innermost orbit in the hydrogen atom, the spectral line belongs to
A) Lyman series
B) Balmer series
C) Paschen series
D) Pfund series

10.How does the energy difference between two consecutive energy levels vary on the quantum number n increases?
A) does not change
B) decreases
C) increases
D) may increase or decrease.

Level 3

1.If the electron in hydrogen atoms is excited to n = 5 state, the number of different frequencies of radiation which may be emitted is:
A) 4 B) 10 C) 8 D) 5

2.The ionisation potential of hydrogen is 13.6 V. The energy of the atom in n = 2 state will be
A) -10.2 ev B) -6.4eV C) – 3.4 eV D) – 4.4 eV

3.The ratio of the energies of the hydrogen atom in its first to second excited state is :
A) ¼ B) 4/9 C) 9/4 D) 1/9

4.When an electron jumps from some outer orb it to the innermost orbit in the hydrogen atom, the spectral line belongs to
A) Lyman series B) Balmer series C) Paschen series D) Pfund series

5.According to classical theory, Rutherford atom is
A) stable B) unstable C) metastable D) semistable

6.For an electron orbit to be non-radiating, it should be
A) such that the angular momentum should be integral multiple of h.
B) circular in nature
C) elliptical in nature
D) none of these

7.The ratio of the angular momentum of an electron in first orbit to that in the second orbit is
A) ½ B)1/4 C) 4/1 D) 2

8.The ionisation energy of hydrogen atom is E. When the electron in a hydrogen atom jumps from the state n = 1 to the state n = 2, the energy absorbed by it is ……
A) 3E/4 B) 4E/3 C) E/4 D) E/3

9.In the Bohr model of the atom, which of the following quantities takes quantized values?**

A) Linear momentum of electron B) Radius of electron orbit

C) Angular momentum of electron D) None of the above

10.The ionization energy of hydrogen is 13.6 eV. The energy required to remove an electron from the second orbit of Li2+ is:

A) 13.6 Ev B) 30.6 eV C) 40.8 eV D) 122.4 eV

2 marks Questions

Level 1

Q1.Define ionisation energy. What is its value for a hydrogen atom?
Q2.Write the expression for Bohr's radius in hydrogen atom.
Q3.What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom?
Q4.Why is the classical (Rutherford) model for an atom—of electron orbiting around the nucleus—not able to explain the atomic structure?
Q5.What is the maximum number of spectral lines emitted by a hydrogen atom when it is in the third excited state?

Level 2

Q1. What are the values of first and second excitation potential of hydrogen atom?
Q.2 The wavelength of some of the spectral lines of obtained in hydrogen spectrum are 1216 A^0 , 6463 A^0 and and 9546 A^0 Which one of these wavelength belongs to the paschen series.
Q3.Name the series of Hydrogen spectrums lying in ultraviolet and visible regions.
Q4. what are results What is 4 Do you expect if alpha particle, scattering experiment is repeatedly using a thin sheet of hydrogen in place of a gold foil?
Q5.Define ionisation energy. What is its value for a hydrogen atom?

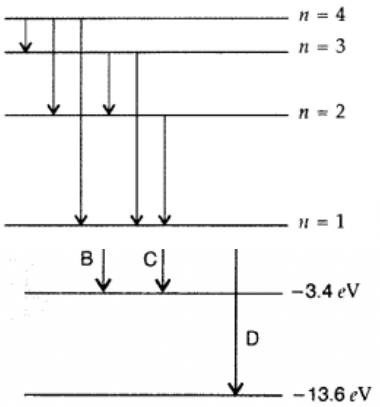
Level 3

Q1.When an electron in hydrogen atom jumps from the third excited state to the ground state, how would the de Broglie wavelength associated with the electron change? Justify your answer.

Q2.The figure shows energy level diagram of hydrogen atom

Find out the transition which results in the emission of a photon of wavelength 496 nm.

Q3.The energy level diagram of an element is given. Identify, by doing necessary calculations, which transition corresponds to the emission of a spectral line of wavelength 102.7 nm



3 marks questions

Level 1

Q1.Calculate the shortest wavelength of the spectral lines emitted in Balmer series.

Q2. Why is the mass of nucleus does not enter the formula for impact parameter but it's charged does ?

Q3.What is the ratio of radii of the orbits corresponding to first excited state and ground state in a hydrogen atom?

Q4 .The radius of innermost electron orbit of a hydrogen atom is 5.3×10^{-11} m. What is the radius of orbit in the second excited state?

Q5 write to postulates of Bohr atomic model

Level 2

Q1.The ground state energy of hydrogen atom is -13.6 eV. What are the kinetic and potential energies of electron in this state?

Q2.Write two important limitations of Rutherford nuclear model of the atom.

Q3.Name the series of Hydrogen spectrums lying in ultraviolet and visible regions.

Level 3

Q1.State the limitations of Bohr's atomic model.

Q2. Define ionization energy. How would the ionization energy change when electron in hydrogen atom is replaced by a particle of mass 200 times that of the electron but having the same charge?

Q3.Show that the radius of the orbit in hydrogen atom varies as n^2, where n is the principal quantum number of the atom.

5 Marks questions

Level 1

Q1.i) In hydrogen atom, an electron undergoes transition from 2nd excited state to the first excited state and then to the ground state. Identify the spectral series to which these transitions belong.

(ii) Find out the ratio of the wavelengths of the emitted radiations in the two cases.

Level 2

Q1.i) In hydrogen atom, an electron undergoes transition from third excited state to the second excited state and then to the first excited state. Identify the spectral series to which these transitions belong.

(ii) Find out the ratio of the wavelengths of the emitted radiations in the two cases.

Level 3

1. Describe brother for atom model. What are the drawbacks of this model?

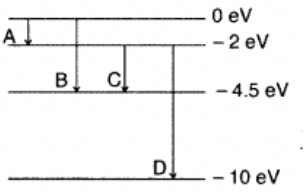
NUMERICALS

Level 1

1.The ground state energy of hydrogen atom is -13.6 electron volt. What are the potential energy of electron in the state?
2.what is the energy possessed by an electron four and tends to be infinity?
3. What is the ratio of radii of orbit corresponding to the first excited state and ground state in hydrogen atom?
4. The radius of inner most electron orbit of an hydrogen atom is 5.3×10^{-11} m. What is the radius of the orbit in second excited state?

Level 2

1.The energy levels of a hypothetical atom are shown below. 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 ?

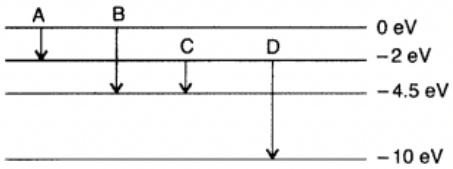


2.Find the ratio of energies of photons produced due to transition of an electron of hydrogen atom from its
(i) second permitted energy level to the first level, and
(ii) the highest permitted energy level to the first permitted level.

3.The ground state energy of hydrogen atom is -13.6 eV. What are the kinetic and potential energies of electron in this state? (All India)

Level 3.

1.The value of a ground state energy of hydrogen atom is -13.6 eV.
(i) Find the energy required to move an electron from the ground state to the first excited state of the atom.
(ii) Determine
(a) the kinetic energy and
(b) orbital radius in the first excited state of the atom.
(Given the value of Bohr radius = 0.53 Å)
2.The energy levels of an atom are as shown here. Which of them will result in the transition of a photon of wavelength 275 nm?



b) Which transition corresponds to emission of radiation of maximum wavelength?
3.The total energy of an electron in the first excited state of hydrogen atom is -3.4 eV. (a) What is kinetic energy of electron in this state? (ii) What is potential energy of electron in this state? (c) Which of the answers above would change if the choice of zero of potential energy is changed?

Case based study question / Source based question

Each element is having specific properties as it emits or shows the specific emission spectrum of radiation. The emission line spectrum has bright lines on the dark surface. The hydrogen spectrum consist of series namely Balmer, Lyman, Paschen, Brackett and Pfund series. The Lyman series is formed in the ultraviolet region while Paschen, Brackett and Pfund series are in the infrared region. According to Bohr's first postulate, electrons are revolving in particular stable orbits without radiating any form of energy. And in his second postulate he told that, these electrons are revolving around the nucleus in stable orbits which are having angular momentum equal to integral multiple of h/2π. And third postulate tells us that, when electron jumps from higher energy state to lower energy state it will emits some amount of energy and which is equal to the energy difference between those energy levels.

And he gave the energy of an electron in an hydrogen atom as $E_n = -13.6/ n^2$ eV

The negative sign shows that electron is tightly bound with the nucleus. And when n = 1, then corresponding energy of electron is called as ground state energy. Bohr's model is only applicable to single electron system like hydrogen and it cannot be applicable to helium atom also which is having two electrons.

Read the above passage and answer the rolling questions .

1.) In hydrogen atom, the ground state energy is given by___
a) +13.6 Ev b) -13.6 J c) -13.6 KJ d) -13.6 eV

2.) According to Bohr's second postulate, the angular momentum L is given by
a) L= h/2π b) L = nh/2π c) L = 2π/h d) L = 2π/ nh

3.) What is the shortest wavelength in the Balmer series
a) 656.3 nm b) 364.6 nm c) 656.3 mm d) 364.6 mm

4.) For ground state of hydrogen atom the value of principal quantum number is___
a) n = 2 b) n = 0 c) n = 1 d) n = infinity

Competency Based Question

Q1.Explain how the observation of spectral lines can be used to identify elements in distant stars.
Q2.Discuss the significance of the Balmer series in the context of hydrogen's atomic spectrum and its application in astronomy.

CCT BASED QUESTION

A hydrogen atom is excited from its ground state (n = 1) to the n = 3 energy level. The atom then returns to the ground state by emitting photons.

1. Describe how the wavelengths relate to the hydrogen emission spectrum.
2. Discuss the implications of these transitions in the context of Bohr's model of the atom.

SELF ASSESSMENT TEST

Total marks =25 Time = 40 Mins.

Question 1 to 6 each of 1 mark
Question 7to8 each of 2 mark
Question 9to 10:each of 3 mark
Question 11 of 4 mark
Question 12 is of 5 marks

Q1.What is the main limitation of Rutherford's model?

- A) Could not explain atomic spectra
- B) Could not explain the charge of the nucleus
- C) Could not explain the mass of the atom
- D) Could not explain the behaviour of neutrons

Q2 The spectral lines of hydrogen were explained using:

- A) Thomson's model B) Rutherford's model C) Bohr's model D) Dalton's model

Q3.Two H atoms in the ground state collide inelastically. The maximum amount by which their combined kinetic energy is reduced is

-A) 10.20 eV - B) 20.40 eV - C) 13.6 eV - D) 27.2 eV

Q4.The Bohr model for the spectra of a H - atom.

- A) will not be applicable to hydrogen in the molecular form
- B) will not be applicable as it is for a He -atom.
- C) is valid only at room temperature
- D) predicts continuous as well as discreeter spectral lines .

Directions for Assertion-Reason Type Questions

In each of the following questions, 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.

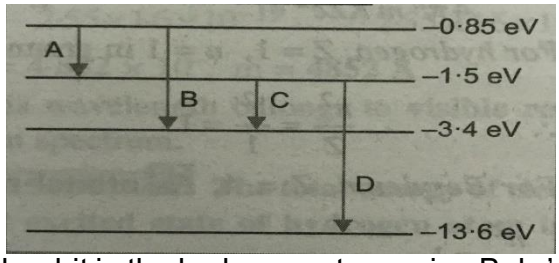
- (d) Assertion (A) is false but Reason (R) is true.

Q5.Assertion (A): in alpha rays, scattering experiment, most of the alpha particle goes on deflected.
Reason (R): most of the space in the atom is empty

Q6.Assertion (A): In Bohr's model of the atom, the angular momentum of the electron is quantized.
Reason (R): The electron in an atom revolves in circular orbits around the nucleus under the influence of electrostatic forces.

Q7.State the limitations of Bohr's atomic model

Q8. The ground state energy of hydrogen atom is -13.6 electron volt. What are the kinetic and potential energy of the electron in the state?



Q9.The energy level diagram of an element is given here . Which transition corresponds to the emission of a spectral line of wavelength 102.7nm?

Q10.Explain the concept of the Bohr radius and derive the expression for the radius of the nth orbit in the hydrogen atom using Bohr's model.

Q11. In the early 20th century, the study of hydrogen atom spectra provided crucial evidence for the development of quantum mechanics. The hydrogen atom, being the simplest atom with only one electron, showed a series of discrete spectral lines that were first observed and recorded in the visible region (Balmer series). Later, other series like the Lyman series (UV region) and Paschen series (IR region) were also discovered. These observations led Niels Bohr to propose his model of the atom, introducing the concept of quantized energy levels.In Bohr's model, an electron revolves around the nucleus in specific, quantized orbits without radiating energy. The electron can only gain or lose energy by jumping from one allowed orbit to another, with the energy difference between these orbits being emitted or absorbed as a photon. This model successfully explained the spectral lines of hydrogen and the Rydberg formula for their wavelengths.

Read the above paragraph carefully and answer the following question .

(I)Explain the significance of the Balmer series in the context of the hydrogen atom spectra.

(II)Why are the spectral lines of hydrogen atom discrete and not continuous?

(III)Describe how Bohr's model of the atom accounts for the stability of electron orbits

(IV)If the ionisation energy of the hydrogen atom is 13.6 eV, what is the energy of the electron in the (n = 2)state?

Q12. State the basic postulates of Bohr's theory is of atomic spectra. Hence, obtain an expression for radius of orbit and the energy of orbital electron in hydrogen atom.

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