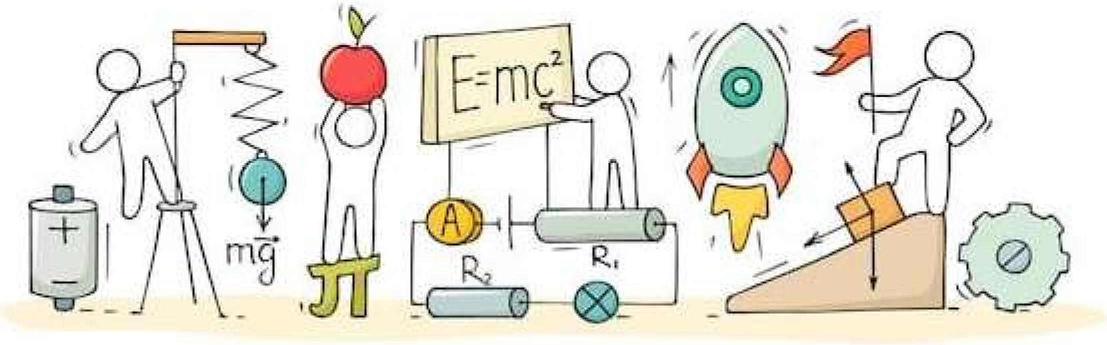
PHYSICS



ATOMS

Atoms:

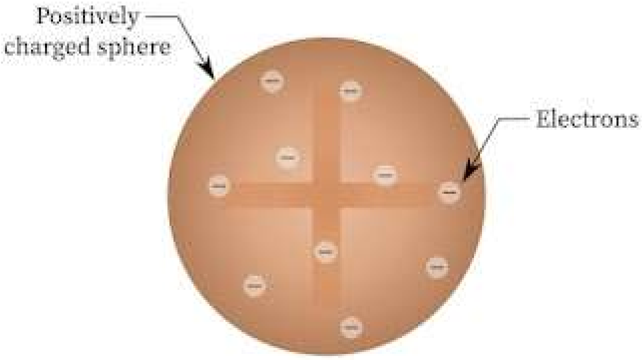
Atoms are made up of the same amount of negative and positive charges. In Thomson's model, atoms were described as a spherical cloud of positive charges with embedded electrons. In Rutherford's model, one tiny nucleus bears most of the mass of the atom along with its positive charges and the electrons revolve around it.

Dalton's Atomic Theory:

All elements are consisting of very small invisible particles, called atoms. Atoms of same element are exactly same, and atoms of different element are different.

Thomson's Atomic Model:

Every atom is uniformly positive charged sphere of radius of the order of 10-10 m, in which entire mass is uniformly distributed and negative charged electrons are embedded randomly.



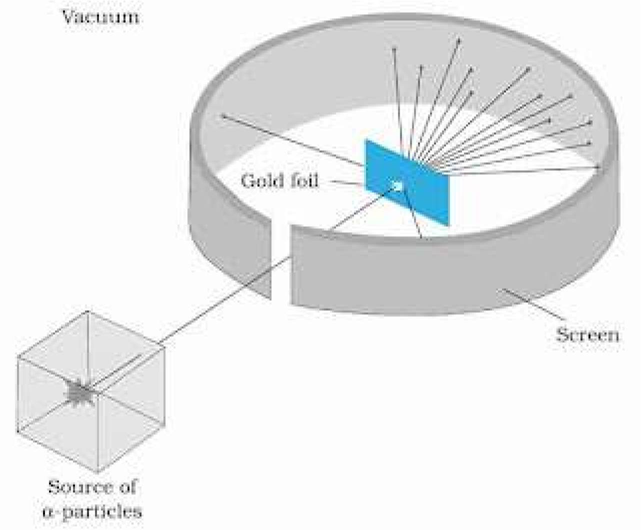
Limitations of Thomson's Atomic Model:

- It could not explain the origin of spectral series of hydrogen and other atoms.
- It could not explain large angle scattering of α – particles.

Alpha-Particle Scattering:

In 1911, Rutherford, along with his assistants, H. Geiger and E. Marsden, performed the Alpha Particle scattering experiment, which led to the birth of the 'nuclear model of an atom'.

They took a thin gold foil having a thickness of 2.1×10^{-7} m and placed it in the center of a rotatable detector made of zinc sulfide and a microscope. Then, they directed a beam of 5.5MeV alpha particles emitted from a radioactive source at the foil. Lead bricks collimated these alpha particles as they passed through them.



After hitting the foil, the scattering of these alpha particles could be studied by the brief flashes on the screen. Rutherford and his team expected to learn more about the structure of the atom from the results of this experiment.

Observations:

Here is what they found:

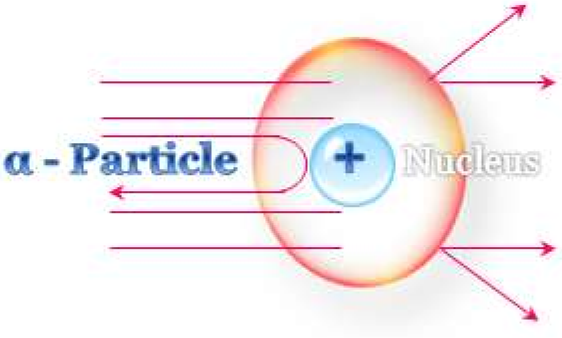
- Most of the alpha particles passed through the foil without suffering any collisions
- Around 0.14% of the incident alpha particles scattered by more than 10.
- Around 1 in 8000 alpha particles deflected by more than 90^o.

Rutherford’s Nuclear Model:

In 1912, Rutherford proposed his nuclear model of the atom. It is also known as Rutherford's planetary model of atom.

Salient features of Rutherford's atom model are as follows:

- Every atom consists of a tiny central core, named nucleus, in which the entire positive charge and almost whole mass of the atom are concentrated. The size of nucleus is typically 10-4 times the size of an atom.
- Most of an atom is empty space.
- In free space around the nucleus, electrons would be moving in orbits just as the planets do around the sun. The centripetal force needed for orbital motion of electrons is provided by electrostatic attractive forced experience by electron due to positively charged nucleus.
- An atom as a whole is electrically neutral. Thus, total positive charge of nucleus is exactly equal to total negative charge of all the electrons orbiting in an atom.



Impact Parameter:

The perpendicular distance of the velocity vector of α-particle from the central line of the nucleus, when the particle is far away from the nucleus is called impact parameter.

Impact parameter $b = \frac{1}{4\pi\varepsilon_0} \cdot \frac{Ze^2 \cot(\frac{\theta}{2})}{E_k}$

where, Z = atomic number of the nucleus, Ek = kinetic energy of the c-particle and θ = angle of scattering.

Bohr Model of the Hydrogen Atom:

It was Niels Bohr (1885-1962) who used the concept of quantized energy, and explained the model of a hydrogen atom in 1913. Bohr combined classical and early quantum concepts and proposed a theory in the form of three postulates.

These postulates are:

- **Postulate I:** An electron in an atom could revolve in certain stable orbits without emitting radiant energy. Each atom has certain definite stable orbits. Electrons can exist in these orbits. Each possible orbit has definite total energy. These stable orbits are called the stationary states of the atom.
- **Postulate II:** An electron can revolve around the nucleus in an atom only in those stable orbits whose angular momentum is the integral multiple of $\frac{h}{2\pi}$ (where h is Planck's constant). Therefore, angular momentum (L) of the orbiting electron is quantised.

  $$mvr = \frac{nh}{2\pi} \text{ where, n = 1, 2, 3, ...}$$

- **Postulate III:** An electron can make a transition from its stable orbit to another lower stable orbit. While doing so, a photon is emitted whose energy is equal to the energy difference between the initial and final states. Therefore, the energy of photon is given by,

$$h\upsilon = E_i - E_f$$

where E_i and E_f are the energies of the initial and final states.

Failure of Bohr's Model:

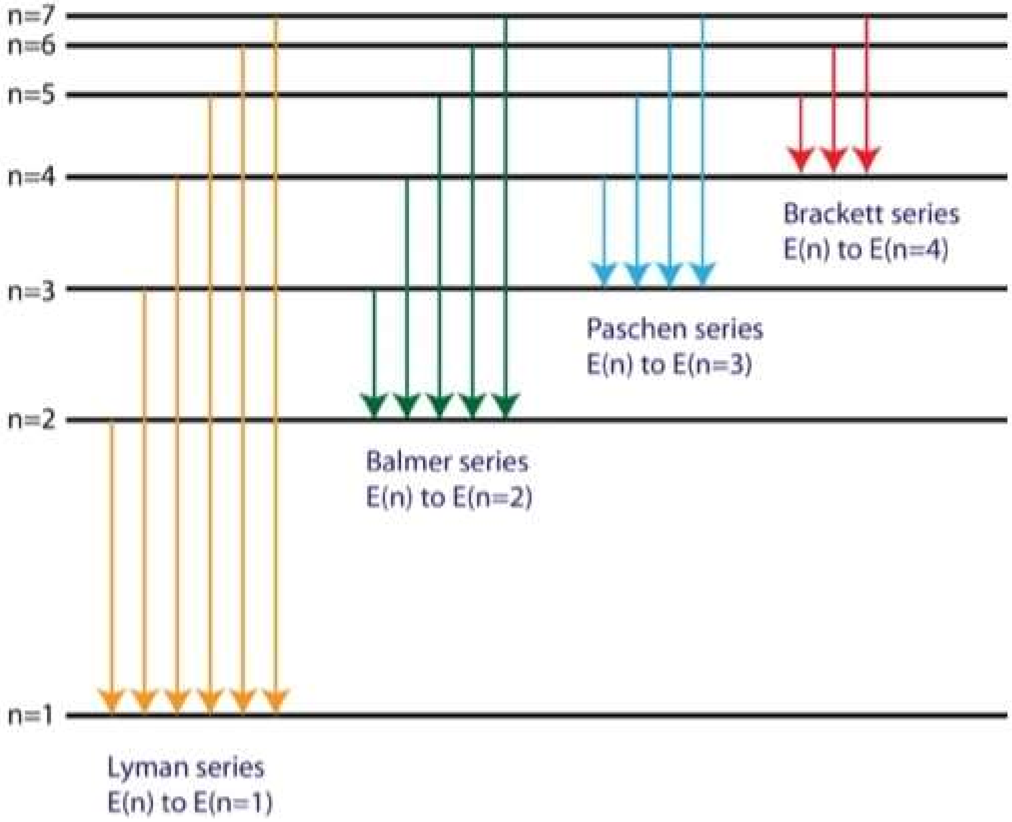
- This model is applicable only to hydrogen-like atoms and fails in case of higher atoms.
- It could not explain the fine structure of the spectral lines in the spectrum of hydrogen atom.

Ground State and Excited States:

The lowest energy level of an atom is called the "ground state" and higher levels are called "excited states". The H-atom has lowest energy in the state for the principal quantum number n = 1. and all other states (i.e, for n = 2, 3, 4…) are excited states. Thus E_2, E_3, E_4 …are called the first, the second, the third …excited states respectively.

Hydrogen Spectrum Series:

Each element emits a spectrum of radiation, which is characteristic of the element itself. The spectrum consists of a set of isolated parallel lines and is called the line spectrum.



There are four visible spectral lines corresponded to transitions from higher energy levels down to the second energy level (n = 2). This is called the **Balmer series.** Transitions ending in the ground state (n = 1) are called the **Lyman series**, but the energies released are so large that the spectral lines are all in the ultraviolet region of the spectrum. The transitions called the **Paschen series** and the **Brackett series** both result in spectral lines in the infrared region because the energies are too small.

Wave Model:

It is based on wave mechanics. Quantum numbers are the numbers required to completely specify the state of the electrons.

In the presence of strong magnetic field, the four-quantum number are:

- Principal quantum number (n) can have value 1,2, … ∞
- Orbital angular momentum quantum number l can have value 0,1, 2, …, (n – 1).
- Magnetic quantum number (me) which can have values – l to l.
- Magnetic spin angular momentum quantum number (ms) which can have only two value $\frac{1}{2}$.

De Broglie’s Hypothesis:

This states that the wavelength of electrons is $\lambda = \frac{\mathrm{h}}{\mathrm{mv}}$ and the whole number of wavelengths is equal to the orbits circumference the main orbit corresponding to the circular standing waves.

Binding Energy:

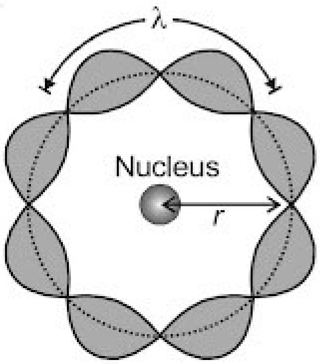
Binding energy of a system is defined as the minimum energy needed to separate its constituents to large distances. This may also be defined as the energy released when its constituents are brought from infinity to form the system. The binding energy of H-atom in ground state is 13.6 eV which is the same as its ionization energy.

Ionization Energy and Ionization Potential:

The minimum energy needed to ionize an atom is called “ionization energy”. The potential difference through which an electron should be accelerated to acquire this much energy is called “ionization potential”. Hence, ionization energy of H-atom in ground state is 13.6 eV and ionization potential is 13.6 V.

de-Broglie’s Explanation of Bohr’s Second Postulate:

de-Broglie explained second postulate of Bohr’s atomic model by assuming an electron to a particle wave. Therefore, it should form standing waves under resonance condition.



According to de-Broglie, for an electron moving in nth circular orbit of radius r,

$$2\pi = n\lambda \; n = 1, 2, 3 \ldots$$

i.e., circumference of orbit should be integral multiple of de-Broglie wavelength of electron moving in nth orbit. As we know that de-Broglie wavelength,

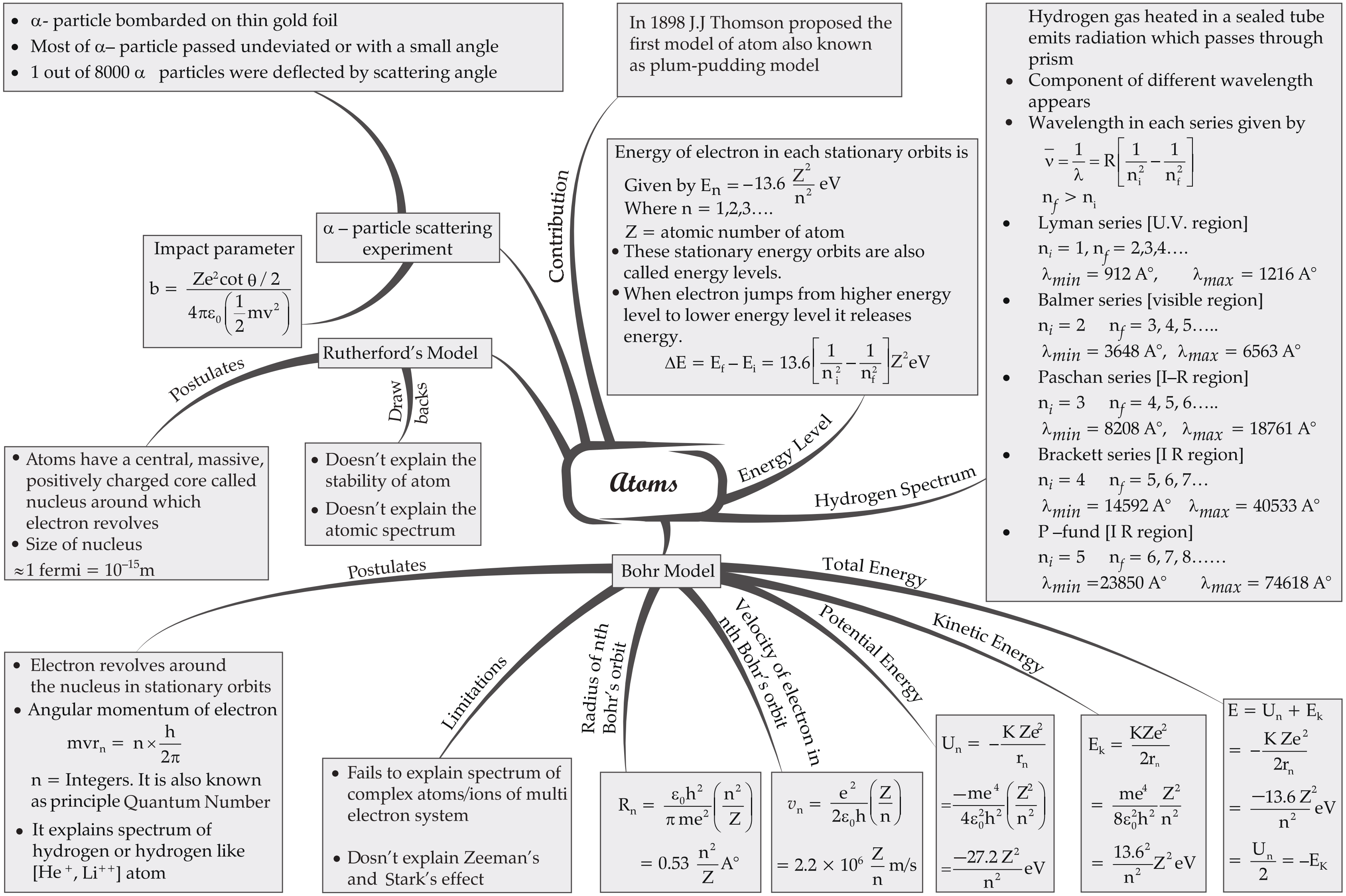
$$\lambda = \frac{h}{mv}$$

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

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

MIND MAP : LEARNING MADE SIMPLE

CHAPTER - 12



Atoms

Contribution

In 1898 J.J Thomson proposed the first model of atom also known as plum-pudding model

α – particle scattering experiment

- α- particle bombarded on thin gold foil
- Most of α– particle passed undeviated or with a small angle
- 1 out of 8000 α particles were deflected by scattering angle

Impact parameter

$$b = \frac{Ze^2 \cot \theta / 2}{4\pi\varepsilon_0 \left(\frac{1}{2}mv^2\right)}$$

Rutherford's Model

Postulates

- Atoms have a central, massive, positively charged core called nucleus around which electron revolves
- Size of nucleus

≈ 1 fermi $= 10^{-15}$m

Draw backs

- Doesn't explain the stability of atom
- Doesn't explain the atomic spectrum

Energy Level

Energy of electron in each stationary orbits is

Given by $E_n = -13.6 \frac{Z^2}{n^2}$ eV

Where n = 1,2,3….

Z = atomic number of atom

- These stationary energy orbits are also called energy levels.
- When electron jumps from higher energy level to lower energy level it releases energy.

$$\Delta E = E_f - E_i = 13.6\left[\frac{1}{n_i^2} - \frac{1}{n_f^2}\right]Z^2 eV$$

Hydrogen Spectrum

Hydrogen gas heated in a sealed tube emits radiation which passes through prism

- Component of different wavelength appears
- Wavelength in each series given by

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

$n_f > n_i$

- Lyman series [U.V. region]
  - $n_i = 1,\ n_f = 2,3,4….$
  - $\lambda_{min} = 912$ A°, $\lambda_{max} = 1216$ A°
- Balmer series [visible region]
  - $n_i = 2 \quad n_f = 3, 4, 5…..$
  - $\lambda_{min} = 3648$ A°, $\lambda_{max} = 6563$ A°
- Paschan series [I–R region]
  - $n_i = 3 \quad n_f = 4, 5, 6…..$
  - $\lambda_{min} = 8208$ A°, $\lambda_{max} = 18761$ A°
- Brackett series [I R region]
  - $n_i = 4 \quad n_f = 5, 6, 7…$
  - $\lambda_{min} = 14592$ A° $\lambda_{max} = 40533$ A°
- P –fund [I R region]
  - $n_i = 5 \quad n_f = 6, 7, 8……$
  - $\lambda_{min} = 23850$ A° $\lambda_{max} = 74618$ A°

Bohr Model

Postulates

- Electron revolves around the nucleus in stationary orbits
- Angular momentum of electron

$$mvr_n = n \times \frac{h}{2\pi}$$

n = Integers. It is also known as principle Quantum Number

- It explains spectrum of hydrogen or hydrogen like $[He^+, Li^{++}]$ atom

Limitations

- Fails to explain spectrum of complex atoms/ions of multi electron system
- Dosn't explain Zeeman's and Stark's effect

Radius of nth Bohr's orbit

$$R_n = \frac{\varepsilon_0 h^2}{\pi me^2}\left(\frac{n^2}{Z}\right)$$

$$= 0.53 \frac{n^2}{Z} A°$$

Velocity of electron in nth Bohr's orbit

$$v_n = \frac{e^2}{2\varepsilon_0 h}\left(\frac{Z}{n}\right)$$

$$= 2.2 \times 10^6 \frac{Z}{n} m/s$$

Potential Energy

$$U_n = -\frac{KZe^2}{r_n}$$

$$= \frac{-me^4}{4\varepsilon_0^2 h^2}\left(\frac{Z^2}{n^2}\right)$$

$$= \frac{-27.2 Z^2}{n^2} eV$$

Kinetic Energy

$$E_k = \frac{KZe^2}{2r_n}$$

$$= \frac{me^4}{8\varepsilon_0^2 h^2} \frac{Z^2}{n^2}$$

$$= \frac{13.6^2}{n^2} Z^2 eV$$

Total Energy

$$E = U_n + E_k$$

$$= -\frac{KZe^2}{2r_n}$$

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

$$= \frac{U_n}{2} = -E_K$$

Important Questions

Multiple Choice questions-

Question 1. The simple Bohr model cannot be directly applied to calculate the energy levels of an atom with many electrons. This is because

(a) of the electrons not being subject to a central force.
(b) of the electrons colliding with each other
(c) of screening effects
(d) the force between the nucleus and an electron will no longer be given by Coulomb's law.

Question 2. A set of atoms in an excited state decay.

(a) in general, to any of the states with lower energy.
(b) into a lower state only when excited by an external electric field.
(c) all together simultaneously into a lower state.
(d) to emit photons only when they collide.

Question 3. The ground state energy of hydrogen atom is -13.6 eV. The kinetic and potential energies of the electron in this state are

(a) -13.6 eV, 27.2 eV
(b) 13.6 eV,-13.6 eV
(c) 13.6 eV,-27.2 eV
(d) 27.2 eV,-27.2 eV

Question 4. If the series limit frequency of the Lyman series is vL, then the series limit frequency of the Pfund series is:

(a) 16 v_L
(b) $v_L/16$
(c) $V_L/25$
(d) 25 v_L

Question 5. The ratio of kinetic energy to the total energy of an electron in a Bohr orbit of the hydrogen atom is:

(a) 1 : 1
(b) 1 : -1
(c) 2 : -1
(d) 1 : -2

Question 6. Ionisation energy for hydrogen atom in the ground state is E. What is the ionisation energy of Li++ atom in the 2nd excited state:

(a) E
(b) 3E
(c) 6E

(d) 9E

Question 7. Hydrogen (H_1^1), deuterium (H_1^2), singly ionised helium ($(He_2^4)^+$) and doubly ionised lithium ($(Li_3^6)^{++}$) all have one electron around their nucleus. Consider an electron transition from n = 2 to n = 1 if the wavelengths of the emitted radiations are λ_1, λ_2, λ_3 and λ_4 respectively then approximately which of the following is correct?

(a) $4\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$
(b) $\lambda_1 = 2\lambda_2 = 2\lambda_3 = \lambda_4$
(c) $\lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$
(d) $\lambda_1 = 2\lambda_2 = 3\lambda_3 = 4\lambda_4$

Question 8. As an electron makes a transition from an excited state to the ground state of a hydrogen like atom/ion:

(a) its kinetic energy increases but potential energy and total energy decrease
(b) kinetic energy, potential energy and total energy decrease
(c) kinetic energy decreases, potential energy increases but total energy remains the same
(d) kinetic energy and total energy decrease but potential energy increases

Question 9. An electron from various excited states of hydrogen atom emits radiation to come to the ground state. Let λ_n, λ_g be the de-Broglie wavelength of the electron in the nth state and the ground state respectively. Let Λ_n be the wavelength of the emitted photon in the transition from the nth state to the ground state. For large n (A, B are constants)

(a) $\Lambda_n = A + B\lambda_n$
(b) $\Lambda_n = A + B\lambda_n^2$
(c) $\Lambda_n^2 = X$
(d) $\Lambda_n = A + \frac{B}{\lambda_n^2}$

Question 10. A spectral line is emitted when an electron:

(a) jumps from lover orbit to higher orbit.
(b) jumps from higher orbit to lower orbit.
(c) rotates in a circular orbit.
(d) rotates in an elliptical orbit.

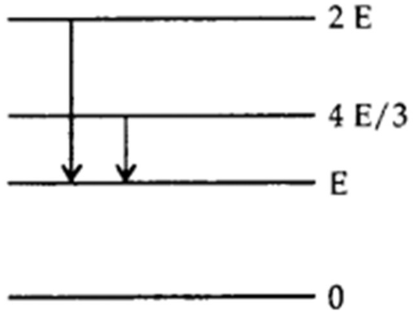
Question 11. The ionisation potential of hydrogen is 13.6 V. The energy of the atom in n = 2 state will be:

(a) -10.2 eV
(b) -6.4eV
(c) – 3.4 eV
(d) – 4.4 eV

Question 12. At the time of total solar eclipse, the spectrum of solar radiation would be:

(a) a large number of dark Fraunhoffer lines
(b) a small number of dark Fraunhofer lines.
(c) All Fraunhofer lines changed into brilliant colours.
(d) None of these.

Question 13. The adjoining figure indicates the energy levels of a certain atom when the system moves from 2 E to E level, a photon of wavelength λ is emitted. The wavelength of photon produced during its transition from $\frac{4E}{3}$ to E is

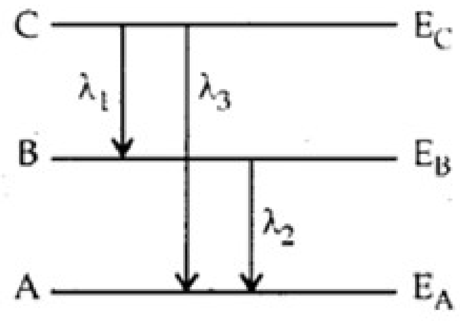


(a) $\frac{\lambda}{3}$
(b) $\frac{3\lambda}{4}$
(c) $\frac{4\lambda}{3}$
(d) 3λ

Question 14. A hydrogen atom is in the p-state. For this, values of J are

(a) $\frac{5}{2}, \frac{3}{2}, \frac{1}{2}$
(b) $\frac{3}{2}, \frac{1}{2}$
(c) $-\frac{1}{2}, \frac{1}{2}, \frac{3}{2}$
(d) $-\frac{1}{2}, \frac{-3}{2}$

Question 15. Energy levels A, B, C of a certain atom correspond to increasing value of energy i.e., $E_A > E_B > E_C$. If λ_1, λ_2 and λ_3 are the wavelengths of radiation corresponding to transition C to B, B to A and C to A respectively, which of these of the following is correct?



(a) $\lambda_3 = \lambda_1 + d\,\lambda_2$

(b) $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$

(c) $\lambda_1 + \lambda_2 + \lambda_3 = 0$

(d) $\lambda_3^2 = \lambda_1^2$ and λ_2^2

Very Short :

Question 1. Name the spectral series which lies in the visible region.

Question 2. What is the maximum number of spectral lines emitted by a hydrogen atom when it is in the third excited state? (CBSE AI 2013C)

Question 3. When is H_α line of the Balmer series in the emission spectrum of hydrogen atom obtained? (CBSE Delhi 2013C)
when an electron jumps from n =3 to n = 2 level.

Question 4.A mass of lead is embedded in a block of wood. Radiations from a radioactive source incident on the side of the block produce a shadow on a fluorescent screen placed beyond the block. The shadow of the wood is faint but the shadow of lead is dark. Give a reason for this difference.

Question 5. What was the source of alpha particles in Rutherford's alpha scattering experiment?

Question 6. If the radius of the ground level of a hydrogen atom is 5.3 nm, what is the radius of the first excited state?

Question 7. Calculate the ratio of energies of photons produced due to the transition of electron of a hydrogen atom from its:
(a) Second permitted energy level to the first level, and
(b) Highest permitted energy level to the second permitted level.

Question 8. The mass of an H-atom is less than the sum of the masses of a proton and electron. Why is this? (NCERT Exemplar)

Question 9. Name the series of hydrogen spectrum lying in ultraviolet and visible region.

Question 10. What is Bohr's quantisation condition for the angular momentum of an electron in the second orbit?

Short Questions :

Question 1. Define electron-volt and atomic mass unit. Calculate the energy in joule equivalent to the mass of one proton.

Question 2. State Bohr’s quantization condition of angular momentum. Calculate the shortest wavelength of the Bracket series and state to which part of the electromagnetic spectrum does it belong. (CBSE Delhi 2019)
Or
Calculate the orbital period of the electron in the first excited state of the hydrogen atom.

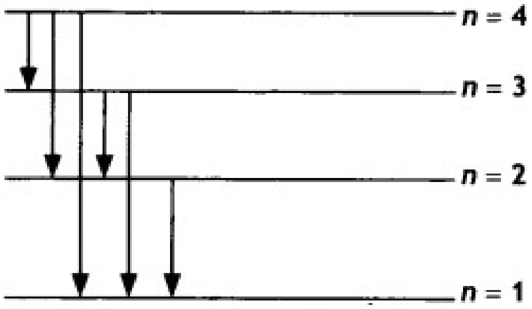
Question 3. Write two important limitations of the Rutherford nuclear model of the atom. (CBSE AI2018, Delhi 2018)

Question 4. Find out the wavelength of the electron orbiting in the ground state of the hydrogen atom. (CBSEAI 2018, Delhi 2018)

Question 5. (a) State Bohr’s postulate to define stable orbits in a 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. (CBSE AI 2018, Delhi 2018)

Question 6. An alpha particle moving with initial kinetic energy K towards a nucleus of atomic number Z approaches a distance ‘d’ at which it reverses its direction. Obtain an expression for the distance of closest approach ‘d’ in terms of the kinetic energy of the alpha particle, K. (CBSEAI2016C)

Question 7.The figure shows the energy level diagram of the hydrogen atom.



(a) Find out the transition which results in the emission of a photon of wavelength 496 nm.
(b) Which transition corresponds to the emission of radiation of maximum wavelength? Justify your answer. (CBSE AI 2015 C)

Question 8. A nucleus makes a transition from one permitted energy level to another level of lower energy. Name the region of the electromagnetic spectrum to which the emitted photon belongs. What is the order of its energy in electron-volts? Write four characteristics of nuclear forces.

Question 9.In accordance with the Bohr's model, find the quantum number that characterises the earth's revolution around the sun in an orbit of radius

$$1.5\times10^{11}\text{m}$$

with orbital speed

$$3\times10^{4}\text{m/s}$$

(Mass of earth.)

$$= 6.0\times10^{24}\text{kg}$$

Question 10. The total energy of an electron in the first excited state of the hydrogen atom is about

$$-3.4\text{eV}.$$

a) What is the kinetic energy of the electron in this state?

b) What is the potential energy of the electron in this state?

c) Which of the answers above would change if the choice of the zero of potential energy is changed?

(a)

Long Questions:

Question 1. Explain Rutherford's experiment on the scattering of alpha particles and state the significance of the results.

Question 2. Using Bohr's postulates, obtain the expression for the total energy of the electron in the stationary states of the hydrogen atom. Hence draw the energy level diagram showing how the line spectra corresponding to the Balmer series occur due to the transition between energy levels. (CBSE Delhi 2013)

Question 3. Hydrogen atoms are excited with an electron beam of energy of 12.5 eV. Find
(a) The highest energy level up to which the hydrogen atoms will be excited.

(b) The longest wavelengths in the (i) Lyman series, (ii) Balmer series of the spectrum of these hydrogen atoms. (CBSE 2019C)

Question 4. Using Bohr's postulates of the atomic model derive the expression for the radius of the 11th electron orbit. Hence obtain the expression for Bohr's radius. (CBSE AI 2014)

Question 5.State Bohr's postulate of the hydrogen atom successfully explains the emission lines in the spectrum of the hydrogen atoms.
Use the Rydberg formula to determine the wavelength of Ha line. [Given Rydberg constant R = 1.03×10^7 m^{-1}] (CBSE AI 2015)

Question 6. Using Bohr's postulates derive the expression for the frequency of radiation emitted when an electron In a hydrogen atom undergoes a transition from a higher energy state (quantum number n-) to the towering state (n,). When an electron in a hydrogen atom jumps from the energy state n_i =4 to n = 3, 2, 1, identify the spectral series to which the emission lines belong. (CBSE Delhi 201 1C)

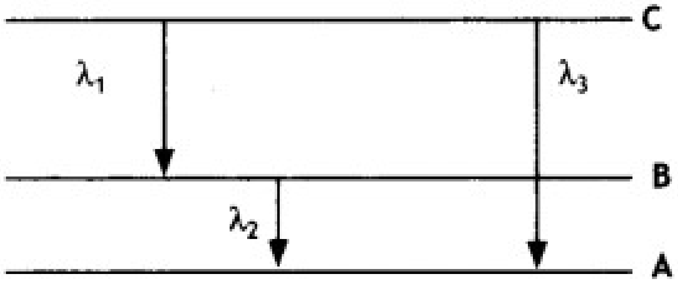
Question 7. Calculate the ratio of the frequencies of the radiation emitted due to the transition of the electron In a hydrogen atom from Its (i) second permitted energy level to the first level and (ii) highest permitted energy level to the second permitted level. (CBSE Delhi 2018C)

Question 8. Monochromatic radiation of wavelength 975 A excites the hydrogen atom from its ground state to a higher state. How many different spectral lines are possible In the resulting spectrum? Which transition corresponds to the longest wavelength amongst them? (CBSE Sample Paper 201819)

Question 9.
(a) Using postulates of Bohr's theory of hydrogen atom, show that
(i) the radii of orbits increases as n^2, and

(ii) the total energy of the electron increases as $1/n^2$, where n is the principal quantum number of the atom.
(b) Calculate the wavelength of H2 line In Balmer series of hydrogen atom, given Rydberg constant R = 1.097×10^7 m^{-1}. (CBSE AI 2011C)

Question 10. State Bohr's quantization condition for defining stationary orbits. How does de Brogue hypothesis explain the stationary orbits?
Find the relation between the three wavelengths λ1 λ2 and λ3 from the energy level diagram shown below. (CBSE Delhi 2016)



Assertion and Reason Questions-

1. For question two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

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

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

(iii) A is true, but R is false.

(iv) A is false and R is also false.

Assertion (A): Total energy of revolving electron in any stationary orbit is negative.

Reason (R): Energy is a scalar quantity. It can have positive or negative value.

2. For question two statements are given-one labelled Assertion (A) and the other labelled Reason (R). Select the correct answer to these questions from the codes (a), (b), (c) and (d) as given below.

a. Both A and R are true, and R is the correct explanation of A.
b. Both A and R are true, but R is NOT the correct explanation of A.
c. A is true, but R is false.
d. A is false and R is also false.

Assertion (A): In He-Ne laser, population inversion takes place between energy levels of neon atoms.

Reason (R): Helium atoms have a meta-stable energy level.

Case Study Questions-

1. Hydrogen spectrum consists of discrete bright lines in a dark background, and it is specifically known as hydrogen emission spectrum. There is one more type of hydrogen spectrum that exists where we get dark lines on the bright background, it is known as absorption spectrum. Balmer found an empirical formula by the observation of a small part of this spectrum, and it is represented by $\frac{1}{\lambda} = R\left(\frac{1}{2^2} - \frac{1}{n^2}\right)$ where n = 3, 4, 5 For Lyman series, the emission is from first state to n^{th} state, for Paschen series, it is from third state to n^{th} state, for Brackett series, it is from fourth state to n^{th} state and for Pfund series, it is from fifth state to n^{th} state.

(i) Number of spectral lines in hydrogen atom is:
- a) 8
- b) 6
- c) 15
- d) ∞

(ii) Which series of hydrogen spectrum corresponds to ultraviolet region?
- a) Balmer series.
- b) Brackett series.
- c) Paschen series.
- d) Lyman series.

(iii) Which of the following lines of the H-atom spectrum belongs to the Balmer series?
- a) 1025A
- b) 1218A
- c) 4861A
- d) 18751A

(iv) Rydberg constant is.

a) A universal constant.

b) A universal constants.

c) Different for different elements.

d) None of these.

(v) Hydrogen atom is excited from ground state to another state with principal quantum number equal to 4. Then the number of spectral lines in the emission spectra will be.

a) 3

b) 5

c) 6

d) 2

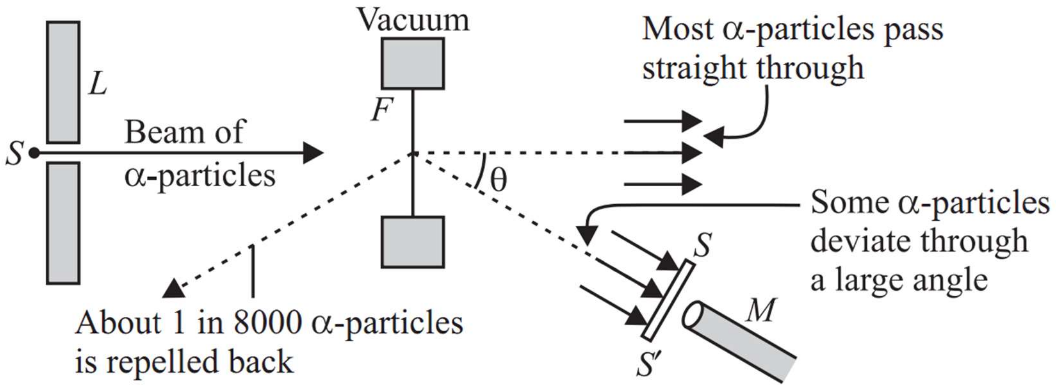
2. In 1911, Rutherford, along with his assistants, H. Geiger and E. Marsden, performed the alpha particle scattering experiment. H. Geiger and E. Marsden took radioactive source $\left({}^{214}_{83}\mathrm{Bi}\right)$ for α- particles. A collimated beam of αα-particles of energy 5.5 MeV was allowed to fall on 2.1×10^{-7} m thick gold foil. The α-particles were observed through a rotatable detector consisting of a Zinc sulphide screen and microscope. It was found that CL-particles got scattered. These scattered αα-particles produced scintillations on the zinc sulphide screen. Observations of this experiment are as follows.

Most of the α-particles passed through the foil without deflection.

Only about 0.14% of the incident α-particles scattered by more than 1°

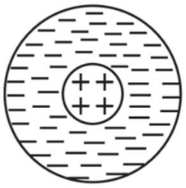
Only about one α-particle in every 8000 α-particles deflected by more than 90°

These observations led to many arguments and conclusions which laid down the structure of the nuclear model of an atom.

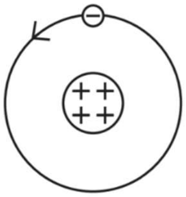


(i) Rutherford's atomic model can be visualised as.

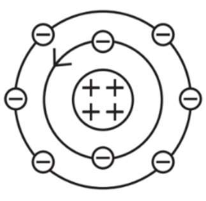
(a)



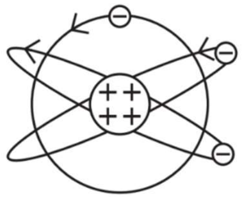
(b)



(c)



(d)



(ii) Gold foil used in Geiger-Marsden experiment is about 10^{-8} m thick. This ensures.

- a) Gold foil's gravitational pull is small or possible.
- b) Gold foil is deflected when α-particle stream is not incident centrally over it.
- c) Gold foil provides no resistance to passage of α-particles.
- d) Most α-particle will not suffer more than 1° scattering during passage through gold foil.

(iii) In Geiger-Marsden scattering experiment, the trajectory traced by an α-particle depends on.

- a) Number of collision.
- b) Number of scattered αα- particles.
- c) Impact parameter.
- d) None of these.

(iv) In the Geiger-Marsden scattering experiment, in case of head-on collision, the impact parameter should be.

- a) Maximum
- b) Minimum
- c) Infinite
- d) zero

(v) The fact only a small fraction of the number of incident particles rebound back in Rutherford scattering indicates that.

- a) Number of αα-particles undergoing head-on-collision is small.
- b) Mass of the atom is concentrated in a small volume.
- c) Mass of the atom is concentrated in a large volume.
- d) Both (a) and (b).

Multiple Choice Answers-

1. Answer: (a) of the electrons not being subject to a central force.
2. Answer: (a) in general, to any of the states with lower energy.

3. Answer: (c) 13.6 eV,-27.2 eV
4. Answer: (c) $V_L/25$
5. Answer: (b) 1 : -1
6. Answer: (a) E
7. Answer: (c) $\lambda_1 = \lambda_2 = 4\lambda_3 = 9\lambda_4$
8. Answer: (a) its kinetic energy increases but potential energy and total energy decrease
9. Answer:

   (d) $\Lambda_n = A + \frac{B}{\lambda_n^2}$
10. Answer: (b) jumps from higher orbit to lower orbit.
11. Answer: (c) – 3.4 eV
12. Answer: (c) All Fraunhofer lines changed into brilliant colours.
13. Answer: (d) 3λ
14. Answer: (b) $\frac{3}{2}, \frac{1}{2}$
15. Answer:

   (b) $\lambda_3 = \frac{\lambda_1\lambda_2}{\lambda_1+\lambda_2}$

Very Short Answers:

1. Answer: Balmer series
2. Answer: Six.
3. Answer: It is obtained
4. Answer: The shadow of the wood is faint because only the a-radiations are stopped by the wood (since a-radiations are least penetrating). The shadow of lead is dark because p and y-radiations are also stopped by lead.
5. Answer: The source was $^{214}_{83}Bi$.
6. Answer: It is 4 × 5.3 = 21.2 nm ($\because r = n^2 r_o$)
7. Answer:

   (b) energy of photon $E_1 = -3.4 - (-13.6) = 10.2$ eV

   (c) energy of photon $E_2 = 0 - (-3.4) = 3.4$ eV

   Ratio $\frac{E_1}{E_2} = \frac{10.2}{3.4} = 3$
8. Answer: Einstein's mass-energy equivalence gives $E = mc^2$. Thus the mass of an H-atom is

$m_p + m_e - B/c^2$ where $B \approx 13.6$ eV

9. Lyman series lies in ultraviolet region while Balmer series lies in visible region.

10. We know that,

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

We are given,

$$n = 2$$

$$\Rightarrow L = \frac{2h}{2\pi}$$

$$\therefore L = \frac{h}{\pi}$$

Therefore, Bohr's quantisation condition for the angular momentum of an electron in the second orbit is found to be,

$$L = \frac{h}{\pi}$$

Short Questions Answers :

1. Answer: Electron volt: It is defined as the energy gained by an electron when accelerated through a potential difference of 1 volt. Atomic mass unit: It is defined as one-twelfth of the mass of one atom of carbon 12.

The mass of a proton is 1.67×10^{-27} kg. Therefore, energy equivalent of this mass is $E = mc^2 = 1.67 \times 10^{-27} \times (3 \times 10^8)^2 = 1.5 \times 10^{-10}$ J

2. Answer: Bohr's Quantisation condition: Only those orbits are permitted in which the angular momentum of the electron is an integral multiple of $h/2\pi$.

For Brackett Series,
The shortest wavelength is for the transition of electrons from $n_i = \infty$ to $n_f = 4$

Using the equation

$$\frac{1}{\lambda} = R\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

$$\frac{1}{\lambda} = R\left(\frac{1}{4^2} - \frac{1}{\infty^2}\right) = \frac{R}{16}$$

Or $\lambda = \frac{16}{R} = \frac{16}{1.09 \times 10^7} = 1467.8 \text{ nm}$

OR

First excited state $n = 2$, $T = ?$

$$T = \frac{2\pi r}{v} = \frac{n^3\, h^3}{4\, \pi^2 m\, e^4\, k^2} \quad \text{where } k = \frac{1}{4\pi\varepsilon_0}$$

Substituting the values, we have

$$T = \frac{(2)^3 (6.6 \times 10^{-34})^3}{4 \times (3.14)^2 \times 9.1 \times 10^{-31} \times (1.6 \times 10^{-19})^4 \times (9 \times 10^9)^2}$$

$$T = 1.22 \times 10^{-15}\,\text{s}$$

3. Answer:

1. Rutherford’s model fails to explain the line spectra of the atom.
2. Rutherford’s model cannot explain the stability of the nucleus.

4. Answer: The wavelength of an electron in the ground state of hydrogen atom is given by

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

or

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

For ground state
E = – 13.6 eV = 13.6 × 1.6 × 10^{-19} J

Hence wavelength of electron in the first orbit

$$\lambda = \frac{hc}{E} = \frac{6.6 \times 10^{-34} \times 3 \times 10^{8}}{13.6 \times 1.6 \times 10^{-19}} = 0.9 \times 10\text{-}7 \text{ J}$$

5. Answer: (a) Bohr’s postulate for stable orbits states the electron in an atom revolves around the nucleus only in those orbits for which its angular momentum is an integral multiple of h/2π (h = Planck’s constant), (n = 1, 2, 3 …)

As per de Broglie’s hypothesis λ = h/p = h/mv
For a stable orbit, we must have a circumference of the orbit = nλ (n = 1, 2, 3,…)
∴ 2πr = nλ

or
$mvr = nh/2\pi$

Thus de-Broglie showed that the formation . of stationary patterns for integral “n” gives rise to the stability of the atom.
This is nothing but Bohr’s postulate.

(b) Energy in the n = 4 level $n_1 = 1$ and $n_2 = 4$

$$\therefore \frac{1}{\lambda} = R_H\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$$

$$= R_H\left(\frac{1}{1^2} - \frac{1}{4^2}\right)$$

$$= R_H\left(1 - \frac{1}{16}\right) = R_H\left(\frac{15}{16}\right) \qquad \ldots(i)$$

$$\because \nu = \frac{c}{\lambda}$$

$$= c \times \frac{1}{\lambda}$$

From eqn (*i*)

$$\nu = c \times R_H\left(\frac{15}{16}\right)$$

$$= 3 \times 10^8 \times 1.09 \times 10^7\left(\frac{15}{16}\right)$$

$$\therefore \nu = 3.1 \times 10^{15}\ \text{Hz}$$

6. Answer: At the distance of the closest approach, the kinetic energy of the alpha particle is converted into the electrostatic potential energy of the alpha particle-nucleus system. Therefore, at the distance of the closest approach

we have
Kinetic energy = Potential energy
Therefore,

$$\frac{1}{2}mv^2 = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{r_{min}}$$

$$\text{or } r_{min} = \frac{1}{4\pi\varepsilon_0}\frac{2Ze^2}{K}$$

where K is the kinetic energy.

7. Answer: (a) The wavelength of photon emitted is given by

$$\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

None of these transitions correspond to a wavelength of 496 nm. The closest is 4 to 2 of 489 nm

(b) Transition 4 to 3 as the frequency of this radiation is maximum.

8. Answer: (a) Emitted photon belongs to gamma-rays part of the electromagnetic spectrum.

(b) the energy is of the order of MeV.

(c) Four characteristics of nuclear forces are:

1) Nuclear forces are independent of charges.
2) Nuclear forces are short-range forces.
3) Nuclear forces are the strongest forces in nature, in their own small range of few fermis.
4) Nuclear forces are saturated forces.

9. Answer: We are given:

Radius of the orbit of the Earth around the Sun,

$$r=1.5\times10^{11}\text{m}$$

Orbital speed of the Earth,

$$\upsilon = 3 \times 104\text{m/s}$$

Mass of the Earth,

$$m= 6.0 \times 10^{24}\text{kg}$$

According to Bohr's model, angular momentum is quantized and could be given as:

$$\text{Mvr} = \frac{\text{nh}}{2\pi}$$

Where,

h=

Planck's constant

$$=6.62\times10^{-34}\text{Js}$$

n=

Quantum number

$$\Rightarrow n = \frac{mvr2\pi}{h}$$

$$\Rightarrow n = \frac{2\pi \times 6 \times 10^{24} \times 3 \times 10^{4} \times 1.5 \times 10^{11}}{6.62 \times 10^{-34}}$$

$$\therefore n = 25.61 \times 10^{73} = 2.6 \times 10^{74}$$

Hence, the quanta number that characterizes the Earth' revolution is found to be

$$2.6\times10^{74}.$$

10. Answer: (a) We are given,

Total energy of the electron,

$$E=-3.4eV$$

Kinetic energy of the electron is equal to the negative of the total energy.

$$\Rightarrow K.E=-E$$

$$\therefore K.E=-(-3.4)=+3.4eV$$

Hence, the kinetic energy of the electron in the given state is found to be

$$+3.4eV.$$

(b) We know that, the potential energy (U) of the electron is found to be

equal to the negative of twice of its kinetic energy.

$$\Rightarrow U=-2K.E$$

$$\therefore U=-2\times3.4=-6.8eV$$

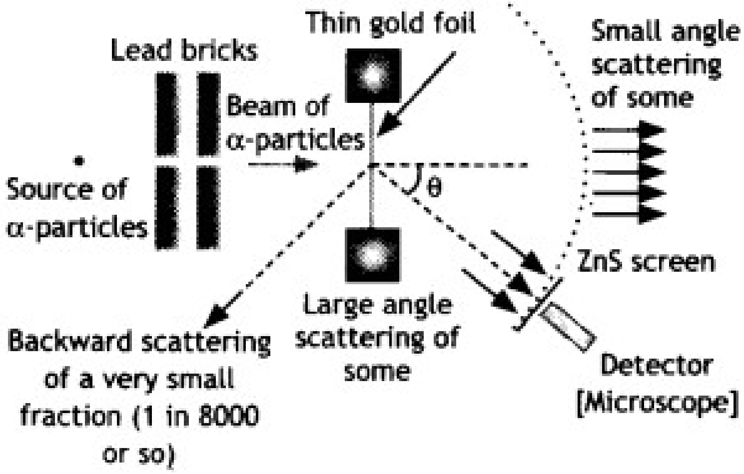
Hence, the potential energy of the electron in the given state is found to be

$$-6.8eV.$$

(d) We know that, the potential energy of a system would depend on the reference point taken. Here, the potential energy of the reference point is taken to be zero. On changing the reference point, then the value of the potential energy of the system would also change. Since, we know that total energy is the sum of kinetic and potential energies, total energy of the system will also change.

Long Questions Answers :

1. Answer: The schematic arrangement in the Geiger Marsden experiment is shown in the figure.



Alpha-particles emitted by a Bismuth ($^{214}{}_{83}Bi$) radioactive source were collimated into a narrow beam by their passage through lead bricks. The beam was allowed to fall on a thin foil of gold of thickness 2.1×10^{-7} m. The scattered alpha-particles were observed through a rotatable detector consisting of a zinc sulfide screen and a microscope. The scattered alpha-particles on striking the screen produced bright light flashes or scintillations. These scintillations could be viewed through the microscope and counted at different angles from the direction of the incident beam.

Significance: The experiment established the existence of a nucleus that contained the entire positive charge and about 99.95% of the mass.

2. Answer: The electron revolving around the nucleus has two types of energy:

Kinetic energy due to its motion.
Potential energy due to it lying in the electric field of the nucleus.

Thus the total energy of the electron is given by
E = K. E. + P. E. …(1)

An electron of mass m moving around the nucleus with an orbital velocity v has kinetic energy given by

$$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}\frac{ke^2}{r} \quad ...(2)$$

Now the potential energy of the electron at a distance r from the nucleus is given by
PE = potential due to the nucleus at a distance r × charge on the electron = V × – e …(3)

Now the potential at a distance r from the nucleus having a charge e is given by

$$V = k\frac{e}{r} \quad .....(4)$$

Substituting in equation (3) we have

$$P.E. = V \times - e = -k\frac{e^2}{r} \quad ...(5)$$

Substituting equations (2) and (3) in equation 1 we have

$$\begin{aligned} E = K.E. + P.E. &= \frac{1}{2}\frac{k\,e^2}{r} - \frac{k\,e^2}{r} \\ &= -\frac{1}{2}\;\frac{k\,e^2}{r} \qquad ...(6) \end{aligned}$$

But the radius of the nth orbit is given by

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

Substituting in equation (6) we have

$$E = -\frac{2\pi^2me^4k^2}{n^2\,h^2} \quad ...(7)$$

This gives the expression for the energy possessed by the electron in the nth orbit of the hydrogen atom.

3. Answer: (a) The maximum energy that the excited hydrogen atom can have is

$$E = -13.6 \text{ eV} + 12.5 \text{ eV}$$

or $E = -1.1 \text{ eV}$

Since $E_n = \dfrac{-13.6}{n^2} eV$

$\therefore$ For $n = 1$, $E_1 = -13.6 \text{ eV}$ $(< 1.1 \text{ eV})$

For $n = 2$, $E_2 = \dfrac{-13.6}{4} = -3.4 \text{ eV}$

$(< -1.1 \text{ eV})$

For $n = 3$, $E_3 = \dfrac{-13.6}{9} = -1.5 \text{ eV}$

$(< -1.1 \text{ eV})$

For n=4, E4 = $\dfrac{-13.6}{16} = -0.85\text{eV}$

$(> -1.1 \text{ eV})$

∴ The electron can only be excited up to n = 3 states.

(b) From energy tevet of hydrogen atom,
we have

$$\frac{1}{\lambda} = R\left[\frac{1}{n_1^2} - \frac{1}{n_2^2}\right]$$

Longest wavelength of Lyman senes

$$\frac{1}{\lambda_L} = R\left[\frac{1}{1^2} - \frac{1}{2^2}\right] = \frac{3}{4}R$$

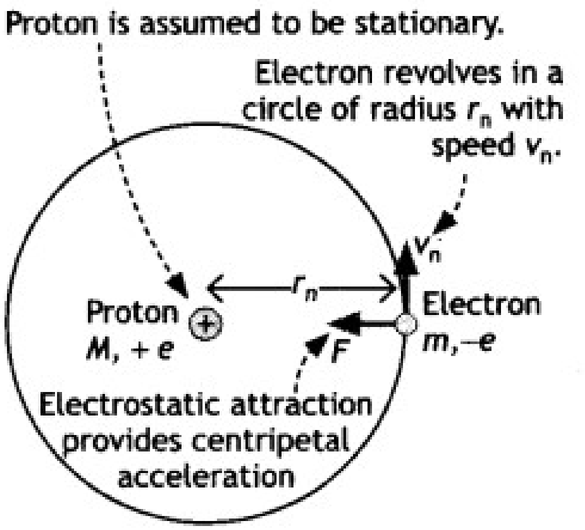
or $\lambda_L = \dfrac{4}{3R} = \left(\dfrac{4}{3 \times 1.1 \times 10^7}\right) m \simeq 1218 \text{ A}^{\circ}$

Longest wavelength of Balmer series

$$\frac{1}{\lambda_B} = R\left[\frac{1}{2^2} - \frac{1}{3^2}\right] = \frac{5}{36}R$$

$\therefore \lambda_B = \dfrac{36}{5R} = \left(\dfrac{36}{5 \times 1.1 \times 10^7}\right) m \simeq 6560 \text{ Å}$

4. Answer: Let us consider a mechanical model of the hydrogen atom as shown in the figure that incorporates this quantization assumption.



This atom consists of a single electron with mass m and charge – e revolving around a single proton of charge + e. The proton is nearly 2000 times as massive as the electron, so we can assume that the proton does not move. As the electron revolves around the nucleus the electrostatic force of attraction between the electron and the proton provides the necessary centripetal force. Therefore, we have

$$k\frac{e^2}{r_n^2} = \frac{mv^2}{r_n}$$

or $$k\frac{e^2}{r_n} = mv^2 \qquad \ldots(1)$$

By Bohr's quantisation condition we have

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

or $$v = \frac{n\,h}{2\,\pi\,mr_n} \qquad \ldots(2)$$

substituting equation 2 in equation 1 we have

$$k\frac{e^2}{r_n} = m\left(\frac{n\,h}{2\,\pi\,mr_n}\right)^2 \qquad \ldots(3)$$

Solving for r we have $$r_n = \frac{n^2\,h^2}{4\,\pi^2 m\,e^2\,k} \qquad \ldots(4)$$

This gives the radius of the nth orbit of the hydrogen atom.
If n = 1 we have r = a_o which is called Bohr's radius.

$$a_o = \frac{h^2}{4\pi^2 me^2 k}$$

5. Answer: It states that an electron might make a transition from one of its specified non¬radiating orbits to another of lower energy. When it does so, a photon is emitted having

energy equal to the energy difference between the initial and final states. The frequency of the emitted photon is then given by

$hv = E_i - E_f$ where E_i and E_f are the energies of the initial and final states

Using the formula $\frac{1}{\lambda} = R_H\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$ we have for Ha Line $n_i = 3$ and $n_f = 2$

$$\text{Therefore, } \frac{1}{\lambda} = 1.03 \times 10^7\left(\frac{1}{2^2} - \frac{1}{3^2}\right)$$

$$\text{or } \lambda = \frac{36}{5 \times 1.03 \times 10^7} = 6.99 \times 10^{-7}\ \text{m}$$

6. Answer: According to Bohr's frequency condition, if an electron jumps from an energy Level E to E_1, then the frequency of the emitted radiation is given by

$hv = E - E_1$ ...(1)

Let ni and nf be the corresponding orbits then

$$E_i = -\frac{2\pi^2 m e^4 k^2}{n_i^2 h^2} \text{ and } E_f = -\frac{2\pi^2 m e^4 k^2}{n_f^2 h^2}$$

substituting in equation (1) we have

$$h\nu = -\frac{2\pi^2 m e^4 k^2}{n_i^2 h^2} - \left(-\frac{2\pi^2 m e^4 k^2}{n_f^2 h^2}\right)$$

$$= \frac{2\pi^2 m e^4 k^2}{h^2}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

Rewriting the above equation we have

$$\nu = \frac{2\pi^2 m e^4 k^2}{h^3}\left(\frac{1}{n_f^2} - \frac{1}{n_i^2}\right)$$

This gives the frequency of the emitted radiation.

When $n_i = 4$ and $n_f = 3$, Paschen series

When $n_i = 4$ and $n_f = 2$, Balmer series

When $n_i = 4$ and $n_f = 1$, Lyman senes

7. Answer: We have

$$h\nu = E_f - E_i$$

$$= \frac{E_0}{n_f^2} - \frac{E_0}{n_i^2}$$

$$(i)\quad h\nu_1 = E_0\left(\frac{1}{1^2} - \frac{1}{2^2}\right) = E_0 \times \frac{3}{4}$$

$$(ii)\quad h\nu_2 = E_0\left(\frac{1}{2^2} - \frac{1}{\infty^2}\right) = E_0 \times \frac{1}{4}$$

$$\therefore\ \frac{\nu_1}{\nu_2} = 3$$

8. Answer: The energy corresponding to the given wavelength:

$$E(\text{in eV}) = \frac{hc}{\lambda} = \frac{6.6\times10^{-34}\times3\times10^{8}}{975\times10^{-10}\times1.6\times10^{-19}}$$
$$= 12.71\,\text{eV}$$

The excited state:

$$E_n - E_1 = 12.71$$

$$-\frac{13.6}{n^2} - (-13.6) = 12.71$$

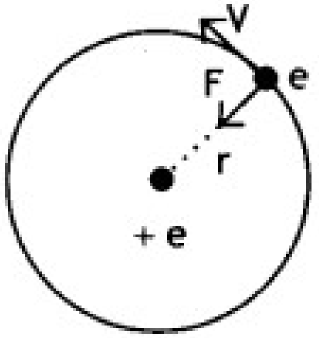
or $n = 4$

Total no. of spectral lines emitted:

$$\frac{n(n-1)}{2} = \frac{4(4-1)}{2} = \frac{12}{2} = 6$$

The longest wavelength Will correspond to the transition n = 4 to n = 3

9. Answer: Let us consider a mechanical. model of the hydrogen atom as shown in the figure.



This atom consists of a single electron with mass m and charge – e revolving around a single proton of charge + e. As the electron revolves around the nucleus the electrostatic force of attraction between the electron and the proton provides the necessary centripetal force. Therefore we have,

$$k\frac{e^2}{r_n^2} = \frac{mv^2}{r_n} \qquad ...(1)$$

or $k\frac{e^2}{r_n} = mv^2$ ...(2)

By Bohr's quantisation condition we have $mvr = \frac{nh}{2\pi}$

or $v = \frac{n\,h}{2\,\pi\,mr_n}$ ...(3)

Substituting equation 3 in equation 2 we have

$$k\frac{e^2}{r_n} = m\left(\frac{n\,h}{2\,\pi\,mr_n}\right)^2 \qquad ...(4)$$

Solving for r we have $r_n = \frac{n^2\,h^2}{4\,\pi^2 m\,e^2\,k}$ ...(5)

This gives the radius of the n^{th} orbit of the hydrogen atom which shows that $E \propto \frac{1}{n^2}$

(ii) the total energy possessed by an electron in the nth orbit of the hydrogen atom is given by
E = T + U ...(1)
i.e. the sum of its kinetic and electrostatic potential energies.

An electron of mass m moving around the nucleus with an orbital velocity v has kinetic energy given by

$$K.E. = \frac{1}{2}mv^2 = \frac{1}{2}\frac{ke^2}{r} \quad ....(2)$$

Now the potential energy of the electron at a distance r from the nucleus is given by
PE = potential due to the nucleus at a distance r × charge on the electron
= V × – e ...(3)

Now the potential at a distance r from the nucleus having a charge e is given by

$$V = k\frac{e}{r} \quad ....(4)$$

Substituting in equation 2 we have

$$P.E. = V \times - e = -k\frac{e^2}{r} \quad ...(5)$$

Substituting equations 2 and 5 in equation 1 we have

$$E = K.E. + P.E. = \frac{1}{2}\frac{k e^2}{r} - \frac{k e^2}{r}$$

$$= -\frac{1}{2}\frac{k e^2}{r} \quad ...(6)$$

But the radius of the nth orbit is given by

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

Substituting in equation 6 we have

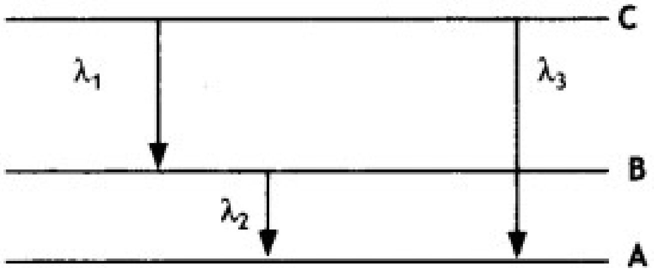
$$E = -\frac{2\pi^2me^4k^2}{n^2h^2} \quad ...(7)$$

This gives the expression for the energy possessed by the eLectron in the nth orbit of the hydrogen atom which shows that $E \propto \frac{1}{n^2}$

(b) For H_2 Line in Balmer series $n_1 = 2$ and $n_2 = 3$

$$\frac{1}{\lambda} = 1.097 \times 10^7\left[\frac{1}{4} - \frac{1}{9}\right] = 1.097 \times 10^7 \times \frac{5}{36}$$

or $\lambda = 656.3$ nm



10. Answer: It states that only those orbits are permitted in which the angular momentum of the electron about the nucleus is an integral multiple of $\frac{h}{2\pi}$, where his Planck's constant.

According to de Broglie, an electron of mass m moving with speed v would have a wavelength λ given by
$\lambda = h/mv$.

Now according to Bohr’s postulate,

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

or

$$2\pi r_n = \frac{nh}{mv}$$

But h / mv = A is the de BrogUe wavelength of the electron, therefore, the above equation becomes $2\pi r_n = n\lambda$ where $2\pi r_n$ is the circumference of the permitted orbit. If the wavelength of a wave does not close upon itself, destructive interference takes place as the wave travels around the loop and quickly dies out. Thus only waves that persist are those for which the circumference of the circular orbit contains a whole number of wavelengths.

$$\Delta E_3 = \Delta E_1 + \Delta E_2$$

$$\frac{hc}{\lambda_3} = \frac{hc}{\lambda_1} + \frac{hc}{\lambda_2}$$

$$\text{or } \frac{1}{\lambda_3} = \frac{1}{\lambda_1} + \frac{1}{\lambda_2}$$

$$\frac{1}{\lambda_3} = \frac{\lambda_2 + \lambda_1}{\lambda_1 \lambda_2}$$

$$\lambda_3 = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}$$

Numerical Problem :

Formulae for solving numerical problems

- Distance of closest approach $r_o = \frac{1}{4\pi\varepsilon_0}\frac{2zE^2}{E_k}$
- Radius of the nth orbit of hydrogen atom rn = $\frac{n^2h^2}{4\pi^2mе^2k}$
- Velocity of eLectron in the ntt orbit v = $v = \frac{c}{137n}$
- Wavelength of radiation emitted when electron jumps form ni to nf $\frac{1}{\lambda} = R_{\mathrm{H}}\left(\frac{1}{n_{\mathrm{f}}^2} - \frac{1}{n_{\mathrm{i}}^2}\right)$
- Energy of electron in the nth orbit of hydrogen atom

  $E = -\frac{2\pi^2me^4k^2}{n^2h^2}$

  or

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

Assertion and Reason Answers-

1. (b) Both A and R are true, but R is NOT the correct explanation of A.

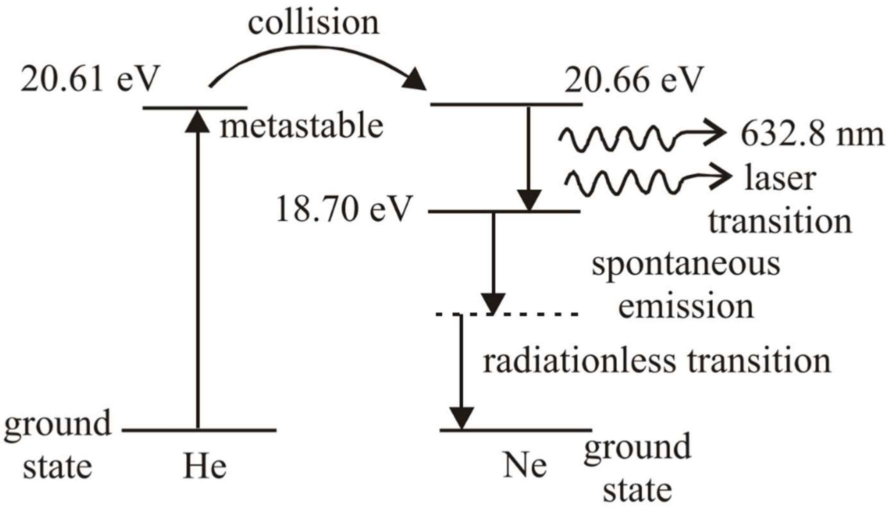
Explanation:

The reason is correct, but does not explain the assertion properly. Negative energy of revolving electron indicates that it is bound to the nucleus. The electron is not free to leave the nucleus.

2. (a) Both A and R are true, and R is the correct explanation of A.

Explanation:

Helium-neon laser uses a gaseous mixture of helium and neon. An electric discharge in the gas pumps the helium atoms to higher energy level, (which is meta stable energy level).



Sequence of transitions in He-Ne laser.

Then these helium atom excite the neon atoms to higher level by collision and produce an inverted population of neon atom which emit radiation when they are stimutated to fall to lower level.

Case Study Answers-

1. Answer :

(i) (d) ∞

Explanation:

Number of spectral lines in hydrogen atom is ∞

(ii) (d) Lyman series

Explanation:

Lyman series lies in the ultraviolet region

(iii) (c) 4861 A

Explanation:

The shortest Balmer line has energy = 1|(3.4 - 1.51)|1eV = 1.89eV and the highest energy = 1(0 - 3.4)1 = 3.4eV The corresponding wavelengths are

$$\frac{12400\text{eVA}}{1.89\text{eV}} = 6561\text{A and } \frac{12400\text{eVA}}{3.4\text{eV}} = 3647\text{A}$$

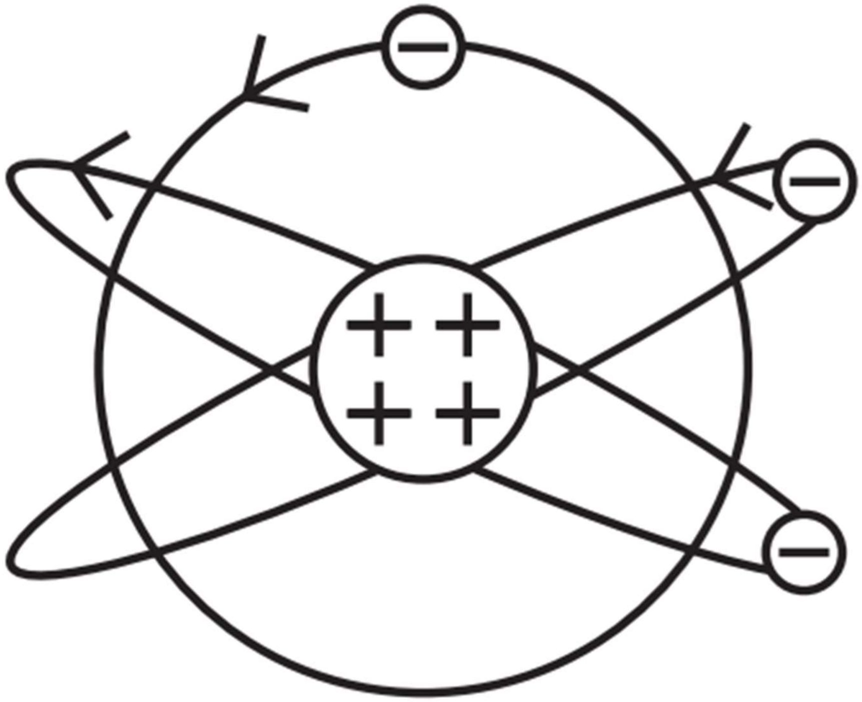
Only 4861A is between the first and last line of the Balmer series.

(iv) (a) A universal constant.

(v) (c) 6

2. Answer :

(d)



(i) (d)

Explanation:

Rutherford's atom had a positively charged centre and electrons were revolving outside it. It is also called the planetary model of the atom, as in option (d).

(ii) (d) Most α-particle will not suffer more than 1° scattering during passage through gold foil.

Explanation:

As the gold foil is very thin, it can be assumed that α-particles will suffer not more than one scattering during their passage through it. Therefore, computation of the trajectory of an αα-particle scattered by a single nucleus is enough.

(iii) (c) Impact parameter

Explanation:

Trajectory of α-particles depends on impact parameter, which is the perpendicular distance of the initial velocity vector of the ααparticles from the centre of the nucleus. For small impact parameter, α particle close to the nucleus suffers larger scattering.

(iv) (b) Minimum

Explanation:

At minimum impact parameter, α particles rebound back $(\theta \approx \pi)$ and suffers large scattering.

(v) (d) Both (a) and (b).

Explanation:

In case of head-on-collision, the impact parameter is minimum and the α-particle rebounds back. So, the fact that only a small fraction of the number of incident particles rebound back indicates that the number of α-particles undergoing head-on collision is small. This in turn implies that the mass of the atom is concentrated in a small volume. Hence, option (a) and (b) are correct.ss