ATOMS

ALPHA-PARTICLE SCATTERING AND RUTHERFORD'S NUCLEAR MODEL OF ATOM

ATOMIC MODEL

A model is essentially a collection of hypotheses grounded in logical and scientific facts. When a model successfully addresses the majority of scientific inquiries through experimental verification, it attains the status of a theory. Conversely, if a model fails to meet the criteria of experimental validation, it remains simply a model and is not accepted as a theory. In essence, it can be summarized that every theory is a model, but not every model qualifies as a theory. As our understanding of substances progressed, various new models, including those proposed by Dalton, Thomsen, Rutherford, Bohr, among others, and emerged to provide clearer insights.

DALTON'S ATOMIC MODEL

1. Each element consists of minute, indivisible entities known as atoms.

2. Atoms belonging to the same element exhibit identical characteristics, both in terms of their physical and chemical properties. Conversely, atoms of distinct elements display differing properties.

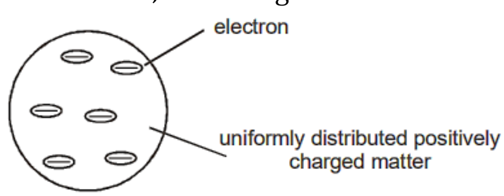
3. All elements are composed of hydrogen atoms. The heaviest atom possesses a mass approximately 250 times that of a hydrogen atom, while its radius is about 10 times larger than that of a hydrogen atom.

4. Atoms are stable and maintain electrical neutrality.

THOMSON'S ATOMIC MODEL (OR PLUM-PUDDING MODEL)

1. An atom is a solid sphere with a positive charge, characterized by a radius on the order of 10^{-10} meters. Within this sphere, electrons are embedded, analogous to seeds within a watermelon.

2. The total charge within an atom is zero, rendering the atom electrically neutral.



ACHIEVEMENTS OF MODEL

Successfully elucidated the phenomena of thermionic emission, photoelectric emission, and ionization.

TYPE OF LINE SPECTRUM

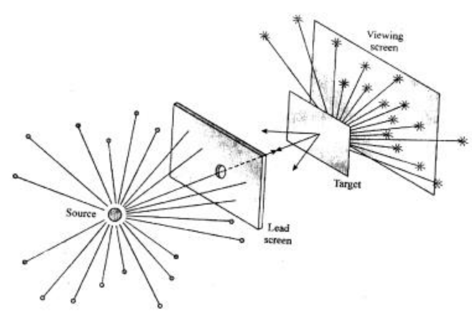
When an atomic gas or vapor, at a pressure lower than atmospheric pressure, undergoes excitation through an electric discharge, the resulting radiation exhibits a spectrum characterized by specific bright lines. This set of emission lines is referred to as an emission spectrum. Such lines are produced when electrons transition from excited states to lower energy states. The wavelength of these emission lines varies for different elements, and each element has a unique emission spectrum. This phenomenon is utilized in determining the composition of unknown substances.

ABSORPTION LINE SPECTRUM

When white light is transmitted through a gas, it is observed that the gas selectively absorbs light of specific wavelengths. The photographic plate, illuminated by the transmitted light, exhibits dark lines on a bright background. These dark lines correspond to the wavelengths that have been absorbed by the gas atoms. This pattern of dark lines on a bright background constitutes the absorption spectrum. The absorption spectrum is generated as a result of the absorption of particular wavelengths, causing the atoms to transition from lower energy states to higher energy states. (In contrast, the emission spectrum is characterized by bright lines on a dark background.)

RUTHORFORD'S ATOMIC MODEL

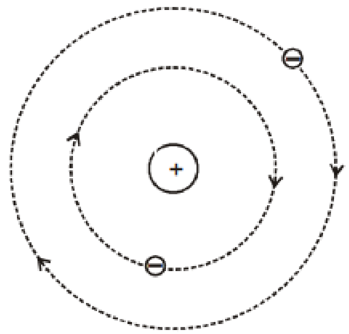
In 1911, Earnest Rutherford conducted a pivotal experiment aimed at assessing the validity of Thomson's atomic model. In this experiment, a stream of positively charged alpha particles, which are essentially helium nuclei, was directed towards a thin gold foil. The observations revealed that a majority of the alpha particles passed through the foil with minimal deviation, as if the foil were mostly empty space. However, some unexpected outcomes were also noted. A notable portion of the alpha particles experienced significant deflections from their original paths, and, surprisingly, a few alpha particles were even reflected backward, undergoing a complete reversal in their direction of travel, as depicted in the experiment.



If we consider Thomson's model to be accurate, where the positive charge is uniformly distributed throughout the volume of an atom, then the alpha particle should not experience significant repulsion, leading to the observed large-angle deflections in the experiment. In light of these observations, Rutherford proposed a new atomic model. In this revised atomic model,

The revised atomic model proposed by Rutherford assumed that the positive charge within the atom was concentrated in a small region relative to the size of the atom. This concentrated positive charge was termed the nucleus of the atom. Electrons associated with the atom were envisioned to move in the larger volume surrounding the nucleus.

To address the question of why these electrons did not spiral into the nucleus due to electrostatic attraction, Rutherford postulated that electrons orbited the nucleus in paths, much like planets orbit the sun. An approximate representation of this atomic model is depicted in the accompanying figure.



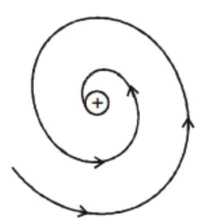
REASON OF FAILURE OF MODEL

1. The model faced a limitation in explaining the line spectrum of the hydrogen atom.

Explanation:
In accordance with Maxwell's electromagnetic theory, any accelerating charged particle emits energy in the form of electromagnetic waves. Therefore, when an electron undergoes circular motion around the nucleus, its frequency should continually vary (i.e., decrease), leading to the continuous emission of lines. However, experimental observations reveal a line spectrum for atoms, which contradicts the predicted continuous spectrum based on the model.

2. The model failed to provide an explanation for the stability of atoms.

Explanation:
The model proposed that a revolving electron would continuously radiate energy, causing the radius of its circular path to continuously decrease. According to this prediction, within a very short time (approximately 10^{-8} seconds), the revolving electron should fall into the nucleus, following a spiral path. However, such a scenario contradicts the observed stability of atoms, where electrons maintain their orbits without collapsing into the nucleus.



Path of electron spiral

DETERMINATION OF DISTANCE OF CLOSEST APPROACH

When a positively charged particle moves towards a stationary nucleus, the repulsion between the two causes a gradual decrease in the kinetic energy of the positively charged particle. There reaches a point where its kinetic energy becomes zero, and from this point onward, it begins to move back along its original path.

DEFINITION

The distance of closest approach refers to the minimum distance between a stationary nucleus and a positively charged particle engaged in a head-on collision, reaching a point where the kinetic energy of the particle becomes zero.

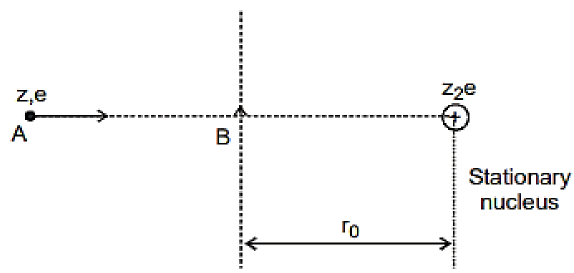
Imagine a positively charged particle, denoted as A, with a charge $q_1 = z_1 e$, moving in from infinity towards a stationary nucleus with a charge $z_2 e$. Let's consider the scenario where at point B, the kinetic energy of particle A becomes zero. According to the law of conservation of energy, the energy at points A and B can be expressed as:

$$\mathrm{TE_A} = \mathrm{TE_B}$$

$$\mathrm{KE_A} + \mathrm{PE_A} = \mathrm{KE_B} + \mathrm{PE_B}$$

$$E + 0 = 0 + \frac{k(z_1 e)(z_2 e)}{r_0} \,(in\ joule)$$

$$\therefore\ r_0 = \frac{k(z_1 e)(z_2 e)}{E} m$$



Example.

An α-particle, possessing a kinetic energy of 10 MeV, is directed towards an immobile point nucleus characterized by an atomic number of 50. Determine the distance at which the particle comes closest to the nucleus.

Solution.

$$\therefore\ \mathrm{TE_A} = \mathrm{TE_B}$$

$$r_0 = 1.44 \times 10^{-14} m$$

$$r_0 = 1.44 \times 10^{-6} A$$