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Organizing The Subject of Atomic Structure, Ruserford and Frank-Gers Experience on The Basis of New Pedagogical Technologies

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Abstract: This article talks about introducing information about the initial ideas about the structure of the atom, the thought of Democritus, the Thomson model of the atom, the experiments of Rutherford and Frank-Gers, the planetary model of the atomic nucleus of Rutherford, and teaching them based on modern pedagogical technologies.
Key words: Atom, Democritus, Thomson, Rutherford, Frank-Gers, planetary model

№	Topic question	I know (+)	I want to know (-)	I found out (+)
1	Do you know about atom, the smallest particle of matter?			
2	Do you know the Thomson model of the atom?			
3	Do you know the Rutherford model of the atom?			

1. Democritus (460-370 c.e.) proposed the idea that the basis of all existence is immutable and indivisible atoms. He believed that the universe consists of empty space and an infinite number of indivisible matter particles - atoms. All

bodies are made of atoms, and these atoms differ from each other in terms of shape, location and distribution. Bodies appear and disappear only due to the addition and division of atoms. The movement is not caused by some unnatural forces, but by the forces inherent in atoms. Democritus' atomic theory was literally a materialistic theory. However, there was an important flaw in his worldview, that is, he assumed that there is empty space. One of the famous ancient thinkers Aristotle opposed this, he rejected the existence of empty space based on the continuity of matter. At the same time, Aristotle denied the existence of indivisible atoms.

2. The experimental discovery of electrons became the basis for the creation of electron theory. Thanks to the work related to the study of the passage of electric current through rarefied gases and vacuum, electron theory took a big step forward. Another great English physicist Thomson measured the mass of the electron, Milliken measured the charge. The subsequent development of electron theory was very fruitful. The theory of electrons was absorbed into the theory of the structure of matter. In addition, the electrical theory of the structure of atoms, molecules and whole substances was created. According to this theory, it was concluded that atoms consist of positive charges and electrons.

In the early stages of the development of the theory of atomic structure, this whole system was assumed to be static. In order to consider electrons as particles in equilibrium, it was assumed as follows: positive electricity is evenly distributed in a sphere, the radius of this sphere is on the order of the radius of the whole atom, that is, on the order of 10^{-8} sm, and electrons Sha walks as if swimming in a positive electric "cloud". The light emission of an atom is considered as the result of very small fluctuations of electrons around equilibrium states (J.J. Thomson model). Although Thomson's model is consistent with some experimental results and is the model that has gained the most attention, it has had great difficulties in explaining atomic phenomena. The second hypothesis was announced in 1903, and according to the author F. Lenard's conclusion, the atoms of different substances are composed of

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different numbers of single elements. The third model belonged to the Japanese physicist H. Nakaoko. According to this model, an electron is located in a circle around a positive charge with a large mass at specific intervals. This model was close to the planetary model of the atom. Thus, the problem before atomic physics required characterizing and observing the existence of positive and negative particles in the internal structure of neutral atoms and their distribution within the atom.

3. By 1911, after J. Perrin's amazing experiments on Brownian motion, the idea of the atomic structure of matter gained a real basis. On the other hand, the experiments of E. Rutherford and F. Soddy put an end to the age-old concept of the atom being indivisible. These experiments showed the existence of the atom and the possibility of radioactive decay into other particles. As a result of the experiments conducted by E. Rutherford, his student G. Geiger and graduate student E. Marsden on the study of the scattering of α-particles from a target, a decisive step was made in the development of ideas about the atomic structure. In 1911, E. Rutherford bombarded the atom with a positive charge emitted from a radioactive substance in order to test J. Thomson's model of the atom. The scheme of the experiment is presented in Fig. 1. The a-particle used in these experiments was a particle with a positive charge of two in the unit of electron charge, and when it attached two electrons to itself, it turned into a neutral helium atom. In his experiments, Rutherford observed the trail of a bunch of α-particles using a photographic plate. The general scheme of Rutherford's experiment is presented in Figure 1.

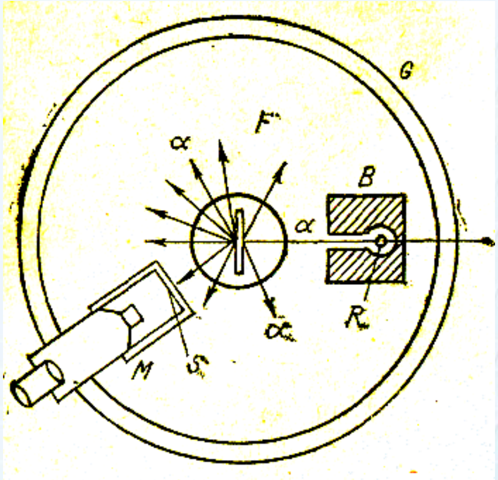

Fig. 1.

A radioactive substance R is placed inside the lead cavity B. Radioactive α-particles coming out in all directions are fully absorbed by the walls of the cavity B - lead, and only one direction - a bunch of α-particles in the form of a thin beam of the cavity - can go out. α - a thin die sprayed with gold is placed on the foil F in the path of the particles. α-particles scattered at an angle θ fall on the screen E and are recorded here. The entire device is placed in a vacuum.

Most α-particles retain their original directions or scatter at small angles when passing through the dice paper, but Rutherford observed that some α-particles scatter at extremely large angles (150^0-180^0). This situation cannot be explained on the basis of existing models. According to existing models, this was, as Rutherford put it, "just as if you fired a fifteen-pound cannonball at a piece of papyrus, and it was as highly improbable that the projectile would come back and hurt you." The assumption that the α-particles are not reflected from the surface of the paper just like light reflected from a mirror was rejected based on a simple experiment. When the paper was made into a bundle and replaced with F, an increase in the number of α-particles scattered at a large angle was observed with the thickening of the bundle. The conclusion was clear: the recoil of α-particles from the paper at a large angle was not a surface phenomenon, but the result of the effect of an unknown force inside the gold substance or atom. The target material was changed to tin, silver, platinum, iron to aluminum.

With the increase in the atomic weight of the metal, an increase in the number of α-particles scattered at a large angle was observed.

As a result of the experiments, Rutherford came to the following conclusions: the scattering of α-particles from a piece of paper can occur only under the influence of the electric field of a large positive charge concentrated in one point. So, the electric power of a very large positive charge in atoms is concentrated in a very small volume. Therefore, the α-particle is scattered at a large angle only when it collides with a large positive charge collected in a small volume of a gold atom. Based on this conclusion, Rutherford published the nuclear model of the atom in 1911.

4. If the atom conforms to Dj. Thomson's model, the gold particle (from Ra-214) deviates from the particle at various angles during transition (Fig. 2). He used a ZnS-coated screen and a microscope that moved in a circle around it to observe the particle that passed through the particle. When a particle hits the screen, it emits light. The light beam is observed using a microscope.

Of course, Rutherford did not bomb a single atom. The entire system is placed in a vacuum so that positive particles do not collide with air molecules. As a result of the experiment, it was found that α-particles scatter at different angles when they pass through a gold particle, and a very small part of it returns from it. The reason for this is that the α-particle collides with the positive nucleus, which is very small in size but has a large mass.

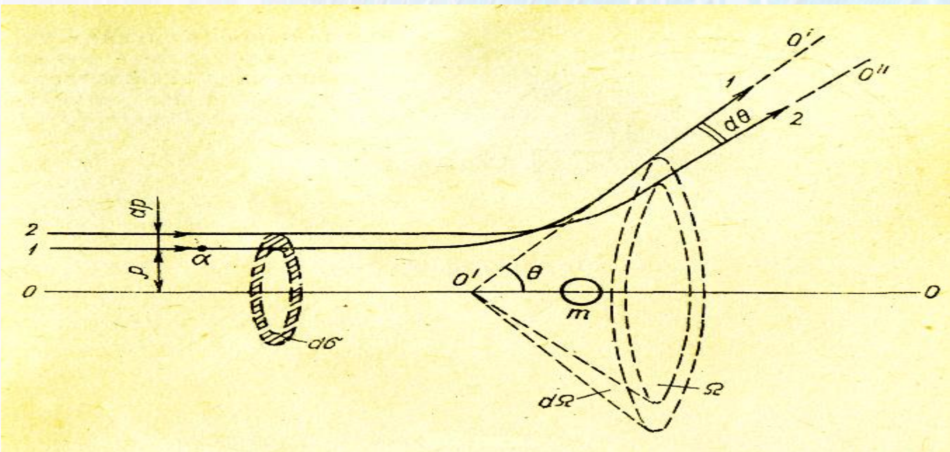

Fig. 2.

Thus, the following was determined from Rutherford's experiments:

1. The number of scattered α-particles is less than the number of falling α-particles;
2. There were α-particles that were scattered to a very large angle and even shot back to the source of α-particles;
3. When the scattering angle increases, the number of scattered particles decreases sharply.

Rutherford explained it as follows. In order for a particle as heavy as α-particle to scatter at a large angle, this particle must collide with a positively charged particle whose mass is equal to or greater than the mass of α-particle. If we assume that there are such particles in the atom, then they interact with the flying α-particles according to Coulomb's law, i.e:

$$F = -\frac{2e^2 Z_e}{r^2} \quad (1)$$

In this $2e$ -α -particle's charge, Z_e-the charge of a particle in an atom (α-particles collide with these particles).

To calculate the deviation angles, we use the results from the theory of motion of two bodies under the influence of central forces expressed by formula (1). In this case, the investigated charged body and α-particle with mass m and charge Ze are obtained. From Figure 2:

$$ctg\frac{\theta}{2} = \frac{\mathrm{m}_\alpha \vartheta^2 \rho}{2Ze^2} \quad (2)$$

The quantity ρ in this formula is called the target distance. The quantity in this formula is called the target distance. $\rho + d\rho$ Flying inside a cylindrical layer bounded by a cylindrical surface α-particles are scattered within a spatial angle $d\Omega$ bounded by a cone with scattering angles θ and $\theta + d\theta$.

ρ and $\rho + d\rho$ face of a cylindrical layer inside a circle with a radius:

$$d\sigma = 2\pi\rho d\rho \quad (3)$$

is equal to. This quantity is the effective cross section of *m* nucleus for scattering of α-particles in the interval of distance ρ and $\rho + d\rho$ in the interval of angle θ and $\theta + d\theta$.

If we take into account the number of atoms of mass m in the substance $1sm^3$ and the number of atoms of the volume ΔV in which the thickness of the scattering layer is equal to n, the general formula will look like this:

$$\Delta N = \frac{nNh}{R^2}\left(\frac{Ze^2}{m_\alpha \vartheta^2}\right)^2 \frac{1}{\sin\frac{\theta}{2}} \qquad (4).$$

formula (4) is called Rutherford's formula. Experiments on the scattering of the α-particle fully confirmed Rutherford's formula. From these experiments, it is concluded that all the positive charge of an atom and almost its entire mass are concentrated in a very small volume of the order of $10^{-13}\,sm$. Rutherford called this part of the atom the atomic nucleus and described the aforementioned planetary or nuclear model of the atom.

The results of Rutherford's experiments did not confirm the Thomson model of the atom. Based on the experiment, Rutherford $\alpha-$developed the theory of particle scattering and based on this, he derived his famous formula. Rutherford's formula is as follows:

$$\frac{d\mathrm{N}}{\mathrm{N}} = n\left(\frac{Ze^2}{2m\vartheta^2}\right)\frac{d\Omega}{\sin^4\frac{\theta}{2}}$$

where $n-$is the scattering nucleus concentration, $\theta-$ scattering angle, $Ze-$ charge of the scattering particle, $\vartheta-$ particle velocity, $\mathrm{N}-$ number of particles falling on the foil, $d\mathrm{N}-\theta,\theta+d\theta$ the number of particles scattered in the angular range, $m-$ the mass of the particle, $d\Omega=2\pi\cdot\sin\theta\cdot d\theta-$ spatial angle. $\theta-$ since the number of particles scattered at an angle strongly depends on the scattering angle and their number increases as the value of the angle decreases. Thus, Rutherford discovered the theoretical and practical planetary model of the atom, managed to determine the distribution of the fraction of $\alpha-$ particles scattered by a given $d\Omega$-spatial angle $\frac{dN}{N}$ - and the size of the nucleus.

An animation of Rutherford's experiment is shown from the Physikon computer program.

5. In 1911, Rutherford proposed a new model of the atom. At the center of the atom is a positively charged nucleus (its size is 10^{-14}m). The size of an atom is 10^{-10} m. Electrons move throughout the rest of the atom. There are no electrons in the nucleus. The nucleus can be imagined as follows. The nucleus consists of positively charged protons and uncharged neutrons. Protons in blue, neutrons in red. The number of electrons in an atom is equal to the number of protons in the nucleus. These numbers determine the sequence number of chemical elements. The mass of an electron is 1800 times smaller than the mass of a proton or a neutron, so all the mass of an atom is concentrated in the nucleus. Different electrons (electrons in each orbit) are bound to the nucleus to different degrees. Some of the electrons can easily be lost by the iron atom (electron in the outer orbit in Fig. 7), in which case the atom becomes a positive ion. If an atom has additional electrons, it becomes a negative ion. Rutherford assumes that electrons move in orbits around the nucleus. For this reason, his model was not even a planetary model. After proving that the charge of the nucleus is multiple of the charge of the electron, the charge of the nucleus is written as follows $+Ze$. Z is the sequence number of a chemical element in Mendeleev's table.

6. The Frank-Gers experience. The planetary model of the atom has difficulty in explaining some experimental results. Disadvantages of the planetary model of the atom:

1. According to Newtonian mechanics, an electron emits light when it moves with acceleration along a circle. But under normal conditions, atoms do not emit light.

2. It is known from our daily life that any atom is stable, that is, one chemical element does not spontaneously change to another element. According to Maxwell's theory, when an electron is irradiated, it should lose its energy and fall into the nucleus, but this phenomenon does not happen. Based on these shortcomings, we can draw the following conclusion: atoms obey laws that are completely different from the laws governing the motion of macroscopic bodies.

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As an experimental confirmation of Bohr's postulates, the experiments of Frank and Hers can be cited.

In 1923, Frank and Gers conducted an experiment to determine the energy required to excite mercury atoms, or the ionization potential. The scheme of the experiment is presented in Figure 3.

The main element of the device is a triode with three electrodes (cathode, grid and anode) inside a glass cylinder that has been sucked in and welded with air. 1 mm in a glass cylinder. sim. above there were mercury vapors under pressure. Electrons from the cathode "K" accelerate in the area between the cathode and grid "T" (accelerating voltage U) and slow down in the area between the grid and the anode "A".

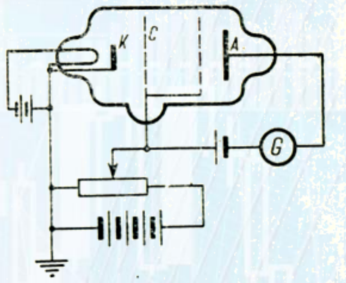


Fig. 3.

Electrons moving from the cathode to the anode collide with mercury atoms. The braking voltage is chosen to be much smaller than the accelerating voltage. Therefore, enough slow electrons reach the anode, that is, electrons that have lost their energy as a result of inelastic collision with mercury atoms.

In the experiment, the dependence of the anode current "I" and the accelerator "U" on the voltage was measured. The experimental curves are maximally 4.9 V apart from each other (Fig. 4). From the appearance of this curve, if $U < 4{,}9V$, collisions of electrons with mercury atoms are elastic. For this reason, there are no awakenings in atoms. As a result, the current increases steadily with the increase in voltage. When the voltage $U = 4{,}9V$ reaches the value, inelastic collisions associated with the awakening of mercury atoms begin. As a result, the current decreases sharply.

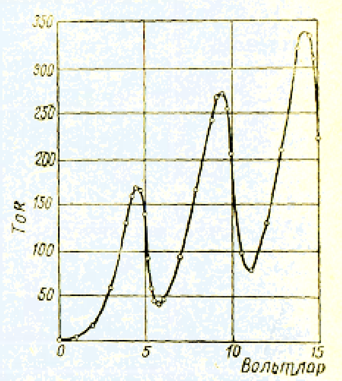
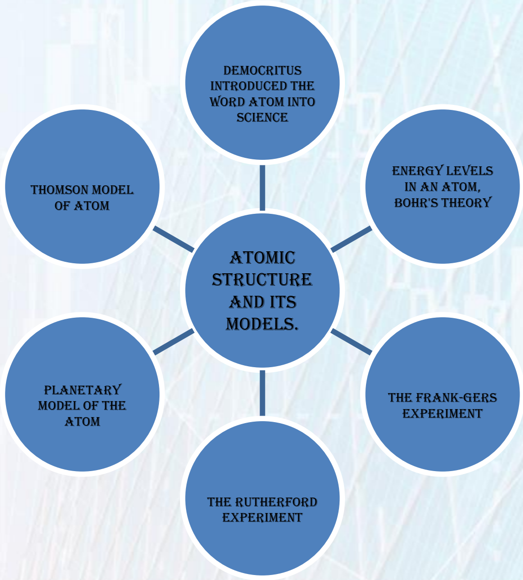


Fig. 4..

As the voltage increases, so does the current. At the value of voltage $U = 9{,}8V$, the awakening of mercury atoms and inelastic collisions begin again. Thus, from the appearance of the I(U) curve, it was determined that 4.9 eV of energy is needed to excite mercury atoms. Based on this experiment, it was found that energy levels differ from each other by discrete values (Fig. 4).

In the reinforcement part of the lesson, the "Cluster method" is used as follows.



Control questions at the end of the session:

1. State the opinion of Democritus about the atomic structure.
2. What is the Thomson model of the atom?
3. Explain Rutherford's experiment.
4. What conclusions were drawn from Rutherford's experiment?
5. Are there any disadvantages of the atomic planetary model?

6. Explain the Frank-Gers experiment.
7. What did the Frank-Gers experiment prove?

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