Teaching methodology of the topic "Stark effect" of the section "Atomic physics" of the course of general physics in higher educational institutions

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Abstract: This article discusses the improvement of the methodology for teaching the topic "Stark Effect" in the course of atomic physics taught at universities and pedagogical universities. Information is provided on pedagogical technologies and didactic games that can be used in the study of this topic, as well as their direct application.

Keywords: Stark effect, K. Schwarzschild, P.S. Epstein, π – component, σ – component, linear Stark effect, quadratic Stark effect, H_β spectral line.

Introduction

An external electric field, like a magnetic field, affects the spectral lines of an atom embedded in it. Under the influence of this field, the charges of atoms can shift to some extent. As a result, the energy of different states of the atom changes in different ways, and as a result, one can observe a violation of atomic energy levels and a change in the spectrum. In 1913, Stark observed the splitting of the lines of the Balmer series of the hydrogen atom under the action of an electric field. Therefore, the process of separation of the spectral lines of atoms in an electric field is called the Stark effect.

The Stark effect is observed in atoms other than hydrogen. From the very beginning it became clear that this effect could not be explained on the basis of classical theory. An attempt was made to explain the Stark effect on the basis of Bohr's semiclassical theory. Such work was carried out in 1916 by K. Schwarzschild (1874-1916) and P.S. Epstein (1886-1966). His main results were confirmed after E. Schrödinger developed the foundations of quantum mechanics. In the theory of K. Schwarzschild and P.S. Epstein used the computational methods of perturbation theory, which were used by Lagrange and Laplace in celestial mechanics and were later reworked for application in quantum mechanics.

Material and Methods

An atom introduced into an external electric field, that is, a light source with spectral lines, more precisely, the oscillation frequency of an electron in an atom depends on whether the oscillation goes in the direction of the electric field strength vector or in a direction perpendicular to it. Given that the radiation is a transverse wave, oscillations always take place in the direction perpendicular to the direction of the electric field strength vector. If the observation line is perpendicular to the direction of the electric field strength vector, then the oscillation occurs in the direction of the electric field strength vector and in the direction perpendicular to it. Since these oscillations have different frequencies, all observed spectral lines are linearly polarized. Some of these lines are polarized in the direction of the electric field strength vector, while the rest is polarized in the direction perpendicular to it. Lines polarized in the direction of the electric field vector are called the $\pi -$component, and lines polarized in the direction perpendicular to it are called the $\sigma -$component.

If the lines of observation are directed towards the vector of the electric field strength, then all oscillations arising due to radiation will be perpendicular to the vector $\vec{E}$. Because of this, only the $\sigma -$component is present in the observed spectrum. All of these components are unpolarized. Because the force acting on an oscillating electron from the electric field does not depend on the direction and modulus of the electron velocity vector. The main difference between the electric field and the magnetic field of an atom that is introduced into these fields is as follows. The force acting on an electron from the side of the magnetic field is directly proportional to the speed of the electron. If the electron's velocity vector changes its direction in the opposite direction, this force also changes its direction in the opposite direction. Therefore, it changes the angular velocity of the electron, which leads to an oscillatory motion of the electron. This change depends on the direction of electron motion. This, in turn, is related to the Zeeman effect. An electric field cannot produce such changes. Therefore, the components of the Stark effect are not polarized in the longitudinal direction. In a direction at an angle to the direction of the electric field lines, these components are polarized.

The occurrence of the Stark effect depends on whether the atom has a dipole moment in the absence of an electric field. If an atom has a dipole moment and this atom is placed in an electric field and limited only by linear terms corresponding to the direction of the field, then the atom will have an additional energy $(-\vec{p}\,\vec{E})$ proportional to the first power of the electric field strength. The shift and separation of the spectral lines is also proportional to the first order of the electric field strength. This phenomenon was observed by Stark. This is called the linear Stark effect.

If the atom does not have its own electric moment, then an induced dipole moment $p = \beta E$ appears in the external electric field. Here $\beta -$is the polarizability of the atom, which is calculated using the methods of quantum mechanics. As the electric field strength increases from 0 to E, the dipole moment of the atom also increases from 0 to p. In this case, work $\frac{pE}{2} = \frac{\beta E^2}{2}$ is done on the atom. According to the law of conservation of energy, this work is equal to the increment of the potential energy of an atom in an electric field. In this case, the displacement and separation of atomic spectral lines remains proportional to the square of the electric field strength E^2. This effect is called the quadratic Stark effect. This effect is much smaller than the linear effect. Therefore, it was discovered later than the linear effect.

An atom with a certain dipole moment in an electric field will have an additional dipole moment. This moment can be considered as a first approximation proportional to the electric field strength. In it, the linear and quadratic Stark effects are added, and the separation of energy levels is asymmetrical. All additional levels formed are shifted towards lower energy levels. The higher these levels, the stronger this shift will be. The spectral lines themselves are slightly shifted to the red region of the spectrum.

After the above information about the Stark effect, we can turn to the question of how to improve the method of teaching this topic. To do this, a professor-teacher can use the methods of innovative pedagogical technology and some types of didactic games.

One of the methods that can be used by the professor-teacher in determining the level of knowledge of students on the subject of "Stark effect" in relation to this group is the "Inventive-smart" method. The content of this method is as follows.

It is important for students to have the ability to think and reflect with the careful assimilation of existing knowledge. The "Inventive-smart" method helps to develop students' quick thinking skills, as well as to determine the speed of their thinking. The method provides a convenient opportunity for students who want to test their personal abilities. They must be able to answer the questions asked by the professor-teacher correctly and accurately within a short period of time. Depending on the difficulty level of the questions, points are awarded for the correct answer returned for each question. The speed of students' thinking is determined on the basis of finding the arithmetic mean of the final scores.

Results and discussion

Scoring ensures that students have a clear understanding of their individual abilities. The method can be used in individual, group and mass work with students. In the “Inventive-smart” method, the professor-teacher can ask students the following questions on the topic "Stark effect": 1) What is the Stark effect? 2) What is the role of an external electric field in the observation of the Stark effect? 3) Why is linear polarization of spectral lines observed during the Stark effect? 4) Define the $\pi-$component of polarized lines. 5) Define the $\sigma-$component of polarized lines.
6) When is the linear Stark effect observed? 7) When is the quadratic Stark effect observed? 8) Write and explain a selection rule expression that explains the appearance of the $\pi-$component. 9) How many components appear as a result of the Stark effect when the spectral line L_β of the Lyman series is split? Show with proof. 10) How many components appear as a result of the Stark effect when the spectral line L_γ of the Lyman series is split? Show with proof.

In addition, the professor-teacher can offer students to create a cluster for the term "Stark effect". To determine the level of knowledge of students and the assimilation of key terms on the topic "Stark Effect", a professor-teacher can use a didactic game called "What, where, when". The professor-teacher announces to the students the topic of the game, the necessary tasks and the list of references to the students at least a week in advance. The group divides students into several small groups. At the beginning of the game, the team captains determine by drawing lots the tasks on which they will work. Thus, they determine the order of participation of teams in this game. In accordance with the serial numbers of the tasks, the teams are seated at the gaming table in order. Questions-tasks on the topic of this game can be as follows: 1. Explain the Stark effect. 2. What can you say about the linear polarization of spectral lines that occurs during the Stark effect? 3. What is the difference between sigma components and pi components arising from the Stark effect? 4. How to explain the linear Stark effect in hydrogen ions? 5. What disappears when an atom is placed in an external electric field? 6. When is the average specific electric moment of an atom equal to zero? 7. What is the splitting of the spectral lines of the Balmer series of the hydrogen atom under the Stark effect? 8. Why is the shift and splitting in the linear Stark effect proportional to the first power of the electric field strength? 9. Is it possible to go from a linear Stark effect to a quadratic Stark effect? 10. What fluctuations are important in the Stark effect? 11. How to justify the non-polarization of sigma-components?

Additional questions include the following examples: a) What is the Stark effect? b) Does the Stark effect occur under the action of an arbitrary electric field? c) Is the Stark effect related to the Zeeman phenomenon? d) Is there a connection between the Stark effect and the Paschen-Back effect? e) Where can the Stark effect be used?

In addition, the following quizzes can be used as handouts to test students' knowledge of the Stark effect.

1. A 3-year student of the Faculty of Physics of the National University of Uzbekistan, who is submitting an independent work on the Stark effect, the Associate Professor of the Department of Nuclear Physics, set the task to insert the appropriate word instead of the ellipsis appearing in the following sentence: “The Stark effect occurs when .... is placed in an external electric field. Which of the following answers will the student choose? A) an atom. B) a molecule. C) a positive particle. D) negative particle.

2. The professor of the department "Physics and methods of teaching it" turned to a 3-year student of the Faculty of Physics and Mathematics of the Tashkent State Pedagogical University with the following question: "What is the influence of an external electric field on the Stark Effect?" Which of the proposed answers can a student choose? A) to molecules. B) to atomic radiation. C) to the arrangement of atomic spectral lines. D) answers B and C are correct.

3. A student of the 3rd year of the Faculty of Physics of the National University of Uzbekistan, who was explaining the Stark effect on the blackboard orally, suddenly stopped. He repeated the following statement several times: "The phenomenon of separation in an atom placed in an external electric field is called the Stark effect." Here the professor told him that he had made a mistake in defining the phenomenon. Which of the given answers corrects the student's mistake? A) The phenomenon of separation in an atom placed in an electric field is called the Stark effect. C) The splitting of atomic spectral lines into additional spectral lines is

called the Stark effect. C) The phenomenon of splitting of atomic spectra introduced into an external electric field is called the Stark effect. D) The splitting of atomic spectral lines into additional spectral lines in an external magnetic field is called the Stark effect.

4. The professor-teacher was interested in which scientists were involved in explaining the Stark effect. Which answer does the student who answered this question think is correct? A) K. Schwarzschild and P.S. Epstein. B) K. Schwarzschild and E. Schrödinger. C) P.S. Epstein and E. Schrödinger. D) K. Schwarzschild, P.S. Epstein and E. Schrödinger.

5. Select the incorrect one from the suggested answers.

A) In a weak electric field, the Stark effect is complicated due to the fine structure. C) Due to the action of an external electric field, when the atomic spectrum is split, placed in this field, a central component always appears. C) The theoretical analysis of the interaction of an atom or electron with an electromagnetic field that exists before radiation or arises in the process of radiation is more complicated. D) Additional multiplet splittings caused by small spin-orbit interactions lead to a fine structure of spectral lines in the Paschen-Back effect.

6. The professor-teacher said to the students present in the audience: “A deeper study of any phenomenon shows that the average specific electric moment of the atom is zero. In this case, when an atom is placed in an external electric field, the energy levels of the atom are split into additional levels. What event did he mean?

A) Paschen-Back effect. C) Linear Stark effect. C) Quadratic Stark effect. d) Zeeman phenomenon.

7. ...., the law of conservation of orbital momentum will not apply. Replace the dots with the appropriate words.

A) in an external magnetic field. C) in a gravitational field. C) in an electromagnetic field. D) In an external electric field.

8. A professor of the Faculty of Physics and Mathematics of the Tashkent State Pedagogical University asked 3rd year students: “How many components arise as a result of the Stark effect when the spectral lines L_β and L_γ of the Lyman series are split? ". Which of the proposed answers will students choose? A) 5. C) 7. C) 12. D) 3.

Conclusion

The use of the above methods when teaching the topic "The Stark effect" will consolidate the knowledge gained by students of universities and higher pedagogical educational institutions on this topic and will help to form skills and abilities on this topic.

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In addition, we hope that this teaching method will contribute to the development of students' creative thinking and abilities.

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