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The New Interpretation of Photoeffect

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Abstract: It has been disclosed that the equation suggested by A. Einstein for the interpretation of photoeffect is a mathematical model of the law of formation of the atom and ion spectra discovered in 1993.

Key words: energy, photon, electron, bond.

INTRODUCTION

It is known that the most acceptable interpretation of experimental dependencies of photoeffect has been suggested by A. Einstein in 1905, for which he got his only Nobel Prize [1], [2], [3]. He made it in the absence of the law of formation of the atom and ion spectra. Now this law has been discovered, and we can check the correctness of its interpretation and the possibility of a deeper understanding of photoeffect [4], [5], [6], [7].

THEORETICS ANALYSIS

The mathematical model suggested by A. Einstein for the interpretation of experimental dependencies of photoeffect has the following form [3]

$$E_k = h\nu - W, \quad (1)$$

where E_k is kinetic energy of the photoelectron emitted by the photocathode; $h\nu$ is energy of the photon (but it is not explained in the papers which photon exactly [1], [2], [3]), W is the photoelectron exit work which is a constant that does not depend on frequency [1], [2], [3]. The main experimental dependencies of photoeffect are given in Figure 1 [2].

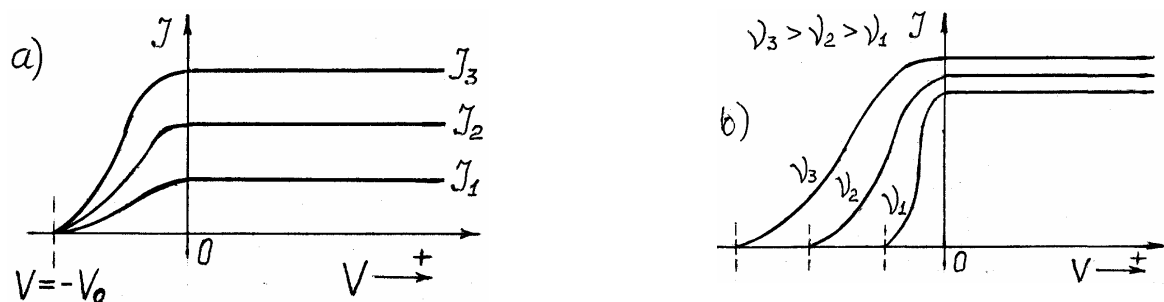


Figure 1. Dependence of photocurrent on light intensity: a) at its constant frequency; b) at different frequency ν .

Photocurrent takes place in the photocathode-collector circuit. If the photocathode is exposed to monochromatic light (Fig. 1a), the value of potential $-V$ retarding the photoelectrons emitted by the photocathode does not depend on light intensity. Increasing light intensity increases photocurrent and does not exert influence on the retarding potential value and consequently, on the kinetic energy of the photoelectrons. If the frequency of light, which strikes upon the photocathode is increased, the value of the negative potential $-V$ retarding the photoelectrons is increased (Fig. 1b).

As the value of the retarding negative potential $-V$ is determined by the kinetic energy E_k of the electrons emitted by the photocathode under the influence of light illumination, it results from the dependence shown in Figure 1b where the kinetic energy E_k of the photoelectrons emitted by them is increased with an increase in the frequency of the photons exposing the photocathode.

Let us try to find a connection of Einstein's equation (1) with the mathematical model of the law of formation of the atom and ion spectra (2). We have already shown that the mathematical model, which describes the spectra of the multi-electron atoms and ions, has the following form [4], [10], [12]:

$$E_{ph} = E_i - \frac{E_1}{n^2}, \quad (2)$$

where E_{ph} is energy of the photon absorbed or emitted by the electron; E_i is ionization energy of the electron; E_1 is energy of the bond of the electron with the atomic nucleus which corresponds to its first energy level; $n = 2, 3, 4, \dots$ is the main quantum number.

The correlation (2) appears from experimental spectroscopy, that is why it is a mathematical model of the law of formation of the atom and ion spectra. Einstein's equation (1) describes a similar process of photon absorption by the electrons. It affords the groundwork for supposition of identity of the equations (1) and (2), and uniformity of their interpretation. It appears from the given equation:

$$E_k = E_{ph}. \quad (3)$$

It means that if the electron loses the bond with the atomic nucleus, its kinetic energy E_k is equal to energy E_{ph} of the absorbed photon. Then

$$h\nu = E_i. \quad (4)$$

It appears from this that the $h\nu$ energy value in Einstein's equation (1) is ionization energy E_i of the electron being emitted by the photocathode material. It appears from equations (1) and (2) that

$$W = \frac{E_1}{n^2} = E_b. \quad (5)$$

The new clarification: the photoelectron exit work W is equal to binding energy of electron E_1/n^2 when it is on a definite energy level in the atom or the molecule.

Experimental investigations of the photoeffect are carried out usually with the photocathodes that are made of alkali metals [1]. For example, it is known that the work of the photoelectron's exit from the lithium photocathode is equal to $W = 2.4$ eV [1]. The ionization energy of this electron is equal to $E_i = 5.392$ eV, and its binding energy with the nucleus corresponds to the first energy level that is equal to $E_1 = 14.05$ eV [4]. If we take it into account and use the mathematical model of the law of formation of the atom and ion spectra (2), we will get a theoretical spectrum of

this electron E_{ph} (theor.) which coincides completely with the experimental spectrum E_{ph} (exp.) (Table 1). Formula (5) gives an opportunity to calculate the binding energies E_b of this electron with the atomic nucleus (according to Einstein, the exit work), which corresponds to all (n) energy levels of this electron [4].

Table 1. Spectrum of the first electron of the lithium atom

Volumes	n	2	3	4	5	6
E_{ph} (exper)	eV	-	3.83	4.52	4.84	5.01
E_{ph} (theor.)	eV	1.88	3.83	4.51	4.83	5.00
E_b (theor.)	eV	3.51	1.56	0.88	0.56	0.39

It is known that the like atoms are united in a molecule with the covalent bond, and the binding energies between valence electrons correspond to fractional quantum numbers n [4]. It allows us to determine what is a photoelectron emission source: atoms or molecules of the photocathode material. If we substitute $W=2.4$ eV and $E_1=14.05$ eV in formula (5), we will find $n=2.4$. As value n is a fractional number, it means that the lithium molecules, not atoms, are the source of the photoelectrons (Table 1) [4].

For a photoelectron of the sodium photocathode, we have: $E_i=5.139$ eV, $E_1=13.086$ eV and $W=2.1$ eV [1], [4]. If we use the mathematical model of the law of formation of the atom and ion spectra (2), we will get a sodium photoelectron spectrum (Table 2) [4].

Table 2. Spectrum of the 1st electron of the sodium atom.

Valumes	n	2	3	4	5	6
E_{ph} (exper)	eV	-	3.68	4.31	4.62	4.78
E_{ph} (theor.)	eV	-	3.68	4.32	4.62	4.77
E_b (theor.)	eV	3.27	1.45	0.82	0.52	0.36

Value n , determined with the help of the formula (5), is equal to $n=2.5$. It appears from this that the sodium molecules, not atoms, are the source of the photoelectrons of the sodium photocathode.

The mathematical model of the law of formation of the atom and ion spectra (2) shows that it has no orbital component of electron energy. It appears from this that the electron has no orbital motion in the atom. The molecules are formed by the combination of the unlike magnetic poles of their valence atomic electrons, which are connected with the nuclear protons by means of the magnetic poles as well [4], [8].

The analysis of the law of formation of the atom and ion spectra (2) as well as the spectrum calculation results (Tables 1 and 2) show that the binding energy E_b of the electron with the atomic nucleus and, consequently, the binding energy of valence electrons of two atoms with each other is changed step by step (5). It appears from this that the kinetic energy of the photoelectrons $E_k = E_{ph}$ and value of retarding potential $-V$ (Fig. 1b) should be changed step by step as well. The photoelectrons can absorb only the photons which correspond to their binding energies in the molecules of the given substance. The greater the binding energy between the electrons in the molecules, the greater photon energy that is required for the break of this bond, the greater the kinetic energy of the photoelectrons being released will acquire, and the greater the potential that

would be required for their retardation on the way to the collector. Let us pay attention to the fact that the given logical chain originates from the mathematical model of the law of formation of the atom and ion spectra (2) and is present in Einstein's equation implicitly (1).

Current is present in the circuit due to the fact that the photoelectrons are being emitted by the photocathode material molecules that are being substituted by free electrons. They should emit the photons whose energy is equal to the binding energy of the electrons in the molecules, but light striking the photocathode does not allow us to see this emission.

CONCLUSION

Mathematically, Einstein's equation describing experimental regularities of photoeffect has deeper physical sense. When the components of this equation are interpreted correctly, it becomes the mathematical model of the law of formation of the atom and ion spectra discovered by us in 1993 and published in the papers [9], [10], [11], [12], [4].

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[Journal Home Page](#)

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