

ON REGULARITIES IN THE EXCITATION CROSS SECTIONS OF THE LOWER LEVELS OF HELIUM BY ELECTRON IMPACT

PHYSICS

1966

SovietRxiv

View the original and related papers at <https://sovietrxiv.org/items/ru-196601.16102>

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

Abstract

Full Text

UDC 539.186.2:546.291

PHYSICS

I. P. Zapesochnyi

ON REGULARITIES IN THE EXCITATION CROSS SECTIONS OF THE LOWER LEVELS OF HELIUM BY ELECTRON IMPACT

(Presented by Academician L. A. Artsimovich on 10 February 1966)

Despite the considerable number of experimental works on the electron excitation of helium, there are still no at all complete data on the absolute excitation cross sections of its most important levels. In the present note some results are set forth of systematic studies of the excitation of helium atoms in collisions with slow electrons.

As was indicated earlier ⁽¹⁾, in the case of excitation of some level of an atom by a monoenergetic beam of electrons from the ground state, the stationarity condition will be simplest, namely

$$n_0 Q_k(v) v N + \sum_{i=k+1}^{\infty} A_{ik} n_i = \sum_{i=0}^{k-1} A_{ki} n_k, \quad (1)$$

where n_0 and n_i are the concentrations of normal and excited atoms; v, N are the velocity and concentration of monoenergetic electrons; Q_k is the excitation cross section of the k -th level; A_{ik} is the probability of transitions $i \rightarrow k$. Since in this case ⁽²⁾

$$I_{ik} = A_{ik} n_i h \nu_{ik}, \quad (2)$$

putting

$$I_{ik}/n_0 N v h \nu_{ik} = Q_{ik}, \quad (3)$$

we shall have

$$Q_k(v) = \sum_{i=0}^{k-1} Q_{ki}(v) - \sum_{i=k+1}^{\infty} Q_{ik}(v). \quad (4)$$

Figure 1

Figure 1: Figure 1

Figure 2

Figure 2: Figure 2

This formula makes it possible to determine the excitation cross section of a level if the excitation cross sections of the spectral transitions indicated in it are measured. As experience shows ⁽³⁾, the excitation cross sections of lines of any series fall off rather sharply with increasing n of the upper level. Therefore, instead of the infinite sum of cascade transitions in expression (4), it is sufficient to restrict oneself to the first few terms of the corresponding series. The presence of proportionality between the transition probabilities and the excitation cross sections of lines with a common upper level ⁽⁴⁾ also greatly reduces the number of lines that must actually be measured. Thus, expression (4) can be adopted as a working formula in the optical method for measuring excitation cross sections of atomic levels.

As a result of experiments carried out under conditions in which expressions (1) and (4) are valid, the excitation cross sections of 32 lines lying in the spectral interval 2900–11 000 Å were measured directly in the range of electron energies from threshold values to 150–250 eV. In this case the width of the energy spread in the beam did not exceed 0.8–1.2 eV. Taking into account data on the polarization of helium spectral lines upon excit–

Fig. 1. Dependence of the excitation cross section of singlet (**A**) and triplet (**B**) levels on the principal quantum number:
 a – S levels, b – P levels, v – D levels

Fig. 2. Energy dependence of the excitation cross sections of the lower levels of helium:
 1 – 2^1P ; 2 – 2^3P ; 3 – 2^1S ; 4 – 2^3S ; 5 – 3^1D , 6 – 3^3D

...electron-atom collisions. On the other hand, with their aid one can estimate the excitation cross sections of the three remaining most important levels of helium, namely: the resonance 2^1P and the two metastable 2^1S and 2^3S . In the case of electron-impact excitation ⁽⁵⁾, from formula (4) the absolute excitation cross sections were found for 4 to 7 lower S -, P - and D -levels of para- and orthohelium (with the exception of the 2^1P -, 2^1S - and 2^3S -levels).

The error in determining the cross sections for the various levels is 35–50%.

The necessary information for some of the measured levels is given in Table 1. From the data obtained it follows, first of all, that the energy dependence of the levels of 5 series, with the exception of the n^3P levels, is characterized not by one maximum (as follows, for example, from (6)), but by 2 maxima, one of them being located near the threshold.

Another significant result is the establishment of a definite regularity in the behavior of the excitation cross sections of levels. As analysis has shown, all the cross sections of the measured lower levels at the excitation maximum can be represented by the formula

$$Q_k(E) = Cn^{-\alpha}, \quad (5)$$

where n is the principal quantum number of the level; C is a certain constant; α is an integer exponent, which assumes different values depending on the other quantum numbers S and L . This is clearly demonstrated by Fig. 1, on which, on logarithmic scales, the level cross sections are plotted as functions of the corresponding principal quantum numbers. From the figures it is seen that the cross sections of the 1P -, 1D - and 3D -levels lie well on straight lines with $\alpha = 3$, the cross sections of the 1S - and 3S -levels with $\alpha = 4$, and the cross sections of the 3P -levels with $\alpha = 9$.

The existence of such regularities, in any case for the lower levels, is evidently of interest for the theory of electron-atom collisions.

The values of the cross sections of these levels, found from the graphs in Fig. 1, are also indicated in Table 1.

It is known⁴ that, for levels of one series, the excitation functions are similar. On this basis, and on the basis of a number of other considerations, one can predict

Table 1

Level	$\lambda, \text{\AA}$ (sin-glets)	$E_{\text{exc}}, \text{eV}$ (sin-glets)	$E_{\text{max}1}, \text{eV}$ (sin-glets)	$E_{\text{max}2}, \text{eV}$ (sin-glets)	$Q_{\text{max}} \cdot 10^{20}, \text{cm}^2$ (ground)	$\lambda, \text{\AA}$ (triplets)	$E_{\text{exc}}, \text{eV}$ (triplets)	$E_{\text{max}1}, \text{eV}$ (triplets)	$E_{\text{max}2}, \text{eV}$ (triplets)	$Q_{\text{max}} \cdot 10^{20}, \text{cm}^2$ (ground)
2S	—	20,61	21,5?	32— 35?	450	—	19,62	20,6?	26,0?	610
3S	7281	22,92	23,6	32— 35	108	7005	22,72	23,6	26,5	120
4S	5048	23,66	24,3	32— 35	24,5	4713	23,58	24,4	27,0	37
5S	4438	24,01	24,9	33— 36	12,3	4121	23,96	24,7	28,0	18
2P	—	21,21	22,5?	100 — 110	1500	10829 — 10830	20,96	—	27,0	2200

Level	$\lambda, \text{\AA}$ (sin- glets)	$E_{\text{exc}},$ eV (sin- glets)	$E_{\text{max}1},$ eV (sin- glets)	$E_{\text{max}2},$ eV (sin- glets)	$Q_{\text{max}},$ $10^{20},$ cm^2 (ground) (sin- glets)	$\lambda, \text{\AA}$ (triplets)	$E_{\text{exc}},$ eV (triplets)	$E_{\text{max}1},$ eV (triplets)	$E_{\text{max}2},$ eV (triplets)	$Q_{\text{max}},$ $10^{20},$ cm^2 (ground) (triplets)
3P	5016	23,08	24,2	100	510	3889	23,0	—	28,0	100
				—						
				110						
4P	3965	23,73	24,6	100	210	3188	23,70	—	29,0	4
				—						
				120						
5P	3614	24,04	24,9	100	105	2945	24,01	—	30,0	0,6
				—						
				120						
3D	6678	23,07	23,8	42—	60	5876	23,07	23,8	27,0	32,3
				46						
4D	4922	23,72	24,57	42—	24	4471	23,73	24,3	27,5	13,7
				46						
5D	4388	24,04	25,2	40—	10,5	4026	24,04	—	29,0	7,4
				45						

the probable course of the energy dependence for these levels. In Fig. 2 such dependences are presented for all six of the lowest helium levels.

Thus, more or less complete information has been obtained on the excitation cross sections of the energy levels of helium in collisions with slow electrons.

Uzhgorod State
University

Received
9 II 1966

REFERENCES

1. S. E. Frish, I. P. Zapesochnyi, *DAN*, **95**, 971 (1954); *Vestn. Leningrad. Univ.*, No. 11 (1954).
2. S. E. Frish, *Optical Spectra of Atoms*, Moscow, 1963.
3. I. P. Zapesochnyi, P. V. Fel' tsan, *Ukr. Phys. J.*, **10**, 1197 (1965).
4. G. Massey, E. Burhop, *Electronic and Ionic Collisions*, IL, 1958.

5. R. McFarland, E. Soltysik, *Phys. Rev.*, **127**, 2090, 19 (1962).

6. R. St. John, F. Miller, C. Lin, *Phys. Rev.*, **134**, A888 (1964).

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.