

# Resonant Charge Exchange of Ions on Atoms of Group II of the Mendeleev Table

Physics

1969

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**Abstract**

**Full Text**

UDC 539.186.3

*Physics*

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## Resonant Charge Exchange of Ions on Atoms of Group II of the Mendeleev Table

*(Presented by Academician M. A. Leontovich, January 2, 1969)*

1. In the present work, the calculation of cross sections for resonant charge exchange on atoms of group II of the Mendeleev table is carried out according to the asymptotic theory (<sup>1-3</sup>). According to this theory, the resonant charge-exchange cross section is determined by the system of equations

$$\sigma = \pi R_0^2/2, \quad \sqrt{\pi R_0/2\gamma} \Delta(R_0) = 0.28v, \quad (1)$$

where  $\gamma = \sqrt{2\varepsilon}$ ;  $\varepsilon$  is the binding energy of the outer electron of the atom;  $\Delta$  is the difference between the energies of the even and odd states of the quasimolecule, i.e., the exchange-interaction energy.

2. For atoms of group II of the Mendeleev table (a filled outer  $s$ -shell), where the resonant transition is made by the outer  $s$ -electron, the exchange-interaction energy is determined by the expression

$$\Delta(R) = A^2 S N e^{-1/\gamma} R^{2/\gamma-1} e^{-\gamma R}. \quad (2)$$

Here  $S = 1/2$  is the probability that the electron participating in charge exchange has a definite spin projection;  $N = 2$  is the number of outer electrons;  $A$  is the asymptotic coefficient, so that the expression for the radial wave function of the outer electron at large distances  $r$  from the nucleus is

$$\varphi = A r^{1/\gamma-1} e^{-\gamma r}. \quad (3)$$

This expression (3) is obtained from the solution of the Schrödinger equation for large  $r$ ,

$$\frac{d^2\varphi}{dr^2} + \frac{2}{r} \frac{d\varphi}{dr} + \left[ \frac{2}{r} - \gamma^2 \right] \varphi = 0. \quad (4)$$

The magnitude of the coefficient  $A$  can be found by comparing the asymptotic expression (3) with the wave function obtained in the Hartree–Fock approximation. However, calculations in the Hartree–Fock approximation are available only for Be and Mg (4). Therefore, in the remaining cas-

**Table 1**

Theoretical values of the cross sections  
(in units of  $10^{-15} \text{ cm}^2$ ) of resonant charge exchange

Atoms	0.1	1	10	100
Be	12.7	10.6	8.4	6.5
Mg	17.6	15.0	12.0	9.5
Ca	25.0	21.5	17.2	13.7
Sr	29.4	25.0	20.0	16.5
Ba	33.0	23.4	24.4	19.6
Zn	14.8	12.3	10.2	8.2
Cd	15.7	14.0	11.2	9.0
Hg	14.2	11.8	10.0	8.1

**Table 2**

Values of the asymptotic coefficient  $A$

Atoms	$\gamma$	$A$	$A_{\text{H-F}}$
Be	0.829	1.7	1.9
Mg	0.756	1.3	1.5
Ca	0.678	0.96	
Sr	0.652	0.87	
Ba	0.620	0.76	
Zn	0.830	1.7	
Cd	0.813	1.6	
Hg	0.878	2.0	

in these cases we find this quantity using a model according to which the asymptotic equation (4) is extended to the entire region in which the outer electron is located. Then, by normalizing the solution of equation (3), we find the coefficient  $A$ .

The values of the coefficients  $A$  for various atoms are collected in Table 2. In the same table, for comparison, values of the coefficient  $A_{\text{H-F}}$  are given, found by matching the asymptotic wave function with the Hartree–Fock wave function of the same atom.

**Table 3**

**Comparison of theoretical and experimental cross sections ( $10^{-15}$  cm<sup>2</sup>) of resonant charge exchange**

Energy, eV	Zn	Cd	Mg	Energy, eV	Hg
36	$\overline{9}$	$\overline{10}$	$\overline{10,5}$	75	$\overline{8,3}$
	—	$\overline{12}$	$\overline{10,4}$		$\overline{9,8}$
64	$\overline{8,5}$	$\overline{9,4}$	$\overline{9,8}$	165	$\overline{7,7}$
	$\overline{8,0}$	$\overline{10,6}$	$\overline{10,1}$		$\overline{8,9}$
100	$\overline{8,2}$	$\overline{9}$	$\overline{9,5}$	425	$\overline{6,9}$
	—	$\overline{0,1}$	$\overline{10,1}$		$\overline{8,0}$
121	$\overline{8,1}$	—	—	990	$\overline{6,3}$
	$\overline{7,5}$	—	—		$\overline{7,2}$

**Note.** The numbers above the line are theoretical values; those below the line are experimental.

The calculated cross sections of resonant charge exchange as functions of the collision energy of the incident particles in the laboratory system are given in Table 1.

In Table 3 the results of the calculations are compared with the experimental values of the resonant charge-exchange cross sections (<sup>5,6</sup>).

Received  
14 XI 1968

## CITED LITERATURE

1. O. B. Firsov, *ZhETF*, **21**, 1001 (1951).
2. B. M. Smirnov, *Atomic Collisions and Elementary Processes in Plasma*, Moscow, 1968.
3. Yu. N. Demkov, *ZhETF*, **45**, 195 (1963).
4. V. F. Brattsev, *Tables of Atomic Wave Functions*, "Nauka," 1968.
5. R. M. Kushnir, B. M. Palyukh, L. S. Savchin, *ZhETF*, **35**, 2212 (1965).
6. B. M. Palyukh, L. A. Sena, *ZhETF*, **20**, 481 (1950).

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

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