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## A CALIBRATION METHOD FOR DETERMINATION OF THE ABSOLUTE VALUES OF THE TOTAL CHARGE-EXCHANGE CROSS SECTIONS IN CROSSED-BEAMS EXPERIMENT

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**Abstract.** A new calibration method of the crossed-beams experimental unit is presented, which allows determination of the absolute values of the total charge-exchange cross section.

**Резюме.** Предложен новый метод калибровки экспериментальной установки с пересекающимися ионным и атомным пучками для определения полных сечений перезарядки.

In the charge-exchange experiments with crossed ion and atomic beams the total charge-exchange cross section  $\sigma_{ex}$ , the current of the slow charge-exchange ions  $I_{ex}$ , the initial ion beam current  $I_i$ , the density  $n(p)$  of the atomic beam in the region of the interaction and the length of this region  $d$  are connected with the relation

$$I_{ex} = I_i \sigma_{ex} n(p) d, \quad (1)$$

where  $p$  is the saturated steam pressure in the atomic source. It is seen from here that in order to determine the absolute cross section  $\sigma_{ex}$  it is necessary to know the geometry and the density of the atomic beam in the interaction region. The direct determination of  $d$  and  $n(p)$  is a difficult experimental problem connected with a great uncertainty, that is why in many cases a suitable calibration of the experimental unit is preferable.

In this work we present a new method for determination of the cross section of the nonresonant charge-exchange process



by means of an experimental unit calibration through the known cross section of the resonant charge-exchange process



The resonant charge-exchange cross sections of many elements are studied quite well and measured to satisfactory accuracy.

The basic scheme of the method is shown in Fig. 1. On the path of the atomic beam after the charge-exchange region an ionizer of original construction is placed. The ionization of the atoms in the beam is realized by the electrons emitted from the

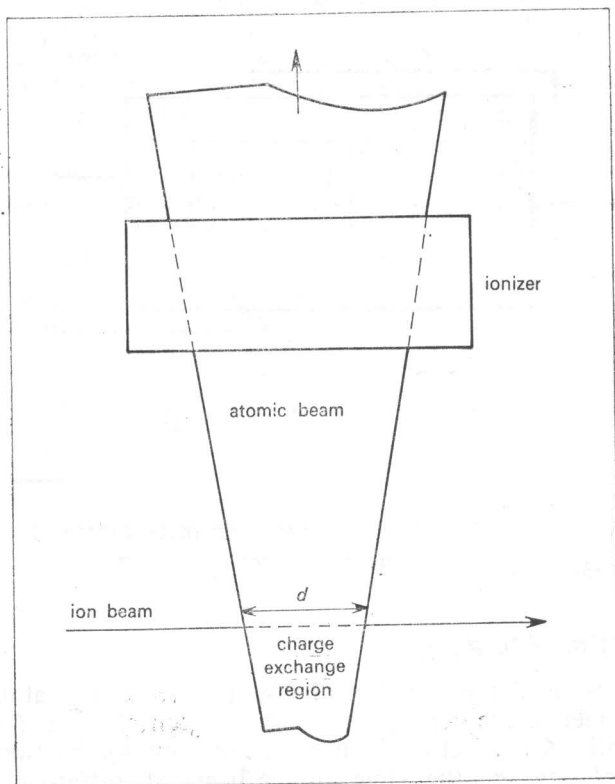


Fig. 1. Basic scheme of the method

hot cathode and accelerated in the field between the cathode and the anode (Fig. 2). The ions arising due to ionization are collected by the collector whose potential with respect to the cathode is slightly negative in order to avoid the falling of the electrons on it.

The ionization current  $I_{iz}$  on the collector is given by

$$I_{iz} = I_e n'(p) f[\sigma_{iz}(E_e), g_a, g_e], \quad (4)$$

where  $I_e$  is the electron current from the cathode to the anode;  $\sigma_{iz}$  is the ionization cross section;  $n'(p)$ ,  $g_a$  and  $g_e$  are the atomic beam density, atomic beam geometry factor and electron beam geometry factor in the ionization region. Since the electrons energy depends on their position between the cathode and the anode, the ionization is realised by electrons having energies in some energetic interval but not by electrons having a fixed energy. That is why there is no product of the ionization cross section  $\sigma_{iz}$  at a given electron energy  $E_e$  and the length of the ionization region in Eq. (4) like in Eq. (1), but a complex functional of  $\sigma_{iz}(E_e)$ ,  $g_a$  and  $g_e$ , noted by  $f(\dots)$ , whose explicit form is of no importance.

Dividing (1) and (4) we obtain:

$$(I_{ex}/I_i) = \beta(I_{iz}/I_e),$$

where

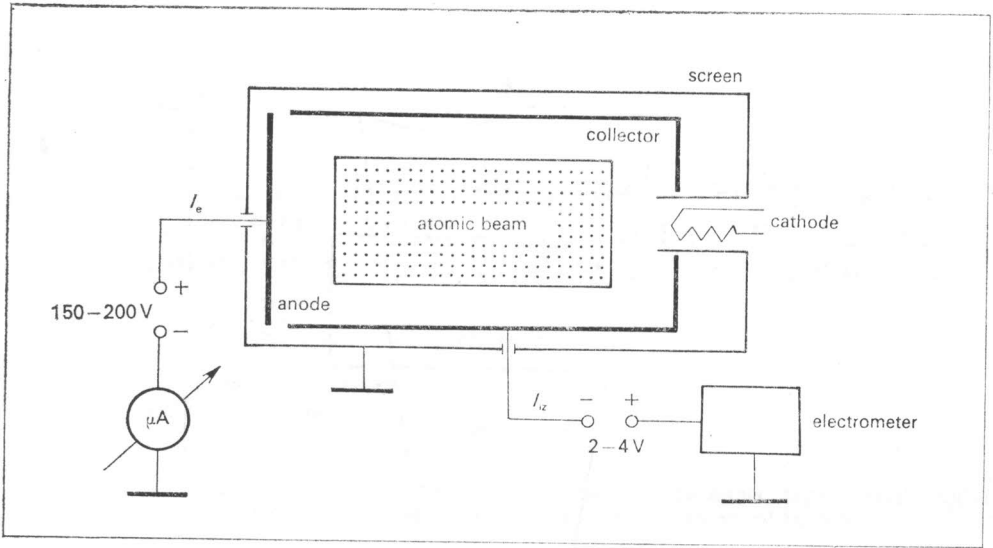


Fig. 2. Sketch of the ionizer

$$\beta = \sigma_{\text{ex}} d [n(p)/n'(p)] / f[\sigma_{\text{iz}}(E_e), g_a, g_e]. \quad (6)$$

Because of the molecular conditions of the flow from the atomic beam source in crossed-beam experiments, the charge-exchange region length  $d$  and the geometry factor  $g_a$  (consequently  $f(\dots)$ ) also do not depend on  $p$ . Furthermore, as  $n(p)$  and  $n'(p)$  are densities of one and the same atomic beam at different distances from the atomic source, the ratio  $(n(p)/n'(p))$  does not depend on the steam pressure  $p$  in the atomic source. Hence, the coefficient does not depend on  $p$  also and can be written in the form:

$$\beta = C \sigma_{\text{ex}}, \quad (7)$$

where  $C$  is a constant which depends on the apparatus parameters and on the kind of atoms of the atomic beam, but not on  $p$ . Hence, if we change the steam pressure  $p$ , the ratios  $(I_{\text{ex}}/I_i)$  and  $(I_{\text{iz}}/I_e)$  will change also, but remaining proportional one to another. Therefore, the dependence (5) of  $(I_{\text{ex}}/I_i)$  on  $(I_{\text{iz}}/I_e)$  is a straight line through the origin with an angular coefficient  $\beta$ .

From all discussed above it follows that in the case of the resonant charge-exchange experiment (3), we can write

$$\beta^0 = C \sigma_{\text{ex}}^0, \quad (8)$$

and in the case of the nonresonant charge-exchange experiment (2)

$$\beta = C \sigma_{\text{ex}}, \quad (9)$$

where the quantities denoted by "0" refer to the case of the resonant charge-exchange. If we determine the angular coefficients  $\beta_0$  and  $\beta$  experimentally we can find  $\sigma_{\text{ex}}$  through  $\sigma_{\text{ex}}^0$  using Eqs (8) and (9):

$$\sigma_{\text{ex}} = \sigma_{\text{ex}}^0 \beta / \beta^0. \quad (10)$$

The practical procedure is as follows: we put the sample of the element  $B$  in the ion source and the sample of the same element  $B$  in the atomic source. Changing the heating power of the atomic source we change the temperature of the sample and hence, the steam pressure  $p$  in the atomic source. For every fixed heating power (fixed value of  $p$ ) we measure  $I_{ex}$ ,  $I_b$ ,  $I_{iz}$  and  $I_e$ , then we construct the dependence of  $(I_{ex}/I_i)$  on  $(I_{iz}/I_e)$  and from the obtained straight line we determine the angular coefficient  $\beta^0$ . Then we change the sample of the element  $B$  in the ion source by the sample of the element  $A$ . After analogous procedure we determine the angular coefficient  $\beta$  and compute via (10) the unknown nonresonant charge-exchange cross section  $\sigma_{ex}$  by means of the known resonant charge-exchange cross section  $\sigma_{ex}^0$  and the coefficients  $\beta$  and  $\beta^0$ .

As an example we present the results of the experiment in which the total cross section of the nonresonant charge-exchange process



is determined through the known total cross section [1] of the resonant charge-exchange process



The corresponding calibration straight lines are shown in Fig. 3. The energy of the initial ion beam is 500 eV in both cases. The coefficient  $\beta$  is determined to be 1.09

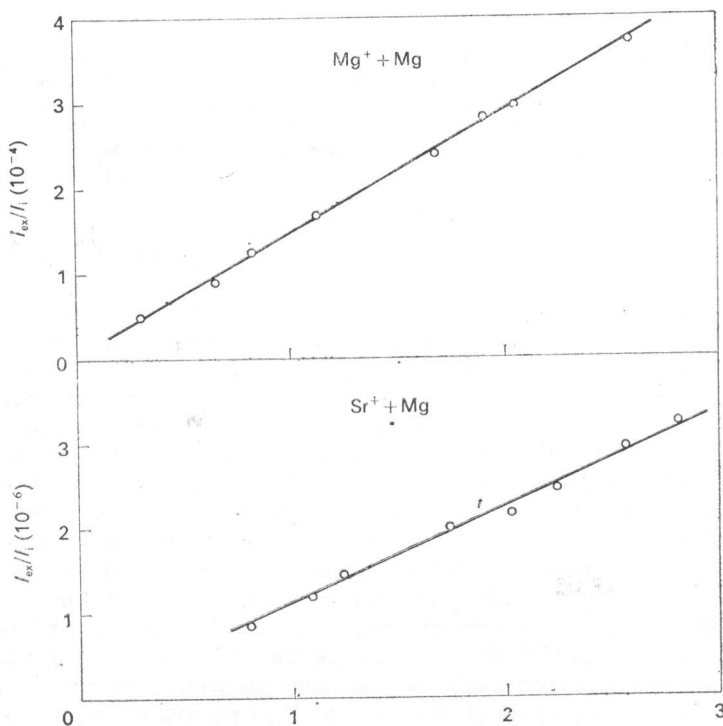


Fig. 3.  $(I_{ex}/I_i)$  as a function of  $(I_{iz}/I_e)$  in the determination of the  $Sr^{++} + Mg$  charge-exchange cross section through the known  $Mg^+ + Mg$  resonant charge-exchange cross section

and the coefficient  $\beta^0$  to be 146. The cross section of the process (12) is  $\sigma_{ex}^0 = 8 \times 10^{-15}$  cm<sup>2</sup>. Hence we obtain the cross section of the process (11) to be  $\sigma_{ex} = 6 \times 10^{-17}$  cm<sup>2</sup>. The uncertainty of  $\sigma_{ex}$  is about 30% and the contribution of the method in this uncertainty is about 5%.

## References

- I. Panev, G. S., A. N. Zaviolopulo, I. P. Zapesochny, O. B. Shpenik. — Sov. JETF, 67, 1974, 1, 47—53.

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