$$\sigma = 15.6 \pm 1.9 \text{ b.}$$

Thus, the question raised in [3], concerning the reasons for observing too large an amount of Kr^{81} in atmospheric krypton, becomes valid, since the rate of Kr^{81} production can be reconciled with the actually observed amount only if the cross section of reaction (1) is close to 100 b.

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DOUBLE IONIZATION OF MAGNESIUM BY THERMAL COLLISIONS WITH HELIUM IONS

E.L. Latush and M.F. Sem
Rostov State University
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We establish in the present study the existence of double ionization of magnesium atoms by thermal collision with helium atoms, and show that this process can serve as an effective source of doubly-ionized impurity atoms, and is therefore important for gas discharges in mixtures.

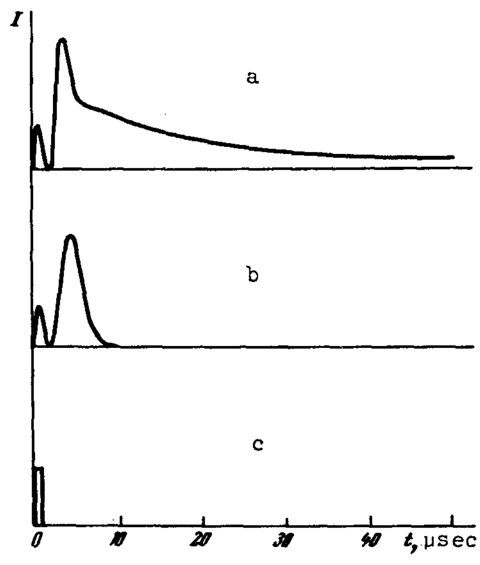
There are about 30 elements whose double-ionization energy is lower than the ionization energy of helium, and for which double ionization by collision with helium atoms

$$He^{+} + A \rightarrow He + A^{++} + e \qquad \text{(I)}$$

is energywise feasible.

Unlike the usual charge exchange at thermal velocities, the process (I) can proceed effectively without energy resonance, since the excess energy, just as in the Penning process [1], can be transferred to the released electron.

To detect the effect, we observed the afterglow of a pulsed gas discharge in a helium-magnesium mixture. Magnesium was chosen because the energy required for its double ionization is lower by 1.95 eV than the helium ionization energy, but is higher than the energies of the metastable states of helium.



Afterglow of Mg II lines: a) in a mixture with helium, b) in a mixture with argon, c) current pulse. Helium and argon pressure 3.5 Torr, magnesium pressure 2×10^{-3} Torr. Discharge tube diameter 8 mm.

The observations of the afterglow have shown the following:

1) At sufficiently strong currents in the pulse, the afterglow in all Mg II lines in the Mg + He mixture consists of a short flash, followed by a prolonged rather intense decreasing part (Fig. a).

2) The prolonged afterglow of the Mg II lines is not connected with the metastable states of helium, since addition of argon to the Mg + He mixture, in amounts at which the argon greatly decreases the concentration of the metastable helium via the Penning effect [2], hardly affected the form of the afterglow of the Mg II lines.

3) The afterglow of the Mg II lines is of the recombination type, since the glow is suppressed when a second small pulse that causes a certain heating of the electron gas is applied after the first pulse at any point of the afterglow. The glow stays suppressed for the duration of the second pulse.

4) When the magnesium vapor pressure is increased, the duration of the afterglow of the Mg II lines decreases. At the same time, the time of decrease of the helium lines, the afterglow of which is connected with recombination of the helium ions, is also shortened.

The observed form of the afterglow of the Mg II lines in the Mg + He mixture can be explained as follows: The current pulse produces a certain number of Mg^{++} particles. After the pulse is terminated and the electrons are cooled off, rapid recombination of the Mg^{++} sets in (as a result of the large coefficient of impact-radiative recombination of the doubly-charged ions [3]). This is indeed the cause of the first intensity flash of the Mg II lines in the afterglow; were it not for the continuing production of the Mg^{++} ions, the afterglow would end together with this pulse (as is indeed observed in the Mg + Ar mixture, Fig. b). The presence of the prolonged afterglow, which in accordance with Item 3 above is also of the recombination type, indicates that the production of the Mg^{++} continues in the afterglow. It follows from items 2 and 4 that the particles responsible for this production can be only the helium ions. The population of the Mg II levels proceeds in this case in accordance with the scheme

$$He^{+} + Mg \rightarrow He + Mg^{++} + e, \qquad \text{(II)}$$

$$Mg^{++} + e + e \rightarrow Mg^{+*} + e. \qquad \text{(III)}$$

The kinetic equations for the processes occurring in the afterglow of the discharge, written under the assumption that the helium ions disappear mainly as a result of diffusion to the walls and neutralization by the magnesium atoms via (II) are given by

$$\frac{dN_b^{++}}{dt} = N_a^{+} Q v_T N_b - N_b^{+} a_b n_e, \qquad (1)$$

$$\frac{dN_a^{+}}{dt} = -\gamma N_a^{+} - N_b v_T Q N_a^{+}. \qquad (2)$$

Here N_a^{+} is the He^{+} concentration, N_b and N_b^{++} are the concentrations of the magnesium atoms and doubly-charged ions, respectively, a_b is the coefficient of impact-radiative recombination of Mg^{++}, Q is the cross section of the process (II), v_T is the average velocity of relative motion, γ is the diffusion constant, and n_e is the electron concentration.

If the observations are carried out at magnesium pressures such that $N_b Q v_T > \gamma$, then $a_b n_e \approx$ const, and with allowance for this condition the solution of Eqs. (1) and (2) for the intensity of the Mg II lines yields

$$I = \text{const} \cdot a_b n_e N_b^{++} = \text{const}\,[C \exp(-a_b n_e t) + N_a^{+}(0) Q v_T N_b \exp(-\gamma t - N_b Q v_T t)]. \qquad (3)$$

At sufficiently large n_e, the first term in (3) shows a rapid decrease at the start of the afterglow, and the second a slow decrease, which is indeed due to double ionization of the magnesium by collisions with the helium ions. The duration τ of the slow decrease depends on the magnesium vapor pressure:

$$\frac{1}{\tau} = \gamma + N_b v_T Q \qquad (4)$$

and from the experimental relation $(1/\tau) = f(N_b)$ we can find the cross section of the process (II). The cross section of the double ionization of magnesium by thermal collisions with helium ions, measured in this manner, turned out to be $(1.6 \pm 0.5) \times 10^{-15}$ cm^2.

It should be added that we have observed coherent lasing in the Mg + He mixture at the Mg II 9244 and 9218 Å lines $4P_{3/2,1/2} - 4S_{1/2}$. The lasing pulse lagged the current pulse by 30 - 50 μsec, i.e., occurred in that afterglow region where it is precisely the processes (II) and (III) which determine the level population of the magnesium ion.

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FORMATION OF INTENSE CHARGED PARTICLE BEAMS IN A CURRENT-CARRYING PLASMA

K.V. Suladze
Sukhumi Physico-technical Institute
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This paper reports an investigation of intense charged-particle beams occurring in a current-carrying plasma as a result of formation of a "break" on which the entire potential difference is concentrated. A strong electric field inside a plasma [1] accelerates the charged particles and the entire discharge current is carried by the beams of electrons [2] and ions. The limiting accelerated-particle current J = env is determined by the plasma concentration and can reach large values.

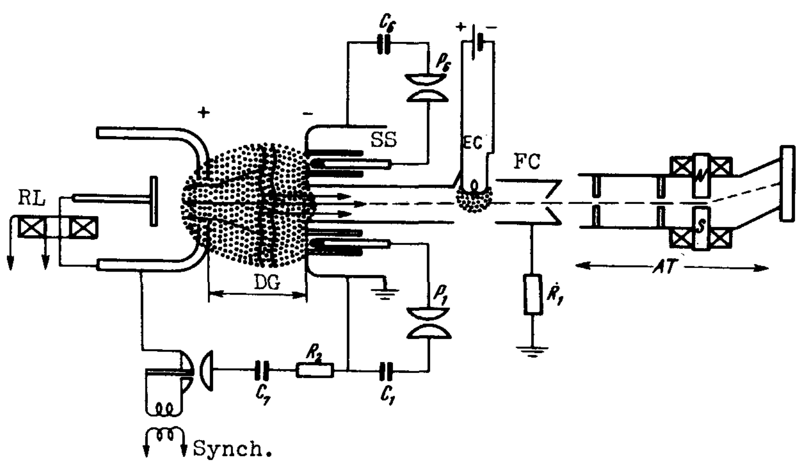

Fig. 1. Schematic diagram of experiments.