Zeitschrift: Helvetica Physica Acta

Band: 41 (1968)

Heft: 3

Artikel: Charge-exchange of low energy protons in potassium vapour

Autor: Schmelzbach, P.A. / Grüebler, W. / König, V.

DOI: https://doi.org/10.5169/seals-113892

Charge-Exchange of Low-Energy Protons in Potassium Vapour

by **P. A. Schmelzbach, W. Grüebler, V. König** and **P. Marmier**
Laboratorium für Kernphysik, Eidg. Technische Hochschule, Zürich

(20. 11. 67)

Summary. One- and two-electron charge-exchange for a proton beam incident upon potassium vapour has been investigated in the energy region from 2.5 keV to 22 keV. Charge components and cross sections were determined.

The production of high-intensity negative-ion beams is of considerable practical interest in the development of ion sources for cyclotrons and tandem electrostatic accelerators. During the construction of a polarized ion source for the ETH tandem Van de Graaff, studies of a gas charge-exchanger have been made in an effort to achieve higher negative-ion beam intensities and better beam quality. The gas charge-exchanger has several advantages over a foil exchanger, although when used with a polarized source precautions must be taken to minimize beam depolarization. A solution to the beam depolarization problem was the subject of an earlier letter [1]. Earlier studies by other authors have been concerned with the charge-exchange of low-energy protons incident upon hydrogen and the inert gases [2, 3], organic compounds [4], atomic hydrogen [5]. In these experiments the yield of negative ions was generally quite small: for this reason it is of interest to study other gas charge-exchangers. The purpose of the present work was to investigate systematically the one- and two-electron charge-exchange processes with low-energy protons in potassium vapour and to study their dependence on the incident proton energy and potassium vapour pressure.

In this experiment protons were produced in a radio-frequency ion source. The ions emitted by the source were focused and accelerated, and then deflected through an angle of 40° by a magnetic analyzer. The protons emerging from the analyzer were collimated by two defining apertures and directed into the collision chamber, a cylindrical oven 20 mm in diameter with entry and exit channels 8 mm in diameter and 15 mm long. The total length of the oven was 70 mm. The purified potassium was vaporized directly in the cylindrical oven, which could be electrically heated to a maximum temperature of 300 °C. The beam intensity was measured at the entrance of the collision chamber with a removable Faraday cup. Secondary electrons from the Faraday cup were rejected by a suppressor electrode in front of the cup. After passing through the collision chamber, the beam was again analyzed magnetically by the selective deflection of the positive or the negative ions through an angle of 10° into a second Faraday cup.

The intensities of the primary beam entering the collision chamber and the positive and negative beam components after charge-exchange have been measured. These values J, J_1 and J_{-1} respectively have been used to determine the charge components F_i. The transmission T through the potassium oven and the 10° analyzing magnet was measured for positive ions with the oven at room temperature. It is assumed that the transmission for negative ions is equal to that for positive ions. The charge components were calculated with the relation

$$F_i = \frac{J_i}{J\,T} \qquad \text{whereby } i = 1, -1 \,.$$

The intensity of the neutral component F_0 is then given by the expression

$$F_0 = 1 - (F_1 + F_{-1}) \,.$$

The measurements have been carried out carefully for a fixed energy, the temperature having been increased until an equilibrium state of the charge component $F_{i\infty}$ was reached. A typical example of such a measurement is shown in Fig. 1 for a proton energy of 3.05 keV. The F_{-1} component was corrected for the fraction of the negative ions formed by collision with residual gas following the first analyzing magnet. The value of this correction was measured with the potassium oven at room temperature. It should be noted that a fraction of the neutral and negative ions produced by collision with the residual gas can undergo charge-exchange collisions with the potassium vapour. An estimate in accordance with the approach of ALLISON [6] and FOGEL [7] shows that this error of F_{-1} should not be larger than 10%. The pattern of the curve F_{-1} in Figure 1 shows that the maximum value $F_{-1\,max}$ is not identical with the equilibrium value $F_{-1\infty}$. In Figure 2 the results of the equilibrium charge components

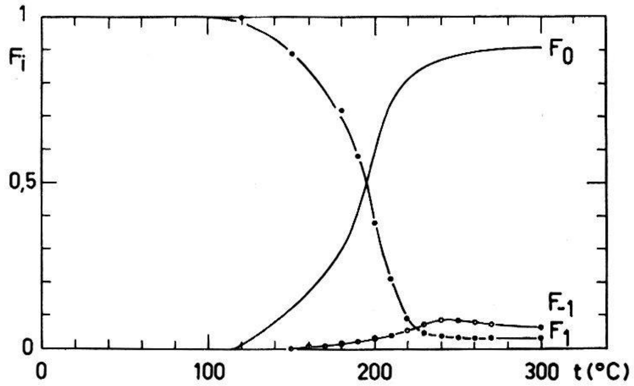

Figure 1

Variation of the charge components as a function of the oven temperature for a proton energy of 3.05 keV.

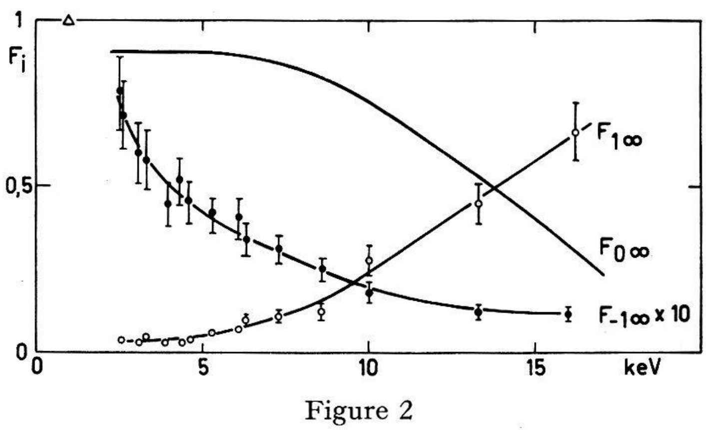

Figure 2

Variation of the equilibrium values of the charge components as a function of the energy. Δ negative component measured by DONNALLY [8].

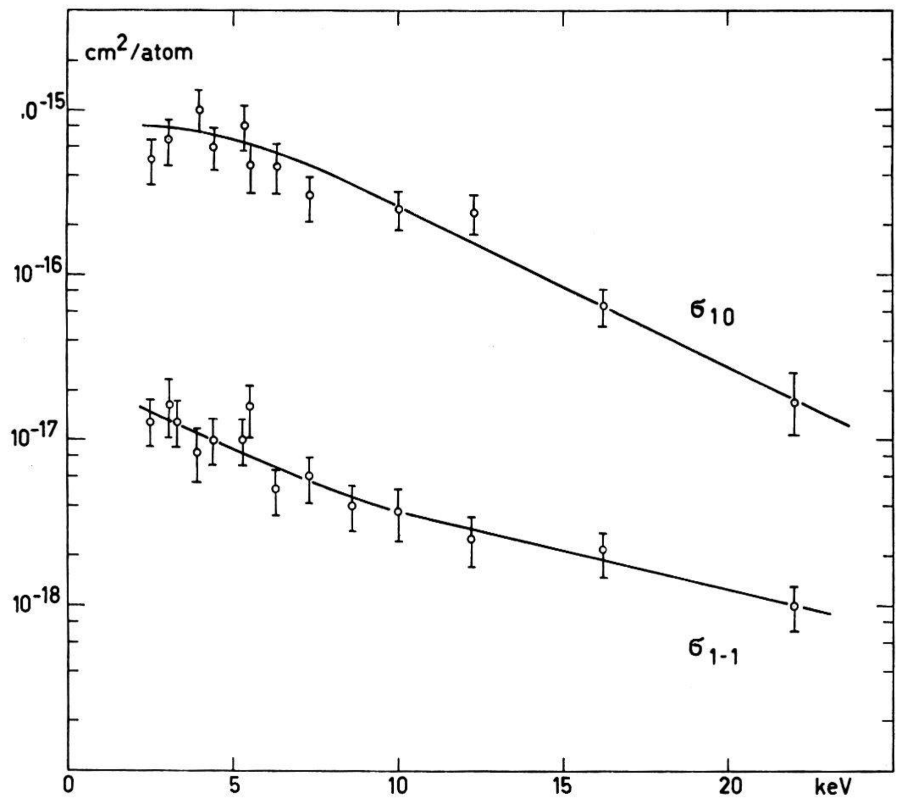

Figure 3

Variation of the cross section as a function of the energy. σ_{10} one-electron charge-exchange. σ_{1-1} two-electron charge-exchange.

$F_{i\infty}$ are shown as a function of the incident proton energy along with a measurement of DONNALLY [8] at a proton energy of 1 keV.

The one- and two-electron charge-exchange cross sections σ_{10} and σ_{1-1} can be determined easily from a representation in which F_0 and F_{-1} are plotted against the vapour density (ϱ) times the effective length (l) of the collision chamber. The cross section is then given by the slope of the linear portion of the curve $F_i\,(\varrho \cdot l)$. To first approximation one can assume that the effective length of the collision chamber is equal to the length of the oven. The results are shown in Figure 3.

Therefore potassium vapour is quite an effective charge-exchanger for hydrogen ions up to about 10 keV. Although direct comparison of foil exchangers to the potassium vapour exchanger is difficult because of substantially different conditions (e.g. the foil exchangers operate at $\sim$50 keV), the gas exchanger gives roughly a factor of ten higher yield than the foil exchanger and also provides substantially better beam quality.

References

[1] W. GRÜEBLER, V. KÖNIG and P. MARMIER, Phys. Letters *24B*, 335 (1967).
[2] V. G. KOZLOV, YA. M. FOGEL and V. A. STRATIENKO, Sov. Phys. JETP *17*, 1226 (1963).
[3] J. F. WILLIAMS, Phys. Rev. *150*, 7 (1966).
[4] S. FAROKHY, Rapport CEA-R-2952 (1966), Commissariat à l'Energie Atomique, France.
[5] A. B. WITTKOWER, G. RYDING, H. B. GILBODY Proc. Phys. Soc. London *89*, 541 (1966).
[6] S. K. ALLISON, Phys. Rev. *109*, 76 (1958).
[7] YA. M. FOGEL, Sov. Phys. Uspekhi *3*, 390 (1960).
[8] B. L. DONNALLY and R. BECKER, Bull. Am. phys. Soc. *12*, 29 (1967).