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The Energy Dependence of Charge Exchange Reactions Favourably Used in Lambshift Type Ion Sources

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The energy dependence of charge exchange reactions * favourably used in Lambshift type ion sources

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Abstract

Iodine and argon can be favourably used in Lambshift type ion sources for selective ionisation by charge exchange collisions. The energy dependence of the selectivity of these charge exchange collisions has been measured by investigating the quenching effect and the nuclear tensor polarization. Both reactions show with increasing energy the same monotonous decrease of the selectivity. For production of polarized deuterons at optimum conditions a Lamb-shift ion source is to be operated below 1 keV beam energy.

In Lambshift-Typ Ionenquellen können Ladungsaustauschreaktionen mit Jod und Argon vorteilhaft für eine selektive Ionisation verwendet werden. Durch Messung des Quenchingeffektes und der Kerntensorpolarisation wurde die Energieabhängigkeit der Selektivität dieser Ladungsaustauschreaktion untersucht. Beide Reaktionen zeigen eine mit steigender Energie monoton abfallende Selektivität. Um optimale Bedingungen zu erreichen, sollte für Lambshift-Quellen für polarisierte Deuteronenstrahlen eine Primärstrahlenergie unterhalb von 1 keV gewählt werden.

The method which takes advantage of the Lambshift and the 2S - 2P level crossing to polarize hydrogen ions is very well suitable to produce either positively or negatively charged ion beams with a high phase space density. The procedure makes use of specific charge exchange reactions to ionize the metastable H(2S) atoms selectively. One of the main features determining the applicability of such reactions for sources of polarized ions is the energy dependence of the selectivity of these charge exchange processes.

We have systematically investigated various reactions with the aspect to determine the selectivity for production of positively and negatively charged polarized hydrogen ion beams as a function of beam energy. Some of the results of measurements with either argon or iodine will be discussed because just these two gases seem to be practicable in polarized ion sources. The argon reaction was firstly proposed for the production of negatively charged beams by Donnally et al. [1]. Their measurements seem to exhibit a maximum of the selectivity at 1 keV deuteron beam energy. Positively charged polarized beams were firstly achieved by using hydrogen or helium as charge exchange partners [2]. Lateron halogens were found to be in advantage [3,4]. L.D. Knutson has measured [3] the selectivity and the relative cross section for iodine at specific iodine vapour pressures but without checking the nuclear polarization. Argon and iodine were investigated at the Karlsruhe polarized ion source (A-LASKA) [5,6,7,8] by variing the vapour pressure as well as the primary beam energy.

The selectivity is in general a function of the vapour pressure in the charge exchange cell as was shown in [5]. This effect is due to a superposition of secondary reactions and increases with increasing vapour density. For a reliable comparison of different reactions we have measured the dependence on the vapour density [7,8] at each beam energy and have compared the selectivities extrapolated to zero vapour pressure. The quantity $d = \frac{A}{B}$ is a measure of the selectivity. d is defined as ratio of the two slopes A and B at zero pressure. A is the slope of the I versus p curve in the case when the primary beam consists of metastable and groundstate atoms. B is the corresponding slope when all the

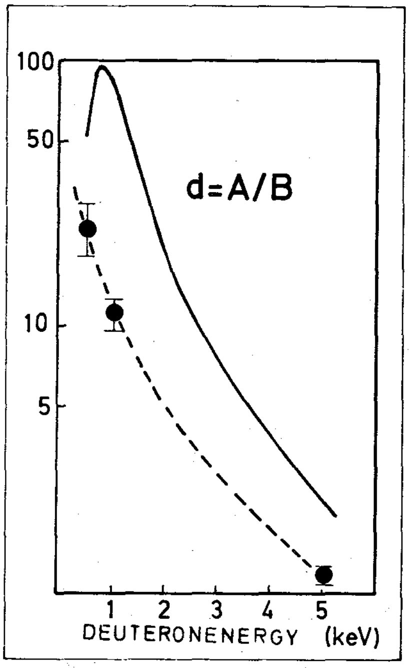

Fig. 1 As a measure of the argon-selectivity the quantity d = A/B is plotted versus the deuteron energy. The solid line gives the quantity d extracted from ref. 1.

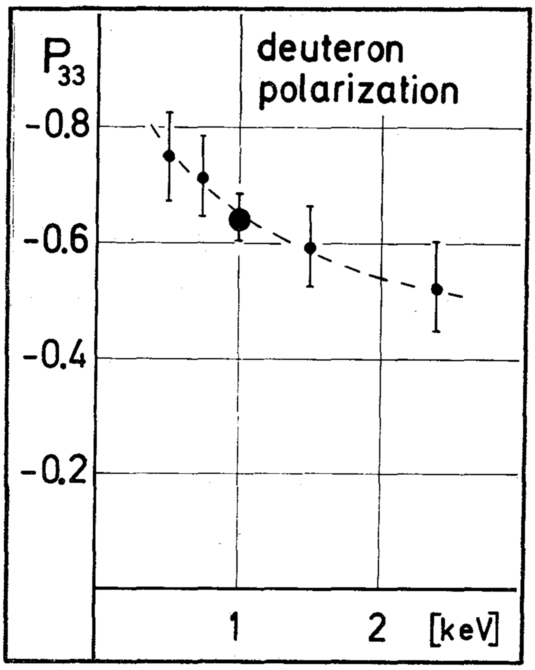

Fig. 2 The deuteron tensor polarization P_{33} as a function of the beam energy obtained by use of iodine as charge exchange partner.

metastable atoms are quenched to the ground state.

d is plotted in fig. 1 in a logarithmic scale versus the beam energy. The dashed line shows that d is decreasing strongly with increasing energy. At somewhat different experimental conditions earlier measurements have shown the same monotonous decrease of d in the energy range between 1 and 5 keV (dashed line). These values are not directly comparable and hence not plotted in fig. 1. For comparison the quantity d was extracted from the measurements of reference [1]) and is shown as a solid curve in fig. 1 additionally. The selectivity does not seem to exhibit the peak reported at 1 keV.

Lambshift type ion sources are also very suitable for the production of positively charged polarized beams [2,3,4,7,8]). Halogen charge exchange partners are at the time the most promising candidates [3,4]). Fig. 2 shows as an example the nuclear tensor polarization P_{33} versus beam energy which was obtained with the same experimental set up by using iodine vapour to produce positively charged ions. Contrary to argon the halogens show a selectivity which is almost independent from the vapour pressure [7]). Consequently one is able to measure the nuclear polarization at the maximum yield. P_{33} is decreasing monotonously with energy. This behaviour seems to be a general feature which can be explained qualitatively with the pseudo-crossing theory. The monotonous decrease was also observed at all the other reactions investigated [8]).

From the measurements it can be concluded that the optimum energy to operate a Lambshift source will depend on the specific geometry used but will surely be in the range between a few 100 eV and 1 keV.

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