Polarized $^3He^{2+}$ ion source based on spin-exchange collisions between $^3He^+$ ion and polarized Rb atoms

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In 1995, a new type of polarized ^{3}He ion source named "EPPIS" (Electron Pumping Polarized Ion Source) was proposed by the RCNP group [1], and its validity was experimentally proven in 1999 [2]. However, the disadvantage of the EPPIS is that it needs for an extremely highly polarized alkali-metal vapor with a thickness larger than 10^{15} atoms/cm^2. Unfortunately, realization of such extreme condition is very difficult [3]. Consequently, the practical EPPIS polarized ^{3}He ion source has not been feasible under the present circumstance until now. Meanwhile, it was found from the detailed analysis of the data on the EPPIS that the

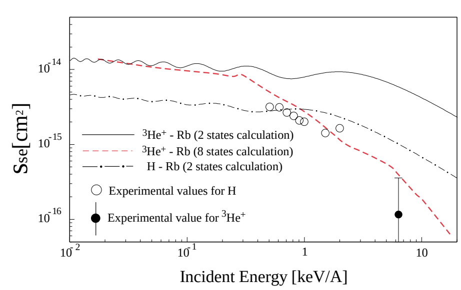

Figure 1: Measured and calculated spin-exchange cross sections for H + Rb and $^3He^+$ + Rb systems.

spin-exchange cross sections observed for the $^3He^+$ + Rb system at a few keV/A impact energy were orders of magnitudes suppressed relative to the theoretical predictions [4], while those for the H + Rb system was in a good agreement with the theoretical ones [5]. This unexpected reduction of the spin-exchange cross section for the $^3He^+$ + Rb system was, in the later work [6], understood in terms of the multiple processes including target excitations and electron transfers. The improved calculation also predicts an interesting behavior of spin-exchange cross sections, σ_{se} at low incident energies, i.e., σ_{se} is increased rapidly according as a decrease of the $^3He^+$ energy as illustrated in Fig. 1. In particular, it is noted that below a few hundred eV/A, $\sigma_{\rm se}$ is expected to exceed 10^{-14} cm^2, which is about 4 times larger than that of the H + Rb system. The large spin-exchange cross section expected at low $^3He^+$ ion energies suggests us possibility of a novel polarized ^{3}He ion source. We name this type of

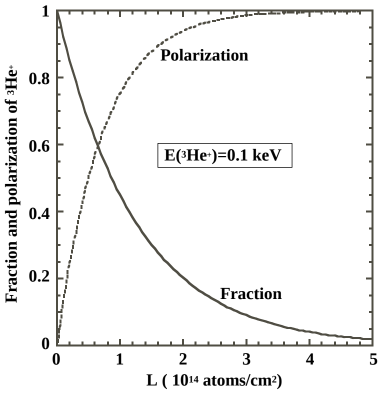

Figure 2: Thickness dependences of the fraction and polarization for ^{3}He$^+$ ions penetrating the completely polarized Rb vapor.

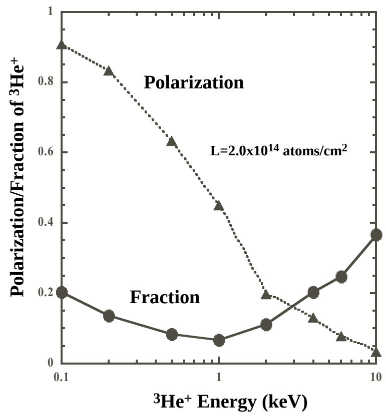

Figure 3: Energy dependence of the fraction and polarization for ^{3}He$^+$ ions penetrating the completely polarized Rb vapor.

the polarized ion source "SEPIS" (Spin Exchange Polarized Ion Source). The numerical calculations were performed on the thickness and incident ^{3}He$^+$ energy dependences of the ^{3}He$^+$ polarizations and fraction outcoming from the polarized Rb vapor [7]. The calculated results are summarized in Fig. 2, and Fig. 2. From these figures, it is suggested that the thickness of polarized Rb vapor needed for realizing the SEPIS is only 2×10^{14} atoms/cm^2, which is almost an order of magnitude less than that imposed for the EPPIS. In fact, it was experimentally established that almost full Rb polarization was obtained at this Rb vapor thickness [8]. Consequently, the polarized ^{3}He ion source based on the SEPIS seems to one of the most promising polarized ^{3}He ion source in the new generation.

Finally, it is noteworthy to mention that the spin-exchange cross sections for the ^{6}Li^{2+} + Rb system at low energies would be much larger than the ^{3}He$^+$ + Rb system [9], which will open up the possibility of the polarized ^{6}Li^{+3} ion source based on the SEPIS.

References

[1] M. Tanaka, M. Fujiwara, S. Nakayama, and L. W. Anderson, Phys. Rev. **A52** (1995) 392.

[2] M. Tanaka, T. Yamagata, K. Yonehara, T. Takeuchi, Y. Arimoto, M. Fujiwara, Y. A. Plis, L. W. Anderson, and R. Morgenstern, Phys. Rev. **A60** (1999) R3354.

[3] K. Yonehara, T. Yamagata, Y. Arimoto, T. Takeuchi, and M. Tanaka, Nucl. Instr. and Meth. **B184** (2001) 391.

[4] Y. Arimoto, N. Shimakura, K. Yonehara, T. Yamagata, and M. Tanaka, Eur. Phys. J. **D8** (2000) 305.

[5] A. N. Zelenski, C. D. P. Levy, W. T. H. van Oers, P. W. Schmor, J. Welz, and G. W. Wight, AIP Conf. Proc. **339** (1995) 650.

[6] Y. Arimoto, N. Shimakura, T. Yamagata, K. Yonehara, and M. Tanaka Phys. Rev. **A64** (2001) 062714-1.

[7] M. Tanaka, Yu. A. Plis, E. D. Donets, N. Shimakura, Y. Arimoto, T. Yamagata, and K. Yonehara, Nucl. Instr. Meth. in review.

[8] A. N. Zelenski, AIP Conf. Proc. **570** (2001) 179.

[9] N. Shimakura, M. Tanaka, and Yu. A. Plis, submitted to Phys. Rev. **A** (2004).