Proposal for the SEPIS polarized ^{6,7}Li ion source

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For a long time, the vector/tensor polarized heavy on beams such as ^{6,7}Li and ^{23}Na have been used for investigating not only the nuclear structure and nuclear reaction mechanism[1, 2] but also fundamental physics like the T-violation test[3, 4] and astrophysics[5] in a wide range of incident energies. As a result, the polarized heavy ion beams are regarded as a powerful tool in modern physics.

In recent years, a new type of the intensive polarized ^{3}He ion source was proposed by Tanaka et al.[6] so as to overcome difficulties encountered in the polarized ^{3}He ion source based on the electron pumping[7]. This ion source uses an unexpectedly large spin-exchange cross section between ^{3}He$^+$ ion and alkali atom (Rb) predicted at low ^{3}He$^+$ incident energies[8]. Through the theoretical calculations prescribed in ref. [8], it was found that the spin-exchange cross sections for the ^{3}He$^+$ and Rb system at low energies less than a few keV/amu was about 5 times larger than those for the H and Rb system [9]. We name this type of the polarized ion source as the SEPIS (Spin-Exchange Polarized Ion Source). This result quickly reminds us of possibility to use it the polarized heavier ion sources because the spin-exchange cross sections seem to be increased according as the projectile atomic number. If this is true, any heavy ions including even radioactive isotopes could be polarized in a common method, i.e., "SEPIS", which would hopefully open up a new field.

The aim of the present work is, therefore, to investigate whether or not the spin-exchange cross sections for heavier ions + Rb atom are enough large as a tool of the polarized heavy ion source. For this purpose, we attempt to evaluate the spin-exchange cross sections for the Li^{2+} + Rb system as the first step. The theoretical calculation employed here is based on the semiclassical close-coupling method with the molecular-orbital expansions which was successfully applied to the ^{3}He$^+$ + Rb system in the previous work[8].

In what follows, we outline the procedure of the calculation and show the preliminary results obtained so far. The detail of the calculation will be published elsewhere[10]. We assume that the initial state is Li^{2+}(1s)-Rb(5s) for a large internuclear distance, whereas at a finite internuclear distance this state becomes a singlet and triplet molecular state denoted by $1^1\Sigma$ and $1^3\Sigma$. We carry out the semiclassical close-coupling calculations based on the molecular-state expansion; the internal electron motions are treated quantum mechanically, while the relative motions of nuclei are treated as the straight-line trajectories classically. A plane-wave-type electon-translation factor (ETF) is employed in the first order of the relative velocity. To account the phenomena more reliable, we took the low lying excited states as well as the ground state of ^{6}Li^{2+} ion as intermediate states. The adiabatic potential energies for the (Li-Rb)$^{2+}$ system are obtained by the valence-band configuration-interaction method modified by inclusion of a Gaussian-type pseudopotential [11]to describe the atomic core of Rb$^+$, and the results of the calculations are shown in Fig. 1. The orbital exponents of the Slater-type orbital for the valence electron of Rb atom were taken from the previous work by Stevens et al., while those for the Li^{2+} ion were obtained by variationally optimizing the energies. Thus, the incident energy dependence of the spin-exchange cross sections

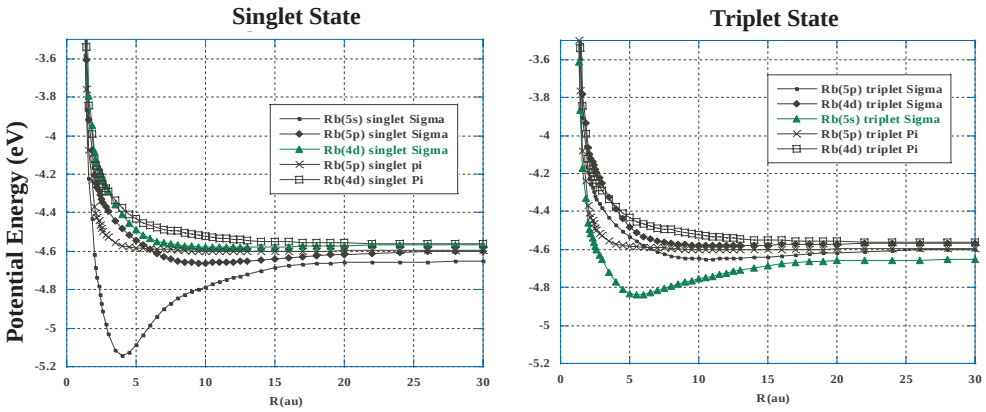

Fig. 1 Potential energies for Li^{2+} + Rb system for the singlet (left) and Triplet (right) molecular orbitals.

were obtained as shown in Fig. 2, where the unit of the incident energy is eV and the unit of the spin-exchange cross sections is 10^{-16} cm^2. As expected from the comparison of the results for lighter ions, the spin-exchange

cross sections (see "Total" in Fig. 2) for the $^6Li^{2+}$ + Rb system at a low energy region are over 1.0×10^{-14} cm^2, which is comparable to the $^3He^+$ + Rb case. In addition, differing from the behavior of the $^3He^+$ + Rb system, the interference terms due to two step processes like inelastic scattering constractly influence. Therefore, the energy dependence for the $^6Li^{2+}$ + Rb system becomes more modest than $^3He^+$ + Rb system case. It should also be noticed that contrary to the guess expectation, the mass number dependence of the spin-exchange cross section seems to be maximized at Z=3. Nevertheless, the magnitude of the spin-exchange cross section at low incident energy is enough large for using it as a polarized ^{6,7}7Li ion source.

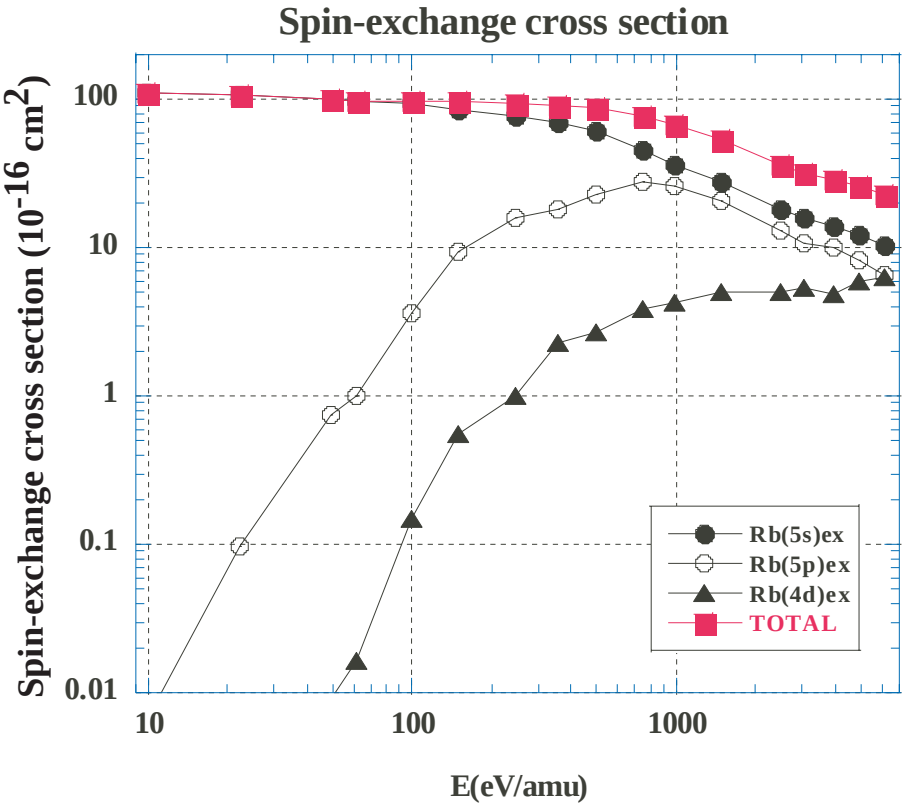

Fig. 2. Calculated energy dependence of the spin-exchange cross sections for Li^{2+} + Rb system.

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