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8.14 Production of Polarized ^{6,7}Li Negative Ions by Electron Transfer between Fast Cs Atoms and Thermal Polarized Li Atoms

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Polarized negative alkali ions for injection into a tandem accelerator have previously been produced by surface ionization of polarized atoms on a hot W surface and subsequent charge exchange of the resulting positive ions in Na vapor[1]. Here we report on a new ion source in which polarized Li^- ions are produced from polarized Li atoms in a one-step process, using the charge transfer reaction

$$\vec{Li}^{o} + Cs^{o} \rightarrow \vec{Li}^{-} + Cs^{+}, \tag{1}$$

where the Cs^o beam has an energy of some 30-40 keV. This ionization method, first proposed by Haeberli[2], has been in use for several years to produce microampere beams of polarized H^- and D^- ions[3]. One especially attractive feature of this method is that one and the same ion source can be used to produce light ions as well as heavy ions.

The polarized Li atomic beam, obtained from an atomic-beam source, is bombarded with a collinear fast Cs^o beam, produced by neutralization of a Cs^+ beam in Cs vapor (see ref. 3). The Cs^+ beam is obtained by surface ionization on a hot porous tungsten surface. Lithium negative ions, produced by charge exchange (eq. 1) in the 35 cm long ionization region, are swept out of the ionization region by a weak electric field (~0.6 V/cm) and accelerated before being deflected 90° by an electrostatic spherical deflector. The ionization region is inside a solenoid which provides a uniform magnetic field of about 60 mT.

The Li atomic beam source is similar to the source used at SLAC for production of polarized electrons[4]. The Li atomic beam intensity was measured by surface ionization on a hot oxygenated tungsten wire which was moved through the beam. Measurements of the integrated Li beam intensity versus oven temperature agree with the measurements made at SLAC except that for all oven temperatures the total output observed in our source is approximately twice as large.

The intensity of the momentum-analyzed polarized Li^- beam was measured in a suppressed Faraday cup. With a Li beam intensity in the ionization region of 3×10^{15} atoms/s (oven temperature 790°C) and a 36 keV Cs^o beam of current density 2.8 particle-mA/cm^2, a beam current of 0.18 μA was obtained. In later tests, using an oven temperature of 810° C and a Cs^o energy of 39 keV, a maximum beam current of 0.28 μA was observed.

The measured beam intensity can be compared to the calculated value (ref. 2),

$$I = jn\sigma, \tag{2}$$

where j is the current density of the Cs^o beam, n is the number of Li^o atoms present in the ionization volume and σ is the cross section for the charge exchange reaction. Equation 2 is valid if the Cs^o current density is uniform over the region occupied by the Li atoms. However, a realistic calculation should take into account the actual intensity distribution of these beams in the region where the ionization takes place. In our calculations, the measured Cs^o current density distribution[5] was folded with the Li^o intensity profile. The calculated current, I = (0.34 ± 0.14) μA, is in reasonable agreement with the measured current of 0.18 μA. Note that the stated uncertainty reflects only the error in the cross section[6] for the charge exchange reaction eq.(1), but no other uncertainties.

The tensor polarization of the accelerated ^{6}Li beam was studied using the reaction $^2H(^6\vec{Li},\alpha)^4He$. It has been shown by Fick[7] that the tensor analyzing power of this reaction is equal to the corresponding quantity in the inverse reaction,

$^6Li(\vec{d}, \alpha)^4He$. Analyzing powers for the latter reaction are reported in ref. 8. Measurements of the tensor polarization were made for a ^6Li beam energy of 11.9 MeV. RF transitions between hyperfine states 2↔6 and 3↔5 were switched on alternately. The results showed that within the statistical error (±0.01), $P_{\zeta\zeta}$ (2↔6) = $-P_{\zeta\zeta}$ (3↔5), where ζ refers to the axis of the solenoidal magnetic field present in the ionization region of the source. The absolute value of the beam polarization was found to be

$$P_{\zeta\zeta} = 0.88 \pm 0.04,$$

where the error is dominated by the uncertainty in the absolute normalization of the deuteron analyzing powers for the inverse reaction[8].

It has been shown that ionization of polarized Li atoms by the colliding-beam method produces useful intensities of Li^- beams with a high degree of polarization. Larger beam intensities can be expected from higher operating voltages of the Cs source, because up to 100 keV Cs^0 energy, both the charge exchange cross section[6] and the Cs current density[5] are known to increase with Cs beam energy. At 55 keV Cs^0 energy, where a current density of 10 particle-mA/cm^2 has been reported[5], the expected Li^- beam currrent is 1.0 μA, while at 75 keV as much as 3.0 μA might be expected. Additional gains may be possible by operating the Li atomic beam source at higher oven temperatures. Thus it is likely that several μA of polarized Li^- ions, as well as other alkali negative ions, could be produced employing the principles outlined here.

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