sible reason for this overestimation is the omission of reaction effects in the calculation. Another possible reason is the fact that, because the nucleon separation energy for ^{3}He is rather small, the low-density region of the ^{3}He wave function is not given well[8] by the Gaussian form[1] used in the calculation,[9] and one would expect this region to be important in backward-peaked exchange phenomena. In order to test this latter hypothesis in a rather crude fashion, the calculation was performed with the rms matter radius of the ^{3}He cluster arbitrarily increased to 1.89 F, and the result is shown as a dashed curve in Fig. 2. The improved agreement with experiment suggests that to explain the present data it is important to describe properly the long-range parts of the cluster wave functions. This could be done, for example, by employing a two-Gaussian description for the ^{3}He wave function such as has been done for the deuteron wave function in a recent study of the $\alpha + d$ system.[10]

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Depolarization of Negative Muons in Low-Z Muonic Atoms with Nonzero Nuclear Spin*

D. Favart,† F. Brouillard,† L. Grenacs,† P. Igo-Kemenes,† P. Lipnik,† and P. C. Macq‡

Centre de Physique Nucléaire, University of Louvain, Louvain-Heverlee, Belgium

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The decay asymmetries resulting from the residual polarization of negative muons were measured in the components of the ground-state hyperfine doublet of ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, and ^{11}B muonic atoms. The results show a characteristic consequence of the muon-nucleus magnetic dipole coupling during the muonic cascade.

The residual polarization of negative muons in the ground state of muonic atoms with nuclear spin $I = 0$ was extensively studied both experimentally and theoretically; the spin-orbit coupling during the muonic cascade causes a strong spin depolarization.[1] Little is known on the residual polarization in muonic atoms with $I \neq 0$ where, in addition to the spin-orbit coupling, the hyperfine coupling between the muon and the nucleus will affect the depolarization. Hoping to obtain some indications about the role played by the hyperfine (hf) interaction in the spin depolarization in muonic atoms with $I \neq 0$, we have measured the decay asymmetries $\alpha^{\pm}$ in the $F^{\pm} = I \pm \frac{1}{2}$ hf ground states of ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, and ^{11}B muonic atoms. The results will be briefly commented on at the end of the present paper.

The measurements were carried out at CERN, using the muon-channel facility at the 600 MeV synchrocyclotron. The method of spin precession in a constant magnetic field was used[2]; the field homogeneity through the $6 \times 6 \times 6$-cm^3 targets and its stability during a run were better than 1×10^{-3}. The muon-stop rate was of the order of 10^4 sec^{-1}. An almost complete backward polarization of the muon beam was obtained by suitable momentum selection at the end of the muon channel. It is of importance to mention here that the decay electron due to a muon stopped in the target was recorded only if this muon stop was neither preceded nor followed by another muon stop in the target or in materials surrounding the target within 6 μsec.

The measurement consisted in the observation of the time distribution $N(t)$ of the decay electrons due to muons stopped in the target. In the case of $I \neq 0$ and for positive nuclear gyromagnetic ratio, this distribution is given by

$$N(t) = N(0)\exp(-\Lambda t)[1 + \alpha^- \cos(\omega^- t + \psi^-) + \alpha^+ \exp(-Rt)\cos(\omega^+ t + \psi^+)], \tag{1}$$

where Λ is the muon disappearance rate; $\alpha^\pm$, $\omega^\pm$, and $\psi^\pm$ are the coefficient, frequency, and phase, respectively, at $t=0$ of the decay asymmetry of the $F^\pm$ hf state; R is the rate of the F^+(upper hf state)$\rightarrow F^-$(lower hf state) conversion.[3]

Figure 1 shows typical precession curves obtained by subtracting the background and removing the trivial exponential dependence from the measured electron time distribution. In the case of ^{6}Li, the experimental points are well fitted with a single cosine function, $\cos(\omega^+ t + \psi^+)$. However, the precession curves obtained with ^{7}Li and ^{9}Be show a nonvanishing residual polarization in both of the hf states. The most striking feature of the results obtained with the ^{10}B and ^{11}B targets is the decrease of the dominant precession amplitude, which in both cases has the frequency of the F^+ state. This decrease is interpreted as the consequence of the $F^+ \rightarrow F^-$ conversion.[4] Nice precession curves were also obtained

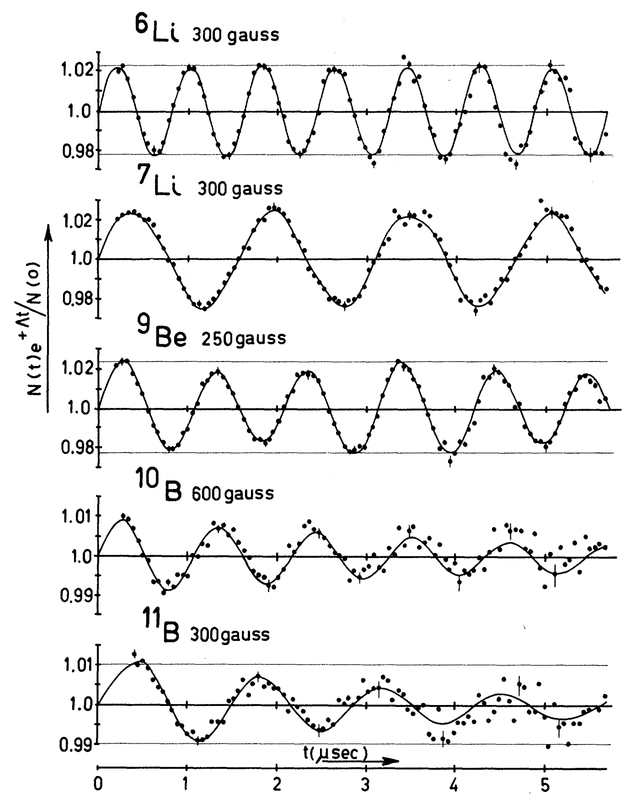

FIG. 1. Typical precession patterns obtained by stopping negative muons in ^{6}Li, ^{7}Li, ^{9}Be, ^{10}B, and ^{11}B targets. The strength of the magnetic field is indicated for each target. The value of the parameter R was found to be $R(^{10}\text{B}) = (2.1 \pm 0.5) \times 10^5$ sec^{-1} and $R(^{11}\text{B}) = (3.3 \pm 0.5) \times 10^5$ sec^{-1}. For ^{6}Li, ^{7}Li, and ^{9}Be, R was found smaller than $(0.2, 0.2, \text{and } 0.5) \times 10^5$ sec^{-1}, respectively.

in graphite with negative muons. The coefficient of the decay asymmetry of negative muons in graphite was found to be $\alpha(^{12}\text{C}) \equiv \alpha_0 = 0.0595 \pm 0.0015$ (uncorrected for target and detector finite-size effects); decay asymmetry of this order of mag-

Table I. Normalized decay-asymmetry coefficients $\alpha^\pm/\alpha_0$.

Target		Isotopic abundance (%)	$10^2\alpha^+/\alpha_0$, measured[a]	$10^2\alpha^+/\alpha_0$, calculated[b]	$-10^2\alpha^-/\alpha_0$, measured[a]	$-10^2\alpha^-/\alpha_0$, calculated[b]
Metallic	^{6}Li	95.6	45.2 ± 1.8	45	<|1.0|	−0.3
Metallic	^{7}Li	99.9	45.5 ± 1.8	38	4.7 ± 1.3	+3.1
Metallic	^{9}Be	100	37.6 ± 1.6	38	6.1 ± 1.4	+3.1
Crystalline	^{10}B	95.0	19.3 ± 2.7	33	1.8 ± 1.3	+5.9
Crystalline	^{11}B	80.4	28.4 ± 3.4	38	2.2 ± 1.4	+3.1

[a]The ratios $\alpha^\pm/\alpha_0$ do not depend on the exact knowledge of the beam polarization or on the corrections due to target and detector finite-size effects. The quoted errors were obtained by external consistency of separated measurements; correlations between variables were taken into account.

[b]Following Ref. 6., it was assumed that the muon-nucleus hf interaction is switched in from the muon orbit $l = 3$ for each muonic atom considered.

nitude is expected when almost fully polarized negative muons are stopped in graphite.[1]

The numerical results, collected in Table I, were obtained by making a least-squares fit of Eq. (1) to the experimental points. In ^{7}Li and ^{9}Be, α^- is surely different from zero, moreover $\alpha^-/\alpha_0<0$. This means that in the F^- state the direction of the muon spin is opposite to that in the muon beam. If the magnetic dipole coupling between the muon and the nucleus is taken into account in the ground state only,[5] one obtains $\alpha^-/\alpha_0>0$ because the spin-orbit coupling alone does not change the direction of the muon spin. The tendency $\alpha^-/\alpha_0<0$ shown by the results is in favor of the model[6] where the magnetic dipole coupling between the muon and the nucleus is taken into account from a given excited state of the muonic atom with orbital quantum number l; these predictions are quoted in Table I, assuming $l=3$ for each muonic atom. As it can be seen, the predicted values of $\alpha^{\pm}/\alpha_0$ are in qualitative agreement with the experimental results.

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†Chercheur, Institut Interuniversitaire des Sciences Nucléaires, Bruxelles, Belgium.

‡CERN Fellow.

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One-Neutron Transfer Reactions ^{9}Be(^{16}O, ^{17}O[0.871])^{8}Be and ^{13}C(^{16}O, ^{17}O[0.871])^{12}C

P. H. Barker, P. M. Cockburn, H. P. Seiler, and P. Marmier

Laboratorium für Kernphysik, Eidgenössiche Technische Hochschule, Zürich, Switzerland

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The total cross sections for the reactions ^{9}Be(^{16}O, ^{17}O[0.871])^{8}Be and ^{13}C(^{16}O, ^{17}O[0.871])^{12}C have been measured at energies well below the Coulomb barrier. The data have been fitted with the Buttle and Goldfarb formulation of distorted-wave Born-approximation theory and spectroscopic factors extracted.

The study of heavy-ion transfer reactions in the neighborhood of the Coulomb barrier has been suggested[1] as a means of extracting nuclear spectroscopic-factor information. The principal advantage of such an experiment is that the nuclear part of the interaction potential can be treated as a perturbation on the well-understood Coulomb interaction. Several one-neutron transfer reactions have been studied at this Laboratory in the region of the Coulomb barrier[2] and analyzed following the distorted-wave Born-approximation (DWBA) approach of Buttle and Goldfarb.[1] The spectroscopic factors obtained from these experiments agree quite well in general with those calculated by Cohen and Kurath[3] where such a comparison is possible.

The present Letter describes the results obtained with a different experimental method which incorporates some improvements over that previously used.[2] By using a Ge(Li) detector to observe the γ rays emitted from states excited via the nucleon transfer process, the total cross sections of several transfer reactions can be measured simultaneously to energies considerably below the Coulomb barrier. The Born-approximation analysis can thereby be simplified in that the interaction can be considered to be purely Coulombic. This technique has been applied to the study of the one-neutron transfer reactions ^{9}Be(^{16}O, ^{17}O)^{8}Be and ^{13}C(^{16}O, ^{17}O)^{12}C,