Observation of munucleonic chlorine atom

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Munucleonic chlorine atoms formed in the course of capture of polarized negative muons by argon atoms in a gaseous argon atmosphere with xenon admixtures were observed by measuring the precession frequencies of their total momentum in 3.0- and 4.4-gauss magnetic fields transverse with respect to muon spin. The coefficient of asymmetry of the electron from the $\mu \to e$ decay is 0.059 ± 0.012

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Two experiments are currently known in which formation of the free munucleonic atoms—muonic atoms with a fully filled electron shell—has been detected.[1–3] The first experiment discovered munucleonic fluorine and the second—hydrogen. Interest in these systems is associated with possibilities of their use as a tool in the study of physico-chemical properties of matter and, also, properties of the muon itself.[1–6] Thus, enlarging the inventory of munucleonic atoms observed experimentally is important.

We investigated the formation of the munucleonic chlorine atom which occurs when negative muons are captured by argon atoms. As is known, the chlorine atom is paramagnetic due to the *P*-state of its outer electron shell. Therefore, the total momen-

tum of a munucleonic atom $F = J + \frac{1}{2}$, where J is the shell momentum and $\frac{1}{2}$ is muon spin, will precess in a weak magnetic field. The time distribution of electrons from the muon decay for the case of P-state shell of a munucleonic atom was calculated elsewhere[2] and it has the following form (in the absence of background):

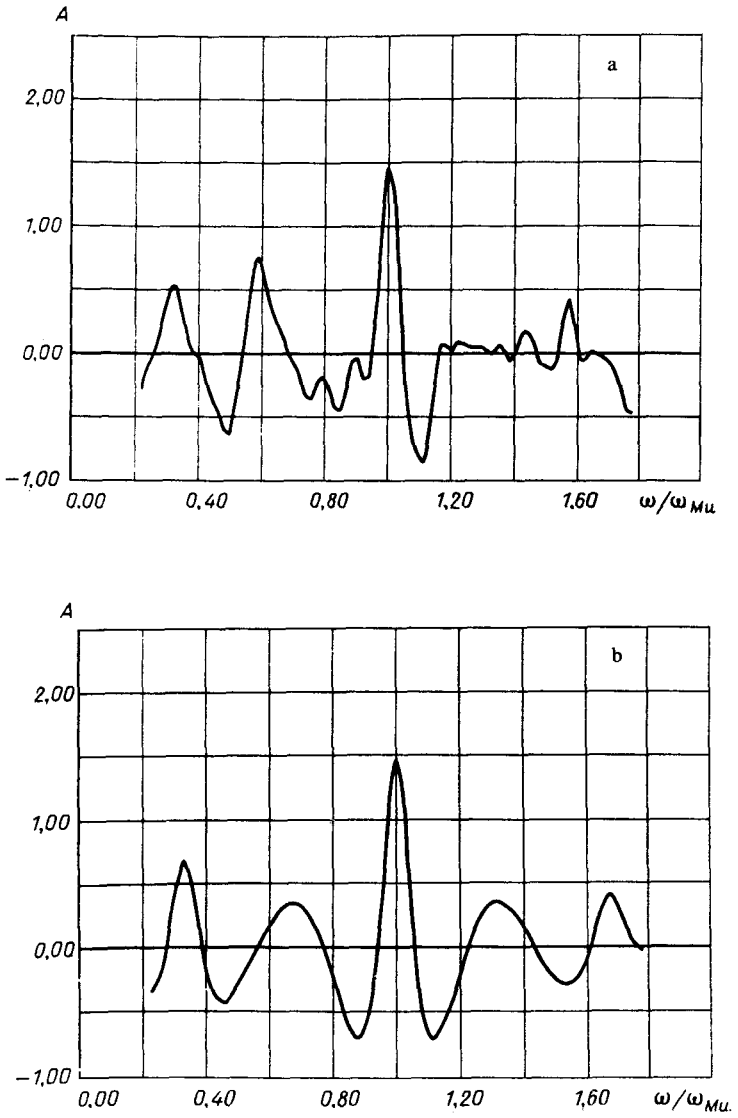

FIG. 1. Results of harmonic analysis of temporal distributions summed over all measurements: a—experimental temporal distribution in argon; b—calculated, expected in the case of generation of munucleonic chlorine atom. Ordinate axis—frequency in ω_{Mu} units (see text), A—amplitude of precession frequency in percent.

$$N(t) = N_0 \exp(-\lambda t)\left\{1 + a\left[\frac{\alpha}{2}\cos\left(\frac{\omega_{Mu}}{3}t + \phi\right) + \frac{(1-\alpha)}{16}\left(5\cos(\omega_{Mu}t + \phi) + \cos\left(\frac{5\omega_{Mu}}{3}t + \phi\right)\right)\right]\right\}.$$

where λ^{-1} is muon lifetime in argon; ϕ is phase; a is the asymmetry coefficient which corresponds to residual polarization of muon in the K-shell in the absence of hyperfine interaction; α is population of the $^2P_{1/2}$-state; $(1-\alpha)$ is the population of the $^2P_{3/2}$-state; ω_{Mu} is precession frequency of triplet muonium in a magnetic field of the same strength. In the case of statistical population $\alpha = 1/3$.

The experiment was carried out in the meson bay of the JINR synchrocyclotron. Search for the munucleonic chlorine atom was carried out by observing the precession of the angular distribution of electrons from the $\mu \to e$ decay in transverse (with respect to muon spin) magnetic fields with strengths of 3 and 4.4 Oe. We used a special gas target to measure the stopping of muons in argon. The target consisted of a hollow stainless steel sphere 150 mm in diameter. It contained a porthole covered with quartz glass through which the entire volume was scanned by a photomultiplier. Stoppages in the gas were identified from the amplitude of the scintillation pulse generated in the course of a muon passage through the target. Moreover, the total contribution of the $\mu \to e$ decay electrons from muon stoppage in the target walls to the experimental electron distribution did not exceed 10%.

The target was filled with the following gas mixtures: 39 atm Ar + 7 atm Xe and 45 atm Ar + 1 atm Xe.

Xenon was used as the electron donor[1] for shaping the fully-filled electron shell of the munucleonic chlorine.

Scrubbing of impurities from the gas mixture was done by circulating the gas through an oven with metallic shavings of calcium and titanium. The muon decay electrons were registered by three scintillation counter telescopes.

The experimental time distributions of the $\mu \to e$ decay electrons were processed with respect to MNK using Eq. (1). The following results were obtained: $a = 5.9 \pm 1.2\%$, $\alpha = 0.23 \pm 0.10$ and $\lambda_{Ar}^{-1} = 571 \pm 20$ nsec. The coefficient of asymmetry for the carbon target—measured with the same beam and experimental geometry—was $a_c = 4.7 \pm 0.1\%$. Figure 1 illustrates the results of harmonic analysis of the total experimental time distribution of the decay electrons. It also shows the expected curve, calculated with an allowance for the experimental conditions for the case of three-frequency precession at $a = 5.9$ and $\alpha = 0.22$.

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