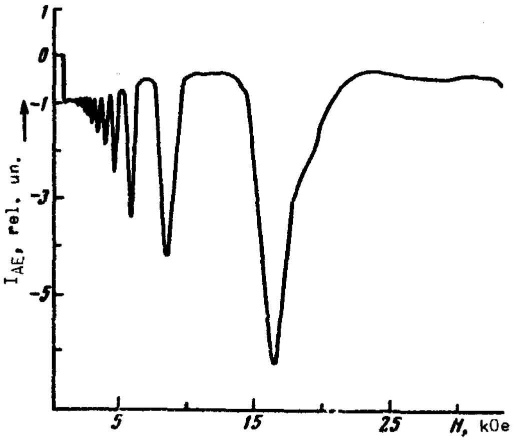

Fig. 2. Dependence of AE current amplitude on the magnetic field, $\vec{q} \parallel \vec{H} \parallel y$, f = 500 MHz, T = 3°K.

oscillations of the sound absorption coefficient. Their amplitude depends linearly on the magnetic field, in agreement with the theory [3, 4]:

$$\Gamma = \frac{\Gamma_0 e\hbar H}{8m^* ckT}, \qquad (1)$$

where Γ_0 is the electronic assorption coefficient in the absence of a field, m* is the effective mass, H is the magnetic field, and the remaining symbols are standard. Figure 2 shows the dependence of the amplitude of the AE current on the magnetic field for the case $\vec{q} \parallel \vec{H} \parallel y$. The interaction of the longitudinal sound wave with the electrons is characterized in this case by the fact that its value predominates for one of the electronic ellipsoids, which is elongated along the y axis, and is negligible for the two others. This results in AE current oscillations having one period and due to the indicated ellipsoid. The amplitude of the oscillation and the absorption line shape agree quite well with data on sound damping [5], so that one can talk of using the proposed method to study the energy spectra of the carriers in conductors.

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EXPERIMENTAL OBSERVATION OF ELECTRON PARAMAGNETISM OF MUONIC ATOMS

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As established by us, in noble gases with spinless nuclei there is no Larmor precession of the μ^--meson spin at the precession frequency of the free muon [1, 2]. It is shown in the present article that this is due to spin-orbit interaction of the muon with the electron shell of the muonic atom[1].

We consider a nucleus Z with a negative muon in the K-orbit, comprising a system measuring $\sim 10^{-10}$ cm and having an effective charge Z - 1 and the magnetic moment of the muon. We shall henceforth call a nucleus with a muon on the K orbit a "mesic nucleus." When the electron shell of the mesic nucleus is completely filled and is disintegrated by cascade transitions of the muon, a muonic atom is produced on the mesic nucleus Z - 1 and has properties equivalent to those of the ordinary atom of the element with charge Z - 1. We note

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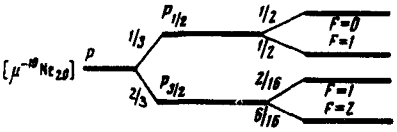
[1] Preliminary results were reported at the Fourth International Conference on the Physics of High Energy and Nuclear Structure, Dubna, 1971 (p. 415).



J	L	S	F	I	g(J)	g(F)	α_i	ω_g/ω_{Mu}
1/2	1	1/2	0	1/2	2/3			
1/2	1	1/2	1	1/2		1/3	1/6	1/3
3/2	1	1/2	1	1/2	4/3	5/3	1/12	5/3
5/2	1	1/2	2	1/2		1	1/4	1

Fig. 1. Mesic-neon atom levels and their quantum numbers: S - electron-shell spin, L - orbital momentum, g(F) - shell Lande factor.

that the system produced on the mesic helium nucleus has properties close to those of muonium.

We have investigated experimentally the mesic neon nucleus $(\mu^{-10}Ne_{20})^{+9}$, which is equivalent to the nucleus $^9F_{20}$ and has the spin and magnetic moment of the μ^- meson. When colliding with the target atoms, the mesic neon nucleus should acquire the electron shell of the fluorine atom, and complete filling of the fluorine shell is possible if the target contains atoms with an ionization potential lower than that of fluorine. We used for this purpose xenon as an additive (I_{xe} = 12.08 eV; I_F = 17.4 eV).

The presence of the magnetic moment of the electron shell of the fluorine atom governs the paramagnetic properties of the atom produced on the mesic nucleus (μ^-Ne). In a weak magnetic field, the total angular momentum of the mesic neon is conserved ($F = J \pm I$, where J is the angular momentum of the shell and I is the angular momentum of the mesic nucleus, i.e., the μ^- meson spin). The precession frequency in the magnetic field of the total angular momentum F is determined by the Lande factor g(F) for the hyperfine structure of the muonic atom.

Figure 1 shows the structure of the levels of the mesic neon atom, their quantum numbers, the relative statistical populations of the polarization-conserving states, and the calculated values of the Lande factor. The precession frequency of the total angular momentum of the mesic neon atom in a weak magnetic field is determined by the expression $\omega = g(F)HM_e$, where H is the magnetic field intensity and M_e is the electron Bohr magneton. It is seen from Fig. 1 that when a μ^- meson is stopped in neon the total angular momentum of the mesic neon atom should precess at three frequencies. The corresponding electron distribution is given by

$$N(t) = N_0 \exp(-\lambda t)\{1 + a[{}^1/_6 \cos({}^1/_3\omega_1 t + \phi) + {}^1/_4 \cos(\omega_1 t + \phi) + + {}^1/_{12} \cos(-{}^5/_3\,\omega_1 t + \phi)]\}, \qquad (1)$$

where λ is the muon lifetime in the mesic atom, a is an asymmetry coefficient corresponding to the residual polarization of the negative muon on the K shell, and $\omega_1 = \omega_{Mu}$ (at g(F) = 1 the precession frequency coincides with the spin precession frequency of triplet muonium, i.e., it is approximately 100 times larger than the precession frequency of the free muon).

To register the stopped muons, we developed a controllable gas target of original design [3], in which the decay electrons from the muons stopped in the gas were registered with high efficiency. The measurements were performed with the gas target filled with the mixture Ne (42 atm) + Xe (1 atm). The experimental decay-electron distribution produced upon precession of the total angular momentum of the mesic neon atom in weak magnetic fields (1.1 and 2.1) was processed by least squares using Eq. (1). The data-reduction results are shown in the table. It is seen from the table that the precession frequency ω_1 coincides within the limits of experimental accuracy with the spin precession frequency of triplet muonium in a magnetic field of the same intensity. In the

Results of least-squares reduction of electron-decay spectra

Beam	Target	Magnetic field 2) (Oe)	Asymmetry coeffic.	Precession frequency (rad/μsec)	Theoretical values of precession freq.(rad/μsec)
μ^-	Ne 1)	1.1	0.13 ±0.03	9.0 ± 0.2	ω_1 = 9,7±0.9
μ^-	Ne	2,1	–	19.8 ±0.4	ω_2 = 18,5 ±0,9
μ^+	Ne	2,1	0,07 ± 0,01	19,5 ±0,2	ω_{Mu} = 18,5±0,9
μ^-	C in gas target	61,2	0.052 ± 0,006	5,34 ± 0.08	ω_μ = 5,23±0,09

1) Ne (42 atm) + Xe (1 atm).
2) The systematic error in the measurement of the magnetic field is ±0.1 Oe.

comparison of the negative-muon data obtained with carbon and neon, notice should be taken of relatively large residual polarization of the muon on the K shell of the mesic neon atom.

Figure 2 shows the results of the reduction using the simple relation

$$N(t) = N_0 \exp(-\lambda t)[1 + b\cos(\omega t + \phi)],$$

with the precession frequency varied in the interval $0.1 < \omega/\omega_{Mu} < 2$. The figure shows also the asymmetry coefficients $b(\omega)$ obtained with such a least-squares reduction of the total statistics. It is clearly seen that the experimental distribution of the decay electrons has natural precession frequencies that agree well with the expected theoretical values.

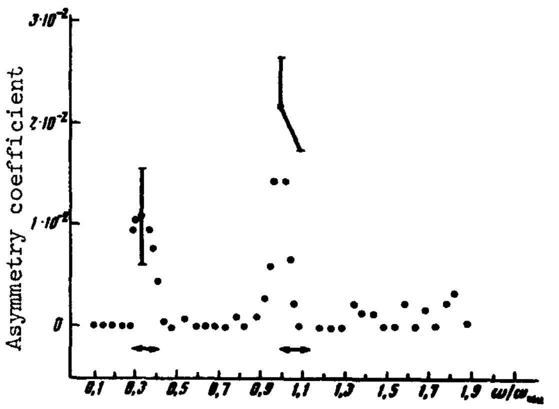


Fig. 2. Asymmetry coefficient b vs. the ratio ω/ω_{Mu} in the reduction of the decay-electron spectra using the functional relation (2). The arrows show the expected theoretical values of the precession frequencies.

Thus, experimental observation of the precession of the total spin of the mesic neon process (i) proves the existence of a stable (during the muon lifetime) mesic neon atom system with the expected paramagnetic properties and (ii) explains the absence of precession of negative muons in noble gases at the Larmor frequency of the free muon in a magnetic field [2].

The study of muonic atoms of the type of the mesic-neon atom using the presession of the total angular momentum of the muonic atom in a magnetic field uncovers new possibilities for research, fully analogous to those arising in the study of muonium in a magnetic field. Whereas in the case of muonium, however, we deal only with a hydrogen-like atom, muonic atoms such as mesic neon can have in principle arbitrary electron shells.

New possibilities are uncovered also in the investigation of hyperfine splittings of muonic atoms (for example, by methods of resonant transitions in the hyperfine structure [4]). A study of the hyperfine structure of the mesic helium atom $[(\mu^-He)^+e^-]$, which has properties close to those of muonium, provides another method of determining the fine-structure constant $\alpha = e^2/\hbar c$.

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LOW-TEMPERATURE PHASE TRANSITION IN $KDy(MoO_4)_2$ PRODUCED BY THE COOPERATIVE JAHN-TELLER EFFECT

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The investigation of the cooperative Jahn-Teller effect has been given greater attention of late, both as a result of the increased theoretical interest in the general problem of phase transition, and as a result of the recent observation of a number of new rare-earth compounds having a structural phase transition at low temperatures because of this effect (e.g., $DyVO_4$ [1]).

A characteristic feature of the cooperative Jahn-Teller effect in these compounds is that it appears in crystals with low structure symmetry. Unlike the previously investigated spinels, where the electron-level degeneracy due to symmetry is lifted, "randomly" degenerate electron levels can participate in the Jahn-Teller effect in this case. For example, for a dysprosium compound with low crystal-structure symmetry, the eightfold Kramers degeneracy of the ground term $^6H_{15/2}$ of the Dy^{3+} ion is completely lifted, but a situation is possible wherein the energies of different Kramers doublets, including the two lower ones, turn out to be equal or close at certain values of the crystal-field constant. Understandably, the "random" degeneracy of a lower level is in principle a rather rare situation, and therefore there is a small number of known low-symmetry crystals in which the cooperative Jahn-Teller effect is observed.

Judging from the calculations for the energy spectrum of the impurity ion Dy^{3+} in the $KY(MoO_4)_2$ crystal with rhombic structure symmetry, which were performed by us from results of measurements of optical, resonance, and magnetic properties [2], the energy distance between the two lower Kramers doublets in the spectrum of the ground term $^6H_{15/2}$ of the Dy^{3+} ion is small for this crystal. We can therefore expect an onset of the cooperative Jahn-Teller effect

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