determine the parameter κ in (4), we also plotted at each temperature curves of $\Delta R(j^2)$, from which we could, knowing the absolute values of ΔR and j, obtain the value of τ_{nr} and then find κ using the values of $\sigma^{(2)}$ given in [10] (neglecting the change of $\sigma^{(2)}$ with changing polarization of the pump). As seen from the figure, there is good agreement between the experimental and the theoretical results.

In the experiments aimed at observing the optical orientation for TPA in InSb, performed at 80°K, a negative result was obtained, due apparently to the smallness of the ratio τ_{sp}/τ (τ_{sp} is the time of spin relaxation) at the indicated temperature. We can therefore only estimate the upper bound of τ_{sp}, by determining τ from the $\Delta R(j^2)$ curve and knowing the sensitivity of the measuring system. We obtained $\tau_{sp} < 10^{-10}$ sec.

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CORRECTION OF μ-MESIC ENERGY LEVELS FOR NUCLEAR POLARIZATION IN THE ADIABATIC APPROXIMATION

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In a number of comparisons of the experimental energies of μ-mesic transitions with the theoretical ones it is necessary to introduce corrections for the polarizability of the nucleus in the muon field [1]. There are as yet no simple and sufficiently reliable methods for calculating such corrections. In nonrelativistic perturbation theory, the correction that must be added to the energy of a μ-mesic atomic level with quantum numbers n, ℓ, and m to account for the polarizability of the nucleus is given by

$$\Delta E^{\mathrm{pol}} = -\sum_{\alpha \neq 0, i} \frac{\langle 0, n\ell m | \Delta V | \alpha, i \rangle \langle \alpha, i | \Delta V | 0, n\ell m \rangle}{E_\alpha - E_0 + \epsilon_i - \epsilon_{n\ell}}, \tag{1}$$

where the perturbing potential is

$$\Delta V = -\sum_k \frac{e^2}{|\vec{r}_k - \vec{\rho}|} - \langle 0 | -\sum_k \frac{e^2}{|\vec{r}_k - \vec{\rho}|} | 0 \rangle . \tag{1'}$$

$|\alpha\rangle$, $|i\rangle$, E_α, and ε_i in (1) and (1') are the states and energies of the nucleus and the muon, respectively, while $\bar{r}_k$ and $\vec{\rho}$ are the radius vectors of the nucleons in the nucleus and of the muon. Such a calculation calls for knowledge of the nuclear excited states and for summation both over the states of the discrete and over the continuous spectra. Usually the main contribution to the correction is made by the integral over the continuous spectrum of the intermediate states. In some papers (cf., e.g., [2, 3]), calculations of this type were made for different approximations and nuclear models. As a rule, the accuracy of the results is low and the error amounts to about 100%.

We wish to note here that the dipole-polarization correction to the energy of μ-mesic atomic levels with $\ell \geq 1$ can be calculated with the aid of a simpler adiabatic approximation by using the potential $V^{pol}(\rho) = (-1/2)\alpha e^2/\rho^4$ for the the polarization interaction between the muon and the nucleus ($\rho \geq R$, R is the dimension of the nucleus, and α is the coefficient of static dipole polarizability of the nucleus). It can be shown rigorously that for not too heavy nuclei, so long as the orbit of the muon in the state $|n, \ell \geq 1|$ lies outside the nuclei, the characteristic energy 10 - 20 MeV of the nuclear dipole transitions is much higher than the characteristic energy of the μ-mesic atomic transitions. Neglecting in the denominator of (1) the energy $\varepsilon_i - \varepsilon_{n\ell}$ in comparison with the energy $E_\alpha - E_0$ (adiabatic approximation) and confining ourselves in the sum to the dipole interaction term, we can derive the formula [4]

$$\Delta E^{dip}_{pol} = -\frac{1}{2}\alpha e^2 \int_{\rho \geq R} \frac{|\phi_{n\ell m}(\vec{\rho})|^2}{\rho^4} d^3\rho \ , \qquad (2)$$

where $\phi_{n\ell m}(\vec{\rho})$ is the muon wave function. α is usually calculated from the formula [5]

$$\alpha = 3{,}5\, A^{5/3} \cdot 10^{-42}\ \text{cm}^3, \qquad (3)$$

where A is the atomic weight. Formula (3) yields for nuclei with $A \gtrsim 20$ values of α that coincide with the experimental ones within 10 - 30%[1]. The table lists the corrections for the polarizability to the energies of the S, P, and D levels of the μ-mesic atoms $\mu^{20}Ne_{10}$, $\mu^{40}Ca_{20}$, and $\mu^{208}Pb_{82}$, obtained from (2) and (3). The wave functions of the muon for a point nucleus, given in (2), are those for a point-like nucleus. Such an approximation does not affect the corrections to the P and D levels of the μ-mesic atoms $\mu^{20}Ne_{10}$ and $\mu^{40}Ca_{20}$. The corrections obtained with a rough allowance for the influence of the non-point-like nature of the nucleus (one-parameter variational approximation) on the wave function are given in the table in parentheses. The table lists also the corrections for the monopole, dipole, and quadrupole polarizabilities, as calculated in [2]. A comparison of the corrections calculated in the adiabatic approximation with the corrections that take deviation from adiabaticity into account shows agreement within 20% for levels with $\ell > 1$. In the adiabatic approximation we can obtain more reliable values for the corrections ΔE^{pol}_{dip} by using in lieu of (3) the experimental values of α. As to the corrections to the S levels, the discrepancies amount to a factor 1 - 4. As seen from the table, the corrections for the monopole and quadrupole polarizabilities cannot be neglected

[1]Actually, the α calculated in this manner is compared with the integral $(1/2\pi)\int\sigma(E)/E^2 dE$, where σ is the total cross section for the photoabsorption by the nucleus. Certain data [6] indicate that the coefficient 3.5 in (3) should be decreased to 2.5 - 3.

$n\ell$	ΔE^{pol}_{dip}, eV	ΔE^{pol}_{dip}, eV [2]	ΔE^{pol}_{mon}, eV [2]	ΔE^{pol}_{qu}, eV [2]
		$\mu^{20}Ne_{10}$		
1S	−12 (−11)	−8,0	−2,0	−3,7
2S	−1,4	−1,00	−0,3	−0,6
2P	−0,032	−0,027	−	$-3{,}2 \cdot 10^{-3}$
3D	$-4{,}8 \cdot 10^{-4}$	$-4{,}4 \cdot 10^{-4}$	−	−
		$\mu^{40}Ca_{20}$		
1S	−110 (−77)	−94	−40	−35
2S	−13	−11	−5	−4
2P	−1,3	−1,1	−0,018	−0,2
3D	−0,025	−0,023	−	-10^{-3}
		$\mu^{208}Pb_{82}$		
1S	−620 (−480)	−800	−3000	−1000
2S	−360	−100	−600	−120
2P	−860 (−650)	−730	−100	−400
3D	−87	−62	−	−40

for heavy μ-mesic atoms. Formula (2) greatly exaggerates the upper limit (by a factor of 10) of the corrections to the S levels of the lightest μ-mesic atoms ($A < 2$) when the characteristic energies of the μ-mesic atomic transitions amount to ∿10 - 100 MeV. In this case it is necessary to take into account the production of $\mu^-\mu^+$ pairs in the intermediate state. The foregoing procedure can be used with very slight modifications to calculate the corrections for the polarizability of pions (kaons, etc.) to the energy levels of μ-mesic atoms and other exotic atoms[2)].

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N O T E

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[2)]The corrections for the pion polarizability were calculated in the adiabatic approximation in [7, 8].