↑Fe - O bond and $f_\sigma = [(\gamma_\sigma^\downarrow + S_\sigma)^2 - (\gamma_\sigma^\uparrow + S_\sigma)^2]/3 = -0.007$ for the ↑Cr - O bond. Here $S_\sigma = \langle 2p_\sigma | d_\sigma \rangle$, $\gamma_\sigma^{\uparrow,\downarrow}$ is the $p_\sigma^{\uparrow,\downarrow} - d_\sigma^{\uparrow,\downarrow}$ transport parameter. In the calculation, ϕ was assumed to be equal to the superexchange Fe - O - Fe or Cr - O - Cr angle (∿156°) [3]. The overlap integrals S_{ns} were calculated from the approximate Slater functions. The values of the wave functions $\Phi_{ns}(0)$ and of the remaining parameters were taken from [5, 4, 6].

The total polarization of the 3s, 4s, and 5s shells of tin at parameter values $a_{5s} = 0.25$ yields hfs fields $h_{Fe} = 41 \pm 2$ kOe and $h_{Cr} = -6 \pm 0.5$ kOe, i.e., values close to the experimental ones, but with opposite signs.

There are published measurements of the hfs fields induced at nuclei of nonmagnetic atoms on a linear magnetic ion - ligand - nonmagnetic ion chain. In particular, ENDOR measurements [6] for the Al^{27} nuclei in the chains $Fe^{3+} - O^{2-} - Al^{3+}$ and $Cr^{3+} - O^{2-} - Al^{3+}$ have shown that in these two cases the magnetic fields induced at the Al^{27} nuclei have opposite signs.

The significant fact in our experiment is that the contributions h_{Cr} to the hfs field at the tin have the same sign as the contributions h_{Fe}. It follows therefore that, in accord with the foregoing calculation, the magnetic moments of the Fe^{3+} and Cr^{3+} ions in the first coordination sphere of the tin should be oppositely directed. It is easily seen that a magnetic structure of this type is realized only when the superexchange interaction $Fe^{3+} - O^{2-} - Cr^{3+}$ has a positive sign.

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[1] J.B. Goodenough, Magnetism and the Chemical Bond, Wiley, 1963 (Russ. transl., Metallurgiya, 1968, p. 134).
[2] V.I. Gol'danskii, V.A. Trukhtanov, M.N. Devisheva, and V.F. Belov, ZhETF Pis. Red. 1, No. 1, 31 (1965) [JETP Lett 1, 19 (1965)]; I Nowik et al., Phys. Lett. 34A, 155 (1971).
[3] K. Motida and S. Miyahara, J. Phys. Soc. Japan 28, 1188 (1970); M. Marezio, J.R. Remeika, and P.D. Dernier, Acta Cryst. B26, 2008 (1970).
[4] G.A. Sawatsky, C. Boekema, and F. van der Woude, Proceedings of the Conference on Mossbauer Spectrometry, p. 238, Dresden, 1971.
[5] J. Lees and P. Flinn, J. Chem. Phys. 48, 882 (1968).
[6] J. Owen and D.R. Taylor, J. Appl. Phys. 39, 791 (1968).

USE OF EXTRACTED SYNCHROCYCLOTRON BEAM TO INVESTIGATE SCATTERING OF 1-GeV PROTONS BY NUCLEI

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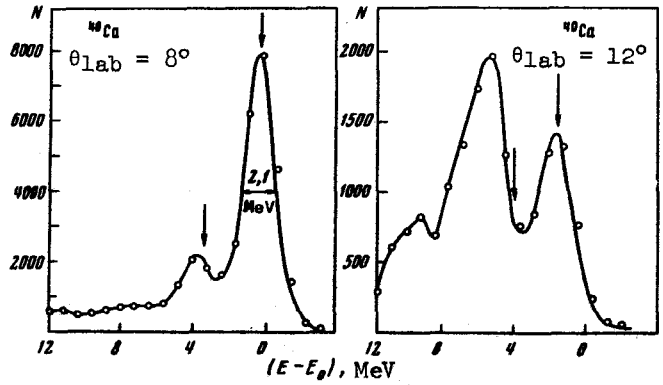
The success of Glauber's theory has increased appreciably the interest in experiments on the scattering of high-energy protons by nuclei. To perform such experiments it is necessary to have apparatus with sufficiently high energy resolution, determined by the distance between the excitation levels of the nucleus. Palevsky's experiment [1, 2] remained until recently the only one performed at an energy close to 1 GeV, in which the elastic scattering was reliably separated from scattering with excitation of low-lying levels of ^{12}C and



Energy spectra of protons with initial energy E_0 = 1 GeV, scattered by ^{40}Ca. The arrows indicate the ground and first-excited (3.35 MeV) state of ^{40}Ca. The energy resolution FWHM = 2 MeV was obtained by using a synchronization technique.

^{16}O. The energy resolution in this experiment (FWHM = 3 MeV) was limited by the spectrometer. The contribution of the energy spread of the beam extracted from the Brookhaven proton synchrotron did not exceed 1 MeV according to the authors' estimates.

The difficulty of performing such experiments with a synchrocyclotron is due to the relatively large energy spread of the extracted beam. In particular, the extracted beam of the synchrocyclotron of our Institute, in which a regenerative extraction system is used [3], has an energy spread FWHM = 10 MeV at a proton acceleration energy 1 GeV [4]. However, the contribution of the energy spread of the beam to the total energy resolution can be greatly reduced by using the correlation between the energy and momentum of the proton extracted from the synchrocyclotron. Let us examine the mechanism of this correlation for the idealized case of zero synchrotron oscillations. In this case all the particles of the internal beam have the same energy, and the radial distribution of the beam is determined completely by the betatron oscillations. The particles enter the regenerator zone because their energy is increased. The extracted particles have the largest betatron-oscillations amplitudes during the initial extraction phase and the smallest in the final stage. Consequently, the particle energy in the extracted beam is uniquely related to the instant of extraction, namely, it grows from the start of the extraction to its end. It follows therefore that if the instant of particle extraction is fixed by synchronization with the frequency of the accelerating field, then its energy is also fixed, i.e., such a temporal tie-in is equivalent to monochromatization of the extracted beam. An analogous situation obtains also in the presence of synchrotron oscillations. In that case, however, owing to the spread of the amplitudes of the radial betatron oscillations, the particles entering the extraction channel at each instant of time have different energies. This means that the instantaneous energy spread of the extracted beam is equal to zero. We note that the spread does not exceed the energy spread of the internal beam.

The figure shows the spectra of protons scattered by ^{40}Ca nuclei. In these measurements, which were performed with a synchronization technique, we used a stretched beam at an extracted-beam pulse duration 8 msec and a time-window width 1 msec. The energy resolution estimated from the widths of the elastic-scattering peaks is FWHM = 2 MeV, while the rated energy resolution of the spectrometer is FWHM = 1.7 MeV. If we take into account the contribution of the spectrometer to the total energy resolution, then an estimate FWHM $\approx$ 1 MeV can be obtained for the energy spread of the beam in measurements with synchronization. It is probable that the beam spread is smaller than this value, since the actual spectrometer resolution in these measurements could be several times worse than the rated value.

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[1] H. Palevsky, J.L. Friedes, et al., Phys. Rev. Lett. 18, 1200 (1967).
[2] J.L. Friedes, H. Palevsky, et al., Nucl. Phys., A104, 294 (1967).
[3] N.K. Abrosimov, V.A. Volchenkov, V.A. Eliseev, G.A. Ryabov, and N.N. Chernov, Preprint FTI-312, Leningrad, 1971.
[4] G.D. Alkhazov, G.M. Amal'skii, S.L. Belostotskii, A.A. Vorob'ev, and Yu.V. Dotsenko, Preprint FTI-323, Leningrad, 1972.

INCREASE OF PARALLEL PARAMAGNETIC SUSCEPTIBILITY BY RESONANT PUMPING

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We report here a multiple increase of the parallel magnetic susceptibility (χ) of a solid paramagnet under conditions when the temperature T_{ss} of the spin-spin interactions is strongly shifted by saturation of the paramagnetic resonance.

The study of the $\chi(\omega)$ dependence at frequencies ω much lower than the paramagnetic-resonance frequency ν_0 is the oldest method of investigating relaxation phenomena in spin system (the "parallel-field method" [1]). This dependence is usually of the form

$$\chi(\omega) = \sum_i \chi_i(\omega) = \sum_i \frac{\chi_i(0)}{1 + i\omega\tau_i}, \qquad (1)$$

where τ_i can denote the spin-lattice relaxation time, the time for the establishment of equilibrium in the entire spin system, or else the cross-relaxation time (τ_{cr}) in a system with several resonance lines with close frequencies [2]. Since none of the $\chi_i(0)$ exceed the static susceptibility χ_0, the sensitivity of the "parallel field" method is low (we recall for comparison that when paramagnetic resonance is observed the susceptibility at the frequency ν_0 is $\chi_0(\nu_0/\delta\nu) \sim (10^2 - 10^3)\chi_0$, where $\delta\nu$ is the half-width of the resonance line.

The possibility of greatly increasing the absolute value of the parallel susceptibility, realized in the experiment described below, is based on a simultaneous application of two alternating magnetic fields to the paramagnetic specimen, a field $H_1e^{i\omega t}$ parallel to H_0 and used to measure $\chi(\omega)$, and a field $h_1e^{2\pi i\nu t}$ perpendicular to H_0 to saturate the paramagnetic resonance on the wing of the resonance line (with a detuning $|\nu - \nu_0| \sim \delta\nu$). As shown by one of us [3], such a saturation, which is known to decrease $|T_{ss}|$ strongly (cf. [4, 5]), should increase all the χ_i values on the order of $(T_0/T_{ss}) \sim (10^1 - 10^3)\chi_0$, where T_0 is the lattice temperature. We have verified this prediction experimentally by measuring $\chi_{cr}(\omega)$. As is well known, the cross-relaxation susceptibility is due to modulation of the z-component of the macroscopic magnetic moment of the sample M_z in the field $H_1e^{i\omega t}$ owing to the redistribution of the Zeeman energy among two spin subsystems having close resonant frequencies $\nu_1 \approx \nu_2$ (it is assumed that the detuning $\Delta_{12} \equiv \nu_1 - \nu_2$ depends on the external magnetic field and is therefore also modulated at the frequency ω). It can be shown (cf., e.g., [2]) that χ_{cr} is proportional to the difference $(\nu_1/T_{z1}) - (\nu_2/T_{z2})$, where T_{z1} and T_{z2} are the Zeeman spin temperatures of the corresponding subsystems. On the other hand, it is known [7, 6] that under the conditions