levels.

We shall now discuss the question of how to obtain information concerning the presence of the levels 2^- and 0^- of nuclei with A = 4 by investigating the reaction $He^4(\pi^+, \pi^0)Li^4$. To this end, we consider the π^0-meson angular distributions corresponding to the excitation of all the levels listed above, and to excitation of the levels $(1^-)_-$ and $(1^-)_+$ only. They are shown in the figure as curves I and II respectively. We see that II is practically symmetrical with respect to the 30° angle, whereas curve I is clearly asymmetrical. This asymmetry is due to the contribution corresponding to excitation of the levels 2^- and 0^-. Thus, if the experiment reveals a noticeable asymmetry in the angular distribution of the π^0 mesons with respect to 30°, then this asymmetry can be ascribed to excitation of the levels 2^- and 0^-. In principle, the obtained experimental curve can be resolved into the curves shown in the figure and corresponding to excitation of individual levels, and by the same token we can determine the relative contributions made by them to the total differential cross sections.

It should be noted that the reasoning presented above was based on the assumption that nuclei with A = 4 have in the considered energy region ($\lesssim$30 MeV) no levels with T = 1 other than those considered here. This is apparently the real situation [2-4].

It is seen from the foregoing example that single charge exchange of $\pi^\pm$ mesons at energies close to the (3, 3) resonance on light nuclei can be used in principle to obtain spectroscopic information concerning the nucleus. It is necessary to use for this purpose such characteristics of this process as the angular distribution of the π^0 mesons and their spectrum at definite scattering angles. As seen from the figure, these processes have a sufficiently large probability.

In conclusion, I am grateful to N. S. Amaglobeli and R. G. Salukvadze as well as the other participants of the Seminar of the Nuclear Physics Research Laboratory of the Tbilisi State University for discussions and valuable remarks.

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POSSIBILITY OF TRANSFORMATION OF AN ANTIFERROMAGNETIC SEMICONDUCTOR INTO A METAL IN A STRONG MAGNETIC FIELD

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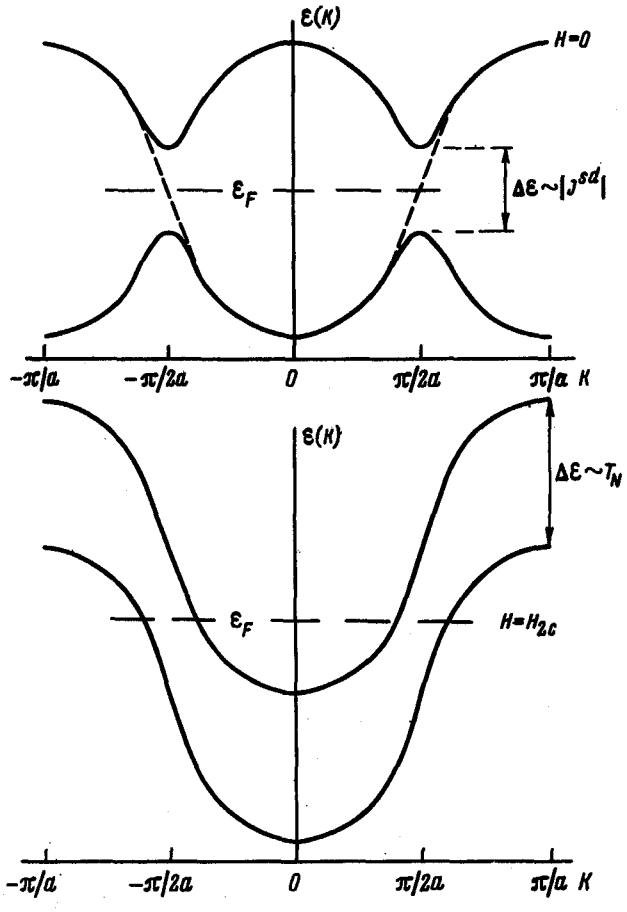
It follows from both theoretical considerations and experiments (see the references in [1-4]) that in some cases the existence of a gap in an antiferromagnetic semiconductor is es-



sentially connected with the presence of antiferromagnetism. Namely, as first noted by Slater [1], the doubling of the period, due to two magnetic sublattices, can lead to the occurrence of a gap (see also [2-3]), whose order of magnitude equals the magnetization integral. The gap can separate the occupied states from the free ones. This effect takes place, for example, in a bcc lattice [1-3] in the simplest case, when there is one nonmagnetic electron per crystal cell, there is no band overlap, and the strong-coupling approximation holds. (The influence of antiferromagnetic correlation can become manifest also in an appreciable change of the width of the energy bands [4]).

The possibility noted in the title, of the transformation of a semiconductor into a metal, pertains to semiconductors of just this type. In a strong magnetic field, reaching values of T_N, the magnetic sublattices become aligned with the field. This transformation, which is accompanied by a decrease of the period from the doubled value to the crystal-chemical one because of the vanishing of the magnetically nonequivalent sublattices, should indeed be accompanied by a transition into a metallic state [1)]. Let us illustrate this by considering the electronic spectrum of an antiferromagnetic metal or semiconductor in a magnetic field with allowance for the magnetization of the "conduction" s electrons by "magnetic" electrons. We describe the latter by means of the mean density of the magnetic moment $\vec{M}$. The bare dispersion law for the conduction electrons $L_0(k)$, in the lattice-point representation, is equivalent to specifying a Hamiltonian

$$L(n - n')a^+_{n\sigma}a_{n\sigma},$$

where $a^+_{n\sigma}$ is the operator of creation of an electron at the point n with spin projection σ. When magnetization is taken into account, it is necessary to distinguish between the sublattices (points f and g). We confine ourselves to the nearest-neighbor interaction.

In the Fourier representation

$$a_{f\sigma} = \left(\frac{2}{N}\right)^{1/2}\sum_k a_{k1\sigma}e^{ikf}, \quad a_{g\sigma} = \left(\frac{2}{N}\right)^{1/2}\sum_k a_{k2\sigma}e^{ikg},$$

---

1) The exchange energy is assumed small compared with the width of the band.

the Hamiltonian of the s-electron with allowance for the magnetization (s-d exchange) and for the external magnetic field (we disregard the diamagnetism) is

$$\hat{H} = \sum_k \hat{a}_k^+ \hat{\Lambda}_k \hat{a}_k ,$$

where

$$\hat{a}_k = \begin{pmatrix} a_{1+} \\ a_{2+} \\ a_{1-} \\ a_{2-} \end{pmatrix}, \quad \hat{\Lambda}_k = \begin{pmatrix} Q_+ L(k) - R & 0 \\ L^*(k) & W_+ \; 0 \; -P \\ -R^* \; 0 & Q_- L(k) \\ 0 \; -P^* & L^*(k) \; W_- \end{pmatrix},$$

$$Q_\pm = L(0) \pm (I_{11}\gamma_1^z + I_{12}\gamma_2^z - g\mu_0 H)\sigma;$$

$$W_\pm = L(0) \pm (I_{11}\gamma_2^z + I_{12}\gamma_1^z - g\mu_0 H)\sigma; \qquad L(k) = \sum_{(h)} L(h) e^{ikh};$$

$$R = \sum_{\alpha=x,y} (I_{11}\gamma_1^\alpha + I_{12}\gamma_2^\alpha) \left\langle \frac{1}{2} | S^\alpha | -\frac{1}{2} \right\rangle;$$

$$P = \sum_{\alpha=x,y} (I_{11}\gamma_2^\alpha + I_{12}\gamma_1^\alpha) \left\langle \frac{1}{2} | S^\alpha | -\frac{1}{2} \right\rangle; \quad L(0) = L(n, n);$$

$$a_{k\,1\sigma} \to a_{1\pm}, \qquad a_{k\,2\sigma} \to a_{2\pm}.$$

Here I_{11} and I_{12} are the exchange integrals for the s and d electrons at one point and at the nearest neighbors, respectively, and $\vec{\gamma}_1$ and $\vec{\gamma}_2$ are unit vectors in the direction of the mean magnetizations of the sublattices. The final diagonalization is carried out with the aid of the canonical transformation $\hat{a}_k = \hat{U}_k \hat{b}_k$, which transforms the Hamiltonian into $H = \sum_k \hat{\epsilon}_k \hat{b}_k^+ \hat{b}_k$. The equation for the unity of the matrix $\hat{U}_k$ is of the form $\hat{\Lambda}_k \hat{U}_k = \hat{U}_k \hat{\epsilon}_k$, where $\hat{\epsilon}_k$ is the diagonal matrix of the eigenvalues of the Hamiltonian.

Let us consider by way of an example an antiferromagnet with negative anisotropy constant. Then [5],

a) $0 \leqslant H < H_{1c}$, $\gamma_{1,2}^\alpha = 0$ $(\alpha = x, y)$, $\gamma_1^z = 1$, $\gamma_2^z = -1$;

b) $H_{1c} < H < H_{2c}$, $\gamma_1^\alpha = -\gamma_2^\alpha$, $\gamma_1^z = \gamma_2^z = H/H_{2c}$;

c) $H \geqslant H_{2c}$, $\gamma_{1,2}^\alpha = 0$, $\gamma_1^z = \gamma_2^z = 1$; $H_{1c}^2 \sim H_{aH}\ H_{2c}$, $\mu_0 H_{2c} \sim T_N$.

The spectrum at different values of the magnetic field is given by:

1) in weak fields $(0 \leq H < H_{1c})$

$$\epsilon(k) = L(0) \pm \frac{1}{2} g\mu_0 H \pm \sqrt{\frac{1}{4}(I_{11} - I_{12})^2 + |L(k)|^2},$$

(when H = 0 the spectrum coincides with that obtained by Irkhin [3]).

2) in medium fields $(H_{1c} < H < H_{2c})$

$$\epsilon(k) = L(0) \pm \left\{\left[\frac{H}{2}\left(\frac{I_{11}+I_{12}}{H_{2c}} - g\mu_0\right) \pm |L(k)|\right]^2 + \frac{1}{4}\left(1 - \frac{H^2}{H_{2c}^2}\right)(I_{11}-I_{12})^2\right\}^{1/2},$$

3) finally, in strong fields ($H \geq H_{2c}$)

$$\epsilon(k) = L(0) \pm \left[\frac{H}{2}\left(\frac{I_{11}+I_{12}}{H_{2c}} - g\mu_0\right) \pm |L(k)|\right].$$

Being unable to discuss all the features of the spectrum, we note only that whereas in weak fields the gap does not depend essentially on the field and does so only as a result of the Zeeman effect, the dependence of the gap on the field becomes quite appreciable even in medium fields and is determined by the exchange interaction of the s electrons with the magnetic sublattices that collapse in the field H_{2c}. The gap then vanishes and the semiconductor becomes a metal. The spectrum in the third region is already characteristic of a ferromagnetic metal, and it can be readily seen that it is necessary to go over to the crystal-chemical cell. We disregarded the reaction of the conduction electron on the system of the d electrons, and also diamagnetic effects.

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EXPLANATION OF INTERFERENCE EXPERIMENTS WITH H I AND He II

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Very interesting results of experiments performed in the USA on interference between the levels of the fine structure of H I and He II, excited by passing through thin foils, have recently been published [1-4]. The authors were unable to explain fully the experimental results obtained by them. The intensity of some of the lines of the characteristic radiation emitted by the particles passing through the foil varied along the beam not in monotonic fashion, but oscillated. Electric or magnetic fields were applied to the beam, several foils were installed, different initial ions were used (e.g., H^+, H_2^+, H_3^+), etc. Beats of the radiation intensity of the H_β, H_γ, H_δ, and H_ϵ, i.e., the lines $n = 4, 5, 6, 7 \to n = 2$, were ob-