Mass Value for the Σ^- Hyperon*

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(Received December 6, 1956)

IN our systematic search for K^- mesons stopping in nuclear emulsion, we have found one event (1*J*40-1) which can be interpreted as a capture by hydrogen according to the reaction

$$K^-+p\rightarrow\Sigma^-+\pi^+. \qquad (1)$$

A projection drawing of this event is shown in Fig. 1.

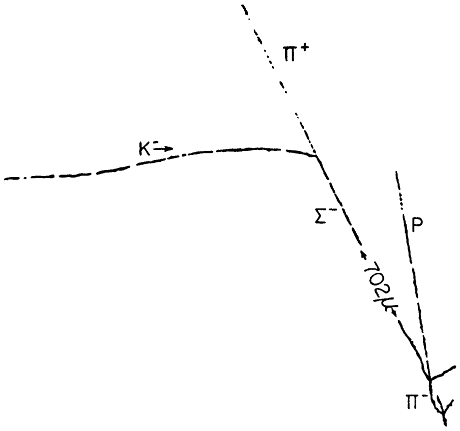

FIG. 1. Projection drawing of Event 1*J*40-1 showing a K^- meson captured in hydrogen according to the reaction $K^-+p>\Sigma^-+\pi^+$.

The tracks had dip angles of 21° before development. The Σ^- hyperon apparently stopped and was captured by an emulsion nucleus in the same pellicle in which it was produced. The resulting three-pronged star consisted of two probable protons with energies of 1 and 24 Mev and a 0.5 Mev negative pion, possibly resulting from a mesonic decay of the Λ^0. This pion was captured in turn, yielding a typical σ star.

The pion and hyperon tracks are collinear to within ±0.5 degree. The measured range of the hyperon is 702±3 microns, the uncertainty quoted being due to the uncertainty in the shrinkage factor of the emulsion (2.2±0.1).

The density of this emulsion at the time of exposure was measured to be 3.850±0.007 g/cc. When one normalizes the measured range to an emulsion density of 3.815 g/cc and includes the intrinsic straggling, the hyperon range becomes 708±10 microns.

If one assumes that the K^- meson and the hyperon came to rest before being captured, the mass of the Σ^- and its velocity at emission can now be calculated from its range, utilizing the range-energy relation on one hand, and the kinematics of reaction (1) on the other. Employing the corrected range-energy curve of Barkas *et al.*[1] (assigning to it an uncertainty of 0.5%), the Cohen[2] pion mass of $(273.25\pm0.12)m_e$, and the τ-meson Q value[3] of 75.08±0.20 Mev [yielding a K-meson mass of $(966.7\pm0.5)m_e$], we have obtained $M_{\Sigma^-}=2340.7\pm1.3m_e$ and $\gamma_{\Sigma^-}=1.0106\pm0.0001$. The errors in these quantities are mainly due to the uncertainty of the Σ^- range caused by straggling. The Σ^- mass obtained here is in good agreement with mass values obtained previously.[4]

We wish to thank Dr. E. J. Lofgren and Dr. W. H. Barkas for arranging the exposure. Our thanks are also due Mr. David Hopp for finding this event.

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* Supported in part by the U. S. Atomic Energy Commission.

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Sources of Error in Experiments on Reorientation Effect in Coulomb Excitation*

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(Received December 12, 1956)

POSSIBILITIES of obtaining information regarding nuclear excited states making use of finite-amplitude effects[1] in Coulomb excitation and of the related nuclear axis reorientation effect[2] have been recently brought out. It is now desired to point out sources of error caused by atomic hyperfine structure (hfs) which in $\gamma-\gamma$ correlations is known to introduce[3,4] factors $[1+(2\pi\nu\tau)^2]^{-1}$, where τ is the mean life and ν the frequency of hfs splitting. The same factors appear in Coulomb excitation and introduce corrections especially for atoms with unbalanced s electrons. In ground states of many atoms with even Z, pairing of s electrons eliminates the effect. However, Coulomb excitation collisions involve ion passage through all electron shells, a condition resulting in atomic excitation. Estimates made for a fixed distance of closest approach to the nucleus corresponding to 5-Mev protons on Pt with variable projectile charge Z_1e, show small probabilities of excitation by protons and appreciable effects roughly proportional to Z_1^2 on outer shells by N^{14}. Removal of s and p electrons gives rise to hfs effects, thus affecting the interpretation of the data.

The effects on inelastic scattering caused by reorientation during the collision are not influenced by the hfs, the collision time being small. It is difficult to estimate the chance of electron excitation with certainty because of possible cooperative effects of several electrons. Disregarding these, estimates indicate removal of outer s electrons as the main and relatively harmless effect. Quantitative interpretation of heavy-ion experiments on reorientation appears possible in view of the following circumstances: (1) excitation of an inner s electron such as $5s$ in Pt is not directly harmful, the life of the hole being short; (2) occupation of shells such as $5p$ and $5d$, as well as small overlap of atomic eigenfunctions for different n, reduces the probability of excitation; (3) removal of an outer electron such as $6s$ of Pt may even be a simplification; (4) coincidence experiments[2] on ions and gamma rays provide an internal consistency test of the theory; (5) application of magnetic fields[3] to the target, especially along the γ-ray direction, should test for the presence of hfs effects and, barring existence of long-lived atomic states with larger than usual hfs, should eliminate them.

A recoil energy of 9.4 Mev is imparted to Pt^{194} by a N^{14} ion with energy adjusted to give the distance of closest approach obtained with 5-Mev protons. The corresponding recoil velocity, $c/98$, suffices for excitation of outer electrons of Pt in atomic collisions and modifies the hfs effect. This effect is largest for head-on collisions which do not produce a reorientation effect on the distribution of γ rays following Coulomb excitation from $I=0$ to $I=2$.

The sources of error mentioned above operate in addition to the well-known possibility of axis deorientation by inhomogeneous electric fields.

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* This research was supported by the U. S. Atomic Energy Commission and by the Office of Ordnance Research, U. S. Army.

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Electronic Structure of *F* Centers in KCl by the Electron Spin Double-Resonance Technique

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(Received December 10, 1956)

THE electron spin resonance absorption in F centers was first observed by Hutchison[1] and investigated in detail by Kip *et al.*[2] They were unable to resolve any hyperfine structure but Kip *et al.*[2] calculated the contact term of the hyperfine interaction from the measured line width. In this letter we wish to report the direct experimental determination of the hyperfine and quadrupole interactions of the F center electron with its nearest neighbors.

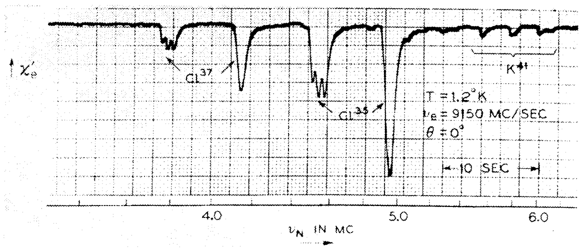

FIG. 1. Interaction of the F center electron in KCl with its nearest chlorines and K^{41}. The magnetic field is parallel to the [100] direction. The additional structure on the chlorine line is the result of quadrupole interaction.

The fact that the F center line is inhomogeneously broadened[3] makes it possible to apply the electron spin double-resonance[4] technique to this problem. In this technique the electron spin resonance line is partially saturated. Upon application of an auxiliary radio-frequency field, whose frequency corresponds to the interaction energy of the F center electron with one of its neighboring nuclei, the saturation parameter is changed, resulting in a change of the microwave signal. Since the nuclear line width was found to be of the order of 20 kc/sec in comparison to 150 Mc/sec for the electron line width, this technique improved the resolution by about four orders of magnitude.

The F centers were produced by bombarding KCl with 1-Mev electrons, which resulted in an F center concentration of 2×10^{17} cm^{-3}. The sample was placed in a magnetic field of $\sim$3000 oersteds at 1.2°K and partially saturated with a microwave field at $\sim$9000 Mc/sec. Figure 1 shows the microwave signal when the auxiliary radio field is swept between 3.4 and 6.2 Mc/sec. This part of the spectrum is due mainly to the interaction of the electron with its nearest chlorines (and partly to the K^{41} which are only 7% abundant). This run was made with the magnetic field parallel to the [100] direction of the crystal. When the angle θ between H_0 and the [100] direction is changed, the pattern changes as indicated in Fig. 2. This anisotropic part of the hyperfine interaction is a measure of the p character of the wave function. Each of the lines in Fig. 2 can be associated with a chlorine at a particular lattice site as shown in Fig. 3. The additional splitting of the lines (see Fig. 1) is due to quadrupole interactions of the chlorines ($I=3/2$) and is a measure of the electric field gradient at the respective nuclei. The interaction of the electron with its nearest potassium nuclei was analyzed in a similar fashion.

The experimental results may be conveniently summarized by writing for the part of the Hamiltonian describing the nuclear interaction in a crystal with axial symmetry[5]:

$$\mathcal{H}=a(\mathbf{I}\cdot\mathbf{S})+b(3I_zS_z-\mathbf{I}\cdot\mathbf{S})+Q'[I_z^2-\tfrac{1}{3}I(I+1)]. \quad (1)$$