II. MICROWAVE SPECTROSCOPY*

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A. CROSS RELAXATION IN RUBY

Additional information has been obtained on the cross-relaxation paradox reported in Quarterly Progress Report No. 72 (pages 14-15). The nonexponential decay has been observed at a number of different two-quantum cross-relaxation configurations with different angles and magnetic fields. All two-quantum cross relaxations observed (approximately equally spaced energy levels) show the anomalous behavior. Also, a number of three-quantum cross relaxations (level spacings approximately in the ratio 2:1) were observed and none show the nonexponential decay.

A hypothesis to explain the effect has been developed. Selection rules for the cross-relaxation process and the symmetry of the wave function are involved. If we label two neighboring chromium ions A and B and label energy levels 1, 2, and 3, then cross relaxation between them may be described by

$$\psi_2(A)\,\psi_2(B) \rightleftarrows \psi_1(A)\,\psi_3(B) \text{ or } \psi_3(A)\,\psi_1(B).$$

As a result of the symmetry properties of the interaction Hamiltonian, the process is actually given by symmetric wave functions:

$$\psi_2(A)\,\psi_2(B) \rightleftarrows \psi_1(A)\,\psi_3(B) + \psi_3(A)\,\psi_1(B).$$

The antisymmetric state described by $\psi_1(A)\,\psi_3(B) - \psi_3(A)\,\psi_1(B)$ cannot cross-relax. The presence of inhomogeneous broadening by aluminum nuclei mixes the wave functions and results in a distribution of relaxation times which has been observed experimentally. The theoretical problem is to explain how there can be long-time memory of the state symmetry properties despite the rapid rate of mutual spin flips between all of the chromium ions. The spin-flip process must be nonergodic. The theory of the memory phenomenon appears to be progressing satisfactorily.

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*This work was supported in part by Purchase Order DDL BB-107 with Lincoln Laboratory, a center for research operated by Massachusetts Institute of Technology, with the support of the U. S. Air Force under Contract AF 19(608)-500.