One must bear in mind that in all these equations m depends on time. It can depend on time either explicitly, or implicitly by means of quantities determining the position or motion of the point. If, for example, $m = f(x_\alpha, \dot{x}_\alpha, t)$, then

$$\frac{dm}{dt} = \frac{\partial m}{\partial x_\alpha}\dot{x}_\alpha + \frac{\partial m}{\partial \dot{x}_\alpha}\ddot{x}_\alpha + \frac{\partial m}{\partial t} \quad (\alpha = 1, 2, 3).$$

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Hyperfine Structure of Paramagnetic Resonance in Copper Tutton Salts at Intermediate Fields

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UP to the present time the hyperfine structure of paramagnetic resonance in compounds of elements of the iron group has been studied at high frequencies, usually of the order of 10^{10} cps. In this frequency region, strong magnetic fields are required to satisfy the conditions for resonance in elements of the iron group. Such fields give rise to splittings at least an order of magnitude greater than the splittings which result from the interactions of electrons with the moments of the nucleus.

At much lower frequencies, say in the decimeter or meter region, conditions obtain which correspond to the intermediate- or weak-field Zeeman effect[1-3]. Low-frequency studies can be useful not only in checking the general theory of paramagnetic resonance absorption in crystals at low and intermediate fields[4], but also in obtaining more precise determinations of the hyperfine structure constant inasmuch as under these conditions the energy splittings produced by the nuclear moments become equal to or greater than the splitting produced by the dc magnetic field.

We have examined the paramagnetic resonance in a $CuK_2(SO_4)_2 \times 6H_20$ single-crystal diluted in an isomorphous zinc salt in the ratio 1:200 at a frequency of 526.74×10^6 cps at liquid air temperature. The paramagnetic resonance was observed using the grid-current method[5] in conjunction with modulation of the dc magnetic field. The free radical α, α-diphenyl β-picryl hydrazyl was used to calibrate the magnetic field. The accuracy in the determination of the resonance values of the field was limited by the width of the absorption line and consequently was not better than 2%.

It is known that the unit cell of a Tutton-salt cyrstal contains two copper ions[6] and that the tetragonal symmetry axes of the electric fields around these ions form an angle of 96°.

We investigated the paramagnetic resonance spectrum in the case for which the dc magnetic field was oriented along one of the tetragonal symmetry axes of the electric field. Six absorption lines were found. The resonance values in oersteds of the dc magnetic field are shown in the Table.

An interpretation of the paramagnetic resonance spectrum at strong fields of the salt which is the subject of this paper was carried out in reference 7 with the use of the following "spin" Hamiltonian:

$$\mathcal{H} = g_\parallel \beta H_z S_z + g_\perp \beta (H_x S_x + H_y S_y) + A S_z I_z + B (S_x I_x + S_y I_y) + Q\left[I_z^2 - \frac{1}{3} I(I+1)\right], \quad (1)$$

where $g_\parallel$ and $g_\perp$ are, respectively, the spectroscopic splitting factors parallel and perpendicular to the tetragonal symmetry axis of the electric field; A, B and Q are hyperfine structure constants of which the first two depend on the magnetic moment of the nucleus and the last depends on the nuclear electric quadrupole moment.

For the frequency which we used, the applied field corresponds to that of the intermediate field

Resonance values of the dc magnetic field in oersteds

Experimental	36	96	143	168	216	250
Calculated	36.11	95.85	140	168.5	221	252.5

case. Thus the calculation of the observed spectrum involves the solution of two algebraic equations of the eighth degree (for Cu^{++}, $S = \frac{1}{2}$, $I = {}^{3}/_{2}$) which derive from the two ions in the unit cell of the crystal. The solution of the equation in the case for which the dc magnetic field is oriented along the tetragonal axis of the electric field is found easily[3]. The probability for magnetic dipole transitions was also calculated for this case. The solutions of the equation for the second ion were found by an approximation method. The dc magnetic field resonance values were obtained using the following values of the constants which appear in Eq. (1): $A = -8.3 \times 10^{-3}$ cm^{-1}, $B = 4.5 \times 10^{-3}$ cm^{-1}, $Q = 1 \times 10^{-3}$ cm^{-1}, $g_{\|} = 2.47$ and $g_{\perp} = 2.08$.

Our values for these constants differ from those given in reference 8, viz. $A = -10.3 \times 10^{-3}$ cm^{-1}, $B = 3.5 \times 10^{-3}$ cm^{-1}, $Q = 1 \times 10^{-3}$ cm^{-1}, $g_{\|} = 2.45$ and $g_{\perp} = 2.12$. This is probably explained by the fact that in the work mentioned above, the experiments were performed at $T = 20°$ K. If one assumes that the size of the tetragonal component of the electric field should become larger with an increase of temperature, it is possible to explain qualitatively a corresponding change of these constants.

* The experimental work was carried out by N. S. Garif'ianov.

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The Representation of Green's Function in Quantum Electrodynamics in the Form of Continual Integrals

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IN quantum electrodynamics, Green's functions for various problems can be written in the form of the matrix elements of various chronologically T-ordered products of the operators for the electron and photon fields, taken between states of the unperturbed vacuum. Thus, for instance, Green's function for the single electron problem has the following form

$$G_{\alpha\beta}(x, x') = \langle T(\psi_\alpha(x)\bar{\psi}_\beta(x')S/S_{\text{vac}}\rangle. \quad (1)$$

Here S_{vac} is the vacuum expectation value of the S-matrix

$$S = \exp\{-i\int H(x)\,dx\}. \quad (2)$$

The symbol T denotes the operation of relativistic invariant time ordering, introduced by Wick[1]. In the case of electrodynamics, the Hamiltonian density $H(x)$ is given by

$$H(x) = -i\bar{\psi}(x)\gamma_\mu A_\mu(x)\psi(x). \quad (3)$$

Analogously, one can write Green's function for other problems.

The aim of the present note is to present an expression for Green's function in the form of continuous integrals in the space of the ψ and A functions*.

According to Hori[3] (see also Anderson[4]), the operation of T-ordering multiplying an expression of the indicated form reduces to multiplication of these expressions by ordering operators for the electric field,

$$e^{\Sigma}, \quad \Sigma = \frac{1}{4}\int_{-\infty}^{\infty} dx \int_{-\infty}^{\infty} dx' S_{F_{\alpha\beta}} \times (x-x') \frac{\delta^2}{\delta\psi_\alpha(x)\,\delta\psi_\beta(x')} \quad (4)$$

and for the photon field