tion of Rh[105]. From the coincidence data, it is estimated that the 0.3-Mev gamma-ray accompanies about eight percent of the beta-rays.

Na[20] from the Gamma-Ray Bombardment of NaF

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ALVAREZ[1] has recently described the production of a delayed alpha-emitter, Na[20], from the proton bombardment of a neon-filled proportional counter. Presumably the reaction is Ne[20](p, n)Na[20]. The Na[20] then emits a positron to an excited state of Ne[20] which alpha decays following the positron half-life. Alvarez observed the delayed alpha-particles, whereas we observed the positron directly.

Using betatron gamma-rays of 76-Mev maximum energy it has been possible to produce Na[20] from NaF. For this purpose a solid cylinder of NaF 8 inches long and $\frac{3}{4}$ inches in diameter was placed directly in the beam. It was counted in place immediately after turning off the beam with a Geiger tube two inches off the center of the beam but parallel to both the beam and the sample. The Geiger tube was shielded from the beam by 6 inches of lead. The betatron and the high voltage supply of the Geiger tube were controlled by a motor-driven timing switch which executed a duty cycle: Betatron—on 3 sec, off 5 sec, on 3 sec, etc., synchronous with counter off 3 sec, on 5 sec, off 3 sec, etc. The scaler pulse was fed directly to one pen of a two-channel Brush recorder. The other pen was fed 60-cycle ac to act as a timer. In this way it was possible to bombard the NaF sample for 3 sec and then count it within milliseconds after the beam was turned off for a period of 5 sec. Since the activity of the Na[20] produced was so weak, it was necessary to sum a number of such runs in order to obtain better statistics. A series of consecutive runs summed is shown in Fig. 1. The half-life, 0.23±0.08 sec, agrees well with the value 0.25 sec reported by Alvarez.
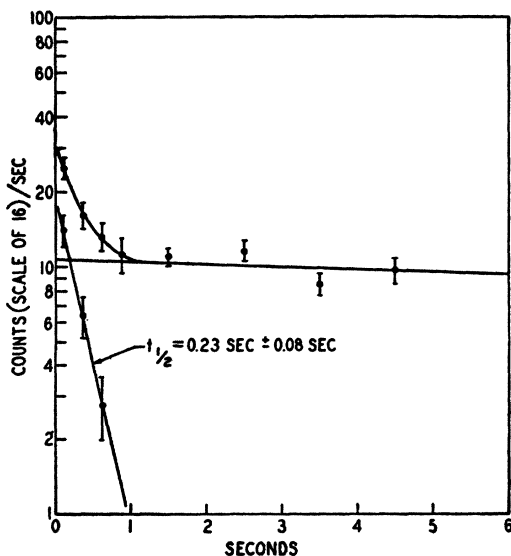

FIG. 1. Decay curve of NaF after bombardment with 0- to 76-Mev gamma-rays.

Using the mass 20.015 for Na[20] one calculates 42.5 Mev as the threshold for the reaction Na[23]$(\gamma, 3n)$Na[20]. However, it was not possible to check this threshold. A series of runs using gamma-rays of 48-Mev maximum energy showed no Na[20] activity. This is understandable in view of the diminution of total energy of the betatron beam with lower maximum energy and the much lower fraction of gamma-rays with energy sufficient to initiate the reaction in the lower maximum energy beam because of the shape of the gamma-ray spectrum.

Because of the low intensity of this second-order reaction it was not possible to measure accurately the energy of the Na[20] activity. However, using the data of Alvarez, it is possible to put limits on the end point of the positron spectrum of 3.5 to 7.3 Mev.

The interest and advice of Professor Willard F. Libby throughout this work was deeply appreciated.

[1] L. Alvarez, Phys. Rev. 80, 519 (1950).

Microwave Resonance Absorption in Manganese Sulfates

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THE microwave resonance absorption in manganese sulfates was measured by Cummerow and others,[1] who observed strong and sharp resonance absorption. Recently we have repeated the experiment, using single crystals of MnSO$_4$·4H$_2$O and MnSO$_4$·5H$_2$O prepared by one of us (H. I.). These crystals are transparent with light pink color, while tetrahydrates are monoclinic ($\beta=90°$ 53′—P. Groth, Chem. Krystal Teil 2, 413) and pentahydrates are triclinic, very similar to CuSO$_4$·5H$_2$O.

The half-value width of tetrahydrate is 920 oersteds when the direction of the static magnetic field is (100), 1310 oersteds at (010), and 1180 oersteds at (001), and that of pentahydrate is 1380 oersteds in the (001) direction. The g-value is about 2.05 in all these cases.

We then measured the absorption at different state of hydration in the following way. A single crystal of tetrahydrate is crushed to powder and the width is measured. Then, by heating the powder in air at 60∼90°C for about an hour, we obtain monohydrate, which is very stable below 200°C and can be checked by weighing. After the width measurement by the powder, it is heated at 280∼300°C to obtain anhydrate.

The absorption curves of polycrystals by the four states are shown in Fig. 1, and the half-widths are shown in Table I with some results in copper sulfates. The widths were reproducible within ±5 oersteds.

If Cummerow's sample was an ordinary commercial one, the measured value may be ascribed to something like monohydrate. In both cases of tetrahydrate and anhydrate, our widths are larger than those of Zavoisky, which may be, according to Van Vleck's considerations,[2] explained by widening action by the crystalline Stark effect which gives wide breadth in high microwave frequency; but it is doubtful whether Van Vleck's considerations can
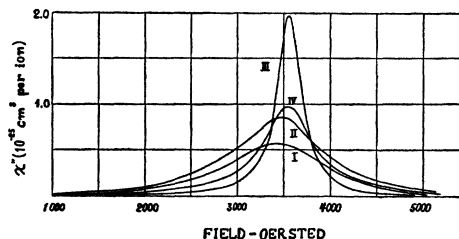

FIG. 1. Microwave resonance absorption curves for four polycrystalline states of manganese sulfate. I—MnSO$_4$·5H$_2$O; II—MnSO$_4$·4H$_2$O; III—MnSO$_4$·H$_2$O; IV—MnSO$_4$.

TABLE I. Half-width in polycrystals.

	Present paper $\lambda = 3.0$ cm	Cummerow[1] $\lambda = 3.2$ cm	Zavoisky (in Van Vleck's paper)	Calc. width by dipolar broadening (Van Vleck)
$MnSO_4 \cdot 5H_2O$	1250 oersteds	...	...	...
$MnSO_4 \cdot 4H_2O$	1140	415	400	1500
$MnSO_4 \cdot H_2O$	305	...	...	...
$MnSO_4$	655	...	300	3500
$CuSO_4 \cdot 5H_2O$	300	318		
$CuSO_4 \cdot H_2O$	310	...		
$CuSO_4$	no absorption			

be applied here because the measured g-values in single crystals of tetrahydrates are almost constant in all orientations.

It is noticeable that, although the half-width of $MnSO_4 \cdot 5H_2O$ is about four times larger than that of $CuSO_4 \cdot 5H_2O$, they are almost equal in the case of $MnSO_4 \cdot H_2O$ and $CuSO_4 \cdot H_2O$. These differences may be ascribed to the different states of Mn^{++} and Cu^{++} ions, as the corresponding crystals have almost the same crystal structure.

The value of maximum χ'' per ion in the four states are shown in Table II.

TABLE II.

	$MnSO_4 \cdot 5H_2O$	$MnSO_4 \cdot 4H_2O$	$MnSO_4 \cdot H_2O$	$MnSO_4$
χ''/ion	0.56×10^{-25}	0.84×10^{-25}	1.97×10^{-25}	0.98×10^{-25}

The microwaves were generated by a demountable klystron continuously evacuated by an oil diffusion pump. The absorption was measured by the change of transmitted power through a resonant cavity containing the sample, the cavity being always kept at resonance. The incident power was monitored by a directional coupler, and the magnetic field was measured by proton resonance. Our thanks are due to Professor T. Mutō and Professor M. Kotani for valuable discussions.

Forbidden Beta-Ray Spectra

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RECENT developments in the study of shapes of forbidden beta-ray spectra have indicated that the interaction responsible for beta-decay may involve some linear combination of the five relativistically invariant forms which have hitherto been used.[1] (S, V, T, A, and P in the usual notation.) These developments are:

(a) The explanation of the shape of the spectrum of Cl^{36} using a combination of interactions.[2]

(b) The explanation of the shapes of a number of spectra, (e.g., Sr^{89}, Sr^{90}, Y^{90}, Y^{91}) using the α-factor.[3] This implies a first-forbidden transition with the tensor or axial vector form of interaction, and would not be affected by using a combination of interactions. (It would be affected by a combination of the tensor and axial vector forms, but this combination is already excluded on other grounds.)[4]

(c) The explanation of the shape of the spectrum of Be^{10} using the D_2 factor,[5] and of K^{40} using the C factor.[6] Neither of these would be affected by a combination of interactions.

In view of this, the cross correction factors for first- and second-forbidden transitions, which arise due to squaring of terms in the interaction, have been worked out and are given here, as they may be of interest to others who are engaged in comparing observed spectra with theoretical predictions. Fierz[4] has shown from consideration of the effect on the allowed spectrum that combinations of S with V and T with A must be excluded. We take as the invariant

$$I = \lambda_S S + \lambda_V V + \lambda_T T + \lambda_A A + \lambda_P P$$

with the understanding that $\lambda_S \lambda_V = \lambda_T \lambda_A = 0$. Using the same notation and method as in reference (1), the first-forbidden cross correction factors are:

$$C_{ST}^1 = i\lambda_S \lambda_T \left[\left\{ \left(\int \mathbf{r} \right)^* \cdot \int \sigma \times \mathbf{r} - \text{c.c.} \right\} (L_1 - M_0) \right.$$
$$\left. - \left\{ \left(\int \mathbf{r} \right)^* \cdot \int \alpha - \text{c.c.} \right\} (\tfrac{1}{3}KL_0 + N_0) \right],$$

$$C_{SA}^1 = -i\lambda_S \lambda_A \left[\left\{ \left(\int \mathbf{r} \right)^* \cdot \int \sigma \times \mathbf{r} - \text{c.c.} \right\} (\tfrac{2}{3}KN_0^- + L_1^- + M_0^-) \right],$$

$$C_{VT}^1 = \lambda_V \lambda_T \left[i \left\{ \left(\int \mathbf{r} \right)^* \cdot \int \alpha - \text{c.c.} \right\} (\tfrac{1}{3}KL_0^- - N_0^-) \right.$$
$$+ i \left\{ \left(\int \mathbf{r} \right)^* \cdot \int \sigma \times \mathbf{r} - \text{c.c.} \right\} (\tfrac{2}{3}KN_0^- - L_1^- - M_0^-)$$
$$- \left\{ \left(\int \alpha \right)^* \cdot \int \sigma \times \mathbf{r} + \text{c.c.} \right\}$$
$$\left. \times (\tfrac{1}{3}KL_0^- - N_0^-) + 2L_0^- \left| \int \alpha \right|^2 \right],$$

$$C_{VA}^1 = \lambda_V \lambda_A \left[i \left\{ \left(\int \mathbf{r} \right)^* \cdot \int \sigma \times \mathbf{r} - \text{c.c.} \right\} (L_1 - M_0) \right.$$
$$\left. + \left\{ \left(\int \alpha \right)^* \cdot \int \sigma \times \mathbf{r} + \text{c.c.} \right\} (\tfrac{1}{3}KL_0 + N_0) \right],$$

$$C_{TP}^1 = -i\lambda_T \lambda_P \left[\left\{ \left(\int \sigma \cdot \mathbf{r} \right)^* \int \gamma_5 - \text{c.c.} \right\} (\tfrac{1}{3}KL_3 + N_0) \right],$$

$$C_{AP}^1 = \lambda_A \lambda_P \left[i \left\{ \left(\int \sigma \cdot \mathbf{r} \right)^* \int \gamma_5 - \text{c.c.} \right\} \right.$$
$$\left. \times (\tfrac{1}{3}KL_0^- - N_0^-) + 2L_0^- \left| \int \gamma_5 \right|^2 \right].$$

The second-forbidden cross correction factors are:

$$C_{ST}^2 = i\lambda_S \lambda_T \left[\left\{ \sum_{ij} R_{ij}{}^* T_{ij} - \text{c.c.} \right\} \left\{ \tfrac{1}{6}K^2(L_1 - M_0) + \tfrac{3}{2}(L_2 - M_1) \right\} \right.$$
$$- \left\{ \sum_{ij} R_{ij}{}^* A_{ij} - \text{c.c.} \right\}$$
$$\left. \times \left\{ (1/30)K^3L_0 + \tfrac{1}{6}K^2N_0 + \tfrac{1}{2}KL_1 + \tfrac{3}{2}N_1 \right\} \right],$$

$$C_{SA}^2 = -i\lambda_S \lambda_A \left[\left\{ \sum_{ij} R_{ij}{}^* T_{ij} - \text{c.c.} \right\} \left\{ (1/15)K^3N_0^- \right. \right.$$
$$\left. \left. + \tfrac{1}{6}K^2(L_1^- + M_0^-) + KN_1^- + \tfrac{3}{2}(L_2^- + M_1^-) \right\} \right],$$

$$C_{VT}^2 = \lambda_V \lambda_T \left[i \left\{ \sum_{ij} R_{ij}{}^* T_{ij} - \text{c.c.} \right\} \right.$$
$$\times \left\{ (1/15)K^3N_0^- - \tfrac{1}{6}K^2(L_1^- + M_0^-) \right.$$
$$\left. + KN_1^- - \tfrac{3}{2}(L_2^- + M_1^-) \right\} + i \left\{ \sum_{ij} R_{ij}{}^* A_{ij} - \text{c.c.} \right\}$$
$$\times \left\{ (1/30)K^3L_0^- - \tfrac{1}{6}K^2N_0^- + \tfrac{1}{2}KL_1^- - \tfrac{3}{2}N_1^- \right\}$$
$$- \tfrac{1}{4} \left\{ \sum_{ij} A_{ij}{}^* T_{ij} + \text{c.c.} \right\}$$
$$\times \left\{ (1/15)K^3L_0^- - \tfrac{1}{3}K^2N_0^- + KL_1^- - 3N_1^- \right\}$$
$$\left. + \sum_{ij} |A_{ij}|^2 \left\{ \tfrac{1}{6}K^2L_0^- + \tfrac{3}{2}L_1^- \right\} \right],$$

$$C_{VA}^2 = \lambda_V \lambda_A \left[i \left\{ \sum_{ij} R_{ij}{}^* T_{ij} - \text{c.c.} \right\} \left\{ \tfrac{1}{6}K^2(L_1 - M_0) + \tfrac{3}{2}(L_2 - M_1) \right\} \right.$$
$$+ \tfrac{1}{4} \left\{ \sum_{ij} A_{ij}{}^* T_{ij} + \text{c.c.} \right\}$$
$$\left. \times \left\{ (1/15)K^3L_0 + \tfrac{1}{3}K^2N_0 + KL_1 + 3N_1 \right\} \right],$$

$$C_{VP}^2 = -i\lambda_V \lambda_P \left[\left\{ \left(\int \alpha \times \mathbf{r} \right)^* \cdot \int \gamma_5 \mathbf{r} - \text{c.c.} \right\} \right.$$
$$\left. \times \left\{ \tfrac{2}{3}KN_0^- + L_1^- + M_0^- \right\} \right].$$