

tion of  $\text{Rh}^{106}$ . From the coincidence data, it is estimated that the 0.3-Mev gamma-ray accompanies about eight percent of the beta-rays.

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<sup>1</sup> Nishina, Yasaki, Kimura, and Ikawa, *Phys. Rev.* **59**, 323 (1941); *Phys. Rev.* **59**, 677 (1941). Sullivan, Sleight, and Gladrow, *Plutonium Project Report CC-1493* (March, 1944), quoted by Seaborg and Perlman, *Revs. Modern Phys.* **20**, 585 (1948). E. Bohr and N. Hole, *Arkiv. Mat., Astron. Fysik* **32A**, paper number 15 (1948).

<sup>2</sup> C. E. Mandeville and E. Shapiro, *Phys. Rev.* **80**, 125 (1950).

<sup>3</sup> R. B. Duffield and L. M. Langer, *Phys. Rev.* **81**, 203 (1951).

## $\text{Na}^{20}$ from the Gamma-Ray Bombardment of NaF

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ALVAREZ<sup>1</sup> has recently described the production of a delayed alpha-emitter,  $\text{Na}^{20}$ , from the proton bombardment of a neon-filled proportional counter. Presumably the reaction is  $\text{Ne}^{20}(p, n)\text{Na}^{20}$ . The  $\text{Na}^{20}$  then emits a positron to an excited state of  $\text{Ne}^{20}$  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  $\text{Na}^{20}$  from NaF. For this purpose a solid cylinder of NaF 8 inches long and  $\frac{3}{8}$  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  $\text{Na}^{20}$  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,  $0.23 \pm 0.08$  sec, agrees well with the value 0.25 sec reported by Alvarez.

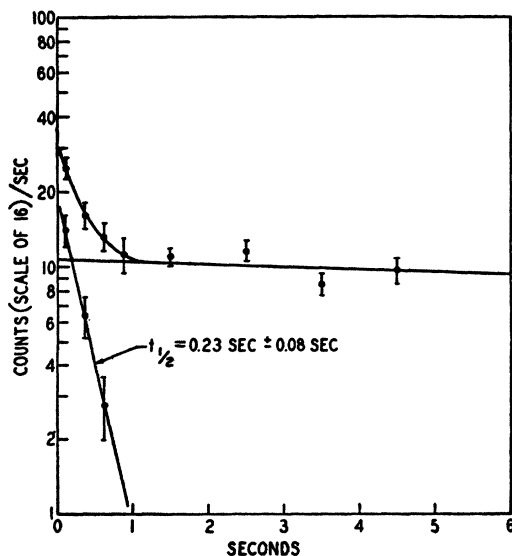


FIG. 1. Decay curve of NaF after bombardment with 0- to 76-Mev gamma-rays.

Using the mass 20.015 for  $\text{Na}^{20}$  one calculates 42.5 Mev as the threshold for the reaction  $\text{Na}^{23}(\gamma, 3n)\text{Na}^{20}$ . However, it was not possible to check this threshold. A series of runs using gamma-rays of 48-Mev maximum energy showed no  $\text{Na}^{20}$  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  $\text{Na}^{20}$  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.

<sup>1</sup> 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,<sup>1</sup> who observed strong and sharp resonance absorption. Recently we have repeated the experiment, using single crystals of  $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$  and  $\text{MnSO}_4 \cdot 5\text{H}_2\text{O}$  prepared by one of us (H. I.). These crystals are transparent with light pink color, while tetrahydrates are monoclinic ( $\beta = 90^\circ 53'$ —P. Groth, *Chem. Krystal Teil 2*, 413) and pentahydrates are triclinic, very similar to  $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ .

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  $60 \sim 90^\circ\text{C}$  for about an hour, we obtain monohydrate, which is very stable below  $200^\circ\text{C}$  and can be checked by weighing. After the width measurement by the powder, it is heated at  $280 \sim 300^\circ\text{C}$  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  $\pm 5$  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,<sup>2</sup> 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

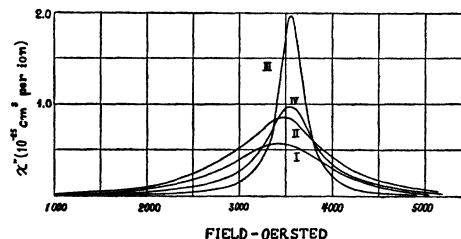


FIG. 1. Microwave resonance absorption curves for four polycrystalline states of manganese sulfate. I— $\text{MnSO}_4 \cdot 5\text{H}_2\text{O}$ ; II— $\text{MnSO}_4 \cdot 4\text{H}_2\text{O}$ ; III— $\text{MnSO}_4 \cdot \text{H}_2\text{O}$ ; IV— $\text{MnSO}_4$ .