duced in U^{235}, 12,000 fast neutron events in U^{238}, 14,000 fast neutron events in Th^{232}, 10,000 photofission events in U^{238}, and 2500 photofission events in Th^{232}.

This work was carried out while the author was still at A.E.R.E., Harwell, and thanks are due to the Director, Sir John Cockcroft, F.R.S., for permission to publish.

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Inter-Ionic Distances and Line Widths in Paramagnetic Resonance Absorption

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(Received July 3, 1951)

IN a previous letter,[1] we have reported some of the results of our precise observations on the line width in microwave paramagnetic resonance absorption by manganese sulfates, in conjunction with the theory of dipolar broadening by Van Vleck.[2] Since then, measurements on several salts containing copper ions were added to our data, which can be compared with theory more thoroughly than before.

Results are summarized in Table I. The widths in the table are

TABLE I. Paramagnetic absorption lines (9970 Mc).

Salts	Single crystal or powder	Shape of absorption line	Range of half-width by crystal orientation (Oersted)	Range of g-values
Mn(NH₄)₂(SO₄)₂·6H₂O (diluted)	single	several peaks not completely resolved	~70	—
Mn(NH₄)₂(SO₄)₂·6H₂O	single	several peaks scarcely resolved	1000–2000	—
MnSO₄·5H₂O	single	one peak, intermediate shape of gaussian and resonance curve	—	—
	powder	one peak, intermediate shape of gaussian and resonance curve	1250	2.06
MnSO₄·4H₂O	single	one peak, intermediate shape of gaussian and resonance curve	980–1500	2.00–2.07
	powder	one peak, intermediate shape of gaussian and resonance curve	1140	2.04
MnSO₄·H₂O	powder	one peak, resonance curve	305	2.00
MnSO₄	powder	one peak, resonance curve	655	2.00
Cu(NH₄)₂(SO₄)₂·6H₂O	single	two peaks, like gaussian curve	~230	2.0 –2.3
Cu(NH₄)₂Cl₄·2H₂O	single	one peak, resonance curve	90–230	2.05–2.20
CuK₂Cl₄·2H₂O	single	one peak, resonance curve	110–250	2.05–2.20
CuSO₄·5H₂O	single powder	one peak, resonance curve	50–220 300	2.04–2.24 —
CuCl₂·2H₂O	single	one peak, resonance curve	55–70	2.03–2.23
CuSO₄·H₂O	powder	one peak, gaussian curve	310	2.19

obtained at half the maximum χ'' irrespective of the line shapes. As the g-values of salts containing Mn^{++}(^6S) are almost isotropic, the half-width in polycrystals of MnSO₄·H₂O and MnSO₄ have definite meanings. In the cases of Cu(NH₄)₂(SO₄)₂·6H₂O and diluted Mn(NH₄)₂(SO₄)₂·6H₂O, the curves are composed of several peaks which can be decomposed to one, and the widths of each are shown in the table. As the line shapes of polycrystals of CuSO₄·H₂O are almost gaussian, it is probable that g-values are nearly isotropic in the single crystal.

We shall consider the line widths for the same kind of paramagnetic ions contained in various salts which have different interionic distances. According to Van Vleck's theory,[2] the widths $(\Delta H)_{\frac{1}{2}}$ owing to dipolar coupling in this case are given approximately as follows:
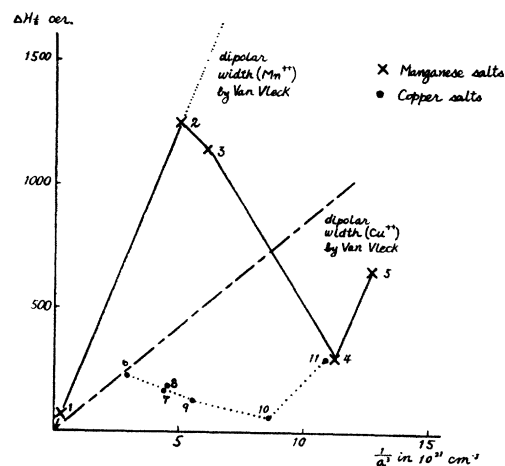
$$(\Delta H)_{\frac{1}{2}} \sim 1/r^3,$$

FIG. 1. Half-widths of salts of Mn^{++} and Cu^{++} and calculated dipolar widths. 1. Mn(NH₄)₂(SO₄)₂·6H₂O diluted; 2. MnSO₄·5H₂O; 3. MnSO₄·4H₂O; 4. MnSO₄·H₂O; 5. MnSO₄; 6. Cu(NH₄)₂(SO₄)₂·6H₂O; 7. Cu(NH₄)₂Cl₄·2H₂O; 8. CuK₂Cl₄·2H₂O; 9. CuSO₄·5H₂O; 10. CuCl₂·2H₂O; 11. CuSO₄·H₂O.

where r is the mean inter-ionic distance, and the line shape is assumed to be gaussian. As a first approximation, we consider the arrangement of ions as simple cubic with lattice constant a; then we can put $(\Delta H)_{\frac{1}{2}} \sim (1/a^3)$. The values of a are given by $a^3\rho = M/N$ where ρ is the density, M the molecular weight related to the single ion of the salt, and N the Avogadro number.

In Fig. 1 the values of $(\Delta H)_{\frac{1}{2}}$ from Table I are plotted against $1/a^3$. The widths indicated in the figure for single crystals are means of those for different orientations. The dotted and dashed straight lines indicate the widths for Mn^{++} and Cu^{++} owing to dipolar broadening, by Van Vleck's calculation.[2] For smaller values of $1/a^3$, the widths are almost equal to those expected by dipolar broadening in both cases of Mn^{++} and Cu^{++}. But when ions are nearer, the width becomes much smaller than those corresponding to the straight lines, because of the effect of exchange interaction. These results agree with the fact that Δ, the departure from Curie's law in the static susceptibility, is 0.7°, 3°, 2°, and 24° for Mn(NH₄)₂(SO₄)₂·6H₂O, MnSO₄·5H₂O, MnSO₄·4H₂O, and MnSO₄, respectively, and that Δ is mainly due to the exchange effect for manganese salts.[3] It is remarkable that the widths become broader again for the smallest value of a, which can be seen in the cases of MnSO₄ and CuSO₄·H₂O. In any case, the curves shown in Fig. 1 may have important bearing on the nature of dipolar and exchange interactions of paramagnetic ions.

Erratum: Angular Distribution of Protons from the D(d, p)T Reaction at 10.3-Mev Bombarding Energy

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THE captions of Fig. 1 and Fig. 2 should be interchanged. This applies also to the angle designations on the histograms, i.e., $\theta = 132.5°$ lab for Fig. 2 and $\theta = 12.8°$ for Fig. 1. In addition, these angles should be transposed in the references of the text to the figures.