solute error to be assigned to these points is 30 percent. For the low energy points the measured total cross section is in essential agreement with the calculated cross section; however, in the region of the meson threshold the experimental cross section is higher by a factor of about 2.5. Assuming the angular distributions of references 2 and 3 and that used by Austern[4] in calculations of the isotropic contribution, an estimate can be made of the electric quadrupole cross section which is found to be about 1 percent of the electric dipole cross section in the energy region of this experiment. An estimate of the isotropic contribution is 40 percent of the electric dipole cross section. The errors in these estimates are obviously large, since they are limited by the counting statistics and the fact that observations were made at only three angles.

* Supported by the joint program of the ONR and AEC.
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Line Width of Paramagnetic Resonance and Exchange Interaction in Salts Containing Mn⁺⁺ and Fe⁺⁺⁺

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IN column 3 of Table I, half-widths $\Delta H_{\frac{1}{2}(\text{obs})}$ of paramagnetic microwave resonance absorption lines, at $\lambda = 3.01$ cm, are shown for nine kinds of polycrystalline salts containing Mn⁺⁺

TABLE I. Half-widths of paramagnetic microwave resonance absorption lines.

Polycrystals	Crystal symmetry	$\Delta H_{\frac{1}{2}(\text{obs})}$ (oersteds)	$\Delta H_{\frac{1}{2}(\text{calc})}$ (oersteds)	θ (°K)	z(calc)
FeNH₄(SO₄)₂	hexa.	580	1680	13[a]	38
Fe₂(SO₄)₃	hexa.	180	2300	70[a,b]	33
MnCl₂	hexa.	1250	2950	−16[a]	32
MnCl₂·2H₂O	...	760	...	...	...
MnCl₂·4H₂O	mono.	1340	1530	−3(≈0)[c]	...
MnSO₄	mono.	655	3400	24[d]	19
MnSO₄·H₂O	mono.	305	2800	...	...
MnSO₄·4H₂O	mono.	1140	1500	2(≈0)[c,d]	...
MnSO₄·5H₂O	tric.	1250	1250	3(≈0)	...

[a] See reference 3.
[b] See reference 4.
[c] See reference 5.
[d] See reference 6.

and Fe⁺⁺⁺. Some of the results have already been reported.[1] When the g value is anisotropic, as in the case of cupric salts, the apparent width for a polycrystalline powder is increased. However, in powders of salts containing Mn⁺⁺ and Fe⁺⁺⁺, there is no such effect since these ions are in S states and the g value is almost isotropic.

The theoretical half-width caused by dipolar coupling in a powdered cubic crystal has been calculated by Van Vleck[2] under the assumption that the shape function is Gaussian. The formula thus obtained is

$$\Delta H_{\frac{1}{2}(\text{calc})} \approx 2.35[\langle \Delta H^2 \rangle_{\text{Av}}]^{\frac{1}{2}} = 2.35 g\beta \{ \tfrac{3}{5} S(S+1) \Sigma_k r_{jk}^{-6} \}^{\frac{1}{2}}. \quad (1)$$

As we have little knowledge of the detailed structure of crystals in the table, we have assumed tentatively, as a first approximation, that the arrangement of ions is simple cubic with lattice constant a. Half-widths calculated by this simplification of (1) are given in the fourth column of the table. In cases where the crystal structure is known from x-ray analysis, as for instance (NH₄)Fe(SO₄)₂, the calculated width for the simple cubic arrangement of ions is generally narrower than that calculated allowing for the correct arrangement of ions in the crystals. However, the resulting change in the calculated half-width is by a factor ranging from about 1 to 1.4, so the difference in ionic arrangements has no significant influence on our rather qualitative discussion.

In some cases, the observed width is much smaller than the calculated one on account of the effect of exchange coupling. The fifth column shows the observed values[3-6] of θ in the Curie-Weiss formula for the static susceptibility, $\chi_s = c/(T+\theta)$. The departures of θ from zero are caused by the exchange coupling of electrons and the splitting of electronic levels by the crystalline field. The inference is clear that when $\Delta H_{\frac{1}{2}(\text{calc})}/\Delta H_{\frac{1}{2}(\text{obs})}$ is large, θ is large. This circumstance can be explained in order of magnitude in the following way.

According to Van Vleck's considerations,[2] $\Delta \nu_{\frac{1}{2}}$ under exchange coupling is given by $\Delta \nu_{\frac{1}{2}} \approx \tau_c \langle \Delta \nu^2 \rangle_{\text{Av}}$, where $\tau_c = h/2J$ and J is the exchange integral. We tentatively set

$$\Delta \nu_{\frac{1}{2}} = \tau_c \langle \Delta \nu^2 \rangle_{\text{Av}} = (h/2J) \langle \Delta \nu^2 \rangle_{\text{Av}}, \quad (2)$$

in which $\Delta \nu_{\frac{1}{2}}$ is $\Delta H_{\frac{1}{2}(\text{obs})} \cdot g\beta/h$.

In our cases of Mn⁺⁺ and Fe⁺⁺⁺, it is probable that the effect of splitting of electronic levels upon θ is negligible and that θ is caused only by exchange coupling.[7] In this case, θ is connected with J by the relation[8]

$$3k\theta = 2JzS(S+1), \quad (3)$$

where k is the Boltzmann constant, S is the spin quantum number (in our case $S = 5/2$), and z is the number of nearest neighbors in the lattice.

We can try calculating values of z by using the formula

$$z_{(\text{calc})} = \frac{3k\theta(2.35)^2 \Delta H_{\frac{1}{2}(\text{obs})}}{(\Delta H_{\frac{1}{2}(\text{calc})})^2 g\beta S(S+1)},$$

which follows from Eqs. (1), (2), and (3). The resulting values of z are shown in the sixth column of the table. They show no large divergences from each other, but they are all several times larger than the values of z deduced from the crystal structures. Further elaborations of our rather qualitative considerations would be futile.

A more detailed report will appear in *J. Phys. Soc. Japan*. Our thanks are due Professor T. Mutô for his cordial discussions.

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Adiabatic Study of the 128°C Transition in Barium Titanate

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THERE has been much discussion about the nature of the so-called Curie point transition in barium titanate. Some writers have classed it as second order,[1] while others have noticed discontinuities typical of a first-order transition.[2,3] A first-order transition would be characterized by a latent heat which in barium titanate has heretofore escaped direct detection. Blattner and Merz[4] observed a specific heat anomaly amounting to 47 cal/mole; however, this was spread over a range of about 15°C and cannot be cited as evidence that the transition is first order. A more convincing argument may be based on the change of temperature which we find takes place when the transition is induced adiabatically by applying an electric field.

For this analysis ceramic disks of barium titanate of the highest obtainable purity were used. These were attached to suitable connecting wires and thermocouple leads and suspended by these wires in a small oven in which air was circulated. Small changes in temperature were detected by a recording galvanometer in the thermocouple potentiometer circuit. The sensitivity of indication

was better than 0.1°C, although the absolute accuracy was not this great since the thermocouple was not individually calibrated.

A step in the heating curve was observed indicating a thermal anomaly between 128.2 and 128.7°C. Essentially the same temperature limits were observed for different heating rates from 0.32°C per min to 2.8°C per min. Upon cooling, the anomaly was observed in a different temperature range, 126.5 to 127.1°C. These anomalies each occur within a much smaller temperature range than that observed by Blattner and Merz, however, they still do not give unequivocal evidence of a latent heat.

Temperature changes could be observed when an electric field was applied. When the temperature reached 130°C, an electric field of 600 v/mm was suddenly impressed. This produced an immediate temperature rise of 0.5°C. When the voltage was turned off, the temperature fell the same amount. This temperature change may be interpreted as that accompanying an adiabatic transition from the cubic to the tetragonal phase.

Upon cooling to 127.7°C the voltage was applied again for one second. This produced an irreversible temperature rise of about 0.5°C, and the usual thermal anomaly between 126.5 and 127.1°C was not observed as cooling continued. These observations indicate that the electric field in this case produced a permanent transition before the material had cooled enough for the transition to take place spontaneously. The temperature change of 0.5°C indicates that the transition has a latent heat. If this figure is multiplied by the average specific heat,[2,4,5] $c_p = 0.13$ cal/g°C and by the molecular weight, a lower limit of 15 cal/mole is obtained for the latent heat of the transition.

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Slow Neutron Liquid Scintillation Detector

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ASIDE from the possibility of discovering a fluorescent boron compound, the problem of detecting slow neutrons with boron at very high efficiencies (~100 percent) reduces to the problem of discovering a boron compound which may be introduced into a fluorescent medium without quenching the fluorescence. The series of esters: methyl, ethyl, propyl, etc.—borate when added to a standard fluorescent solution of phenylcyclohexane, terphenyl, and diphenylhexatriene—satisfies the above requirement. The only effect on the "alpha" pulse height due to the addition of these borates to the "phenyl" solution is to reduce it in proportion to the dilution of the original fluorescent solution. Even this loss of pulse height may be regained by addition of more terphenyl.

Enriched (B^{10}) methyl borate contains the least number of extraneous atoms and has the highest density of the series. A one-to-one solution by volume of methyl borate-"phenyl" used in conjunction with a 5819 photomultiplier tube has the following properties: (1) "alpha" pulse height of ~30 electrons at the cathode; (2) neutron lifetime in the medium of ~0.4 μsec.

It should be observed that with this short a lifetime, the presence of hydrogen is no obstacle to the use of such a counter for slow neutron time-of-flight velocity selection. In fact, the presence of hydrogen aids in keeping faster neutrons in the detecting medium. To use the counter in a practical way, however, it is desirable to use either liquid air cooling of the photomultiplier tube or to employ coincidences, and to bias out electrons of ~100 kev and higher in energy.

Relative Probabilities of Diverse Photonuclear Reactions from Zn^{64} and Fe^{54}

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BY the use of a high energy x-ray beam from the Iowa State College synchrotron with the maximum energy adjustable up to 67 Mev, measurements have been made leading to relative cross sections as a function of quantum energy for (γ, n), (γ, pn), and $(\gamma, 2np)$ reactions[1] on the same parent isotope Zn^{64} or Fe^{54}. The curves obtained are shown in Figs. 1 and 2.

The values for the integrated cross sections are evaluated and listed in Table I. The values for zinc agree well with the values reported by Strauch[2] from transition curves in lead for 330-Mev bremsstrahlung. The relative values for $\sigma_{\gamma, 2n}$ and $\sigma_{\gamma, pn}$ also agree well with those given by Ghoshal,[3] who produced the compound nucleus Zn^{64} by $Ni + \alpha$ and $Cu + p$ reactions. In addition, the shapes
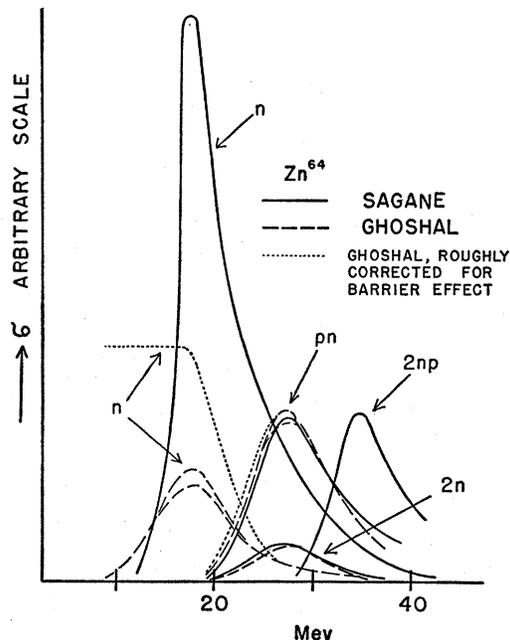

FIG. 1. Relative cross sections vs $E_h\nu$ for (γ, n), (γ, pn), $(\gamma, 2n)$, and $(\gamma, 2np)$ reactions on Zn^{64}. Excitation functions for n, pn, and $2n$ emission from the same compound nucleus, Zn^{64}*, as reported by Ghoshal are also given.

of these cross section curves vs energy agree with the shapes of Ghoshal's curves. Since he showed that his results are in good accord with the statistical theory of the compound nucleus excited to an energy of the order of 30 Mev, this agreement with the present data shows that competition in the excited nucleus can satisfactorily explain the results for $(\gamma, 2n)$ and (γ, pn) processes. It is also to be noted, however, that the (γ, n) cross section reported here is relatively seven times higher than that obtained by Ghoshal. Since the processes of excitation are different and it is known that the cross section for excitation to 18 Mev by charged particles will be lower than that for excitation to 30 Mev (by a factor of 1.5 to 2, because of the potential barrier which is particularly significant for incoming particles with large l values), this difference in $\sigma_{\gamma, n}/(\sigma_{\gamma, 2n} + \sigma_{\gamma, pn})$ must indicate that the cross section for gamma-ray absorption is several times larger at 18 Mev than at 30 Mev. In addition, it is to be noted that, for Zn^{64}, $\sigma_{\gamma, p}$ is probably at least as large as $\sigma_{\gamma, n}$ in the region of 18 Mev.[4] It seems