We have made a rough measurement of the cadmium ratio for scandium in the G.L.E.E.P., which shows it to be approximately a $1/v$ absorber. This is confirmed by Harris *et al.*[5] For a $1/v$ absorber the pile neutron cross section is the same as the thermal neutron cross section. We would, therefore, expect the three values quoted above to be in agreement.

In view of the violent disagreement between these values a new measurement was undertaken. The scandium used was in the form of "spec-pure" Sc_2O_3. The measurement was made using the G.L.E.E.P. oscillator by the method described by Colmer and Littler,[6] and the value obtained for the pile cross section was 23.2 barns (±4 percent), assuming the absorption cross section of boron at 2200 m/sec to be 710 barns (±2 percent).

The sample was then analyzed by the Chemical Inspectorate, Chatham, for forty elements, including the rare earths. It was found that the contribution to the cross section from impurities was less than 2.4 barns. Allowing for this, our value for the pile neutron absorption cross section, and also the cross section at 2200 m/sec, becomes $23\binom{+1}{-3}$ barns.

As a result of this measurement we communicated with Pomerance, and have heard from him that he has remeasured his sample and now obtains a value of 23 barns.[7] Since Harris *et al.* state that their scandium was impure, their measurement can presumably be discounted, and the values obtained by the other experimenters are now in agreement with our value of 23 barns.

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Intensities of Nuclear Magnetic Resonances in Cubic Crystals

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A RECENT communication[1] reports puzzling results from attempts to determine the spin of Si^{29} by comparing the intensity of its magnetic resonance absorption with that of I^{127}, of spin 5/2, in cubic crystalline KI. Some observations made a year ago on the shapes and intensities of the nuclear magnetic resonance lines of Br^{79}, Br^{81}, and I^{127} in crystalline KBr and KI are briefly reported here because they seem particularly relevant to the interpretation of the above results. The intensities were determined relatively and absolutely by use of the calibrating circuit briefly described previously.[2]

In well-annealed single crystals of optical quality, narrow, symmetrical lines were observed. However, it was discovered that the integrated observable intensities were considerably smaller than would be expected for their respective spins. The observed intensities of Br^{79} and Br^{81}, both of spin 3/2, were each only 0.4, and that of I^{127}, of spin 5/2, only 0.3 as large as expected. In powdered samples, or in single crystals which had been subjected to linear compression resulting in plastic flow and "work-hardening," the lines were found to be broader and unsymmetrical, with a stronger tail on the low frequency side. In these highly strained samples, the observed intensities of the resonances of bromine were still 0.4 of the full values and that of I^{127} had decreased to about 9/35.

These effects have been interpreted as arising from the interaction of the quadrupole moments of the nuclei with electric field gradients of random position and orientation produced by internal strains in the crystals. A quadrupole interaction introduced as a first-order perturbation causes the normal magnetic resonance line to split into $2I$ lines equally spaced by an amount determined by the magnitude and orientation of the field gradient relative to the direction of the magnetic field.[3] For odd half-integral spin, the central line occurs at the unperturbed magnetic absorption frequency. Field gradients having a range of intensities and random orientations would smear the satellite lines over a wide frequency range, leaving only the central line as observable. The fractional intensity associated with the central line is just 4/10 for $I=3/2$, and 9/35 for $I=5/2$. This suggests that only the central lines were observed in the single crystal of KBr. In the single crystal of KI, we were evidently observing, as well as the central line, a small residual contribution from the satellites. A broadening of the central line, with an asymmetry in the same direction as that observed in the highly strained samples, can be explained by carrying the perturbation to second order as required for larger gradients.

An attempt has been made to estimate the magnitude of the internal strains associated with lattice imperfections of the dislocation type. The changes in line shape found to accompany plastic flow seem consistent with the increase in concentration of dislocations required to account for the flow. However, if a concentration of 10^8–10^{10} cm^{-2} is assumed for the well-annealed crystal, using reasonable values for the nuclear quadrupole moments,[4] one finds that the field gradients at the nuclei must be a factor $\beta \sim 2$–20 times greater than would be produced by just the charged alkali neighbors displaced under strain. Another estimate of about 10 for this factor β was made from observations of a small reversible effect of linear compression upon the line shape of Br^{79} in a highly work-hardened crystal of KBr. Both of these observations indicate that the symmetry of the electronic wave function of the halogen ion itself is a larger contributant to the field gradient than is the direct effect of the displacement of the neighboring ions from cubic lattice sites. The details of this calculation as well as the experimental results quoted in this letter will be published later.

If this interpretation is correct, it is evident that a nucleus with a moderate quadrupole moment can serve as a very sensitive monitor of internal strains in crystals. The resonances observed here are poor for this because they are really too sensitive, the first-order smearing being almost completely effective even in the most perfect crystals. A nucleus with a smaller quadrupole moment (or smaller β) would be better. Detailed analysis of its line shape could give information about both the magnitude and distribution of internal strains in even the most "perfect" available single crystals. Intensity observations on Li^7 in LiF revealed no effects of this sort.

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The Cross Section for $Ta^{181}(\gamma, 2n)Ta^{179}$ at 17.6 Mev

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THE variation with energy of the total nuclear absorption cross section of complex nuclei for gamma-rays has not yet been determined. The well-known "resonances" of the (γ, n) cross section alone may or may not persist when competing reactions are taken into account; if they persist, then it may be that some specific nuclear model[1] is needed or that some specific aspect of nuclear forces is involved. It is also important to determine whether there exists the considerable cross section for higher order processes needed[2] in the interpretation of the total neutron yield through the dipole sum rule.[3]

We have measured the ratio of the (γ, 2*n*) cross section for Ta^{181} at 17.6 Mev to the (γ, *n*) cross section at 14.6 Mev and found 0.29±0.11; the details of the method will be published elsewhere. We have used the *form* of the (γ, *n*) cross section as measured by Haslam, Smith, and Taylor.[4] If we make the assumption that the *form* of the (γ, 2*n*) cross section above 18 Mev is the same as that of the (γ, *n*) process,[5] while that at lower energies is derivable from the total cross section and the statistical theory[6] of the (γ, *n*) *versus* (γ, 2*n*) competition, we may from our measurement at one energy construct the (γ, 2*n*) cross section and hence the total nuclear absorption cross section.[7] This is shown in Fig. 1. It is seen that there is a considerable (γ, 2*n*) cross section above the threshold[2] (14.0 Mev) but that the total cross section retains a sufficiently sharp peak to warrant further consideration of specific theories such as that of Goldhaber and Teller.[1] The importance of the (γ, 2*n*) process may be somewhat less than estimated indirectly by Eyges,[8] who suggests 0.41 for our measured ratio.

Since we completed our measurements, Halpern, Nathans, and Mann[9] have published a total neutron excitation function for tantalum. In Fig. 2 we compare their measured points with the neutron yield curve expected from the cross sections of Fig. 1.

Halpern, Nathans, and Mann have seen in their results evidence for a second maximum in the total cross section at about 20.5 Mev due to (γ, 2*n*). If this second maximum indeed exists, it appears probable that two separate mechanisms are at work to produce the two maxima. We may seek to identify the second maximum with resonance dipole absorption in the alpha-particle or with the lowest quadrupole mode in the extension of the Goldhaber-Teller theory by Danos and Steinwedel[10] and Danos,[11] but in the latter case the experimental resonance energy spacing of 6.5 Mev is rather less than the theoretical 8.5 Mev, and the experimental cross section appears too large by a factor of order two. It is also difficult to understand why the (γ, 2*n*) cross section should not rise from its threshold much more rapidly than suggested by Halpern, Nathans, and Mann whether or not there exists a second maximum. It seems, therefore, in view of the fair agreement between our own suggestions and the neutron yield results, that this second maximum must be treated with some reserve; its definite establishment would be of the greatest importance for the theory of these processes.

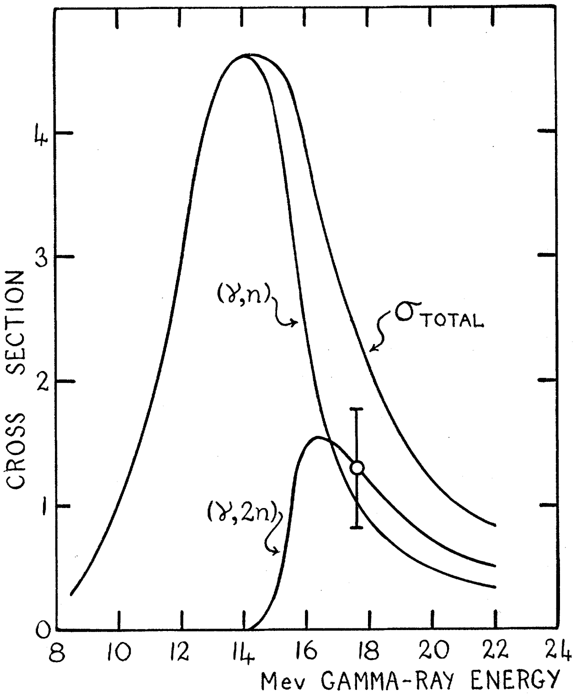

FIG. 1. $\mathrm{Ta}^{181}(\gamma, n)\mathrm{Ta}^{180}$ cross section (in arbitrary units) as a function of gamma-ray energy (measured by Haslam, Smith, and Taylor) with the present measurement of the (γ, 2*n*) cross section at 17.6 Mev, the full (γ, 2*n*) cross section constructed with its aid and the resultant total absorption cross section.

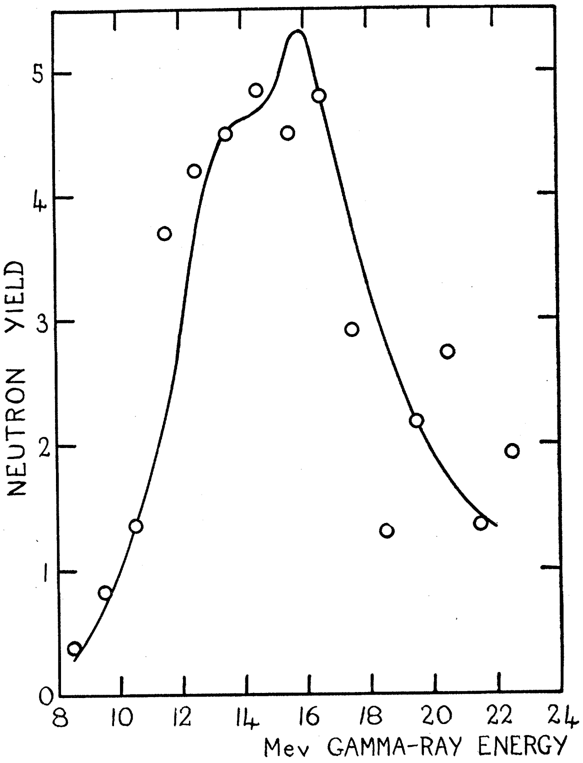

FIG. 2. Total neutron yield (in arbitrary units) as measured by Halpern, Nathans, and Mann (circles) compared with the yield expected from the cross sections of Fig. 1 (full line).

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[5] Above 18 Mev the (γ, *n*) cross section must be due almost wholly to direct interaction [E. D. Courant, Phys. Rev. **82**, 703 (1951)] since the neutron multiplicity for compound nucleus formation is almost two; it is reasonable that the probability of exciting a compound nucleus following an initial direct interaction should remain almost constant within the restricted range of interest here, so the (γ, 2*n*) cross section should at any rate not fall less rapidly than the (γ, *n*).

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A Theory of the Paramagnetism of Uranyl-Like Ions*

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A CONSIDERABLE amount of data concerning the paramagnetic properties of the transuranic ions has recently been accumulated[1,2] in an attempt to ascertain the electronic configurations of these ions. However, a detailed theoretical discussion of any particular salt has not yet been given, and in some cases it is still in doubt whether the paramagnetism is due to 5*f*