of the fission results from reactions in which only a fraction of the total energy of the helium ion is utilized to form a fissioning compound nucleus of mass around 240, a mechanism similar to that of slow neutron fission results. Thus a number of mechanisms may prevail ranging from this one to that in which a number of neutrons are emitted before the fission process, giving rise to symmetrical cleavage as the most probable process, with the latter mechanism perhaps predominating in view of the shape of the distribution curve.

The fission yield curve definitely extends to higher and lower mass numbers than is the case for the fission of uranium with lower energy particles. At the low energy end the products down to the region of atomic number about 27 seem definitely to be fission products, but the source of the $_{24}Cr^{55}$ is doubtful in that the uranium may have contained sufficient iron impurity to account for the small yield of this isotope. It may be noted that if there are fission products with mass number as low as about 55 it should be expected that there be heavy fission products extending up to about mass number 180, and hence joining with the region of spallation products.

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Cross Section for the Reaction $C^{12}(\gamma,n)C^{11}$

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PURE graphite has been irradiated by x-rays from the betatron operating at 50 and 98 Mev at measured quantum intensities. The number of (γ,n) processes occurring per unit time was determined by observation of the C^{11} activity with a calibrated Geiger-Müller counter.

The quantum intensity was determined for both 50- and 98-Mev betatron operation first by calibrating an ionization chamber monitor at low level with an absolute x-ray spectrum analyzer designed by one of the authors,[1] and second by a careful measurement of the relative ion chamber response from the low level operation to the high levels used in the C^{12} bombardment. While this second calibration step seems simple and straightforward, it was found somewhat difficult because of the large intensity range covered (about 10^5), the desired accuracy (about 5 percent), and the fluctuating nature of the betatron x-ray beam. The spectrum analyzer, used to calibrate the ion chamber at low level in terms of the absolute quantum intensity, counts electron-positron pairs ejected from a thin target of chosen material and weight. This analyzer first uses a collimator which defines a beam aperture and, by means of a magnetic field region, clears the beam of charged particles. A pair-forming target, magnetic field, and Geiger-counter array then serves to register electron and positron events; finally, an analyzing circuit registers electron-positron events of given total energy, which is, therefore, essentially the pair spectrum. This instrument at present registers pairs in energy channels 15 Mev in width; the number of quanta in each energy channel is obtained from the pair data, the pair-forming target thickness, and the cross section for pair production. This last cross section is now known theoretically and experimentally.[1]

The spectrographic graphite powder irradiated was held in an aluminum mount in a layer of uniform thickness and known area. The mount was accurately positioned so that the graphite layer subtended exactly the same part of the beam subtended by the pair radiator.

After irradiation for a known time at nearly constant and known intensity, all the powder was formed into a pellet of standard geometry; the subsequent decay of the 20-minute C^{11} activity was followed. The geometry, counting arrangements, and correction methods for absorption, self-absorption, and back-scattering were the same as those used for studies of relative yields x-ray induced nuclear reactions.[2] After the counting measurements were completed, the graphite was weighed and the target thickness calculated. The activity was calculated to saturation bombardment, and it was corrected for the geometrical efficiency of the end-window counter. This efficiency (34 percent of the total solid angle) was determined with the aid of a thin weighed U_3O_8 deposit—the UX_2 beta-rays of which were counted through an absorber sufficiently thick to remove the soft UX_1 radiations.

Results of the measurements are shown in Table I. The numbers in column II are calculated by dividing the number of pairs per minute in the 15-Mev wide band (centered at 30 Mev) by the width, and then dividing by the cross section for pair production at 30 Mev and also by the pair-forming target thickness. The quantity, σ, shown in the fourth column is essentially the ratio of column III to column II and represents the product of cross section by the level width of the γ-n reaction,

TABLE I.

I X-ray energy (Mev)	II No. of quanta/ Mev minute (at 30 Mev)	III No. of (γ,n) processes/min. mg atom cm^{-2}	IV $\sigma=\frac{\text{III}}{\text{II}\times 6.02\times 10^{20}}$
98	4.74×10^{7}	4220	1.48×10^{-25} Mev cm^2
98	4.74×10^{7}	4220	1.48×10^{-25} Mev cm^2
50	1.24×10^{7}	1090	1.46×10^{-25} Mev cm^2

providing the level is at approximately 30 Mev. The uncertainty in the absolute cross section is estimated to be ±20 percent; however, the comparison of cross sections at 50 and 98 Mev is probably good to 5 percent.

The fact that the cross sections based on the intensity at 30 Mev are the same with both 50-Mev and 98-Mev x-rays shows that quanta above 50 Mev in energy do not contribute appreciably to the (γ,n) process on C^{12}. It is worth pointing out that this conclusion is independent of absolute pair production cross section, efficiency of pair counting, and corrections applied to the counting data for the C^{11}. It is probable that this conclusion applies to (γ,n) reactions generally, in view of the fact that relative yields for these at 50 Mev and at 100 Mev follow the same trend.[2]

A theory to account for some of the observations on x-ray induced nuclear relations has been put forward by M. Goldhaber and E. Teller.[3] A cross section of about 1-Mev barn is predicted for the reaction $Cu^{63}(\gamma,n)Cu^{62}$. The $Cu^{63}(\gamma,n)$ cross section can be deduced from the measured $C^{12}(\gamma,n)$ cross section by use of the reaction resonance energy,[4] the relative yields of the two reactions,[2] and the relative quantum intensities at the two resonance energies. The result obtained in this way is 1.5-Mev barns.

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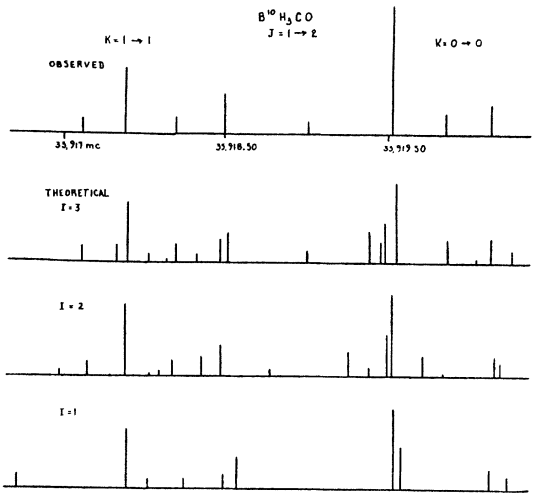

FIG. 1. Comparison of observed hyperfine structure of the $J=1\rightarrow2$ transition of $B^{10}H_3CO$ with that predicted for different assumed spin values of B^{10}.

calculated for other spin values but not shown here are not in agreement with observation.

The nuclear quadrupole coupling, $eQ(\partial^2V)/(\partial z^2)$, for B^{10} is -3.30 ± 0.10 and that for B^{11} is -1.55 ± 0.08. Thus the quadrupole moments of the two boron isotopes are of the same sign, and that of B^{10} is 2.13 times that of B^{11}.

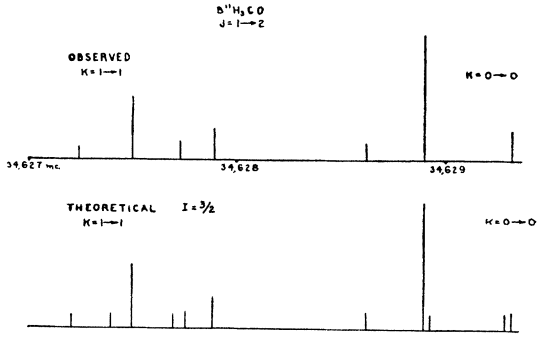

FIG. 2. Comparison of observed hyperfine structure of the $J=1\rightarrow2$ transition of $B^{11}H_3CO$ with that predicted for a B^{11} spin of 3/2.

Nuclear Spins and Quadrupole Moments of B^{10} and B^{11}

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FROM microwave absorption measurements on pure rotational transitions of borine carbonyl, the nuclear spin of B^{10} has been determined as 3 and that of B^{11} as $\frac{3}{2}$. Figure 1 shows a comparison of the observed and calculated hyperfine structure for the $J=1\rightarrow2$ transition of $B^{10}H_3CO$. Insofar as the spectrum could be resolved, there is good agreement between the observed spectrum and that calculated with $I=3$. The values of 1 and 2 can definitely be eliminated, and, of course, a zero value is eliminated by the fact that a hyperfine structure exists. The value of 3 is also substantiated by the fact that broad lines were observed where groups of unresolvable lines were predicted. Likewise, there is good agreement between the observed hyperfine structure of $B^{11}H_3CO$ and that calculated with $I=\frac{3}{2}$. (See Fig. 2.) The theoretical hyperfine structures

The symmetric-top configuration for borine carbonyl has been proved, though the bond orbitals of the boron are not tetrahedral. As may be expected from its chemical instability, the molecule is easily distorted by centrifugal forces. Because of these distortions the $K=1$ lines of the $J=1\rightarrow2$ transition occur at lower frequencies than do the $K=0$ lines: 1.34 mc for $B^{10}H_3CO$ and 1.50 mc for $B^{11}H_3CO$.

Further details, including data on other transitions, will be given in a later report.

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