observable part of our results was due to positron contamination.

An apparent anisotropy can be caused by secondary quanta scattered from one counter to the other. This effect was observed and appropriate lead shielding arranged to remove it. Its absence in the final experiments was shown by observations using Fe^{59}, which emits[8] two non-coincident gamma-rays of 1.1 Mev and 1.3 Mev. The coincidence rate was equal to the expected chance and cosmic-ray background, and was independent of angle.

It is interesting to note that the observed values of ϵ are consistent, within the experimental errors, with the values of ΣA_i predicted,[1] if the gamma-rays of Co^{60} and Sc^{46} are quadrupole radiation and the angular momenta of the nuclear states are 4, 2 and 0 in order of decreasing excitation energy in both cases. These spin assignments are in good agreement with considerations based on selection rules.[4] Further experiments are in progress. We wish to thank Mr. A. C. Miller for help in taking data. This work was supported in part by the Office of Naval Research.

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Preliminary Analysis of the Microwave Spectrum of SO_2*

B. P. Dailey, S. Golden,** and E. Bright Wilson, Jr.
Mallinckrodt Chemical Laboratory, Harvard University, Cambridge, Massachusetts

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THE purpose of the present note is to indicate the progress made to date on the analysis of the rotational spectrum of SO_2 as observed in the frequency range 20,000–30,000 mc/sec.[1,2]

Although thirty-two lines have been observed, approximate measurements of intensity and of temperature coefficients of intensity indicate that only five lines correspond to transitions of moderately low J of $S^{32}O_2^{16}$ in the ground vibrational state. The remainder includes lines presumably caused by high J transitions, by transitions of molecules in higher vibrational states, and by isotopic species such as $S^{34}O_2^{16}$, etc. In the analysis, SO_2 was considered to be a rigid asymmetric rotor, with effective moments of inertia replacing equilibrium moments of inertia.

From the Stark splitting of the lines at 23,413 and 29,460 mc/sec., it was possible to determine the values of the main quantum numbers, J, involved in the transitions. Without placing some limits on the range of values of the moments of inertia it seems quite difficult to pursue the analysis beyond this point. If however, the S–O distance is limited to values between the single-bond and triple-bond distances determined from normal covalent radii (1.37A–1.70A), and the O–S–O angle is limited to 70–180°, a unique identification of the two resolvable lines can be made.

These transitions permitted a sufficiently accurate determination of the rotational constants to predict a line that could be easily identified with the line observed at 25,392 mc/sec. Using these three transitions (of lowest J), a readjustment of the rotational constants was made that permitted additional lines to be identified with little difficulty. After the identification was made, the rotational constants were evaluated by applying the method of least squares to the five lines listed in Table I.

Consistency of the identification was tested in two ways:

(1) Comparison of the observed quantity

$$\Delta^0 = I_c^0 - I_a^0 - I_b^0$$

with that calculated from the fundamental frequencies of $S^{32}O_2^{16}$ with the aid of the formula given by Darling and Dennison.[3] The results are

$$\Delta^0(\text{obs.}) = 0.20\times 10^{-40}\text{ g cm}^2,$$
$$\Delta^0(\text{calc.}) = 0.24\times 10^{-40}\text{ g cm}^2.$$

(2) Comparison of the observed Stark effect with that computed from the rotational constants. The results for the component frequencies measured relative to the unsplit line are

$[6_{1,5}\rightarrow 5_{2,4}]$ at 23,412 mc/sec.

$$\Delta\nu(\text{obs.}) = (0.27 - 0.013M^2)\epsilon^2(\text{e.s.u.}),$$
$$\Delta\nu(\text{calc.}) = (0.224 - 0.0110M^2)\epsilon^2(\text{e.s.u.}),$$

$[3_{1,3}\rightarrow 4_{0,4}]$ at 29,460 mc/sec.

$$\Delta\nu(\text{obs.}) = (0.31 - 0.034M^2)\epsilon^2(\text{e.s.u.}),$$
$$\Delta\nu(\text{calc.}) = (0.294 - 0.0325M^2)\epsilon^2(\text{e.s.u.}).$$

The effective moments of inertia based upon the above assignment are

$$I_c^0 = 95.14\times 10^{-40}\text{ g cm}^2,$$
$$I_b^0 = 81.16\times 10^{-40}\text{ g cm}^2,$$
$$I_a^0 = 13.78\times 10^{-40}\text{ g cm}^2.$$

Since the effect of centrifugal distortion was neglected, the assignments given and the values of the effective moments of inertia must be taken to be tentative. Because of the influence of zero-point vibration and other factors, it is not possible to determine the molecular parameters directly from the effective moments of inertia. However,

TABLE I. Tentatively identified lines of the rotational spectrum of SO_2.

ν, mc/sec.	Tentative assignment	Relative intensity	$I_{-70°C}/I_{27°C}$	Comments
20,420	$13_{2,12}\rightarrow 12_{3,9}$	2	4	
23,413	$6_{1,5}\rightarrow 5_{2,4}$	1.5	5	5 components observed
24,037 or	$9_{1,9}\rightarrow 8_{2,6}$	5	2	
24,083		5	3	
25,392	$7_{2,6}\rightarrow 8_{1,7}$	10	3	2 components observed
29,460	$3_{1,3}\rightarrow 4_{0,4}$	—	—	2 components observed

an estimate may be made using the values obtained for the smallest and intermediate moments of inertia. The results are

effective S−O distance = 1.433A,
effective O−S−O angle = 119.5°.

These are in good agreement with the results obtained from electron-diffraction measurements.

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** National Research Council Predoctoral Fellow.

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Excitation Curves for the Reactions $C^{12}(d, dn)C^{11}$ and $C^{12}(\alpha, \alpha n)C^{11}$ at High Energies

R. L. THORNTON AND RICHARD W. SENSEMAN
Radiation Laboratory, University of California, Berkeley, California
September 22, 1947

THE energy dependence of the reactions $C^{12}(d, dn)C^{11}$ and $C^{12}(\alpha, \alpha n)C^{11}$ has been investigated to energies of 195 and 390 Mev, respectively. The usual technique was employed of bombarding a stack of plates of pure graphite of total thickness sufficient to contain the range of the deuterons or alpha-particles and determining the induced C^{11} activity (20.5 min.) of the individual plates. The ion beam of the 184-inch cyclotron was deflected inward by a pulsed electrostatic deflector of angular length about 120 degrees. The deflected beam reaches its maximum radius 360 degrees from the start of the deflector and there has an increase in radius of two to three inches.[1] The deflected beam is incident on the stack of plates which was mounted in a lead-shielded box on the end of the target probe and could be withdrawn through a vacuum lock. The ion beam was defined by a window in a lead plate one-inch thick immediately in front of the graphite plates. Experiment showed that the overlap of the plates over the window opening was sufficient to contain the beam within the area of the plates. Plates of both $\frac{1}{4}$- and $\frac{1}{16}$-inch thickness were used simultaneously in determining the excitation curve. The majority of the thin plates were used in the region where the curve was changing most rapidly, but others were interspersed between $\frac{1}{4}$-inch plates at other points. Since for the same current and energy the thin plates gave lower activity, it was necessary to adjust the two resulting curves. This was done by multiplying the measured activities of the thin plates by a factor which would bring the curves into coincidence at the high energy region where the excitation curve was found to be slowly varying.

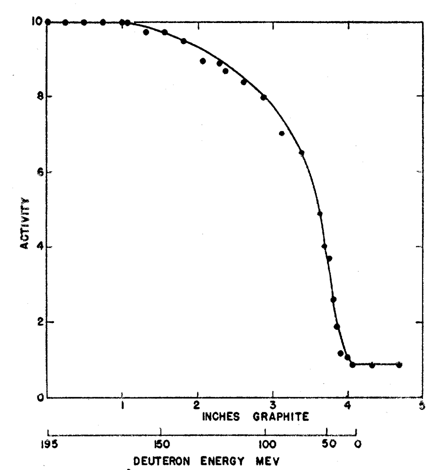

FIG. 1. Relative yield of C^{11} activity as a function of deuteron range in graphite.

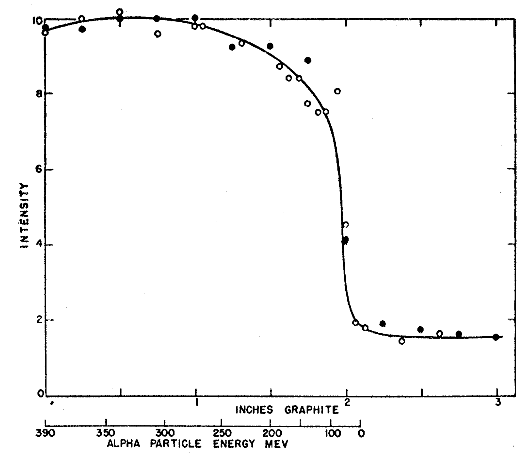

FIG. 2. Relative yield of C^{11} activity as a function of alpha-particle range in graphite. The open and solid circles give results from independent runs adjusted to average coincidence at high energies.

The radioactive decay curves of the plates show an exponential decay of period corresponding to C^{11}. In the case of deuteron activation, an indication was observed of a shorter period on plates near the end of the deuteron range. This is presumably caused by the reaction $C^{12}(d, n)N^{13}$ which, however, was not observed at higher energies. The results obtained are presented in Figs. 1 and 2. It will be noted that residual activity is observed at thicknesses greater than the range of the ions. This is due to fast neutron activation by the $(n, 2n)$ reaction; in the alpha-particle curve additional background arises from the deuteron contamination of the ion beam.

It is interesting to note that in neither curve is there apparent a tendency for the yield to fall off at high energies because of the increasing probability of more complicated competing reactions. This would suggest that the maximum energy of the incident particle is not, in general, available for such reactions, but that it is more probable that only a fraction of this energy is transferred to the nucleus. On the other hand, experiments with elements of higher atomic number, and the frequent