$$\frac{1}{4\pi\sigma_0}\Sigma_{nr}=\left(3\frac{\mu^2}{4M^2}+\beta^2\gamma^2\right)\left[\frac{1}{\mu^2/4M^2+\beta^2\gamma^2}+\frac{2\mu^2/4M^2}{2\mu^2/4M^2+\beta^2\gamma^2}\ln\frac{\mu^2/4M^2}{\mu^2/4M^2+\beta^2\gamma^2}\right]. \qquad (6)$$

For $\mu=326m_e$, we obtain the curves shown in Fig. 1. The strong influence of the interference terms is to be noted.

The dependence of the potential energy on the separation $r=|\mathbf{r}'-\mathbf{r}^2|$, of the nucleons can be shown to have the form (in the Born approximation):

$$V(r)=(g/\kappa)^2(1+P_\tau)(i\gamma_5'((\kappa)^2-\Delta)^{\frac{1}{2}}-\boldsymbol{\sigma}'\cdot\nabla)\times(i\gamma_5^2((\kappa)^2-\Delta)^{\frac{1}{2}}-\boldsymbol{\sigma}^2\cdot\nabla)e^{-\kappa r}/r, \qquad (7)$$

with $P_\tau=\frac{1}{2}(1+\boldsymbol{\tau}'\cdot\boldsymbol{\tau}^2)$. Relation (7) may be simplified.[3]

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A Suggested Slow Neutron Crystal Counter*

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A SINGLE mixed crystal of lithium and silver bromide when annealed and cooled to liquid nitrogen temperature has been found to count ionizing radiation and neutrons. The crystal, grown by Bridgman's method, was 0.75 cm in thickness and 1.2 cm^2 in area and contained approximately four times as many silver atoms as lithium atoms.

In the experiment a field of 2700 volts/cm was maintained across the crystal. The radiation was provided by a 25-millicurie radium-beryllium source imbedded in an eight-inch cube of paraffin and shielded by four inches of lead. A $\frac{1}{32}$-in. sheet of cadmium placed between the lead and the paraffin was used as a shutter for slow neutrons.

Differential pulse-size distribution curves as shown in Fig. 1 were obtained with and without the cadmium shutter. The difference between the upper two curves gives the contribution from slow neutrons. For comparison, a similar curve (not shown) was taken for gamma-rays from a 0.1-millicurie radium source. The maximum pulse height for these gamma-rays was estimated to be about 70 volts. Thus, the pulses due to neutrons are seen to extend considerably beyond those due to gamma-rays from radium.

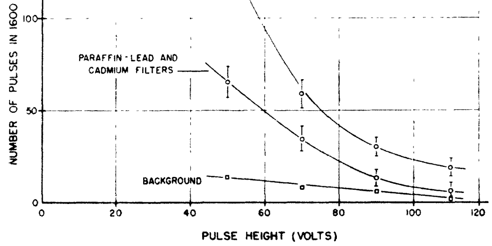

FIG. 1. Pulse height distribution for lithium bromide-silver bromide crystal counter irradiated by neutrons from a radium-beryllium source. Top curve: source filtered by paraffin—lead. Middle curve: source filtered by paraffin—lead and cadmium. Bottom curve: background with source absent.

The energy of the particles released in the neutron capture by Li^6 is 4.7 Mev, while the maximum energy of the gamma-rays from the radium is 2.4 Mev. Since the neutron pulses seem to have a high energy tail in the region where the gamma-ray pulses fall to zero, it would appear that the value of energy per ion pair for heavy particles (namely H^3 and He^4) released within the crystal is not more than twice, and may well be equal, to the value for beta-particles. This observation is to be contrasted with a result of Van Heerden[1] with silver chloride that the energy per ion pair for alpha-particles from an external source is four to six times the energy per ion pair for beta-particles. It is possible that the discrepancy is due to surface effects.

The slow neutron capture cross sections for naturally occurring lithium and silver are approximately equal.[2] Thus, in the crystal studied only one-fifth of the slow neutrons are captured by Li^6 nuclei, and four-fifths by silver nuclei. These latter decay quickly to give beta-rays with maximum energy about the same as that for the gamma-rays from radium.

The present counter of natural isotopes and of 0.75-cm thickness has an efficiency of the order of 5 percent for slow neutron detection. The efficiency and selectivity can be considerably improved by using a thicker crystal of lithium enriched in Li^6. It would then be expected that a crystal one- or two-centimeters thick with the same proportion of lithium to silver would have an efficiency of the order of 70 percent.

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Microwave Spectrum of Formaldehyde

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FIVE lines of the pure rotation spectrum of formaldehyde have been observed in the region 18,300–27,500 megacycles. Comparison of the observed spectrum with that calculated for a wide range of the molecular parameters, and the resolution of the Stark pattern of the $9_{2,8}\rightarrow 9_{2,7}$ transition, permits an unambiguous identification of four of the lines. The analysis was facilitated by the fact that only transitions between the two components of "K-doublets" are expected in the region surveyed; this is a result of the small moments of inertia.

The observed spectrum is given in Table I; listed for comparison are the calculated frequencies, and the centrifugal distortion corrections which were applied. The rigid rotor frequencies were calculated by the method of Golden.[1] Wang[2] has given a simple expression for the splitting of K-type doublets which was useful for preliminary analysis but not sufficiently accurate for precise calculations. In the final calculation of the spectrum with $\kappa=-0.9612$, the continued fraction method[3] was used to provide precise values of the rigid rotor frequencies.

The corrections for centrifugal distortion were obtained by a method due to Golden,[4] based on the theory of Wilson.[5] Necessary values of the valence-type force constants were taken from Ebers and Nielsen.[6] The uncertainty in these cor-

TABLE I. The observed microwave spectrum of formaldehyde.

Transition	Observed freq. (mc/sec.)	Calculated (mc/sec.)	Centrifugal distortion correction	Temperature* coefficient of intensity	Intensity
$25_{4,22}\rightarrow 25_{4,21}$	19595.23	19,593	−305	1/5	*m*
	20736.64			1/2	*w*
$9_{2,8}\rightarrow 9_{2,7}$	22,965.71	22,966	− 30	2	*s*
$17_{3,15}\rightarrow 17_{3,14}$	24,068.31	24,036	−147	1/3	*m*
$26_{4,23}\rightarrow 26_{4,22}$	26,358.70	26,390	−396	1/5	*w*

* Approximately, $I(-78°\text{C})/I(25°\text{C})$.

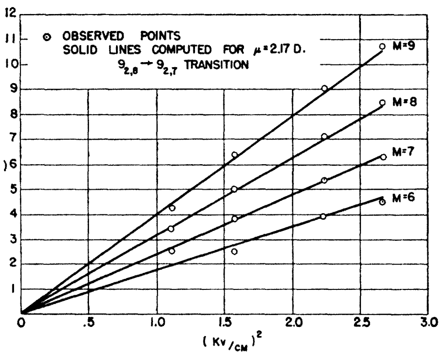

FIG. 1. Stark effect of formaldehyde absorption line at 22965.71 Mc/sec.

rections is rather large, since the results of calculation represent differences in large numbers, in which inadequacies in the assumptions made, or small discrepancies in the force constants, may be magnified. It is possible, for example, to change the correction to the $26_{4,23}\rightarrow 26_{4,22}$ transition by 10 megacycles simply by varying the HCO bending force constant within the limits of uncertainty quoted by Ebers and Nielsen. The magnitude of these corrections is due to the small moment of inertia about the twofold axis.

Four Stark components of the $9_{2,8}\rightarrow 9_{2,7}$ transition were resolved (see Fig. 1): their behavior as a function of frequency served to establish the identity of the line. The dipole moment in the ground vibrational state was calculated to be 2.17 ± 0.02 Debye units, using asymmetric rotor theory.[7] As far as we know, the only previously reported value is[8] 2.27, measured at 420–520°K.

The identity of the line at 20,737 is not known: it cannot be identified with any pure rotational transition below $J=35$ on the basis of the present assignment. Nevertheless, one cannot interpret even three lines of the spectrum on the basis of any other choice of rotational constants. The present assignment predicts that the strong $3_{1,3}\rightarrow 3_{1,2}$ transition should fall at $29{,}058\pm 50$ megacycles.

Further work is planned on the identification of the 20,737 line, and on refinement of the centrifugal distortion corrections, with the eventual object of providing close estimates of the limits of accuracy of the present theory of the semirigid rotor. It is hoped the work will lead to an independent set of force constants, which may then be compared with those determined from vibrational spectra.

The values of the effective molecular parameters on which the calculated spectrum is based are $\kappa=-0.9612\pm 0.0001$ $\times(a-c)/2=1.2482\times 10^5\pm 0.006\times 10^5$ megacycles. These are in essential agreement with the values -0.9623 and 1.2391 10^5 calculated from the results of the ultraviolet spectrum.[9] The value of κ can be given rather precisely because the frequency of the high J transitions is extremely sensitive to the parameters; there is a corresponding large uncertainty in the value of $(a-c)/2$. Observation of the $3_{1,3}\rightarrow 3_{1,2}$ transition would suffice to determine the latter parameter with precision.

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The Emission of Protons from Boron and Argon on Bombardment with Po α-Particles

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BORON.—Earlier reports on the reaction $B^{10}(\alpha,p)C^{13}$ show that the compound nucleus $_7N^{14*}$ may decay with the emission of a proton leaving the final nucleus in the ground state or one of its excited states. The ground state transition ($Q=4.14$ Mev) escaped observation for a long time because of its feeble intensity. However, Brubaker and Pollard's[1] experiments gave a Q value of 4.7 ± 0.5 Mev for the protons emitted from the ground state. Later this result was confirmed by other workers. Jentshke[2] and Merhaut[3] obtained the values 3.86 and 3.85 Mev, and Joliot and Zlotowski[4] 4.3 Mev for protons of the longest range group.

The Q valves corresponding to the protons which are emitted from the compound nucleus, leaving the final nucleus C^{13} in an excited state are 3.3, 0.5, 0.1, −0.78, and −1.86 Mev.

The present experiment, utilizing a cloud chamber was chiefly concerned with the investigation of the angular distribution of the protons arising from the various states. The polonium source, strength 5 mc, was deposited on a silver foil 2 mm×2 mm and the beam of α-particles was canalized through a slit arrangement before striking the target, the thickness of which was 0.8 cm air equivalent.

In the course of over 700 photographs 86 protons were obtained. Figure 1 shows the variation of the yield of protons with the incident α-particle energy. The curve does not indicate a well defined level. From considerations of the barrier

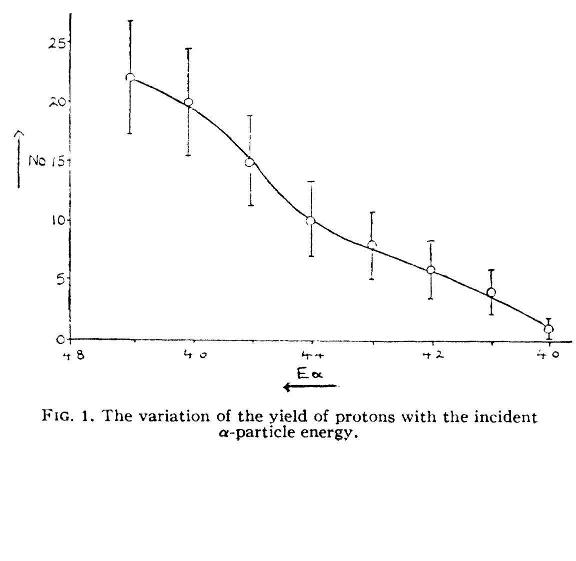

FIG. 1. The variation of the yield of protons with the incident α-particle energy.