

Gamma-Ray Neutrons and the Fermi Proton Effect

We have observed that neutrons emitted by γ -rays from beryllium (Chadwick-Szillard effect) also show the Fermi proton effect.¹ Iodine was the element irradiated and a product with a half period of 24 minutes obtained.

Our neutrons were produced from 80 g of powdered Be (placed in a water-proof waxed paper cylinder of 75 mm diameter) by γ -rays from 0.50 g Ra contained in needles and filtered through 0.5 mm of Pt.

An iodine beaker was made by evenly coating the walls of a 600 cc Pyrex beaker (diameter=8.5 cm, height=11.5 cm) with 150 g of the element. The neutron source was placed in the iodine beaker and the latter in a 4.0 lit. beaker (diameter=15.5 cm, height=26.5 cm); the whole was placed in a safe protected with 2 cm of Pb.

The irradiation was run for 18 hours, (1) in *air* and (2) with the beakers filled to the rim with *water*. The results are plotted in Fig. 1.

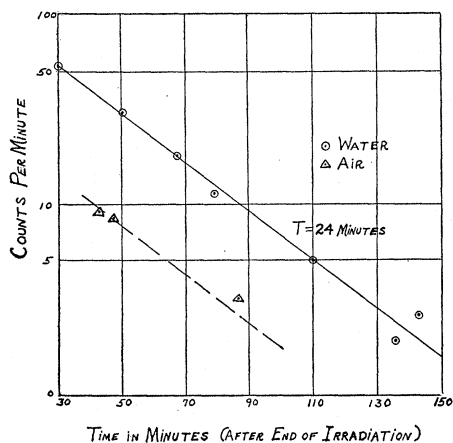


FIG. 1. Variation of time of the activity produced by bombarding iodine with neutrons produced by γ -rays.

Here, as with neutrons emitted by α -particles, the presence of water *increases* the induced radioactivity by a factor of *five*.

Again we are indebted to Dr. M. Cutler of Michael Reese Hospital for the source and to Dr. W. D. Harkins for the beryllium.

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December 12, 1934.

¹ E. Fermi, E. Amaldi, B. Pontecorvo, F. Rasetti and E. Segré, *La Ricerca Scientifica* 2, No. 7-8, No. 9-10 (1934).

The Interaction Between Vibration and Rotation for Symmetrical Molecules

The problem of the vibration-rotation interaction in symmetrical molecules has recently been studied by Teller¹ who has shown that it will account for the anomalous

spacing observed in the infrared bands of methane and of the methyl halides. We have somewhat extended the theory and have been able to revise Teller's calculations. The results appear to be of sufficient importance to warrant a preliminary report, reserving until later an account of the proofs on which they are based.

Teller has shown that the fine structure spacing of the zero branches ($\Delta K = \pm 1$, $\Delta J = 0$) in a perpendicular band of an axial symmetrical molecule has the form,

$$\Delta\nu = [(1-\zeta)/C - 1/A]h/4\pi^2,$$

where ζ is the angular momentum in units of $h/2\pi$ due to the vibratory motion alone. The value of ζ depends upon the potential constants of the molecule and may be computed in terms of them. The sum of the ζ 's for all the first excited states of a given symmetry type is, however, independent of the potential constants and is a function only of the masses and dimensions of the system. Thus the sum of the line spacings of the fundamental bands of a given type (say the perpendicular bands) will yield information about the moments of inertia providing $\Sigma\zeta$ is known. Since $\Sigma\zeta$ is independent of the particular force constants it may be computed for extreme force fields where the motion of the system is readily obtainable. In this way we have found that for the symmetrical molecule YX_3 , $\Sigma\zeta = C/2A - 1$, where C and A are the moments of inertia along and \perp to the figure axis, respectively. For the molecule ZYX_3 (to which type the methyl halides belong) we find $\Sigma\zeta = C/2A$. Thus the sum of the line spacings of the three bands of the methyl halides should be, $\Sigma\Delta\nu = (3/C - 5/2A)h/4\pi^2$. These bands have been observed by Bennett and Meyer² who found the sum of the three line spacings to be, 24.65, 27.15, 28.32 and 28.5 cm^{-1} for CH_3F , CH_3Cl , CH_3Br and CH_3I , respectively. The moment of inertia A is known to be 39.5×10^{-40} for CH_3F . In the case of the other methyl halides its value has been estimated³ to be 61, 89 and 99×10^{-40} , respectively. Combining these data we obtain $C = 5.90, 5.65, 5.55$ and 5.55×10^{-40} for CH_3F to CH_3I . The H-H distance for these molecules is accordingly 1.88, 1.84, 1.83 and 1.83×10^{-8} .

The methane molecule possesses two active fundamental frequencies and for these we compute $\Sigma\zeta = \frac{1}{2}$, a result which agrees with Teller's conclusions. Using the line spacings found by Cooley⁴ we obtain $I = 5.47 \times 10^{-40}$, H-H = 1.81 and C-H = 1.11×10^{-8} . It thus appears that the methyl group has essentially the same dimensions in the methyl halides and in methane. These values for the moments of inertia are based on the assumption that the motion is purely harmonic and hence may be subject to slight revision.

Dr. Rosenthal⁵ has shown that the general potential function for the methane molecule contains five constants, A, B, C, D and E . These have not hitherto been evaluated since the molecule possesses but four normal frequencies. A fifth relation is now at hand since ζ_3 or ζ_4 may be computed as a function of the potential constants. We find

$$\zeta_i = (6\delta_i - 1)/(6\delta_i + 2) \quad i = 3, 4,$$

where $\delta_i = 8D^2/(3m\lambda_i - A)^2$. By using this relation together

TABLE I. Fundamental frequencies of the molecules of CH₄, CH₃D, CH₂D₂, CHD₃, CD₄.

| CH ₄ | (2914) | (1520) | 3014 | | | 1304 | | |
|--|--------|----------------|----------|---------|----------|----------|---------|--------|
| (CH ₃ D) ₊ | 2944 | 1460 ⊥ | 2183 , | 3013 ⊥ | 1300 , | 1151 ⊥ | | |
| (CH ₃ D) ₋ | 2694 | 1406 ⊥ | 2993 , | 2796 ⊥ | 1036 , | 1289 ⊥ | | |
| (CH ₂ D ₂) ₊ | 2141 M | (1317), 1424 M | 2227 G, | 2969 M, | 3013 L | 1228 G, | 1019 M, | 1082 L |
| (CH ₂ D ₂) ₋ | 2461 M | (1317), 1245 M | 2768 G, | 2771 M, | 2536 L | 989 G, | 1089 M, | 1285 L |
| (CHD ₃) ₊ | 2101 | 1286 ⊥ | 2992 , | | 2222 ⊥ | 994 , | 1020 ⊥ | |
| (CHD ₃) ₋ | 2475 | 1136 ⊥ | 2166 , | | 2549 ⊥ | 1163 , | 1007 ⊥ | |
| CD ₄ | (2061) | (1075) | 2227 | | | 987 | | |

with the four normal frequencies it is found that,

$$\begin{aligned} A &= 7.670 \times 10^5 \text{ dynes/cm} & D &= \pm 1.278, \\ B &= 0.476 & E &= 0.313. \\ C &= 0.341. \end{aligned}$$

The fundamental frequencies of the molecules CH₃D, CH₂D₂, CHD₃ and CD₄ may now be calculated using the equations developed by Dr. Rosenthal.⁵ There are two solutions corresponding to the positive and negative values for the constant D . Our results are collected in Table I. The inactive frequencies are enclosed in brackets. In the case of CH₂D₂ the letter following the frequency indicates whether the electric moment vibrates along the axis of least, middle or greatest moment of inertia.

Professor Barker and Mr. Ginsburg have continued their investigation of the absorption spectra of the heavy methanes and they have very kindly allowed us to state that their results appear to conform very satisfactorily with the bands predicted by the solution using $D = +1.278$. The band reported by them⁶ at 1090 cm⁻¹ is thus probably due to CH₂D₂. If this identification is correct, it would of course invalidate their estimate of the moment of inertia of methane.

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December 13, 1934.

¹ E. Teller, Hand- und Jahrbuch d. Chem. Phys. 9, 125 (1934).

² W. H. Bennett and C. F. Meyer, Phys. Rev. 32, 888 (1928).

³ S. L. Gerhard and D. M. Dennison, Phys. Rev. 43, 197 (1933).

⁴ J. P. Cooley, Astrophys. J. 62, 73 (1925).

⁵ J. Rosenthal, Phys. Rev. 45, 538 (1934).

⁶ E. F. Barker and N. Ginsburg, J. Chem. Phys. 2, 299 (1934).

The Temperature Function of X-Ray Reflection in the Neighborhood of the Melting Point of a Crystal

In connection with some more extended work concerning the temperature variations of physical properties of metal crystals the following deviations from the Debye-Waller function concerning the temperature dependence of x-ray reflections have been observed in the neighborhood of the melting point of Bi crystals.

The apparatus used was the Bragg-spectrometer with stationary ionization chamber, described previously,¹ with added arrangements for heating the crystal in a neutral atmosphere under well controlled temperature conditions

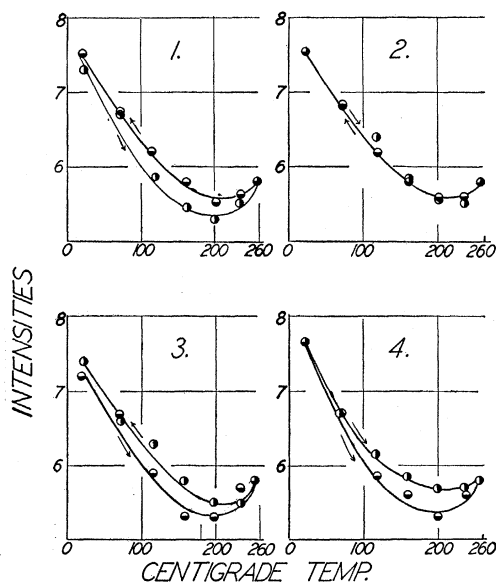
up to the melting point of Bi (272°C). The direction was along [111], the radiation used Mo K α in third order.

Whereas the Debye-Waller law requires a continuous decline with increasing temperature for the relative integrated intensity following:

$$I/I_0 = e^{-kT \cdot \sin^2 \theta}$$

it was found that at approximately 210°C I/I_0 passed through a minimum after which it increased with T to a value equivalent to $T \sim 150^\circ\text{C}$ for the highest observed temperature (265°C) (Fig. 2).

The reversibility of the $I/I_0(T)$ function proved to be largely depending upon the thermal history of the crystal although only crystals without any indication of crystallographic irregularities were used. Figs. 1 and 3 represent the $I/I_0(T)$ function of crystals having been raised to approximately 220°C and then quenched in liquid air



Figs. 1-4. The ordinate represents the relative integrated intensity of third order Mo K α radiation reflected from Bi (111); the abscissae the temperature in C. In Figs. 1 and 3 the crystal was "quenched" before measurements with increasing temperatures were taken. In Fig. 2 the crystal was annealed before measurement. In Fig. 4 the crystal was heated after annealing (upper curve), then quenched and reheated (lower curve). The arrows indicate the temperature direction of the measurement.