pressed in terms of the cross section of the nucleus, assuming that every deuteron which strikes within that cross section produces a transmutation and that all others do not. For Mg^{26}, 11 percent of the total number of atoms of Mg present, this cross section, from the data given, is 2.4×10^{-26} cm^2 at 3 MEV. Both this cross section and the yield as given above are certainly too low.

I am very greatly indebted to Professor Lawrence for the opportunity of using the cyclotron and for the facilities of the laboratory. To Professor Oppenheimer and Dr. McMillan I owe many thanks for helpful discussions and cooperation with some of the calculations. Thanks for financial assistance to the laboratory are also due the Research Corporation and the Chemical Foundation.

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The Infrared Absorption Spectrum of Germane

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The infrared spectrum of GeH_4 has been measured to determine the fundamental vibration frequencies and to investigate the rotational structure of the bands. Intense absorption regions were found, enumerated in the order of their intensities, at 4.74μ (2110 cm^{-1}), 10.7μ (934 cm^{-1}), 3.4μ (2922.7 cm^{-1} and 3031 cm^{-1}) and 2.3μ (4300 cm^{-1}) which have respectively been identified as ν_3, ν_4, $\nu_1+\nu_4$, $\nu_3+\nu_4$, and $2\nu_3$. A much weaker absorption peak near 5.7μ is identified as $\nu_2+\nu_4$. From the spacings between the principal rotation lines in the fundamentals ν_3 and ν_4 a value 7.0×10^{-40} g-cm^2 for the moment of inertia of the molecule and values 1.37×10^{-8} and 2.06×10^{-8} cm, respectively, for the Ge-H and the H-H distances are indicated.

THE recent measurements on the infrared spectrum of methane[1] and silane[2] have shown that the observed bands conform very well in a general way with the predictions of the theory for molecules of the regular tetrahedral type, but that there exists a definite complexity of the rotational structure in many of the bands which is not readily accounted for. This lack of agreement between observation and theory and the obvious desirability of finding the values of the fundamental vibrations has seemed sufficient to warrant investigating the infrared spectrum also of germane (GeH_4) a molecule which also must certainly belong to the tetrahedral XY_4 type.

A sample of chemically pure GeH_4 was obtained as a gift from Professor Warren C. Johnston of the Department of Chemistry, University of Chicago. Like silane (SiH_4) this gas should be manipulated in the absence of air or oxygen to guard against explosions. Two absorption cells of glass fitted with windows of polished rocksalt were used, one 30 cm long filled with gas to a pressure of 50 cm of Hg for measurements on weaker bands and another 10 cm long filled with gas to 10 cm Hg pressure for measurements on the more intense regions of absorption.

A set of preliminary measurements extending from 1.0μ to 13.0μ was made with a prism spectrometer of the Wadsworth type, to determine the approximate positions of the principal regions of absorption and their relative intensities. Four fairly intense regions were found, enumerated in the order of their intensities at 4.74μ, 10.7μ, 3.4μ, and 2.3μ. A much weaker peak was found near 5.7μ. Of these the three regions at 3.4μ, 4.74μ and 10.7μ have been studied under high dispersion using a prism grating spectrometer described in relation to earlier experiments, and two different echellette gratings ruled by Wood, one with 4800 lines to the inch for the 4.0μ region and another with 800 lines to the inch for the 10μ region.

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[1] A. H. Nielsen and H. H. Nielsen, Phys. Rev. **48**, 864 (1935).

[2] W. B. Steward and H. H. Nielsen, Phys. Rev. **47**, 828 (1935).

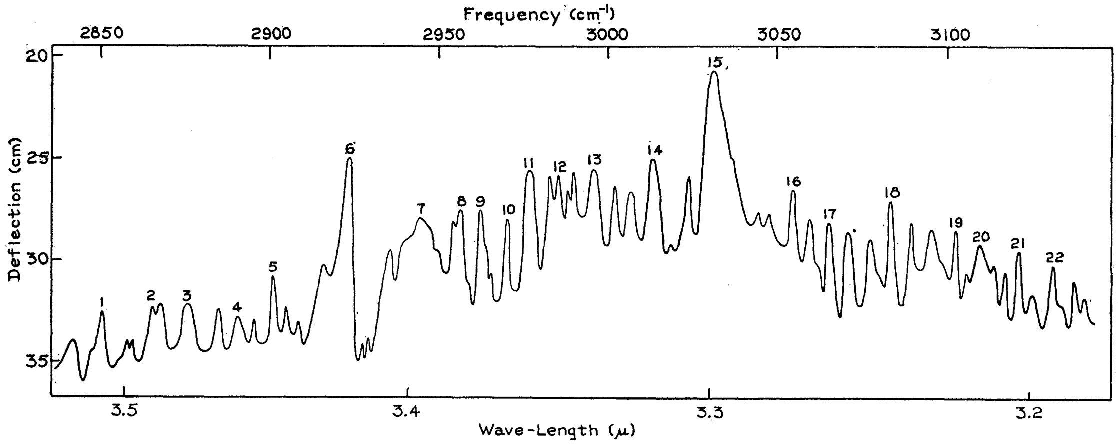

FIG. 1. 3.3μ region of GeH₄.

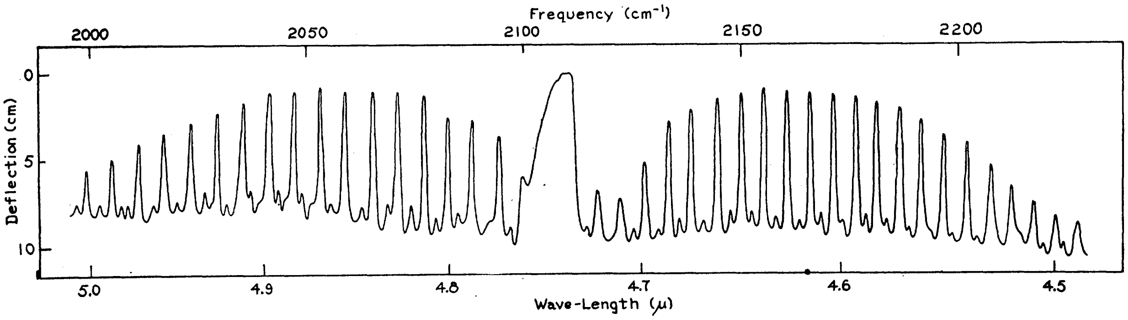

FIG. 2. 4.7μ band of GeH₄.

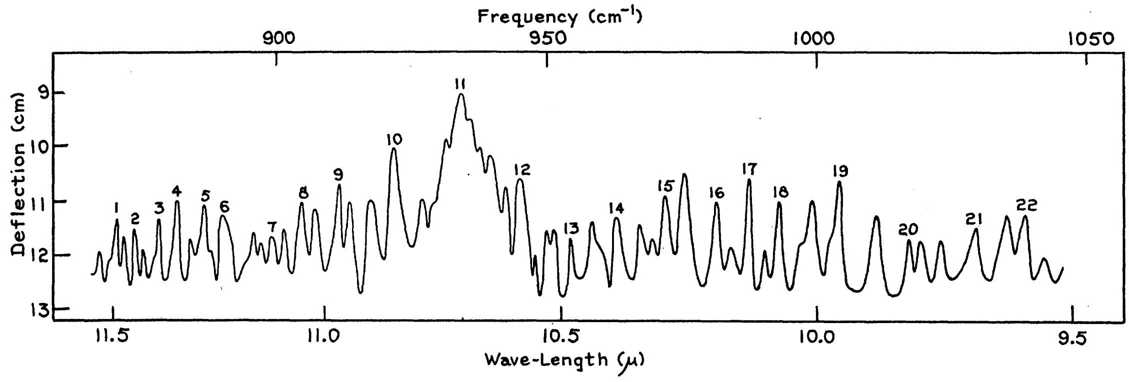

FIG. 3. 10.7μ region of GeH₄.

In these regions, spectrometer slits equivalent to frequency intervals in the spectrum of 0.8 cm^{-1}, 0.8 cm^{-1} and 0.6 cm^{-1}, respectively, could be used and galvanometer deflections were taken at divisions on the circle equal to the spectral range subtended by the spectrometer slit in each case. Moreover, all three of these regions are quite free from lines of atmospheric absorption so that the data have been recorded throughout in terms of galvanometer deflections. The absorption patterns for these regions obtained by plotting galvanometer deflections as ordinates

TABLE I. *3.3μ region of GeH₄.*

Line No.	Freq. (cm⁻¹)	Line No.	Freq. (cm⁻¹)	Line No.	Freq. (cm⁻¹)
	2841.6	8	2956.7	17	3065.8
1	2850.3	9	2962.8		3071.8
2	2864.8	10	2970.1		3078.1
	2868.0	11	2977.2	18	3084.3
3	2875.7		2983.7		3090.0
	2885.0	12	2986.0		3095.8
4	2890.0		2990.2	19	3102.8
	2894.9	13	2996.1	20	3109.2
5	2901.1		3002.0		3113.7
	2905.0		3006.8		3117.6
	2908.3	14	3013.4	21	3121.5
	2915.1		3023.7		3126.0
6	2922.7	15	3031.0	22	3131.9
	2936.0	16	3054.9		3138.3
7	2945.5		3059.9		3141.0

TABLE II. *4.7μ region of GeH₄.*

Line No	Freq. (cm⁻¹)	Line No.	Freq. (cm⁻¹)	Line No.	Freq. (cm⁻¹)
1	1998.9	15	2082.7	29	2166.1
2	2005.1	16	2088.4	30	2171.3
3	2011.7	17	2094.3	31	2176.5
4	2017.5	18	2099.8	32	2181.8
5	2023.3	19	2110.1	33	2187.1
6	2029.4	20	2116.8	34	2192.0
7	2035.3	21	2122.4	35	2197.1
8	2041.4	22	2128.0	36	2202.4
9	2047.5	23	2133.6	37	2207.1
10	2053.4	24	2138.9	38	2212.2
11	2059.3	25	2144.6	39	2217.0
12	2065.1	26	2150.0	40	2222.1
13	2071.2	27	2155.1	41	2226.9
14	2077.1	28	2160.9		

TABLE III. *10.7μ region of GeH₄.*

Line No.	Freq. (cm⁻¹)	Line No.	Freq. (cm⁻¹)	Line No.	Freq. (cm⁻¹)
1	870.0		913.5	16	981.1
	871.3		917.1		983.5
2	873.3	10	921.4	17	986.9
	875.2		926.6		990.2
3	877.9	11	934.0	18	992.8
4	881.2	12	944.5		998.7
	883.8		949.9	19	1004.7
5	885.8		951.5		1010.8
6	889.2	13	954.6	20	1017.0
7	898.4		958.5		1018.8
	901.1	14	963.2		1022.4
8	904.3		967.2	21	1028.7
	906.8	15	971.7		1034.2
9	912.1		974.9	22	1037.9

against a scale of frequencies and wave-lengths are given in Figs. 1, 2 and 3 and accompanying each figure is a tabulation of frequencies of the principal lines (Tables I–III).

The region near 3.3μ apparently corresponds to the 2.3μ region in the methane spectrum and the 3.2μ region in the silane spectrum, and like these it consists of two badly overlapping bands with centers at 2922.7 cm⁻¹ and 3031.0 cm⁻¹. By analogy to the spectra of methane and silane these two bands have been identified as $\nu_1+\nu_4$ and $\nu_3+\nu_4$, respectively. Because of the overlapping, it is impossible to find any regularity of line spacing except perhaps on the high frequency side of the band at 3031 cm⁻¹ where an average over several nearly equally spaced lines leads to a value of 6.2 cm⁻¹ for the separation between lines.

The 4.7μ band with its center at 2110 cm⁻¹ undoubtedly corresponds to the 3.3μ band in the methane spectrum and the 4.5μ band in the silane spectrum and is accordingly designated as ν_3. It is the most intense of the bands measured in the germane spectrum. Like the corresponding bands in the spectra of methane and silane, it consists of a strong central line with a series of sharp rotation lines on either side forming *P* and *R* branches. As may be seen from Fig. 3, there occurs also here a background which we do not believe can be ascribed to observational errors since it has been repeated almost exactly a number of times. The background is here not as predominant as in the corresponding band in the silane spectrum and neither is the *Q* branch so extremely broad, so that as a whole this region resembles the corresponding one in the methane spectrum a great deal more than that in the silane spectrum. Some convergence of the principal lines is observed towards higher frequencies and the average separation between lines taken over the entire band is found to be 5.56 cm⁻¹.

The long wave-length region has its center at 934 cm⁻¹ and is taken to correspond to the 7.7μ band in the methane spectrum and to the 9.5μ band in the silane spectrum. It is consequently identified as ν_4. It should be pointed out that while the high frequency fundamentals in the methane and silane spectra appear to be less intense than the low frequency fundamentals, the opposite is here true, but aside from this the 10.5μ region in the germane spectrum resembles the 7.7μ methane band a great deal, in fact much more so than the corresponding silane band which occurs as two overlapping bands. While here as in methane some regularity of rotation a structure is discernible, especially on the high frequency side where a separation of about 6.0 cm^{-1} seems to establish itself, the structure is quite definitely not the simple structure to be expected for so symmetrical a molecule.

It is felt that these measurements as well as the earlier ones on methane and silane emphasize the importance of remeasuring the bands of all the X-tetrahydrides (XH_4) at much reduced temperatures, to establish whether the complex structure observed in many cases can be ascribed to overlapping bands arising from transitions between higher vibration levels or whether a more involved explanation is to be sought. We hope soon to be able to report on such measurements.

When the spacings in the two optically active fundamentals vibrations ν_3 and ν_4 have been determined, it is possible by the method of Dennison and Johnston[3] to compute the value for the moment of inertia of the molecule. This we have done also for the germane molecule taking the spacings between lines in the two fundamentals ν_3 and ν_4 to be 5.6 cm^{-1} and 6.0 cm^{-1}, respectively. These spacings lead to a value for the moment of inertia of the germane molecule of 7.0×10^{-40} g-cm^2 and to the values 1.37×10^{-8} and 2.06×10^{-8} cm for the Ge-H and the H-H distances. It must be emphasized that the structure of ν_4 is so irregular and its spacing constant so doubtful that the above values are highly uncertain.

TABLE IV. *Summary of assignments of the absorption bands of germane.*

OBSERVED ν	COMPUTED ν	IDENTIFICATION
—	820 cm^{-1}	ν_2
934.cm^{-1}	—	ν_4
1754	—	$\nu_2+\nu_4$ (?)
—	1988.7	ν_1
2110.1	—	ν_3
2922.7	—	$\nu_1+\nu_4$
3031.0	3044.1	$\nu_3+\nu_4$
4250	4220.2	$2\nu_3$.

For convenience we have restated in Table IV our identification of the bands observed in the spectrum of germane.

We wish to express our gratitude to Professor Warren C. Johnston for the sample of germane gas which he so kindly presented to us.

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[3] D. M. Dennison and M. Johnston, Phys. Rev. 47, 93 (1935).

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The Infrared Absorption Bands of Methane

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The two fundamental vibration-rotation bands ν_3 and ν_4 of methane have been remeasured with greater resolution than that available in the earlier investigation of Cooley. Whereas the band at 3.3μ showed no essentially new details, the fundamental band at 7.7μ was found to possess a somewhat more complex rotational structure than was observed by Cooley. Many of the lines given in Cooley's curve are here resolved into groups of closely spaced components. The separation between the components within a group appears to increase with the ordinal number of the line counted outward from the center of the band. In addition to these measurements, the two combination bands $\nu_1+\nu_4$ at 4218 cm^{-1} and $\nu_3+\nu_4$ at 4315 cm^{-1} have been at least partially resolved and appear to have line spacings of about 5.3 cm^{-1} and 13.5 cm^{-1}, respectively.

RECENT measurements on the absorption spectrum of silane[1] in the infrared have shown that the rotation lines are not single sharp lines, but are accompanied by satellite components. Because of the apparent similarity between the methane and silane molecules it has seemed worth while to remeasure the known absorption bands in methane under the improved conditions made available since the investigation by Cooley[2] was made.

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[1] W. B. Steward and H. H. Nielsen, J. Chem. Phys. 2, 712 (1934); Phys. Rev. 47, 828 (1935).

[2] J. P. Cooley, Astrophys. J. 62, 73 (1925).