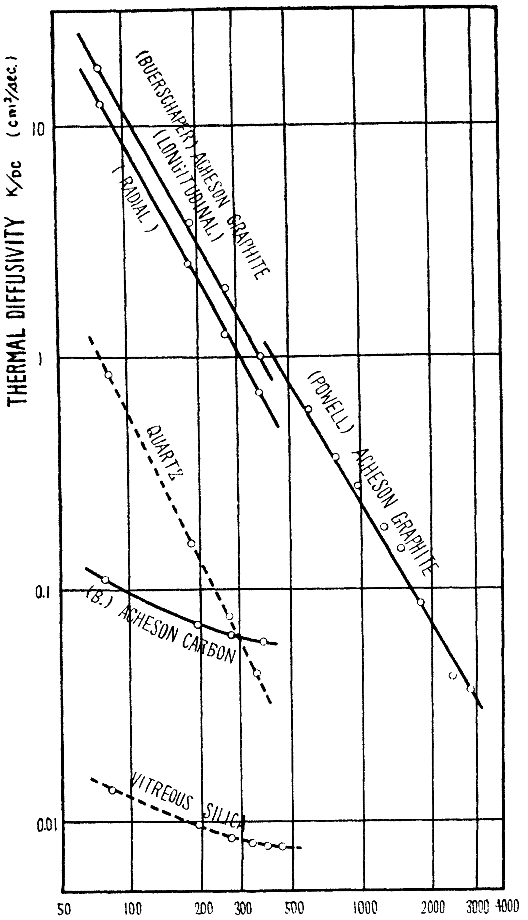

FIG. 2. Variation with temperature of the thermal diffusivities of carbon and silica.

for the impurity scattering. This result may be attributed to the dependence of the energy on the wave number vector, which is linear near the Fermi surface, and to the proportionality of the effective mass to temperature. On the other hand, the electrical conductivity of amorphous carbon, such as pitch coke which has been heated at low temperatures, was found to be expressed approximately by $\sigma = A\exp(-E/kT)$, where A is a constant. The activation energy E varied from about 0.10 ev to 0.03 ev for specimens heated between 520°C and 715°C. Films of organic substance remaining at the crystallite boundaries are probably playing an important role in these cases.

It has been noted that there is a remarkable difference between the thermal conductivity of graphite and that of amorphous carbon. This can be explained by the difference of the mean free paths of thermal elastic waves in the two media. The thermal conductivity K is expressed in terms of the propagation velocity u and the mean free path l as $K/DC = lu/3$, where D is the density and C is the specific heat. Values of the thermal diffusivity are plotted in Fig. 2 against temperature for artificial graphite and amorphous carbon using the experimental data obtained by several investigators.[3,4] For comparison, curves for quartz and vitreous silica are included there also. It is evident from this figure that there is a close resemblance between these two sets of curves. Therefore, the mean free path is considered to be determined by mutual collisions in the case of graphite and by the crystallite boundaries in the case of amorphous carbon, just as for the two allotropic forms of silica.[5] In fact, the mean free path in amorphous carbon was estimated to be the order of 50A, which may be compared with the crystallite size of several tens of angstroms measured by x-ray methods for many kinds of amorphous carbon.

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Some Molecular Dipole Moments Determined by Microwave Spectroscopy

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A STARK modulation type absorption cell has been constructed in which the electrode spacing is known to ±0.2 percent. The dipole moments of several compounds have been measured and these are listed in Table I.

TABLE I. Dipole moments from Stark effect measurements.

Formula	Compound	$\mu\times10^{18}$ (esu)	Transition observed
OCS	Carbonyl sulfide	0.712 ± 0.004	$J_{1\to2}$
HNCO	Isocyanic acid	1.592 ± 0.010	$0_{0,0}\to1_{0,1}$
H_2CO	Formaldehyde	2.339 ± 0.013[a]	$9_{2,8}\to9_{2,7}$
		2.340 ± 0.019	$3_{1,3}\to3_{1,2}$
CHF_3	Fluoroform	1.645 ± 0.009	$J_{0\to1}$

[a] The absolute accuracy of the value 2.17±0.02 Debye units, reported by J. K. Bragg and A. H. Sharbaugh [Phys. Rev. **75**, 1774 (1949)], was in error because of an irregularly spaced Stark electrode. Use of the new precision cell precludes this possibility in the present work.

The experimental error quoted is the sum of the precision error of the particular measurement and the systematic errors. These are: (1) Electrode spacing, ±0.2 percent. (2) Voltage divider, ±0.06 percent, and (3) Error in the measurement of the displacement of the absorption line, under the applied field, ±0.1 percent, due to uncertainty in the frequency of the undisplaced line. This error can be neglected in the measurements for OCS, since the dipole moment was calculated from Stark components which moved to higher and lower frequencies.

A reduction of 0.7 percent has been applied to the calculated dipole moments to account for field inhomogeneities and the fact that the average of the displacements caused by the top and bottom of the square wave does not yield the displacement corresponding to the applied dc voltage.

Shulman and Townes[1] have recently reported a value of 0.7085 ±0.004 Debye units for the dipole moment of OCS. Our measurements agree with this figure within experimental error. Carbonyl sulfide should prove to be a convenient compound for calibrating a microwave spectroscope in which the systematic errors have not been accurately determined by direct measurement.

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Microwave Spectrum of Methyl Mercaptan

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THE study of the K-Band microwave spectrum of CH_3SH is currently in progress. In the spectroscope, a 48-foot absorption cell is used with a double modulation method which employs both wide range saw-tooth 60 cycle/sec modulation and narrow range sinusoidal 87 kc/sec modulation. This technique in conjunction with a low noise input circuit described by Good[1] for the 87 kc/sec amplifier and a low pass filter gives a sensitivity of 1×10^{-7} nepers/cm as judged by the ability to detect all of the weak $N^{15}H_3$ lines tabulated by Kisliuk and Townes.[2]

The observed spectrum consists of some 55 lines extending from 19,940 Mc/sec to 25,656 Mc/sec with only a few scattered lines between 23,790 Mc/sec and 24,980 Mc/sec suggesting two groupings of lines. The region from 25,656 Mc/sec to 25,920 Mc/sec which is the present upper limit of our equipment is void of lines. The complete tabulation of lines is shown in Table I, where the frequencies are given to an estimated 5 Mc/sec as measured by a wavemeter calibrated against the known frequencies of the NH_3 lines.[2]

TABLE I. Methyl mercaptan microwave spectra. Frequencies are known to an estimated 5 Mc/sec.

Frequency (Mc/sec)	Frequency (Mc/sec)	Frequency (Mc/sec)
19,909	22,414	24,485
19,996	22,558.0	24,995
20,052	22,561.2[a]	25,015
20,136	22,663	25,125
20,163	22,830	25,145.0
20,380	23,071.5	25,147.0[a]
20,645	23,075.0[a]	25,150.5
20,712.5	23,233[b]	25,152.0[a]
20,714.0[a]	23,260	25,210
21,058	23,340	25,225
21,522	23,500	25,290.0
21,735	23,525.0	25,290.4[a]
21,770	23,532.3[a]	25,565
21,866	23,565	25,660
21,878	23,622	
21,903	23,780	
21,945	23,805	
21,976	23,995	
22,270	24,072	
22,333	24,420	
	24,455	

[a] For each pair of lines so marked the separation of the two lines of the pair is known to an estimated 20 percent and the mean frequency of the pair to 5 Mc/sec.

[b] The accuracy of this frequency assignment is considered to be good to 0.5 Mc/sec. This is known by reference to an ammonia line at 23,232.20 Mc/sec.

The interpretation of this spectrum has not yet been achieved. The CH_3SH molecule is a slightly asymmetric rotator with moments of inertia for the S^{32} isotope[3] consistent with a pure rotational transition $J_0=0\rightarrow J_0=1$ at approximately 24,600 Mc/sec. Because of the small Boltzmann factor for all vibrational levels other than $v_i=0$ this transition would be expected to yield a single strong line accompanied by a large number of extremely weak lines due to the excited vibrational levels. The 4.18 percent naturally occurring S^{34} would give a similar spectrum of intensity ratio 1 to 24 with respect to that of S^{32}. The observed spectrum does not fit this scheme. There exists, however, the splitting of the torsional vibration $v=0$ level into three levels as a result of hindered internal rotation. This splitting depends upon the quantum number K in a complex manner.[4] Transitions between these levels could easily yield the large number of lines observed.

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β-Recoil Experiments with Kr^{89}

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THE maximum energy and the average value of the energy divided by the charge of the recoil from the β-decay of Kr^{89} have been measured. The experimental method is similar to that used previously[1] in the investigation of recoils from Kr^{88}. However, the technique has been improved in order to permit a study of short-lived activities since the half-life of Kr^{89} (3.18 min) is much shorter than that of Kr^{88} (2.77 hr).

The following results were obtained. The maximum recoil energy is equal to 115±5 ev corresponding to a maximum β-energy of 3.9±0.1 Mev. This agrees with the value 4.0 Mev found from absorption measurements.[2] The average value of the energy divided by the charge of the recoils amounts to 58±2 ev. The charge is always $\geqslant 1$ and consequently 58 ev is a lower limit for the average recoil energy. Because of the uncertainty of the charge of the recoil atoms and the incomplete knowledge of the decay scheme the results do not permit a detailed comparison with the various possible angular correlations in β-decay.[3] However, certain possibilities may be excluded; in particular the data seem difficult to reconcile with the assumption of a backward neutrino emission with respect to the direction of emission of the β-particle. A forward neutrino emission would also in general be expected if the β-decay is forbidden, as seems to be the case for Kr^{89} judging from the ft value.

The half-life of Kr^{89} was measured, and the result, 3.14 min, agrees with the result found in the mass spectroscopic investigation.[2] Also the relative fission yield of mass numbers 88 and 89 was estimated. The result is $y_{89}/y_{88}=1.5\pm0.2$.

A more detailed account of these experiments will be published elsewhere.[4]

We wish to express our gratitude to Professor N. Bohr and to Professor J. C. Jacobsen for their interest in our work.

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Short-Lived Krypton Isotopes and Their Daughter Substances

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THE isotopes Kr^{89}, Kr^{90}, Kr^{91}, and their daughter substances have been investigated. Krypton formed in fission of uranium was pumped through a 10-m long tube directly from the cyclotron into the ion source of the isotope separator. The cyclotron and the isotope separator were operated simultaneously, and the counting could begin immediately after the interruption of the separation. The rubidium and strontium daughter substances were separated chemically; strontium was precipitated as carbonate. Half-lives were measured and an absorption analysis of the radiations was carried out. The results are given in Table I.

TABLE I. Observed radiations.

Isotope	Half-life	Radiation	$E_\beta^{\max}$	Spectrum
Kr^{89}	3.18 min (2.6)	β^-, γ	4.0 Mev	Complex
Kr^{90}	33 sec (33)	β^-, γ	3.2 Mev	Complex
Rb^{90}	2.74 min	β^-, γ	5.7 Mev	Complex
Kr^{91}	10 sec (9.8)	β^-, γ probable	~3.6 Mev	Complex
Rb^{91}	100 sec	β^-, γ	4.6 Mev	Complex
Rb^{91}	14 min	β^-, γ	3.0 Mev	Complex

Previous data (see N.B.S. Circular 499: Nuclear Data) are given in parentheses.

It was found that at least 35 percent of the decays of Kr^{89} lead to an excited state of Rb^{89} which lies ~2 Mev above the ground state. This result is of importance for the interpretation of the β-recoil experiments with this krypton isotope.[1]