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

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.

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]

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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[1] W. E. Good, Westinghouse Research Paper 1538.
[2] P. Kisliuk and C. H. Townes, J. Research Natl. Bur. Standards **44**, 611 (1950).
[3] Russel, Osborne, and Yost, J. Am. Chem. Soc. **64**, 165 (1942).
[4] Koehler and Dennison, Phys. Rev. **57**, 1006 (1940).

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]

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[1] J. C. Jacobsen and O. Kofoed-Hansen, Phys. Rev. **73**, 675 (1948).
[2] O. Kofoed-Hansen and K. O. Nielsen, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. See also O. Kofoed-Hansen and K. O. Nielsen, Phys. Rev., following letter.
[3] D. R. Hamilton, Phys. Rev. **71**, 457 (1947).
[4] O. Kofoed-Hansen and P. Kristensen, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. (to be published).

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_β^{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]

Furthermore it was found that Rb^{91} has an isomeric state. Both these states of Rb^{91} (half-lives 100 sec and 14 min, respectively) decay to the well-known Sr^{91} 9.7 hr which again decays to the 60-day and the 50-min isomers of Y^{91}. All these radioactivities were found in the samples of mass number 91.

A more detailed account of the experiments will be published elsewhere.[2]

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[1] O. Kofoed-Hansen and P. Kristensen, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. (to be published); see also Phys. Rev., preceding letter.
[2] O. Kofoed-Hansen and K. O. Nielsen Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. (to be published).

The Nuclear Magnetic Moment of I^{129}

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The nuclear resonance of long-lived radioactive I^{129} has been observed in a nuclear induction apparatus of the type originated by F. Bloch and similar to that recently described by Proctor.[1] The sample contained 33 mg of total iodine, as iodide, in a hydrazine solution. The iodine was isolated from fission products by one of the authors (G. H.). The I^{129} content was estimated to be 80 percent, the remainder being stable I^{127}. Heavy water was added to the solution, and all frequency ratio measurements were relative to deuterium. No magnetic catalyst was added. Frequency measurements were made with a Signal Corps type BC-221 frequency meter calibrated with harmonics from an external 100 kc, crystal-controlled oscillator which in turn was compared with WWV at 10 Mc. Frequency measurements made at nominal fields of 9500 and 12,200 gauss gave

$$\nu(I^{129})/\nu(D)=0.86744\pm0.0001.$$

Measurements were also made on I^{127}, but, since the resonance was weak in the original sample, a separate, chemically similar solution was used with a larger amount of I^{127} added. Measurements at nominal fields of 7500 and 9300 gauss gave

$$\nu(I^{127})/\nu(D)=1.30337\pm0.0002.$$

Measurements on I^{127} were also made in a sodium iodide solution and were not significantly different from the above.

Using Levinthal's[2] deuteron-to-proton frequency ratio of 0.1535059, the above ratios yield the following frequency ratios relative to the proton:

$$\nu(I^{129})/\nu(H)=0.13316$$
$$\nu(I^{127})/\nu(H)=0.20007_5.$$

With an iodine diamagnetic correction of 0.545 percent,[3] a spin of 7/2 for I^{129} [4] and 5/2 for I^{127},[5] and a value of 2.79268 nuclear magnetons[6] for the proton moment, these ratios give the following values of nuclear magnetic moments, in units of the nuclear magneton

$$\mu(I^{129})=+2.6173\pm0.0003$$
$$\mu(I^{127})=+2.8090\pm0.0004$$
$$\mu(I^{127})/\mu(I^{129})=1.0732.$$

The indicated estimated accuracy of the above values does not include the uncertainty in the diamagnetic correction. The sign of the I^{129} magnetic moment was obtained by comparison with I^{127} and D which are known to be positive.[1]

A previous measurement[7] of the nuclear magnetic moment of I^{129} made by microwave spectroscopy gave 2.74±0.14 nuclear magnetons, which is consistent with the above value. The I^{127} results can conveniently be compared with published data in terms of the ratio of the I^{127} frequency to the proton frequency. Pound's[8] ratio for I^{127} relative to Na^{23}, 0.75664±0.0002, has been converted to the ratio relative to the proton by using Bitter's[9] Na^{23}-to-proton ratio of 0.26450±0.000026. This ratio and the ratio relative to the proton determined by Zimmerman and Williams[10] are compared below with the ratio obtained in this work.

$\nu(I^{127})/\nu(H)$	
0.20013 ±0.00005	Pound
0.20003 ±0.00007	Zimmerman and Williams
0.20007_5±0.00003	This work.

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‡ Work performed under contract with the AEC.

[1] W. G. Proctor, Phys. Rev. **79**, 35 (1950).
[2] E. C. Levinthal, Phys. Rev. **78**, 204 (1950).
[3] W. C. Dickinson, Phys. Rev. **80**, 563 (1950).
[4] Livingston, Gilliam, and Gordy, Phys. Rev. **76**, 149 (1949).
[5] S. Tolansky, Proc. Roy. Soc. (London) **A-170**, 205 (1939).
[6] Sommer, Thomas, and Hipple, Phys. Rev. **80**, 487 (1950).
[7] Gordy, Gilliam, and Livingston, Phys. Rev. **76**, 443 (1949).
[8] R. V. Pound, Phys. Rev. **73**, 1112 (1948).
[9] F. Bitter, Phys. Rev. **75**, 1326 (1949).
[10] J. R. Zimmerman and D. Williams, Phys. Rev. **76**, 350 (1949).

Evidence Concerning the Reaction $p+p\rightarrow\pi^{+}+d$*

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The mesons produced by protons on protons have been reported[1,2] by various observers. The strong forward high energy peak in the cross section found in the early work indicated that a deuteron may be produced in the reaction. The shape of the peak and the energetics of the reaction have given further evidence that this is the case.[3,4]

We have observed the reaction $p+p\rightarrow\pi^{+}+d$ by coincidence counting technique. By using a magnetic field to determine the momentum of the particles and finding the range of both in aluminum, we have essentially identified the reaction products by measuring the masses of both the meson and deuteron.

The arrangement is shown in Fig. 1. The 340-Mev external proton beam of the Berkeley cyclotron strikes a 1-inch thick polyethylene target. Typical trajectories are shown for the meson and deuteron in the forward direction. The orbits were located by using a wire with known current and tension. Each counter

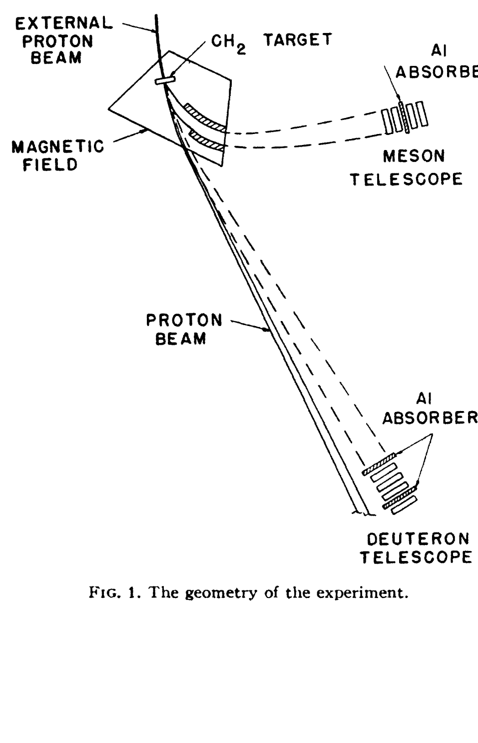

FIG. 1. The geometry of the experiment.