states of Co^{59} and Cu^{63}. No experimental evidence was secured for the existence of such states in the disintegration of Ni^{59} and Ni^{63}.

We greatly appreciate the financial help given by the Graduate School for this research and the grant-in-aid for the construction of equipment extended by The Ohio State University Development Fund.

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Non-Linear I-V Characteristic of Ge at Very Low Temperatures

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BOTH Estermann[1] and Gerritsen[2] have found in pure Ge samples, in the temperature region of liquid He, that the current-voltage relation is non-linear and usually shows a small asymmetry. At sufficiently high temperatures, however, the non-linearity and asymmetry disappear and at room temperature, a linear $I-V$ characteristic is found.

These facts may be qualitatively understood if we assume, as was done by Estermann, that in the "pure" samples, the concentrations of donors and acceptors are (almost) equal. In that case, we must expect local fluctuations in the concentrations causing the existence of n type domains and p type domains with $n-p$ barriers between them. As has been pointed out by James,[3] who considered an analogous situation for PbS, we may expect that the domains will combine to form a small number of continuous n type paths or p type paths. In each path there will be islands and pensinsulas of the other type. The current will mainly flow in the n paths and p paths, avoiding the islands and peninsulas and therefore it uses only a fraction of the total cross section. This is so because the $n-p$ barriers are quite high at low temperatures namely about 0.7 ev for Ge.

A qualitative explanation of the observed non-linear $I-V$ characteristic follows now directly from the above picture. For let us consider a p type island in an n type path with the electron current flowing in the direction of the arrow (see Fig. 1). The flow

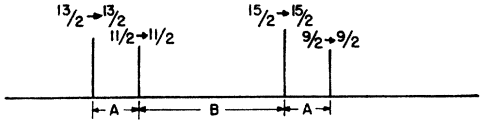

FIG. 1.

through the island will be prevented by barrier a as the flow is in the backward direction for this barrier. As soon, however, as the voltage over the specimen has been increased to such a value that the voltage difference between a and b becomes 0.7 V, the barrier at a will be wiped out and the current will flow through the island too. An analogous reasoning holds for the peninsulas. Also if a favorable voltage difference develops between a certain point of an n path and the adjacent point of a p path, the barrier between them may break down, thus causing a more favorable flow pattern. The described effects will cause a non-linear $I-V$ characteristic of the observed type in which the current increases "too much" with increasing voltage. At higher temperatures the effect will be much less marked because the conductivity increases so quickly that it will be hard to build up sufficient voltage between a and b without causing disturbing heat effects at the same time.

The slope of the characteristic at $V=0$ gives the resistance of the continuous n paths and p paths and its temperature dependence should be characteristic of the material without barriers.

In order to account for the asymmetry we must realize that the electron current can pass from the p path to the adjacent n path but not in the other direction. Therefore, the flow pattern will usually not be the same for both directions of applied voltage. As, however, there are a large number of obstructions for the current in both directions we must expect only a small resultant asymmetry. As this asymmetry is caused by the recifying property of $n-p$ barriers, it will not show up for voltage drops across the barrier corresponding with kT. Therefore we will find less asymmetry at higher temperatures where the applied voltage will be low in order to limit the current density. Furthermore, the barrier height is less at higher temperatures.

The shape of the $I-V$ characteristic is determined by the distribution of the $n-p$ barriers and the conductivities of the n and p paths. The fact that the shape of the $I-V$ characteristic is almost invariant with temperature in the liquid He range is in accordance with the experimental result that the conductivity of the n and p paths is independent of temperature in that range. However, an explanation for this behavior of the conductivity appears to be missing.

If the above considerations are correct we expect the high frequency resistance of pure Ge in the liquid He range to be considerably lower than the d.c. resistance and the $I-V$ characteristic shluld be linear at very high frequencies.

The author is indebted to Professor G. E. Uhlenbeck and Dr. I. Estermann for their encouragement and advice.

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A Preliminary Report on the Fine Structure of the Microwave Absorption Spectrum of Oxygen*

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USING a Zeeman modulation spectrograph, we have observed the microwave absorption spectrum of oxygen at low pressures ($\sim 10^{-1}$ millimeters of Hg), where the fine structure is completely resolved. Though several previous studies of the microwave absorption of oxygen have been made at pressures of the order of an atmosphere, no one has before detected this absorption at sufficiently low pressures to resolve completely the fine structure,** which has been theoretically predicted by Van Vleck.[1] Some experimental evidence for the fine structure was obtained by Beringer[2] in his wartime measurement of the resonance absorption of oxygen in the region of 5 millimeters wave-length. Recently, this work has been repeated by Strandberg, Meng, and Ingersoll[3] at pressures of 80 cm of Hg with the result that somewhat better evidence was obtained for the fine structure. The overlapping absorption of many lines at such high pressure prevented the accurate measurement of several properties of oxygen such as the line breadth parameter and the spacing of the fine structure levels.

In our work an absorption line is detected by a narrow-band, phase sensitive detector and is displayed on an Esterline Angus Automatic Recorder. The receiver operates at 4000 c.p.s. The absorption lines are modulated at the same frequency with an alternating magnetic field, which is applied by means of a solenoid which is placed around the wave guide cell. The field strength used in modulation is usually the order of a gauss. To reduce eddy currents, the wave guide cell is slotted down the center.

So far, sixteen of the fine structure lines have been detected and measured with a cavity wave meter. These tentative frequencies are listed in Table I. They are now being measured more precisely

TABLE I.

K	Transition*	Theoretical freq.** mc/sec.	Actual freq.† mc/sec.
11	−	57,620	57,610
9	−	58,330	58,330
3	+	58,460	58,420
7	−	59,170	59,160
5	+	59,600	59,610
7	+	60,430	60,440
9	+	61,140	61,120
11	+	61,780	61,800
13	+	62,380	62,420
3	−	62,470	62,480
15	+	62,960	62,970
17	+	63,520	63,530
19	+	64,060	64,100
21	+	64,630	64,640
23	+	65,140	65,220
25	+	65,680	65,770

* (+) indicates $J=K+1\rightarrow K$, (−) indicates $J=K-1\rightarrow K$.
** From Schlapp formulas, R. Schlapp, Phys. Rev. **51**, 342 (1937).
† Actual frequency tentatively measured as $f/2$ wave meter accuracy. Estimated error ~15 mc/sec., now being remeasured with a frequency standard.

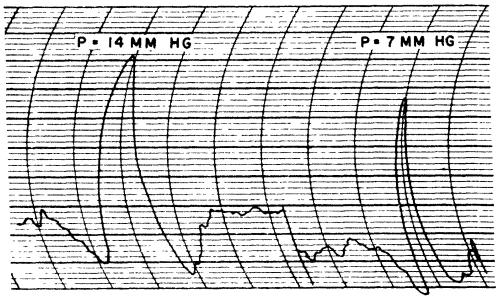

FIG. 1. Recorder tracing of the $J=12\rightarrow11$, $K=11$ transition of oxygen at pressures of 14 and 7 mm of Hg.

with an electronic frequency standard monitored by station WWV. Figure 1 shows the recorder tracings of one of these lines at different pressures. Over the range of pressures so far studied, the line breadth appears to be proportional to the first power of the pressure. The observed frequencies agree with the theoretical ones within experimental error (about ±15 = mc) for low K values, but a consistent deviation is observed for high K numbers. Reassignment of theoretical parameters will be made when the precision frequency measurements are completed.

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** The interesting recent work of Beringer in the 3-cm wave region, which included measurements at pressures down to 1.5 cm of Hg was concerned with paramagnetic relaxation in a strong magnetic field (R. Beringer, Phys. Rev. **70**, 53 (1946)).
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Lifetimes of Mercury and Potassium Atoms in Excited States

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FOR any $S-P$ transition, the lifetime T is given by the equation

$$T^{-1}=\frac{1}{2JH}\frac{64\pi^4\nu^3}{3hc^3}\Sigma|\psi_i r\psi_f d\tau|^2=3.54\times10^5\,(\text{energy emitted in ev})^3\times\left[\int_0^\infty S_i r^3 S_f dr\right]^2\text{sec.}^{-1},\quad(1)$$

TABLE I. Calculated and observed lifetimes for $S-P$ transitions in mercury and potassium.

Atom	Calculated lifetime	Observed lifetime	Observer	Year
Mercury	0.6×10^{-9} sec.	0.3×10^{-9} sec.	Garrett[1]	1932
		1.6×10^{-9} sec.	Ladenburg and Wolfsohn[2]	1930
		1.3×10^{-9} sec.	Wolfsohn[3]	1930
Potassium	2.28×10^{-8} sec.	2.7×10^{-8} sec.	Weiler[4]	1939

where

$$S=Pr^{-\frac{1}{2}}.$$

Using the above formula the lifetimes of the excited mercury and potassium atoms were calculated. The ground state of mercury is $(6S)^2$ and that of potassium $4S$. The radial wave functions of the above ground states have been calculated by Hartree. Using the same self-consistent field method $6P$ and $4P$ wave functions of mercury and potassium atoms were calculated and the lifetime was evaluated by Eq. (1). Observation of Table I will indicate that the agreement between theoretical and experimental values is satisfactory. The high accuracy of potassium is due to polarization of the core being taken into consideration in the calculation of the wave function.

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On the Nature of the π-Meson

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WE want to discuss briefly some aspects of the question of the nature of the π-meson. Following a well-known argument of Oppenheimer and Serber[1] it seems quite proved that the spin of the π-meson is integral, and so we have only two reasonable possibilities for its spin: either it is one or zero. Professor Wentzel[2] has already suggested a method of distinguishing between these two possibilities; furthermore, there are several theoretical reasons which make unlikely the existence of elementary particles having spin one.[3]

We want, therefore, to discuss now the spin zero possibility only. If we were sure that the nuclear forces are due to the π-mesons only, we could conclude that they cannot be scalar. However, we are not sure that this is really the case, and the question, therefore, whether the π-mesons are scalar or pseudoscalar remains open. It has been pointed out, for instance, that the cross section of production of a π-meson by a gamma-ray should increase with the energy just above the threshold more quickly in the case of the scalar meson than in the case of a pseudoscalar meson.[4] There are already some data about the production of mesons by gamma-rays;[5] however, it is not clear whether the energy dependence of the relevant cross section is modified by the fact that in the actual case the production process takes place in a complex nucleus and not in a single nucleon, as it is supposed in the calculations. In order to decide experimentally the question whether the π-meson is scalar or pseudoscalar, it seems therefore surer to devise an experiment in which only a simple process and a very simple nucleus are involved. Such a very simple nucleus could be a nucleus of hydrogen or deuterium only. One of us[6] has already considered the absorption process of a meson in deuterium, pointing out that scalar and pseudoscalar mesons of a very low energy should behave very differently with respect to such a process. In fact, owing to the Pauli exclusion principle, scalar meson waves of even azimuthal quantum number cannot be