

the energy of the hydrogen bond derived from the heat of sublimation.^{4,5}

¹ Murphy and Morgan, *Bell Sys. Tech. J.* **38**, 502 (1939).

² Pauling, *Nature of the Chemical Bond* (Cornell University Press, Ithaca, New York, 1945), p. 301.

³ Schaeffer and Matossi, *Das Ultrarote Spektrum* (Verlag. Julius Springer, Berlin, 1930), p. 243.

⁴ Fox and Martin, *Trans. Faraday Soc.* **36**, 910 (1940).

⁵ Bernal and Fowler, *J. Chem. Phys.* **1**, 515 (1933).

An Attempt to Detect Thermal Energy Positrons*

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IT has been assumed that positrons diffuse through a solid during their lifetime.¹ It was considered worth investigating whether they would diffuse through and out of various materials. The number, n_s , of positrons of thermal energies diffusing out of a unit surface per unit time can be estimated as follows. The "average diffusion length" L is expressed by the formula $L = (\frac{1}{3}\lambda v\tau)^{\frac{1}{2}}$, where λ is the mean free path for elastic collisions, v the average thermal velocity, and τ the mean life. Assuming λ to be of the order of 10^{-8} cm, τ of the order¹ of 10^{-9} sec., the average diffusion length in a heavy metal would be of the order of $6 \cdot 10^{-6}$ cm. This means that the number of thermal positrons diffusing out of a metal should be of the order of the number of positrons stopped in a layer $6 \cdot 10^{-6}$ cm thick. This number may be compared with the number, n_f , of fast positrons emitted by the same material, assuming the radioactive atoms to be uniformly distributed. Fast positrons emerge from a layer of thickness equal to the range, or rather, in view of the continuous energy spectrum, of the order of the reciprocal of the absorption coefficient.

An experiment was attempted using as sources copper foils of initial activity of the order of 10 to 30 mC. The absorption coefficient of the positrons of Cu^{64} in copper may be taken² as 30 cm^2/g , hence fast positrons emerge from a layer 0.032 g/cm^2 or 0.0038 cm thick. Then the ratio n_s/n_f should be of the order of $5 \cdot 10^{-3}$.

In order to detect a small fraction of thermal energy positrons above the larger background of fast positrons, the following arrangement was used. The positron source was mounted at one end of an evacuated tube, containing, at a distance of 80 cm from the source, a thin aluminum foil kept at a negative potential and acting as positron collector. A pair of scintillation counters, placed opposite the collector and at 180° from each other, detected the positrons falling on the collector by means of coincidences between the two quanta of the annihilation radiation. The collector subtended approximately 5×10^{-5} of the total solid angle from the source, hence it absorbed less than that fraction of the fast positrons emerging from the copper foil. To increase the efficiency of collection of slow positrons, the tube was placed in an axial magnetic field of the order of 100 gauss. The tube, including a grid placed at 1 cm from the source, was at zero potential, and the source was either at +150 or -150 volts. Under these conditions with a positive source potential we expect the collector to capture most of the emerging thermal energy positrons, whereas none would reach the collector when the source is at a negative potential. From this calculation we might expect the effect of the thermal energy positrons, given by the difference in the numbers of counts with positive and negative source potentials, to be as much as 100 times greater than the fast positron background. Even allowing for a margin of error in the estimate of the mean life and mean free path, there should still be a considerable effect.

No difference in the number of counts exceeding the statistical error (about five percent) was observed. In order to avoid the possible unfavorable effect of the oxide layer on the copper surface, clean surfaces of various materials were used. A thin platinum foil heated at 1450°C in order to eliminate surface layers of adsorbed gases and other impurities gave negative results. No effect was

observed with potassium evaporated in vacuum. Finally, assuming that positrons might diffuse in a liquid but not in a solid, we tried a thin, liquid layer of gallium evaporated in vacuum, and also obtained a negative result. No effect was observed with insulating layers of glass, mica, celluloid, and octoil.

In all these experiments the annihilation radiation from fast positrons reaching the collector was readily detectable, giving 20 to 100 counts per minute. The number of counts was almost doubled when the magnetic field was turned on, owing to partial focusing of the low energy portion of the positron spectrum. However, the effect was totally insensitive to the polarity of the source potential, showing that it was not due to positrons with energies of less than 150 ev.

In order to be certain that failure to observe the effect was not due to improper arrangement of the electric and magnetic fields, insufficiently good vacuum, or other imperfect experimental conditions, the identical arrangement was tested with electrons by coating the above-mentioned platinum foil with emitting oxides. With the filament at -150 volt, we immediately recorded large currents on the collector, even with much weaker magnetic fields than had been used in the previous experiments, showing the high efficiency of our focusing arrangement.

The conclusion is that thermal energy positrons do not appear to diffuse out of solids or liquids. Possible reasons are: (1) positrons do not diffuse through a crystal lattice, but are trapped in potential minima and annihilate before moving appreciable distances; (2) positrons diffuse through the lattice but are trapped at the surface; and (3) positronium is formed, and even if it should diffuse out of the material, it would not be detected in these experiments.

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* This document is based on work performed for the AEC.

¹ DeBenedetti, Cowan, Konneker, and Primakoff, *Phys. Rev.* **77**, 205 (1950).

² E. Bleuler and W. Zünti, *Helv. Phys. Acta* **19**, 375 (1946).

Nuclear Magnetic Resonance in Metallic Hydrides

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THE method of nuclear magnetic resonance has been applied to the determination of the resonance absorption line widths at room temperature in some of the metal hydrides. The latter range in structure from true compounds to absorption mixtures, interstitial compounds, and solid solutions. It is frequently difficult to decide, in the cases of certain hydrides, which of these structures is present, especially since the same hydride may have different structures depending on the concentration of hydrogen present. Thus, palladium hydride is thought to exist as two immiscible solid solutions approaching a true compound as the concentration of hydrogen is increased.¹ As the concentration of hydrogen increases, tantalum is believed to go from a body-centered cubic phase to a hexagonal phase and back again to a body-centered cubic phase.¹ In some of these it is difficult to make out whether the hydrogen atoms or molecules wander freely through the metal lattice or cluster about certain fixed positions. A clue as to these possibilities is offered by observations of the nuclear magnetic absorption line widths due to proton resonance.

The experimental apparatus was similar to that of Bloembergen, Purcell, and Pound² except for the use of a twin T radio-frequency bridge. A phase-sensitive detector of about 1-cycle band width was used, since the resonance signals were too weak to be observed directly on an oscilloscope.

The spread between the maximum and minimum slopes of the absorption lines, as indicated on the output meter of the lock-in amplifier, was taken as a measure of the line width. The resonances

were observed as 28 Mc in a magnet which had a field inhomogeneity of about one gauss over the volume occupied by most of the samples.

Of the various metallic hydrides which were available to us, the line width data of titanium and tantalum are most significant.³ The titanium hydride was available with hydrogen concentrations of 157, 72, and 38 atomic percent.⁴ The absorption line measured was 12 gauss wide, within 10 percent accuracy and was independent of hydrogen concentration to this accuracy. This is quite a broad line and indicates on the one hand that line narrowing, due to internal motion of the hydrogen, is not a strong effect and that the hydrogen atoms present are sufficiently close, probably in molecular form, to allow the strong interaction necessary to produce a broad line. The lattice is thus a rigid one, the hydrogen molecules remaining in relatively fixed positions. The fact that changes in concentration do not affect the line widths shows further that the molecules settle into these fixed positions even when they are few in number and that any phase changes due to changes in concentration do not affect materially the relative distances of the interacting protons.

In contrast to this is the case of tantalum hydride which for all concentrations tried (66.9, 40.8, 24.5, and 11 percent) has a very narrow line width of less than one gauss. In this case the width was determined by the inhomogeneity of the magnetic field over the samples. Thus, rapid internal motion is indicated. According to the theory proposed by Bloembergen, Purcell, and Pound,² such motion in the case of liquids will produce a narrowing in the absorption line. Similarly, in the case of certain solids narrowing due to internal motion is known to occur.⁵ To determine more precisely the kind of internal motion producing this narrowing it will be necessary to measure temperature effects on the line widths. The results of such measurements will be submitted in a more detailed report in the near future.³

The remaining hydrides examined are known to be true compounds which absorb hydrogen in a fundamentally different way. They are of lesser interest and are merely recorded here with their absorption line widths:

Calcium hydride	9.9 gauss
Lithium aluminum hydride	8.7 gauss
Sodium hydride	6.3 gauss
Lithium boron hydride	6.0 gauss
Sodium boron hydride	6.0 gauss.

¹ C. J. Smithells, *Gases and Metals* (Chapman and Hall, Ltd., London, 1937); F. Ephraim, *Inorganic Chemistry* (Oliver and Boyd, Ltd., Edinburgh, 1943).

² Bloembergen, Purcell, and Pound, *Phys. Rev.* **73**, 679 (1948).

³ In the same class as titanium and tantalum, to be investigated, are the hydrides of palladium, zirconium, vanadium, thorium, and cerium. Line widths and measurements of relaxation times down to low temperatures on these hydrides will be reported on in the near future.

⁴ The atomic percent is defined as the ratio of the number of atoms of hydrogen to that of the metal.

⁵ Gutowsky, Kistiakowsky, Pake, and Purcell, *J. Chem. Phys.* **17**, 972 (1949).

Internal Conversion of the Gamma-Rays from Rh¹⁰⁶

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THE cascade gamma-rays emitted in about 17 percent¹ of the disintegrations of Rh¹⁰⁶ exhibit very pronounced angular and polarization correlations.^{2,3} The coefficients of these correlations, however, do not fit any of the predictions⁴ for the possible combinations of quadrupole transitions and the existence of a strong cos³-term eliminates pure dipole radiation. Moreover, an investigation of the interference effects in the case of mixed dipole and quadrupole radiations⁵ was not able to explain the experimental data. Therefore, if one accepted the disintegration scheme proposed by Peacock,¹ he was compelled to attribute at least one of

the two gamma-rays to transitions of multipole orders higher than quadrupole.⁶

For electric octupole radiation, which is the least converted of the higher multipole radiations, the tables of Rose *et al.*⁶ give *K* conversion coefficients of $(13.4 \pm 1.5) \times 10^{-3}$ and $(4.5 \pm 0.4) \times 10^{-3}$ for the gamma-ray energies of 0.51 ± 0.02 Mev and 0.73 ± 0.02 Mev, respectively.¹ As these conversion coefficients are of an order of magnitude which can be determined experimentally even in the presence of an intense beta-ray spectrum, we investigated the electron spectrum⁷ of Rh¹⁰⁶ with a thin lens spectrometer.

For the evaluation of our data we used the value of 18 percent given by Peacock¹ for the abundance of the 2.3-Mev partial beta-ray spectrum. We assumed that 17 percent of all disintegrations give rise to the gamma-ray cascade. The remaining one percent was attributed to the 1.25-Mev transition, although the position of this line in the disintegration scheme has not been determined beyond doubt. The experimental values for the *K* conversion coefficients (N_e/N_γ) obtained under these assumptions, are compared in Table I with the theoretical values⁶ for electric quadrupole and electric octupole transitions.

TABLE I. Internal conversion of Pd¹⁰⁶ gamma-rays.

<i>E</i> (Mev)	Exp. value $\alpha_K \times 10^3$	Theoretical values	
		El. quadrupole $\alpha_K \times 10^3$	El. octupole $\alpha_K \times 10^3$
0.51	5.4 ± 1.5	4.90	13.4
0.73 ^a	<2.5	1.95	4.5

^a Owing to the small conversion we can only give an upper limit for the conversion coefficient of this line. The resolution of the spectrometer was three percent.

The error indicated takes care of the uncertainty in the knowledge of the abundance of the partial beta-ray spectrum (18 ± 2 percent).

From Table I it is evident that neither of the two main transitions in Pd¹⁰⁶ can be of a multipole order higher than quadrupole. Thus the results of our conversion measurements sharply contradict the conclusions drawn from the correlation experiments. In order to explain both results, we must assume that the disintegration scheme used so far¹ does not represent the actual situation in detail. These conclusions are in line with an observation of Goldhaber, der Mateosian, and Katcoff⁸ that there is present to two to three percent a hard gamma-ray with an energy above the photo-threshold of deuterium, and also with a recent statement of Spiers⁹ that it might be necessary to assume a more complicated decay scheme in order to explain the correlation data.

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¹ W. C. Peacock, *Phys. Rev.* **72**, 1049 (1947).

² E. L. Brady and M. Deutsch, *Phys. Rev.* **74**, 1541 (1948).

³ M. Deutsch and F. Metzger, *Phys. Rev.* **74**, 1542 (1948).

⁴ D. R. Hamilton, *Phys. Rev.* **58**, 122 (1940).

⁵ D. J. Ling and D. L. Falkoff, *Phys. Rev.* **76**, 431, 1639 (1949).

⁶ Rose, Goertzel, Spinrad, Harr, and Strong, *Phys. Rev.* **76**, 104 (1949).

⁷ The radioactive material was obtained from Oak Ridge.

⁸ M. Goldhaber (private communication).

⁹ J. A. Spiers, *Phys. Rev.* **78**, 75 (1950).

On the Isotope Effect in Superconductors

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THE occurrence of the diamagnetic currents and their stability in the presence of the thermal vibrations of the lattice above the absolute zero of temperature is a primary phenomenon which is difficult to explain in developing an atomistic theory of super-