

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 $30 \text{ cm}^2/\text{g}$, hence fast positrons emerge from a layer $0.032 \text{ g}/\text{cm}^2$ 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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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