

We know that³

$$|\Gamma(\alpha + i\beta)| = \frac{\Gamma(1 + \alpha)}{\alpha} \prod_{n=0}^{\infty} \left[1 + \frac{\beta^2}{(\alpha + n)^2} \right]^{-1}, \quad (3)$$

where α and β are real. Making use of relation (3) we have

$$F(z, W) = f p^{2s-2} e^{\pi\delta} \prod_{n=0}^{\infty} \left[1 + \frac{\delta^2}{(s+n)^2} \right]^{-1}, \quad (4)$$

where f is a factor independent of W . If we set $s=1$, we have the nonrelativistic Kurie approximation

$$F_k = f e^{\pi\delta} \prod_{n=0}^{\infty} \left[1 + \frac{\delta^2}{(n+1)^2} \right]^{-1} \\ = f 2\pi\delta / (1 - e^{-2\pi\delta}). \quad (5)$$

Therefore

$$F = F_k p^{2s-2} \prod_{n=0}^{\infty} \left\{ \left[1 + \frac{\delta^2}{(n+1)^2} \right] / \left[1 + \frac{\delta^2}{(n+s)^2} \right] \right\}. \quad (6)$$

The infinite product in (6) converges at a reasonable rate. Table I gives the accuracy of the different prevailing approximations for the three typical cases of the light nucleus S^{36} , the medium nucleus Cu^{64} (negatron emission), and the heavy nucleus RaE , and the comparison with the exact calculations. In this table F is an abbreviation for $F(z, W)$ as given in Eq. (6), F_B denotes Bethe's approximation

$$F_B = F_k p^{2s-2} (\delta^2 + \frac{1}{4})^{s-1}, \quad (7)$$

F_F denotes Fermi's approximation for heavy nuclei

$$F_F = 1/p - 0.355 \quad (8)$$

where p is the momentum in units of mc.

* This research was assisted by the joint program of the ONR and AEC. † Present address: National Research Council, Ottawa, Canada.

¹ C. Longmire and H. Brown, *Phys. Rev.* **75**, 264 (1949); I. Feister, *Phys. Rev.* **78**, 375 (1950); H. Hall, *Phys. Rev.* **79**, 745 (1950).

² E. J. Konopinski, *Revs. Modern Phys.* **15**, 209 (1943).

³ Godefroy, *La Fonction Gamma* (1901), p. 14.

Internal Motion of Hydrogen Absorbed in Tantalum

MARTIN A. GARSTENS

Electricity Division, Naval Research Laboratory, Washington, D. C.

November 30, 1950

THE metals which absorb hydrogen are usually divided into two groups, the so-called good absorbers (Ti, Zr, Th, V, Ta, Pd), which have decreasing solubility of hydrogen with temperature, and the poor absorbers (Ni, Fe, Co, Cu), which have increasing solubility of hydrogen with temperature. The poor absorbers are thought to allow the protons to move freely through the lattice without any effect on the lattice structure whereas the good absorbers are believed to form definite metal hydrides having a different lattice structure from the pure metal. The latter are supposed to have the hydrogen atoms tightly bound to the metal atoms.¹

Previous observations of nuclear magnetic resonance² absorption lines indicated, however, that in tantalum the protons have strong internal motion at room temperature. To verify this result further an experiment was performed to freeze in the proton motion by lowering the temperatures of the tantalum lattice. This was done successfully at a temperature of about 215°K. Beginning with a line width of less than one gauss at room temperature the line remains narrow down to 215°K. Over a range of 20° about this point it undergoes a pronounced widening, indicating that the protons are being frozen in position.

Thus in the range of temperature where solubility measurements of hydrogen in metals have been made in the past³ (i.e., from room temperature up) our experiment indicates that the hydrogen atoms are not tightly bound to the metal atoms. In this respect tantalum resembles the poor absorbers.

The tantalum sample was in powdered form and had a hydrogen concentration of 53.5 atomic percent. Previous observation showed that the line width, at least at room temperature, was not affected appreciably by the degree of concentration of hydrogen. However, at this temperature the tantalum line is so narrow as to be determined by the magnetic field inhomogeneity so that small differences in line width due to differences in concentration may be masked.

Specific heat anomalies have been observed in the tantalum-hydrogen system, within the temperature range where our line width changes have been detected.⁴ The specific heat curves have maxima in the region 220° to 265°K, the height of the maxima and the temperatures at which they occur being proportional to the amount of dissolved hydrogen. However, only small concentrations of hydrogen have been used in these experiments (i.e., 0 to 12 atomic percent). According to Hagg⁵ the structure of the tantalum lattice changes from a body centered cubic lattice to hexagonal close packing at about 12 atomic percent hydrogen. The sample used in our experiment would then have a lattice which is hexagonal close packed. This may account for the fact that the specific heat anomalies occur at slightly higher temperatures than the resonance line width discontinuity.

Kelley⁴ suggests that the specific heat anomaly is due "to the differences in the number of possible ways of arranging the hydrogen particles among the positions in the tantalum lattice available at the higher and lower temperatures." This, of course, conforms to the idea that the protons are frozen in at the lower temperatures.

¹ R. H. Fowler and C. J. Smithells, *Proc. Roy. Soc. (London)* **A160**, 37 (1937).

² M. A. Garstens, *Phys. Rev.* **79**, 397 (1950).

³ C. J. Smithells, *Gases and Metals* (1937).

⁴ K. K. Kelley, *J. Chem. Phys.* **8**, 316 (1940).

⁵ Hagg, *Z. physik. Chem.* **B11**, 433 (1931).

Erratum: Acceleration of Stripped C¹² and C¹³ Nuclei in the Cyclotron

[*Phys. Rev.* **80**, 486 (1950)]

J. F. MILLER, J. G. HAMILTON, T. M. PUTNAM, H. R. HAYMOND, AND G. B. ROSSI

Crocker Laboratory, Divisions of Physics, Medical Physics, Medicine, and Radiology, University of California, Berkeley and San Francisco, California

THE Editors regret a typographical error in the list of authors of this letter as originally printed. "Putnam" should be replaced by "Putnam" as above.

Ratio of the Quadrupole Moments of Cl³⁵ and Cl³⁷

S. GESCHWIND, R. GUNTHER-MOHR, AND C. H. TOWNES

Columbia University,* New York, New York

November 14, 1950

RECENT measurements of the ratio of the quadrupole moments of Cl³⁵ and Cl³⁷ by several observers using different methods are in disagreement by amounts which are considerably

TABLE I. Data on the quadrupole coupling constants of Cl³⁵ and Cl³⁷.

Method	$eqQ(Cl^{35})/eqQ(Cl^{37})$
Direct quadrupole transitions in solid <i>trans</i> -dichloroethylene $CHCl = CHCl$	1.2661 ± 0.0002 ^a
Atomic beam magnetic resonance method. Cl	1.2795 ± 0.0008 ^b
Microwave spectra of CH ₃ Cl	1.273 ± 0.004 ^c
Microwave spectra of FCl	1.2704 ± 0.004 ^d
Microwave spectra of BrCl	1.2768 ± 0.004 ^e

^a H. G. Dehmelt and H. Krüger, *Naturwiss.* **37**, 111 (1950).

^b Davis, Feld, Zabel, and Zacharias, *Phys. Rev.* **76**, 1076 (1949).

^c Gordy, Simmons, and Smith, *Phys. Rev.* **74**, 243 (1948).

^d Gilbert, Roberts, and Griswold, *Phys. Rev.* **76**, 1723 (1948).

^e Smith, Tidwell, and Williams, *Phys. Rev.* **79**, 1007 (1950).