

If the breakdown is indeed promoted by sedimenting impurities one would expect the threshold power to increase in time if the liquid is kept in the superfluid state:

- 1) When the liquid was maintained at 1.9 °K for 30 minutes we observed an increase of the threshold power by one order of magnitude.
- 2) At the same temperature the threshold power decreased again by similar amount if the sedi-

mentation of the impurities was prevented, for example, by simply stirring the liquid mechanically.

All these observations lead to the conclusion that the presence of impurities in liquid helium plays a very important role in the observed process of optical breakdown.

The authors are greatly indebted to Prof. K. DRANSFELD for many stimulating discussions.

Curie-Weiß Temperature Dependence of Paraelasticity *

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Dedicated to Professor Dr. H. Maier-Leibnitz on his 60th Birthday

Anelastic strains exceeding elastic strains up to a factor of 30 have been observed close to the critical point of H in Nb. The temperature dependence of the relaxation strength follows a Curie-Weiß law for temperatures

$$(T - T_c)/T_c \geq 6 \cdot 10^{-3}.$$

1. Introduction

The Curie-Weiß type temperature dependence of magnetic or dielectric susceptibilities as well as of the compressibility of real gases have been known for long time. Only recently the analogous temperature dependence has been discovered for the elastic response of a solid, namely niobium loaded with hydrogen¹. Actually this system shows elastic properties which are a mixture of those of a solid and a real gas. This peculiar behaviour results from the fact that hydrogen in metals like Nb behaves like a gas in the space of the metallic host lattice². The phase diagram for H in Nb³ shows a miscibility gap separating the lattice-gas and lattice-liquid-phases and ending in a critical point.

The properties of the lattice gas can be studied experimentally by means of the elastic diffusional relaxation process (Gorsky effect)⁴. The relaxation strength Δ_E of the Gorsky effect is given by⁵

$$\Delta_E = \frac{\varepsilon_a}{\varepsilon_e} \sim \left(\frac{\partial \mu}{\partial \rho} \right)_{\text{iso}}^{-1} \sim \chi_{\text{iso}},$$

ε_e = elastic strain, ε_a = total anelastic strain, μ = chemical potential, ρ = density of the lattice gas, χ_{iso} = isothermal compressibility of the lattice gas.

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* Troubles caused by elastic after-effects of gold foils in a gold-leaf electrometer were the starting point for a research program, initiated by Prof. H. MAIER-LEIBNITZ, finally leading to the discovery of ferro-elasticity.

¹ G. ALEFELD, G. SCHAUMANN, J. TRETKOWSKI, and J. VÖLKL, Phys. Rev. Letters 22, 697 [1969].

² G. ALEFELD, Phys. Stat. Sol. 32, 67 [1969].

³ R. J. WALTER and W. T. CHANDLER, Trans. AIME 233, 762 [1965].

⁴ G. SCHAUMANN, J. VÖLKL, and G. ALEFELD, Phys. Rev. Letters 21, 891 [1968].

⁵ G. ALEFELD, J. VÖLKL, and G. SCHAUMANN, Phys. Stat. Sol. 37, 337 [1970].

For the critical density ρ_c the compressibility approaches infinity for $T \rightarrow T_c$. Therefore the relaxation strength should diverge as it approaches the critical point.

II. Experiments

Static Gorsky-effect measurements have been performed in a torsion pendulum apparatus. The sample consisted of a Nb-spring, loaded with the critical concentration of 34 at.-% H. Both the relaxation strength and the relaxation time have been measured as a function of temperature. More experimental details have been published in Ref. 6.

1) Relaxation Strength

Usually, elastic after-effect phenomena are at maximum in the percent region of the elastic strain. Fig. 1 shows as a counter-example an elastic after-effect curve as measured for a NbH_{0.34} — sample at 181 °C. The anelastic strain ε_a exceeds the elastic strain by a factor of 20, and still remains fully reversible. Fig. 2, in which

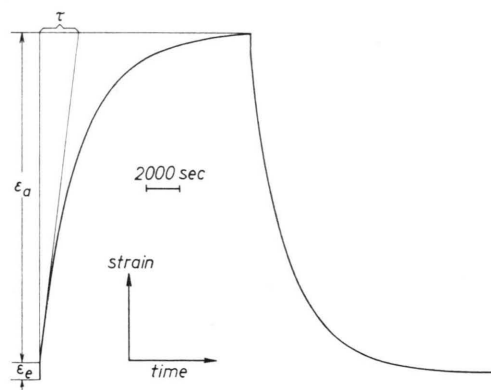


Fig. 1. Recorder chart of a measured elastic after-effect curve for Nb+34 at.-% H at 181 °C.



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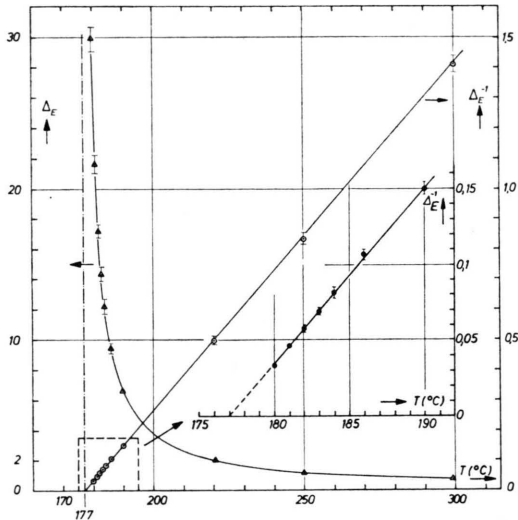


Fig. 2. Relaxation strength and reciprocal relaxation strength as a function of temperature.

the relaxation strength Δ_E is plotted versus temperature, shows the divergence of ε_a as it approaches T_c . To avoid nonlinear anelastic effects the total strain was always kept in the region of 10^{-5} by reducing the applied stress corresponding to the increase in Δ_E , thus keeping the gradient in hydrogen concentration approximately constant. The plot Δ_E^{-1} versus temperature (Fig. 2) yields a Curie-Weiß law for the temperature range investigated. By an extrapolation to $\Delta_E^{-1} = 0$ one obtains a critical temperature $T_c = (177 \pm 0.5)^\circ\text{C}$.

2) The Diffusion Coefficient

According to Eq. (51) in Ref. ⁵ the diffusion coefficient D is given by

$$D = B \varrho (\partial \mu / \partial \varrho)$$

$[B(\varrho, T) = \text{mobility}]$. Usually the mobility determines the temperature dependence of D . Close to a critical point the temperature dependence of $\partial \mu / \partial \varrho$ becomes significant resulting in "critical slowing down". Using the relation $13.55 D \tau = d^2$ (d = diameter of cylindrical sample) the diffusion coefficient D can be determined from the relaxation time τ . Fig. 3 shows the strong decrease of D near T_c . The largest experimental relaxation time was about 3000 sec, this limit being given by electronic and temperature drifts.

In the upper curve of Fig. 3 the diffusion coefficient D is multiplied by $T/(T - T_c)$. By this procedure the singular part of the temperature dependence resulting from $\partial \mu / \partial \varrho$ is eliminated. The thus corrected diffusion coefficient, representing essentially the temperature dependence of the mobility B , shows no singularity on approach of the critical point. It is interesting to

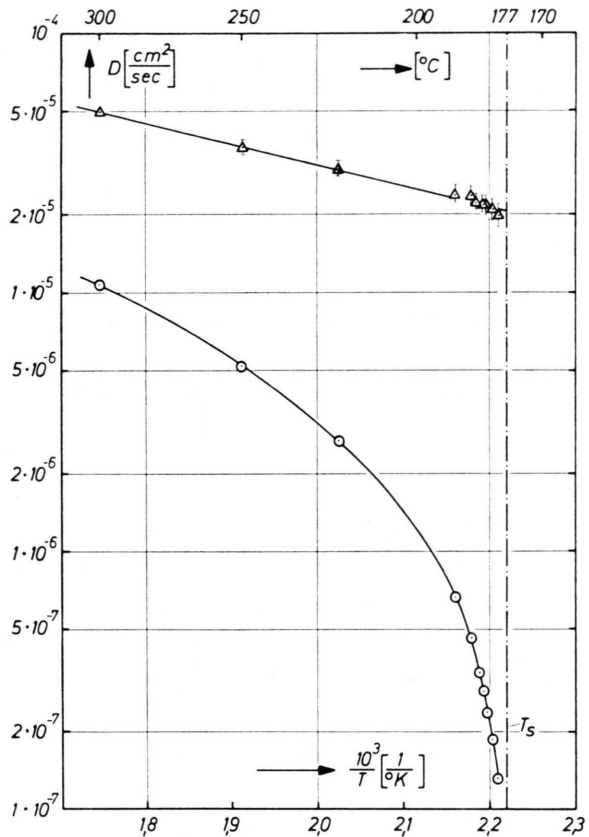


Fig. 3. Logarithm of the diffusion coefficient as a function of the reciprocal temperature (lower curve). For upper curve see explanation in the text.

note that the absolute value at 300°C coincides with that measured for infinite dilution⁶, whereas the temperature dependence is appreciably stronger [$U = (0.15 \pm 0.01)\text{eV}$, $D_0 = (3 \pm 2) \cdot 10^{-3}\text{cm}^2/\text{sec}$ compared to $U = (0.106 \pm 0.006)\text{eV}$, $D_0 = (5 \pm 1) \cdot 10^{-4}\text{cm}^2/\text{sec}$ for infinite dilution].

III. Discussion

The essential results of this paper are the following:

1) No deviation from the Curie-Weiß type temperature dependence for $(T - T_c)/T_c \geq 6 \cdot 10^{-3}$ (as demonstrated in the enlarged insert in Fig. 2).

2) No singularity in the mobility B for the same temperature range.

Two reasons can be stated which make the validity of the mean field approximation this close to the critical point plausible:

a) There exists strong evidence that the interaction responsible for the condensation of the lattice gas is

⁶ G. SCHAUmann, J. VÖLKL, and G. ALEFELD, Phys. Stat. Sol. **42**, 401 [1970].

the elastic dipole-dipole interaction^{7,8} which is long range, thus favoring the mean field approximation⁹.

b) The essential shortcoming of Landau's theory is the neglect of the interaction of fluctuations. On the other hand there are reasons to assume that in the system studied critical fluctuations with wavelength short compared to sample size are suppressed due to coherency strains in the host lattice¹⁰. Therefore, if only very few modes of the density fluctuations become critical, the interaction of the fluctuations may indeed be neglected.

⁷ G. ALEFELD, J. VÖLKL, and J. TRETROWSKI, J. Phys. Chem. Solids **31**, 1765 [1970].

⁸ G. ALEFELD, JÜL-Bericht, Jül-699-FF, Jülich 1970, and Proc. Battelle Colloquium, Geneva and Gstaad 1970, in Materials Science and Engineering, Mc-Graw-Hill, in print.

The nonsingular behaviour of the mobility may also be attributed to the nonsingular behaviour of nearly all of the fluctuation modes.

Acknowledgments

The authors are grateful to K.-H. KLATT, G. WOLLENWEBER, and M. BEYSS for assistance in sample preparation and measurements.

⁹ R. H. BROUT, Phasetransitions, Benjamin Inc. New York, Amsterdam 1965.

¹⁰ W. CAHN, Acta Met. **9**, 795 [1961].

Die Emission geladener Teilchen nach dem Einfang langsamer Neutronen in ^{22}Na

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on his 60th birthday*

Der Einfangsquerschnitt für thermische Neutronen von ^{22}Na , einem Positronenemitter mit $T_{1/2} = 2,6$ a beträgt $35,9 \pm 1,2$ kb^{1,2}. Im gegenwärtigen Experiment wurde das Spektrum der geladenen Teilchen (s. Abb. 1) nach dem Einfang langsamer Neutronen untersucht.

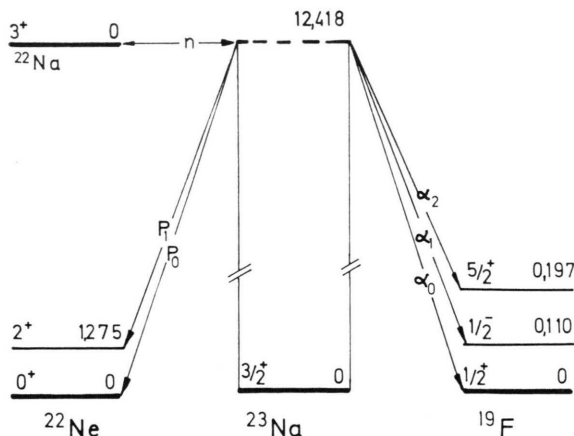


Abb. 1. Reaktionen nach dem Einfang langsamer Neutronen in ^{22}Na .

Die Messungen wurden durchgeführt am Strahlrohr QRII des Forschungsreaktors München bei einem Fluß

von 3×10^6 n/sec·cm². Der mittels ^6LiF -Absorbern auf einen Durchmesser von 0.5 cm abgeblendete Strahl fiel auf eine ^{22}Na -Quelle der Aktivität $2 \mu\text{Ci/cm}^2$, die durch Bedampfen einer Aluminiumfolie mit trägerfreier $^{22}\text{Na}_2\text{CO}_3$ -Lösung hergestellt wurde. Die geladenen Teilchen wurden mit einem Si-Detektor (100 mm² Fläche, max. 300 μm Dicke) nachgewiesen, der in einer Vakuumkammer außerhalb des Neutronenstrahls aufgestellt war (s. Abb. 2). Zur Verringerung der Untergrundzählrate, verursacht durch Target und Strahlrohr, wurde die Spannung am Detektor entsprechend dem Nachweis einer maximalen Protonenenergie von 4 MeV gewählt, also größer als $E(p_0)$.

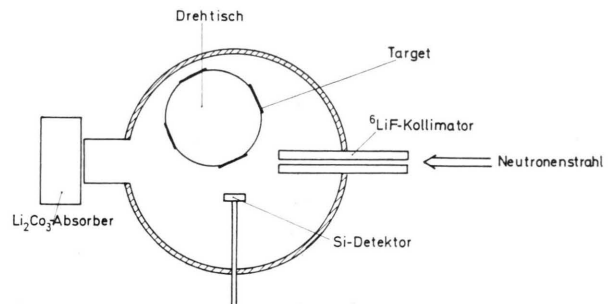


Abb. 2. Schematische Ansicht der experimentellen Anordnung.

Abb. 3 zeigt ein Spektrum der geladenen Teilchen aus der $(^{22}\text{Na} + n)$ -Reaktion. Während die Protonengruppe von 2.25 MeV vom Zerfall des Compoundkerns ^{23}Na zum ersten angeregten Zustand von ^{22}Ne als sehr starke Linie im Spektrum auftritt, konnten weder die Protonengruppe zum Grundzustand von ^{22}Ne noch die bei der Reaktion $^{22}\text{Na}(n, \alpha)^{19}\text{F}$ entstehenden α -Teilchen beobachtet werden. Die beiden Linien bei den Energien 1.43 MeV bzw. 1.77 MeV wurden als α -Gruppen der

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¹ G. M. S. SIMS, J. Inorg. Nucl. Chem. **29**, 593 [1967].

² U. FARINELLI, Neutron Dosimetry, Vol. I, International Atomic Energy Agency, Vienna 1963, 211.