

Letters to the Editor

PUBLICATION of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is, for the issue of the 1st of the month, the 8th of the preceding month and for the issue of the 15th, the 23rd of the preceding month. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length.

The Origin of Excess Ultrasonic Absorption in Water

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THE origin of the excess ultrasonic absorption in many liquids very likely lies in a lag in the rearrangement of the molecules during a compression. This note sketches the theory upon which an approximate calculation of absorption in water has been made which agrees with experimental values within the accuracy of such data.

Under acoustic compression some of the water molecules break their intermolecular hydrogen bonds and jump to sites of closer packing. Characteristic of such transitions are a decrease of volume and a rate-determining activation energy. The activation energy should be close to that for shear viscous flow, while the configuration of closer packing should be approximately that of closest possible packing, hexagonal or cubic.

The acoustic wave perturbs the transition rate to and from closer packing through the work performed by or against it in the volume change. Assuming the possibility of representation by two energy states, the unperturbed reaction or transition equation, $-\partial N_1/\partial t = k_1 N_1 - k_2 N_2$, will have its rate constants, k_1 and k_2 , and populations, N_1 and N_2 , perturbed by the acoustic radiation to $k_1 = k_1^0 + p(\partial k_1/\partial p)_0$; $N_1 = N_1^0 + p(\partial N_1/\partial p)_0$, etc. The excess pressure is p , while $N_1 + N_2$ is Avogadro's number. From the solution of this perturbed reaction equation for $(\partial N_1/\partial p)_0$ one obtains for the compressibility

$$-\frac{1}{V} \left(\frac{\partial V}{\partial N_1} \right) \frac{\partial N_1}{\partial p} = \frac{(\Delta V/V)^2 (V/RT)}{1 + \cos(\Delta F/RT)} \frac{1}{1 + i\omega[(1/k_1^0) + (1/k_2^0)]}$$

$$= \frac{\beta_r}{1 + i\omega\tau}$$

where ΔF is the difference in free energy between the two states; and $\Delta V/V$ is the volume change per molecule-transition.

This mechanism is equivalent hydrodynamically to a relaxational or complex isothermal compressibility. The rapid compressibility, β_i , arising from a uniform decrease in the intermolecular distances (aside from molecular rearrangement) such as occurs in crystals, may be estimated from the Bernal-Fowler model of water or the compressi-

bility of ice. Since the relaxational compressibility, β_r , is also $=\beta_0 - \beta_i$, where β_0 = the static value, β_i can aid in the evaluation of quantities occurring in the derived expression for β_r .

Neglecting small effects, the absorption due to rearrangement lag is given by

$$2\alpha/\nu^2 = 4\pi^2\tau \cdot \beta_r/c\beta_0$$

2α being the amplitude absorption coefficient (per centimeter), ν , the frequency, and c , the velocity of sound.

From the rate expression, $k_1 = (kT/h) \exp[-\Delta F^*/RT]$, given by Eyring in absolute reaction rate theory, the relaxation time, $\tau = (1/k_1^0 + 1/k_2^0)$, may be determined and is

$$\tau = h/kT \cdot \exp[\Delta F^*/RT]/1 + \exp[\Delta F/RT]$$

where ΔF^* is the free energy of activation for flow.

Up to the present, experimental error in absorption measurements in water has been estimated at 30 percent. The values computed thus far agree most closely with the observed values of Fox and Rock recently published in *The Physical Review*. A complete account is in preparation.

The present approach should be applicable to other liquids.

A Note on Rotational Motion in Relativity Theory

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IN a recent paper Rosen¹ has examined the rotating disk problem in relativity theory from the point of view of Born's 4-dimensional definition of rigid body motion. This gives a welcome extension of the writer's 3-dimensional analysis.² However, Rosen's analysis leads him to reaffirm the conclusion that one should retain the linear speed-distance law, despite the fact that this limits the size of a disk which can rotate with a given angular velocity. This limitation arises, of course, from the fundamental condition that the parts of the disk cannot exceed the speed of light, and is in no way a result of the physical properties of the material. Since I find myself still unable to accept this conclusion, it seems pertinent to consider the question again briefly.

It seems to me that the basic problem here is not how a given physical disk would behave if set in rotation. The more fundamental question is whether one can find a group of transformations representing relatively rotating coordinate systems; in the sense of the theory of continuous groups any member of the set should then represent a reference system in uniform relative rotation with respect to any other member of the set. This problem has an obvious solution in classical kinematical theory, but is unsolved as yet in relativity theory. The classical group must appear naturally as a degenerate case for an infinite value of the speed of light.

Starting with an extended body of any size in a given "laboratory" system, on passing to another member of the family of reference systems the body should appear to be in uniform rotation in the sense in which such motion was

defined by the transformation group. It is difficult to imagine how any condition could arise to limit the size of the body in such a treatment if the group possessed infinitesimal elements, and so could describe rotations with infinitesimal angular velocity.

Although this version of the rotation problem underlay my earlier attack, I have not yet been able to give it an acceptable solution, and may take this occasion to pose it as one needing an answer.

¹ N. Rosen, Phys. Rev. **71**, 54 (1947).

² E. L. Hill, Phys. Rev. **69**, 488 (1946).

Remarks on C. Frondel's Letter: "Elastic Deficiency and Color of Natural Smoky Quartz"

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HAVING just seen C. Frondel's interesting letter¹ I should like to make two remarks.

1. Anomalies after irradiation with radium and x-rays have also been observed in the piezoelectric constant of quartz, this constant in some cases being increased by irradiation.²

2. The fact that the natural color of smoky quartz is more stable than the color produced artificially in irradiated quartz does not contradict the theory that this natural color is of radioactive origin.

As I have frequently pointed out, only the most stable color and luminescence centers will be produced in nature owing to the very small intensity of the radiation acting during long periods, as compared with the strong artificial irradiation during a short time. I have called this "the principle of natural selection of the most stable."³

That colorless or relatively light colored bands in natural smoky quartz are more deeply affected by artificial irradiation shows that they contain more unstable centers than stable ones.

¹ C. Frondel, Phys. Rev. **69**, 543 (1946).

² J. Laimböck, Wien. Anz. (May 18, 1928); F. Seidl, Wien. Ber. IIa, **142**, 467 (1933); F. Seidl and E. Huber, Zeits. f. Physik **97**, 671 (1935).

³ K. Przibram, Zeits. f. Physik **68**, 413 (1931).

The Magnetic Quenching of Superconductivity

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THE only previously expressed generalization regarding temperature dependence of magnetic threshold fields for superconductors^{1,2} appears to be the often-quoted statement that the functional relation is roughly parabolic for a given substance. It has been noted that the curves for mechanically "soft" elements (as well as for a few alloys) tend to display smaller initial slopes than those for "hard" elements (and most alloys) of similar upper critical temperature (*vide infra*). More careful examination of the threshold curves for the "soft" superconductors Pb, Hg, Sn, In, Tl, CuS, Au₂Bi, Zn, and Cd indicates that each is reproduced with remarkable accuracy by a law of the form $H_T = A(T_C^3 - T^3)$. Here T_C represents the upper

critical temperature—i.e., at zero field, whereas T represents the critical temperature in a longitudinal field of H_T gauss. A remarkable generality is indicated by the fact that the parameter A is found to have nearly the same value for all of the substances listed, the deviations being of the same order as those for the individual curves. For the initial slope at $T = T_C$, one derives

$$(dH_T/dT)_{T_C} = -\frac{3}{2}AT_C^2.$$

The practical identity of A for the various substances is most readily verified by use of this corollary law, since the initial slopes are generally measured with greatest accuracy. For the listed substances (with a range of T_C from 7.26 to 0.54°K) the average value of A is some 50 gauss-degree⁻³, with a mean deviation of only a few percent. Studies of thin films and wire, as well as of colloidal particles^{1,2} of "soft" superconductors, have shown the threshold fields to increase for sufficiently small linear dimensions, by a factor which is the greater, the closer the approach to the critical temperature. This suggests that mechanical sufficient to cause a micro-lamellar, fibrous, or mosaic structure in a massive sample should result in serious deviations from the above law—in the sense of an increase in the parameter A , differentially greater the higher the temperature. The threshold curves for the few "hard" superconductors subjected to careful study seem to bear some such relation to those of "soft" superconductors of similar upper critical temperature, the ratio of initial slopes being much greater than the ratio of extrapolated threshold fields at the absolute zero. It is proposed that the above law represents the limiting "ideal" behavior for a truly homogeneous specimen of macroscopic dimensions. The apparent exceptions displayed by the more numerous class of "hard" superconductors are attributed to irreducible structural inhomogeneities on a micro-scale. The incompleteness of the Meissner effect (expulsion of magnetic flux) in typical "hard" superconductors is further evidence of such structural inhomogeneities.

A law of such simplicity as the above suggests that the electronic nature of the superconducting state may prove to be simpler than has usually been proposed. In particular, a satisfactory model must presumably allow the experimental value of the parameter A to be found by combination of universal constants only.

¹ E. F. Burton, H. Grayson Smith, and J. O. Wilhelm, *Phenomena at the Temperature of Liquid Helium* (Reinhold Publishing Corporation, New York, 1940).

² D. Shoenberg, *Superconductivity* (Cambridge University Press, 1938).

Decay of Mesons Stopped in Light Materials

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WE are carrying out an experiment to observe the decay of mesons stopped in different light materials. The preliminary results seem to indicate that there are more decay electrons emitted for each stopped meson if the meson is brought to rest in material of low atomic number than if it is stopped in aluminum or some material with a higher atomic number.