IX. ULTRASONIC PROPERTIES OF SOLIDS*

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RESEARCH OBJECTIVES

The general goal of our ultrasonic investigations is to obtain information about bulk systems near phase transitions or critical points. In particular, ultrasonic velocities give direct information about equilibrium thermodynamic properties and ultrasonic attenuation provides data about dynamical behavior. The majority of the work is concerned with order-disorder lambda transitions in solids, but other systems (such as a fluid near its critical point) are also being studied. During the past year, a variety of new projects have been started. The design and construction of special equipment is essentially complete for all of these, but detailed experimental results are not yet available. A brief statement of the objectives and progress in each area will be given.

Order-disorder transitions in NH_4Br are of interest, since two different ordered phases are known — a cubic, parallel ordering of NH_4^+ ions and a tetragonal, antiparallel ordering. High-pressure acoustic measurements on NH_4Br have been limited, in the past, by our inability to work below ~240°K. A new high-pressure cell and extensive modifications of the thermostat bath will permit work up to 6 kbar for temperatures constant within ±0.01° and as low as 120°K. In preparation for this work at lower temperatures, changes in transducer size, transducer-sample bonding, and hydraulic pressure fluid have all been made and tested. Most important, several large single crystals of NH_4Br have been grown and (when necessary) oriented and cut for acoustic work. Thus, the preparations are complete and experimental observations have now begun.

Our recent work on NH_4Cl indicates an instability and a first-order transition very close to the expected lambda point. The α-β quartz transition at 847°K is of the lambda type, and there are some indications that this transition may also show a first-order instability. As a precise check on this first-order character, velocity measurements are planned on ultrasonic waves that are <u>not</u> attenuated. Attenuation measurements on other waves are planned as a function of temperature and frequency. These data will provide information about the dynamical relaxation of long-range ordering near this cooperative transition. The principal experimental problems are related to the high temperature of this transition. A furnace and associated control equipment capable of maintaining the temperature constant to better than ±0.1°K has been built and is being tested. A buffer-rod, pulse-echo technique will be used, and a special sample holder is now complete. A large synthetic quartz crystal was obtained from Bell Telephone Laboratories, Inc. and has been oriented and cut into a variety of samples. High-temperature sealing materials are now being tested.

Present interest in the liquid-vapor critical point is very great, and work is in progress on xenon near its critical point at 16.6°C and 58 bar. Recent measurements on helium strongly suggest that the adiabatic sound velocity goes to zero at a critical point,

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in contradiction to the classical theoretical view that it will approach a finite minimum. We plan to measure the velocity for $\Delta T/T_c$ values as small as 3×10^{-6} (an order of magnitude better than the helium work) in order to test this behavior. Accurate acoustic attenuation measurements are also planned over a wide range of frequencies in order to obtain information about the dynamical response of a fluid near its critical point. The difficulties to be overcome are (a) the very high attenuation and therefore the small path lengths required, and (b) the need for excellent temperature and pressure stability. A bath temperature control of ±0.001°C can be achieved, and a quartz thermometer (capable of a resolution of better than 0.001°C) is available for measuring the sample temperature. Pressure stability of $\pm 5 \times 10^{-4}$ bar is expected, and the absolute value of p can be measured with an uncertainty of ±0.01 bar. Major work on a complex, variable-path, high-pressure cell is now complete and testing of this unit has begun. Components for an ultrasonic "sing-around" method are available and this is also being tested.

New ultrasonic attenuation work is just beginning on potassium dihydrogen phosphate (KDP) near its ferroelectric Curie point at ~120°K. Information obtained in the MHz range about the relaxation time of the polarization will be compared with higher frequency data obtained from laser work which is in progress elsewhere.

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Publications

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