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NASA TECH BRIEF

Ultrasonic Propagation in Gases at High Temperatures

Quantitative information on properties of gases at extremely high temperatures is not only of fundamental interest, but is also required in a variety of astrophysical problems and in the understanding of certain phenomena such as combustion, detonation, and high speed gas dynamics. Of prime interest are the transport properties, collisional relaxation time for electronic excitation, and ionization rates.

An ultrasonic pulse method (1 to 3 MHz) has been used to measure both sound speed and absorption in monatomic and polyatomic gases in a temperature range of 300° to 20,000°K at atmospheric pressure. In monatomic gases in a temperature range where no ionization occurs, the ultrasonic technique described may be used to determine shear viscosity and thermal conductivity (see Note 1). In nitrogen and oxygen, in the range 5000° to 10,000°K, relaxation times, due to the excitation of bound electrons, have been determined. In argon at $T > 8000°K$, the effects of ionization and radiation on sound propagation have been investigated. Analyses show how variations of experimental conditions may lead to a determination of radiation properties as well as transport properties at $T > 10,000°K$. The gases investigated were helium, nitrogen, oxygen, and argon.

Helium, at temperatures up to 1300°K, was the first gas considered and, being a monatomic gas, has no interval states. Because the highest temperature investigated was below the ionization point, there was only one species present. The conclusion was that only shear viscosity and translational thermal conductivity contribute to the sound loss in helium in this temperature range. It is thus made clear that, at least below ionization temperatures, ultrasonic pulses are useful in determining the transport properties of helium.

In the investigation of nitrogen it was found that, below the dissociation temperature of 5200°K, the ultrasonic data yielded transport properties once the rotational effects had been accounted for. As the temperature began to exceed 5200°K, nitrogen began to dissociate at a known rate, by which the relaxation time was determined and the effects of dissociation on the sound loss could be theoretically calculated. In the temperature range $5000°K \leq T \leq 12,000°K$, the predominant sound loss mechanism was the relaxation of the electronic states of the atom. Determination of the maximum sound loss due to this mechanism and the relaxation time associated with this excitation have been demonstrated. With nitrogen, within the temperature range covered, the effects due to ionization, including chemical reactions as well as diffusion of electrons, were negligible. It was also established that continuum radiation does not contribute to the sound loss in this range.

In the investigation of oxygen, which began to dissociate at a lower temperature (2300°K) than nitrogen, it was shown that below the dissociation temperature the ultrasonic data depended on transport properties and on bulk effects. Above the dissociation temperature, electronic excitation accounted for the excess sound loss. Relaxation times for these excited states were determined and it was further found that above 10,000°K, the effects of ionization had to be considered.

The final gas investigated was argon. The ultrasonic technique clearly yielded accurate viscosity measurements up to temperatures of about 8000°K. Above 10,000°K, and at one atmosphere, argon began to ionize more rapidly and at ultrasonic frequencies in the MHz range, the effects of both ionization and radiation were found to contribute significantly to sound

(continued overleaf)

loss. It was concluded that an appropriate choice of pressures, temperatures, and sound frequencies may have permitted determination of the contribution due to ionization or radiation alone.

Notes:

1. Ultrasonic absorption measurements of the type reported may be extended to measure relaxation times, reaction rates, and transport properties in other complex gases of importance to propulsion systems and gas laser systems. In addition, by varying the gas pressure and ultrasonic frequency, this technique may be used to determine the integrated optical absorption coefficient. This technique is complementary to conventional methods since it emphasizes the ordinarily inaccessible vacuum ultraviolet.
2. The following documentation may be obtained from:

   Clearinghouse for Federal Scientific
   and Technical Information
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.65)

   Reference:
   AD-670192 (N68-30724), Experimental Determination of Gas Properties, at High Temperatures and/or Pressures

   Source: E. H. Carnevale, S. Uva, C. Carey, and L. C. Lynnworth of Panemetrics, Incorporated
   under contract to
   NASA Headquarters
   (HQN-10498)