ULTRASONIC VELOCITY AND ABSORPTION IN OXYGEN

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Abstract

The velocity and absorption in oxygen at room temperature were measured at five ultrasonic frequencies located in the two octaves, 316 to 1264 kc/sec. The observed velocities reduced to 0°C do not differ more than 0.2% from Dulong's observed value of V_0 for audible sound (317.2 m/sec). The theoretical value ($V_0 = (\gamma p/d)^{1/2}$) is 314.76 m/sec. The observed absorption values vary with frequency as expected but the deviations from the theoretical values are greater than the velocity deviations.

IN MAKING the velocity and absorption determinations for air published in an earlier article[1] deviations from the theoretical values were found. These deviations are thought to be due to various causes. In order to gain more information on the subject it was decided to test oxygen and nitrogen separately.

Apparatus

The sources of the high frequency sound were piezoelectric oscillators made of quartz. These square slabs of natural crystal were sputtered with platinum on their two large faces as stated in the earlier article.[1] The electric circuit was altered but slightly. The radiometer was fitted with a small 45 degree reflector so as to render the vertical sound beam horizontal so it could be directed against the pressure vane. The radiometer could be interchanged with the interferometer mirror without any further alteration of the apparatus. With the lowest frequency crystal it was necessary to put a tuned inductance and capacity in series with the load coil in order to supress a neighboring frequency. The oxygen was dried by bubbling it through concentrated H_2SO_4 and by placing a dish of P_2O_5 or $CaCl_2$ in the gas chamber For the later measurements a hair hygrometer was placed in the box.

Results

Tables I and II present the results of individual runs although a number of runs were made at each frequency. The number of significant figures given in the tables is justified by the precision of the data and by the slopes of the absorption curves for individual cases but the variation in the successive values of V_0 at a given frequency is about 0.1 percent and the variation in the values of A_t is too great to be explained by the temperature changes between runs.

[1] The Pierce acoustic interferometer as an instrument for the determination of velocity and absorption. Phys. Rev. **34**, 1184 (1929).

V_t, in Table I, represents the observed velocity at the temperature, t, given in the second column; V_0 represents the velocity reduced to 0°C;

TABLE I. *Interferometer determinations.*

Frequency Kilocycles	t °C	V_t m/sec	V_0 m/sec	k_t /cm	A_t cm	Humidity %	Date
1219.0	23.5	330.91	317.52	0.42	$3.1(10)^{-4}$	Approx. 20	Dec. 31, 1930
1166.0	20.8	329.18	317.32	0.44	3.5 "	18	May 15, 1930
655.5	21.3	329.58	317.43	0.21	5.3 "	Approx. 20	3-22-30
389.3	24.4	331.1	317.2	0.103	7.4 "	" "	4-2-30
316.2	25.9	332.3	317.7	0.102	11.2 "	24	6-3-30

K_t represents the ordinary absorption constant defined by the equation $I = I_0 e^{-kx}$; A_t is defined as $A_t = k_t \lambda^2$; similarly for Table II.

TABLE II. *Pressure vane determinations.*

Frequency Kilocycles	t °C	k_t /cm	A_t cm	Date	Humidity %
1219	19.6	0.533	$3.85\,(10)^{-4}$	1-21-30	—
1166	26.5	0.583	4.68 "	5-10-30	26
655.5	21.0	0.219	5.51 "	3-18-30	—

Theoretical $V_0 = (\gamma p/d)^{1/2} = 314.76$ m/sec
Dulong's Observed $V_0 = 317.2$ m/sec (for audible sound)

$$\text{Theoretical } A_{20} = \frac{4\pi^2}{ap}\left[\frac{4}{3}u' + \left(\frac{C_p}{C_v} - 1\right)\frac{K}{C_p}\right] = 3.65(10)^{-4}$$

DISCUSSION OF RESULTS

On account of an originally greater variation in the values of V_0 the crystal frequencies were checked. Radio crystals with oven controlled frequency were used as standards for this purpose. Some of these were at hand in the college broadcasting station, where the checking was done, but frequencies from crystals in Philadelphia and other cities were used also. The lowest frequency (316.2 kc/sec) was not redetermined.

A slightly decreasing velocity with diminishing sound intensity was observed. In a few runs minor peaks, due to higher order reflections, were observed, which, when used to calculate V_0, gave values near the theoretical value, 314.76 m/sec. Data of this type for another paper are being taken. Instead of substituting in the formula, $V = (\gamma p/d)^{1/2}$, directly, the ratio of the value of $(\gamma p/d)^{1/2}$ for O_2 and its value for air was multiplied by the theoretical value of V_0 for air. This method is not subject to uncertainty in the value of g and hence in p if the two densities were determined at the same place. For this calculation the *relative* density (1.1053) of oxygen and air was used; i.e. $V_0 = 331.60(\gamma')/\gamma(1.1053)^{1/2}$. Here γ' designates the ratio C_p/C_v for oxygen. Its value is given by Lummer and Pringsheim as 1.3977.

The close agreement of the velocity values in Table I with each other and with Dulong's value probably indicates that all were made at somewhat

the same sound intensity. This was roughly determined for crystal A, by using a vane suspended by a tungsten wire of known diameter. Near the crystal it was approximately 15 ergs/sec per cm^2.

This investigation shows the velocity and absorption deviations for oxygen to be similar to those for air. Many observers have published values for V_0 in air very near the theoretical value but for oxygen this is not the case.

Apparently the excess absorption band for O_2, as for air has its upper limit near 1200 kc/sec. The *radiometer* values of k and A are probably the more reliable because they are more directly related to the readings.