THE DIELECTRIC CONSTANTS OF ARGON AND NEON

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Abstract

The heterodyne beat method has been used to measure at room temperatures the dielectric constants of argon and neon relative to air. The value for air is assumed to be 1.000589 and the values found for argon and neon are 1.000574 and 1.000148 respectively, for normal temperature and pressure. Simultaneous refractive index measurements agree with previous determinations and indicate that the gases contain no appreciable impurities. An oscillator employing a shield grid tube is described for which the frequency is very little affected by changes in the various battery voltages.

Apparatus

The heterodyne beat method has been used to measure the dielectric constants of argon and neon. The apparatus is a modification of that used in a previous work.[1] Two radio frequency oscillators are used, a 1651 kc crystal controlled oscillator of an ordinary type and the special shield grid oscillator shown in Fig. 1. The frequency of the beat note between these two oscillators is compared with that of an electrically driven tuning fork as in the previous work. Capacity changes caused by changing the gas pressure in the test condenser C are compensated by changing the capacity of condenser Cc, thus maintaining a constant frequency as indicated by a constant beat note. The condensers C and Cc and the arrangement for varying

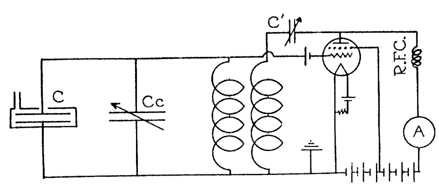

Fig. 1. Shield grid oscillator.

the gas pressure are the same as previously used. However, the test condenser has been dismantled and reassembled and its capacity is apparently now larger than before. A Jamin refractometer has been attached to the apparatus to permit refractive index measurements which are useful as an indication of the purity of the gases.

The oscillator shown in Fig. 1 has proven satisfactory in that its frequency is quite constant and very little influenced by changes in the various battery voltages. A type SP122 tube is used with voltages 3.3, -1.5, 45 and 135

[1] A. B. Bryan and I. C. Sanders, Phys. Rev. **32**, 302 (1928).

volts on the filament, control grid, shield grid and plate respectively. The grid circuit coil has 11 turns of No. 14 bare copper wound on 4 inch paper tubing and spaced about 0.75 cm. It is made in two sections the distance between which may be varied for rough adjustment of the frequency. The plate circuit coil has 19 turns of the same wire spaced 0.3 cm and is 5.5 inches in diameter. It is supported outside of and coaxially with the grid circuit coil. The feed back condenser C' is a small variable air condenser having seven semicircular plates 3 cm in diameter, spaced about 0.17 cm. No shielding is used, the adjustments of Cc being made from a distance by suitable means.

The following results show the effect of various factors on the oscillator frequency. Increasing the filament voltage by 10 percent produces a frequency decrease of about 0.5 cycle per second. Decreasing it by the same amount causes a frequency increase of 1.1 cycles per second. Increasing or decreasing the shield grid voltage by 10 percent increases or decreases the frequency by 26 cycles per second. Increasing or decreasing the plate voltage by 10 percent increases or decreases the frequency by 2.8 cycles per second. Increasing the setting of C' from one third to one half maximum decreases the frequency by 1200 cycles per second and incidentally raises the d.c. plate current from 1.37 to 1.68 milliamperes.

The frequency normally decreases steadily at the rate of about 1.3 cycles per second in one minute and Cc must be decreased by 0.005 divisions per minute to hold it constant. This drift is probably caused principally by the slow rise in room temperature which always occurs while measurements are being made.

Results

The experimental results are shown in Table I. As in the previous work the readings have been taken in a way which eliminates the slow steady frequency drift and have been made on various parts of the scale of Cc. The second column shows the absolute temperature, the third the change in pressure of the gas in the test condenser and the fourth the resulting capacity change in divisions on Cc. The last column gives the capacity change for a pressure change of one atmosphere and a tempreature of 0°C, obtained from δC_1 on the assumption that the effect is directly proportional to the pressure change and inversely to the absolute temperature. The measurements on air are made to calibrate the apparatus, the previously found value $K = 1.000589$ for air being used. Since $K-1$ is proportional to δC we have for argon $K-1 = 0.000589\ (1.949/2.001) = 0.000574$ and for neon $K-1 = 0.000589\ (0.5026/2.001) = 0.000148$.

Dry carbon dioxide free air was used. The argon and neon were purchased in liter flasks and were supposed to be specially purified. No additional purification was attempted except drying over P_2O_5. Refractive index measurements made after the gas was in the apparatus give 0.000292, 0.000282 and 0.0000663 as the values of $n-1$ for air, argon and neon, respectively, sodium light being used. The first two are in good agreement with previous determinations.[2] The value for neon seems to be about one percent low and may indicate a slight helium impurity but the difference is probably within the range of experimental error.

The only previous dielectric constant measurement on either argon or neon seems to be that of Braunmühl[3] on argon. He also uses the heterodyne beat method and his value 1.000571 is in as good agreement with the above as

TABLE I. *Change in capacity of test condenser as pressure of gas is changed.*

Gas	T	δP	δC_1	δC
Air	297.1	53.32	1.293	2.006
"	297.3	53.38	1.288	1.997
Argon	296.8	53.25	1.265	1.963
"	297.1	43.47	1.027	1.954
"	297.3	43.48	1.025	1.951
"	297.5	52.85	1.235	1.935
"	296.4	52.32	1.235	1.948
"	297.0	44.06	1.035	1.942
				mean 1.949
Neon	299.1	51.59	0.315	0.5084
"	299.4	51.63	0.310	0.5006
"	299.9	52.75	0.317	0.5017
"	300.0	52.77	0.315	0.4986
"	299.1	53.76	0.323	0.5003
"	299.1	53.86	0.325	0.5025
"	299.4	53.91	0.322	0.4978
"	299.6	48.56	0.293	0.5033
"	299.8	48.58	0.297	0.5103
				mean 0.5026
Air	299.2	53.60	1.287	2.000
"	299.4	53.61	1.287	2.001
"	299.7	51.07	1.225	2.001
"	299.9	51.11	1.225	2.001
				mean 2.001

could be expected, especially since it is based on the somewhat uncertain value 1.000547 for oxygen. The gases were purchased from Air Reduction Sales Company, 342 Madison Avenue, New York, who state that the argon was as pure as is commercially practicable but probably contained a very small fraction of one percent of nitrogen, the actual quantity being too small to be determined by analysis. They also state that the neon contained less than one percent of helium and that no other impurities were present in either of the gases.

[2] Landolt-Börnstein Tabellen.

[3] H. J. v. Braunmühl, Phys. Zeits. **28,** 141 (1927).