Physics. — "*Preliminary measurements concerning the dielectric constants of liquid hydrogen and liquid oxygen and its dependence on temperature as regards the latter*". By G. Breit and H. Kamerlingh Onnes. Communication N°. 171*a* from the Physical Laboratory at Leiden.

(Communicated at the meeting of September 27, 1924).

§ 1. *Introduction.* The following measurements concerning the dielectric constants of liquefied gases are the first performed again at Leiden after those of Hasenöhrl[1]). Such determinations had remained on the program indeed and had even obtained a large interest, when a maximum of density had been found for liquid helium, but they had to be neglected again and again for more urgent problems. We also, when we got the opportunity to take at hand the determinations mentioned by means of high frequency oscillations — Hasenöhrl used low frequency — could perform this research as second place work only. Further, the departure of one of us (G. B.) caused it to be stopped before the certainty and the accuracy of the measurements had been increased to the required degree. So we cannot but consider our results as preliminary ones only. Yet the first determination of a so interesting quantity as the dielectric constant of liquid hydrogen seems to deserve to be published. The same holds for the observations showing that within the limit of their (though small) accuracy the change of the dielectric constant of liquid oxygen with temperature down from the boiling point can be expressed by the formula of Clausius-Mosotti.

As regards liquid hydrogen it could only be stated, that the change in dielectric constant is of the same order as indicated by the formula mentioned.

§ 2. *Method and apparatus.* We used sustained oscillations of a frequency of the order of 100,000 produced by means of triode valves. The circuit of the triode valve was coupled loosely to the circuit of the condenser placed in the cryostat and filled with liquefied gas.

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[1]) These Proceedings II (1899), p. 211, Leiden Comm. N⁰. 52.

Two procedures have been employed:

1. We substituted for the experimental condenser a calibrated measuring condenser that could be adjusted to the required capacity (substitution method).

2. We connected the experimental condenser in parallel with a calibrated measuring condenser of larger capacity which had been first adjusted to resonance and readjusted it again to resonance after the connexion had been made. The difference of the two settings gives the capacity of the experimental condenser plus that of the leads (parallel connexion method).

The measuring condenser (capacity about 460 $\mu\mu f$) consists of two sets of zinc plates supported each by a set of three vertical brass columns (six columns in all). The columns were mounted in two ebonite rings. The whole condenser was shielded electrostatically by means of a cylinder of german silver with a number of perforations allowing a free circulation of the liquid. The leads to the condenser were of bare copper and were insulated from the cap of the cryostat by means of glass tubing and KOTHINSKY cement. In the silvering of the vacuumglasses of the cryostats vertical slits had been left unsilvered allowing one to follow the level of the liquid.

The measurements were performed in the following order:

1. The cryostat was evacuated and the capacity of the condenser and leads was measured when at atmospheric temperature;

2. the cryostat was cooled and the capacity of the condenser and leads was measured;

3. the cryostat was filled with the liquefied gas, the pressure of evaporation was kept constant, the level of the liquid was noted and the capacity of the condenser was measured;

4. the pressure in the cryostat was then reduced, the level of the liquid noted and the capacity measured again.

In observations at different temperatures the pressure had to be always used first at high and then at low values so as to provide for proper circulation of the liquid.

The experimental condenser was calibrated at ordinary temperatures at the Bureau of Standards in Washington D. C., U. S. A. and the Cruft Laboratory of the Harvard University and also at Leiden by comparison with a condenser which has been later calibrated in Washington. The correction for the leads has been ascertained by special trial measurements.

§ 3. *Dielectric constant of liquid hydrogen.* The measurements have been performed on May 24, May 26 and June 24, 1922. As in the later measurements use could be made of the experience gained in the earlier ones, those of June 24 are the most reliable. In those of May 24 the cap of the cryostat had not yet been earthed. However, in table I we give all the results. The dielectric constant K is given as compared with that of vacuum, the pressure of the evaporating gas in international cms mercury, the temperature on the provisional international KELVIN scale. In the last column the ratio $\frac{K-1}{K+2} \cdot \frac{1}{D}$, which according to the formula of CLAUSIUS-MOSOTTI had to be a constant is given. The latter column cannot show much more than that the change in K is of the same order of magnitude as required by the formula of CLAUSIUS-MOSOTTI.

TABLE I.

Liquid hydrogen

Date	Method	Pressure	Temperature[1])	Density [2])	K	$\frac{K-1}{K+2} \cdot \frac{1}{D}$
24 May 1922	Subst.	76.3 cm	20°.37 K	0.0708	1.211	0.928
26 „ „	Parall.	76.7	20.38	708	1.220	0.964
	Subst.	76.7	20.38	708	1.214	0.946
	„	17.7	16.30	749	1.229	0.943
24 June „	„	76.1	20.36	709	1.220	0.964
		7.1	14.42	767	1.236	0.951

§ 4. *Agreement of the change of the dielectric constant of liquid oxygen below the boiling point with the formula of* CLAUSIUS-MOSOTTI. The determinations were performed at June 27 and July 12, 1922. In all of them the substitution method was employed. The object of the first was mainly to determine the dielectric constant at the boiling point and to investigate the influence of a large change in temperature, that of the second set in which greater accuracy of setting was obtained, to study the effect of a change in temperature in more detail. They are recorded in table II, that has been arranged in the same way as table I.

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1) P. G. CATH and H. KAMERLINGH ONNES, these Proceedings 26, p. 490: Leiden Comm. No. 152a.

2) E. MATHIAS, C. A. CROMMELIN and H. KAMERLINGH ONNES, these Proceedings 29, p. 935; Leiden Comm. No. 154b.

TABLE II.

Liquid oxygen					
Date	Pressure	Temperature[1]	Density [2]	K	$\frac{K-1}{K+2} \cdot \frac{1}{D}$
27 June 1922	77.2 cm	90°.29 *K*	1.145	1.463	0.1167
	15.2	77.12	1.210	1.493	0.1167
	13.2	76.19	1.214	1.496	0.1169
12 July „	76.0	90.11	1.146	1.464	0.1168
	41.0	84.61	1.174	1.478	0.1172
	25.0	80.70	1.193	1.487	0.1172
	9.6	74.16	1.223	1.504	0.1176
	5.4	70.75	1.239	1.504	0.1173

HASENÖHRL [3]) found at the boiling point 1.465.

The junior author held a National Research Fellowship (U. S. A.) while the above work was done.

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[1]) P. G. CATH, these Proceedings 27, p. 553; Leiden Comm. No. 152*d*.

[2]) E. MATHIAS and H. KAMERLINGH ONNES, these Proceedings 13, p. 939; Leiden Comm. No. 117.

[3]) l.c.