

Citation:

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To prevent too rapid an evaporation of the bath the cryostat-vessel S_7 (fig. 1) is protected by a tube with liquid air.

If the available neon is not quite pure and if it is still desired to start the work with it without the previous purification by means of the circulation under pressure over carbon cooled in liquid air, it will be possible instead of the drying tube D_1 to insert between 4 and 5 a carbon-tube D_2 , arranged for purification under ordinary air-pressure, immersed in liquid-air with a drying-apparatus preceding it.

In the experiments the liquid gas in the bath was always obtained in a perfectly transparent condition. Only the first quantity of liquid neon which flows into the cryostat-vessel and evaporates there very rapidly, left behind a little of a white substance (solid nitrogen or solid air?) which dissolved again in the liquid gas which flows in afterwards. A slight ring-shaped deposit was also noticed above the liquid surface in the evaporation of the bath. The gas had thus not been quite pure; as a matter of fact this can hardly be expected, as long as it is allowed to come into contact with the oil of the gasometers. The use of the latter, however, simplifies the operations considerably, and the very slight impurity does not give the least trouble.

It was found that the quantity of liquid in the bath could be made as much as 400 cc.

I am glad to thank Mr. G. J. FLIM, chief instrumentmaker in the cryogenic laboratory, once again for his help in the construction of the apparatus described in this paper.

Physics. — "*Isothermals of monatomic gases and of their binary mixtures XVII. Isothermals of neon and preliminary determinations concerning the liquid condition of neon.*" By Prof. H. KAMERLINGH ONNES and C. A. CROMMELIN. (Communication 147d from the Physical Laboratory at Leiden).

(Communicated in the meeting of June 26, 1915).

1. *Isothermals of neon.* This section contains a first instalment of the isothermal-determinations, by which we hope to obtain the equation of state of neon at low temperatures. The isothermals of 0° C. and 20° C. have been investigated from 20—93 and from 20—84 atmospheres respectively; they give sufficient data for the connections which are required for the reduction of the observations concerning the isothermals of lower temperatures. Parts of isothermals for —182°.6 C., —200°.1 C., —208°.1 C., —213°.1 C. and —217°.5 C. are also given, which may serve as a first survey and even now

allow a preliminary application of the law of corresponding states to be made.

In Table I and II the symbols θ , p , d_A , and v_A , have the usual meaning.

TABLE I. Isothermals of neon								
Series	No.	θ	p	d_A	pv_A (obs)	pv_A (calc)	calc. - obs.	calc - obs in %
VI	1	+ 20° 00	22.804	21 046	1.0835	1.0843	-0.0008	-0 06
VI	2		25.015	23.052	852	854	- 2	-0 02
VI	3		26.575	24.464	863	862	+ 1	+0 01
VI	4		29.090	26.757	872	875	- 3	-0 03
VI	5		32.572	29.891	897	892	+ 5	+0.04
VIII	1		34.887	32.002	902	904	- 2	-0.02
VI	6		35.423	32.447	917	907	+ 10	+0.09
VI	7		37 812	34.601	928	919	+ 9	+0.08
VIII	2		39.168	35.843	928	926	+ 2	+0.02
VIII	3		44.762	40.862	955	956	- 1	-0.01
VIII	5		54.149	49.213	1003	1005	- 2	-0.02
VIII	6		59 717	54.161	026	035	- 9	-0.08
VIII	7	65.021	58 797	059	063	- 4	-0.04	
VIII	9	77.360	69.338	131	128	+ 3	+0.03	
VIII	10	82.545	73.967	160	158	+ 2	+0.02	
VIII	11	88.239	78.886	186	189	- 3	-0.03	
VIII	12	93.298	83.154	220	217	+ 3	+0.03	
VII	1	0°	22.064	21.869	1.0089	1.0095	-0.0006	- 0 06
VII	2		23.555	23 314	103	101	+ 2	+0.02
VII	3		25.867	25 558	121	112	+ 9	+0.09
VII	4		28.468	28.089	135	124	+ 11	+0.11
VII	5		30.790	30.345	147	135	+ 12	+0.12
IX	1		39.753	39.098	168	178	- 10	-0.10
IX	2		44.892	44.030	196	203	- 7	- 0.07
IX	5		59 777	58.234	265	279	- 14	- 0.14
IX	6		66.104	64.135	307	311	- 4	- 0.04
IX	7		74.059	71.495	359	353	+ 6	+0.06
IX	8		79.108	76.127	392	380	+ 12	+0.12
IX	9		84.662	81.347	408	411	- 3	-0.03

TABLE II. Isothermals of neon.					
Series	N ^o .	θ	p	d_A	pv_A (obs)
V	1	-182° 6	[67.468	211 34	0.31924]
V	2		[74.232	234.61	31641]
V	3		[79.168	251.84	31436]
III	1	-200° .1	61.657	263.77	0 23375
III	2		67.456	291.10	23172
III	3		73.850	320.85	23017
III	4		79.923	348.59	22928
IV	1	-208° .1	58.472	308.32	0.18965
IV	2		64.451	345.22	18670
IV	3		69.692	377 89	18443
IV	4		74.532	409.18	18215
IV	5		79.228	439.12	18043
II	1	-213° .1	53.896	334 59	0.16108
II	2		59.769	382.03	15645
II	3		66.271	435.46	15218
II	4		72.858	484.75	15030
II	5		79.698	534.62	14908
I	1	-217° .5	49.930	358.51	0.13927
I	2		53.528	395.62	13530
I	3		59.618	458.40	13006
I	4		64 975	511.85	12694
I	5		71 649	571.69	12533
I	6		79 417	632.23	12561

2. *Virial-coefficients.* So far virial-coefficients have been calculated for the temperatures of 20° C. and 0° C. only, in both cases using least squares. The following values were found.

TABLE III. Virial-coefficients of neon.			
θ	A_A	$B_A \times 10^3$	$C_A \times 10^6$
20° C.	+ 1.0731	+ 0.51578	+ 0.82778
0°	+ 0.99986	+ 0.41334	+ 1.1538

The differences between the observed values of pv_A and those calculated with the above coefficients are found in Table I in the last two columns. As the table shows, the isothermal of 20° C. seems to be slightly more accurate than that of 0° C., a circumstance which may be connected with the fact of its being more difficult to keep a vessel at a constant temperature of 0° C. than at one of 20° C., when an efficient thermostat is being used.

The communication of the value of the virial-coefficients for low temperatures, as also the calculation of the BOYLE-point ($B_A = 0$) we defer to a subsequent paper.

3. *Boiling point, vapour-pressures, liquid densities, triplepoint.*

The vapour-pressures were directly determined as the pressures of a bath of liquid neon, in which a helium-thermometer was placed, the same as served for the measurements by KAMERLINGH ONNES and WEBER.¹⁾

The value found for the pressure at the triple-point differs but

TABLE IV. Vapour-pressures and liquid densities of neon.		
$\theta =$ $T - 273^{\circ}.09$ K.	vapour-pressure in cm. mercury	liquid density
- 245.68 C.	81.62	
- 245.88	76.71	1.204
- 245.92 ²⁾	76.00 boiling point	
246.66	60.52	
- 247.49	45.16	
- 248.51	32.50	1.248
- 248.67	32.35 triple point	

¹⁾ H. KAMERLINGH ONNES and S. WEBER, These Proceedings supra. Comm. N° 147b.

²⁾ Calculated by interpolation.

little from that given Comm. 112, June 1909. Our results (yet of a preliminary kind) were (see table IV p. 518).

The density of the liquid was measured by a small hydrometer for densities of 1.20 to 1.30, floating in the bath, which after a preliminary trial was specially made for this purpose.

4. *Preliminary investigation of the behaviour of neon with respect to the law of corresponding states.*

The pieces of isothermals of low temperatures given in § 2 are too short and have therefore too few characteristic features, to be able to yield the critical constants of neon by the method of drawing them in a logarithmic diagram and making this fit the logarithmic diagram of another substance of known critical data, by parallel motions in two directions.

They are still insufficient for this purpose, if the improved method is used of taking as one of the coordinates in the diagram in which the isothermals are drawn the expression $\frac{pv}{T}$, which has the same value for all substances in corresponding states, so that now only a motion in one direction is required. Definite results are to be obtained, however, if in addition the value of the critical pressure (Comm. 112 June 1909) is utilized, although it is only a preliminary value. Following this plan we have placed the net of isothermals of neon in a $\frac{pv}{T} - \log p$ -diagram on top of that of hydrogen, oxygen and argon and by ascertaining what temperatures the isothermals which coincide belong to for each of the substances, we have arrived at a few estimates of the critical temperature.

The results were as follows:

1. *Hydrogen.* (KAMERLINGH ONNES and BRAAK).

a. The isothermals $-200.^{\circ}1_{Ne}$ and $-217.^{\circ}41_{H_2}$ coincide and cover each other completely over a long distance. Taking for the critical temperature of hydrogen the value found experimentally by BULLÉ $\theta_{kH_2} = -241.^{\circ}14$ C., we get

$$\theta_{kNe} = -231.^{\circ}2 \text{ C.}, \quad T_{kNe} = 41.^{\circ}9 \text{ K.}$$

b. The isothermals $-182.^{\circ}6_{Ne}$ — $200.^{\circ}6_{H_2}$ coincide. This gives:

$$\theta_{kNe} = -233.^{\circ}2 \text{ C.}, \quad T_{kNe} = 39.^{\circ}9 \text{ K.}$$

In this case we used also $\theta_{kH_2} = -241.^{\circ}14$ C., but, as this value belongs to monatomic hydrogen and hydrogen at -200° C. is certainly

not yet completely monatomic, whereas at the higher temperatures much higher critical reduction-temperatures have undoubtedly to be used, no weight can be attributed to the latter determination.

2. *Oxygen* (AMAGAT).

The isothermals $-198^{\circ}.4_{Ne}$ and $0^{\circ}_{O_2}$ coincide, so that, with $\theta_{kO_2} = -118^{\circ}.84$ C. (according to KAMERLINGH ONNES, DORSMAN and HOLST),

$$\theta_{kNe} = -230^{\circ}.9 \text{ C.}, \quad T_{kNe} = 42^{\circ}.2 \text{ K.}$$

3. *Argon* (KAMERLINGH ONNES and CROMMELIN).

a. The isothermals $-217^{\circ}.5_{Ne}$ and $-87^{\circ}.05_{Ar}$ coincide. With $\theta_{kAr} = -122^{\circ}.44$ C., according to CROMMELIN this leads to:

$$\theta_{kNe} = -228^{\circ}.2 \text{ C.}, \quad T_{kNe} = 44^{\circ}.9 \text{ K.}$$

b. The isothermals $-200^{\circ}.1_{Ne}$ and $-28^{\circ}.1_{Ar}$ coincide; hence

$$\theta_{kNe} = -228^{\circ}.2 \text{ C.}, \quad T_{kNe} = 44^{\circ}.9 \text{ K.}$$

c. The isothermals -191°_{Ne} and 0°_{Ar} coincide; which yields:

$$\theta_{kNe} = -227^{\circ}.9 \text{ C.}, \quad \text{and } T_{kNe} = 45^{\circ}.2 \text{ K.}$$

It will be seen that on the one hand the two values obtained from hydrogen and oxygen and on the other the three values from argon agree closely, the mutual agreement between these two groups of values being much less perfect.

If, using the critical temperature as obtained by the comparison with argon, the data of Table IV are plotted in the diagram of reduced vapour-pressure curves (p as function of t , where t is the reduced temperature for the several substances) and in that of the reduced liquid- (and vapour-) densities (Comm. 131a fig. 3 Oct. 1912) respectively, the curves for neon range themselves very well between those of the other substances in their proper order.

Neon thus appears to correspond closely with argon and to deviate from it in the direction indicated by its lower critical temperature. We hope to be able soon to be in a position to communicate fuller data regarding the equation of state of neon, especially to replace the preliminary measurement of the critical pressure by a more accurate one and to give a direct determination of the critical temperature.

We are glad to record our thanks to Mr. P. G. CATH for his assistance in the investigation of the liquid state of neon.