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**Physics.** — “*Isotherms of monatomic gases and of their binary mixtures. VII. Isotherms of argon between + 20° C. and — 150° C.*” By Prof. H. KAMBERLINGH ONNES and C. A. CROMMELIN. Comm. N<sup>o</sup>. 118<sup>b</sup> from the physical laboratory at Leiden.

(Communicated in the meeting of October 29, 1910).

§ 1. In the first publication<sup>1)</sup> of determinations of isotherms of gases at low temperatures made when these had already been a long time in progress mention was made of the desirability of an investigation of argon and helium; to these we may now add neon<sup>2)</sup>. We were able to publish helium measurements as early as 1907<sup>3)</sup>, but argon data were not accessible until a sufficient quantity of argon (about 25 L.) with not more than 0.1% impurity was obtained at a much later period (1909). The method of obtaining this has already been described<sup>4)</sup>. This degree of purity is sufficient for isotherm determinations. Measurements of vapour pressures, of critical constants<sup>5)</sup> and also of coexisting liquid and vapour densities<sup>6)</sup> have already been made with the same gas as was used for the isotherms.

As was the case with hydrogen<sup>6)</sup> care was taken in the determination of the argon isotherms given below that the observed points should be appropriately distributed over each isotherm and that suitable temperatures for these should be selected. Still, the shape of the isotherms made it desirable that the points observed should not be so closely packed in normal positions as was the case with hydrogen.

Since all required densities cannot be obtained with one and the same piezometer reservoir, points for each isotherm must be divided into groups. The various groups of points which afterwards constitute a single isotherm were as far as possible observed at the same temperature by suitable adjustment of the cryostat pressure; corrections given by graphical evaluations of  $\frac{d(pv_A)}{dt}$  were subsequently applied

1) Proc. April 1901. Comm. No. 69.

2) Proc. June 1909, Comm. No. 112.

3) Proc. Dec. 1907, Febr. and March 1908, Comm. No. 102, a, b and c.

4) Proc. May 1910, Comm. No. 115, and C. A. CROMMELIN, Thesis for the doctorate, Leiden, 1910.

5) Proc. Dec. 1910 Comm. No. 118<sup>a</sup>.

6) Proc. March 1907. Comm, 97<sup>a</sup>, Dec. 1907, Comm. No. 99<sup>a</sup>, Dec. 1907, Comm. No. 100.

to reduce these to the same temperature. These corrections could not be made with the same degree of certainty as for hydrogen, for then the temperature differences were always less than  $0^{\circ}.2$ , while differences of fully  $0^{\circ}.4$  were experienced in several instances in our present argon measurements.

That the individual coefficients<sup>1)</sup> for each isotherm may be calculated without adjustment from other isotherms, it is of special importance that points observed at temperatures which lie close together should be reduced to the same temperature.

There is yet another circumstance to cause the accuracy of the argon isotherms to be less than that reached in the hydrogen measurements. It has already been shewn<sup>2)</sup> that the desired degree of accuracy (from 1 to 0.5 per 1000) cannot be reached with reservoirs of content less than 5 cc. Hence the fact that quite a number of points have been got with a reservoir volume of 2.5 cc. can also account for the smaller degree of accuracy of many points. The following table gives for the various series rough values of the volumes in cc. of the large reservoir in the compression chamber and of the small reservoir that is kept at low temperature.

Series.	Large reservoir.	Small reservoir.
I—XII	600	2.5
XIII—XVIII	2000	5
XIX—XXI	600	2.5
XXII—XXIII	600	5
XXIV—XXXV	600	15
XXXVI—XXXVIII	600	2.5

§ 2. The argon used was made according to the methods indicated in § 1—3 Part I of Comm. 115. For the sake of completeness we now publish some further diagrams of the apparatus used.

Fig. 1<sup>3)</sup> shews the circulating apparatus following that used by FISCHER and RINGE<sup>4)</sup>.

<sup>1)</sup> Proc. June 1901, Comm. No. 71.

<sup>2)</sup> Proc. April 1901 Comm. No. 69 § 6, and Proc. March 1903, Comm. No. 84 § 19.

<sup>3)</sup> Proc. May 1910, Med. 115, Part I § 1b.

<sup>4)</sup> F. FISCHER and O. RINGE. Ber.<sup>1</sup> d.d. chem. Ges. 41. 2017. 1908.

- A*, a dry gas meter, (air inlet).  
*B*, two potash drying towers.  
*C*, three iron tubes<sup>1)</sup> containing a mixture of 90% calcium carbide and 10% calcium chloride, heated in a coke furnace so as to absorb oxygen and nitrogen.  
*D*, a porcelain tube containing copper oxide, and heated in a chemical combustion furnace so as to get rid of hydrocarbons (especially acetylene).  
*E*, two drying tubes containing potash and phosphorus pentoxide.  
*F*, a mercury jet circulating pump (more detailed in Fig. 2).  
*G*, Töpler pump for drawing off the gas that has been treated and an oil gasometer for storing it in.

During the working cycle the valves  $C_1$  and  $C_2$  are closed: the gas travels the path indicated by arrows.

Fig. 2. <sup>2)</sup> Apparatus for a working cycle over HEMPEL mixture.

- A*, iron tube containing HEMPEL mixture, and heated in a chemical combustion furnace for absorption of nitrogen.  
*B*, a hard glass tube of copper oxide heated in a small furnace to absorb traces of hydrocarbons that come from the mixture.  
*C*, two drying towers filled with potash and phosphorus pentoxide.  
*D*, circulating pump: a Prytz-pump  $D_1$  worked by an electric motor  $D_2$  raises the mercury. The mercury does not pass through any taps, and the apparatus can be evacuated without allowing any air to force its way in through the pump. The pump can be worked for all pressures in the apparatus less than 1 atm. If the tube of the Prytzpump breaks the gas in the apparatus can neither escape nor be contaminated.  
*E*, side tubes for removing and supplying gas.  
*F*, manometer.  
*G*, two vessels each of about 5 L. content, to increase the capacity of the apparatus.  
*H*, phosphorus pentoxide drying tube.  
*I*, a side tube to allow of the removal of the gases developed when the HEMPEL mixture is heated at the beginning.  
*J*, side tube for the removal of the purified gas, which is then stored in a high pressure cylinder as shown in Fig. 3.

Fig. 3. <sup>3)</sup> Apparatus for the separation of argon and neon by fractional distillation.

- A*, High pressure cylinder containing argon still contaminated with neon.  
*B*, manometer.  
*C*, reservoir surrounded by liquid oxygen boiling under strongly reduced pressure; in this the argon freezes. A mercury suction pump *E* brings the neon along *D* to the bulb *F*. A Töpler pump then removes the argon along *G*. *H* is the pressure side of this pump, from which the argon at an over pressure of about 1 atm. is passed into the chamber *I*, immersed in liquid air boiling under reduced pressure. When that chamber is filled with solid argon, it is warmed, and the gas blows off to the pure gas storage cylinder *J*.

<sup>1)</sup> These tubes, have already served for the preparation of helium, cf. Proc. May-June 1908, Comm. N<sup>o</sup>. 108.

<sup>2)</sup> Proc. May 1910. Comm. N<sup>o</sup>. 115, Part. I § 1c.

<sup>3)</sup> Proc. May 1910. Comm. N<sup>o</sup>. 115, Part. I. § 3.

§ 3. For description of the *apparatus* used for determinations of the normal volume and of the individual isotherms we may refer to earlier publications <sup>1)</sup>. In one respect we introduced an improvement for we took our readings through a telescope with a micrometer eye piece; in this way they could be made at twice the rate possible when using the nonius of the cathetometer. Pressure and temperature readings were made in exactly the same manner as before in determinations of vapour pressures etc., <sup>2)</sup> and the remarks made in the communication of those results apply equally well here. Measurements of pressures below 20 atm. were made with the standard open manometer. <sup>3)</sup>

We gratefully acknowledge our indebtedness to Miss G. I. LORENTZ and Mr. W. J. DE HAAS for their measurements and calculation of the temperatures, and also to Dr. C. DORSMAN Jr., and Mr. G. HOLST for their measurements with the open manometer.

§ 4. As regards the calculations themselves we may also refer to earlier communications <sup>4)</sup> for there is not much fresh to be said about them. First, isotherms for  $+20^{\circ}\text{C}$ . and  $0^{\circ}\text{C}$ . were calculated using the expansion coefficients for oxygen taken from an earlier paper <sup>5)</sup>; the critical constants for argon and oxygen differ but slightly from each other. Then the coefficients of the empirical equation of state <sup>6)</sup>  $A_A$  and  $B_A$  were calculated to a first approximation, and using the critical constants <sup>7)</sup> a value for  $C_A$  was got from the set of reduced coefficients VII. 1 <sup>8)</sup>. From the equation to which the operations led the expansion coefficients for various densities were calculated, and with these values the calculation of the isotherms was repeated. From these new isotherms to a second approximation, the coefficients were recalculated to a second approximation. For our present purpose a third approximation was found to be unnecessary.

The expansion coefficients at low temperatures which were necessary for the much smaller corrections for that portion of the glass capillary inside the cryostat were at first deduced from AMAGAT's <sup>9)</sup>

<sup>1)</sup> Proc. April 1901, Comm. N<sup>o</sup>. 69, Proc. April 1902, Comm. N<sup>o</sup>. 78, Proc. Sept. 1906, Comm. N<sup>o</sup>. 94f, Proc. March 1907, Comm. N<sup>o</sup>. 97a.

<sup>2)</sup> Proc. May 1910, Comm. N<sup>o</sup>. 115.

<sup>3)</sup> Proc. Nov. 1898, Comm. N<sup>o</sup>. 44.

<sup>4)</sup> Proc. April 1902, Comm. N<sup>o</sup>. 78, Proc. March 1907, Comm. N<sup>o</sup>. 97a.

<sup>5)</sup> Proc. April 1902, Comm. N<sup>o</sup>. 78.

<sup>6)</sup> Proc. June 1901, Comm. N<sup>o</sup>. 71.

<sup>7)</sup> Proc. May 1910, Comm. N<sup>o</sup>. 115.

<sup>8)</sup> Suppl. N<sup>o</sup>. 19. (May 1908) p. 18.

<sup>9)</sup> E. H. AMAGAT, Ann. d. Chim. et d. phys (6). 29, June and Aug. 1893.

oxygen isotherms with the aid of the law of corresponding states. Subsequently, when we could avail ourselves of a portion of our experimental data, the expansion coefficients or rather the densities which are in this case easier to manipulate were graphically determined. The degree of accuracy afforded by this method was found to be quite sufficient for our purpose. The second approximations were found to be sufficient for all the isotherms.

In the calculations we have made no use of the RAMSAY and TRAVERS <sup>1)</sup> isotherm at  $+11^{\circ}.2$  C., for their observations shewed such marked deviations from ours that we could place no reliance upon them.

§ 5. The *results* are contained in the following tables. In the first column is given the date, in the second the series, and in the third the number of the observation; in the fourth is given the temperature in Kelvin degrees <sup>2)</sup>  $-273^{\circ}.09$ ; the fifth and sixth contain the pressure in atmospheres ( $p$ ) and the density in terms of the normal density respectively, the results gives the product of  $p$  into the volume expressed in terms of the normal volume  $pv_A$  and finally the eighth contains the values of  $v_A$ .

Such observations as were for any reason deemed less accurate than the others are placed between square brackets.

Observations marked by an asterisk were made by way of control after the measurements proper were completed because uncertain indications of one of the metal manometers made us for a moment suspect that something had happened to the pressure measurement. The table of deviations given in a subsequent section shows that this fear was baseless.

§ 6 A general survey of the region which the present isotherms in connection with earlier papers <sup>3)</sup> enable us to regard as known is given by the accompanying  $pv_A$  diagram for all observations <sup>4)</sup>. Observed points are represented by small circles. For data for the boundary curve we may refer to the other papers just mentioned. Points calculated from the liquid and vapour densities are given by squares, and points extrapolated from the isotherms are given by triangles <sup>5)</sup>.

<sup>1)</sup> W. RAMSAY and M. W. TRAVERS. Phil. Trans. (A) 197, 47, 1901.

<sup>2)</sup> Proc. Dec. 1907. Comm. N<sup>o</sup>. 101b.

<sup>3)</sup> Proc. May 1910. Comm. 115, Proc. Dec. 1910, Comm. N<sup>o</sup>. 118a.

<sup>4)</sup> Fig. 5.

<sup>5)</sup> In order to make the diagram not uselessly long, the volumes above 0.040 are omitted. The isotherms of  $+20^{\circ}.39$  C.,  $0^{\circ}.00$  C. and  $-57^{\circ}.72$  C. therefore ought to have been drawn until the line  $v_A = 0.040$ .

Isotherms of argon.

TABLE Ia.

Data.	Series.	No.	$\theta$	$p$	$d_A$	$pv_A$	$v_A$
May 11, 1910	XXXV	1	+20° 39	21.783	20.409	1.0627	0.048783
» »	XXXV	2		27.320	25.750	606	38824
» »	XXXV	3		34.487	32.590	582	30684
July 2, »	XXXVIII	1		*37.248	35.330	543	28205
Dec. 23, 1909	X	1		37.673	35.750	535	27965
» »	X	2		49.604	47.319	483	21134
July 9, 1910	XXXVIII	2		*31.697	50.134	434	16011
Dec. 23, 1909	X	3		61.741	59.250	420	16373
Dec. 23, 1909	IX	1	+18° 30	37.264	35.401	1 0526	0.028248
» »	IX	2		49.586	47.355	471	21117
» »	IX	3		62.489	60.000	405	10650
May 11, 1910	XXXIV	1	0° 00	20.576	20.877	0.98560	0.047910
» »	XXXIV	2		26.070	26.581	98077	37621
» »	XXXIV	3		31.572	32.302	97740	30358
Dec. 22, 1909	VIII	1		36.743	37.782	97250	26468
» »	VIII	2		49.871	51.840	96201	19290
» »	VIII	3		62.230	65.125	95261	15308
May 10, 1910	XXXII	1	-57° 72	17.872	23.509	0.70023	0.042537
» »	XXXII	2		[21.488	28.575	75200	34996]
» »	XXXII	3		25.228	33.793	74654	29592
Dec. 20, 1909	VI	1		35.127	48.116	73004	20783
» »	VI	2		46.209	64.948	71148	15397
» »	VI	3		62.079	90.695	68448	11026
May 10, 1910	XXXIII	1	-87° 05	16.178	25.152	0.64320	0.031758
» »	XXXIII	2		21.651	34.467	62816	22013
Dec. 21, 1909	VII	1		33.266	55.822	59616	17914
» »	VII	2		41.094	71.444	57519	13997
» »	VII	3		51.533	94.625	54460	10568
» »	VII	4		61.830	119.84	51594	0.0033446

## Isotherms of argon.

TABLE 1b.

Data.	Series.	No.	$\theta$	$p$	$d_A$	$\bar{p}v_A$	$v_A$
May 6, 1910	XXXI	1	-102°.51	14.864	25.571	0.55130	0.039107
» »	XXXI	2		19.790	35.077	56420	28509
Apr. 6, »	XXII	1		[0.143	47.893	54587	20880]
» »	XXII	2		[28.840	53.752	55654	18604]
Dec.14, 1909	I	1		32.394	62.240	52047	16067
Apr. 6, 1910	XXII	3		[ 5.784	69.954	51153	14295]
Dec.14, 1909	I	2		40.976	84.002	48780	11904
» »	I	3		45.088	95.802	47063	10438
» »	I	4		51.398	115.88	44354	0.0086296
» »	I	5		56.882	135.65	41935	73722
» »	I	6		62.239	158.01	39388	63286
May 6, 1910	XXX	1	-109°.88	14.443	26.242	0.55039	0.038107
» »	XXX	2		18.653	34.807	53589	8730
Dec.18, 1909	V	1		31.515	65.142	48379	15351
July 1, 1910	XXXVII	1		*31.929	66.530	47993	15031
Dec.18, 1909	V	2		39.166	87.176	44927	11471
» »	V	3		43.718	102.76	42544	0.0097315
» »	V	4		49.315	125.56	39435	79612
» »	V	5		54.250	148.32	35577	67424
July 1, 1910	XXXVII	2		*34.859	152.79	35929	65451
Dec.18, 1909	V	6		59.616	180.84	32966	55298
Dec.17, 1909	IV	1	-113°.80	31.001	67.078	0.46216	0.014908
» »	IV	2		38.005	88.889	42756	11250
» »	IV	3		42.682	106.68	40010	0.0093741
» »	IV	4		47.655	129.17	36894	77450
March 4, 1910	XV	1		51.752	152.71	33889	65483
Dec.17, 1909	IV	5		52.188	155.40	33583	64350
March 4, 1910	XV	2		55.763	182.13	30617	54905
Dec.17, 1909	IV	6		55.991	184.82	30295	54107
March 4, 1910	XV	3		58.858	212.99	27653	46950



Isotherms of argon.

TABLE Ic.

Data.	Series.	No.	$\theta$	$p$	$d_A$	$pv_A$	$v_A$
Dec. 15, 1909	II	1	-115°.86	31.323	69.947	0.44781	0.014296
» »	II	2		37.788	91.308	41385	10252
» »	II	3		41.908	108.02	38796	0.0092574
» »	II	4		46.648	131.51	35469	76037
» »	II	5		50.224	155.12	32442	64464
March 2, 1910	XIV	1		73.204	179.94	29568	55575
Dec. 15, 1909	II	6		[51.865	183.35	29923	54539]
March 2, 1910	XIV	2		57.493	235.47	24416	42468
» »	XIV	3		61.626	319.52	19287	31297
May 4, 1910	XXVIII	1	-116°.62	13.863	26.480	0.52353	0.037765
» »	XXVIII	2		17.697	34.939	50650	28621
Dec. 16, 1909	III	1		39.681	69.630	44705	14571
» »	III	2		57.250	90.563	41131	11042
» »	III	3		41.943	110.19	38063	0.0090749
» »	III	4		46.496	133.69	34779	74800
» »	III	5		50.250	159.71	31468	62612
March 2, 1910	XIII	1		50.447	161.75	31489	61824
Dec. 16, 1909	III	6		[53.059	186.15	28503	53719]
March 2, 1910	XIII	2		54.922	210.02	26151	47615
» »	XIII	3		[57.617	260.61	22108	38371]
» »	XIII	4		60.669	331.29	18313	30185
May 6, 1910	XXIX	1	-119°.50	13.766	26.871	0.51230	0.037215
» »	XXIX	2		17.378	34.965	49700	28600
Jan. 7, »	XI	1		[30.376	70.314	43200	14222]
March 16, »	XIX	1		30.303	70.481	42994	14188
July 4, »	XXXVI	1		*30.365	70.580	43021	14168
March 16, »	XIX	2		34.052	83.257	40900	12011
Jan. 7, »	XI	2		37.641	96.834	38872	10327
March 16, »	XIX	3		37.923	98.863	38359	10115
» »	XIX	4		43.006	124.97	34414	0.0080022
Jan. 7, »	XI	3		[46.082	143.71	32065	69583]
March 16, »	XIX	5		47.972	156.36	30233	63955
March 4, »	XVI	1		[49.294	172.25	28617	58054]
» »	XVI	2		51.679	222.69	23207	44906
» »	XVI	3		53.044	275.02	19287	36361
» »	XVI	4		54.244	336.89	16101	29683

*Isotherms of argon.*

TABLE 1d.

Data.	Series.	No.	$\theta$	$p$	$d_A$	$pv_A$	$v_A$
March 16, 1910	XX	1	-120° 24	30 809	72.627	0.42421	0.013709
» »	XX	2		33.776	82.816	40784	12075
» »	XX	3		37 836	93 246	38124	10076
» »	XX	4		41 668	118.51	35160	0 0084380
» »	XX	5		44 510	136 31	32654	73403
March 5, »	XVII	1		47 705	165.79	28774	60317
» »	XVII	2		50 351	206 57	24375	48410
» »	XVII	3		52 253	280 25	18645	35582
» »	XVII	4		53.191	338.95	15693	29503
May 4, 1910	XXVII	1	-121° 21	43.754	27.326	0 50333	0.036595
» »	XXVII	2		47 225	35.283	48818	28342
March 17, »	XXI	1		30 122	71.459	42153	13794
» »	XXI	2		34.070	85 581	57811	11685
» »	XXI	3		37 465	100.33	37343	0.0096674
» »	XXI	4		[41.932	123.85	33856	80711]
» »	XXI	5		45 282	148.95	30402	67139
March 5, »	XVIII	1		47.094	170 05	27693	58805
» »	XVIII	2		49 865	234 13	21298	42714
» »	XVIII	3		50.885	333 75	15247	29963
Apr. 2°, 1910	XXIV	1	-130° 38	42 773	27 394	0 40625	0.036504
» »	XXIV	2		[14 384	31 581	45430	31663]
» »	XXIV	3		15.664	31.726	45108	28797
Apr. 6, »	XXIII	1		22 861	55.867	40964	17919
» »	XXIII	2		25.519	65 125	39185	15355
Jan. 7, »	XII	1		28.878	77.821	37108	12850
» »	XII	2		[32.993	101.71	32438	0 0098318]
Apr. 30, 1910	XXV	1	-133° 62	11.986	28.122	0.42620	0.035559
» »	XXV	2		14.586	35.573	41003	28111
Apr. 30, 1910	XXVI	1	-149° 60	11.150	29 183	0.38205	0.034106
» »	XXVI	2		12.788	34.046	36910	28863

Finally, a diagram of the  $\frac{pv_A}{T}$ ,  $d_A$  isotherms is added to this paper<sup>1)</sup>.

§ 7. *Individual virial coefficients.*<sup>2)</sup>

An attempt was made to represent the isotherms by the empirical equation of state

$$pv_A = A_A + \frac{B_A}{v_A} + \frac{C_A}{v_A^2} + \frac{D_A}{v_A^3} + \frac{E_A}{v_A^4} + \frac{F_A}{v_A^5},$$

and to evaluate the individual virial coefficients.

Seeing that we could not avail ourselves of measurements at such small densities as was the case with hydrogen and hence could not calculate values of  $A_A$  for each individual isotherm from the observations, the calculation was made by means of the equation

$$A_{A_T} = A_{A_0}(1 + 0.0036618 \theta)$$

$A_{A_0}$  was first calculated as accurately as possible from

$$A_{A_0} = 1 - B_{A_0} - C_{A_0}$$

since for  $p=1$ ,  $v_{A_0}=1$  and  $D_{A_0}$  etc. may be made  $=0$ ) and

Individual virial coefficients of argon. TABLE II.						
$t$	$A_A$	$10^3 B_A$	$10^6 C_A$	$10^{12} D_A$	$10^{18} E_A$	$10^{24} F_A$
+20°.30	+1.07545	-0.60271	+0.66360	+4.32836		
0°.00	<b>+1.00074</b>	-0.73969	+0.00487	+3.00635		
-57°.72	+0.78922	-1.30460	+1.64016	-0.67139		
-87°.05	+0.68174	-1.63902	+2.1711	-2.83014	+10.5566	
-102°.51	+0.62511	-1.81649	+2.28125	-4.10121	+10.4013	
-109°.88	+0.59810	-1.92881	+2.57060	-4.76310	+10.3251	
-113°.80	+0.58372	-1.97263	+2.36239	+2.40001	+10.2947	
-115°.86	+0.57617	-2.03892	+2.74407	-2.15810	+10.2837	-2.35600
-116°.62	+0.57340	-2.02273	+2.56235	-1.20499	+10.2806	-2.31432
-119°.20	+0.56393	-2.04406	+2.31445	+0.65126	+10.2759	-2.17669
-120°.24	+0.56012	-2.05472	+2.50248	-0.67211	+10.2764	-2.12230
-121°.21	+0.55658	-2.05084	+2.37741	+0.13359	+10.2783	-2.07246

<sup>1)</sup> Fig. 4.

<sup>2)</sup> Proc. June 1901. Comm. No. 71.

Deviations of $pv_A$ in percents of $pv_A(R)$ TABLE III.											
+20°.39		0°.00		-57°.72		-87°.05		-109°.51		-109°.88	
$d_A$	$W-R$ in %	$d_A$	$W-R$ in %	$d_A$	$W-R$ in %	$d_A$	$W-R$ in %	$d_A$	$W-R$ in %	$d_A$	$W-R$ in %
20.499	-0.07	20.877	+0.03	23.509	+0.10	25.152	+0.21	25.571	+0.20	26.242	+0.21
25.759	+0.02	26.581	-0.03	[28.575	-0.17]	34.467	+0.06	35.077	0.00	34.807	+0.34
32.590	+0.16	32.302	+0.06	33.793	-0.06	55.822	-0.06	[47.893	+0.47]	65.142	+0.11
*35.330	-0.07	37.782	-0.03	48.116	-0.03	71.444	-0.05	[53.752	+0.47]	*66.530	-0.24
35.759	-0.12	51.840	-0.04	64.948	+0.01	94.625	-0.16	62.240	+0.08	87.176	+0.01
47.319	-0.01	65.325	+0.02	90.695	+0.01	119.84	+0.12	[69.954	+0.48]	102.76	-0.25
59.134	+0.12							84.002	-0.13	125.56	-0.24
*59.250	+0.01							95.802	-0.22	148.32	-0.17
								115.88	-0.22	*152.79	-0.46
								135.65	0.00	180.84	+0.31
								158.01	+0.31		

-113°.80		-115°.86		-116°.62		-119°.20		-120°.24		-121°.21	
$d_A$	$W-R$ in %	$d_A$	$W-R$ in %	$d_A$	$W-R$ in %	$d_A$	$W-R$ in %	$d_A$	$W-R$ in %	$d_A$	$W-R$ in %
67.078	+0.02	69.947	-0.20	26.480	+0.36	26.871	+0.32	72.627	+0.03	27.326	+0.20
88.889	+0.09	91.308	+0.27	34.939	+0.13	34.965	+0.34	82.816	+0.18	35.283	+0.21
106.68	-0.09	108.02	+0.07	68.630	+0.10	[70.314	+0.08]	99.246	+0.12	71.459	-0.15
129.17	-0.03	131.51	-0.06	90.563	+0.03	70.481	-0.33	118.51	-0.02	85.580	-0.10
152.71	-0.03	155.12	-0.12	110.19	-0.22	*70.580	-0.23	136.31	+0.05	100.33	-0.06
155.40	+0.02	179.94	-0.10	133.69	-0.19	83.257	-0.53	165.79	-0.07	[123.85	-0.10]
182.13	+0.11	[183.35	+2.24]	159.71	-0.13	96.834	+0.24	206.57	+0.72	148.95	0.00
184.82	-0.03	235.47	+0.35	161.75	-0.23	98.863	-0.25	280.25	(+2.71)	170.05	0.00
212.99	+0.04	319.52	-0.09	[186.15	+0.14]	124.97	-0.20	338.95	-0.00	234.13	(+1.95)
				210.02	(+0.52)	[143.71	+0.72]			333.75	0.00
				[260.61	+1.44]	156.36	+0.26				
				331.29	-0.05	[172.25	+1.06]				
						222.69	(+2.47)				
						275.02	(+4.42)				
						336.89	-0.12				

H. KAMERLINGH ONNES and C. A. CROMMELIN. "Isotherms of monatomic gases and of their binary mixtures. VII. Isotherms of argon between + 20° C. and - 150° C."

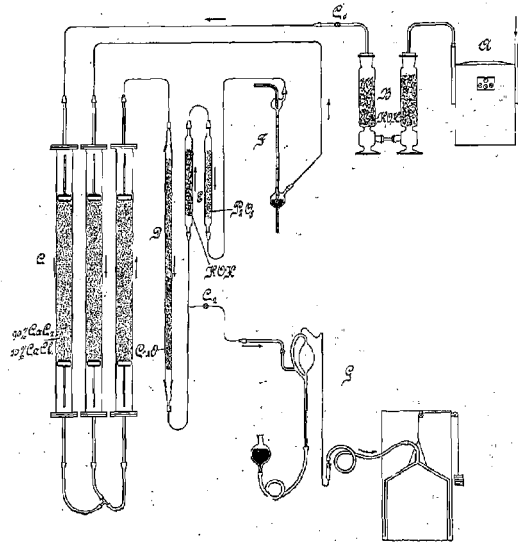


Fig. 1.

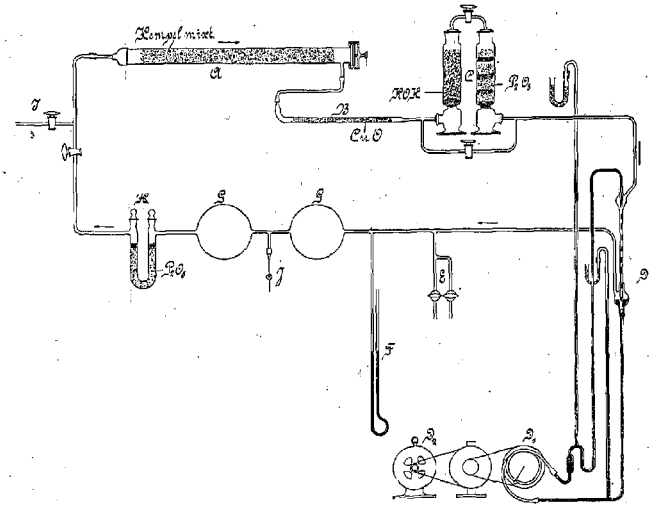


Fig. 2.

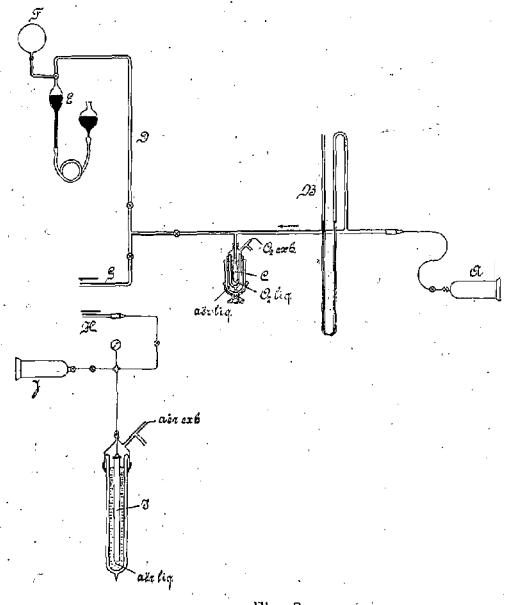


Fig. 3.

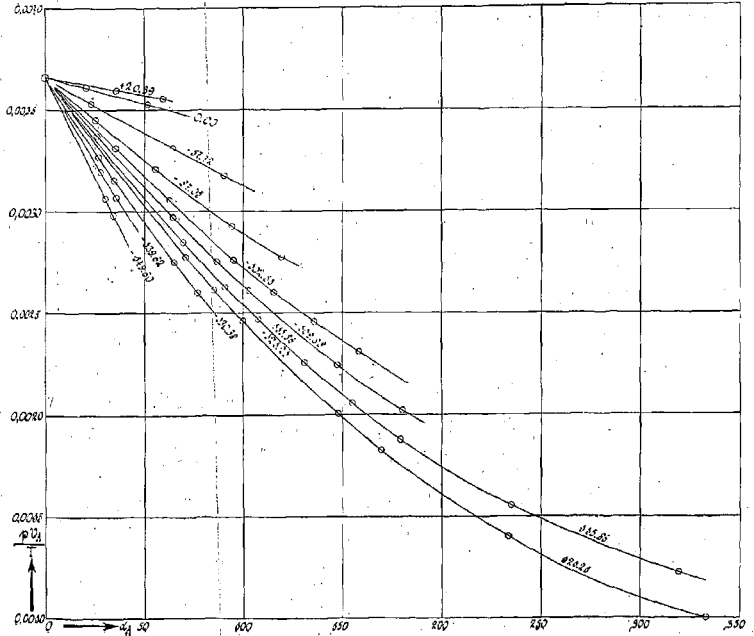


Fig. 4.



$$pv_{A_0} = 1 - B_{A_0} - C_{A_0} + \frac{B_{A_0}}{v_{A_0}} + \frac{C_{A_0}}{v_{A_0}^2}$$

And seeing on the other hand that the densities attained are not sufficiently great to allow of the calculation of the last coefficients, values of  $E_A$  and  $F_A$  and sometimes too of  $D_A$  (insofar as they had to be allowed for) were obtained by combining the critical constants published a short time ago with the set of reduced virial coefficients VII. 1. Solutions for the other coefficients were then obtained for each isotherm from a number of suitable chosen points, and were tested with the observed results. Finally, correspondence was made as satisfactory as possible either by least squares or by the method of E. F. VAN DE SANDE BAKHUYZEN<sup>1)</sup>:

In this way the individual coefficients for each isotherm given in table II were obtained. Numbers borrowed from the reduced coefficients VII. 1., are printed in italics.

With these coefficients values of  $pv_A$  were calculated; table III gives percentage deviations of calculated results from observed ones. In this table [ ] and ' have the same significance as before. Deviations placed between ( ) are so treated because the observations to which they belong were not used in the adjustment of coefficients; this was done from consideration of the difficulty of obtaining agreement with a formula of whose constants only three are derived from observations in that neighbourhood.

**Chemistry.** — “*On the reaction products of potassium isocyanate and diaminoacetone hydrochloride. Amino- and ureopropylene-ureine.*” By Prof. A. P. N. FRANCHIMONT and Dr. J. V. DUBSKY.

(Communicated in the meeting of November 26, 1910).

More than three years ago (February 23 1907) I called attention to the importance which the knowledge of acetoneureine would have in answering the question as to the action of nitric acid on heterocyclic compounds consisting of two CO-, two NH- and two CH<sub>2</sub> groups. Of the eleven theoretically possible isomers, there are two which are urea derivatives, namely hydro-uracil and acetoneureine. The first has been investigated as to its behaviour with nitric acid by myself and FRIEDMANN, the second has not been obtained as yet.

<sup>1)</sup> Proc. July 1906, Comm. No. 95a.