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THE PRESSURE-VOLUME-TEMPERATURE VALUES FOR AMMONIA TO ONE THOUSAND ATMOSPHERES FROM 30 TO 200°

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The results herewith reported have been obtained from measurements carried out with the assistance of Mr. Robert B. Brownlee in 1913. It has been my intention to repeat the work using the improved apparatus which has resulted from a continuation of the program of measuring physical properties but a reëxamination of the old results indicates that they are quite consistent enough to be of practical use. Moreover, it will be some time before new measurements can be made for liquid ammonia. The results are believed to be accurate with a maximum error of one-fourth per cent. The relative precision is much greater.

Apparatus Used.—The method and apparatus have already been described.[1] The pressures were obtained by using a piston gage of the type developed in this Laboratory.[2] The constant of the gage determined in 1911 before the present measurements were made was 4.1351[3] international mm. of mercury per gram of weight on the piston. Bridgeman[4] has recently redetermined the constant of the same piston and found 4.1346 mm. using the value 26144.7 mm. for the vapor pressure of carbon dioxide at 0°.

Temperatures were determined by the use of the platinum resistance thermometer. The quality of the platinum available at the time of the measurements was inferior to that now in use in this Laboratory but the temperatures can only differ appreciably from the present scale[5] above 100°. In any case the temperature at 200° probably does not differ from the present scale by more than 0.05.

The volumes of the fluid under pressure are difficult to measure with the same precision as the pressures or the temperatures. Ordinary mild steel was used for the container and data for the elastic constants as a function of temperature were at the time not known. The temperature expansion

[1] F. G. Keyes, *J. Am. Soc. Refrig. Eng.*, **1**, 9 (1914); F. G. Keyes and R. B. Brownlee, THIS JOURNAL, **40**, 25 (1918).

[2] F. G. Keyes and Jane M. Dewey, *J. Optical Soc. Am.*, **14**, 491 (1927).

[3] F. G. Keyes and R. B. Brownlee, THIS JOURNAL, **40**, 25 (1918).

[4] O. C. Bridgeman, *ibid.*, **49**, 1174 (1927).

[5] The scale in use at this Laboratory at present is that based on the use of 0.1-mm. platinum wire with a mean temperature coefficient between 0 and 100° of 0.0039 or greater. The Callendar formula is employed using a δ value determined from the resistances at the ice, and boiling points of water and sulfur. The normal boiling point of the latter is assumed to be 444.6°.

TABLE I

PRESSURE–VOLUME PRODUCTS FOR AMMONIA (UNITS, CC./G., ATM., DEGREES C.)

t	V, cc./g. 1.5	1.55	1.60	1.65	1.70	1.75	1.80	1.85	1.90	1.95	2.00
29.84	1548.0	1013.2	547.2	174.0							
34.86	1703.5	1161	681.5	308.1	31.0						
44.81	(1790.8)	1327	885.0	526.0	235.0						
49.83	(2052)	1576	1106	707.7	385.0	139.0					
54.88	(2070)	1604	1150	763.0	462.3	228.5	44.5				
64.88		(1800)	1371	986.0	676.0	424.5	222.0	64.5			
75.065		(2069)	1660	1263.0	936.0	671.0	453.5	285.8	148.5		
85.21		(2243)	(1882)	1519.5	1176	895.0	670.0	482.8	336.8	222.0	126.5
95.46			(2084)	1768	1451	1153	904.0	709.9	549.0	418.0	309.0
100.306			(2159)	1851	1537	1245	991.2	791.0	626.0	492.2	384.0
105.01			(2243)	1947	1651	1363	1107	893.5	724.0	583.0	472.0
115.01					1884	1610	1345	1122	938.0	788.0	661.2
129.862					(2082)	1859	1636	1423	1227	1060	918.2
139.51					(2236)	(2026)	1818	1609	1417	1250	1106
160.286							(2163)	(1977)	1792	1619	1466
180.709								(2312)	2143	1975	1819
200.701										2294	2140

t	V, cc./g. 2.05	2.10	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0
95.46	219.0	144.5								
100.306	297.0	224.5								
105.01	382.0	310.0								
115.01	557.7	474.4								
129.862	802.5	708.0	372.0	326.0						
139.51	985.0	884.0	493.0	428.3	453.2	508.8	564.2	620.0	676.0	731.8
160.286	1338	1227	760.5	646.8	650.0	697.5	748.5	804.0	860.0	913.2
180.709	1682	1566	1032	870.2	851.5	885.0	932.2	982.0	1032	1082
200.701	2002	1877	1302	1095	1055	1074	1112	1158	1206	1254

Conversion factors are as follows: (cu. ft./lb.)/(cc./g.), 0.016018; (lb./sq. ft.)/atm., 2116.2; Amagat units/(cc./g.), 0.0007715; (lb./sq. ft.)/atm. × (cu. ft./lb.)/(cc./g.), 33.9. The atmosphere is defined as the pressure per sq. cm. due to a column of mercury 76 cm. long at zero and g, 980.665, (the density of mercury being taken as 13.5951 g./cc.).

was likewise but inaccurately known (±3%). Means for determining the temperature dilation of the steel sample were not available. In computing the volumes given in the following tables the best available data have been employed. Nevertheless it is believed that the maximum error had best be assumed to be within one-fourth per cent.

Summary of Experimental Results

Rather than present the experimental results as obtained, it was decided to correlate the experimental data by means of graphs. A total of 191 volume and pressure measurements were available at 17 temperatures. The data were plotted to a large scale using pressure–volume products and volumes as coördinates. Table I gives the *pv* values at the actual temperatures observed for volumes from 1.50 cc./g. to 6 cc./g. In Table II, a table is given for even pressures from 100 international atmospheres to 1100 atmospheres and for each ten degrees of temperature to 200°. All numbers in brackets represent extrapolated values of the corresponding *pv* products.

TABLE II

PRESSURE–VOLUME PRODUCTS FOR AMMONIA (UNITS CC./G., ATM., DEGREES C.)

	$P_{atm.}$										
t	100	200	300	400	500	600	700	800	900	1000	1100
0	(155)	(316)	(458)	(612)	(757)	(900)	(1045)	(1189)	(1333)	(1482)	(1628)
10	158.5	318.5	466.0	619.3	766.8	911.0	1055	1200	1342	1489.5	1634
20	162.0	322.0	474.1	627.9	777.2	922.2	1066	1211	1353	1499	1643
30	165.8	327.5	482.5	637.0	788.8	935.2	1080	1224	1367	1511	1654
40	169.2	333.2	492.2	648.0	802.0	949.2	1096	1240	1382	1526	1669
50	173.0	340.7	503.8	660.5	816.8	965.0	1116	1259	1402	1545	1687
60	178.0	349.2	516.0	675.0	832.2	982.2	1135	1280	1423	1567	1709
70	183.7	359.0	529.2	690.0	849.5	1002	1156	1303	1448	1592	1735
80	190.0	370.7	543.2	706.5	868.2	1024	1179	1328	1473	1620	1764
90	199.0	384.2	558.7	725.2	888.5	1047	1203	1354	1501	1649	1793
100	208.2	399.5	575.8	745.5	910.0	1071	1228	1382	1530	1678	1824
110	223.5	416.0	594.8	767.2	934.0	1098	1255	1410	1560	1710	1857
120		436.0	617.2	790.5	960.0	1125	1283	1440	1591	1742	1891
130		462.0	643.5	817.8	988.2	1154	1313	1471	1623	1776	1926
140		498.5	674.0	848.0	1018	1184	1344	1502	1656	1810	1960
150		554.0	710.3	881.8	1050	1216	1376	1535	1690	1844	1996
160		638.0	751.7	919.2	1085	1249	1410	1569	1724	1879	2032
170		748.0	805.0	962.2	1124	1287	1446	1604	1761	1916	2069
180		887.0	869.0	1010	1168	1328	1481	1642	1798	1952	2108
190		1055	950.0	1068	1217	1370	1518	1680	1836	1992	2147
200		1255	1052	1128	1269	1416	1556	1720	1877	2032	2186
210									1921	2073	2225

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