

DENSITY OF HYDROCHLORIC ACID

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Recently I had occasion to consult the literature for the density of 2 *N* HCl at 15° C referred to water at 4° C. This paper is intended to show the lack of agreement on data on the density of hydrochloric acid, a lack which may be typical of published density data in general, and to give the results of my own work on the density of hydrochloric acid.

From each investigator's work I have selected the concentration nearest to 2 *N* and from the density of that acid have calculated the density of 2 *N* acid, assuming $\frac{\Delta D}{\Delta C} = K$ as given in the following table:

Investigator	Percent HCl	N	Density 15° C	$\frac{\Delta D}{\Delta C}$
Lunge	12.38	3.60	1.0609	0.00494
	9.99	2.87	1.0491	—
	7.84	2.23	1.0384	0.00498
	5.18	1.46	1.0251	0.00500
	2.93	0.81	1.0140	0.00493
Cheneveau	11.93	3.46	1.0587	—
	8.12	2.31	1.0398	0.00496
	4.13	1.15	1.0200	0.00497
Kohlrausch (18°)	9.81	2.82	1.0487	—
	4.74	1.33	1.0236	0.00495
Average, 0.00496				

$\frac{\Delta D}{\Delta C}$ varies in the above range of concentration from the average value by as much as 0.00004. 2 *N* Hydrochloric acid contains 7.05 percent of HCl as calculated from Lunge's figures. So in calculating the density of 2 *N* HCl even from the density of 2 percent acid or of 12 percent acid, an error of no greater than 5×0.00004 or 0.0002 could be introduced. Most of the conversions covered a much shorter range.

In converting from a given temperature to 15° C, I have used the temperature coefficient given by Lunge and Marchlewski¹ of 0.00023 per degree, which is in accord with the value given by Schüncke.² When unable to discover whether water at the temperature of the experiment, at 4° C, or at 0° C, was used as the standard of reference, I have used the temperature which brings the result nearest the average of the results. In no case did the temperature difference exceed 5°; hence a ten percent error in the temperature coefficient could not change the calculated density by more than one unit in the fourth decimal place.

Thus for example:

Given that:

7.15 percent HCl has a density of 1.0357 at 15.5° C referred to water at 15.5° C.

Density of H₂O at 15.5° C is 0.99905.

$1.0357 \times 0.99905 = 1.0347 = d$ referred to H₂O at 4° C.

$1.0347 + (0.5 \times 0.00023) = 1.0348 = D_{4^{\circ}}^{15^{\circ}}$.

$1.0348 - [(7.15 - 7.05) \times 0.00496] = 1.0343$.

Result: Density of 2 N HCl at 15° C referred to water at 4° C is 1.0343.

Also having found that $1.0348 = D_{4^{\circ}}^{15^{\circ}}$ of 7.15 percent HCl calculations could be made as follows:

Since one litre at 15° C contains 1034.8 grams

$0.0715 \times 1034.8 = 73.98 = \text{wt. of HCl per litre.}$

Now one liter of 2 N HCl contains 72.94 gram HCl.

$$0.0348 \times \frac{72.94}{73.98} = 0.0343.$$

$$\text{Density} = 1.0343.$$

All the data from the literature were given to four or five places of decimals. The literature references are given at the end of the article.

¹ Zeit. angew. Chem., 1891, 133.

² Zeit. phys. Chem., 14, 331 (1894).

Density of Hydrochloric Acid

Determined by	Conc. of HCl	Density	Temp. °C	Referred to water at °C	Calculated Density of 2N HCl 15 °C 4 °C
Ireund ¹⁷	2 N	1.0356	15.65	4.0	1.0357
Kolb ³	6.26%	1.0310	15.0	0.0	1.0349
Edwards ⁷	5.31%	1.0261	16.0	4.0	1.0347
Schuncke ⁸	6.49%	1.0340	15.0	4.0	1.0346
Ure ¹	6.52%	1.0318	15.0	4.0	1.0345
Lunge and Marchlewski ³	7.84%	1.0384	15.0	4.0	1.0344
Chênevau ¹⁶	8.12%	1.0398	15.0	4.0	1.0344
Mfg. Chem. Ass'n. ²⁰	7.15%	1.0357	15.5	15.5	1.0343
Worden and Motion ¹⁴	5.71%	1.0274	15.0	4.0	1.0340
Graham ²	7.90%	1.0380	15.5	—	1.0340
Forchheimer ¹³	7.17%	1.0334	20.0	4.0	1.0340
Ferguson ¹⁵	10.74%	1.0525	15.0	4.0	1.0339
Pickering ⁶	6.38%	1.0315	15.0	15.0	1.0339
Kohlrausch ⁹	9.81%	1.0486	18.0	18.0	1.0339
Barnes and Scott ¹¹	6.56%	1.0305	19.5	4.0	1.0338
Loomis ¹⁰	1 N	1.0165	18.0	4.0	1.0337
Sidersky ¹⁹	5.00%	1.0242	15.0	15.0	1.0336
Conroy ¹²	1 N	1.0163	18.0	4.0	1.0333
Jones ¹⁸	2 N	1.0341	20.0	4.0	1.0331
Kohlrausch ⁴	1.0014 N	1.0161	18.0	4.0	1.0328

Experimental

In my own determination of the density of hydrochloric acid, the Davis pycnometer¹ was used. Conductivity water was prepared by treating distilled water with potassium dichromate, acidified with sulphuric acid. This was distilled into baryta water and again distilled. A block tin condenser was used and a trap was inserted between the last still and the condenser. Grasselli "strictly chemically pure" hydrochloric acid was distilled into this conductivity water. The resulting acid solution was stored in an old hydrochloric acid bottle which had been cleaned and steamed out. The pycnometers were thoroughly cleaned and steamed out and then dried by passing dry air through them. The freshly prepared conductivity water was used to determine the volumes of the pycnometers. The thermostat used was regulated at 15° C to $\pm 0.05^\circ$ (thermometer standardized by the Bureau of Standards). Two pycnometers were used and the determinations with each pycnometer were run in triplicate. The filled pycnometers were allowed to remain in the thermostat for twenty minutes. After adjustment, the ends were capped and the pycnometers were hung in the balance case until the weight was constant to four-tenths of a milligram. Two different concentrations of acid were used so as to determine the concentration coefficient, and the density of one of the concentrations was measured at two temperatures so as to determine the temperature coefficient.

The composition of the acid was found by the silver chloride method, using the Gooch crucible, two determinations being made of each concentration. The silver chloride precipitate was treated with hydrochloric acid and nitric acid and heated at 200° C until the weight was constant to ± 0.0001 gram. The hydrochloric acid solution was weighed in weighing bottles with gas-tight ground glass stoppers to prevent any evaporation during weighing, care being taken that none of the solution came in contact with the capillary of the ground

¹ Jour. Am. Chem. Soc., 37, 1198.

glass stopper. Conductivity water was used in all the analytical work. The results of the investigation are given in the following tables.

Composition:

Analysis No.	Corrected weight of HCl solution in vacuum Grams	Corrected weight of AgCl in vacuum Grams	Weight of HCl Grams	Composition Percent
I A	2.0908	0.8158	0.2076	9.927
II A	2.1795	0.8502	0.2163	9.925
I B	2.9998	0.8418	0.2142	7.140
II B	3.0459	0.8543	0.2175	7.138

Density $\frac{15^\circ}{4^\circ}$

Pycno-meter No.	Corrected weight of water content in vacuum Grams	Volume Cc	Corrected weight of HCl solution content in vacuum Grams	Density
I A	18.9762	18.9933	19.9182	1.04870
2 A	18.6070	18.6238	19.5308	1.04870
I B	18.9762	18.9933	19.6543	1.03480
2 B	18.6070	18.6238	19.2717	1.03479

Density $\frac{20^\circ}{4^\circ}$

I C	18.9610	18.9952	19.6323	1.03354
2 C	18.5924	18.6259	19.2508	1.03355

Calculations as in above table on page 116. Results given to four places of decimals for comparison:

Conc. of HCl Percent	Density	Temp. °C	Referred to water at °C	Calculated Density of 2N HCl at $\frac{15^\circ}{4^\circ}$
9.926	1.04870	15°	4°	1.0344
7.139	1.03480	15°	4°	1.0344
7.139	1.03355	20°	4°	1.0344

Calculation of concentration coefficient:

Percent HCl	N	Density 15°_4	$\frac{\Delta D}{\Delta C}$
9.926	2.854	1.04870	0.004986
7.139	2.023	1.03480	

Calculation of temperature coefficient:

Percent HCl	Temp.	Density	$\frac{\Delta D}{\Delta T}$
7.139	15°	1.03480	0.000250
7.139	20°	1.03355	

Discussion of Accuracy of Work

In determining the composition of the hydrochloric acid solutions, the silver chloride was weighed to two units in the fourth decimal place. This might involve an error of five units in the fifth decimal place in the weight of the HCl or about a 0.03 percent error which would effect the percent composition by two units in the third decimal place. A change in the composition of 1 percent changes the density 0.00496. An error of 0.002 in the percent composition would be equivalent to a change in the density of 0.00001.

The pycnometers were weighed to four units in the fourth decimal place. This could introduce an error of 0.002 percent, which would effect the density by 0.00002. The capillaries in the pycnometers were 0.12 cm in diameter and the meniscus was set to within 0.02 cm of the mark. This might introduce an error of 0.0002, which is within the error of weighing.

¹ Ure: Handwörterbuch prakt. Chemie., 99 (1825).

² Graham: Phil. Trans. (1850).

³ Kolb: Comptes rendus, 74, 737 (1872).

⁴ Kohlrausch: Wied. Ann., 26, 174 (1885).

⁵ Lunge and Marchlewski: Zeit. angew. Chem., 1891, 133.

⁶ Pickering: Ber. deutsch. chem. Ges., 26, 278 (1893).

⁷ Edwards: Am. Chem. Jour., 16, 629 (1894).

⁸ Schuncke: Zeit. phys. Chem., 14, 345 (1894).

⁹ Kohlrausch: Wied. Ann., 53, 33 (1894).

- ¹⁰ Loomis: *Wied. Ann.*, **60**, 550 (1897).
- ¹¹ Barnes and Scott: *Jour. Phys. Chem.*, **2**, 546 (1898).
- ¹² Conroy: *Proc. Roy. Soc.*, **64**, 315 (1898).
- ¹³ Forchheimer: *Zeit. phys. Chem.*, **34**, 28 (1900).
- ¹⁴ Worden and Motion: *Jour. Soc. Chem. Ind.*, **24**, 178 (1905).
- ¹⁵ Ferguson: *Jour. Soc. Chem. Ind.*, **24**, 781 (1905).
- ¹⁶ Chèneveau: *Ann. Chim. Phys.*, (8) **12**, 214 (1907).
- ¹⁷ Freund: *Zeit. phys. Chem.*, **66**, 555 (1909).
- ¹⁸ Jones and Pearce: *Carnegie Inst. Pub.*, 80 (1913).
- ¹⁹ Sidersky: "Constantes Physico-Chimiques," p. 50.
- ²⁰ Mfg. Chemists' Ass'n. of U. S. A., "Scott's Standard Methods of Analysis."

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