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Schedule for

Density-composition tables for aqueous solutions of hydrochloric acid

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- British Laboratory Ware Association
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- Department of Trade and Industry (National Weights and Measures Laboratory)
- Institute of Brewing
- Institute of Petroleum
- National Sulphuric Acid Association
- Royal Society of Chemistry
- Scientific Glassware Association
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- Society of Glass Technology

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Contents

	Page
Committees responsible	Inside front cover
Foreword	ii
1 Scope	1
2 Basis of Table 1	1
3 Application of Table 1	1
Appendix A Correction of readings taken on BS hydrometers	18
Appendix B BS hydrometers available for use in conjunction with the tables	21
Appendix C Examples of the use of Table 1 in conjunction with BS hydrometers	23
Table 1 — Density-composition table for aqueous solutions of hydrochloric acid	2
Table 2 — Corrections to be applied to obtain density at t	18
Table 3 — Temperature corrections for BS hydrometers	18
Table 4 — Surface tensions of aqueous solutions of hydrochloric acid at 20 °C	19
Table 5 — Maximum errors introduced by ignoring surface tension when reading BS hydrometers, adjusted for 55 mN/m, in aqueous solutions of hydrochloric acid in an ordinary hydrometer jar	19
Table 6 — Maximum errors due to omission of all corrections to BS hydrometers adjusted for 55 mN/m	20
Table 7 — BS hydrometers available for use in aqueous solutions of hydrochloric acid	22
Publications referred to	Inside back cover

Foreword

This British Standard has been prepared under the direction of the Laboratory Apparatus Standards Committee.

This British Standard was first published in 1941 and was revised in 1957. This revision supersedes the 1957 edition which is withdrawn.

The United Kingdom participated in the preparation by Technical Committee TC 47, Chemistry, of the International Organization for Standardization (ISO), of the related ISO Recommendation ISO/R 905:1968, but disapproved it on technical grounds. The United Kingdom did not disapprove of the conversion of ISO/R 905:1968 into ISO 905:1976 *“Hydrochloric acid for industrial use — Evaluation of hydrochloric acid concentration by measurement of density”*.

Together with hydrometers the tables provide a simple means of determining the strength of any given aqueous solution of hydrochloric acid, or making up solutions of known strength. The tables may, of course, be used with other methods of determining density (for example, see BS 733).

The previous edition of this British Standard made reference to density and specific gravity hydrometers complying with BS 718:1953. When BS 718 was revised in 1979 it was aligned as far as possible with the intentions of Technical Committee 48, Laboratory glassware and related apparatus, of the International Organization for Standardization (ISO). The term “specific gravity” was replaced by “relative density”, scales of relative density were excluded, and scales marked in kilograms per cubic metre were introduced as an alternative to grams per millilitre. Users who had a continuing need for relative density hydrometers ($d_{60/60}^{\circ F}$) were referred to ISO 650.

The readings of a 60/60 °F relative density hydrometer can readily be corrected (see Appendix A) to yield density (in kg/m³) of the liquid at the temperature at which the hydrometer is used.

Within 1 to 2 parts in 1 000 readings at a temperature t (in °C) of a 60/60 °F relative density hydrometer can be taken as the density (in kg/m³) at t . To an accuracy which is very frequently adequate (within 1 part in 1 000) the reading at a temperature t between 10 °C and 40 °C on a 20 °C or 15 °C density hydrometer complying with BS 718 may be accepted as the density (in kg/m³) of the liquid at t . Density and relative density hydrometers therefore may often be used without correction. Appendix A gives information on how the highest accuracy can be obtained. Recommendations as to the choice of suitable hydrometers for use in conjunction with these tables are given in Appendix B. Appendix C gives examples of the use of density-composition tables in conjunction with these hydrometers.

The principal differences between BS 976:1957 and this edition are:

- a) density, in Table 1, is given in kilograms per cubic metre instead of grams per millilitre;
- b) SI units have been used throughout and, where applicable, the tables have been recomputed;
- c) recommendations as to the choice of suitable hydrometers for use in conjunction with Table 1 have been revised to accord with BS 718;
- d) the temperature calculations given in Table 3 have been computed using the value of the thermal cubical expansion coefficient quoted in ISO 1768 for the use in preparation of measurement tables for liquids.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 24, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This British Standard gives tables that enable the composition of an aqueous solution of hydrochloric acid to be determined from its density at temperatures between 0 °C and 40 °C.

Appendix A gives information on the corrections that are necessary when density is determined by a hydrometer complying with BS 718¹⁾.

Appendix B gives information on the choice of BS hydrometers that are suitable for the determination of the density of hydrochloric acid solutions.

Appendix C gives examples of the use of a BS hydrometer in conjunction with Table 1.

NOTE The titles of the publications referred to in this standard are listed on inside back cover.

2 Basis of Table 1

Table 1 is based on data obtained from the International Critical Tables (1928) Vol. III, page 54, supplemented by density-composition determinations in solutions containing more than 30 % of hydrochloric acid by mass at 10 °C, 20 °C and 30 °C, which were carried out at the suggestion of the Technical Committee responsible for this standard. The results of the latter determinations support the data which appear in the International Critical Tables, though at a given density the concentrations given in certain other data, published since the International Critical Tables were compiled, are appreciably greater. In particular the percentages given by Akerlöf and Teare²⁾ are about 0.5 greater at about 1.15 g/mL (i.e. about 30 % HCl).

It should be observed that the table relates to mass, not to apparent mass in air.

3 Application of Table 1

Table 1 is arranged primarily for ease in determining the strength of an aqueous solution of hydrochloric acid of known density. The density of a solution of known strength can, however, be obtained quite readily from the table. Moreover, by the application of small allowances (see Appendix A) Table 1 can be used to find the strength of solutions of known relative density or the relative density of solutions of known strength.

Consider, for example, a solution containing 10 g of HCl in 100 g of solution, i.e. one for which $g = 10$.

By looking up the value of D_t corresponding to the value $g = 10$ under any particular temperature in Table 1, the density of the solution at that temperature can be obtained. Thus, for example, the density of the solution of 1 050 kg/m³ at 10 °C, 1 047 kg/m³ at 20 °C, etc. Due allowance, based on the density of water at the various temperatures concerned, can then be made to find the corresponding relative densities at the same temperature as the acid.

It should be observed that the percentage composition g of a solution is independent of its temperature, but G , the number of grams of hydrochloric acid in 1 L of solution, varies with the temperature of the solution owing to the change in volume of the solution with change in temperature. Hence, the concentration G should always be associated with a particular temperature. For a given value of G applicable at a particular temperature, Table 1 can be used to obtain the density of the solution at the specified temperature or at any other temperature within the range of the table. The value of G for the solution at temperatures other than the specified one can also be obtained. For example, consider a solution 1 L of which, at 20 °C, contains 199 g of HCl. Under 20 °C in Table 1 the value of D_t corresponding to $G = 199$ is 1 089 kg/m³ and the corresponding value of g is 18.2 g. By tracing the value $g = 18.2$ g through the table, and interpolating where necessary, the density D_t at various temperatures of the solution containing 199 g of HCl in 1 L of solution at 20 °C can be obtained and also the number of grams of HCl in 1 L of the solution at various temperatures. The following are examples of values which may thus be obtained.

t °C	HCl in 100 g of solution g	Density of solution at t kg/m ³	HCl in 1 L of solution at t g
0	18.2	1 097	200
10	18.2	1 093	199
20	18.2	1 089	199
30	18.2	1 084	198
40	18.2	1 080	197

¹⁾ From hereon referred to as a BS hydrometer.

²⁾ *J. Amer. Chem. Soc.*, **60** (1938), 1226.

Table 1 — Density-composition table for aqueous solutions of hydrochloric acid

D_t is the density (mass per unit volume) of solution (in kg/m³) at a temperature t (in °C) [for many purposes it can be assumed that irrespective of the value of t the reading of a BS density hydrometer at t gives the density D_t , and that the reading of a 60/60 °F relative density hydrometer at t is numerically 0.001 greater than $D_{t/1\,000}$ (see Appendix A)].

t	0 °C		5 °C		10 °C		15 °C	
D_t	g	G	g	G	g	G	g	G
1 000	0.0	0	0.0	0	0.1	1	0.2	2
1 001	0.2	2	0.2	2	0.3	3	0.4	4
1 002	0.4	4	0.4	4	0.5	5	0.6	6
1 003	0.6	6	0.6	6	0.7	7	0.8	8
1 004	0.8	8	0.8	8	0.8	8	1.0	10
1 005	1.0	10	1.0	10	1.0	10	1.2	12
1 006	1.1	12	1.2	12	1.2	12	1.4	14
1 007	1.3	13	1.4	14	1.4	14	1.6	16
1 008	1.5	15	1.5	16	1.6	16	1.8	18
1 009	1.7	17	1.7	18	1.8	18	2.0	20
1 010	1.9	19	1.9	19	2.0	20	2.2	22
1 011	2.1	21	2.1	21	2.2	22	2.4	24
1 012	2.3	23	2.3	23	2.4	24	2.6	26
1 013	2.5	25	2.5	25	2.6	26	2.8	28
1 014	2.6	27	2.7	27	2.8	28	3.0	30
1 015	2.8	29	2.9	29	3.0	30	3.2	32
1 016	3.0	31	3.1	31	3.2	32	3.4	34
1 017	3.2	33	3.3	33	3.4	34	3.6	36
1 018	3.4	34	3.4	35	3.6	36	3.8	38
1 019	3.6	36	3.6	37	3.8	38	4.0	40
1 020	3.8	38	3.8	39	4.0	40	4.2	42
1 021	3.9	40	4.0	41	4.2	42	4.4	44
1 022	4.1	42	4.2	43	4.4	45	4.6	47
1 023	4.3	44	4.4	45	4.6	47	4.8	49
1 024	4.5	46	4.6	47	4.8	49	5.0	51
1 025	4.7	48	4.8	49	5.0	51	5.2	53
1 026	4.9	50	5.0	51	5.2	53	5.4	55

Table 1 — Density-composition table for aqueous solutions of hydrochloric acid

g is the mass (in g) of HCl in 100 g mass of solution.

G is the mass (in g) of HCl in a quantity of solution occupying 1 L at the temperature stated at the head of the column.

20 °C		25 °C		30 °C		35 °C		40 °C		t
g	G	g	G	g	G	g	G	g	G	D_t
0.3	3	0.6	6	0.9	9	1.2	12	1.6	16	1 000
0.5	5	0.8	8	1.1	11	1.4	14	1.8	18	1 001
0.8	8	1.0	10	1.3	13	1.6	16	2.0	20	1 002
1.0	10	1.2	12	1.5	15	1.8	18	2.2	22	1 003
1.2	12	1.4	14	1.7	17	2.1	21	2.4	24	1 004
1.4	14	1.6	16	1.9	19	2.3	23	2.6	26	1 005
1.6	16	1.8	18	2.1	21	2.5	25	2.8	29	1 006
1.8	18	2.0	20	2.3	23	2.7	27	3.1	31	1 007
2.0	20	2.2	22	2.5	25	2.9	29	3.3	33	1 008
2.2	22	2.4	24	2.7	28	3.1	31	3.5	35	1 009
2.4	24	2.6	27	2.9	30	3.3	33	3.7	37	1 010
2.6	26	2.8	29	3.1	32	3.5	35	3.9	39	1 011
2.8	28	3.0	31	3.3	34	3.7	38	4.1	41	1 012
3.0	30	3.2	33	3.6	36	3.9	40	4.3	43	1 013
3.2	32	3.4	35	3.8	38	4.1	42	4.5	46	1 014
3.4	34	3.6	37	4.0	40	4.3	44	4.7	48	1 015
3.6	36	3.9	39	4.2	42	4.5	46	4.9	50	1 016
3.8	38	4.1	41	4.4	45	4.8	48	5.1	52	1 017
4.0	40	4.3	43	4.6	47	5.0	51	5.4	54	1 018
4.2	43	4.5	46	4.8	49	5.2	53	5.6	57	1 019
4.4	45	4.7	48	5.0	51	5.4	55	5.8	59	1 020
4.6	47	4.9	50	5.2	53	5.6	57	6.0	61	1 021
4.8	49	5.1	52	5.4	55	5.8	59	6.2	63	1 022
5.0	51	5.3	54	5.6	58	6.0	61	6.4	66	1 023
5.2	53	5.5	56	5.8	60	6.2	64	6.6	68	1 024
5.4	55	5.7	58	6.0	62	6.4	66	6.8	70	1 025
5.6	58	5.9	61	6.3	64	6.6	68	7.0	72	1 026

Table 1 — Density-composition table for aqueous solutions of hydrochloric acid

D_t is the density (mass per unit volume) of solution (in kg/m³) at a temperature t (in °C) [for many purposes it can be assumed that irrespective of the value of t the reading of a BS density hydrometer at t gives the density D_t , and that the reading of a 60/60 °F relative density hydrometer at t is numerically 0.001 greater than $D_{t/1.000}$ (see Appendix A)].

t	0 °C		5 °C		10 °C		15 °C	
D_t	g	G	g	G	g	G	g	G
1 027	5.1	52	5.2	53	5.4	55	5.6	57
1 028	5.3	54	5.4	55	5.5	57	5.8	59
1 029	5.5	56	5.6	57	5.7	59	6.0	61
1 030	5.6	58	5.8	59	5.9	61	6.2	63
1 031	5.8	60	6.0	61	6.1	63	6.4	66
1 032	6.0	62	6.2	64	6.3	65	6.6	68
1 033	6.2	64	6.4	66	6.5	68	6.8	70
1 034	6.4	66	6.6	68	6.7	70	7.0	72
1 035	6.6	68	6.8	70	6.9	72	7.2	74
1 036	6.8	70	7.0	72	7.1	74	7.4	77
1 037	7.0	72	7.1	74	7.3	76	7.6	79
1 038	7.2	74	7.3	76	7.5	78	7.8	81
1 039	7.4	77	7.5	78	7.7	80	8.0	83
1 040	7.6	79	7.7	80	7.9	83	8.2	85
1 041	7.8	81	7.9	82	8.1	85	8.4	87
1 042	7.9	83	8.1	85	8.3	87	8.6	90
1 043	8.1	85	8.3	87	8.5	89	8.8	92
1 044	8.3	87	8.5	89	8.7	91	9.0	94
1 045	8.5	89	8.7	91	8.9	93	9.2	96
1 046	8.7	91	8.9	93	9.1	95	9.4	98
1 047	8.9	93	9.1	95	9.3	98	9.6	101
1 048	9.1	95	9.3	97	9.5	100	9.8	103
1 049	9.3	97	9.5	99	9.7	102	10.0	105
1 050	9.5	99	9.7	102	9.9	104	10.2	107
1 051	9.7	101	9.9	104	10.1	106	10.4	109
1 052	9.8	104	10.1	106	10.3	108	10.6	112
1 053	10.0	106	10.3	108	10.5	111	10.8	114