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ELECTROCHEMICAL DATA

PART X

ELECTROLYTIC CONDUCTIVITY OF AQUEOUS SOLUTIONS OF THE ALKALI METAL HYDROXIDES

Prepared for

National Aeronautics and Space Administration

NASA Contract Number: R-09-022-029

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by
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and
Walter J. Hamer

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Electrochemical Data X. Electrolytic Conductivity of Aqueous Solutions of the Alkali Metal Hydroxides

ABSTRACT

This report gives a critical evaluation of the available data on the electrolytic conductivity of aqueous solutions of the alkali metal hydroxides. Results are given for sodium hydroxide at 15, 20, 25, 30, 40, 50, 60, 75, 80 and 100 °C; for potassium hydroxide at 25, 30, 60, and 100 °C, and for lithium hydroxide at 25 °C.

I. Introduction

This report gives a critical evaluation of available data on the electrolytic conductivity of aqueous solutions of the alkali metal hydroxides. Data were found on the conductivity of aqueous NaOH solutions at 15, 20, 25, 30, 40, 50, 60, 75, 80 and 100 °C [1,2,3,4,5]. One seemingly good source [6] of NaOH data was not available for study. It was found that the conductivity of aqueous KOH solutions had been measured at 25, 30, 60 and 100 °C [2,4,7]; and LiOH at 25 °C [2]. No modern data on the conductivity of aqueous RbOH and CsOH were found. The latest reference [8] to measurements on these solutions is cited in the International Critical Tables VI.

The rounded values of electrolytic conductivity given in the tables are consistent with the Jones-Bradshaw [9] conductivity standard, ^{12}C scale of atomic weights, and the absolute electrical units [10].

II. Λ_o Values

The data of Marsh and Stokes [1] on NaOH solutions in the concentration range 0.000826 - 0.0097339N at 15, 25, 50 and 75 °C were used to obtain Λ' values according to the Fuoss-Accascina [11] procedure, and extrapolated to obtain Λ_o values at these temperatures with the results shown below:

t °C	Λ_o	J(a)c	S	E	s
15	205.60	263	93.66	90.06	0.08
25	249.25	322	117.97	112.17	0.04
50	364.48	510	188.36	178.44	0.09
75	483.86	707	271.77	263.47	0.09

A least squares fit of Λ_o versus t °C gave the following equation which was used to calculate Λ_o values at other temperatures as shown in the following table.

$$\Lambda_o = 143.88 + 3.9412t + 1.2463 \times 10^{-2}t^2 - 6.0953 \times 10^{-5}t^3 \quad s = 0.0$$

t °C	Λ_o	t °C	Λ_o
15	205.60	60	412.05
20	227.20	65	435.98
25	249.25	70	459.93
30	271.69	75	483.86
35	294.48	80	507.73
40	317.57	85	531.49
45	340.92	90	555.10
50	364.48	95	578.51
55	388.21	100	601.68

The Fuoss-Accascina method was used on the data of Darken and Meir [3] for LiOH, NaOH, and KOH solutions to obtain the following Λ_0 values at 25 °C.

	Λ_0	J(a)c	s
LiOH	237.3	173	0.11
NaOH	248.9	332	0.07
KOH	271.9	507	0.01

In the foregoing, and in the tables, _s_ represents the standard deviation of the fit.

III. Results

The results of the study of the data on the electrolytic conductivity of NaOH solutions are given in Tables 1-10, on KOH solutions in Tables 11-13, and on LiOH in Table 14. In much of the original data the conductivity was expressed only as specific conductance, and to three digits. In these cases we calculated the equivalent conductance to three digits, which explains why many of the rounded values in the tables are expressed only to this degree of exactness.

IV. Conclusions

Our study shows that with the possible exception of aqueous solutions of sodium and potassium hydroxide, research on the electrolytic conductivity of the alkali metal hydroxides has been badly neglected It is hoped that this situation will be remedied at an early date.

V. References

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[10] Natl. Bur. Standards Circular 459 (1947).

[11] R. M. Fuoss and F. Accascina, Electrolytic Conductance, p. 197, Interscience Publishers, Inc., New York, 1959.

Table 1 - Equivalent conductance of NaOH - H_2O at 15 °C [1]

c	Λ	c	Λ
0.001	202.59	0.007	198.28
.002	201.42	.008	197.83
.003	200.56	.009	197.42
.004	199.87	.01	197.03
.005	199.28	.02	193.94
.006	198.75	---	----

$\Lambda = 205.60 - 93.66c^{1/2} + 90.06c \log c + 105.26c + 5066.2c^{3/2} - 48{,}966c^2 + 137{,}922c^{5/2}$ $s = 0.06$

Table 2 - Equivalent conductance of NaOH - H_2O at 20 °C [2]

c	Λ	c	Λ
0.01	218	0.7	179
.03	214	.8	174
.05	211	.9	169
.07	209	1.0	164
.1	207	2.0	125
.2	202	3.0	109
.3	198	4.0	88.4
.4	194	5.0	71.2
.5	189	6.0	57.1
.6	184	7.0	46.0

0.01-2.26N: $\Lambda = 227.20 - 105.52c^{1/2} + 203.63c - 242.99c^{3/2} + 81.829c^2$ $s = 0.01$

2.26-7.0N: $\Lambda = 227.20 - 105.52c^{1/2} + 84.082c - 62.734c^{3/2} + 18.448c^2 - 1.7948c^{5/2}$ $s = .00001$

Table 3 - Equivalent conductance of $NaOH-H_2O$ at 25 °C [1,3,3]

c	Λ	c	Λ
0.001	245.49	0.8	186.1
.003	242.91	.9	182.6
.005	241.25	1.0	179.2
.007	239.96	2.0	148.8
.01	238.39	3.0	123.4
.02	234.52	4.0	100.8
.03	231.64	5.0	81.24
.04	229.55	6.0	64.73
.05	227.9	7.0	51.26
.06	226.3	8.0	40.67
.07	224.8	9.0	32.69
.08	223.5	10.0	26.99
.09	222.3	11.0	23.20
.1	221.2	12.0	20.90
.2	212.8	13.0	19.64
.3	206.8	14.0	18.96
.4	201.9	15.0	18.39
.5	197.5	16.0	17.43
.6	193.5	17.0	15.60
.7	189.7	18.0	12.40

0.001-0.043N: $\Lambda = 249.25 - 117.97c^{1/2} + 112.17c \log c + 247.32c + 2506.7c^{3/2} - 23{,}692c^2 + 56{,}633c^{5/2}$ $s = 0.03$

0.043-2.0N: $\Lambda = 249.25 - 117.97c^{1/2} + 123.35c - 111.33c^{3/2} + 41.473c^2 - 5.5360c^{5/2}$ $s = 0.2$

2.0-18.0N: $\Lambda = 249.25 - 117.97c^{1/2} + 98.721c - 70.741c^{3/2} + 19.869c^2 - 1.8541c^{5/2}$ $s = 0.1$

Table 4 - Equivalent conductance of $NaOH\text{-}H_2O$ at 30 °C [4]

c	Λ	c	Λ
0.01	259.6	0.6	210.8
.02	255.2	.7	207.3
.03	252.1	.8	203.9
.04	249.6	.9	200.5
.05	247.4	1.0	196.9
.06	245.6	2.0	157.9
.07	243.9	3.0	130.8
.08	242.5	4.0	110.7
.09	241.1	5.0	92.6
.1	239.9	6.0	75.4
.2	230.9	7.0	60.0
.3	224.7	8.0	49.8
.4	219.4	9.0	41.2
.5	214.3	10.0	30.3

0.01-0.5N; $\Lambda = 271.69 - 130.97c^{1/2} + 107.92c - 24.876c^{3/2} - 39.813c^2$ s = 0 [illegible]

0.5-3.0N; $\Lambda = 271.69 - 130.97c^{1/2} + 66.817c + 69.445c^{3/2} - 117.33c^2 + 37.248c^{5/2}$ s = 0.[illegible]

3.0-6.0N; $\Lambda = 271.69 - 130.97c^{1/2} + 81.172c - 52.573c^{3/2} + 16.371c^2 - 2.0327c^{5/2}$ s = 0.0

6.0-10.0N; $\Lambda = 271.69 - 130.97c^{1/3} + 367.50c - 358.54c^{3/2} + 123.72c^2 - 14.343c^{5/2}$ s = 0.0

Table 5 - Equivalent conductance of $NaOH-H_2O$ at 40 °C [2]

c	Λ	c	Λ
0.01	301	0.7	209
.02	294	.8	207
.03	288	.9	205
.04	284	1.0	204
.05	280	2.0	188
.06	276	3.0	153
.07	273	4.0	131
.08	270	5.0	112
.09	267	6.0	95.0
.1	264	7.0	79.8
.2	244	8.0	66.5
.3	232	9.0	54.8
.4	223	10.0	44.9
.5	217	11.0	36.6
.6	212	12.0	29.9

0.01-2.25N: $\Lambda=317.57-158.59c^{1/2}-101.25c+244.41c^{3/2}-98.525c^2$ $s = 0.002$

2.25-12.0N: $\Lambda=317.57-158.59c^{1/2}+83.863c-40.175c^{3/2}+8.4969c^2-0.59771c^{5/2}$ $s = 0.0$

Table 6 - Equivalent conductance of NaOH-H_2O at 50 °C [1]

c	Λ	c	Λ
0.001	358.47	0.007	349.62
.002	356.09	.008	348.72
.003	354.33	.009	347.89
.004	352.90	.01	347.11
.005	351.68	.02	340.98
.006	350.59	.03	336.35

$\Lambda = 364.48-188.36c^{1/2}+178.44c \log c +388.24c+3828.1c^{3/2}-34,549c^{2}+78,275c^{5/2}$ $s = 0.09$

Table 7 - Equivalent conductance of $NaOH-H_2O$ at 60 °C [2]

c	Λ	c	Λ
0.01	390	1.0	253
.02	380	2.0	230
.03	373	3.0	201
.04	367	4.0	176
.05	362	5.0	155
.06	357	6.0	136
.07	352	7.0	120
.08	348	8.0	105
.09	345	9.0	91.7
.1	341	10.0	80.5
.2	314	11.0	70.9
.3	296	12.0	62.8
.4	283	13.0	56.0
.5	273	14.0	50.5
.6	266	15.0	46.1
.7	261	16.0	42.7
.8	257	17.0	40.1
.9	255	18.0	38.1

0.01-1.54N: $\Lambda = 412.05 - 220.22c^{1/2} - 42.812c + 66.766c^{3/2} + 104.44c^{2} - 66.970c^{5/2}$ s = 0.0

1.54-18.0N: $\Lambda = 412.05 - 220.22c^{1/2} + 120.15c - 53.471c^{3/2} + 11.131c^{2} - 0.81864c^{5/2}$ s = 0.0

Table 8 - Equivalent conductance of $NaOH-H_2O$ at 75 °C [1,5,5,5,5]

c	Λ	c	Λ
0.001	475.11	10.0	96.8
.002	471.65	11.0	85.3
.003	469.10	12.0	77.3
.004	467.01	13.0	68.1
.005	465.20	14.0	60.4
.006	463.59	15.0	54.9
.007	462.13	16.0	51.1
.008	460.78	17.0	48.3
.009	459.53	18.0	45.9
.01	458.35	19.0	43.2
.02	449.91	20.0	39.5
1.0	327	21.0	34.2
2.0	294	22.0	31.3
3.0	261	23.0	28.9
4.0	227	24.0	26.6
5.0	193	25.0	24.4
6.0	164	26.0	22.3
7.0	145	27.0	20.4
8.0	128	28 0	18.7
9.0	111	29.0	17.3

0.001-0.02N: $\Lambda=483.86-271.77c^{1/2}+263.47c\log c+361.55c+12,326c^{3/2}-134,355c^{2}+443,381c^{5/2}$ s=0.05

1.0-6.0N: $\Lambda=483.86-271.77c^{1/2}+137.18c+5.0226c^{3/2}-34.836c^{2}+7.9709c^{5/2}$ s = 0.0

6.0-12.2N: $\Lambda=483.86-271.77c^{1/2}+79.524c+11.916c^{3/2}-13.754c^{2}+2.1366c^{5/2}$ s = 0.0

12.2-21.1N: $\Lambda=483.86-271.77c^{1/2}+311.03c-185.05c^{3/2}+43.138c^{2}-3.4400c^{5/2}$ s = 0.0

21.1-30.0N: $\Lambda=483.86-271.77c^{1/2}+24.019c+18.346c^{3/2}-5.0263c^{2}+0.36708c^{5/2}$ s = 0.0

Table 9 - Equivalent conductivity of NaOH-H_2O at 80 °C [2]

c	Λ	c	Λ
0.01	477	1.0	313
.02	465	2.0	300
.03	455	3.0	253
.04	446	4.0	224
.05	439	5.0	198
.06	432	6.0	175
.07	426	7.0	155
.08	421	8.0	138
.09	416	9.0	121
.1	411	10.0	108
.2	376	11.0	97.1
.3	355	12.0	87.9
.4	340	13.0	80.4
.5	330	14.0	74.4
.6	323	15.0	69.5
.7	318	16.0	65.6
.8	315	17.0	62.3
.9	314	18.0	59.3

0.01-2.2N: $\Lambda = 507.73 - 290.05c^{1/2} - 170.66c + 442.91c^{3/2} - 177.34c^2$ $s = 0.04$

2.2-18.0N: $\Lambda = 507.73 - 290.05c^{1/2} + 183.62c - 86.599c^{3/2} + 18.810c^2 - 1.4580c^{5/2}$ $s = 0.0$

Table 10 - Equivalent conductivity of $NaOH-H_2O$ at 100 °C [2 and 5]

c	Λ	c	Λ
0.1	484	11.0	133
.2	444	12.0	121
.3	420	13.0	111
.4	404	14.0	103
.5	393	15.0	95.9
.6	386	16.0	90.0
.7	380	17.0	81.5
.8	376	18.0	74.4
.9	373	19.0	68.3
1.0	370	20.0	63.1
2.0	333	21.0	58.8
3.0	304	22.0	55.2
4.0	278	23.0	52.1
5.0	254	24.0	49.4
6.0	231	25.0	46.8
7.0	208	26.0	44.3
8.0	186	27.0	41.5
9.0	166	28.0	38.4
10.0	148	29.0	34.7

0.1-1.2N: $\Lambda = 601.68 - 367.38c^{1/2} - 196.06c + 705.36c^{3/2} - 463.39c^{2} + 90.229c^{5/2}$ $s = 0.0$

1.2-11.0N: $\Lambda = 601.68 - 367.38c^{1/2} + 190.38c - 48.360c^{3/2} + 0.51221c^{2} + 0.89279c^{5/2}$ $s = 0.0$

11.0-16.0N: $\Lambda = 601.68 - 367.38c^{1/2} + 278.05c - 136.25c^{3/2} + 29.658c^{2} - 2.3083c^{5/2}$ $s = 0.0$

16.0-30.0N: $\Lambda = 601.68 - 367.38c^{1/2} + 247.55c - 101.21c^{3/2} + 18.298c^{2} - 1.1813c^{5/2}$ $s = 0.0$

Table 11 - Equivalent conductance of $KOH-H_2O$ at 25 °C [3,3,3,3 and 7]

c	Λ	c	Λ
0.0001	270.7	0.2	238.5
.0005	269.2	.3	233.7
.001	268.2	.4	229.7
.002	266.7	.5	226.1
.003	265.6	.6	222.7
.004	264.7	.7	219.5
.005	264.0	.8	216.7
.006	263.3	.9	213.9
.007	262.7	1.0	211.2
.008	262.1	2.0	185.4
.009	261.6	3.0	162.4
.01	261.1	4.0	142.2
.02	257.5	5.0	123.9
.03	254.9	6.0	106.0
.04	252.9	7.0	90.6
.05	251.2	8.0	77.1
.06	248.8	9.0	65.3
.07	248.5	10.0	55.2
.08	247.4	11.0	46.4
.09	246.3	12.0	38.8
.1	245.4	13.0	32.1

0.0001-0.02N: $\Lambda = 271.91 - 123.18c^{1/2} + 124.24c \log c + 590.01c - 2649.9c^{3/2} + 7238.1c^2$ $s = 0.01$

0.02-0.6N: $\Lambda = 271.91 - 123.18c^{1/2} + 170.87c - 165.09c^{3/2} + 56.770c^2$ $s = 0.04$

0.6-5.8N: $\Lambda = 271.91 - 123.18c^{1/2} + 156.22c - 134.34c^{3/2} + 49.254c^2 - 6.0732c^{5/2}$ $s = 0.4$

5.8-13.0N: $\Lambda = 271.91 - 123.18c^{1/2} + 111.47c - 70.654c^{3/2} + 17.869c^2 - 1.5638c^{5/2}$ $s = 0.6$

Table 12 - Equivalent conductance of $KOH-H_2O$ at 30 °C [4]

c	Λ	c	Λ
0.01	277.2	0.6	246.8
.02	276.0	.7	243.5
.03	274.9	.8	240.0
.04	273.9	.9	236.4
.05	272.9	1.0	232.8
.06	271.9	2.0	205.2
.07	271.0	3.0	179.4
.08	270.1	4.0	158.0
.09	269.2	5.0	134.9
.1	268.4	6.0	117.6
.2	261.6	7.0	98.0
.3	256.8	8.0	84.9
.4	253.1	9.0	81.2
.5	249.9	10.0	60.4

0.01-2.0N: $\Lambda = 278.34 - 120.43c + 233.29c^2 - 282.00c^3 + 154.00c^4 - 30.422c^5$ $s = 0.0$

2.0-5.0N: $\Lambda = 228.59 + 43.488c - 56.172c^2 + 19.844c^3 - 3.1484c^4 + 0.18574c^5$ $s = 0.0$

5.0-10.0N: $\Lambda = 2380.8 - 1763.2c + 554.16c^2 - 86.163c^3 + 6.5506c^4 - 0.19448c^5$ $s = 0.0$

Table 13 - Equivalent conductance of $KOH-H_2O$ at 60 and 100 °C [7]

60 °C		100 °C	
c	Λ	c	Λ
1.0	330.6	1.0	485.2
2.0	287.9	2.0	410.6
3.0	255.9	3.0	360.6
4.0	226.9	4.0	321.3
5.0	200.2	5.0	284.8
6.0	176.0	6.0	253.6
7.0	154.2	7.0	226.6
8.0	135.1	8.0	202.8
9.0	118.2	9.0	181.2
10.0	103.2	10.0	161.2
11.0	89.7	11.0	142.4
12.0	75.5	12.0	124.9
13.0	66.4	13.0	109.4

<u>60 °C</u>

1.0-5.3N: $\Lambda=402.55-96.442c+30.948c^2-7.2351c^3+0.85022c^4-0.038681c^5$ $s = 0.0$

5.3-13.0N: $\Lambda=323.49-12.737c-5.6190c^2+0.88691c^3-0.053817c^4+0.0012029c^5$ $s = 0.0$

<u>80 °C</u>

1.0-4.24N: $\Lambda=605.46-151.57c+36.186c^2-5.1049c^3+0.26796c^4+0.0011734c^5$ $s = 0.0$

4.24-13.0N: $\Lambda=539.15-70.456c+4.0354c^2+0.071924c^3-0.023207c^4+0.00083222c^5$ $s = 0.0$

Table 14 - Equivalent conductance of $LiOH-H_2O$ at 25 °C

c	Λ	c	Λ
0.001	233.6	0.08	207.6
.002	232.0	.09	206.0
.003	230.8	.1	204.6
.004	229.7	.2	194.2
.005	228.9	.3	187.1
.006	228.1	.4	181.6
.007	227.3	.5	176.8
.008	226.7	.6	172.5
.009	226.1	.7	168.6
.01	225.5	.8	165.0
.02	221.0	.9	161.7
.03	217.7	1.0	158.8
.04	215.1	2.0	133.7
.05	212.9	3.0	113.0
.06	211.0	4.0	94.87
.07	209.2	5.0	79.79

0.001-0.1N: $\Lambda = 237.35 - 115.23c^{1/2} + 105.83c \log c + 154.79c + 406.53c^{3/2} - 2149.6c^2 + 2357.3c^{5/2}$ s=0.1

0.1-1.0N: $\Lambda = 237.35 - 115.23c^{1/2} + 2.1567c + 172.89c^{3/2} - 229.83c^2 + 91.496c^{5/2}$ s = 0.1

1.0-5.0N: $\Lambda = 237.35 - 115.23c^{1/2} + 54.630c - 16.603c^{3/2} - 2.9135c^2 + 1.5281c^{5/2}$ s = 0.2

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