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PROJECT TRIDENT
TECHNICAL REPORT

ELECTRICAL CONDUCTIVITY, COMPRESSIBILITY, AND VISCOSITY OF AQUEOUS ELECTROLYTIC SOLUTIONS

ARTHUR D. LITTLE, INC.
35 ACORN PARK CAMBRIDGE, MASSACHUSETTS

DEPARTMENT OF THE NAVY
BUREAU OF SHIPS
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PREFACE

This report was prepared by Arthur D. Little, Inc., as part of its effort on Project TRIDENT, under Contract NObsr-81564 with the Bureau of Ships, Department of the Navy.

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I. INTRODUCTION AND SUMMARY

As part of the TRIDENT effort in the general area of ocean environment, the literature data on electric conductivity, compressibility, and viscosity of sea water have been reviewed and collected. These physical properties affect such processes as galvanic corrosion, the operation of sea-return cables, and the performance of sea-water-activated batteries.

Although experimental values are not available over the full range of temperatures, pressures, and concentrations encountered in the oceans, they can often be estimated from the corresponding values for pure single electrolytes. Data for pure electrolytes may also prove useful, for example, in predicting the performance of electrolytic cells exposed to deep-sea pressures.

A short explanatory section provides a minimal background for interpreting the tables and figures. Since current theory does not predict adequately the properties of any but very dilute solutions, this report emphasizes experimental results and empirical formulae.

II. ELECTRICAL CONDUCTIVITY

Solutions of ionized compounds are electric conductors. Since the specific conductance, κ, of a particular solution increases with ion concentration, a molar conductance (or equivalent conductance) Λ is defined[1] as

$$\Lambda = \frac{1000\kappa}{c}$$

where c is the concentration in moles per liter (or equivalent per liter) of solution; $\kappa = 1/R$; and R is the resistance, in ohms, of one cm^3 of solution under a potential gradient of one volt/cm.

Table I gives the specific conductances of representative types of materials.

The conductance Λ is ordinarily determined[1] by measuring the resistance R_m between two platinum electrodes immersed in the solution. The measured resistance depends on the dimensions and separation of the electrodes and on the voltage. To refer such resistances to a common standard, measurements in the same conductance cell are also made on a reference electrolyte (commonly KCl in water), giving a resistance R'_m. Absolute values of the corresponding specific conductance κ' have been determined[1] from measurements made in cells of very accurately known dimensions. The equalities

$$\kappa' R'_m \equiv K = \kappa R_m \tag{1}$$

define the cell constant K and permit the calculation of κ .

Table II lists equivalent conductances of dilute aqueous solutions of the common electrolytes at 25 °C.

A. THEORETICAL RELATIONS

The limiting molar conductance Λ_o can be obtained by extrapolating Λ to infinite dilution (c = o). The curve of Λ against $\sqrt{c}$ is nearly linear at low concentration and therefore lends itself particularly well to accurate extrapolation.

Figures 1 and 2 illustrate, with values for sodium chloride solutions, the dependence of molar conductance on concentration and square root of concentration, respectively.

The latter extrapolation has a theoretical basis in the Debye-Hückel equation[1]

$$\Lambda = \Lambda_o - b\sqrt{c} \qquad (2)$$

Onsager improved the theoretical calculations underlying (2) and thereby predicted the value of the constant b. For a 1-1 electrolyte* in water at 25°C, the Onsager equation[1] is

$$\Lambda = \Lambda_o - (0.229\,\Lambda_o + 60.2)\sqrt{c} \qquad (3)$$

The present theory fails badly in all but very dilute solutions. In concentrated solutions substantial interionic forces create theoretical difficulties not yet resolved. Only experimental data and empirical formulae can be considered reliable in even moderately concentrated solutions.

The limiting conductance of a compound can be attributed to a positive and a negative ion current. Thus, for NaCl

$$\Lambda_o^{NaCl} = \lambda_o^{Na^+} + \lambda_o^{Cl^-} \qquad (4)$$

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*A salt such as NaCl, one molecule of which dissociates into one positive and one negative ion each bearing only one charge, is called a 1-1 electrolyte.

Kolrausch's law[1] states that such a division into independent positive and negative limiting ionic conductances is always possible. The law remains valid[2] at arbitrary pressure p:

$$\Lambda_{o,\,p} = \lambda^{+}_{o,\,p} + \lambda^{-}_{o,\,p}$$

The additivity exemplified by (4) is also closely maintained at finite concentrations (up to about 0.02 mole per liter for nearly all 1-1 electrolytes), but deviates from experimental results at higher concentrations.

Table III gives limiting ionic conductances for the common ions.

B. VARIATION OF CONDUCTANCE WITH TEMPERATURE

Since the viscosity of solutions decreases with rising temperature, ionic mobilities and therefore conductances generally increase. Many conductance data can be represented over the range 5 - 55°C by the equation[3]

$$\lambda_{o,\,t^\circ} = \lambda_{o\,,\,25^\circ} + a(t-25) + b(t-25)^2 + c(t-25)^3 \qquad (5)$$

where t is the temperature, and a, b and c are empirical parameters. Agreement of calculated with observed results is excellent, the differences averaging less than 0.02%.

Table IV presents values of $\lambda_{o\,,\,25^\circ}$ and the parameters a, b and c of equation 5, for nine common ions.

Table V compares, for six electrolytes, experimental values of Λ_o at several temperatures, with values calculated by equation 5.

Figure 3 shows, for sodium chloride solutions, the temperature dependence of the limiting molar conductance Λ_o.

The specific conductance of sea water has been measured[4] as a function of temperature and chlorinity.* Values for the entire range of naturally occurring temperatures and chlorinities were obtained by interpolation.

Table VI presents these calculated values of the specific conductance of sea water.

Figure 4 illustrates some of these data.

C. VARIATION OF CONDUCTANCE WITH CONCENTRATION

Most theories of conductance hold only near infinite dilution. Several empirical formulae which have been used to correlate data at higher concentrations are discussed by Harned and Owen.[5] One which has proved valid up to 2.0 molar for a large number of electrolytes is

$$\Lambda = \Lambda_o - \frac{A\sqrt{c}}{1 + B\sqrt{c}} + Dc$$

The conductivity of concentrated solutions of 1-1 electrolytes can be represented by[6]

$$\Lambda = \Lambda_{satd} + \frac{A}{\eta C_{satd}} \left(1 - \frac{C}{C_{satd}}\right)$$

where Λ and Λ_{satd} are molar conductances of the solution at hand and the saturated solution, C and C_{satd} are molar concentrations of the two solutions, and η is viscosity. This equation has been successful in representing the conductivity of concentrated (>1.0 molar) solutions of NaCL, KCl, $NaNO_3$ and KNO_3 over a wide range of temperatures.

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*Chlorinity is defined in the note to Table I.

D. CONDUCTANCE OF SOLUTIONS OF MIXED ELECTROLYTES

According to theory,[5] ions of like sign and widely different mobilities should exhibit mobilities in mixed solutions that differ from their mobilities in single electrolyte solution. Thus, in a mixture of hydrochloric acid and potassium chloride, theory predicts that the hydrogen-ion mobility is smaller, and the potassium ion mobility larger, than in solutions of the pure single electrolytes at the same concentrations. This effect has been qualitatively verified.[5, 7, 8, 9] Several other mixtures have been studied;[10] but, in general, experimental data are scarce. (For a general discussion of this topic, see Harned and Owen's monograph.[5])

E. CONDUCTANCE OF SOLUTIONS UNDER PRESSURE

Conductivity data for solutions subjected to pressure are often tabulated as molal conductances (in which the unit of concentration is moles per kg of solvent) to avoid the necessity for a concentration correction to molar conductance. The most important relations in high-pressure conductivity are those empirically proposed by Walden:[11]

$$\Lambda_o \eta_o = \text{constant}$$

$$\lambda_o^j \eta_o = \text{constant}$$

where η_o is viscosity of solvent, and λ_o^j refers to ion j. This approximate constancy holds over a wide range of temperatures, pressures, and solvents. Qualitatively, even in solutions at finite concentration, conductance changes in a direction opposite to viscosity. Thus, decreasing temperature, increasing pressure, and increasing concentration all usually lead to an increase in viscosity (Section IV), and hence to a decrease in conductance.[12]

Tables VII and VIII record molal conductances of several simple compounds under pressure, at 25 °C and 45°C, respectively.

Table IX presents the analogous results for limiting molar conductances.

Table X gives the pressure dependence of relative conductance for many electrolytes.

Figure 5 illustrates this pressure dependence at two temperatures.

III. COMPRESSIBILITY

A pressure of one (normal) atmosphere is defined as the pres exerted by a column of mercury 760 mm high, with a density of 13.5951 in a gravity field of 980.665 cm/sec^2. In terms of other unit systems, following relations hold:[11]

1 atm = 14.696 psi = 29.921 inches of Hg
at 32°F = 1.0332 kg/cm^2 = 1.0133×10^6 dynes/cm^2
= 1.0133 bars = 10.133 decibars = 760 Torrs.

The volume of any substance in stable equilibrium decreases creasing pressure, at constant temperature.[12] One measure of this com bility is given by the relation[13]

$$k = - \frac{V^P - V^{P_0}}{V^{P_0}}$$

where V^P and V^{P_0} are volumes at pressures P and P_0 (normally P_0 is as one atmosphere), and k is the bulk compression. Note that k depend the pressure range used.

Table XI reproduces some experimental values of bulk compression of aqueous solutions over the range 1 to 1000 bars.

The data in Table XI are accurately represented by the equation

$$A/r_2 = a + b\sqrt{c}$$

where a and b are empirical parameters; c is the concentration (g/cm^3) 25°C and 1 bar; x_1 and x_2 are weight fractions of water and solute, respe $r_2 = x_2/x_1$, and A is the change in specific volume per weight fraction of solute, $A = -(v^P - v^{P_0})/x_1$.

Table XII gives the parameters a and b of the compression equation 7 for a number of electrolytes at 25 °C.

Table XIII shows representative values of compressibility.

Data for sea water are customarily tabulated as mean compressibility k', defined as the bulk compression per unit increase in pressure:

$$k' = \frac{k}{P - P_0}$$

Knowledge of k at a given pressure permits the direct computation of k', and vice versa.

Table XIV gives the mean compressibility of sea water of salinity 34.85 °/₀₀.

The mean compressibility of sea water at any temperature (T), salinity (S) and pressure (P) can be computed from the equation,[15,16]

$$k' = [\ a(P) + b(T,P) + c(T,P,S)\ ] \times 10^{-6} \qquad (8)$$

where the functions a(P), b(T, P) and c(T, P, S) have been determined empirically.

Table XV lists the values of these three parameters over the whole range of the variables T, P, and S.

Changes in density and specific volume with pressure can be computed from k. Thus, an aqueous solution containing 5.88% KCl by weight has a specific volume v of 0.9682 cm^3/g at 1 bar pressure, and its bulk compression at 1000 bars is 363.2×10^{-4}. (See Table XI.) The specific volume at 1000 bars is obtained from equation 6,

$$363.2 \times 10^{-4} = - \frac{v^{1000} - 0.9682}{0.9682}$$

giving for the specific volume at 1000 bars $v^{1000} = 0.9331\ \mathrm{cm}^3/\mathrm{g}$ and for the density $\rho = 1/v^{1000} = 1.072\ \mathrm{g/cm}^3$.

The coefficient of isothermal compressibility β (often called[16] the true compressibility K, or[17] the reciprocal of the isothermal bulk modulus B_T) is defined[13] by

$$\beta = - \frac{1}{V} \left(\frac{\partial V}{\partial P} \right)_{T,\ \mathrm{composition}}$$

Similarly, the adiabatic coefficient of compressibility β_s, (the reciprocal of the adiabatic bulk modulus B) is given by

$$\beta_s = - \frac{1}{V} \left(\frac{\partial V}{\partial P} \right)_{S,\ \mathrm{composition}}$$

where S is entropy. It can be shown[18] that

$$\frac{\beta}{\beta_s} = \frac{c_p}{c_v} \tag{9}$$

and that

$$\beta - \beta_s = v \frac{\alpha^2 T}{c_p} \tag{10}$$

where c_p is the heat capacity at constant pressure, c_v the heat capacity at constant volume, and α the coefficient of thermal expansion defined by

$$\alpha = \frac{1}{V} \left(\frac{\partial V}{\partial T} \right)_{p,\ \mathrm{composition}}$$

Furthermore, it follows that

$$\beta = \frac{k' + p\left(\frac{\partial k'}{\partial p}\right)}{1 - k'p} \text{T, composition} \qquad (11)$$

Conversely, the mean compressibility k' may be obtained as a function of β by solving the differential equation 11:

$$k' = \frac{1}{p}\left[1 - \exp\left(- \int_{p_o}^{p} \beta \, dp\right)\right]$$

For dilute solutions, accurate compressibility values are obtained by measuring the velocity of sound u(cm/sec) through the solution. The classical equation[13]

$$u = \sqrt{\frac{10^6}{\rho\beta_s}}$$

where the factor 10^6 arises from the fact that β_s is expressed in bars^{-1}, and where ρ is density (g/cm^3), can be immediately solved for β_s. Relations (9) and (10) then permit evaluation of β.

Table XVI lists densities, sound velocities and adiabatic compressibilities at 30 °C for aqueous solutions of several salts.

Figure 6 illustrates these compressibility data.

Table XVII gives the sound velocity and compressibility for these salt solutions at the concentrations at which the individual salts are found in sea water. The differences between these values and the values for distilled water are shown as increments. The observed velocity and compressibility for sea water are seen to be the result of a linear summation of these increments.

IV. VISCOSITY

A. DEFINITIONS

Consider the fluid lying between two parallel planes moving past each other at a velocity v. The tangential force exerted by the fluid on each of the planes is given by the expression

$$F = \eta \frac{Av}{d}$$

where A is the area of each plane, d is their separation, and η is the coefficient of (dynamic) viscosity. Using c.g.s. units, the unit of viscosity is the poise (dyne-sec-cm^{-2}).

Viscosity is often expressed relative to that of some reference fluid (thus defining specific viscosity). Water at 20°C, which has[19] an absolute viscosity of 0.01002 poise, is often chosen as the reference fluid. The terms kinematic viscosity (viscosity/density, which in c.g.s. units is measured as stokes--cm^{2}-sec^{-1}) and fluidity (reciprocal of viscosity) also appear in the literature. The experimental measurement of viscosity is discussed by Hatschek.[20]

B. VARIATION WITH PRESSURE

The viscosity of most pure liquids rises exponentially with increasing pressure.

Figure 7 illustrates this viscosity increase for several liquids.

Water is exceptional in that its viscosity decreases[21] over the first 1000 atm at temperatures less than about 30°C, although it increases normally at higher pressures and temperatures. The presence of a dissolved electrolyte removes this anomaly.[22]

Table XVIII gives the relative viscosity of pure water.

Table XIX presents the viscosity of sea water at various temperatures and salinities.

More extensive tables of viscosities for water and aqueous solutions at atmospheric pressure, and for organic liquids, are available in the Handbook of Chemistry and Physics, and in International Critical Tables.

C. VARIATION WITH TEMPERATURE

At constant pressure, the viscosity of all known pure liquids and solutions decreases with rising temperature.[23] However, since the viscosity of electrolyte solutions decreases less rapidly than that of pure water, the relative viscosity actually increases. Hatschek[23] lists a number of empirical formulae which have been proposed to account for the temperature dependence of viscosity in pure liquids.

With the exception of some salts (particularly halides) of potassium, rubidium, cesium and ammonium, the presence of dissolved electrolytes increases the viscosity of water.[23] The change is ordinarily not large.

Variation with Concentration

At atmospheric pressure, the viscosity of many salt solutions (up to about 0.1 normal) is given accurately by[24]

$$\eta/\eta_0 = 1 + A\sqrt{c} + Bc \qquad (12)$$

where η_0 is the viscosity of the solvent, A and B are constants for a given solute, and c is the concentration in moles per liter.

Figure 8 illustrates the evaluation of parameters A (the intercept) and B (the slope) from the curve of $(\eta/\eta_0 - 1)/\sqrt{c}$ against $\sqrt{c}$.

Table XX gives numerical values of parameters A and B for a large number of electrolytes at 25 °C.

The viscosities of solutions containing one[25] or more[26] electrolytes may be estimated, using the fact that B is approximately an additive property of the ions.

The parameter B may be positive or negative, but since its temperature coefficient is always positive, at sufficiently high temperature, the effect of added salts is always to increase viscosity.

Table XXI illustrates the influence of temperature on parameter A.

The viscosity of concentrated (>1.0 molar) solutions of several 1-1 electrolytes can be represented by the equation[27]

$$\eta_p = Ae^{Bc_p}$$

where $\eta_p = \eta_{\text{solution}} / \eta_{\text{saturated solution}}$, c_p is the ratio of the mole fraction of solute to the mole fraction of solute in the saturated solution, and A and B are empirical constants depending on the solute and on temperature.

TABLE I

REPRESENTATIVE VALUES OF SPECIFIC CONDUCTANCE

Substance	Specific Conductance (Ω^{-1} cm^{-1})	Temperature (°C)
Copper	6.4×10^5	0
Copper	5.8×10^5	20
Lead	4.9×10^5	0
Iron	1.1×10^5	0
4 molar H_2SO_4	0.75	18
Sea water (Cl = 19 $^{0}/_{00}$)*	0.04758	20
0.1 molar KCl	0.0128	25
0.01 molar KCl	0.00141	25
1 molar acetic acid	0.0013	18
0.001 molar acetic acid	4×10^{-5}	18
Water	4×10^{-8}	18
Xylene	1×10^{-19}	25

*Chlorinity (Cl) in parts per thousand ($^{0}/_{00}$) is defined (H. U. Sverdrup, M. W. Johnson and R. H. Fleming, The Oceans, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1942, p. 51) by

$$\text{Salinity} = 0.03 + 1.805 \times \text{Chlorinity}$$

where salinity is in turn defined as the "total amount of solid material in grams contained in one kilogram of sea water, when all the carbonate has been converted to oxide, the bromine and iodine replaced by chlorine, and all organic material completely oxidized."

Source: E. U. Condon and H. Odishaw, Handbook of Physics, McGraw-Hill Book Co., New York, 1958, p. 4-141.

TABLE II

THE EQUIVALENT CONDUCTANCES OF ELECTROLYTES IN AQUEOUS SOLUTION AT 25°C

(Λ in cm^2 Ω^{-1} equiv.$^{-1}$)

Solute	c* = 0	0.0005	0.001	0.005	0.01	0.02	0.05	0.1
HCl	426.16	422.74	421.36	415.80	412.00	407.24	399.09	391.32
LiCl	115.03	113.15	112.40	109.40	107.32	104.65	100.11	95.86
NaCl	126.45	124.50	123.74	120.65	118.51	115.76	111.06	106.74
KCl	149.86	147.81	146.95	143.55	141.27	138.34	133.37	128.96
NH_4Cl	149.7	--	--	--	141.28	138.33	133.29	128.75
KBr	151.9	--	--	146.09	143.43	140.48	135.08	131.39
NaI	126.94	125.36	124.25	121.25	119.24	116.70	112.79	108.78
KI	150.38	--	--	144.37	142.18	139.45	134.97	131.11
KNO_3	144.96	142.77	141.84	138.48	132.82	132.41	126.31	120.40
$KHCO_3$	118.00	116.10	115.34	112.24	110.08	107.22	--	--
NaO_2CCH_3	91.0	89.2	88.5	85.72	83.76	81.24	76.92	72.80
NaOH	247.8	245.6	244.7	240.8	238.0	--	--	--
$AgNO_3$	133.36	131.36	130.51	127.20	124.76	121.41	115.24	109.14
$MgCl_2$	129.40	125.61	124.11	118.31	114.55	110.04	103.08	97.10
$CaCl_2$	135.84	131.93	130.36	124.25	120.36	115.65	108.47	102.46
$SrCl_2$	135.80	131.90	130.33	124.24	120.29	115.54	108.25	102.19
$BaCl_2$	139.98	135.96	134.34	128.02	123.94	119.09	111.48	105.19
Na_2SO_4	129.9	125.74	124.15	117.15	112.44	106.78	97.75	89.98
$CuSO_4$	133.6	121.6	115.26	94.07	83.12	72.20	59.05	50.58
$ZnSO_4$	132.8	121.4	115.53	95.49	84.91	74.24	61.20	52.64

*Concentrations expressed in equivalents per liter.

Source: H. S. Harned and B. B. Owen, The Physical Chemistry of Electrolytic Solutions, Reinhold Publishing Corp., New York, 3rd Ed., 1958, p. 697.

TABLE III

LIMITING IONIC CONDUCTANCES IN WATER AT 25°C

(Conductances λ_0 in cm^2 Ω^{-1} $equiv.^{-1}$)

Cation	λ_0^+	Anion	λ_0^-
H^+	349.8	OH^-	197.8
Li^+	38.66	Cl^-	76.35
Na^+	50.11	Br^-	78.20
K^+	73.52	I^-	76.9
Cs^+	77.3	NO_3^-	71.44
Ag^+	61.92	$CH_3CO_2^-$	40.9
NH_4^+	73.4	$SO_4^=$	80.0
Mg^{++}	53.06		
Ca^{++}	59.50		
Sr^{++}	59.46		
Cu^{++}	54		
Zn^{++}	53		

Source: H. S. Harned and B. B. Owen, The Physical Chemistry of Electrolytic Solutions, Reinhold Publishing Corp., New York, 3rd Ed., 1958, p. 231.

TABLE IV

PARAMETERS OF EQUATION 5 EXPRESSING THE TEMPERATURE DEPENDENCE OF LIMITING IONIC MOBILITIES BETWEEN 5 AND 55°C

Parameters a, b and c of the equation

$$\lambda_{o,t^\circ} = \lambda_{o,25^\circ} + a\,(t-25) + b\,(t-25)^2 + c\,(t-25)^3$$

Ion	$\lambda_{o,25^\circ}$ ($cm^2\ \Omega^{-1}\ mole^{-1}$)	a	b	c
H^+	349.85	4.81595	-1.03125×10^{-2}	-0.7670×10^{-4}
Li^+	38.64	0.88986	+0.44075	-0.2042
Na^+	50.15	1.09160	0.47150	-0.1150
K^+	73.50	1.43262	0.40563	-0.3183
Rb^+	77.81	1.47953	0.38400	-0.4533
Cs^+	77.26	1.44790	0.38250	-0.2050
Cl^-	76.35	1.54037	0.46500	-0.1285
Br^-	78.17	1.54370	0.44700	-0.2300
I^-	76.90	1.50993	0.43750	-0.2170

Source: H. S. Harned and B. B. Owen, The Physical Chemistry of Electrolytic Solutions, Reinhold Publishing Corp., New York, 3rd Ed., 1958, p. 233.

TABLE V

CALCULATED AND EXPERIMENTAL VALUES* OF Λ_0

(Λ_0 in $cm^{-2}\Omega^{-1}$ $mole^{-1}$)

Solute/Temp. °C	5°	15°	25°	35°	45°	55°	Notes**
HCl	297.53	362.16	426.16	489.11	550.34	609.38	C
	297.57	362.07	426.24	489.15	550.30	609.47	E
			426.16				E
LiCl	70.28	91.62	114.99	140.17	166.94	195.15	C
	70.30	91.60	114.99	140.18	166.92	195.14	E
			115.03				E
			114.95				E
NaCl	77.81	101.14	126.50	153.74	182.69	213.23	C
	77.84		126.49			213.38	E
		101.18	126.45	153.75	182.65		E
			126.45				E
KCl	94.23	121.03	149.85	180.41	212.43	245.67	C
	94.26		149.88			245.69	E
		121.07	149.85	180.41	212.41		E
			149.86				E
KBr	95.99	122.81	151.67	182.23	214.17	247.15	C
	96.00		151.68			247.15	E
		122.81	151.64	182.24	214.17		E
			151.63				E
KI	95.35	121.87	150.40	180.62	212.20	244.82	C
	95.32	121.83	150.34	180.60	212.13	244.73	E
			150.47				E
			150.38				E

*All values have been adjusted to the primary standard of G. Jones and B. C. Bradshaw, J. Am. Chem. Soc., 55, 1780 (1933).

**C = Calculated, E = Experimental; calculated from equation 5, page 4.

Source: H. S. Harned and B. B. Owen, The Physical Chemistry of Electrolytic Solutions, Reinhold Publishing Corp., New York, 3rd Ed., 1958, p. 234.

TABLE VI

SPECIFIC CONDUCTANCE OF SEA WATER AT VARIOUS TEMPERATURES AND CONCENTRATIONS

Chlorinities* are in parts per thousand. Conductivities are in Ω^{-1} cm^{-1}

Cl °/oo	0°	5°	10°	15°	20°	25°
1	.001839	.002134	.002439	.002763	.003091	.003431
2	.003556	.004125	.004714	.005338	.005971	.006628
3	.005187	.006016	.006872	.007778	.008702	.009658
4	.006758	.007845	.008958	.010133	.011337	.012583
5	.008327	.009653	.011019	.012459	.013939	.015471
6	.009878	.011444	.013063	.014758	.016512	.018324
7	.011404	.013203	.015069	.017015	.019035	.021121
8	.012905	.014934	.017042	.019235	.021514	.023868
9	.014388	.016641	.018986	.021423	.023957	.026573
10	.015852	.018329	.020906	.023584	.026367	.029242
11	.017304	.020000	.022804	.025722	.028749	.031879
12	.018741	.021655	.024684	.027841	.031109	.034489
13	.020167	.023297	.026548	.029940	.033447	.037075
14	.021585	.024929	.028397	.032024	.035765	.039638
15	.022993	.026548	.030231	.034090	.038065	.042180
16	.024393	.028156	.032050	.036138	.040345	.044701
17	.025783	.029753	.033855	.038168	.042606	.047201
18	.027162	.031336	.035644	.040176	.044844	.049677
19	.028530	.032903	.037415	.042158	.047058	.052127
20	.029885	.034454	.039167	.044114	.049248	.054551
21	.031227	.035989	.040900	.046044	.051414	.056949
22	.032556	.037508	.042614	.047948	.053556	.059321

Notes: 1) These values were derived by interpolation from measurements at several chlorinities and temperatures. For a discussion of possible errors, see D. W. Pritchard, "The *in situ* Measurement of 'Salinity' with the Induction-Conductivity Indicator and Comments on the Use of Sound Velocity for *in situ* Measurements of 'Salinity'" in *Conference on Physical and Chemical Properties of Sea Water*, National Academy of Sciences - National Research Council Publication 600 (1959) pp. 146-154; M. J. Pollak, *J. Marine Research*, *13*, 228 (1954).

2) There appears to have been no measurement of the variation of conductivity of sea water with pressure.

*Defined in the note to Table I.

Source: B. D. Thomas, T. G. Thompson, and C. L. Utterback, Conseil Perm. Intern. p. l'Explor. de la Mer, *Jour. du Conseil*, *9*, 28 (1934).

TABLE VII

MOLAL CONDUCTANCES OF COMPRESSED AQUEOUS SOLUTIONS AT 25°C

Solute	Concentration (moles/kg)	Molal Conductance ($gm\,\Omega^{-1}\,cm^{-1}\,mole^{-1}$) Pressure (atm) 1	1000	2000	3000
KOH	0.00200	266	283	291	295
KCl	0.0100	140	147	153	151
HCl	0.00188	420	456	480	496
HCO_2H	0.0127	45.0	57.0	69.7	80.2
CH_3CO_2H	0.0115	15.2	20.5	25.7	31.2
CH_3CO_2K	0.00963	105	109	110	109

Source: S. D. Hamann and W. Strauss, Trans. Faraday Soc., 51, 1684 (1955).

TABLE VIII

MOLAL CONDUCTANCES OF COMPRESSED AQUEOUS SOLUTIONS AT 45°C

Molal Conductance Λ (gm Ω^{-1} cm^{-1} mole^{-1})

Pressure (atm)	HCl 0.00871*	KCl 0.0100	KOH 0.00911	NH_4Cl 0.00986	NH_4OH 0.01093	Sp. Conductance of Water Ω^{-1} cm^{-1}
1	523	199	343	199	14.9	1.70×10^{-6}
1,100	596	209	370	212	25.4	3.07
2,500	642	215	392	219	49	5.4
4,000	669	211	394	213	83	7.7
6,800	712	195	404	196	151	11.8
9,600	718	172	394	172	214	13.4
12,000	710	152	385	147	248	16.2

*Concentration, moles solute per 1000 grams water.

Source: S. D. Hamann and W. Strauss, Trans. Faraday Soc., 51, 1684 (1955).

TABLE IX

EFFECT OF PRESSURE ON LIMITING MOLAR CONDUCTANCE Λ_0 OF AQUEOUS SOLUTIONS

(Λ_0 in cm^2 Ω^{-1} mole^{-1})

Solute	Temp. (°C)	Pressure (atm) 1	1,000	2,000	3,000	4,000	8,000	12,000
KCl	25	149	153	149	144			
KCl	45	218		218		205	166	126
NH_4Cl	25	149	153	151	144			
NH_4Cl	45	218		218		206	169	131
KO_2CCH_3	25	113	113	111	106			
HCl	25	427	444	453	454			
HCl	45	535		591		604	596	560
KOH	25	272	277	274	269			
KOH	45	349		361		361	332	303

Source: S. D. Hamann, Physico-Chemical Effects of Pressure, Butterworth's Scientific Publications, London, 1957, p. 123.

TABLE X

RELATIVE CONDUCTANCE Λ/Λ_0 OF AQUEOUS SOLUTIONS AT 30°C

Pressure (kg/cm^2)	HCl	LiCl	NaCl	KCl	$CaCl_2$
1	1.0000	1.0000	1.0000	1.0000	1.000
500	1.0265	1.0135	1.0078	1.0098	1.0114
1,000	1.0464	1.0256	1.0100	1.0100	1.0153
1,500	1.0616	1.0240	1.0016	1.0039	1.0100
2,000	1.0715	1.0202	0.9924	0.9945	0.9980
3,000	1.0812	0.9915	0.9545	0.9582	0.9625
5,000	1.0780	0.9078	0.8618	0.8660	0.8668
10,000	1.0055	0.6600	0.6146	0.6168	0.6000

Pressure	NaBr	NaI	KI	Na_2SO_4	$BaCl_2$
1	1.0000	1.0000	1.0000	1.0000	1.000
500	1.0034	0.9940	0.9980	1.0075	1.0100
1,000	1.0005	0.9722	0.9878	1.0080	1.0095
1,500	0.9915	0.9640	0.9728	1.0034	1.0030
2,000	0.9700	0.9400	0.9514	0.9945	0.9925
3,000	0.9294	0.8845	0.8965	0.9674	0.9546
5,000	0.8250	0.7687	0.7926	0.8865	0.8570
10,000	0.5771	0.5233	0.5514	0.6586	0.6016

Source: W. A. Zisman, *Phys. Rev.*, **39**, 155-156 (1932).

TABLE XI

SPECIFIC VOLUMES AND BULK COMPRESSIONS OF AQUEOUS SOLUTIONS AT 25 °C

Solute	Weight % of Solute	Bulk Compression* (k)	Sp. Vol.** (v)	Solute	Weight % of Solute	Bulk Compression (k)	Sp. Vol. (v)
KCl	0.00	393.5 x 10^{-8}	1.0029	LiCl	0.00	393.5 x 10^{-8}	1.0029
	5.88	363.2	0.9682		4.44	361.1	0.9778
	10.91	342.2	.9365		7.66	340.0	.9605
	13.79	330.2	.9198		9.82	326.4	.9492
	16.84	316.7	.9023		15.06	298.6	.9227
	20.00	303.9	.8844			297.8	
	23.22	292.9	.8665		19.66	277.5	.9002
	25.52	284.6	.8554		27.91	246.1	.8594
					34.62	222.2	.8265
KBr	0.00	393.5	1.0029		39.30	206.1	.8035
	8.26	369.4	0.9446			205.3	
	13.79	353.1	.9063				
	20.00	334.9	.8636				
	26.47	317.2	.8196				
	32.88	299.1	.7762				
	39.02	281.7	.7354				
KNO_3	0.00	393.5	1.0029	$BaCl_2$	0.00	393.5	1.0029
	8.16	366.3	0.9535		5.00	371.9	0.9593
	13.68	348.2	.9210		9.96	350.8	.9167
	20.22	328.3	.8835			351.7	
	26.53	309.2	.8484		15.00	331.2	.8741
					19.70	311.9	.8346
					24.79	290.8	.7924
						289.2	

TABLE XI (Continued)

Solute	Weight % of Solute	Bulk Compression* (k)	Sp. Vol.** (v)	Solute	Weight % of Solute	Bulk Compression (k)	Sp. Vol. (v)
NaBr	15.00	341 x 10^{-4}	.8901	Acetic	0.00	393.5 x 10^{-4}	1.0029
	25.00	304	.8167	Acid	6.81	382.7	0.9935
	35.00	270	.7446		11.62	377.7	.9874
	45.00	236	.6743		16.89	375.6	.9807
					31.16	375.3	.9650
Na_2CO_3	0.00	393.5	1.0029		41.17	384.9	.9558
	3.86	354.3	0.9646		50.53	399.8	.9489
	8.39	311.8	.9205		69.18	443.5	.9404
	13.88	268.0	.8745		79.37	480.6	.9392
	16.78	246.5	.8505		89.80	536.9	.9428
	20.26	211.4	.8231		94.33	571.5	.9470
		221.1			99.5	634.3	.9571
Li_2SO_4	0.00	393.5	1.0029	$MgSO_4$	0.00	393.5	1.0029
	5	348.4	0.9613		5	352.9	0.9540
	10	309.7	.9218		10	313.5	.9077
	15	272.5	.8847		15	276.2	.8634
	20	241.5	.8493		20	241.1	.8211
	25	213.2	.8154		25	210.0	.7805
Na_2SO_4	0.00	393.5	1.0029	$ZnSO_4$	0.00	393.5	1.0029
	5	356.2	0.9594		4.97	363.8	0.9530
	10	321	.9182		11.48	326.6	.8902
	15	288	.8788		17.82	287.4	.8312
	20	259	.8410		25.04	245.2	.7665
	22	245.9	.8264		27.08	232.7	.7487
	24	236	.8119				

TABLE XI (Continued)

Solute	Weight % of Solute	Bulk Compression* (k)	Sp. Vol.** (v)	Solute	Weight % of Solute	Bulk Compression (k)	Sp. Vol. (v)
Cs_2SO_4	0.00	393.5 x 10^{-4}	1.0029	$CdSO_4$	0	393.5 x 10^{-4}	1.0029
	10	362.5	0.9202		10	351.4	0.9090
	20	332.3	.8405		15	328.7	.8633
	30	300.2	.7593		20	305.4	.8185
	40	265.3	.6809		30	257.6	.7308
	50	229.3	.6041		40	211.7	.6555
H_2SO_4	5.36	387.8	0.9686				
	12.86	370.4	.9239				
	26.67	331.7	.8415				
	33.01	315.1	.8066				
	59.52	268.4	.6717				
	77.67	245.5	.5898				
	78.98	246.1	.5847				
	88.35	240	.5603				
	92.77	267	.5490				

The original articles also contain data for many other salts. The bulk compressions at 25°C over the range 100 to 300 bars are reported by E. H. Lanmann and B. J. Mair, J. Am. Chem. Soc., 56, 390 (1934) for solutions of LiCl, NaCl, KCl, KOAc, LiOh, NaOH, KOH, HCl and HOAc.

*Bulk compression over range 1 to 1000 bars.

**Volume in cm^3 of 1 gram of solution, at 1 bar pressure.

Sources: R. E. Gibson, J. Am. Chem. Soc., 56, 4 (1934); Ibid, 57, 284 (1935).

TABLE XII

COEFFICIENTS OF BULK COMPRESSION EQUATION FOR AQUEOUS SOLUTIONS AT 25°C

Parameters* of the equation

$$A/r_2 = a + b\sqrt{c}$$

Solute	a	-b
NaCl	612.0×10^{-4}	510.5×10^{-4}
KCl	446.5	454.3
LiCl**	715.7	793.0
$BaCl_2$	413.2	258.6
$CeCl_3$	535.2	356.9
NaBr	307.3	217.7
KBr	212.4	172.8
CsBr	88.40	70.12
LiI	97.30	74.10
KI	82.5	60.00
KCNS	172.3	201.7
KNO_3	225.8	215.7
K_2CrO_4	537.7	427.2
Na_2CO_3	1206.0	1112.7
CH_3COOH	-83.7	370.17

*Definitions: c = concentration of solute in grams per cc at 25°C and 1 bar pressure.

$$r_2 = \frac{x_2}{x_1}$$

x_1, x_2 = weight fractions of solvent (water) and solute respectively.

$A = \Delta P_V / x_1$

ΔP_V = change in specific volume of solution due to pressure P (here 1000 bars).

**Equation fails to represent data above $x_2 = 0.30$.

Source: R. E. Gibson, J. Am. Chem. Soc., 57, 288 (1935).

TABLE XIII

COMPRESSIBILITIES OF VARIOUS SUBSTANCES

Substance	Temp. (°C)	Pressure* (atm)	Compressibility (atm^{-1})
Nitrogen	0	100-200	453.3×10^{-5}
Benzene	20	1	9.50
Water	20	1	4.63
Ice	-7	300	1.2
Lithium	20	99-493	0.91
Mercury	20	1	0.40
Quartz	25	1	0.275
Vermont Marble	25	300	0.27
Glass (506/602)	--	--	0.26
Silver Chloride	20	300	0.240
Westerly Granite	25	2000	0.20
Zinc	20	99-493	0.17
Aluminum	20	0-9870	0.134
Silver	20	0-9870	0.098
Copper	20	0-9870	0.076
Iron (0.2% C)	20	0-9870	0.061
Gold	20	0-9870	0.058
Nickel	20	99-493	0.0435
Platinum	20	99-493	0.039

*When a single pressure is given, the isothermal compressibility is tabulated; when a range of pressure is given, the mean compressibility over that range is tabulated.

Sources: International Critical Tables and Handbook of Chemistry and Physics. Recalculated to the proper units when necessary.

TABLE XIV

MEAN COMPRESSIBILITY OF SEA WATER OF SALINITY 34.85 ‰

Mean Compressibility k' in bars^{-1}

Temp.	Pressure (bars)				
(°C)	0	100	200	400	1000
0	4659 x 10^{-8}	4582 x 10^{-8}	4508 x 10^{-8}	4368 x 10^{-8}	4009 x 10^{-8}
5	4531	4458	4388	4256	3916
10	4427	4357	4291		
15	4345	4278			
20	4281				
25	4233				
30	4197				

Source: H. U. Sverdrup, M. W. Johnson and R. H. Fleming, The Oceans, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1942, p. 68.

TABLE XV

MEAN COMPRESSIBILITY OF SEA WATER

Parameters of equation 8
for mean compressibility k'

$$k' = [a + b + c] \times 10^{-8}$$

a. Parameter a

Depth (m)	a	Depth (m)	a
0	4658	5,500	4262
500	4617	6,000	4230
1,000	4580	6,500	4198
1,500	4542	7,000	4167
2,000	4505	7,500	4136
2,500	4468	8,000	4106
3,000	4432	8,500	4077
3,500	4397	9,000	4047
4,000	4362	9,500	4020
4,500	4328	10,000	3993
5,000	4295		

b. Parameter b

Temp.	Depth (m)										
(°C)	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
-2	59	57	55	53	51	50					
0	0	0	0	0	0	0	0	0	0	0	0
2	-54	-52	-50	-49	-47	-45	-44	-42	-41	-40	-39
4	-105	-101	-98	-94	-92	-88	-85	-83	-80	-77	-75
6	-151	-146	-141	-136	-132	-126					
8	-193	-186	-180	-174	-168	-162					
10	-232	-224	-216	-209	-202	-195					
12	-268	-259	-250	-242	-234						
14	-300	-290	-280	-271	-262						
16	-329	-318	-307								
18	-355	-343	-332								
20	-378	-365	-353								
22	-399	-386	-373								
24	-418	-404	-392								
26	-434	-420									
28	-449	-435									
30	-462	-447									

TABLE XV (Continued)

c. Parameter c

Depth (m)/Temp. (°C)	Salinity 30	31	32	33	34	35	36	37	38	39	40
0-500/											
0	57	46	34	22	10	-2					
5	51	42	31	20	9	-2	-13	-24	-35	-45	-56
10	48	38	28	18	8	-2	-12	-22	-32	-42	-52
15	45	36	27	17	8	-2	-11	-20	-30	-39	-48
20	42	33	25	16	7	-1	-10	-19	-28	-36	-45
25	41	32	24	16	7	-1	-10	-18	-27	-35	-44
30	40	31	23	15	7	-1	-10	-18	-26	-34	-42
1,000-3,000/											
0					10	-2					
5					9	-2	-12	-23	-33	-43	-54
10					8	-2	-11	-21	-30	-40	-49
15					8	-1	-11	-20	-28	-38	-46
20					7	-1	-10	-18	-27	-35	-43
4,000-6,000/											
0					9	-2	-12	-22	-32	-43	
5					8	-2	-11	-21	-30	-40	
10					8	-1	-10	-19	-28	-37	
7,000-10,000/											
0					8	-2	-11				
5					7	-1	-10				

Source: Landolt-Bornstein, Zahlenwerte und Funktionen, Springer-Verlag, Berlin 6th Edition, 1952, Band III, p. 432.

TABLE XVI

PROPERTIES AT 30°C OF PURE SOLUTIONS OF SALTS FOUND IN SEA WATER

Molarity	Ionic Strength	Density (g/ml)	Sound Velocity (m/sec)	Adiabatic Compressibility (cm^2/dyne)
(a) Sodium Chloride				
0.0	0.0	0.9956	1510.0	44.052 x 10^{-12}
0.1	0.1	0.9996	1516.4	43.504
0.2	0.2	1.0039	1522.8	42.957
0.4	0.4	1.0117	1534.4	41.981
0.8	0.8	1.0281	1558.0	40.071
1.0	1.0	1.0372	1570.0	39.115
2.0	2.0	1.0736	1626.0	35.230
4.0	4.0	1.1463	1732.0	29.081
(b) Magnesium Sulfate				
0.1	0.4	1.0071	1522.0	42.863
0.2	0.8	1.0196	1534.1	41.674
0.4	1.6	1.0415	1561.6	39.374
0.8	3.2	1.0858	1615.9	35.271
1.0	4.0	1.1116	1643.5	33.305
2.0	8.0	1.2178	1780.0	25.917
3.0	12.0	1.3181	1934.0	20.283
(c) Magnesium Chloride				
0.1	0.3	1.0030	1520.9	43.102
0.2	0.6	1.0112	1531.7	42.152
0.4	1.2	1.0265	1552.3	40.429
0.8	2.4	1.0564	1595.8	37.172
1.0	3.0	1.0712	1617.1	35.699
2.0	6.0	1.1417	1714.1	29.811
4.0	12.0	1.2724	1877.4	22.298
(d) Calcium Chloride				
0.1	0.3	1.0047	1518.2	43.183
0.2	0.6	1.0142	1526.5	42.314
0.4	1.2	1.0313	1544.3	40.658
0.8	2.4	1.0657	1576.6	37.750
1.0	3.0	1.0823	1590.2	36.538
2.0	6.0	1.1644	1666.8	30.912
4.0	12.0	1.3181	1788.9	23.707

TABLE XVI (Continued)

Molarity	Ionic Strength	Density (g/ml)	Sound Velocity (m/sec)	Adiabatic Compressibility (cm^2/dyne)
(e) Potassium Chloride				
0.1	0.1	0.9990	1515.7	43.523×10^{-12}
0.2	0.2	1.0047	1521.5	42.995
0.4	0.4	1.0139	1530.9	42.083
0.8	0.8	1.0315	1550.2	40.342
1.0	1.0	1.0404	1560.5	39.470
2.0	2.0	1.0843	1603.0	35.891
4.0	4.0	1.1679	1683.7	30.204
(f) Sodium Bicarbonate				
0.1	0.1	1.0015	1517.7	43.349
0.2	0.2	1.0074	1525.6	42.650
0.4	0.4	1.0194	1542.0	41.256
0.8	0.8	1.0428	1572.0	38.817
1.0	1.0	1.0530	1587.7	37.673
(g) Sodium Bromide				
0.1	0.1	1.0034	1512.4	43.572
0.2	0.2	1.0112	1514.9	43.092
0.4	0.4	1.0258	1519.9	42.199
0.8	0.8	1.0573	1530.9	40.356
1.0	1.0	1.0725	1535.7	39.536
2.0	2.0	1.1483	1559.8	35.794
4.0	4.0	1.2965	1612.5	29.664
(h) Potassium Bromide				
0.1	0.1	1.0038	1511.5	43.065
0.2	0.2	1.0118	1513.6	43.140
0.4	0.4	1.0287	1517.2	42.230
0.8	0.8	1.0619	1524.2	40.535
1.0	1.0	1.0776	1527.2	39.788
2.0	2.0	1.1591	1543.3	36.222
4.0	4.0	1.3186	1572.0	30.689

Source: A. Weissler and V. A. DelGrosso, *J. Acoust. Soc. Am.*, **23**, 222 (1951).

TABLE XVII

SOUND VELOCITY AND COMPRESSIBILITY INCREMENTS FOR SEA WATER CONSTITUENTS AT 30°C

Solute	Concentration* g/kg	Concentration* Molarity	Velocity (m/sec)	Velocity Increment	Adiabatic Compressibility (cm^2/dyne)	Compressibility Increment
Dist. H_2O			1510.0	0.0	44.052 x 10^{-12}	-0.000
NaCl	26.518	0.4649	1538.2	28.2	41.672	-2.380
$MgSO_4$	3.305	0.0281	1513.4	3.4	43.718	-0.334
$MgCl_2$	2.447	0.0263	1512.9	2.9	43.802	-0.250
$NaCl_2$	1.141	0.0105	1510.9	0.9	43.961	-0.091
KCl	0.725	0.00997	1510.6	0.6	43.999	-0.053
$NaHCO_3$	0.202	0.00246	1510.2	0.2	44.035	-0.017
NaBr	0.083	0.00083	1510.0	0.0	44.048	-0.004
				Σ = 36.2		Σ = -3.128
Sea water, observed			1545.8		40.95	
Same, calculated by summation			1546.2		40.92	

*Concentrations at which each salt is present in sea water.

Source: A. Weissler and V. A. Del Grosso, J. Acoust. Soc. Am., 23, 222 (1951).

TABLE XVIII

RELATIVE VISCOSITY OF PURE WATER

Viscosity η relative to
viscosity at 0°C and 1 kg/cm^2

Pressure (kg/cm^2)	Temperature (°C)		
	0	10.3	30
1	100.0×10^{-2}	77.9×10^{-2}	48.8×10^{-2}
500	93.8	75.5	50.0
1000	92.1	74.3	51.4

Source: Landolt-Börnstein, Zahlenwerte and Funktionen, Springer-Verlag, Berlin, 6th Ed., 1952, Band III, p. 433. Additional data is given in International Critical Tables and in P. W. Bridgman, Proc. Amer. Acad. Arts Sci., 61, 57 (1926); Ibid., 77, 115 (1949).

TABLE XIX

RELATIVE VISCOSITY OF SEA WATER

Viscosity η relative to pure water*
at atmosphere pressure and 0°C

Temp. (°C)	Salinity** (°/₀₀) 0	10	20	30	40
0	100.0×10^{-2}	101.7×10^{-2}	103.2×10^{-2}	104.5×10^{-2}	105.9×10^{-2}
5	84.7	86.3	87.7	89.1	90.5
10	73.0	74.5	75.8	77.2	78.5
15	63.6	64.9	66.2	67.5	68.8
20	56.2	57.4	58.6	59.9	61.1
25	49.9	51.0	52.1	53.3	54.5
30	44.9	46.0	47.0	48.1	49.1

*The absolute viscosity of water under these conditions is 0.01797 poise.

**Defined in note to Table I.

Source: Landolt-Börnstein, Zahlenwerte und Funktionen, Springer-Verlag, Berlin, 6th Ed., 1952, Band III, p. 433.

TABLE XX

RELATIVE VISCOSITY OF AQUEOUS SOLUTIONS AT 25°C

Parameters A and B of the Equation

$$\eta/\eta_0 = 1 + A\sqrt{c} + Bc,$$

where η_0 is the viscosity of water at 25°C

Solute	Valence Type	A	B	Applicable Concentration Range*
NH_4Cl	1-1	57×10^{-4}	-0.0144	0-0.2
NaCl	1-1	67	0.0244	0.2
KCl	1-1	52	-0.0140	0.2
KBr	1-1	47.4	-0.0480	0.1
KNO_3	1-1	50	-0.053	0.1
$KClO_3$	1-1	50	-0.031	0.1
$AgNO_3$	1-1	63	0.045	0.1
K_2SO_4	1-2	140.6	0.194	0.1
K_2CrO_4	1-2	133	0.152	0.1
$BaCl_2$	2-1	201	0.207	0.1
$MgSO_4$	2-2	225	---	---
$MnSO_4$	2-2	231	---	---
$CuSO_4$	2-2	230	0.540	0.01
$ZnSO_4$	2-2	229	---	---

*Equivalents per liter.

Source: H. S. Harned and B. B. Owen, The Physical Chemistry of Electrolytic Solutions, Reinhold Publishing Corp., New York, 3rd Ed., 1958, p. 241.

TABLE XXI

TEMPERATURE DEPENDENCE OF VISCOSITY

Influence of Temperature on Parameter A
of the Viscosity Equation

$$\eta/\eta_o = 1 + A\sqrt{c} + Bc$$

Temp. (°C)	NaCl	Li_2SO_4	$FeCl_2$
12.5	58×10^{-4}	--	--
15	58	160×10^{-4}	150×10^{-4}*
25	62	167	164
35	65	170	172
42.5	71	173	178**

*15.5°C.

**40°C.

Source: M. Kaminsky, Z. Physik. Chem., Neue Folge, 8, 173 (1956).

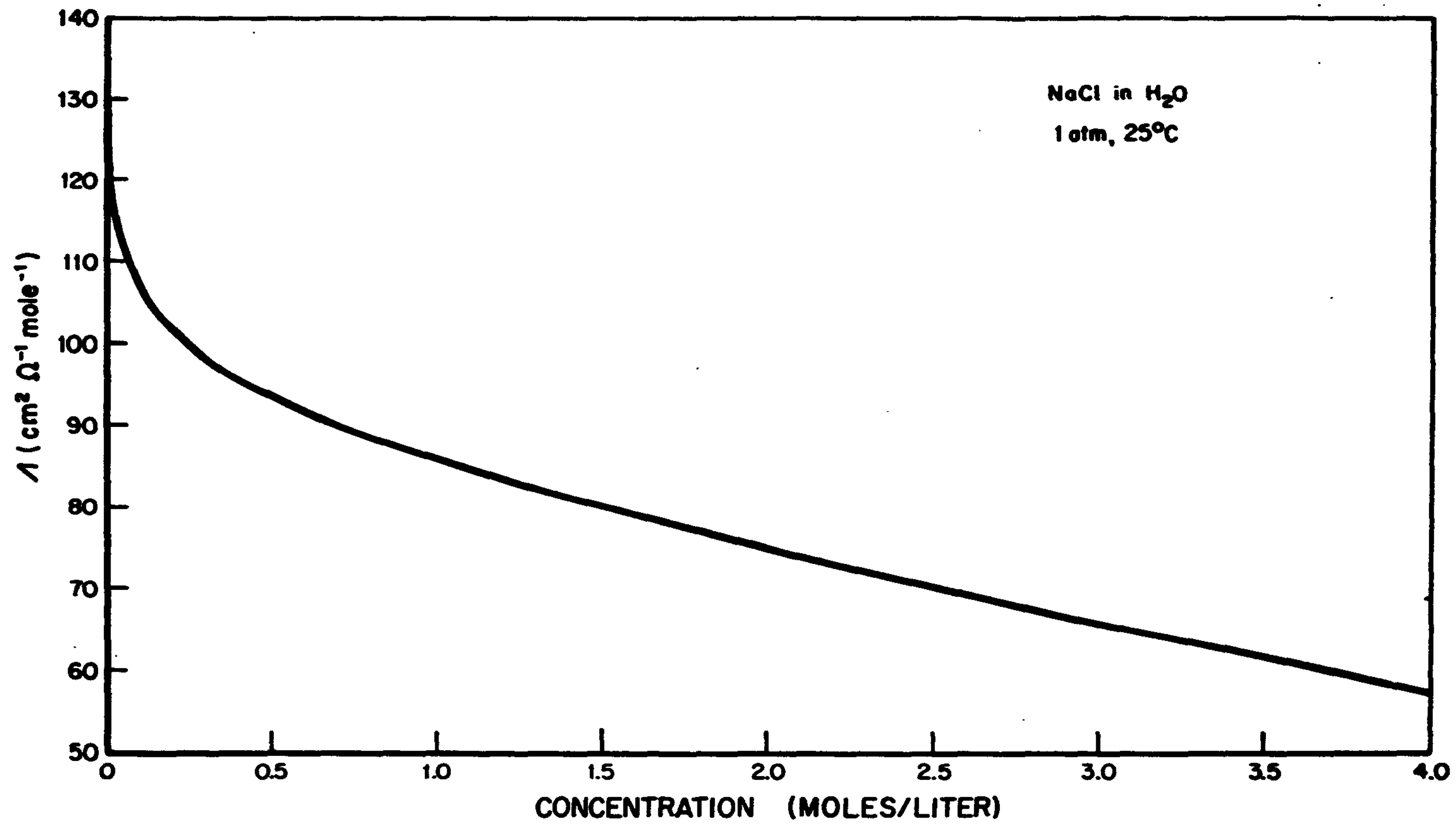

FIGURE 1 Dependence of Molar Conductance Λ on Concentration

SOURCE: H. S. Harned and B. B. Owen, <u>The Physical Chemistry of Electrolytic Solutions</u>, Reinhold Publishing Corp., New York, 3rd ed., 1958, p. 697.)

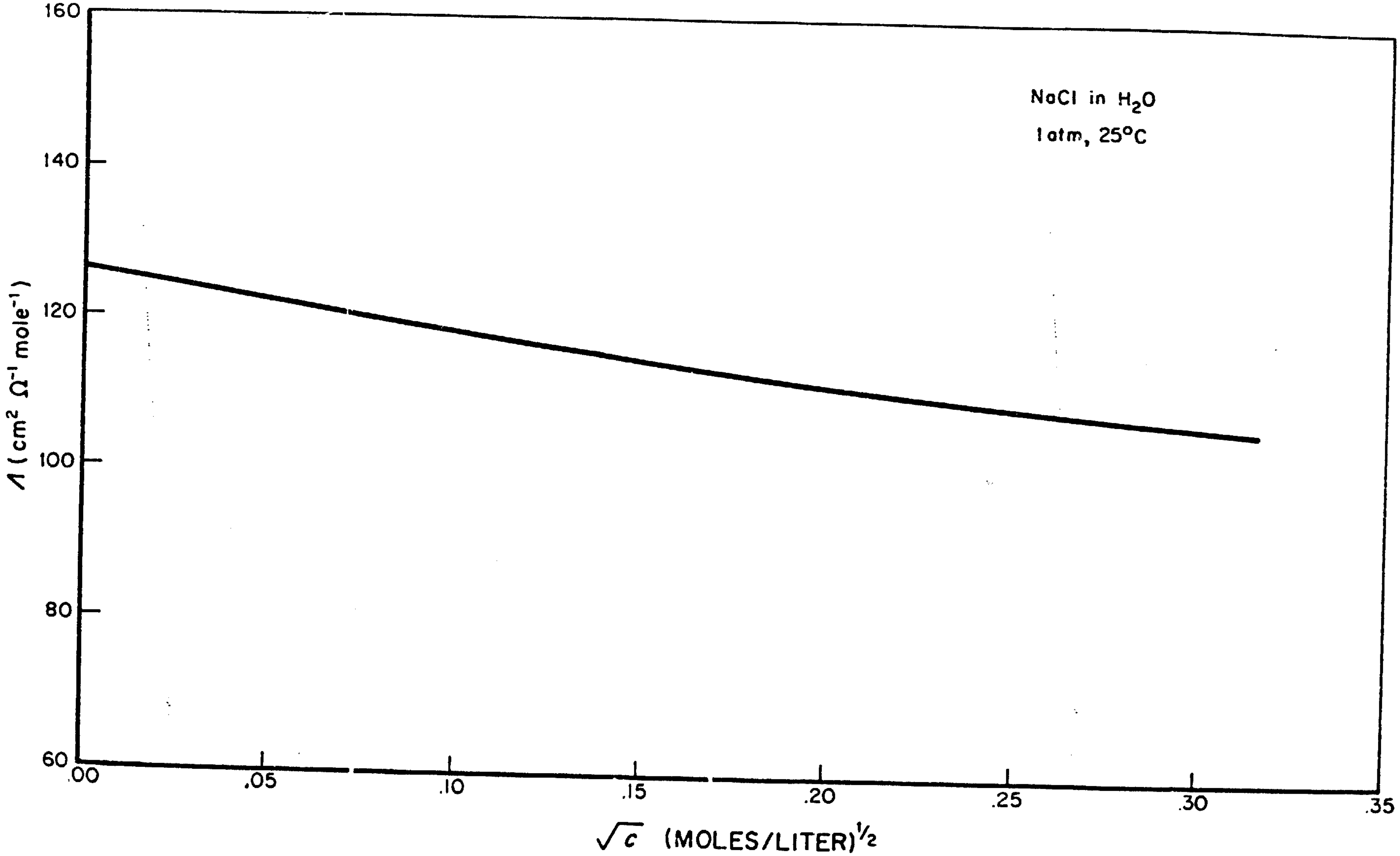

FIGURE 2 Dependence of Molar Conductance Λ on Square Root of Concentration

SOURCE: H. S. Harned and B. B. Owen, <u>The Physical Chemistry of Electrolytic Solutions</u>, Reinhold Publishing Corp., New York, 3rd ed., 1958, p. 697.

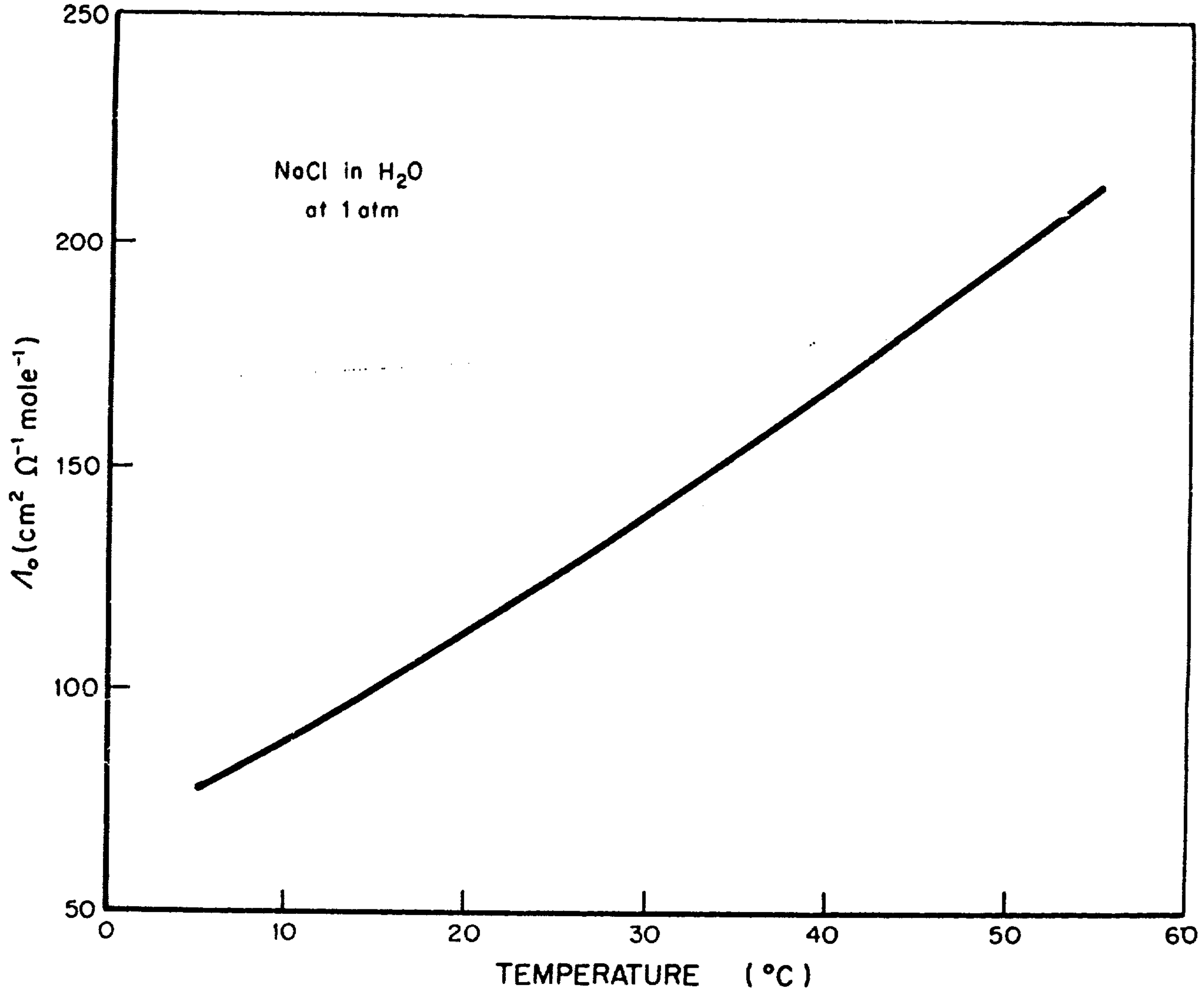

FIGURE 3 Temperature Dependence of Limiting Molar Conductance Λ_0

SOURCE: H.S. Harned and B. B. Owen, The physical Chemistry of Electrolytic Solutions, Reinhold Publishing Corp., New York, 3rd ed., 1958, p. 234.

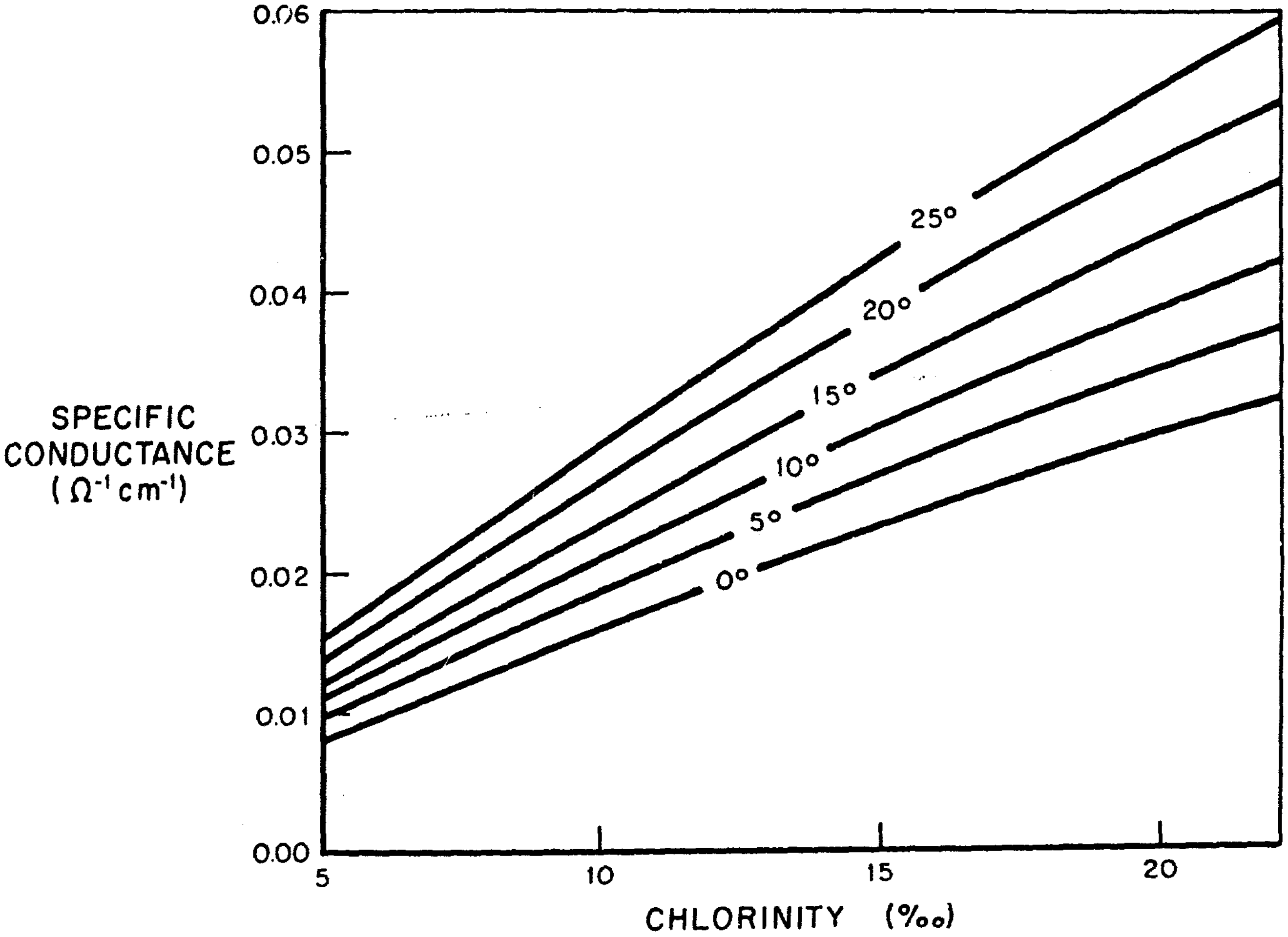

FIGURE 4 Specific Conductance of Sea Water

SOURCE: H. U. Sverdrup, M. W. Johnson and R. H. Fleming, The Oceans, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1942, p. 72.

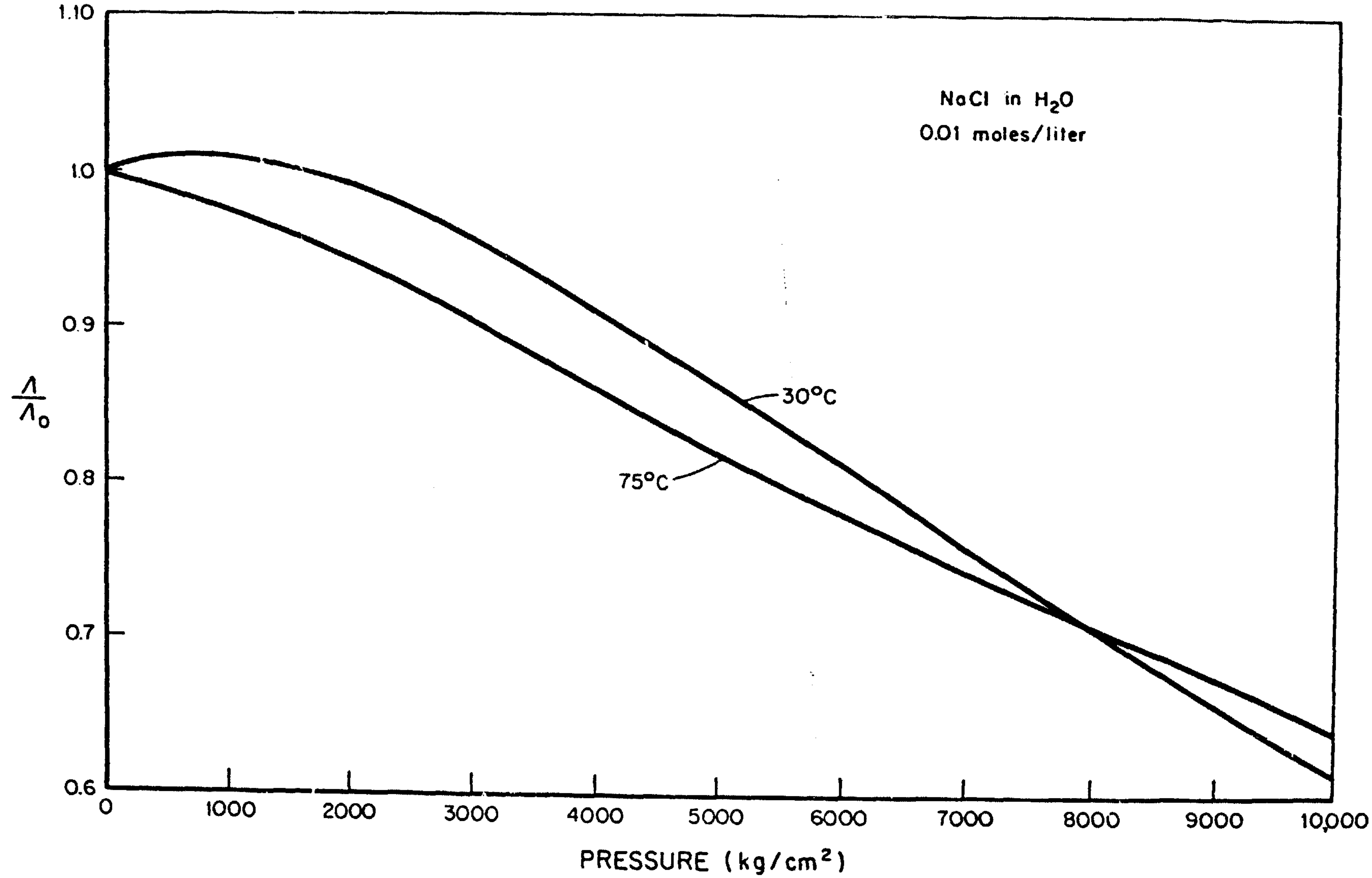

FIGURE 5 Pressure Dependence of Relative Conductance Λ/Λ_0

SOURCE: W. A. Zisman, Phys. Rev., 39, 155 (1932)

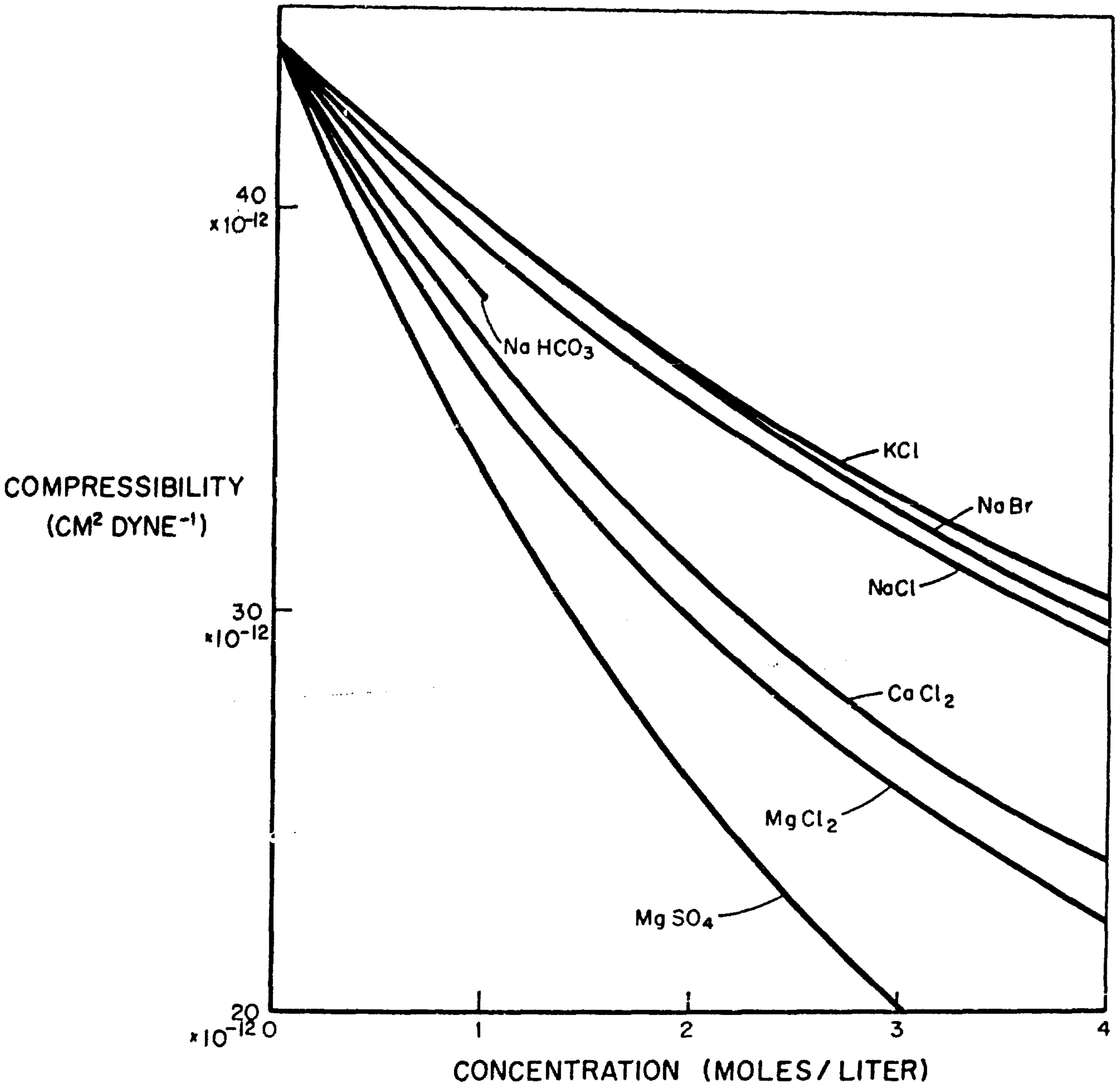

FIGURE 6 Adiabatic Compressibility of Aqueous Solutions at 30°C

SOURCE: A. Weissler and V. A. Del Grosso, J. Acoust. Sci. Amer., 23, 222 (1951).

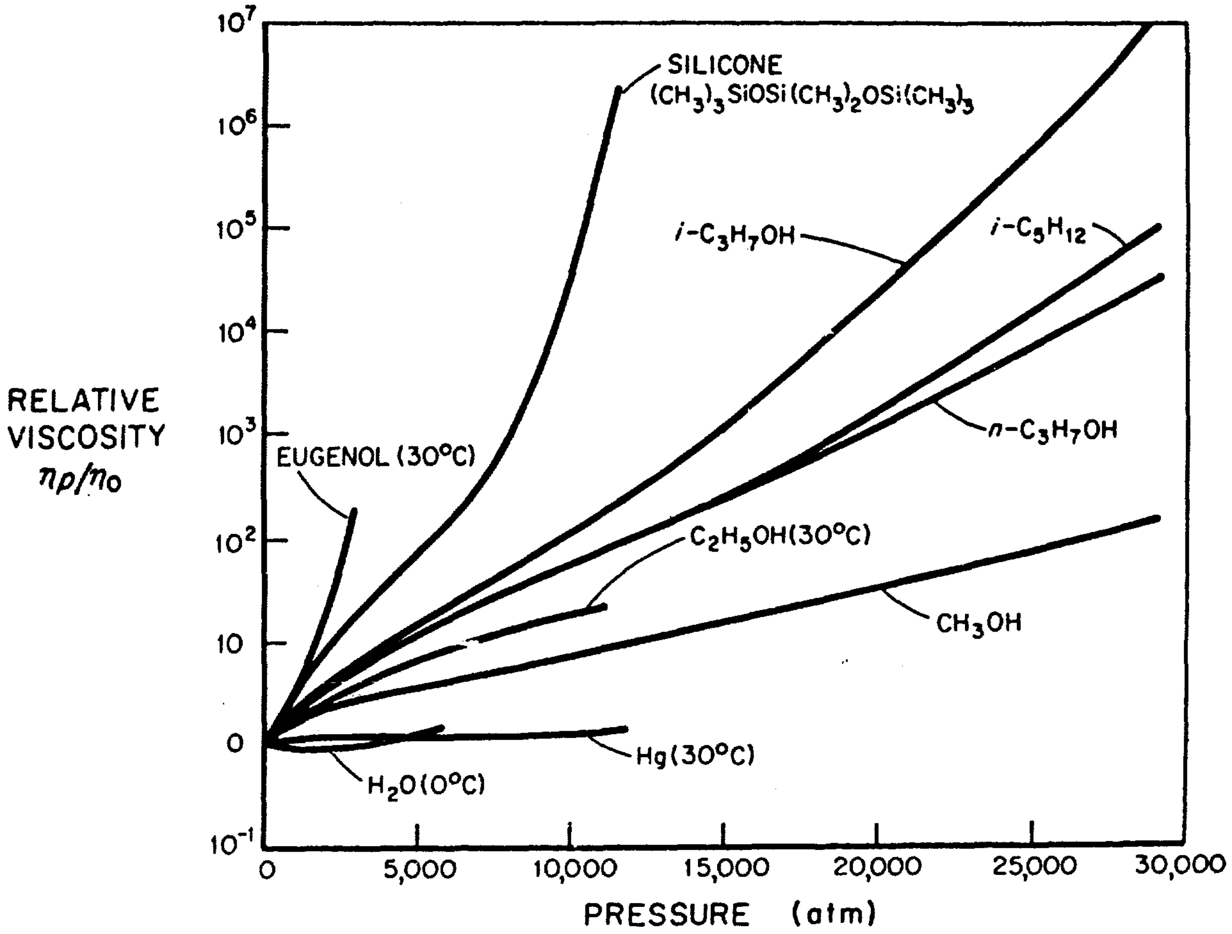

FIGURE 7 The Viscosities of Some Compressed Liquids (Measurements made at room temperature unless otherwise indicated.)

SOURCE: S. D. Hamann, Physicô-Chemical Effects of Pressure, Butterworths Scientific Publications, London, 1957, p. 82.

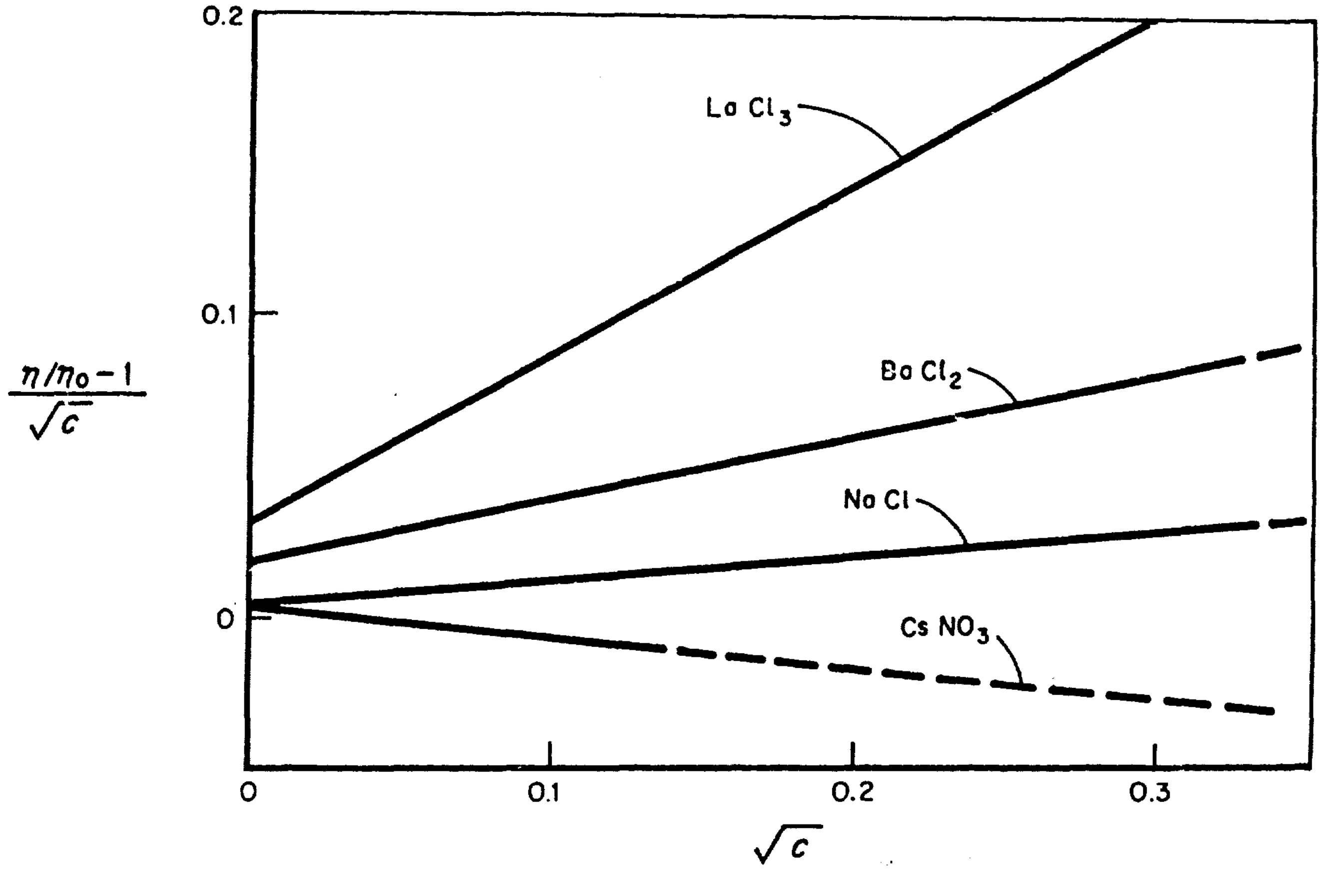

FIGURE 8 Evaluation of the Limiting Slopes for Relative Viscosity at 25°C

SOURCE: H. S. Harned and B. B. Owen, The Physical Chemistry of Electrolytic Solutions, Reinhold Publishing Corp., New York, 3rd ed., 1958, p. 238.

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