

Correlation of Solubility Data: III. The Isopleth Reference Method for Predicting Solubility Data for Long Chain Homologous and Analogous Compounds¹

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Abstract

A new graphical method for correlating and predicting solubility data for homologous and analogous compounds is described. It complements the isotherm and isopleth methods which are applicable only to long chain homologous compounds. This method is based upon the linear relationship, $\frac{1}{T} = \frac{\Delta H'_f}{\Delta H_f} \frac{1}{T'} + C$, derived from the approximate freezing point depression equation in which T and T' are the primary freezing points of two analogous compounds at the same molar concentration in a given solvent. The basic assumption that $\Delta H'_f/\Delta H_f$ remains essentially constant for homologous and analogous compounds in the same solvent over wide ranges of temperature was validated by construction of isopleth reference plots using both published and new experimental solubility data for a number of long chain fatty acids and fatty acid derivatives in a variety of solvents. Complete solubility data are reported for behenic, stearic, palmitic, heptadecanoic, brassidic, erucic, petroselaicid and petroselinic acid in acetone, methanol, toluene and isopropyl ether. Complete solubility data are also included for elaidic acid in acetone, toluene and isopropyl ether and oleic acid in isopropyl ether.

Introduction

In recent publications from this Laboratory the isotherm (1) and isopleth (2) interpolative methods were developed for predicting the solubilities of missing members of homologous series. The methods were based upon the observation that a smooth curve is obtained either by plotting the logarithm of the molar solubilities of the higher members of a homologous series in a given solvent at a given temperature against the total number of carbon atoms in the molecule (1), or by plotting the reciprocal of the primary freezing points at given molar concentrations against the reciprocal of the total number of carbon atoms in the molecule (2) in a given solvent. It was shown that these isotherm (constant temperature) and isopleth (constant composition) curves can be drawn accurately on the basis of the experimentally determined solubilities of a few members of a series and used to determine the solubilities of the missing intermediate members by interpolation. These methods, however, are limited to homologous series. The present paper deals with a third method of correlation which will be referred to as the isopleth reference method. On the basis of this new method, solubility predictions can be extended to

include analogous as well as homologous compounds and over an even wider range of temperatures and concentrations.

Theoretical Derivation

The simple solubility equation for ideal dilute solutions at constant pressure is written

$$\ln N = -\frac{\Delta H_f}{R} \frac{1}{T} + c_1 \quad [1]$$

where N is the mole fraction of the compound with which the solution is saturated, ΔH_f is its heat of fusion in calories per mole, T is the primary freezing point of the solution in degrees absolute, R is the molar gas constant, and c_1 is a constant.

A similar equation can be written for a second compound

$$\ln N' = -\frac{\Delta H'_f}{R} \frac{1}{T'} + c_2 \quad [2]$$

At the same concentration in the same solvent, i.e., where $N = N'$, the two equations can be combined to give, on rearranging,

$$\frac{1}{T} = \frac{\Delta H'_f}{\Delta H_f} \frac{1}{T'} + C \quad [3]$$

For ideal solutions, the $\log N$ vs. $1000/T$ plots are straight lines and $\Delta H'_f/\Delta H_f$ is constant over the whole range of concentrations. Since the solubilities of most compounds in organic solvents tend to deviate from ideality, the $\log N$ vs. $1000/T$ plots are generally not straight lines, but smooth curves which extend over wide ranges of temperature and concentration. In the case of the solubilities of homologous and analogous compounds in a given solvent this deviation from ideal behavior is quite regular. Hence, plots of $1/T_a$ vs. $1/T_r$ (analogous vs. reference) will in most cases give smooth slightly curved lines and even straight lines over small concentration ranges.

Procedure for Constructing Isopleth Reference Plots

In order to construct the isopleth reference curves for homologous or analogous compounds in a given solvent, a large scale $\log N$ vs. $1000/T$ plot is first constructed for the reference compound for which there are sufficient experimental solubility data. Values of $1/T_r$ at selected values of N , i.e., those values of N for which the solubility temperature for the analogous compound in that solvent are known, are then read from the curve and the $1/T_a$ vs. $1/T_r$ plot constructed. Two or three points in addition to the freezing point are generally suf-

¹ Presented at the AOCs Meeting, San Francisco, April 1969.
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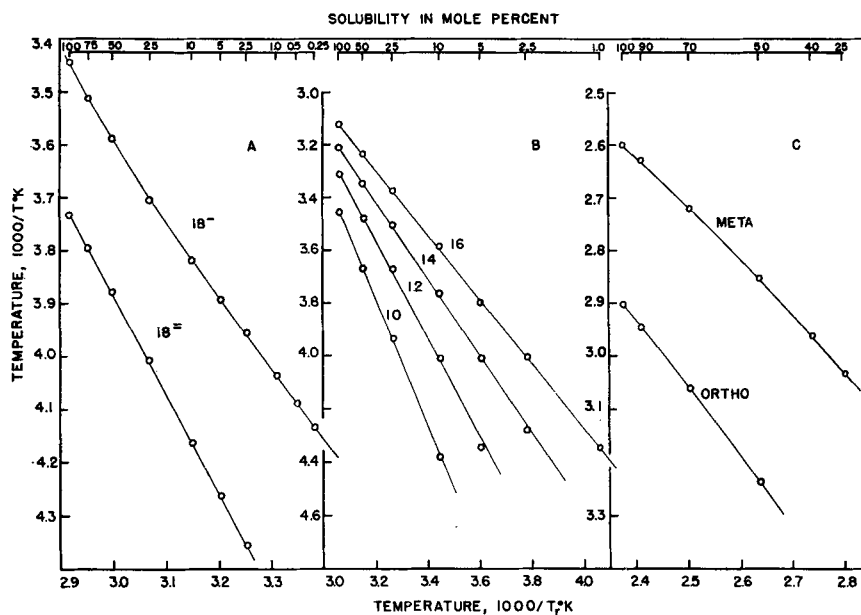


Fig. 1. Isopleth reference curves illustrating relation between solubility temperatures (expressed as $1000/T^{\circ}\text{K}$) and concentration (mole %) for stearic, oleic and linoleic acids in acetone, A; normal primary amines in chloroform, B; and *o*, *m*, and *p*-nitroanilines in acetone, C.

ficient to establish the contour of the line. Inspection of the plot will indicate whether any additional points may be required. The $1/T_a$ value for any desired concentration can thus be determined by graphical interpolation since the molar concentration at $1/T_r$ is known and at the intersection of $1/T_a$ and $1/T_r$ the molar concentrations are equivalent.

The validity and the scope of the isopleth reference method was established by constructing $1/T_a$ vs. $1/T_r$ plots from some of the published data of Ralston, Harwood, Hoerr and coworkers

who have made careful, extensive studies of the solubilities of homologous fatty acids (3-5), methyl esters of fatty acids (6), symmetrical and unsymmetrical ketones (7,8), primary, secondary and tertiary amines (9-11), primary alcohols (12), nitriles (13), normal hydrocarbons (14) and haloalkanes (15), in such solvents as *n*-hexane (16), benzene, cyclohexane, carbon tetrachloride, chloroform, *o*-xylene, diethyl ether, chlorobenzene, 1,2-dichlorobenzene, nitrobenzene, *p*-dioxane, furfural, ethyl and butyl acetate, acetone, methanol, 95% ethanol, 2-propanol, *n*-butanol, nitromethane, nitroethane, acetonitrile and acetic acid. Straight or slightly curved lines were obtained in most instances, as expected, except for some of the highly polar solvents such as acetonitrile, nitromethane and nitroethane in which a number of the compounds were soluble to a very limited degree. A typical plot, constructed for oleic and linoleic acids in *n*-hexane (17) in which stearic acid is used as the reference compound is illustrated in Figure 1A. Figure 1B illustrates the homologous series of primary amines in chloroform with stearyl amine as the reference compound. The method was also found applicable to aromatic isomers typified by the *o*, *m*, and *p*-nitroanilines in acetone (18) with *p*-nitroaniline as the reference, illustrated in Figure 1C. It should be noted that in general not all of the solubility data reported in the literature will result in satisfactory isopleth reference plots since solubility data obtained by different methods don't always agree.

Application of $1/T_a$ vs. $1/T_r$ Plots to Predicting Solubilities

New complete solubility data covering a uniform range of concentrations down to 0.1 mole per cent were obtained for stearic, palmitic and petroselaic acids in acetone, methanol and toluene for elaidic acid in toluene and for palmitic acid in isopropyl ether. Experimental data were also obtained at two or three selected compositions of behenic, stearic, palmitic, heptadecanoic, brassidic, erucic, petroselaic, petroselinic, elaidic and oleic acids in these solvents.

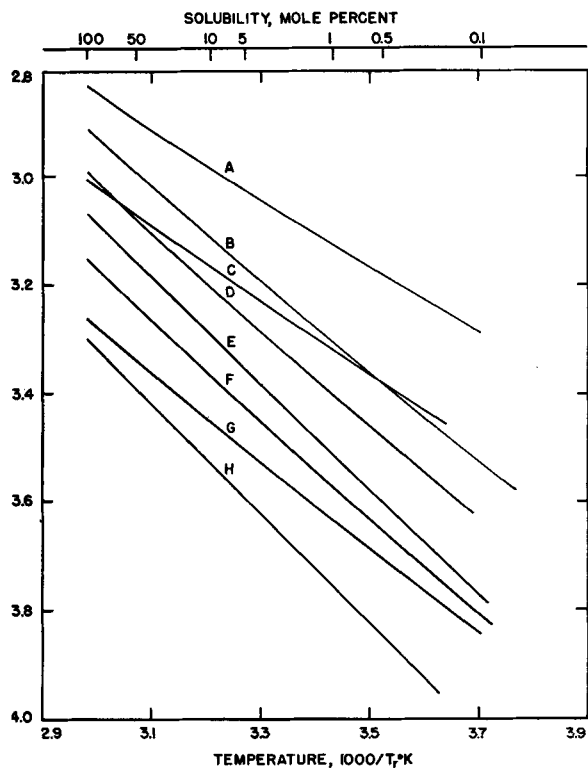


Fig. 2. Isopleth reference curves for a number of fatty acids in acetone with palmitic acid as the reference acid; A, behenic; B, stearic; C, brassidic; D, heptadecanoic; E, petroselaic; F, elaidic; G, erucic; and H, petroselinic.

TABLE I
Solubility Data for Long Chain Fatty Acids in Weight Per Cent^a
in Isopropyl Ether

Behenic	Stearic		Palmitic		Heptadecanoic		Brassicidic		Erucic		Petroselaiddic		Petroselinic		Elaidic		Oleic	
	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC
90.0	76.2	(91.92)	(66.0)	(59.4)	91.4	57.2	93.0	56.9	93.0	30.8	91.7	48.4	91.7	25.8	91.7	40.0	91.7	8.7
83.3	72.6	80.7	(79.01)	(54.3)	79.9	53.0	83.3	53.6	83.3	27.8	(81.94)	(45.6)	80.6	21.5	(79.84)	(36.4)	80.6	4.6
69.0	68.0	(74.47)	(59.7)	(47.3)	63.8	47.9	68.8	49.6	68.8	24.0	64.8	38.5	64.8	16.1	64.8	31.1	64.8	1.3
45.5	60.6	(40.02)	(47.8)	(36.3)	39.8	39.3	45.1	43.1	45.1	17.8	(40.50)	(30.7)	40.9	7.9	(39.84)	(22.8)	(53.53)	3.8
(38.56)	(54.9)	23.6	(40.7)	(31.81)	(22.25)	(30.2)	(36.50)	(33.19)	(33.19)	(14.5)	23.5	22.8	(27.19)	(2.5)	23.5	16.4	40.9	(-0.1)
22.5	51.9	19.5	38.3	(17.92)	22.3	29.3	22.3	34.8	22.3	10.4	19.4	20.4	19.4	(-1.9)	(17.62)	(12.8)	(23.67)	4.9
17.5	49.2	15.1	35.3	(13.81)	14.5	26.1	17.5	32.3	17.5	8.0	(17.37)	(19.8)	15.0	4.8	15.0	11.2	19.4	(-11.8)
12.2	45.5	10.4	31.1	(9.87)	9.9	21.5	12.1	28.5	12.1	4.5	11.4	13.1	11.4	9.2	11.4	7.2	19.4	(-14.9)
6.4	39.3	(4.60)	(22.4)	(5.55)	5.1	13.6	6.3	(3.43)	6.3	1.6	(5.43)	(6.5)	5.3	16.2	(5.25)	(0.5)	15.0	(-17.7)
(3.16)	(33.2)	2.7	(17.0)	(2.47)	(2.52)	(5.6)	(15.6)	(4.21)	(4.21)	(-5.2)	2.7	(-1.1)	2.7	(-33.2)	2.7	(-6.7)	(12.33)	(-21.6)
2.6	30.3	2.2	14.7	(3.4)	2.1	3.1	2.6	13.0	2.6	(-10.1)	2.2	3.6	2.2	(-35.2)	2.2	(-9.2)	11.4	(-35.9)
2.0	27.7	1.7	11.8	(0.0)	1.6	0.2	2.0	10.1	2.0	(-12.9)	1.6	(-6.1)	1.6	(-32.5)	1.6	(-12.3)	9.2	(-21.3)
0.8	25.7	(1.12)	(7.81)	(-4.7)	1.1	(-5.0)	1.3	6.0	1.3	(-17.0)	1.1	(-10.7)	1.1	(-32.5)	1.1	(-25.1)	4.6	(-19.6)
(0.38)	(17.0)	(0.36)	(-2.3)	(-13.6)	(0.28)	(-20.5)	(0.33)	(-6.8)	(0.3)	(-32.3)	0.3	(-24.5)	0.3	(-32.5)	0.3	(-32.5)	(-24.2)	(-19.6)

^a Values in parenthesis were experimentally determined.

To insure consistency in the data over the entire temperature range, the freezing points and solubility determinations were made by the thermostatic sealed tube method (19-21) which gives the true equilibrium temperature to within 0.2 C.

The pure fatty acids, prepared by procedures previously described (22), had the following freezing points: behenic 79.8 C, stearic 69.5 C, palmitic 62.4 C, heptadecanoic 61.1 C, brassidic 59.7 C, erucic 33.4 C, petroselaiddic 52.8 C, petroselinic 29.9 C, elaidic 43.7 C and oleic 13.3 and 16.2 C. The solvents were all reagent grade. The acetone, methanol and toluene were distilled and the isopropyl ether was percolated through an alumina column.

Isopleth reference plots were constructed for each of the above systems with palmitic acid as the reference compound. Straight or slightly curved lines were obtained for each of the systems as is typified by the acetone systems illustrated in Figure 2. Standard deviations for those systems for which complete experimental data were available (stearic and petroselaiddic acids in acetone, methanol and toluene and elaidic acid in toluene) were less than 0.35 C.

By interpolation from the isopleth plots, complete solubility data were obtained for each of the systems for which the experimental data were incomplete. Both the experimental and interpolated data are presented in Tables I-IV.

Isopleth reference plots were also constructed using elaidic, petroselaiddic and stearic acids as the reference acids to predict the solubility of petroselinic acid in isopropyl ether on the basis of two experimental points and the melting point. The data inclusive of those data obtained using palmitic acids as the reference acid are presented in Table V. The closeness of the agreement in the predicted solubility temperatures for petroselinic acid over the entire concentration range obtained using four different reference acids typifies the accuracy with which predicted solubility data can be obtained using the isopleth reference method.

It is interesting to note that less soluble polymorphic forms were observed for certain compositions of stearic and erucic acids in toluene, for palmitic acid in acetone and for heptadecanoic acid in methanol and isopropyl ether.

Discussion

The scope of the isopleth reference method is much broader than that of either the isotherm or isopleth methods previously described (1,2) which apply only to homologous series. For example, they require complete solubility data for at least three members of a series to predict the data for the intermediate missing members. However, no experimental data are necessary for the missing members. These methods are also restricted to homologous series showing a regular increase in melting point with molecular weight. The odd carbon and even carbon numbered series must therefore be treated separately.

The isopleth reference method is applicable to analogous as well as homologous compounds. The complete solubility curve for a given compound can be obtained from two or three experimental determinations if complete solubility data are known for a single analogous or homologous compound.

The isopleth reference method, like the isotherm and isopleth methods, can also be use to smooth and locate discrepancies in existing data. The procedures used are essentially the same as those described for

TABLE II
Solubility Data for Long Chain Fatty Acids in Weight Per Cent*
In Acetone

Behenic	Stearic		Palmitic		Heptadecanoic		Brassicidic		Erucic		Petroselaiddic		Petroselinic		Elaidic	
	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC
95.9	(94.37)	(65.8)	(94.64)	(59.1)	94.9	57.7	95.9	57.1	95.9	30.8	(94.30)	(49.0)	95.1	27.1	95.1	41.1
89.8	(89.00)	(63.5)	(87.88)	(55.6)	87.5	54.1	89.7	54.3	89.7	28.0	(87.21)	(45.9)	87.9	23.9	(87.89)	(38.4)
79.6	(76.11)	(58.5)	(74.64)	(50.5)	75.6	49.2	79.5	50.6	79.5	24.3	(76.99)	(42.3)	76.4	19.8	(76.4)	(34.3)
59.4	(59.50)	(53.9)	(56.40)	(45.5)	53.8	43.0	59.1	45.7	59.1	19.7	(68.00)	(39.6)	54.9	14.4	(55.58)	(29.3)
39.5	(38.63)	(48.4)	(42.91)	(38.4)	34.1	38.4	39.3	41.5	39.3	14.8	(35.60)	(30.8)	35.1	9.8	(35.1)	(24.2)
33.8	(30.20)	(46.3)	(27.74)	(36.8)	28.8	36.8	33.6	40.7	33.6	14.8	(26.78)	(28.0)	29.7	8.7	(27.48)	(21.6)
(28.72)	(26.81)	(45.1)	(22.61)	(35.0)	(23.91)	(35.2)	(27.00)	(39.2)	(24.70)	(12.55)	(16.82)	(23.6)	(25.35)	(7.1)	(23.7)	(17.9)
19.6	(17.11)	(41.6)	(15.54)	(31.3)	16.2	31.5	19.5	32.7	19.5	10.8	(9.10)	(18.4)	16.8	3.8	(16.8)	(12.2)
10.7	(9.41)	(35.8)	(8.13)	(24.6, 26.7)	8.7	25.7	10.5	32.1	10.5	6.3	(4.94)	(12.3)	9.0	1.5	(9.11)	(6.7)
(5.09)	(4.62)	(32.6)	(4.26)	(18.4)	(5.10)	(21.2)	(5.6)	27.6	(5.6)	6.3	(4.17)	(10.7)	(4.81)	(—)	(4.7)	(—)
4.5	(3.28)	(27.2)	(3.44)	(16.3)	3.6	18.4	4.5	24.2	(4.48)	(1.4)	(1.95)	(3.6)	3.8	8.6	(3.8)	(—)
3.4	(3.28)	(19.1)	(2.59)	(13.5)	2.7	15.9	3.4	24.1	(3.4)	(—)	(1.72)	(2.4)	2.9	—	(2.43)	(0.8)
2.3	(40.2)	(14.3)	(1.90)	(10.0, 12.0)	1.8	12.6	2.3	21.5	2.3	(—)	(0.69)	(—)	2.0	—	(2.0)	(—)
(1.04)	(34.5)	(7.8)	(0.84)	(2.5, 5.5)	(0.75)	(5.4)	(1.18)	(16.8)	(0.92)	(—)	(0.21)	(—)	(1.08)	(—)	(1.08)	(—)
0.6	(0.10)	(—4.3)	(0.44)	(—3.6)	0.5	1.4	0.6	12.1	0.6	(—12.6)	(0.11)	(—22.9)	(0.5)	(—27.3)	(0.49)	(—10.8)

* Values in parenthesis were experimentally determined.

TABLE III
Solubility Data for Long Chain Fatty Acids in Weight Per Cent*
in Methanol

Behenic	Stearic		Palmitic		Heptadecanoic		Brassicidic		Erucic		Petroselaiddic		Petroselinic		Elaidic	
	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC
97.7	(94.85)	(64.5)	(96.97)	(59.7)	97.1	58.4	97.7	55.8	97.7	30.4	(98.17)	(50.4)	97.2	27.9	(97.2)	(—)
94.1	(87.39)	(60.4)	(90.52)	(54.9)	92.7	54.9	94.1	52.6	94.1	23.7	(95.91)	(49.0)	93.0	25.2	(93.0)	(—)
87.6	(83.74)	(54.1)	(84.22)	(51.7)	84.9	50.8	87.6	48.4	87.6	19.4	(95.20)	(48.4)	85.5	21.1	(85.5)	(—)
72.7	(68.68)	(51.2)	(60.57)	(43.5)	67.8	44.5	72.4	45.3	72.4	19.4	(85.11)	(43.5)	(69.34)	(15.9)	(69.34)	(—)
(55.43)	(30.09)	(47.6)	(47.07)	(39.3)	(48.30)	(39.9)	(53.74)	(43.4)	(54.23)	(16.8)	(78.10)	(40.8)	49.5	10.9	(49.5)	(—)
48.0	(44.6)	(44.6)	(41.04)	(38.8)	42.3	38.8	47.9	43.1	47.9	16.1	(68.87)	(37.7)	43.4	9.9	(43.4)	(—)
62.3	(15.16)	(42.2)	(33.81)	(38.1)	35.0	37.4	42.6	40.3	42.6	15.4	(48.88)	(32.12)	43.4	8.2	(43.4)	(—)
30.7	(13.00)	(41.5)	(29.24)	(30.8)	26.0	35.8	30.7	42.3	30.6	14.9	(40.00)	(31.1)	26.9	7.7	(26.9)	(—)
17.8	(7.46)	(37.9)	(14.04)	(33.6)	14.7	33.0	17.6	41.2	17.6	18.4	(26.84)	(25.4)	15.3	5.0	(15.3)	(—)
(9.81)	(57.2)	(25.6)	(8.14)	(29.1)	(8.00)	(30.4)	(9.72)	(39.4)	(11.1)	(—)	(15.49)	(20.7)	8.2	1.0	(8.2)	(—)
7.9	(0.70)	(18.4)	(6.06)	(26.0)	6.4	29.5	7.9	38.5	7.9	10.0	(8.12)	(6.6)	6.6	—	(6.6)	(—)
55.7	(0.26)	(10.0)	(4.61)	(23.0)	4.8	28.6	5.0	37.2	5.0	8.5	(8.53)	(14.0)	5.1	—	(5.1)	(—)
6.0	(0.086)	(1.1)	(2.53)	(16.5)	3.3	27.1	4.1	35.2	4.1	6.4	(0.87)	(5.9)	5.1	—	(5.1)	(—)
2.1	(0.045)	(—3.4)	(1.28)	(9.6)	1.7	24.6	2.1	30.7	2.1	2.1	(0.36)	(—)	1.7	—	(1.7)	(—)
(1.09)	(0.040)	(—4.5)	(0.57)	(3.0)	(0.86)	(21.9)	(1.09)	(26.0)	(1.10)	(—1.7)	(0.084)	(—18.3)	0.9	—	(0.9)	(—)

* Values in parenthesis were experimentally determined.

TABLE IV
Solubility Data for Long Chain Fatty Acids in Weight Per Cent*
in Toluene

Behenic	Stearic		Palmitic		Heptadecanoic		Brassicidic		Erucic		Petroselaiddic		Petroselinic		Elaidic	
	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC	%	tC
93.7	(91.97)	(66.3)	(91.55)	(58.3)	92.2	56.4	93.6	55.7	93.6	28.2	(90.80)	(48.3)	92.5	26.1	(90.80)	(38.8)
84.7	(80.05)	(60.4)	(80.67)	(53.3)	81.5	51.0	(87.07)	(54.0)	84.6	22.9	(81.52)	(44.3)	82.1	21.4	(79.88)	(34.8)
71.1	(64.53)	(53.7)	(66.24)	(46.9)	66.2	44.5	(76.48)	(49.8)	71.0	16.5	(66.26)	(37.9)	67.1	15.4	(64.83)	(29.1)
48.0	(40.80)	(44.1, 44.8)	(56.69)	(43.7)	42.3	35.3	(53.20)	(41.4)	47.7	8.1	(55.46)	(33.0)	(44.0)	(6.4)	(55.77)	(25.5)
(28.92)	(21.49)	(35.9, 36.7)	(23.62)	(30.5)	(24.63)	(28.4)	(29.0)	(31.1)	(29.48)	(2.1)	(42.81)	(28.1)	25.4	—	(42.94)	(20.5)
24.3	(14.39)	(32.2, 33.0)	(21.97)	(29.78)	20.3	25.9	(25.90)	(30.0)	24.2	0.1	(25.64)	(20.7)	21.0	—	(24.84)	(12.9)
19.1	(9.46)	(28.6, 30.2)	(15.08)	(25.9)	15.8	23.6	19.0	27.1	19.0	—	(18.66)	(17.3)	16.4	—	(18.34)	(9.6)
18.3	(3.53)	(22.6)	(10.39)	(22.5)	10.9	20.4	13.3	24.5	13.3	4.8	(11.43)	(13.95)	(—)	(7.0)	(11.41)	(5.6)
(7.0)	(0.92)	(15.8)	(6.03)	(18.2)	(5.7)	(15.4)	(6.65)	(16.5)	(6.9)	(—)	(6.07)	(8.1)	(5.9)	(—)	(5.85)	(0.9)
(3.64)	(35.9)	(20.5)	(2.73)	(20.8)	2.3	9.3	3.6	(16.0)	(3.71)	(—12.7)	(3.07)	(3.6)	(2.99)	(—17.2)	(2.96)	(—)
2.9	(0.55)	(11.3)	(2.20)	(10.9)	2.3	7.6	2.9	14.9	2.9	(—)	(1.32)	(2.4)	(1.8)	(—)	(1.8)	(—)
2.2	(0.22)	(6.1)	(1.65)	(9.0)	1.7	6.0	2.2	13.4	2.2	(—)	(0.29)	(—)	1.2	(—)	(1.2)	(—)
1.5	(0.084)	(0.6)	(0.94)	(5.3)	0.6	5.2	1.5	11.3	1.5	(—)	(—)	(—)	0.6	(—)	(0.6)	(—)
0.7	(0.055)	(—5.7)	(0.55)	(1.9)	0.6	1.0	(1.1)	(9.6)	0.7	(—20.6)	(—)	(—)	0.6	(—)	(0.6)	(—)
(0.38)	(24.4)	(—)	(0.20)	(—3.9)	(0.29)	(—2.7)	(0.41)	(4.9)	(0.39)	(—23.4)	(—)	(—)	0.3	(—)	(0.3)	(—)

* Values in parenthesis were experimentally determined.

TABLE V
Solubility of Petroselinic Acid in Isopropyl Ether

Mole %	Elaidic as reference C	Petroselinic as reference C	Stearic as reference C	Palmitic as reference C	Average dev. C
80.0	26.5	26.4	26.0	25.8	0.3
60.0	22.4	22.1	21.8	21.5	0.3
40.0	17.1	16.5	16.5	16.1	0.2
20.0	8.5	8.1	8.3	7.9	0.2
10.0	0.7	0.7	0.6	0.5	0.1
5.0	-6.3	-6.2	-6.7	-6.7	0.2
3.0	-11.2	-11.6	-11.9	-12.1	0.3
2.0	-15.2	-15.9	-15.2	-16.2	0.4
1.0	-22.5	-23.0	-22.7	-23.2	0.3
0.5	-30.2	-30.0	-29.4	-31.1	0.4

the isotherm and isopleth methods. In taking advantage of the isotherm and isopleth methods, now complemented by the isopleth reference method, complete solubility data for a large number of compounds in a variety of solvents can be obtained with a minimum of experimental effort.

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[Received June 11, 1969]