The Physico-chemical Constants of Binary Systems in Concentrated Solutions

VOLUME 2

TWO ORGANIC COMPOUNDS

(at least One a Hydroxyl Derivative)

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Preface to Volume 2

With this second volume of my book, we have collected all the numerical data published about the concentrated binary solutions of organic compounds.

In many cases, the reader will be shocked by the low degree of precision of the measurements since, when different authors made research on the same subject, the quantitative discrepancies are obvious.

This may be due, at least to two kinds of difficulties: different methods on the physical side, and the impurity of the used samples. The possibility of this second cause of error is not considered with sufficient care by most of the authors.

In the case of organic compounds, this is historically easy to understand. Before the twentieth century, organic compounds were generally considered to be too unstable to warrant great care in their purification: only Mendeleev, in his classical studies on ethyl alcohol (1869), and later de Visser (1891) with acetic acid, took the necessary care and found exact values of the measured constants; S. Young, from 1884 on, in his well-known researches on the equation of state, prepared some thirty organic compounds in a very pure state, which has given a lasting value to his quantitative measurements and has proved the possibility to attain such a goal with certainty.

Therefore, it is a pity that so much work has been done with too little care in that direction; this diminishes the value of numerous numerical data, whatever the care given to the physical methods used.

Presently such errors are no longer admissible because, in many cases, it is easy to obtain the necessary pure samples from different sources, as for example from the Chemical Division of the National Bureau of Standards, in Washington, or from the National Chemical Laboratory in Teddington (England); it is also easy to find out what is known about the methods of purification and the numerical values of physical constants in my own book, Physico-chemical Constants of Pure Organic Compounds, published by Elsevier (Amsterdam - New York) in 1950, to which a Supplement of Addenda and Corrigenda will soon be published.

June, 1959

Jean Timmermans

Notice for Users

1. Scope of the work

The data compiled refer only to binary systems, concentrated solutions.

As components, I have accepted all kinds of substances, elements or compounds, with the exception of metallic alloys, a category covered by many other books.

As concentrated solutions, I choose to consider arbitrarily systems between 10 and 90 per cent by weight; I left also out of consideration data relating to dilute solutions, if there is only one measure between 10 and 20 %.

All data, so far as possible, have been reproduced from the original publications, if available; in other cases, the actual source of the data is given in the bibliographic reference. Preference has been given to the experimental data, rather than to values interpolated from a formula; in many cases we had to read the data from graphs, with help of a grating (this is denoted by "fig").

2. General Plan

All data are classified by systems, since values of different properties may help to caracterise their physical nature.

The systems have been arranged in four categories, one for each volume of this book, as follows:

A. Both components are organic compounds, excepting the hydroxyl derivatives.

B. Both components are organic compounds, one at least being a hydroxyl derivative.

C. One at least of the components is a metallic compound.

D. All other systems.

In that volume are also included the general table of bibliographic references and the general table by substances.

I consider as non-metals the following twenty elements:

B - C,Si - N,P,As - O,S,Se,Te - H,F,Cl,Br,I - He,Ne,Ar,Kr,Xe

I call non-metallic compounds those with only these elements; and organic compounds all such compounds with at least one atom of C. As metallic compounds, I consider all those with at least one metallic atom. Ex.: CSi is an organic compound, sodium benzoate a metallic one, and HCl a non-metallic one.

3. Order of the systems

In each section, the binary mixtures are brought together in great divisions, according to the degree of physico-chemical similitude of their components; for ex., in the third volume, the first part deals with mixtures of two metallic salts, the second one with solutions of metallic salts in water and the third, with solutions of these salts in all other solvants, non-metallic or organic.

In each of these divisions, the binary mixtures are listed, according to the order of the first component, and, for each of them, according to the order of the second component; for ex., all systems with methane come first, methane + butane being listed before methane + benzene, since butane comes before benzene in my classification.

a) For organic compounds, the general order is: hydrocarbons, halogen derivatives, oxygen derivatives (excluding the hydroxyl ones), nitrogen, mixed oxygen and nitrogen derivatives, and last the hydroxyl derivatives of any kind.

In each of these groups, the aliphatic derivatives come first (saturated and then unsaturated), then the polymethylenes, the aromatic compounds and finally the heterocyclic ones.

The sulfur derivatives are listed after the corresponding oxygen ones, the phosphorus, after the nitrogen ones, the silicon and boron after the carbon ones. In each group, the derivatives produced by halogen substitution are placed at the end of the respective group; for ex., ethylenchlorhydrin comes at the end of the alcohol group.

In accordance with this rule, we have the following arrangement:

Hydrocarbons: paraffins, ethylenic and acetylenic hydrocarbons, polymethylenes and aromatic hydrocarbons.

Halogen derivatives: derivatives of the same hydrocarbon are grouped together, in order of the number of hydrogen atoms substituted by halogen atoms, fluorine derivatives first, then chlorine, bromine and iodine derivatives.

Oxygen derivatives: first the ether oxides, with open chain (ethyl ether) or closed ring (dioxane), the aldehydes and ketones, the anhydrides, and finally the esters.

Nitrogen derivatives: nitriles and amines.

Mixed Oxygen and Nitrogen derivatives: compounds of the amide type, and then nitroso- and nitro- derivatives.

Hydroxyl derivatives: first the alcohols and oximes, then the phenols and finally the acids.

N.B. The presence in the molecule of a chemical function listed later, relegates this compounds to the end of that category, for ex., acetoacetic esters come after the esters.

b) Metallic Compounds. Most of them are electronic compounds which are classified as follows:

The salts, oxides, sulfides, etc. come together, so long as the metal has the same electrovalency, for ex., the ferrous compounds are classified with nickel, cobalt, manganese ones. but the ferric compounds, with aluminum and chromic salts.

The metallic ions are classified in series of the same electrovalency, according to the periodical table:

Li, Na, K, Rb, Cs, Tl^{+} - Cu^{+}, Ag, Au^{+}, Hg^{+}

Be, Mg, Ca, Ba, Sr, Sn^{++}, Pb^{++} - Zn^{++}, Cd^{++}, Hg^{++}, Cu^{++}, Mn^{++}, Fe^{++}, Ni^{++}, Co^{++}

Al, Ga, In, Tl^{+++}, Cr^{+++}, Fe^{+++}, Rare Earths - Sb^{+++}, Bi^{+++}.

Ge, Ti, Th, Sn^{++++}, Pb^{++++} - Uranyl.

For each metallic ion, the salts are arranged according to the valency of the anion and the oxygenated salts after all others, as follows:

fluorides, chlorides, bromides, iodides, cyanides, thiocyanates, etc.;

oxides, sulfides, selenides, etc. - nitrides, borides, carbides, silicides;

hydrates, thiohydrates - nitrites, chlorites...

chlorates, bromates, iodates, nitrates;

phosphites, arsenites;

perchlorates - permanganates;

phosphates, arsenates, etc.;

carbonates, sulfites, metasilicates;

sulfates, selenates, chromates, manganates;

orthosilicates.

4. Order of the constants.

So far as possible, especially for systems where the data are particularly numerous, the order in which the properties are classified is as follows:

a) Heterogeneous equilibria:

Critical constants; saturates vapour pressure for the triphase equilibrium.

Vapour pressure curve; boiling curve and azeotropes.

Composition of liquid and vapour coexisting phases.

Densities of coexisting phases and rectilinear diameter.

Composition of the two liquid phases and eventually of the saturated vapour; critical solution point.

Freezing and melting curve; eutectic and transition points.

Equilibria of the condensed phases under high pressure.

b) Properties of phases: first for the gas, then the liquid and finally the mixed crystals:

Densities, coefficients of expansion and of compressibility.

Viscosity and surface tension.

Refractive index and optical dispersion.

Dielectric constant; electrical conductivity.

Optical rotatory power.

Magnetic rotation; magnetic susceptibility.

c) Thermal constants:

Specific heat; heat of solution or mixing.

Heat of vaporization and fusion.

Thermal conductivity.

5. Choice of units.

So far as possible, we have always used units of the c.g.s. system; when necessary, we have converted the original results into these units, so far as it did not involve the use of a coefficient whose value has changed sometimes. Ex: we could, without any ambiguity, transform specific volumes into densities, or density d_t^t into d_4^t; but to transform molar concentration in weight concentration, if not made by the author himself, would have involved a somehow arbitrary choice of atomic weights.

All our numerical data have been taken as given in the original paper; we always gave priority to direct experimental results, rather than recalculated curves.

Here follow some additional details about the choice of units:

Viscosity: in poises . 10^5

Surface tension: in dynes/cm

Temperature: t in centigrade; T = absolute temperature = t + 273.16

Pressure: p - in mm Hg; P - in atmospheres; P_{kg} - in kg/cm^2

π and τ represent pressure or temperature coefficient of the constant considered, which means its change by kg or by degree; but when it relates to volume changes, π and τ are coefficients of compressibility or expansion, as given by the formulae:

$$v_t = v_o \cdot (1 + \tau.t) \quad \text{and}$$

$$v_P = v_1 \cdot (1 - \pi.P)$$

Specific heat: in calories / gram of mixture

Heat of mixing, heat of vaporization, etc. - in calories / mole of mixture.

In case other units were exceptionally used, this is expressely stated in column headings.

N.B. Scientists of the whole world always agree to give their results in units of the metric system; only in Anglo-Saxon countries, did some authors give also their results in British units, for the ease of their technicians. But in recent years some American physico-chemists, namely Sage and his co-workers, have published in Industrial and Engineering Chemistry some extensive tables of data on isotherms of mixtures of hydrocarbons, only in British units (°F, pressure in Lb/sq.in., etc.), without any corresponding tables in metric values, which makes them quite unsuitable for general use in other countries. We have made in most cases the necessary calculations to reproduce these data in metric units, but this work is so laborious and tedious that we were unable to give the complete data; and we wish to protest here with energy against this new mode of publication, which takes no notice of the international scientific public.

6. Nomenclature and bibliographical data.

A. Nomenclature.

Inside this work the common names of the substances are used, with their molecular formulae; but in the Table at the end of the 4th volume, they are classified in the same order as in the Chemical Abstracts, with the different synonyms. For ex., the compound we call ethylene chloride in the book itself, is also named: 1,2-dichlorethane, in the table.

B. Bibliographical data.

Inside the book, the data are reproduced under the name of their author, with the year of publication. The complete bibliographical reference is to be found in the alphabetical list of authors, at the end of this book.

For the transcription of Russian names, we have applied the rules used in Chemical Abstracts. But in case of a Russian author, all of whose quoted publications have been printed in Latin caracters, we have reproduced his name as he had it transcribed himself; when necessary, we give also in the list of authors, the alternative transcription of his name.

7. Symbols and abbreviations.

α	Rotatory power, for the length = 10 cm
(α)	Specific rotatory power
$(\alpha)^{mol}$	Molar "
$(\alpha)_{magn}$	Specific magnetic rotatory power
$(\alpha)^{mol}_{magn}$	Molar " "
ε	Dielectric constant
η	Viscosity, in poises $(.10^5)$*
$\varkappa$	Specific conductivity $(.10^4)$
λ	Equivalent conductivity
π	Pressure coefficient $(.10^6)$
σ	Surface tension, in dynes/cm
τ	Temperature coefficient
χ	Magnetic susceptibility $(.10^6)$ (specific)
C	Crystal
C.S.T.	Critical solution temperature
C.V.T.	" vaporization "
D	Diffusion coefficient $(.10^5)$
D_{therm}	Thermal diffusion coefficient
D b.t.	Boiling temperature difference
D f.t.	Freezing " "
Dp	Pressure difference
Dt	Temperature "
Dv	Volume "
E	Eutectic
L	Liquid
M	Molarity
N	Normal concentration
P	Pressure, in atmospheres
P_{kg}	" in kg/cm^2
Q comb	Heat of combustion (cal/gram mixture)
Q dil	" dilution (cal/mole mixture)
Q diss	" dissolution "
Q melt	" fusion "
Q mix	" mixing "
Q trans	" transition "
Q vap	" vaporization "

R	Resistivity
S	Solid
T	Absolute temperature
U	Specific heat (cal/gram mixture)
V	Vapour
aq	Aqua, water
atm	Atmosphere
b.t.	Boiling temperature
c	g/100 cc solution
cc	Cubic centimeter
cal	Calorie (small)
crit.	Critical
d	Density (t/4)
dissoc.	Dissociation
e	Electromotive force (in volts)
f.t.	Freezing temperature
g	Gram
l	Liter
m	Molality
mm	Millimeter
mg	Milligram
min	Minutes
mol	Molar
m.t.	Melting temperature
n	Refractive index
p	Pressure in mm Hg
sat.t.	Saturation temperature (mutual solubility)
sol	Solution
s. or sym.	Symmetrical
t	Temperature, centigrade
tr.t.	Transition temperature
trans.	Transition
vol	Volume
v_o	Volume at 0%
w.l.	Wave length (in Ångström unit)
%	Weight percent
I, II, etc.	Polymorphic forms
I - II	Transition of form I into form II

* The given powers for some units are systematically used in the Tables, unless otherwise stated.

Contents

H. HYDROCARBONS + HYDROXYL DERIVATIVES

XXI. HYDROCARBONS + ALCOHOLS .

Methane (CH_4) + Ethyl alcohol (C_2H_6O)

Frolich, Tauch and al., 1931

P	a
0	0
20	8
40	16
60	25
80	33
100	41
120	50

$a = \frac{\text{vol. of gaz}}{\text{vol. of liq.}}$ at 25° and 1 atm.

Methane (CH_4) + Isopropyl alcohol (C_3H_8O)

Frolich, Tauch and al., 1931

P	a
0	0
20	9
40	20
60	32
80	43
97	52

Ethane (C_2H_6) + Methyl alcohol (CH_4O)

Kuenen, 1897 and 1902 - 1903

t	P	t	P
Critical points			
241.2	80.0	51.9	121.5
241.1	80.45	45.8	118.5
240.0	81.5	41.7	116.5
219.0	100.0	36.0	114.5
216.1	101.5	33.8	114.7
160.8	136.5	26.4	113.0
156.5	138.0	18.6	114.7
154.2	138.7	13.2	118.0
151.5	139.7	12.4	118.5
131.9	143.5	-0.6	144
128.5	144.0	-1.5	150
126.0	144.5	-2.5	155 (?)
78.4	135.0	-2.6	152
74.6	133.0	-3.6	156.5
70.8	131.5	-4.4	161.5
66.4	129.5	-5.3	168
62.3	127.0	-6.3	175
57.0	124.5		

C.V.T.

0%		sat.sol.	
32.16	48.9	35.37	52.0

Kuenen and Robson, 1899

t	P_2	Rem.
14.95	33.62	V + L
31.95	50.99	normal condensation

with less alcohol

t	P_1	P_2	Rem.
15.1	33.44	33.77	V + L_1 + L_2
22.9	39.45	-	"
22.95		39.91	"
31.55	47.16	47.48	"

t	P	Rem.
31.75	47.46	V + L_1 + L_2
34.2	49.81	"
35.1	50.76	"
35.37 crit.t.	51.99	"

P_1 and P_2 = pressures resp. at the beginning and end of condensation.

P = middle pressure

Ethane (C_2H_6) + Ethyl alcohol (C_2H_6O)

Kuenen and Robson, 1899

t	P_2	Rem.
14.97	32.97	V + L

t	P	Rem.
31.90 crit.t.	46.25	
31.95	46.34	
32.15	46.49	
32.55	46.90	
34.85	46.05	
39.15	53.23	V + L_1 + L_2
40.67 crit.t.	54.90	

with more alcohol

t	P	Rem.
32.65 crit.t.	47.12	
32.75	47.16	V + L_1 + L_2
32.95	47.30	
40.75 crit.t.	54.68	

with still more alcohol

t	P_2	Rem.
14.95	32.81	V + L
32.75 crit.t. P	47.04	V + L_1 + L_2
32.95	47.26	

Ethane (C_2H_6) + Propyl alcohol (C_3H_8O)

Kuenen and Robson, 1899

t	P	Rem.
38.67 crit.t.	52.78	V + L_1 + L_2
38.75	52.85	
38.95	53.12	
39.95	54.09	
41.7 crit.t.	56.01	
39.55	54.22	Sat.t. L_1 + L_2 retrograde condensation.
39.75	54.47	
40.35	55.39	
41.75	57.43	
42.2	58.22	
43.35	59.81	

with more alcohol

t	P_2	Rem.
14.96	32.76	V + L
31.8	46.17	normal condens.
31.96	46.35	
38.05	52.25	
38.75	53.03	V + L_1 + L_2
38.85	53.09	normal condens.
39.65	53.91	
38.82	53.14	L_1 + L_2
38.95	53.27	
39.65	54.29	
40.55	55.70	C. S. T lower
43.35	59.76	
49.75	68.83	
55.95	75.76	
82.1	103.2	retrograd condens.
91.4	106	

Ethane (C_2H_6) + Butyl alcohol ($C_4H_{10}O$)

Kuenen and Robson, 1899

t	P	Rem.
14.95	32.86	L + V
22.9	38.88	
31.95	46.66	
33.35	48.04	
41.23	56.55	
50.15	68.49	

with less alcohol

t	P	
15.3	33.48	L + V
22.95	39.36	
31.95	47.07	
38.1 crit.t.	-	L + L_1 + L_2
38.55	53.67	
38.75	53.97	
39.8	55.04	
38.75	54.22	sat.t. L_1 + L_2
39.75	55.81	
39.95	56.19	
50.0	70.04	
60.0	81.78	

Ethane (C_2H_6) + Amyl alcohol ($C_5H_{12}O$)

Kuenen and Robson 1899

t	P	Rem.
14.95	31.78	L + V normal condens.
31.95	46.12	
52.55	68.85	

with less alcohol

t	P	Rem.
14.95	33.34	L_1 + L_2 + V normal condens.
31.95	47.16	
41.95	57.99	
59.5	80.13	
69.9	93.12	
78.15	101.0	

with still less alcohol

t	P	Rem.
14.95	33.59	L + V normal condens.
31.95	47.37	
43.15	59.91	C.S.T. lower
44.95	62.40	
45.75	63.46	
50.35	69.56	
55.77	75.27	
100.0	115.6	retrograd condens.
107.6	118.2	

Propane (C_3H_8) + Methyl alcohol (CH_4O)

Kuenen, 1897

C.S.T.	P	C.S.T.	P
21.15	10	18.6	55
20.85	11	18.05	70
20.8	13	17.85	79
20.05	23	17.8	82
19.85	26	17.65	85
19.4	34.5	17.5	93
19.2	39	17.4	95
19.0	46	17.2	100

Propane (C_3H_8) + Methyl ricinoleate ($C_{19}H_{36}O_3$)

Hixson and Bockelmann, 1942

10.5 vol % sat.t. = 91.3°

Butane (C_4H_{10}) + Methyl alcohol (CH_4O)

Timmermans, 1907

C.S.T.= 16.6° dt/dp (20-150Kg/cm²) = +0,007

Kuenen, 1911

C.S.T. = 17.0°

Butane (C_4H_{10}) + Ethyl alcohol (C_2H_6O)

Kuenen, 1911

C.S.T. = 37.5°

Butane (C_4H_{10}) + Methane-thiol (CH_4S)

Lecat, 1949

%	b.t.	
0	0.6	
25	-0.5	Az
100	6.3	

Isobutane (C_4H_{10}) + Methyl alcohol (CH_4O)

Timmermans and Kohnstamm, 1909 - 1910

C.S.T. = 20.1° dt/dp (10-140kg/cm²) = +0.008

Isobutane (C_4H_{10}) + Methane-thiol (CH_4S)

Brooks and Nixon, 1953

Az : 17.5 mol% -13.0°

Pentane (C_5H_{12}) + Methyl alcohol (CH_4O)

Lecat, 1949

%	b.t.		Dt mix
0	36.15		
7	30.8	Az	-1.3
100	64.65		

Zieborak, Maczynska and Maczynski, 1956

C.S.T. = 14°

Kuenen, 1897 and 1911

C.S.T.	P
19.4	0
19.75	15.5
20	27
20.25	40
21.8	91
22.0	100

Mondain-Monval and Quiquerez, 1944

C.S.T. = 14.5°

Pentane (C_5H_{12}) + Ethyl alcohol (C_2H_6O)

Ishii, 1935

mol%	P -10°	P 0.0°	P 10°	P 20°
100	6.10	12.30	23.90	44.55
95	50.7	79.5	116.8	190.5
90	81.8	134.1	188.1	309.5
85	101.3	168.1	242.1	385.0
80	114.4	188.0	281.5	433.6
75	123.4	199.3	304.7	459.7
70	129.0	207.3	316.8	476.3
65	132.7	213.1	322.9	488.8
60	135.3	217.2	328.0	498.4
55	137.1	220.0	331.7	505.3
50	138.1	222.1	334.8	510.5
45	138.4	223.8	337.5	514.6
40	138.4	225.4	340.0	517.8
35	138.5	226.5	341.9	520.5
30	139.0	227.3	343.3	522.8
25	"	227.5	344.2	524.3
20	"	227.6	345.0	524.5
15	"	227.5	344.5	524.4
10	138.9	227.3	344.3	522.3
5	138.7	226.8	343.6	516.0
0	138.3	222.0	340.4	505.6

mol%	P_1 -10°	P_1 0.0°	P_1 10°	P_1 20°
100	44.8	67.5	94.0	148.0
95	76.0	123.5	166.5	269.0
90	95.6	157.0	221.3	345.8
85	108.8	177.3	261.5	395.4
80	117.9	188.4	284.7	422.7
75	123.6	196.8	296.8	439.5
70	127.4	202.6	304.0	452.3
65	130.0	206.7	309.0	462.2
60	131.8	209.7	313.5	469.5
55	132.7	211.6	316.8	475.0
50	133.1	213.3	319.5	479.3
45	"	214.9	322.0	482.8
40	133.2	216.0	324.0	485.5
35	133.7	216.8	325.0	487.8
30	133.8	217.0	326.7	489.8
25	134.0	217.2	327.5	490.5
20	134.2	217.3	328.0	491.4
15	134.4	217.5	328.3	493.0
10	135.0	218.2	331.5	405.0
5	138.3	222.0	340.4	500.6

mol%	P_2 -10°	P_2 0.0°	P_2 10°	P_2 20°
100	5.9	12.0	22.8	45.2
95	5.8	11.6	21.6	50.5
90	5.7	11.1	20.8	39.2
85	5.6	10.7	20.0	38.2
80	5.5	10.5	"	37.0
75	5.4	"	19.8	36.8
70	5.3	"	18.9	36.5
65	"	"	18.7	36.2
60	"	"	18.2	35.8
55	5.3	10.5	18.0	35.5
50	"	"	"	35.3
45	"	"	"	35.0
40	"	"	17.9	"
35	"	"	"	"
30	5.2	"	17.5	34.5
25	5.0	10.4	"	34.0
20	4.8	10.2	17.3	33.0
15	4.5	9.8	16.0	29.3
10	4.2	8.6	12.1	21.0

Lecat, 1949

%	b.t.	Dt mix
0	36.15	
4	34.2 Az	
5	-	-1.0
100	78.3	

Poppe, 1934

Two liquid phases lower than 0°

Pentane (C_5H_{12}) + Propyl alcohol (C_3H_8O)

Beck, 1928

vol%	f.t.
100	-127
71.5	-150 -165
62.5	-180
50	-170
0	-131

Pentane (C_5H_{12}) + Isopropyl alcohol (C_3H_8O)

Lecat, 1949

%	b.t.	Dt mix
0	36.15	
6	35.35 Az	
10	-	-2.0
100	82.4	

Pentane (C_5H_{12}) + Tert. Butyl alcohol ($C_4H_{10}O$)

Lecat, 1949

%	b.t.
0	36.15
3	35.9
100	82.45

Pentane (C_5H_{12}) + Ethane-thiol (C_2H_6S)

Lecat, 1949

%	b.t.	Dt mix
0	36.15	
20	-	-0.8
57	32.6 Az	
100	35.8	

Denyer, Fidler and Lowry, 1949

Az : 55 mol% (51 wt%) 30.46° d^{20} = 0.714
n_D^{20} = 1.3864

Isopentane (C_5H_{12}) + Methyl alcohol (CH_4O)

Lecat, 1949

%	b.t.	Dt mix
0	27.95	-
4	24.55 Az	-
15	-	-2.0
100	64.65	-

Kuenen, 1911

C.S.T. = 10.5°

Isopentane (C_5H_{12}) + Ethyl alcohol (C_2H_6O)

Lecat, 1949

%	b.t.	Dt mix
0	27.95	
3.5	26.75 Az	
5	-	-1.0
100	78.3	

Kuenen, 1911

C.S.T. = -30°

Isopentane (C_5H_{12}) + Isopropyl alcohol (C_3H_8O)

Lecat, 1949

%	b.t.	Dt mix
0	27.95	
5	27.7 Az	
50	-	-2.8
100	82.4	

Isopentane (C_5H_{12}) + sec.Butyl alcohol ($C_4H_{10}O$)

Roland, 1928

mol%	P_1
0.32°	
100	260.6
76.61	248.8
54.30	228.5
39.02	209.0
24.84	174.1
6.77	80.4

Veltmans, 1926

%	d	$(\alpha)_D$
	20°	
0	0.6198	0
20	0.6504	3.74
39.9	0.6841	6.78
60	0.7210	9.13
80	0.7618	11.35
100	0.8069	13.87

Isopentane (C_5H_{12}) + Ethanethiol (C_2H_6S)

Lecat, 1949

%	b.t.
0	27.95
15	27.1 Az
100	35.8

10% 18° Dt =-0.5

Denyer, Fidler and Lowry, 1949

Az : 32 mol% (29 wt%) 25.72°

n_D^{20} = 1.3703

Hexane (C_6H_{14}) + Methyl alcohol (CH_4O)

Ferguson, 1932

mol% L	mol% V	P	P_1	P_2
		45.0°		
100	100	327.9		327.9
92.82	51.9	611.0	293.9	317.1
92.26	52.55	601.7	285.6	316.1
91.85	52.61	606.9	287.6	319.3
90.98	50.14	617.2	307.7	311.5
89.57	50.70	618.1	304.7	313.6
87.49	50.70	624.1	307.7	316.4
77.60	49.93	628.3	314.7	313.6
76.87	49.19	630.3	320.2	310.1
51.33	49.88	630.2	315.8	314.4
24.18	49.33	626.4	317.5	308.9
11.37	48.44	619.3	319.3	300.0
4.5	41.72	549.8	320.4	229.4
0	0	333.0	333.0	-

Schukarew, 1910

%	p
43.8°	
100	290.8
83.7	509
78.6	529
68.95	539
54.79	554
33.70	556
32.16	557
25.50	547
17.30	550
0	309.5

Lecat, 1949

%	b.t.		Dt mix
0	68.8		
28	50.5	Az	
50	-		-3.5
100	64.65		

Kuenen, 1897

t	P	t	P
C.S.T.			
37.0	0	41.4	143
37.9	33	42.4	175
38.6	55	42.6	182
39.4	81	43.8	228
40.25	105	44.8	264
41.3	141		
C.V.T.			
0%		minimum	
234.8	29.6	210.2	56.0
100%			
241.2	80.0		

Rothmund, 1898

%	sat.t	%	sat.t.
75.96	4.45	30.41	42.52
73.60	9.95	22.89	42.85
67.75	21.67	13.76	40.05
65.60	24.52	9.65	36.60
59.39	32.40	4.56	23.95
49.60	39.17	3.35	15.22
41.33	41.10	3.32	9.00
36.44	41.82		

Bingham, 1907

C.S.T. = 42.8°

Howard and Patterson, 1926

C.S.T. : 20% = 42.0°

Freed, 1933

C.S.T. = 34.6

Krishnan, 1935

C.S.T. : 30 % 29°

Sieg, 1951

t	mol % L₁	mol % L₂
10	85	-
15	82	-
20	80	-
22	79	20
25	78	22
30	74	27
32	66	36
34	50	

Quantie, 1954

C.S.T. = 32.6 %   28.1°

Zieborak, Maczynska and Maczynski, 1956

C.S.T. = 34.8°

Kogan, Deizenrot and al., 1956

% L₁	% L₂	sat.t.
4.14	74.92	2
4.92	72.11	10

Timmermans and Kohnstamm, 1909 - 1910

C.S.T. = 42.2°   dt/dp (1-105 kg/cm²) = +0.032

Leibnitz, Könnecke and Niese, 1957

t	d L₁	d L₂	σ interface (L_1/L_2)
20	0.7924	0.6679	0.283

Smirnov and Predvoditelev, 1954   (fig.)

mol%	d 25.0°	30.02°	36.10°	38.98°	45.84°
0	0.657	0.652	0.646	0.643	0.636
10	0.659	0.655	0.649	0.646	0.640
15	0.660	0.656	0.650	0.647	0.641
20	-	0.659	0.653	0.650	0.642
25	-	-	0.656	0.652	0.645
40	-	-	0.665	0.662	0.654
50	-	-	-	0.670	0.663
65	-	-	0.690	0.685	0.680
80	0.725	0.720	0.715	0.714	0.707
90	0.750	0.747	0.744	0.740	0.735
100	0.787	0.785	0.776	0.774	0.767

Wolf, 1943

mol%	σ 20°
0	22.31
10	19.46
25	18.60
50	18.58
75	18.56
90	18.54
100	18.52

Smirnov and Predvoditelev, 1954   (fig.)

mol%	velocity of sound (m/sec.) 20°	25°	30°	33°
100	1140	1120	1105	1095
95	1120	1100	1085	1075
88	1105	1085	1065	1055
83	1095	1080	1060	1050
80	-	1078	1058	1045
75	-	-	1055	1040
25	-	-	-	1040
10	1105	1083	1060	1045
0	1120	1095	1074	1060

mol%	velocity of sound (m/sec.) 35°	36.6	40°	43°
100	1090	1085	1070	1060
95	1070	1060	1050	1040
88	1045	1040	1030	1020
83	1040	1035	1025	1015
75	1035	1030	1015	1005
65	1030	1025	1010	995
50	-	1020	1008	994
35	1030	1022	1008	995
25	1033	1025	1010	996
10	1038	1032	1016	1004
0	1050	1042	1026	1013

Krishnan, 1935

Depolarization at 29-50°

Bennett and Vines, 1955 (fig)

mol %	$K.10^6$ 78.0°	98.4°	121.4°
0	42.4	47.6	53.8
25	45.8	50.8	57.2
50	48.0	53.0	59.2
75	48.4	53.8	59.8
100	46.8	51.9	57.6

K = thermal conductivity (cal $cm^{-1}sec^{-1}deg^{-1}$)

Gerts and Filippov, 1956 (fig.)

Heat conductivity, expressed as function of the potential difference ε on the Weatstone bridge .

t	1/e L_1		L_2	L
		33.7%		39%
34.85	5.65		5.20	-
35.00	5.61		5.22	-
35.25	5.53		5.28	-
35.45		5.38		5.46
35.50		"		"
35.70		"		"

Wolf, Pahlke and Wehage, 1935

Q mix/mole alcohol 20° = -5900

Hexane (C_6H_{14}) + Ethyl alcohol (C_2H_6O)

Lecat, 1949

%	b.t.	Dt mix
0	68.8	
21	58.68 Az	
35	-	-2.55
100	78.38	

Kuenen, 1897

C.S.T. = -65°

Smyth and Stoops, 1925

t	d 1.53	5.79	9.62	20.76
	mol%			
-90	0.7820	0.7842	0.7844	0.7945
-80	0.7742	0.7755	0.7763	0.7857
-70	0.7660	0.7670	0.7682	0.7771
-60	0.7574	0.7582	0.7593	0.7703
-50	0.7483	0.7495	0.7525	0.7611
-40	0.7397	0.7408	0.7430	0.7518
-30	0.7310	0.7321	0.7344	0.7423
-20	0.7220	0.7235	0.7256	0.7330
-10	0.7130	0.7148	0.7169	0.7240
0	0.7040	0.7066	0.7076	0.7143
+10	0.6956	0.6955	0.6983	0.7051
20	0.6859	0.6874	0.6890	0.6960
30	0.6766	0.6782	0.6797	0.6864
40	0.6671	0.6690	0.6760	0.6770
50	0.6577	0.6589	0.6601	0.6670
60	0.6476	0.6480	0.6501	0.6571

Harms, 1938

mol%	d 6°	30°
0	0.68707	0.66527
0.497	0.68723	0.66538
1.179	0.68747	0.66556
2.019	0.68779	0.66579
4.864	0.68906	0.66704
7.955	0.69054	0.66839
13.914	0.69365	0.67142
20.389	0.69745	0.67516
24.511	0.70006	0.67778
50.064	0.72049	0.69840
80.753	0.75981	0.73855
16.618	0.79250	0.77182
100	0.80133	0.78078

Smyth and Stoops, 1925

t	ε 1.53	5.79	9.62	20.76
	mol%			
-90	2.093	2.160	2.255	3.418
-80	2.077	2.144	2.248	3.360
-70	2.060	2.129	2.232	3.295
-60	2.045	2.114	2.214	3.225
-50	2.030	2.098	2.197	3.156
-40	2.016	2.083	2.179	3.075
-30	2.002	2.068	2.162	2.996
-20	1.989	2.034	2.145	2.913
-10	1.976	2.040	2.128	2.830
0	1.964	2.026	2.111	2.755
+10	1.952	2.014	2.056	2.687
20	1.940	2.002	2.082	2.622
30	1.928	1.990	2.069	2.563
40	1.914	1.978	2.054	2.507
50	1.898	1.968	2.039	2.453
60	1.882	1.958	2.025	2.403

Trieschmann, 1935

mol%	σ
	22°
0	18.49
25.76	18.52
49.18	18.64
68.45	19.05
78.14	19.58
89.23	20.73
100.00	21.96

Wolf, 1948

mol%	σ
	20°
0	22.08
10	20.67
25	19.46
50	18.71
75	18.60
90	18.54
100	18.52

Wolf, Pahlke and Wehage, 1935 (fig.)

mol%	Q mix by mol alcohol
	at room temperature
0.1	-5700
1	3900
5	1500
10	990
20	600
25	500
50	260
75	120

Hexane (C_6H_{14}) + Propyl alcohol (C_3H_8O)

Lecat, 1949

%	b.t.	Dt mix
0	68.8	
4	65.65 Az	
41	-	-2.4
100	97.2	

Wolf, Pahlke and Wehage, 1935 (fig.)

mol%	Q mix (by mol alcohol)
	room temperature
0.1	-5600
1	3800
5	1500
10	1000
20	600
25	500
50	240
75	100

Hexane (C_6H_{14}) + Isopropyl alcohol (C_3H_8O)

Lecat, 1949

%	b.t.	Dt mix
0	68.8	-
23	62.3 Az	-
26	-	-2.7
100	82.4	-

Poltz, 1936

mol %	d
	22°
0	0.6709
17.920	0.6814
33.283	0.6934
47.034	0.7068
59.009	0.7200
69.742	0.7978
79.276	0.7476
87.858	0.7815
100	0.7840

mol%	n 5893 Å	5000 Å	4500 Å	4000 Å
0	1.3796	1.3834	1.3866	1.3914
17.920	1.3778	1.3817	1.3850	1.3898
33.283	1.3771	1.3808	1.3841	1.3889
47.034	1.3767	1.3804	1.3837	1.3886
59.009	1.3766	1.3803	1.3835	1.3884
69.742	1.3765	1.3802	1.3835	1.3884
79.276	1.3765	1.3802	1.3835	1.3884
87.858	1.3767	1.3804	1.3836	1.3884
100	1.3769	1.3806	1.3838	1.3886

mol%	(α) magn. 5893 Å	5000 Å	4500 Å	4000 Å
0	1.553	2.216	2.794	3.840
17.920	1.443	2.059	2.595	3.387
33.283	1.351	1.927	2.424	3.167
47.034	1.268	1.807	2.277	2.971
59.009	1.196	1.707	2.145	2.796
69.742	1.129	1.610	2.029	2.641
79.276	1.071	1.520	1.919	2.505
87.858	1.020	1.445	1.822	2.382
100	0.940	1.342	1.695	2.216

mol%	(α) magn. 3500 Å	3000 Å	2800 Å
0	4.963	7.236	8.647
17.920	4.622	6.742	8.065
33.283	4.316	6.312	7.587
47.034	4.063	5.937	7.114
59.009	3.816	5.605	6.740
69.742	3.609	5.303	6.374
79.276	3.431	5.045	6.060
87.858	3.262	4.800	5.774
100	3.031	4.458	5.359

Girard and Abadie, 1939 (fig.)

w.l. (cm)	dispersion	absorption
	60%	20°
7	0.08	0.14
10	0.10	0.18
30	0.30	0.37
50	0.45	0.47
100	0.75	0.47
200	0.90	0.28
500	0.95	0.18

dispersion= $(\varepsilon'-\varepsilon_0)/(\varepsilon_1-\varepsilon_0)$

absorption= $\varepsilon''/(\varepsilon_1-\varepsilon_0)$

Wolf, Pahlke and Wehage, 1935 (fig.)

mol%	Q mix (mole alcohol)
	room temperature
0.1	-5900
1	3800
6	1500
10	1000
20	760
25	670
50	350
75	150

Hexane (C_6H_{14}) + Butyl alcohol ($C_4H_{10}O$)

Trieschmann, 1935

mol%	σ
	22°
100.00	24.3
59.23	20.2
35.11	19.22
23.58	18.85
18.48	18.72
10.96	18.55
6.27	18.53
0	18.49

Wolf, 1943

mol%	σ
	20°
100	24.20
90	23.00
75	21.48
50	19.73
25	18.93
10	18.62
0	18.52

Wolf, Pahlkeand Wehage, 1935

mol%	Q mix (mole alcohol)
	at room temperature
0.1	-5500
1	3900
5	1500
10	1000
20	580
25	480
50	200
75	100

Lecat, 1949

Hexane (C_6H_{14}) (b.t.=68.8) + Alcohols.

2nd comp. Name	Formula	b.t.	Az %	b.t.	Dt mix.
Isobutyl alcohol	($C_4H_{10}O$)	108.0	2.5	68.1	-2.35 (46%)
Sec.Butyl alcohol	($C_4H_{10}O$)	99.5	8.5	67.1	-0.7 (8%)
Tert. Butyl alcohol	($C_4H_{10}O$)	82.45	23	64.2	-