THE PARACHORS OF ORGANIC COMPOUNDS

AN INTERPRETATION AND CATALOGUE

OSBORNE R. QUAYLE

Department of Chemistry, Emory University, Emory University, Georgia

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CONTENTS

I. INTRODUCTION

One of the great long-range aims of the chemist has been to correlate the structure of molecules with their chemical and physical properties. If our knowledge were complete, the knowledge of the structure of a molecule should give complete and accurate knowledge of its properties; conversely, an informed knowledge of its properties should indicate its structure. Many lifetimes of conscientious labor have been devoted to the correlation of the physical properties and structure of organic compounds. Numerous promising relationships have been established, but none gives a complete answer. It is not surprising that no single physical property seems to be readily correlated with all types of differences in structure. One of the most promising physical constants in this respect is the parachor. The parachor is a secondary derived function dependent upon the primary properties of surface tension, density, and molecular weight.

Since it is inconceivable that such changes as the position of attached groups would not change the shape and size of a molecule, molecular volume was one of the first properties seriously studied in the effort to correlate physical properties and structure. Molecular volumes based upon densities measured near the boiling point were extensively investigated by Kopp (31), Traube (63), and Le Bas (34). Definite quantitative relationships were observed, and atomic values were derived to be used in an additive manner. These values have been useful, but exact mathematical relationships have constantly eluded workers in this field. Perhaps the greatest single obstacle encountered has been the difficulty, if not impossibility, of comparing molecules in the same or corresponding states.

One effort to overcome this difficulty led to the determination of the so-called "*nullpunkt's* volume." This was obtained by the extrapolation of temperature–density curves to absolute zero. A reasonably successful analysis of this function was made by Biltz, Fischer, and Wünnenberg (2). Another promising approach is based upon Guldberg's rule (21). Since the boiling point of a substance is approximately two-thirds of its critical pressure, molecular volumes have been compared at temperatures which are some constant fraction of the boiling point. In general, however, it may be said that the several promising theoretical modifications of the simple molecular volume concept have been, in the final analysis, somewhat disappointing.

Perhaps the most successful attempt to devise comparable conditions for the measurement of molecular volume or a directly related function had a purely empirical origin. Macleod (38) in 1923 discovered the simple relationship between surface tension and density, $\gamma = C(D - d)^4$, where D and d are the densities of a liquid and its vapor, respectively, γ is the surface tension at the same temperature, and C is a constant characteristic of the liquid. It has since been shown that this relationship may be theoretically deduced (15). Sugden (56) in 1924 revised the Macleod equation to express the equivalence of the constant in molar proportions and called the new constant the parachor. The revised equation has the form:

$$P = \gamma^{1/4} \frac{M}{(D - d)}$$

where M is the molecular weight. When the vapor density is negligibly small in comparison with that of the liquid, the relationship reduces to

$$P' = V_m \gamma^{1/4}$$

where V_m is the molecular volume. If the surface tension is unity, the expression further reduces to

$$P'' = V_m$$

Thus the parachor may be regarded as the molecular volume of a liquid of a surface tension equal to unity. A comparison of the parachors of liquids is thus equivalent to a comparison of molecular volumes under such conditions that the liquids have the same surface tension. Sugden (57) himself states the advantage of the parachor as follows:

> "The chief significance to be attached to a comparison of molecular volumes at constant surface tensions instead of at constant temperature, or at a constant reduced temperature (e.g. the boiling point) is that this method does make some allowance for the effect upon molecular volumes of the forces due to molecular attractions. The large internal pressure due to these forces cannot, unfortunately, be measured directly, but the theories of the liquid state all lead to the conclusion that surface tension and internal pressure are closely related to one another. The general equations of Laplace show indeed that the ratio of the surface tension to the cohesion is a quantity of the order of magnitude of the range of the molecular forces and in Young's theory is taken as equal to this range. . . . Further evidence is obtained for the view that the parachor is a true measure of the molecular volume when this constant is compared with the critical volume and with the mean collision area."

To the extent that comparisons of parachors actually are more nearly comparisons made under corresponding states than in the use of other functions, the parachor may be expected to be superior to the other functions.

The impractibility of the measurement of surface tension over the wide temperature range necessary for the adjustment of values to the same surface tension would appear to discredit the usefulness of the parachor. However, for most unassociated liquids the parachor is subject to only a minor temperature difference. When this condition does not obtain the fact is readily recognized, and the comparison of the parachors of liquids of similar structure at an arbitrary temperature in general introduces little error.

II. THE DETERMINATION OF ATOMIC AND STRUCTURAL CONSTANTS

The parachor was first considered to be an additive function and atomic constants were calculated. The most important value for organic compounds is that of the CH_2 unit. Occurring so many times as a unit, it is of greater importance than the value of carbon or hydrogen. By comparing the successive members of various homologous series Sugden arrived at the value of 39.0 for this CH_2 unit. Subtracting n CH_2 from the saturated hydrocarbons C_nH_{2n+2} gave the value for 2H and subtracting this from 39.0 gave the value for C. Assuming these values to be correct and purely additive, the values for other elements may be calculated by a similar process. Sugden early saw that in addition to the additive elemental constants certain constitutive features such as a double bond or ring could be assigned a value. He arrived at the values given in table 1.

Use of these values gave theoretical values for the parachors of many compounds which corresponded closely to the values calculated from observed sur-

TABLE 1

Sugden's atomic and structural parachor values

UNIT	PARACHOR	UNIT	PARACHOR
C	4.8	Br	68.0
H	17.1	I	91.0
N	12.5	Double bond	23.2
P	37.7	Triple bond	46.6
O	20.0	Three-membered ring	16.7
S	48.2	Four-membered ring	11.6
F	25.7	Five-membered ring	8.5
Cl	54.3	Six-membered ring	6.1
		O_2 (in esters)	60.0

face tensions and densities. For example, the parachor of a chlorotoluene would be calculated as follows:

7 carbon atoms, each 4.8	=	33.6
7 hydrogen atoms, each 17.1	=	119.7
1 chlorine atom, 53.8	=	53.8
3 double bonds, each 23.2	=	69.6
Theoretical parachor	=	282.8

The observed value for *o*-chlorotoluene was found to be 280.8; for *p*-chlorotoluene 283.6. It was first considered that position isomerism in aromatic compounds did not vary the parachor value.

Sugden (56) surveyed the then existing data in the chemical literature for surface tensions and densities and calculated the parachors of 167 substances. These values were compared with those obtained by adding the appropriate atomic and structural constants. Agreement within 2 per cent was found for 145 compounds and within 1 per cent for 104 compounds. Since the experimental values were obtained by different observers, in different laboratories, frequently using different methods of measurement, and upon compounds of varying degrees of purity, the correlation was striking. It is significant that Sugden, while stressing the additive nature of the parachor, early assessed structural constants to varying degrees of unsaturation and ring structures. He also recognized a constitutive effect in the difference between oxygen in ester groups and in alcohols, and noted the temperature effects due to association.

It should be pointed out that no value was or is given to a single bond. The value given to hydrogen includes the parachor of the hydrogen atom plus one-half of the parachor of a single bond. Similarly, the value given to carbon includes one-half of the parachor of four single bonds. Thus, the value assigned to the double bond is *not* strictly that of the double bond but the *additional* increment that must be used in calculating unsaturated compounds. It is a plus value obtained by subtracting from the value of two hydrogens the decrease in parachor observed between a saturated and an unsaturated molecule containing one double bond.

Although various modifications have been necessary in Sugden's values, they did produce correlations between observed and calculated values for parachors better than had been obtained by the use of other properties. Sudgen's parachor presented historical evidence for the existence of such structures as the semipolar bond, singlet linkages, and the triple-bonded isocyanide grouping. Various extensions and refinements of the concept have appeared which have changed and extended its usefulness. Being primarily refinements they do not diminish but rather have increased the importance of Sugden's contribution.

TABLE 2

Atomic and structural constants

UNIT	VALUES ASSIGNED BY			
	Sugden	Mumford and Phillips	Vogel	Quayle
CH_2	39.0	40.0	40.0	40.0
C	4.8	9.2	8.6	9.0
H	17.1	15.4	15.7	15.5
O	20.0	20.0	19.8	
O_2 (in esters)	60.0	60.0	54.8	
N	12.5	17.5		
S	48.2	50.0	49.1	
F	25.7	25.5		
Cl	54.3	55.0	55.2	
Br	68.0	69.0	68.8	
I	91.0	90.0	90.3	
Singlet bond	−11.6	−9.5		
Double bond	23.2	19.0	19.9	
Triple bond	46.6	38.0	40.6	
Three-membered ring	16.7	12.5		
Four-membered ring	11.6	6.0		
Five-membered ring	8.5	3.0		
Six-membered ring	6.1	0.8		
Seven-membered ring		4.0		

Mumford and Phillips (40) detected certain shortcomings in Sugden's attractively simple treatment of the parachor as an additive function. They examined the apparent anomalies in the parachors of a series of fatty acids reported by Hunten and Maass (24) and concluded that the discrepancies were due to an incorrect value for the methylene increment. They objected to Sugden's failure to distinguish between isomers and particularly to disregarding chain branching. By basing their calculations on data from homologous series of the same type of structure—all normal, all secondary, or all tertiary—they arrived at a mean CH_2 value of 40.0. They proposed a "strain constant" for secondary branching of −3 units, and for tertiary branchings one of −6 units. This was an important contribution in establishing what has proven to be a better value for the methylene increment and, also, in further suggesting the truly constitutive nature of the parachor.

Mumford and Phillips' (40) reëvaluations of the atomic parachors are shown in table 2. These are probably the most widely used values at the present time. Later refinements, particularly those of Vogel, are also included in table 2.

Since the value for CH_2 is taken as the basis upon which all other values are calculated, its correctness is of primary importance. As the essential constitutive nature of the parachor has gradually been recognized, it has also become apparent that the value for CH_2 in saturated hydrocarbons is almost unique in its constancy. The value for CH_2 has consequently been repeatedly measured and independently checked.

TABLE 3

Comparison of independent determinations of parachors of n-alkanes

A. Surface tensions at 20°C.

ALKANE	γ	
	Wibaut	Quayle
Pentane	15.98	15.97
Hexane	18.41	18.39
Heptane	20.26	20.31
Octane	21.71	21.80
Nonane	22.91	22.92
Decane	—	—
Undecane	21.29	21.31
Dodecane	18.10	18.12

B. Parachors at 20°C.

ALKANE	P		
	Wibaut	Quayle	Vogel
Pentane	230.7	231.0	231.8
Hexane	270.7	270.8	270.9
Heptane	310.8	311.3	312.0
Octane	350.6	351.1	350.5
Nonane	390.5	391.1	390.7
Decane	—	431.2	429.5
Undecane	—	470.6	470.6
Dodecane	—	510.1	510.0

Vogel (65) recalculated the CH_2 increment from homologous series of *n*-alkyl chlorides, bromides, iodides, and esters and arrived at a CH_2 value of 40.3 with hydrogen as 14.4 and carbon as 11.5. Later Vogel (66) revised his values upon the basis of further purified alkyl halides; the average value for the CH_2 increment, calculated by the method of least squares, was 40.02.

As compounds of exceedingly high purity became available[1] and as techniques

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[1] Five pure hydrocarbons of the American Petroleum Institute–National Bureau of Standards series were used, together with three repurified samples from the Eastman Kodak Company.

of measurement improved, Quayle, Day, and Brown (45) considered it essential to reëxamine further the accepted value for the methylene unit. They measured a series of normal hydrocarbons from pentane through dodecane. They arrived at an average value for the CH_2 increment of 40.0 and also concluded that there was no apparent change in this value as the chain length increased within the limits of the series investigated. Added validity is attached to the determination, as the average values were obtained from individual values with very small deviations. Their constants for carbon and hydrogen, 9.0 and 15.5, respectively, are slightly different from these obtained by Vogel or Mumford and Phillips.

The methylene value has thus been independently determined by several workers and upon several different series of compounds. This fundamental unit, used in calculating the constants for other groups, may be considered to have been established at 40.0, since three modern groups arrived at identical values.

Wibaut (70) and his coworkers also synthesized a series of highly purified alkanes and cycloalkanes. Table 3 shows the remarkable agreement between their values, those of Vogel (67), and those of Quayle, Day, and Brown. The agreement is the more striking in that Vogel used a different method of measuring surface tension (capillary rise) from that used by Wibaut and Quayle (maximum bubble pressure).

III. CONSTITUTIVE CONSTANTS

In the earlier work upon the parachor, agreement of theoretical values with those based upon observation to within 1.0–1.5 per cent was considered quite satisfactory. As methods of obtaining compounds of the highest purity have advanced, and as the techniques of the measurement of surface tension have improved, greater precision and accuracy have become possible. A precision which permits determinations within 0.1 per cent is now readily possible. The limits of accuracy earlier prevailing account for the early assumption that position isomerism caused no change in the parachor and for the failure to observe other very real constitutive changes. With greater accuracy it has been gradually found that the parachor, while grossly additive, is sensitive to almost any change in structure and is particularly sensitive to any change in degree of unsaturation.

At first thought the lack of strict additivity would appear to decrease the value of the parachor. However, once the minor changes have been evaluated, the correlation between observed and calculated values becomes much better and the usefulness of the function increases. The changes in parachor produced by changes such as the position of a double bond or the variation in the effect of branching the chain as its position is shifted are of a lower order of magnitude than the atomic constants. These smaller corrections in turn are average values and not absolutely constant. The differences here, however, are of a still lower order of magnitude and in the present state of development are seldom of sufficient size to obscure the conclusions obtained. It is important that their existence be recognized, however, since it is probable that *any* change in structure causes some change in the parachor.

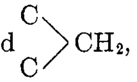
A. The CH_2 *unit*

The CH_2 unit in saturated chains has been considered by most modern observers as unique in its constancy and has been used as such in evaluating other variations. This has proven to be a valid practical assumption leading to the establishment of other useful constants for other groups and structures even if not entirely sound upon a theoretical basis. Gibling (19) has found that even this CH_2 value in the hydrocarbon chain is not absolutely constant. The deviations in its value are, however, small and do not appear to become significant until the chain contains from 16 to 20 carbons. The use of the parachor function is made considerably more complicated with little added accuracy in the great majority of compounds if corrections for the CH_2 value are used.

Gibling (19) objects to the use of atomic and structural constants based upon any average values.[2] He states that "the volume contribution of any atom, such as C, is not constant but varies according to the nature of the other atoms with which it is linked" and that "no allowance has been made for the 'interference' between the non-linked atoms." In each case the effective contribution of the carbon in CH_2 is decreased in comparison with that of carbon in CH_3, and this decrease will vary as the interference changes with different length chains attached.

Gibling's work comprises the most comprehensive theoretical treatment of the parachor in recent years (20) and has been successfully applied to numerous classes of organic compounds. It warrants consideration in some detail. It is based upon a fundamental change in the concept of the parachor and in the logical outgrowth and extension of the ideas of several of the other workers who have pointed out constitutive variations. Although his concept historically followed much other work upon the constitutive nature of the parachor, it will be considered at this point because of the primary importance of an accepted value or values for the CH_2 unit in assessing the values for other elements and groups.

Gibling's interpretation involves a more complicated scheme than the simpler concept and does not outmode the latter (in the opinion of the author) in practical use except for molecules having extremely long carbon chains (twenty or more carbons).

Gibling objects chiefly to Sugden's tacit assumption that the contribution of any atom to the molecule is the same no matter to what other atoms it may be united by single bonds, and to his disregard of interference which may occur when atoms not directly united are brought into rather close conjunction by the natural angles of a carbon chain. He also pointed out the failure of Mumford and Phillips to differentiate between $—CH_3$ and  $\genfrac{}{}{0pt}{}{C}{C}\!\!>\!CH_2$, even though they had recognized

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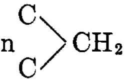
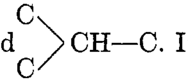
[2] The author would agree with this objection in theory and has studied variations in the parachor upon the basis of this assumption. However, many of the variations caused by slight changes in structure are below the least obtainable experimental error. Consequently, many additive and structural constants based upon average values are of distinct practical value.

the volume reduction between  $\genfrac{}{}{0pt}{}{C}{C}\!>\!CH_2$ and  $\genfrac{}{}{0pt}{}{C}{C}\!>\!CH\text{—}C$. It is asserted that the CH$_2$ value appears to show progressively higher values throughout any homologous series, owing to interference effects.

In 1945 Gibling (19) reviewed his proposed method of calculation on the basis of data for the normal alkanes reported by Quayle, Day, and Brown (45). Parachor reductions observed in homologous series are by this new concept due to overlapping of spheres of influence of non-linked atoms. Gibling makes corrections for these overlappings and terms the newly calculated values "reduced parachors." These "R. P." values for a series of successive branchings have a constant increment of 2.2 in the reduction caused by the branching.

Gibling proposes for the calculation of the parachors of normal paraffins the equation:

$$P = [2C + (n - 2)k]f^n$$

where $C = 55.2$ (CH$_3$ contribution), $k = 39.8$ (CH$_2$ contribution), $f = 1.0004165$, and n is the number of carbon atoms. The value of $2C + (n - 2)k$ is taken as the reduced parachor, R. P. (preferred to the earlier name, "standard value" or S. V.). R. P. values are allotted to the different groups formed in the molecules of paraffins and olefins and certain interference reductions are assessed. The CH$_2$ differences starting at 39.9 for $n = 2$ or 3 would become 40.2 for $n = 10$ or 11; for $n = 2$ to 12 the mean CH$_2$ would be somewhat more than 40.0; for $n = 59$ or 60 it would be 41.8, with the mean just under 40.9 between $n = 2$ and 60.

Gibling asserts that the magnitude of the CH$_2$ increment depends upon the magnitude of the parachors but is independent of the type of compound; expansion occurs at exactly the same rate for various homologous series.

Gibling further finds that a second correction value in addition to the "interference correction" is necessary. He terms this an "expansion correction" or E. C. The following equations define the reduced parachor, the calculated parachor, P, and the expansion correction, E. C.:

$$\begin{aligned} \text{R. P.} &= 2C + (n - 2)k \\ P &= [2C + (n - 2)k]f^n \\ P - \text{R. P.} &= \text{E. C.} \end{aligned}$$

The reduced parachors were derived from values in *A List of Parachors* compiled by the British Association for the Advancement of Science[3] with revision whenever warranted by more recent values. These R. P. values have been found to be truly additive and constitutive functions. However, Gibling's apportionment of a parachor value to a group which involves the linkage of heterogeneous atoms cannot be effected by using available data. For instance, to obtain a value for (C)—O—(C) as in dimethyl ether it was necessary to arbitrarily allot to

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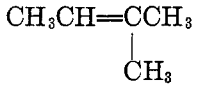
[3] This list appears as an appendix to Sugden's *The Parachor and Valency*, G. Routledge and Sons, Ltd., London (1930).

$CH_3(O)$ the same value as for $CH_3(C)$; the desired value was found by difference. The method of assessing group values is illustrated by the following evaluation of $\mathrm{(C)\!-\!\overset{O}{\overset{/\!/}{C}}\!-\!O\!-\!(C)}$:

[P], $CH_3COOCH_2CH_3$ = 216.6 (mean of recorded values)
−E. C.[4] = −0.4
R. P., $CH_3COOCH_2CH_3$ = 216.2
Deduct $(C)CH_2(O)$ at 39.4 = −39.4
R. P., CH_3COOCH_3 = 176.8
Deduct $2CH_3$ at 55.2 = −110.4
R. P., $\mathrm{(C)\!-\!\overset{O}{\overset{/\!/}{C}}\!-\!O\!-\!(C)}$ = 66.4

The method of calculation is applied to 2-methyl-2-butene in the following illustration:



$$\mathrm{CH_3CH{=}\underset{\displaystyle CH_3}{\underset{|}{C}}CH_3}$$

$3CH_3(C)$ at 55.2 = 165.6
$(C)CH{=}(C)$ at 34.3 = 34.3
$\mathrm{(C){=}C\!\begin{smallmatrix}\diagup (C)\\ \diagdown (C)\end{smallmatrix}}$ at 16.7 = 16.7
216.6
Expansion correction, E. C. = +0.4
217.0
Observed parachor = 216.9

Compounds containing a markedly polar group such as $(C)Cl$, $(C)Br$, $(C)I$, $ROC(C)$, and $C_6H_5(C)$ exhibit regularity in the CH_2 increment only after the first few (generally five) members in a series. Reductions in the parachor by these groups seem to be due to interaction between atoms of these and neighboring groups—a tendency of the chains to bend back to form a partly closed ring as a consequence of polarity. Corrections in the alkyl chains have been assessed by a consideration of the effect of homology, which leads to the conclusion that the configuration of the carbon chain is determined primarily by the polarity of that part of the molecule to which it is attached.

Additional reductions in the parachor occur in alkyl carbonates with propyl

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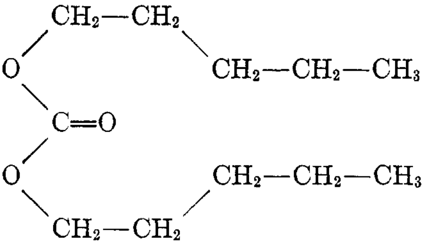
[4] If one lets $\mathrm{-\overset{O}{\overset{/\!/}{C}}-}$ equal CH_2, then the expansion correction for ethyl acetate is the same as that for diethyl ether, −0.4. In evaluating the $(C)—O—(C)$ of ethers O was assumed equal to C; thus E. C. for diethyl ether was derived from pentene, listed in Gibling's table for various hydrocarbons.

or longer chains and in other compounds with the possibility of parallel chains, apparently caused by the close-packing of such chains.



Interference constant = 2.2(n + 2)

Gibling has also successfully applied his concepts to a number of other special cases, particularly to cases involving polar groups. His values show good agreement for branched-chain paraffins except for compounds containing (*1*) two adjacent $>$CH's, to one or both of which is attached an ethyl or higher radical as in 2,3- and 2,4-dimethylheptanes, and (*2*) trisubstituted derivatives of trimethylmethane, as in 3-ethylpentane.

The group values and various corrections of Gibling are given in table 4.

Gibling has applied his concepts and values with remarkable success. It has been possible to calculate the parachors of more than four hundred compounds to within 0.2 per cent. His values and method of calculation are particularly superior to those of other workers in the field when applied to long-chain compounds. This is brought out by table 5.

In the face of the remarkable success of Gibling's use of his concept and the constants derived from its application, many observers (including this author) have continued to use the simpler system of atomic and group constants. There is considerable justification for this in the great majority of cases. Gibling, as has been pointed out, reviewed his method upon the basis of the values for normal alkanes given by Quayle, Day, and Brown (45). The latter claim an accuracy such that their error is less than 0.1 per cent. Within this limit and up to compounds containing twelve carbon atoms the "interference effect" does not apparently reduce the validity of their values. The theoretical values of the normal alkanes from pentane through dodecane, when compared with the values calculated from observed surface tensions and densities, show a maximum deviation of 0.1 per cent and an average deviation of 0.045 per cent.

Telang (61) and Ferguson and Kennedy (14) consider the parachor to be more correctly expressed in the revised form

$$P = M\gamma^{1/n}/(D - d)$$

where experimental determinations of surface tension are applied in the evaluation of n for similar compounds. The use of this form of the equation, in the limited experience of the author, has not resulted in improved correlations which would encourage its use over the classical form of Sugden. Neither would the determination of n for a group of compounds appear to obviate the necessity of the use of constitutive corrections.

TABLE 4

Gibling's parachor values

A. Group values

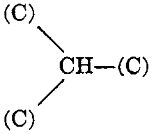
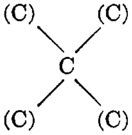
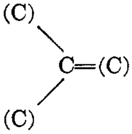
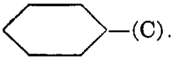
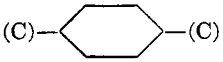
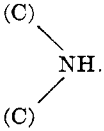
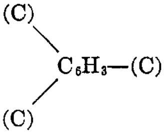
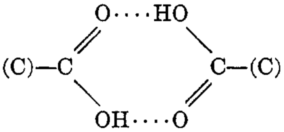
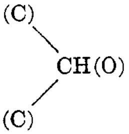
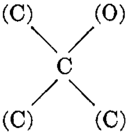
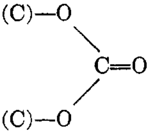
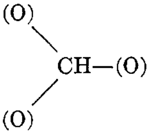
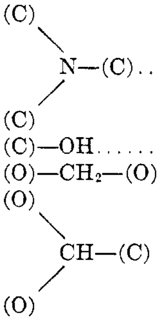
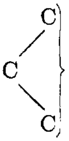
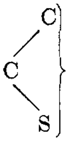
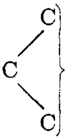
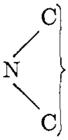
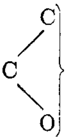
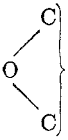
GROUP	R. P.*
CH_3—(C)	55.2
(C)—CH_2—(C)	39.8
 $\mathrm{(C)_2CH{-}(C)}$	22.2
 $\mathrm{C(C)_4}$	2.4
CH_2=(C)	49.7
(C)CH=(C)	34.3
 $\mathrm{(C)_2C{=}(C)}$	16.7
(C)—O—(C)	21.5
(C)—CHO	67.4
(C)—CO—(C)	51.0
(C)—COO—(C)	66.4
O=C[O(C)]$_2$	85.5
C_6H_5—(C)	190.2
C_6H_5—(N)	190.0
C_6H_5—(O)	189.8
	224.9
	208.5
(C)—CH_2—(N)	39.6
(C)—NO_2	76.8
(C)—O—N=O	75.3
(C)—N=N—(C)	51.8
(C)=N=N	53.2
(C)—N=N=N	79.9
(C)—CN	66.6
(C)—NC	66.8
(C)—NH_2	47.9
 $\mathrm{(C)_2NH}$	32.0
(C)—C_6H_4—(C)	174.8
 $\mathrm{(C)_2C_6H_3{-}(C)}$	159.4
	149.4
(C)—C_6H_4—(N)	174.6
(C)—C_6H_4—(O)	174.4
(N)—C_6H_4—(O)	174.2
(C)CH_2(O)	39.4
 $\mathrm{(C)_2CH(O)}$	21.4
 $\mathrm{(C)_3C(O)}$	1.2
HCOO(C)	82.8
 $\mathrm{[(C){-}O]_2C{=}O}$	85.5
 $\mathrm{(O)_2CH{-}(O)}$	17.7
(C)—CH_2Cl	96.1
(C)—CH_2Br	110.3
(C)—CH_2I	131.6
(C)COOCO(C)	114.5 (at 15°C.) to 115.7 (at 50°C.)
(C)—S—(C)	52.0
(C)—S—S—(C)	103.1
(C)—SH	68.2
(C)—CH_2—(S)	39.3

TABLE 4—*Continued*

GROUP	R. P.*	GROUP	R. P.
	13.0	C_6H_5—(S)	189.7
		$[(C)O]_2SO$	109.0
		$[(C)O]_2SO_2$	127.0
		$[(C)O]_3PO$	119.8
(C)—OH	39.2		
(O)—CH_2—(O)	38.3		
	19.9		

B. Interference corrections†

GROUP	CORRECTION	GROUP	CORRECTION
	−2.2		−2.7
	−2.2		−3.1
	−2.6		−3.7
	−2.4		−5.2
$\underbrace{C_6H_5\text{—}N}O_2$	−6.4		

SUBSTITUTION INCREMENTS‡

—CH_3	39.8	—Cl	38.2
—OCH_3	59.4	—Br	52.1
—NO_2	57.2	—I	74.5

Disubstitution corrections on benzene or cycloalkanes

POSITION	CORRECTION	POSITION	CORRECTION	POSITION	CORRECTION
1,2-	−2.7	1,3-	−1.7	1,4-	−2.2

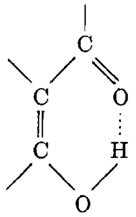
TABLE 4—*Concluded*

Ring corrections for derivatives of cycloparaffins

C_nH_{2n} with n =	3	4	5	6	7
	+5.9	+0.1	−5.4	−10.7	−15.7

Ring correction $= (26.1 - 7.63n + 0.35n^2 - 0.016n^3)$

Parachor reduction due to chelation



−17.9

C. Corrections in alkyl chains

GROUP	CH_2	CH_2	CH_2	CH_2	CH_2	TOTAL
O ‖ —C—		−2.0	−0.8	−1.7	—	−4.5
O_2N—		−1.0	−2.7	−1.0	—	−4.7
NC—		−1.3	−0.8	−2.6	−1.1	−5.8
Br— or I—		—	−0.7	−1.5	−0.6	−2.8
HOOC—		—	−2.0	−0.8	−1.7	−4.5
C_6H_5—		—	−2.4	−0.6	−1.3	−4.3
—S—		—	−1.0	−0.6	−1.0	−2.6
—S—S—		−0.9	−1.3	−0.6	−1.0	−3.8
—S—SO—O—		−0.8	(−2.2 extra for each following pair of carbon atoms)			
—S—SO_2—O—		−1.1	(−2.2 extra for each following pair of carbon atoms)			
—O \\ PO—O— / —O		−1.4	(−6.6 extra for each following trio of carbon atoms)			
C_6H_5—O—	−1.5	−2.0	—	—	—	−3.5
Si		—	−1.9	—	—	
N		—	−1.5	—	—	
—O—		—	—	−0.7	—	

* R. P. values include corrections for interference whenever it occurs within the group as written. Thus the value for (C)—O—(C) includes a negative correction of −5.2; the ideal R. P. would be 26.7.

In this table, the values in the column headed R. P. do not include the atoms enclosed in parentheses.

† These corrections are included in the group values listed in part A of table 4 whenever interference occurs within the group.

‡ The increments are added to the R. P. of benzene (205.6).

Telang has also considered the parachor as resolvable into two components, a constant volume factor for each element or group and a variable surface-energy factor wherein constitutive effects are manifest. Seemingly, the approach of Telang differs from the classical approach primarily in terminology. As the parachor has come to be recognized as subject to constitutive influences, the classical concept has, in fact, been gradually modified to that of Telang. The value is now generally considered to include the "core volume" of the atoms involved and the sphere of influence of the molecule. Changes in the parachor brought about by differences in the position of groups, by changes in saturation, and by other constitutive factors would seem to be equally reflected by either interpretation and to require the same method of evaluation.

TABLE 5

Comparison of parachor values for normal alkanes

	SUGDEN	MUMFORD AND PHILLIPS	VOGEL	DESREUX*	BAYLISS†	QUAYLE	GIBLING	OBSERVED
C	4.8	9.2	11.5	8.3	9.1	9.0		
H	17.1	15.4	14.4	15.8	15.4	15.5		
CH_3	56.1	55.4	54.7	55.7	55.3	55.5	55.2‡	
$—CH_2—$	39.0	40.0	40.3	39.9	39.9	40.0	39.8	
n-$C_{26}H_{54}$	1048	1071	1077	1069	1068	1071	1077	1082
n-$C_{32}H_{66}$	1282	1311	1318	1308	1308	1311	1322	1322
n-$C_{60}H_{122}$	2374	2431	2447	2426	2425	2431	2480	2480
Mean difference, per cent	3.6	1.4	0.7	1.5	1.6	1.4	0.2	

* Bull. soc. chim. Belg. **44,** 249 (1935).

† J. Am. Chem. Soc. **59,** 444 (1937).

‡ Reduced parachor.

TABLE 6

Comparison of theoretical and actual parachors of normal alkanes

	P		Δ	Δ PER CENT
	Theoretical	Observed at 20°C.		
Pentane	231.0	231.0	0.0	0.00
Hexane	271.0	270.8	0.2	0.06
Heptane	311.0	311.3	0.3	0.10
Octane	351.0	351.1	0.1	0.03
Nonane	391.0	391.1	0.1	0.02
Decane	431.0	431.2	0.2	0.05
Undecane	471.0	470.6	0.4	0.08
Dodecane	510.0	510.1	0.1	0.02
Average derviation				0.045 per cent

As has been pointed out, although the parachor was first considered a simple additive function it has been found to be, on the contrary, quite susceptible to any and all changes in structure. The effects of minor changes in structure in general cause small but very real changes in the parachor. These were masked at first by the relatively large experimental error. With increasing accuracy greater information has been obtained upon variations in the value attributable to branching of the chain, to the ethylene linkage, to the carbonyl linkage and to aromatic position isomers, to hydrogen bonding, to conjugated systems, etc.

B. Chain branching

Mumford and Phillips (40) observed the anomalous results obtained by using the parachor as a strictly additive atomic function in branched-chain compounds.

TABLE 7

Parachors of seventeen isomeric octanes

COMPOUND	PURITY IN MOLE PER CENT	AVERAGE PARACHOR	PER BRANCH
n-Octane	99.95 ± 0.04	351.20	
2-Methylheptane	99.66 ± 0.18	348.82	−2.38
3-Methylheptane	99.64 ± 0.23	347.35	−3.85
4-Methylheptane	99.89 ± 0.07	347.24	−3.96
2,2-Dimethylhexane	99.77 ± 0.11	345.90	−2.65
2,3-Dimethylhexane	99.75 ± 0.20	343.44	−3.88
2,4-Dimethylhexane	99.75 ± 0.20	345.31	−2.95
2,5-Dimethylhexane	99.73 ± 0.09	347.01	−2.10
3,3-Dimethylhexane	99.75 ± 0.20	343.02	−4.09
3,4-Dimethylhexane	99.75 ± 0.20	342.70	−4.25
3-Ethylhexane	99.75 ± 0.20	344.98	−6.22
3-Ethyl-2-methylpentane	99.93 ± 0.04	338.12	−6.54
3-Ethyl-3-methylpentane	99.78 ± 0.11	344.23	−3.49
2,2,3-Trimethylpentane	99.68 ± 0.20	340.27	−3.64
2,2,4-Trimethylpentane	99.88 ± 0.05	343.73	−2.49
2,3,3-Trimethylpentane	99.79 ± 0.08	339.03	−4.06
2,3,4-Trimethylpentane	99.83 ± 0.06	340.78	−3.47

They proposed a "strain constant" of −3 units for each branch in a chain. This value has been found to vary with the position and length of the chain. However, since it may be shown to be a negative correction in all cases, the use of the "constant" −3 gave values in closer agreement with observed values than if no "constant" had been used. Particularly is this true since the negative correction is approximately 3 in many of the simpler compounds with short branched chains. It was, moreover, of particular value in that it clearly recognized the constitutive nature of the parachor.

A comparison between the parachors of *n*-octane (351.0) and 2-methylheptane (349.4) gives a "strain constant" for the single branch of −1.6. A comparison between *n*-octane and 3-ethylhexane (345.0) gives a "strain constant" of −6.0. Numerous other equally divergent values could be cited, and the value is obviously not constant.

The seventeen isomeric octanes available to Donaldson and Quayle (11) from the American Petroleum Institute and the National Bureau of Standards through A.P.I. Research Project 44 afforded an excellent opportunity to more closely evaluate chain branching in compounds of the highest purity. Table 7 summarizes the parachor data upon these compounds. The parachor values given are the average of the values obtained at 20°, 30°, and 40°C. The parachors were calculated by using density values supplied by the Bureau of Standards and determinations of the surface tension made by these observers. Each surface tension value used at each temperature was obtained from an average of at least seven determinations. The maximum deviation of any of the 126 surface tension measurements from the value used was 0.018 in the case of *n*-octane at 40°C. (from the accepted value of 19.803). The mole per cent purity given was supplied by the Bureau of Standards (41).

By inspection it will be noted that the correction is obviously not constant; moving the branched chain toward the center of the molecule causes an increase in the correction, as does an increase in the length of the chain. In general, two branches closer together but upon separate carbons, compared with two more separated chains, also cause an increase in the correction.

If the parachor is a function of the effective volume of the molecule, it is not surprising that any change in the molecule which would change this volume or affect its shape would in turn affect the parachor. In the compounds given in table 7 it is apparent that changes which would tend to produce a more compact molecule cause a decrease in the parachor value. It would also seem reasonable that once a particular grouping has been evaluated, it might be used in an additive manner in calculating a value for a more complex molecule. By the same token the joining together of two evaluated units would to some degree affect the values of these units. However, the evaluation of common groupings and the use of such group values would in all cases decrease the number of factors in the molecule for which compensation is not made. In the case of complex units separated some distance by a methylenic chain, which has a constant or nearly constant CH_2 value, the evaluated complex units might be expected to be able to be treated in a truly additive manner.

Donaldson (10) has evaluated certain group values from a study of the parachors of the octanes (table 7). Robinson (50) has determined the parachors of eight heptanes and thirteen nonanes, also made available by the National Bureau of Standards and the American Petroleum Institute through A.P.I. Research Project 44, and has compared the theoretical parachors (using the values calculated by Donaldson) with the observed parachors. By no means were perfect correlations obtained, but the average deviation obtained in the twenty cases was 0.23 per cent or approximately one-third the deviation of 0.63 per cent obtained by using the simpler "strain constant" of −3 originally proposed by Mumford and Phillips.

Structural units, as used by Donaldson and Robinson, were evaluated by subtracting from the molecular parachor of a compound, in which the unit occurs joined to a straight chain of two or more carbon atoms, that amount of the parachor contributed by the portion of the molecule which is not a part of the unit.

For example, the parachor contribution of the 1,1,2-trimethylpropyl group was evaluated as 243.5 parachor units by subtracting from the experimentally determined parachor of 2,3,3-trimethylpentane (339.0) the amount attributable to an ethyl group (95.5), on the basis that each methylene group contributes 40.0 units and the third hydrogen on a methyl group 15.5 units. In a similar manner the value for the 1,1-dimethylpropyl group was derived from 3,3-dimethylhexane and that for the 1,2-dimethylpropyl group from 2,3-dimethylhexane. Table 8 gives the group contributions to molecular parachors as computed by Donaldson. The use of the twelve "constants" derived by Donaldson is not particularly convincing when applied to the same seventeen compounds measured by him from which they were derived, particularly as there are nearly as many constants used as compounds. That they do, however, permit a closer approximation of calculated values to those derived from direct measurement is shown by Robinson in his application of Donaldson's values to heptanes and nonanes. His results are shown in table 9.

TABLE 8

Hydrocarbon group contributions to molecular parachors

SYMBOL AND GROUP	VALUE	SOURCE OF EVALUATION
A: Methylene	40.0	Previously determined
B: Hydrogen	15.5	
C: 1-Methylethyl	133.3	2-Methylheptane
D: 1-Methylpropyl	171.9	3-Methylheptane
E: 1-Methylbutyl	211.7	4-Methylheptane
F: 1-Ethylpropyl	209.5	3-Ethylhexane
G: 1,1-Dimethylethyl	170.4	2,2-Dimethylhexane
H: 1,1-Dimethylpropyl	207.5	3,3-Dimethylhexane
I: 1,2-Dimethylpropyl	207.9	2,3-Dimethylhexane
J: 1,1,2-Trimethylpropyl	243.5	2,3,3-Trimethylpentane
K: Secondary-secondary carbon adjacency	−1.6	2,3-Dimethylhexane
L: Secondary-tertiary carbon adjacency	−2.0	2,2,3-Trimethylpentane
M: Tertiary-tertiary carbon adjacency	−4.5	Estimated
N: Chain length increase from methyl to ethyl*	37.5	3-Ethylpentane
R: 2-Methylpropyl	173.3	1-Methylheptane

* Applied in table 9 by Robinson in the case of 3,3-diethylpentane only.

In brief, the parachor values for saturated aliphatic hydrocarbons and the hydrocarbon portion of more complex structures is usually calculated using the "strain constant" of −3.0 parachor units for each branching of the chain. This value is not a constant, and calculated parachors showing appreciably less deviation from experimental values may be arrived at by using the somewhat more complicated method illustrated above with heptanes, octanes, and nonanes.

C. *Ethylenic linkages*

The ethylenic linkage was first given an average value of 23.2 by Sugden (57)[5] and later a value of 19.0 by Mumford and Phillips (40). These average values were obtained by considering all available values for unsaturated linkages, including some values showing considerable deviation from the average. With the passage of time it has become more and more apparent that the parachor is a highly constitutive function and is particularly sensitive to changes in unsaturation. It might be expected, therefore, that ethylenic linkages of certain types would have a lower parachor than others, just as certain ethylenic linkages show greater activity in chemical additions than other types. Specifically it might be expected that terminal ethylenic linkages would be more unsaturated, in this

TABLE 9

Comparison of observed and calculated parachors of heptanes and nonanes

COMPOUND	EXPERIMENTAL	SUM*	CALCULATED	DEVIATION	CALCULATED ASSUMING THE MUMFORD-PHILLIPS STRAIN CONSTANT (−3)	DEVIATION
				per cent		*per cent*
2-Methylhexane	309.6	C + 4A + B	308.8	0.25	308.0	0.52
3-Methylhexane	307.8	D + 3A + B	307.4	0.13	308.0	0.06
3-Ethylpentane	305.4	F + 2A + B	305.0	0.13	308.0	0.86
2,2-Dimethylpentane	306.6	G + 3A + B	305.9	0.23	305.0	0.52
2,3-Dimethylpentane	304.9	I + 2A + B	303.4	0.49	305.0	0.03
2,4-Dimethylpentane	307.5	2C + A	306.6	0.29	305.0	0.82
3,3-Dimethylpentane	304.2	H + 2A + B	303.0	0.39	305.0	0.27
2,2,3-Trimethylbutane	302.4	G + C + L	301.7	0.23	302.0	0.13
n-Nonane	390.6	9A + 2B	391.0	0.10	391.0	0.10
2,2,3-Trimethylhexane	380.4	G + E + L	380.1	0.08	382.0	0.42
2,2,4-Trimethylhexane	381.6	G + A + D	382.3	0.18	382.0	0.10
2,2,5-Trimethylhexane	383.9	G + 2A + C	383.7	0.05	382.0	0.49
2,3,3-Trimethylhexane	378.3	J + 3A + B	379.0	0.16	382.0	0.98
2,3,5-Trimethylhexane	381.8	I + A + C	381.2	0.16	382.0	0.05
2,4,4-Trimethylhexane	379.8	C + A + H	380.8	0.26	382.0	0.58
3,3,4-Trimethylhexane	378.2	H + D + L	377.4	0.21	382.0	1.00
2,2,3,3-Tetramethylpentane	372.9	G + H + M	373.4	0.13	379.0	1.64
2,2,3,4-Tetramethylpentane	376.1	G + I + L	376.3	0.05	379.0	0.77
2,2,4,4-Tetramethylpentane	378.5	2G + A	380.8	0.35	379.0	0.13
2,3,3,4-Tetramethylpentane	373.6	J + C + L	374.8	0.32	379.0	1.45

* See table 8.

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[5] Sugden arrived at the value of 23.2 as the parachor contribution of the double bond, whether the double bond was ethylenic, or in the carbonyl group, or of some other unsaturated type. In compiling his average, he had available values from only sixteen compounds, and the double-bond value for individual compounds varied from 21.2 to 27.1.

meaning of the word, and would have a larger parachor than similar bonds in the 2,3- or 3,4-position. Johnston (26) has reported values for a number of ethylenic compounds which support this view.

His determinations, as reported, include values for ethylenic compounds containing terminal linkages derived from the parachors of American Petroleum Institute–National Bureau of Standards pure hydrocarbons and others of less certain purity. Using only the values obtained from the A.P.I.–N.B.S. samples, where suitable compounds were available he obtained an average value for the terminal ethylenic bond of 19.1. Values for the 2,3-position show greater individual deviations from the average value of 17.3. However, the maximum value obtained for any 2,3 bond was below that obtained for any terminal bond. Sufficient reliable data were not obtained to permit any evaluation of the bond in the 3,4-position. The average of the determinations made on the 3,4-position does, however, indicate a somewhat lower value for the linkage in this position.[6] Johnston's (26) determinations are shown in table 10.

TABLE 10

Parachors of ethylenic linkages

A. Terminal position

COMPOUND	SOURCE*	EXPERIMENTAL PARACHOR	P $(CH_2)_n$	DOUBLE-BOND VALUE
1-Pentene	A	219.4	200.0	19.4
1-Hexene	A	259.0	240.0	19.0
1-Heptene	A	299.1	280.0	19.1
1-Octene	A	338.8	320.0	18.8
1-Nonene	B	379.0	360.0	19.0
Average				19.1

B. 2,3-Position

COMPOUND	SOURCE*	EXPERIMENTAL PARACHOR	P $(CH_2)_n$	DOUBLE-BOND VALUE
2-Pentene	E	218.2	200.0	18.2
2-Hexene	E	258.1	240.0	18.1
2-Heptene	E	298.0	280.0	18.0
2-Octene	E	335.7	320.0	15.7
2-Nonene	E	376.6	360.0	16.6
Average				17.3
Average omitting 2-octene				17.7

* A = A.P.I.-N.B.S. pure hydrocarbon, A.P.I. Research Project 44.
B = prepared by E. H. Clower and C. T. Lester, Emory University.
E = prepared by E. W. Wilson and C. T. Lester, Emory University.

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[6] The author believes that the use of the value 19.1 for the terminal linkage is valid and that 17.3 is a sufficiently close approximation to the value of the bond in the 2,3-position, so that its use with a recognized uncertainty is warranted. For bonds in the 3,4-position, or further from the end of the chain, no reliable value has been obtained. If it were neces-

D. Carbonyl linkages

The carbon–oxygen double bond was, as an unsaturated linkage, first given the same value as the ethylenic linkage. It has since been shown to have values of its own, which vary greatly with the group attached. It has been shown that the decrease in the parachor attributed to the unsaturated portion of the molecule parallels, in at least a qualitative manner, the decrease in chemical activity as larger groups are attached to the carbonyl. Owen, Quayle, and Clegg (43) determined the parachors for all of the ketones with normal chains and no more than eleven carbon atoms. The parachor value of the carbonyl group was found to be definitely constitutive and to decrease with regularity as the size of the attached alkyl group increased. Their work is reported in terms of the complete $>C=O$ linkage, which showed a decrease from 51.3 for acetone to 41.6 for diamyl ketone. Expressed in terms of the double-bond value alone, the change is from 22.3 to 12.6. The values for the parachor agree well with the incomplete series reported by Cowan, Jeffery, and Vogel (9). Table 11 lists the parachors as determined by Clegg and includes the independent values recorded by Vogel. It will be seen by examination of this table that, in all possible series, the parachor for the carbonyl group decreases with an increase of the size of the alkyl

TABLE 11

Parachors of fifteen normal ketones

KETONE	P_c*	P_v†	CARBONYL VALUE BASED UPON P_c	DOUBLE-BOND VALUE FROM P_c
Dimethyl	162.1	161.6	51.3	22.3
Ethyl methyl	199.8	199.5	49.0	20.0
Methyl propyl	238.4	238.0	47.9	18.9
Butyl methyl	277.8	277.5	46.9	17.9
Amyl methyl	318.1	319.5	47.3	18.3
Diethyl	237.3	237.4	47.0	18.0
Ethyl propyl	276.2	277.3	45.6	16.6
Butyl ethyl	315.0		44.4	15.4
Amyl ethyl	354.3		43.8	14.8
Dipropyl	314.9	315.1	44.1	15.1
Butyl propyl	354.6		44.3	15.3
Amyl propyl	393.3		42.7	13.7
Dibutyl	394.0		43.4	14.4
Amyl butyl	432.5		42.0	13.0
Diamyl	471.8		41.6	12.6

* P_c = values of Owen, Quayle, and Clegg at 24.8°C. (43).

† P_v = mean values of Cowan, Jeffery, and Vogel (9).

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sary to make an estimate of the parachor for a compound containing such a linkage, the author would use a value of 16–16.5 and realize that his calculated parachor was only an approximation though probably somewhat better than using either of the older general double-bond values of 23.2 or 19.0.

group, within the experimental value of 0.1 per cent claimed by the authors. There can hardly be any question but that the carbonyl value is highly constitutive and that no average value should be used for all carbonyl groups.

E. Alcohols

1. Primary and secondary alcohols

Alcohols represent a class of compounds known to associate. To the extent that association gives a more compact structure, with a smaller volume, it should produce a lowering of the parachor. It is found that alcohols do give lower parachor values than those calculated upon a simple additive basis. It is also true that the anomaly decreases with increase in the temperature of measurement. Association should, of course, be less at higher temperatures. Sugden (57) has given data for a wide temperature range for methyl and ethyl alcohols (table 12). An examination of the parachor given in the appendix for normal primary alcohols up to 1-decanol would show a number of cases with no apparent decrease in the anomaly with increase in temperature. The anomaly expressed in terms of percentage appears to be as great for 1-nonanol, 1-decanol, and 1-undecanol as for methanol, ethanol, and 1-propanol. Mumford and Phillips gave the value 10 for hydrogen in the alcoholic OH group, rather than 17.1 as given by Sugden or 15.5 as used in table 12. Since the values for almost all simple alcohols are higher than calculated, such a decrease in the value used for the alcoholic hydrogen would result in an average improvement. It would not, however, in any way produce uniform values for the hydroxyl group. It appears as if the alcohols are particularly susceptible to constitutive changes.

TABLE 12

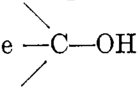
*Parachors of methyl and ethyl alcohols**

METHANOL			ETHANOL		
t	Observed parachor	Anomaly	*t*	Observed parachor	Anomaly
°C.			°C.		
−65	86.7	−4.3	−57	124.2	−6.8
−35	86.8	−4.2	−30	125.4	−5.6
0	87.9	−3.1	0	126.4	−4.6
20	88.3	−2.7	20	126.9	−4.1
70	89.3	−1.7	80	128.8	−2.2
130	90.6	−0.4	140	129.7	−1.3
190	91.9	+0.9	200	131.0	−0.0

* CH_2 = 40, C = 9.0, H = 15.5.

Considerable discrepancy exists among the several determinations upon single compounds. The CH_2 increment as the chain increases is not constant; neither does it appear to follow any regular pattern. In the opinion of the author, further careful determinations should be made upon highly purified normal primary and secondary alcohols.

2. Tertiary alcohols

Certain regularities have been pointed out in a study of fifteen tertiary alcohols (42). Assuming the constancy of the hydrocarbon chain values, the effective volume of the  $>C{-}OH$ linkage decreases with the size of the alkyl groups attached. Among isomers the more symmetrical, more closely packed alcohol shows the lowest parachor. For example, dimethylpentylcarbinol has a parachor of 357.1, diethylpropylcarbinol one of 351.2, dimethylhexylcarbinol one of 398.3, and ethyldipropylcarbinol one of 389.1.

From fifteen tertiary alcohols a table was devised for the calculation of parachors of tertiary alcohols (42). Nine additional alcohols were synthesized and measured. Using this table with the new alcohols a deviation of 0.0 per cent was found between calculated and measured parachors in three cases, a 0.1 per cent deviation in five cases, and a deviation of 0.3 per cent in a single case.

TABLE 13

Calculation of parachors of tertiary alcohols

$(H\cdots CH_2)_3C{-}OH$ = 201.3; each additional CH_2 = 40.0

GROUP	CORRECTIONS				
	Number of CH_2 units in group				
	2	3	4	5	>5
R, longest alkyl group	−2.5	−3.1	−4.3	−4.5	−4.5
R′, second alkyl group	−3.4	−4.7	−6.2	−7.6	−7.6
R″, shortest alkyl group	−4.1	−5.2	−5.9	−5.9	−5.9

Total corrections = sum of corrections R + R′ + R″

Assuming the measured parachor for *tert*-butyl alcohol of 201.3 as correct, deviation or correction constants can be applied to calculate the parachor of any other tertiary alcohol having unbranched alkyl groups. These corrections are shown in table 13. The use of this table may be illustrated by the calculation of the parachor of butylethylmethylcarbinol:

Parachor of *tert*-butyl alcohol	= 201.3
Four additional CH_2 units, 4 × 40	= 160.0
Uncorrected *P*	= 361.3
Correction for the longest group: 4 carbon atoms	= −4.3
Correction for the second group: 2 carbon atoms	= −3.4
Correction for the shortest group (included in *tert*-butyl)	= 0.0
Total correction	= −7.7
Corrected parachor	= 353.6
Observed parachor	= 353.6

The effect of tertiary branching and the change in this effect are also clearly shown in a similar series of tertiary chlorides (46). A similar table of corrections may be derived from these compounds; calculated values and observed parachors show an average deviation of 0.2 per cent and a maximum deviation of 0.5 per cent. The average deviation using a uniform "strain constant" is 1.8 per cent. It should be pointed out that as precise values would not be expected with tertiary chlorides as with alcohols because of the difficulty of obtaining pure samples of the former (46).

TABLE 14

Comparison of experimental and calculated parachors of ditertiary glycols and chlorides

COMPOUND	PARACHOR				
	Experimental	Calculated*	Per cent deviation	Per cent deviation (uncorrected)†	Per cent deviation (corrected)‡
Four or more carbons between groups					
3,11-Diethyl-3,11-tridecanediol	712.1	708.9	−0.45	3.9	3.1
2,11-Dimethyl-2,11-dodecanediol	615.9	603.0	−2.1	0.7	−0.3
3,12-Diethyl-3,12-tetradecanediol	756.6	748.0	−1.1	3.1	2.3
4,13-Dipropyl-4,13-hexadecanediol	906.1	903.2	−0.3	3.7	3.1
2,7-Dichlorodecane	505.2	502.8	−0.5	1.0	−0.2
3,8-Dichlorododecane	649.5	646.6	−0.5	3.1	2.4
4,9-Dichlorododecane	802.4	802.8	0.1	3.4	2.7
2,10-Dichloroundecane	624.3	620.7	−0.6	0.9	−0.1
3,11-Dichlorotridecane	770.0	764.5	−0.7	2.6	1.8
2,11-Dichlorododecane	666.0	660.2	−0.9	0.6	−0.3
3,12-Dichlorotetradecane	811.7	804.0	−1.0	2.3	1.5
4,13-Dichlorohexadecane	964.9	961.6	−0.3	2.6	2.0
Two carbons between groups					
3,6-Dimethyl-3,6-octanediol	511.2	519.8	1.7	5.6	4.5
2,5-Dichlorohexane	425.2	427.8	0.6	1.1	−0.3
3,6-Dichlorooctane	566.2	575.2	1.6	4.2	3.1
4,7-Dichlorodecane	720.6	731.4	1.5	4.0	3.2

* Based upon tables of references.

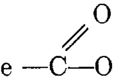
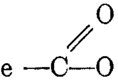
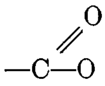
† No correction for branching.

‡ Using the strain constant of Mumford and Phillips.

Further indication of the possibility of obtaining a correction for tertiary structures not limited to any one type of compound is shown by the application of the corrections obtained for the alcohols to the chlorides. Deviations of 0.5 per cent or less were obtained, with one exception (54).

Unit values such as those just described are of value in showing a consistent pattern within a series, for the calculation of missing members of a series, and for other compounds of a similar type. If large groups, when once evaluated, may be used in an additive or nearly additive manner, the value of such evaluation is increased. Johnston and Quayle (27) have reported upon a number of ditertiary glycols and chlorides. Use of the previously reported values for tertiary grouping reduces from one-half to one-third the error between calculated and observed values when the two functional groups are separated by four or more carbons. The error is also decreased when only two carbons separate the two groups but, as might be expected, is still appreciable (table 14).

F. Esters

The parachors of well over 350 esters have been determined. It became apparent relatively early that the value for oxygen as used in alcohols, ethers, etc. was not correct for esters. A special average value for the two oxygen atoms in esters was included in Sugden's (57) list of structural constants, together with values for the double bond, for the triple bond, and for rings containing from three to six members. Sugden gave the general value for O as 20.0 and that for O_2 in esters as 60.0 or 64.8 for the  $-\overset{O}{\overset{/\!/}{C}}-O$ linkage. Vogel (68) found, upon the basis of more recent determinations, 63.4 as an average value for the  $-\overset{O}{\overset{/\!/}{C}}-O$ group and 54.8 (using a different value for carbon) as the parachor increment for O_2 in esters. Gibling calculated the reduced parachor of  $-\overset{O}{\overset{/\!/}{C}}-O$ as 66.4. Quayle, Owen, and Estes (47) determined the parachors of fifteen normal isomeric esters ($C_{16}H_{32}O_2$) and found the parachor maxima of 695.3 and 699.1 at the ends of the series and a minimum of 689.3 near the center of the series. This corresponds to a maximum value of 59.1 for O_2 in esters, and a minimum of 49.3.

It appears that, while an average value of 54.8 for the two oxygen atoms in esters is of use, the true value varies with the alkyl groups attached. It should be capable of being evaluated, with separate constants for increasing the carbon chain in the acid and the alcohol parts of the ester.

G. Alkylbenzene derivatives

The early recognition of the gross additive nature of atomic parachors and the rather large experimental error considered then to be inherent in the earlier measurements once more obscured small parachor effects that occur of a constitutive nature. Sugden (57), in fact, states that "the first indication that the parachor could be treated as an additive property was obtained by comparing this constant for isomeric substances. For isomers which differ in structure only by the position of groups or linkages in the molecule, it was found that the parachors were identical, *within the limits of experimental error.*[7] He cited a num-

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[7] Italics by author.

ber of examples, including the following parachors of disubstituted benzene derivatives:

DERIVATIVES OF BENZENE	ORTHO	META	PARA
Xylenes	283.3	283.8	283.8
Nitrotoluenes	301.1	300.6	302.8
Chloronitrotoluenes	299.1	298.9	300.0
Bromonitrotoluenes	312.9	313.5	313.5
Tolunitriles	290.6	295.6	294.4

Sugden was quite correct that the difference between isomers is less than the then considered experimental error. It should be pointed out, however, that in every case the value observed for the para compound was larger than for the ortho.

TABLE 15

Parachor differences in position isomers

COMPOUNDS	ORTHO AND META		META AND PARA		ORTHO AND PARA	
	Units	Per cent	Units	Per cent	Units	Per cent
Xylenes	1.80	0.6	0.24	0.1	2.04	0.7
1,2,3-Trimethylbenzene and 1,3,5-trimethylbenzene	2.15	0.7				
Ethylmethylbenzenes	2.95	1.0	0.47	0.15	3.42	1.15
Diethylbenzenes	3.37	0.9	0.38	0.10	3.75	1.0

With increasingly purer compounds becoming available and with continued improvements in techniques of measurement, it has become increasingly apparent that these small differences are real and that they may be, at least approximately, evaluated.

Donaldson and Quayle (11) have reported the parachors of twenty-one American Petroleum Institute–National Bureau of Standards pure aromatic hydrocarbons (benzene and homologs) ranging in purity from 99.98 ± 0.02 mole per cent to 99.68 ± 0.20 mole per cent. Densities were available from the National Bureau of Standards. A minimum of seven surface tension determinations was made upon each compound at each of three temperatures. The average deviation of the individual surface tension measurements from the value accepted is as high as 0.010 in only three of the sixty-three determinations. It becomes quite obvious that ortho, meta, and para isomers do not have the same parachor values. In each case where comparisons are possible the ortho compounds have the least value and the para the largest. The differences between the meta and para isomers are of the same order of magnitude as the experimental error, but the observed value in each case is greater for the para compound. A summary of position differences is given in table 15.

The percentage differences between the values for ortho and meta isomers or between the values for ortho and para isomers, while not constant, are apparently meaningful, as they are from six to ten times the estimated experimental error.

Donaldson (10) also calculated a number of positional corrections for the introduction of groups into alkylbenzenes. These were tested upon alkyl-*p*-xylenes from methyl to *n*-octyl. The average deviation between experimental and calculated values was 0.15 per cent and the *maximum* was 0.31 per cent; without these corrections the average deviation was 2.0 per cent and the *minimum* was 1.2 per cent.

TABLE 16

Influence of cyclization on the parachor

COMPOUND	*P*	STRAIGHT-CHAIN ANALOG	*P**	CYCLIZATION
Cyclopentane	205.0	*n*-Pentane	231.0†	5.0
Methylcyclopentane	244.2	2-Methylpentane	268.8†	6.4
Ethylcyclopentane	283.3	3-Methylhexane	307.8	6.5
n-Propylcyclopentane	323.2	4-Methylheptane	347.2§	7.0
Isopropylcyclopentane	321.2	2,3-Dimethylhexane	343.4§	8.8
n-Butylcyclopentane	362.9	4-Methyloctane	387.2‡	6.7
Isobutylcyclopentane	360.8	2,4-Dimethylheptane	385.0‡	6.8
1,1-Dimethylcyclopentane	281.2	2,2-Dimethylpentane	306.6	5.6
Cyclohexane	241.7	*n*-Hexane	270.8†	1.9
Methylcyclohexane	281.7	2-Methylhexane	309.6	2.1
Ethylcyclohexane	320.5	3-Methylheptane	347.4§	4.1
n-Propylcyclohexane	360.4	4-Methyloctane	387.2‡	4.2
Isopropylcyclohexane	357.0	2,3-Dimethylheptane	383.4‡	4.6
n-Butylcyclohexane	400.3	5-Methylnonane	427.2‡	4.1
Isobutylcyclohexane	397.7	2,4-Dimethyloctane	425.0†	3.7
sec-Butylcyclohexane	397.6	3,4-Dimethyloctane	422.0‡	6.6
tert-Butylcyclohexane	394.7	2,2,3-Trimethylheptane	420.1‡	5.6
1,1-Dimethylcyclohexane	318.5	2,2-Dimethylhexane	345.9§	3.6
1,1,3-Trimethylcyclohexane	356.9	2,2,4-Trimethylhexane	381.6	6.3

* To be reduced by 31.0 units, the value of two hydrogen atoms.

† Reference 45.

‡ Calculated.

§ Reference 10.

H. Ring constants

In his first tables of atomic and structural parachors Sugden (57) recognized structural constants or increments for unsaturated linkages and ring structures (table 2). Mumford and Phillips, upon the basis of later values, arrived at smaller increments for all rings from three to six carbon atoms. In view of the fact, later shown, that there is no truly uniform "strain constant" for branching of the chain, it is not surprising that various alkylcycloalkanes of the same size ring do not give a constant ring increment.

As has been pointed out (table 8), Donaldson (10) has attempted to evaluate group and position constants in straight-chain hydrocarbons. Robinson (50) has calculated values for ring-closure for eight cyclopentanes and nine cyclohexanes, using these constants and comparing open-chain and cyclic compounds containing the same alkyl groups. The cyclic compounds measured were American Petroleum Institute–National Bureau of Standards pure hydrocarbons. The values obtained are shown in table 16.

For the closure of a five-membered saturated ring, values from 5.0 to 8.8 were obtained and for a six-membered ring values from 1.9 to 6.8. Obviously no constant increment can be given for either structure. Since the corrections are positive in all cases, it is equally obvious that the use of an average correction value will bring about closer correlation between experimental and calculated parachors than would be obtained in the absence of any correction. The average obtained by Robinson is 6.6 units for five-membered ring cyclization and 4.3 for six-membered ring cyclization. Sugden obtained 8.5 and 6.1, respectively, while Vogel obtained 3.0 and 0.8.

TABLE 17

Influence of ring expansion on the parachor

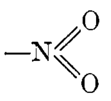
FIVE-MEMBERED RING	P	SIX-MEMBERED RING	P	INCREASE IN P
Cyclopentane	205.0	Cyclohexane	241.7	36.7
Methylcyclopentane	244.2	Methylcyclohexane	281.7	37.4
Ethylcyclopentane	283.3	Ethylcyclohexane	320.5	37.2
n-Propylcyclopentane	323.2	*n*-Propylcyclohexane	360.4	37.2
Isopropylcyclopentane	321.2	Isopropylcyclohexane	357.0	35.8
n-Butylcyclopentane	362.9	*n*-Butylcyclohexane	400.3	37.4
Isobutylcyclopentane	360.8	Isobutylcyclohexane	397.7	36.9
1,1-Dimethylcyclopentane	281.2	1,1-Dimethylcyclohexane	318.5	37.3

Robinson does, however, obtain rather consistent values for ring expansions from five- to six-membered rings. He compared the parachors of eight cyclopentanes with those of eight cyclohexanes containing the same groups. An average parachor increase of 37.0 units was found. Assuming the added CH_2 to have 40.0 units, the ring constant for six-membered rings is 3.0 less than for five-membered rings. His results are shown in table 17. In only one case, the isopropyl compounds, is the deviation from the average increment above 0.1 per cent of the value of the parachors measured. In all other cases the deviations are well within the limits of error of 0.1 per cent for each determination claimed by Robinson.

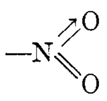
I. Semipolar double bonds

The semipolar bond or coördinate linkage is, of course, well established at present. The parachor, however, early supplied definite experimental evidence for this bond, predicted by the octet rule. Sugden (58) calculated its value as −1.6 units. He used, at this time, the parachor as evidence for the structure of the nitro group. The suggested structures for the nitro group and the calculated parachors were:

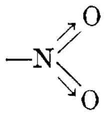
(1)



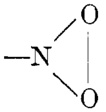
(2)



(3)



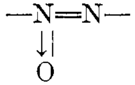
(4)



$P =$ 98.9 74.1 49.3 69.2

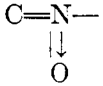
The parachor value for the group in the compounds measured varied from 71.6 to 75.9 with a mean of 73. This would eliminate structures 1 and 3 and favor 2 over 4.[8]

In a similar manner the structure of azoxy compounds was indicated as

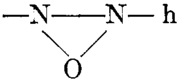


$$\begin{array}{l}-N=N-\\ \;\;\downarrow\|\\ \;\;\;O\end{array}$$

and that of the nitrogen ethers of oximes as



$$\begin{array}{l}C=N-\\ \;\;\;\;\|\downarrow\\ \;\;\;\;O\end{array}$$

Good agreement between observed and calculated values was found for these structures. If both double bonds were non-polar, the parachor would be 24.8 units higher; if both were semipolar, 24.8 units less. Such differences would be approximately 10 per cent, far beyond any possible experimental error. The azoxy structure  has been eliminated, as the monosubstitution derivatives of azoxybenzene have been shown to exist in two isomers depending upon which ring is substituted.

Sugden (57) somewhat later revised his semipolar bond value to 0, the same as the value for the normal covalent single bond.

Buehler, Gardner, and Clemens (5) in 1938 reported determinations upon seven semipolar compounds for which parachor values were established over a relatively wide temperature range. They found that the value for this linkage is not constant with change of temperature, and they reaffirmed the zero value as the most suitable approximation. Typical of their results are the data for ethyl sulfate, ethyl nitrate, and methyl *p*-toluenesulfonate (table 18). They point out that since the covalent bond has little or no temperature coefficient, the definite change with temperature of the value for the semipolar bond affords

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[8] In general, the parachor supplies confirmatory evidence rather than proof of structure. Since different observers calculate structural values in different manners, they do not always agree. When alternate structures do not show a great difference in the parachor, one set of values has been known to indicate one structure and a second table of values another structure.

a means of distinguishing between the two, although both should be used with a zero value.

TABLE 18

Parachors of compounds containing semipolar bonds

COMPOUND	TEMPERATURE	P (OBSERVED)	P (CALCULATED)*	$P_{obsd} - P_{calcd}$
	°C.			
Ethyl nitrate	30.0	189.2	190.8	−1.6
	40.0	189.5		−1.3
	50.1	190.6		−0.2
	60.2	190.8		0.0
Ethyl sulfate	40.0	315.9	318.4	−3.1
	70.3	317.3		−1.1
	100.9	320.2		1.8
	130.4	320.8		2.4
Methyl *p*-toluenesulfonate	40.0	389.9	393.3	−3.4
	70.3	392.5		−0.8
	100.9	393.5		0.2
	130.4	395.8		2.5

* Not including any value for the semipolar bond.

TABLE 19

Parachors of chelate compounds and their isomers

COMPOUNDS	ORTHO	META	PARA
Nitrophenols:			
Observed	274.7	283.3	283.2
Calculated	289.1	283.0	283.0
Deviation	−14.4	0.3	0.2
Methyl hydroxybenzoates:			
Observed	322.1		331.8
Calculated	337.0		330.9
Deviation	−14.9		0.9
Hydroxybenzaldehydes:			
Observed	268.0	274.5	278.2
Calculated	281.2	275.1	275.1
Deviation	−13.2	−0.6	3.1

J. Chelated compounds

Sugden (57) also showed that parachor determinations are consistent with calculated values for a number of metallic chelated compounds, assuming singlet linkages for the "residual valencies." He used as examples a number of beryllium, thallium, and aluminum compounds. He also discussed a number of nonmetallic hydrogen-bridge compounds, pointing out the opportunity of using the parachor to indicate the extent of hydrogen-bridge formation in diketones. Sidgwick and Boyles (52) have determined the parachors of a number of chelate compounds and found the parachor value for the hydrogen bridge to be − 14.4 units. Typical examples of their data are given in table 19.

The values were considered as if independent of temperature and no allowance was made for the differences between positional isomers found to exist some years later in compounds where chelation is not possible. However, even if these points had been considered and correction made for the decrease produced by ortho-substitution, the value for the chelated compounds would deviate from the calculated value by 10–11 units.

Buehler (5) has studied the effect of temperature upon the parachor of these and other similar hydrogen-bridge compounds and their isomers. He finds in general that with the ortho compounds an increase in temperature is accompanied by no change in their parachor, that is, no change in the value to be attributed to the bridge. For the meta and para compounds an increase in the parachor results with increased temperature. Since the chelate compounds would be expected to have little or no association, in contrast to the meta and para isomers, the effect of temperature is as might be expected.

IV. THE RELATIONSHIP OF THE PARACHOR TO OTHER PROPERTIES

If the parachor is, in fact, a means of measuring the volume of a molecule in direct relation to its size and shape, it might be expected to have certain ascertainable relationships to other physical constants,—certainly to the critical volume and, in turn, to the other critical constants.

Sugden (56) in 1924 proposed the parachor from a consideration of Macleod's (38) empirical formula for surface tension

$$\gamma^{1/4}/(D - d) = C$$

where γ is the surface tension and D and d are the densities of the liquid and its vapor, respectively. Almost simultaneously Ferguson (12) produced the same equation by combining van der Waals' (64) equation relating surface tension and critical temperature:

$$\gamma = \gamma_0(1 - T/T_c)^n$$

(where γ is the surface tension, γ_0 is a function of the critical constants, and temperatures are in degrees Kelvin) with Katayama's (28) modification of the Eötvös equation to include vapor density:

$$\gamma(M/D - d)^{2/3} = KT_c(1 - T/T_c)$$

(where M is the molecular weight, D and d are the densities of the liquid and vapor, respectively, and K is the temperature coefficient which, for non-associated liquids, is a constant and equal to 2.1). Fowler in 1937 (7) showed that the relationship may be theoretically deduced.

Sugden (57) has rather fully discussed the fundamental background of the liquid state and its relationship to the parachor as well as the mathematical theory of surface tension measurements; hence no attempt will be made to repeat this material. A modern critical analysis of the theoretical background has been given by Reilly and Rae (49).

Sugden has discussed the empirical relations between surface tension, density, and temperature, including his conclusion that the parachor is a true measure of molecular volume. He based this conclusion primarily upon a comparison of the parachor with the mean collision area and with the critical volume.

Sugden stated that "the mean collision areas (a) for a number of substances (eleven) are compared with the two-thirds root of the parachor, which, for symmetrical molecules, should be proportional to the cross-sectional area of the molecule. . . . The ratio $[P]^{2/3}/a$ is found to be roughly constant for all substances quoted; better agreement could not be expected, since many of the molecules are far from being symmetrical." The theoretical ratios of the compounds listed varied from 2.01×10^{16} to 2.54×10^{16}.

A. Critical volume

Sugden compared the parachor and critical volume for fourteen substances and arrived at the intriguingly simple relationship $P/V_c = 0.77$. In the cases cited the constant varied from 0.74 to 0.81. Unfortunately, this relationship was later found to show deviations as high as ±30 per cent. Numerous attempts have been made to arrive at expressions which are more nearly valid.

Herzog (23) has reviewed these relationships, including particularly equations by Lautie (33), Meissner and Redding (39), and Ferguson (13). He considered the equation of Ferguson to be upon the most rational basis, a dimensional analysis of the parachor, although it is partially empirical.

Herzog rewrote Ferguson's equation in the form

$$V_c = kP^{1.2}/T_c^{0.3}$$

and empirically separated the data studied into two groups. Group 1 includes compounds having a $>\!\text{C}{=}\text{O}$, $-\text{C}{\equiv}\text{N}$, $-\text{COOH}$, or $-\text{OH}$ group and from one to three non-functional carbon atoms. Data from such compounds fit the equation

$$V_c = 3.34P^{1.2}/T_c^{0.3}$$

with a reliability of a 10 per cent maximum deviation. Group 2 is composed of all other compounds tested, and for these the constant K is 2.92. They fit the equation

$$V_c = 2.92P^{1.2}/T_c^{0.3}$$

with a reliability of a 6.5 per cent maximum deviation. He pointed out that certain other empirical equations when applied to a limited field, such as a single homologous series, may give as great or greater reliability but are not capable of being broadly used.

B. Critical temperature

Herzog (23) also reviewed the several relationships between parachors and critical temperature which have been formulated. Lewis (35) derived two useful relationships between critical temperature, T_c, normal boiling point, T_B, and the parachor, P.

$$T_c = aP + b; \qquad T_B = cP + d \tag{1}$$

$$T_c = e \log P + f; \qquad T_B = g \log P + h \tag{2}$$

Equations 1 have been applied to various groups of chemically similar compounds having the same number of atoms, and equations 2 to various homologous series. The constants a and h are different for each group or series, and the equations are therefore limited to those cases where experimental data are available for their evaluation.

Herzog suggested the equation

$$T_c/T_B = a - b \log P$$

which appears to be more generally applicable. The constants a and b must be evaluated, but 140 compounds fell into only six groups. He tested the reliability of this equation and compared it in reliability with those of Lewis and of Meissner and Redding (39). The equation of Herzog shows somewhat greater validity. Since the groupings used by Meissner and Redding are different, it is possible to use one as an independent check upon the other. Herzog's groups, the constants a and b, and the reliability of his calculated values expressed in terms of maximum per cent deviations for each class are given in table 20. Average deviations were 40 per cent of the maximum.

TABLE 20

Relation between the critical temperature and the parachor

$T_c/T_B = a - b \log P$

CLASS OF COMPOUND	a	b	MAXIMUM DEVIATION, T_c
			per cent
1. Saturated hydrocarbons	2.501	0.4176	2.2
2. Aromatics and cyclics	2.640	0.4634	5.4
3. Substituted aliphatics containing halogen or sulfur	2.602	0.4449	4.7
4. Aliphatic esters, ethers, acetals, and oxides	2.544	0.4429	2.5
5. Aliphatic ketones, aldehydes, carboxylic acids, and nitrogen compounds	2.301	0.3548	4.4
6. Aliphatic alcohols and anhydrides	1.783	0.1479	2.3

C. Critical pressure

The critical pressure is usually estimated by equations involving T_c and V_c and consequently may also be estimated by using the parachor. The reliability of estimates for the critical pressure is in general less than for the critical temperature or the critical volume. They are, however, of some use because of the limited amount of critical pressure data available.

Herzog has reviewed the equations of Lautie (33), Wohl (69), and Meissner and Redding (39) and has compared their validity. Wohl suggested the relationship $P_c = 21.75T_c/V_c$, and Meissner and Redding $P_c = 20.8T_c/(V_c - 8.00)$. Herzog found the latter superior for hydrocarbons but no improvement over the simpler equation of Wohl in general. Herzog derived the equation

$$\log P_c = a' - b' \log P$$

which is of the same form as his relationship between the parachor and the critical temperature. He studied approximately one hundred compounds and in this case also divided them into six classes and evaluated a' and b'. Herzog's equation proved more reliable in five of the six classes than Wohl's. The latter is, however, broader and may be applied to types not included in Herzog's specific lists. These lists of classes for Herzog's equation for critical pressure are more limited than in the case of critical temperature.

D. Other properties

Relationships have been proposed between the parachor and several other properties, including viscosity, molecular refraction, molal heat of combustion, molecular sound velocity, etc.

The viscosity of gases depends upon the molecular weight and the molecular cross-sectional area. From Andrew's principle of the continuity of state, Lewis (36) investigated the possibility of the same relationship holding with liquids. He developed the equation:

$$\log P^{2/3}\eta = (A \log M - B)/T - C$$

where η = the viscosity, P = the parachor, M = the molecular weight, and A, B, and C are constants. A, B, and C are independent of temperature and are probably configurational or cohesive functions characteristic of a particular type of molecule. Calculated and observed values for η agree well (to within 1 per cent) for alkyl bromides and isoparaffins. The relationship has not been broadly tested. Chen (7) suggested the equation:

$$\log_{10} P\eta = AM + C$$

A and C are constants characteristic of a specific homologous series and a function of the absolute temperature. The equation has been applied to paraffins, esters, alkyl bromides and iodides, and normal fatty acids. Calculated and experimental values correspond in general within the limits of experimental error.

Telang (59) related the heat of vaporization to the parachor by the equation:

$$Ml = \Delta H_m = 0.818P_cP$$

where ΔH_m = the molal heat of vaporization, P_c = the critical pressure in atmospheres, and Ml/T_b = Trouton's constant. From the equation of Kistyakovskiĭ (30) relating latent heat of vaporization and molal volume, and the equations of Meissner and Redding (39), empirical equations for six groups of types of compounds have been derived involving the parachor (8). The relationship has been applied to a large number of paraffins with success.

Telang (60) also related the parachor to molecular dimensions by the expression

$$\sigma = 0.92P^{0.4} \times 10^{-8}\ \text{cm.}/T_c^{0.1}$$

which has a reliability of ±2.2 per cent for all compounds except those having $>C{=}O$, $-C{\equiv}N$, $-COOH$, or $-OH$ groups and one to three non-functional carbon atoms. For these latter the constant 0.92 becomes 0.96.

The parachor has been employed chiefly as a comparative instrument, its absolute value as a measure of volume being minimized. Bayliss (1), however, assuming that the carbon atom is a sphere having a radius of 0.77 Å., has calculated that one parachor unit is equivalent to 0.210 Å. On this assumption, he has calculated values which show reasonable agreement with experimental data.

The molar heat of combustion (44) has been related to the parachor by the empirical equation $P = a + bQ$. The constants a and b are characteristic of a given homologous series. Values for a and b have been calculated for nine series. Agreement between calculated and experimental values is satisfactory.

Samygin (51) has related molar refraction and parachor by the equation:

$$\gamma = \left(KU + \frac{Cd}{M}\right)^4$$

where γ = the surface tension, d = the density, M = the molecular weight, and $U = (n^2 - 1)/(n^2 + 2)$. K and C are constants. Good agreement is obtained between calculated and observed data. K and C for (*1*) saturated hydrocarbons, (*2*) alcohols, (*3*) carboxylic acids, (*4*) aldehydes, and (*5*) ketones are 8.49 and 16.52, 8.49 and 17.2, 8.49 and 20.9, 8.49 and 22.02, and 8.24 and 25.6, respectively.

Gardner (18) has proposed a modification of the Samygin equation which is reported to be more useful.

$$PR = \frac{M\gamma^{1/4}(nD^2 - 1)}{D(nD^2 + 2)}$$

Lagemann and Dunbar (32) have shown that there is a linear relationship between the parachor and molecular sound velocity, molecular refraction, Souder's viscosity constant, van der Waals' b, and molecular magnetic rotation. Lagemann, by the method of least squares, has derived numerical coefficients for certain of these relationships.

Lima (37) has shown that since a number of properties do show straight-line relationships, a broader generalization can be made. In a homologous series some property F (e.g., the parachor) contributes n times the CH_2 contribution plus the contribution of any special characteristic, such as double or triple bonds, carbonyl groups, rings, etc., and the value for any remaining hydrogen of the chain. This may be expressed as

$$F = nF_{CH_2} + F_1$$

where F_1 = the contribution of the structural characteristics of the series plus the additional hydrogens not included in the CH_2 groups.

For another additive-constitutive property G we have the similar relationship:

$$G = nG_{CH_2} + G_1$$

These two equations may be combined to yield the form:

$$F = GF_{CH_2}/G_{CH_2} - G_1F_{CH_2}/G_{CH_2} + F_1$$

which is a linear relationship:

$$F = aG + b$$

This shows why the slope F_{CH_2}/G_{CH_2} is the same for the components of any series, as observed by Lagemann.

The equation was tested for the relationship between Souder's viscosity constant and the parachor, and for the parachor and the molecular refraction. The divergence between experimental and calculated values was less than 1 per cent.

Because of the relationship observed between the parachor and several other properties, other derived properties related to the parachor have been suggested. Bogdan (4) has suggested the neoparachor or $P_n = T^{1/4}V^{5/6}$, where T = the absolute boiling point and V = the molecular volume. Friend (16) and Hargreaves (17) have derived an empirical viscosity function related to constitution, named the rheochor, which shows promise of taking a place with the parachor. It is expressed as:

$$R = M\eta^{1/8}(D + 2d)$$

where η is the viscosity in centipoises and D and d are the densities of liquid and vapor, measured at or extrapolated to the boiling point of the liquid. The rheochor has been used additively, and a number of rheochor increments have been determined. Agreements between the experimental and calculated values of the function are of the order of magnitude of the earlier work with the parachor.

V. PARACHORS IN SOLUTION

Since the determination of the parachor depends upon the measurement of surface tension, its direct evaluation is obviously limited to liquids or fused solids. Its usefulness would be greatly extended if it were possible to measure solids at room or relatively low temperatures. Various attempts have been made to accomplish this through the measurement of the surface tensions of solutions of known concentration, using solvents of known surface tension.

Hammick and Andrew (22) calculated the parachors of a number of solutes on the assumption that parachors obey the straight-line mixture law

$$P_m = P(1 - x) + P_xX$$

where P_m is the parachor of the mixture, P that of the pure solvent, P_x that of the solute, and X the mole-fraction of the solute. They examined solutions of non-associated liquids in non-associated liquids, associated in associated, and non-associated in associated. They also sought to vary the chemical nature and surface tensions of the components of the solutions studied. Parachors of solutes were calculated by first finding the parachor, P_m, of the solution containing a mole-fraction X of solute in a solvent of known parachor P.

$$P_m = M_m \gamma^{1/4}(D - d)$$

where γ and D are the surface tension and density of the solution and M_m is the mean molecular weight of the solution, again assuming the straight-line mixture law. The density of the vapor, d, is negligible within the overall accuracy of the experiments and is eliminated. They found pairs in which the calculated parachors of the solutes were independent of concentration, and also cases showing a straight-line relationship, with the calculated parachor of the solute increasing with increasing concentration. They also found anomalous results with water as a solvent.

TABLE 21

Effect of concentration upon calculated parachors of solutes

A. Independent of concentration: carbon tetrachloride in benzene

X	D	γ	P_m	P_x
0.3419	1.130	27.69	211.1	219.2
0.4512	1.208	27.74	213.3	220.8
0.7326	1.405	26.98	216.8	220.2
0.8527	1.487	26.64	218.0	220.0
1.0000	1.585	26.20	—	219.5

Mean P_x = 220.1; P_{CCl_4} = 219.5; P_{calcd} = 222.0; $P_{C_6H_6}$ = 207.1

B. Dependent upon concentration: nitrobenzene in benzene

X	D	γ	P_m	P_x
0.2129	0.9517	30.26	215.9	249.0
0.3707	1.0070	31.99	223.8	252.0
0.4822	1.0435	33.15	229.6	253.7
0.6109	1.0860	35.24	236.8	255.7
0.7063	1.1130	36.51	242.6	257.4
1.0000	1.1988	42.87	—	262.5

P_{calcd} = 264.1; $P_{C_6H_6}$ = 207.1

In the cases which they reported they found solute parachors independent of concentration where the surface tensions of the pure components do not differ by more than 5–6 dynes/cm. Nitrobenzene in benzene showed the greatest slope of the parachor–mole-fraction curve. In this case the two components show a difference in surface tension of 14.5 dynes/cm. They concluded that "application of the mixture law to the mean parachor of a series of solutions will give either the parachor of the pure solute or a series of values from which a value for the pure solute can be obtained by straight-line extrapolation." An example of each type is given in table 21 and a summary of their results in table 22.

TABLE 22

Examples of determination of parachors of solutes

Independent of concentration

SOLUTION	MEAN P_x*	P_s†	P_s (CALCULATED)‡
A. Non-associated solutes in non-associated solvents			
Carbon tetrachloride in benzene	220.1	219.5	222.0
m-Xylene in benzene	285.3	285.1	285.1
Cyclohexane in benzene	241.1	240.1	
Chloroform in benzene	183.1	183.4	184.8
Ethyl acetate in carbon tetrachloride	215.7	216.1	216.0
B. Associated solutes in non-associated solvents			
Ethyl alcohol in benzene	125.3	126.0	132.2
Acetic acid in benzene	132.5	132.2	141.2
Acetone in benzene	160.5	161.1	160.2
C. Non-associated solute in associated solvent			
Ethyl acetate in acetic acid	216.8	216.8	216.0
D. Associated liquids in associated solvents			
Acetic acid in ethyl alcohol	132.8	132.2	141.2
Acetone in ethyl alcohol	161.6		160.2
Acetone in acetic acid	160.5	161.1	160.2

Dependent upon concentration

SOLUTION	P_x (EXTRAPOLATED)§	P_s (CALCULATED)‡
Nitrobenzene in benzene	262.5	264.1
Nitromethane in benzene	131.8	130.2
Acetophenone in benzene	292.4	294.1
Ethyl ether in benzene	211.0	210.2

* P_x = parachor of solute as determined in solution.

† P_s = parachor of solute determined directly.

‡ P_s (calculated) = parachor of solute calculated using Sugden's constants.

§ P_x (extrapolated) = parachor of solute determined by extrapolation.

In general it will be observed from table 22 that the parachors of the solute calculated from the solution agree excellently with those obtained by direct measurement and with those calculated from atomic values (Sugden's constants).[9]

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[9] The comparison with more recent determinations and with revised constants is somewhat less favorable but still very good.

Unfortunately, correlations as excellent as these are by no means always obtained, although Ray (48) and Bowden and Butler (3) agree with Hammick and Andrew that the parachor of a solute in a non-ionizing solvent may be determined to an accuracy of 1 per cent.

Bowden and Butler (3) discussed the surface tensions of several solutions in the light of the formula

$$\gamma = \gamma_1\gamma_2/(\gamma_1 N_2 + \gamma_2 N_1)$$

deduced by Stakhorskiĭ (55) in 1928, where γ, γ_1, and γ_2 are surface tensions of the solution and components and N_1 and N_2 are mole-fractions. Fairly good results were obtained with ethyl acetate–benzene, ethyl acetate–carbon tetrachloride, nitrobenzene–benzene, nitrobenzene–ethyl acetate, and ethyl carbonate–acetonitrile solutions. Less satisfactory results were obtained with an ethyl carbonate–nitrobenzene solution and complete failure with methyl carbonate–benzene and ethyl carbonate–chloroform solutions. Table 23 gives three examples typical of their results.

TABLE 23

Surface tensions of solutions

ETHYL CARBONATE IN BENZENE			ETHYL CARBONATE IN ACETONITRILE			ETHYL CARBONATE IN NITROBENZENE		
N_1	γ		N_1	γ		N_1	γ	
	Calculated	Observed		Calculated	Observed		Calculated	Observed
0.0497	28.08	27.99	0.1601	28.03	27.84	0.0519	41.62	41.05
0.2690	27.49	27.22	0.3017	27.60	27.22	0.3010	35.79	34.55
0.5186	26.85	26.54	0.5035	27.03	26.74	0.5535	31.35	30.47
0.6588	26.03	25.82	0.7927	26.24	26.06	0.8519	27.47	27.16

They pointed out, from a consideration of Gibbs' adsorption formula, that if adding A to B lowers the surface tension, the surface concentration of A will be greater than in the bulk of the solution. If B likewise produces a lowering of surface tension when added to A, the concentration of B will be greater in the surface. Therefore, there will be a solution with a minimum surface tension where the concentrations of A and B in the surface will be the same as in the bulk of the solution. In only such a solution should one expect reliable results, as in only such a solution is the apparent concentration the actual concentration in the surface which is measured. Methyl carbonate in benzene produces such a minimum at 0.35 *M*, and ethyl carbonate in chloroform at 0.80 *M*.

The calculation of parachors of solutes, they state, fall into three classes: (*1*) The parachor of the solute as calculated is independent of dilution. The curve P_x–C is a straight line. (*2*) The solute parachor is dependent upon concentration and P_x–C is a straight line rising with the mole-fraction of solute. (*3*) The solute parachor is dependent upon concentration and P_x–C is not a straight line.

They obtained type 1 curves when the surface tensions of the components differed no more than 5 dynes/cm., type 2 curves when the difference was up to 14 dynes/cm., and type 3 curves when the difference was 17 or more dynes/cm.

Parachors of types 1 and 2 are illustrated by the two classes in the results of Hammick and Andrew given in table 20.

A number of other observers have also determined parachors in solution. Appendix II illustrates the nature of the results obtained. No attempt has been made to make this a complete catalogue. The illustrations chosen are for the more common compounds in simple solvents. The development of entirely satisfactory techniques for the measurement of surface tensions of solutions and methods of the calculation of the parachors of solids in solution would open up many possibilities and warrants much additional most careful work. There are certain inherent difficulties in the determination of the parachor of solutes. The work is tedious at the present development of the art. To determine a single compound determinations should be made in more than one solvent, at three or more temperatures, and at three or more concentrations. The greatest accuracy obtainable is necessary, since in using the simple mixture law the accuracy of the calculated value for the solute is always less than the measurement upon the solution.[10] In the maximum bubble pressure method the passage of bubbles through the solution would change the concentration of the solute in the solvent during the course of the determinations, unless the air drawn through the bubbler contained solute and solvent in the same concentration before and after passing through the bubbler. There is no reason to believe, however, that these or other difficulties are insurmountable, particularly in problems where an error of 0.5 per cent is not too great.

VI. EXPERIMENTAL METHODS

The experimentally determinable quantities required in the calculation of parachors are surface tension, liquid density, and boiling point. The latter is used to calculate vapor density.

A. Liquid densities

Densities may be determined by any approved method, such as the density balance method employed by the National Bureau of Standards, or by the method of weighing a precisely known volume of liquid in a calibrated pycnometer. Densities should be determined to the fourth decimal place.

B. Vapor densities

For the determination of vapor densities boiling-point data obtained in the process of obtaining pure samples are sufficiently accurate. The determinations are made in the manner described by Sugden (57). Where this is impractical, estimated values obtained as described by Kinney (29) will suffice.

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[10] The author experienced a number of cases where a mole-fraction of approximately 0.12 gave more satisfactory results than more concentrated or dilute solutions. In this case the error for the solute would be approximately eight times the experimental error in determining the parachors of the solution and the solvent.

C. Surface tensions

Several methods have been applied to the experimental determination of surface tension. Any may be used. There is no single best method.[11] Sugden used the maximum bubble pressure method and has discussed its theoretical background (57). This method has been used in parachor work more than any other. It has been suggested that different surface tension values may be obtained by different methods. Discrepancies which have been observed in independent observations using different methods are more probably the result of differences in the purity of the samples used than of differences in the method. It should be remembered that in very few cases did the experimenter record or know the actual purity of the samples used. An interesting comparison of parachor values for a number of ketones is available from the work of Owen, Quayle, and Clegg (43) and that of Cowan, Jeffery, and Vogel (9). These ketones were made by different methods and were purified differently, and the surface tension was measured by different methods in different laboratories.

TABLE 24

*Comparison of independent determinations of the parachors of ketones**

KETONE	P_c†	P_v†	Δ PER CENT
Dimethyl	162.1	161.6	0.3
Ethyl methyl	199.8	199.5	<0.1
Methyl propyl	238.4	238.0	0.2
Butyl methyl	277.8	277.5	0.1
Amyl methyl	318.1	319.5	0.5
Diethyl	237.3	237.4	<0.1
Ethyl propyl	276.2	277.3	0.3
Dipropyl	314.9	315.1	<0.1

* No compounds measured by both experimenters have been omitted from the table.

† P_c, values of Owen, Quayle, and Clegg (43); P_v, values of Cowan, Jeffery, and Vogel (9).

The familiar method of capillary rise is capable of extreme accuracy. The maximum bubble pressure method is, however, both simple and convenient and as developed is of comparable satisfactory accuracy. It has the advantage of being readily used with a small sample and over a wide range of temperature.

The principle underlying the maximum bubble pressure method originated with Simon (53) in 1851 and was developed by Jaeger (25) in 1891. Cantor (6) furnished the first correct theory of the relation between surface tension and the formation of bubbles in a liquid, but it remained for Sugden to develop the method for the practical measurement of surface tension. The method has been

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[11] *Physical Methods of Organic Chemistry*, edited by A. Weissberger, 2nd edition, Part I, Chap. IX, pp. 355–426, Interscience Publishers, Inc., New York (1949). An excellent review by W. O. Harkins of the theory, methods, and apparatus for the determination of surface tension.

criticized by some because it is dynamic, but this is considered rather to be a definite advantage in that a fresh surface is presented with each observation.

Sugden's method involves the measurement of a pressure differential developed within the system as bubbles of dry air are drawn alternately through two tubes with different radii immersed to the same depth in a liquid. The pressure differential is developed by a mercury aspirator and is read on a xylene manometer in parallel with the system.

As the system is aspirated a bubble, in the process of forming at a tip of internal radius r immersed in a liquid of density D to a depth h, is subject to an internal pressure equivalent to the sum of the hydrostatic pressure and a pressure which is a function of the surface tension (γ) of the liquid. The equation for bubble pressure p is

$$p = hDg + 2\gamma/x$$

where g is gravitational acceleration and x is the momentary radius of curvature of the growing bubble. As the bubble continues to grow, the radius of curvature decreases until the bubble is hemispherical and of radius of curvature r, at which instant the bubble pressure has attained a maximum corresponding to a minimum radius of curvature. Further growth of the bubble produces an increase in the radius of curvature, and the bubble then requires for maintenance a pressure less than that already developed. The bubble consequently breaks from the tip, rises to the surface, and explodes to restore the system to atmospheric pressure. Maximum bubble pressure is reflected as a minimum pressure within the system. The successive formation of bubbles causes the meniscus of the manometer fluid to rise and fall rhythmically between atmospheric pressure and a minimum pressure which occurs simultaneously with and is precisely equivalent to the maximum bubble pressure. The equation for maximum bubble pressure is

$$p_{\max} = hDg + 2\gamma/r$$

The maximum bubble pressure is approached slowly to permit accurate observation. The subsequent behavior of the bubble is of no consequence.

The differential maximum bubble pressure is

$$p_{\max} - p'_{\max} = 2\gamma(1/r - 1/r')$$

The radius r of the larger tip is measured accurately under magnification. The radius r' of the smaller tip is not measured directly but is considered as it influences the function A, introduced below, which is evaluated by calibration of the bubbler using a liquid of known surface tension.

The handling of computations is facilitated by the introduction of the expression

$$\gamma = (p_{\max} - p'_{\max})/2(1/r - 1/r') = PA\phi$$

where P is the differential pressure, A is a function of the radii of the tips, and ϕ is an empirical factor dependent upon the temperature and upon the liquid. The factor ϕ is defined by the equation

$$\phi = 1 + 0.69rgD/P$$

where all terms have been previously defined. The pressure differential P is defined by the equation

$$P = Hgd'$$

where H is the pressure differential in centimeters of manometer fluid of which d' is the density. The factor A is determined by calibration with a liquid of known surface tension γ_s by the equation

$$A = \gamma_s/Hg\phi d'$$

and is independent of both temperature and liquid. In practice A and g are evaluated as a combined quantity. The equations in the forms employed in the determination of surface tension are

$$\phi = 1 + 0.69rD/Hd'$$

and

$$\gamma = AgH\phi d'$$

Sugden claimed an accuracy of 0.5 per cent when the diameter of the larger tip is within the optimum range of 0.1–0.2 cm. The diameter of the smaller tip is determined by practical considerations. The smaller the tip the greater will be the pressure differential; however, it has been found impractical to use a tip less than 0.005 cm. in diameter.

The original bubbler as described by Sugden (57) is simple in construction. There are, however, several inherent difficulties in the use of such a design if results of highest accuracy are desired. In many cases the simple bubbler is adequate. However, if small differences in the parachor are essential for the purpose of the measurement, several relatively simple modifications of the bubbler and system may be made which will greatly improve the surface tension measurements.

A most satisfactory assembly is shown schematically in figure 1, in which the mercury aspirator is designated A, the calcium sulfate tubes B, the manometer system C, the bubbler D, and the constant-temperature water bath E. The latter is maintained constant to within approximately 0.02°C. A detailed diagram of the bubbler is shown in figure 2.

A number of practical suggestions are in order. The illumination of the manometer and meniscus is of some importance and is conveniently accomplished by indirect lighting from two parallel fluorescent lights. Such lighting will give slight and uniform heating to the manometer reservoir. The temperature of this reservoir is recorded after each measurement. Time spent in adjusting the lighting to secure the best possible illumination with no reflections or other irregularities in the meniscus is well spent.

The meniscus of the xylene gauge is much improved and will appear sharp and black if the lower half of the glass manometer reservoir is wrapped with a sheet of carbon paper and a second sheet is placed under the base.

It is essential that the two capillary tubes of the bubbler be vertical and that they be immersed to the same depth in the liquid being measured. This is conveniently checked with each observation. After a reading is made, the head of the bubbler is rotated 180° at the 29/42 (upper) ground-glass joint, reversing the positions of the two bubbler tubes from right to left. If check readings are obtained, the tubes are vertical and immersed equally.

Once the observer is assured that the tubes are vertical, the bubbler is clamped in place by the large ground-glass collar. If this collar is securely clamped the bubbler may be removed after a determination, cleaned, a new sample inserted, and when placed again in the collar the tubes will again be vertical. This obviates the period of 20–30 min. frequently found necessary to secure verticality with each new sample when using a simple bubbler.

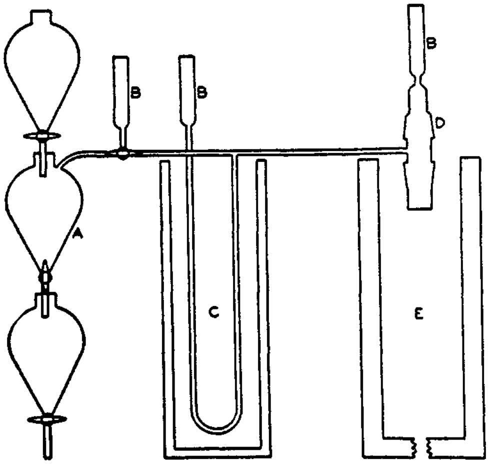

FIG. 1

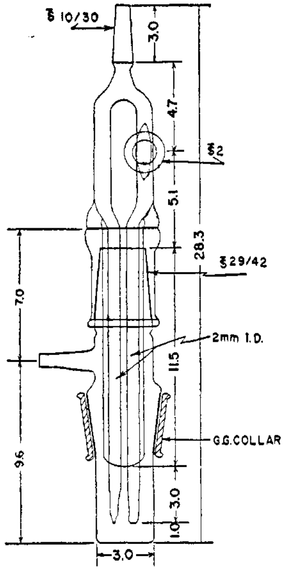

FIG. 2

FIG. 1. Diagram of assembly used in determining surface tension by the maximum bubble pressure method.

FIG. 2. Detailed diagram of the bubbler

It is desirable to keep the internal volume of the apparatus to a minimum. If the volume is too great, the release of a single bubble will not equalize the pressure and a series of several bubbles will be released almost simultaneously. The maximum bubble pressure cannot be successfully measured in this case. Examination of figure 2 will show a glass envelope extending from the head of the bubbler approximately four-fifths the length of the two bubble tubes. This envelope encloses a large portion of the internal space within the bubbler and keeps the volume of the system to a minimum. The author has never had trouble with multiple bubbles when using a bubbler of this design.

The size of the small tip governs the sensitivity of the bubbler. Several tips are drawn out and, before sealing on to the bubbler, are tested until one is found that gives a difference in pressure of approximately the magnitude desired. The capillary may then be adjusted by carefully contracting or expanding it as desired, by blowing it while moderately heating it *in* a flame.

A drying tube is attached at the 10/30 joint at the top of the bubbler. A constriction in this tube will aid in preventing a "bouncing" of the meniscus after the release of each bubble. The constriction, of course, should not be so great as to interfere with complete recovery in the rise of the meniscus some several seconds before the following bubble is released.

The interval between bubbles and consequently between observations is a matter of choice of the observer and can be regulated by the flow of mercury in the aspirator. Different observers will consistently read the height of the meniscus somewhat differently, using either the large or small capillary, depending upon their judgment of when the image of the moving meniscus touches the cross hair of the cathetometer. Since it is the difference between the heights of the meniscus with the two tubes, no error is introduced provided the observers are consistent in their observations.

The bubbler is calibrated against a liquid the surface tension of which has previously been accurately determined. Benzene has most frequently been used. Its surface tension has been repeatedly determined and by more than one method. Its value may be accepted as 28.23 dynes/cm. at 25°C. or 28.87 dynes/cm. at 20°C. Sugden (57) and others have described a standard method for obtaining "pure" benzene.

In the opinion of workers in this laboratory, the calibration of a bubbler is more readily accomplished by the use of a higher-boiling liquid. We have found it most convenient to calibrate a bubbler against *n*-octane, using an American Petroleum Institute–National Bureau of Standards pure hydrocarbon sample. The calibration has been routinely checked against a similar sample of *n*-heptane. Repeated checks against benzene give the same bubbler constant. The use of such a standard of known purity removes any question of the purity of the sample used as a primary standard. Less trouble is also experienced in the actual determination, using any material whose boiling point is considerably above any temperature used in the calibration. Any stable liquid, the surface tension of which is accurately known, could be used.

VII. SUMMARY AND CONCLUSIONS

The parachor has proven to be one of the most fruitful of the many physical properties whose correlation with the structure of organic compounds has been attempted. It makes use of surface tension, as related to a summation of the internal forces of a liquid, in an attempt to measure molecular volumes of liquids in corresponding states.

It was first considered to be strictly an additive function, but it has been found to be susceptible to minor as well as major changes in structure. Once these structural variations have been evaluated, the parachor becomes of greater rather than of less value. A number of such variations have been evaluated, such as (*1*) chain branching, (*2*) the ethylenic and carbonyl linkages, (*3*) tertiary

TABLE 25

Recommended parachor values[a]

GROUP	INCREMENT
CH_2 in —$(CH_2)_n$	
$n < 12$	40.0
$n > 12$	40.3[b]
C	9.0
H	15.5
in OH	10.0
in HN	12.5
O	19.8
O_2 in esters	54.8
N	17.5
S	49.1
P	40.5
F	26.1
Cl	55.2
Br	68.0
I	90.3
Se	63
Si	31
Al	55
Sn	64.5
As	54
Ethylenic bond	
Terminal	19.1
2,3-Position	17.7
3,4-Position	16.3
Triple bond	40.6
Carbonyl bond in ketones[c]:	
$R + R' =$ 2	22.3
3	20.0
4	18.5
5	17.3
6	17.3
7	15.1
8	14.1
9	13.0
10	12.6
Single bond	0.0
Semipolar bond	0.0
Singlet linkage	−9.5
Hydrogen bridge	−14.4[d]
Chain branching, per branch	−3.7[e]
Secondary-secondary adjacency	−1.6
Secondary-tertiary adjacency	−2.0
Tertiary-tertiary adjacency	−4.5
Alkyl groups[f]	
1-Methylethyl	133.3
1-Methylpropyl	171.9
1-Methylbutyl	211.7
2-Methylpropyl	173.3
1-Ethylpropyl	209.5
1,1-Dimethylethyl	170.4
1,1-Dimethylpropyl	207.5
1,2-Dimethylpropyl	207.9
1,1,2-Trimethylpropyl	243.5
Position differences in benzene:	
Ortho–meta	1.8–3.4
Meta–para	0.2–0.5
Ortho–para	2.0–3.8
Ring-closure	
3-membered ring	12.5
4-membered ring	6.0
5-membered ring	3.0[g]
6-membered ring	0.8[g]
7-membered ring	4.0
Tertiary alcohols[h]	

[a] Average values.

[b] Somewhat greater beyond 20 —CH_2—.

[c] See table 11.

[d] Includes any ortho effect.

[e] Varies from −2.1 to −6.5.

[f] Complete group, including branching.

[g] See also tables 16 and 17.

[h] See table 13.

branching, (*4*) the semipolar bond, (*5*) the hydrogen bridge, (*6*) ring-closure, and (*7*) position isomerism in alkylbenzenes. Others remain to be studied.

The parachor has been shown to be related to various other fundamental constants, such as critical temperature and pressure, molecular refraction, and viscosity.

The parachor has been determined for solids in solution. This determination presents several difficulties and warrants further study.

The technique of measurement is not difficult. Several relatively simple modifications have been made in the apparatus used in early work which increase the ease of measurement as well as the overall precision and accuracy.

A catalogue of parachors of organic liquids and typical examples of determinations in solution are given in Appendix I and Appendix II.

A compilation of parachor values is given in table 25.

The author wishes to acknowledge gratefully the contribution to the study of the parachor in this laboratory by his associates and graduate students over the past fifteen years. He particularly wishes to acknowledge that of Mrs. Katherine Owen Smart, who was associated with all of the earlier work, and the more recent work, some of it previously unpublished, of Dr. Thomas P. Johnston, Dr. Raymond E. Donaldson, and Dr. A. Eugene Robinson. He also wishes to express his appreciation to the University Center in Georgia and through them to the Carnegie Foundation of New York for a grant-in-aid in support of the literature search for compiling the catalogue of parachors. Finally, his thanks go to Professor Charles T. Lester and to Miss Mary Nancy Green, who was primarily responsible for this search.

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APPENDIX I: A CATALOGUE OF PARACHORS OF ORGANIC COMPOUNDS

A. *Table of contents*

B. Preface

While no claim is made for the completeness of the catalogue, complete coverage of the literature through 1950 was attempted. Where several observers have reported upon the same compound, no attempt has been made to evaluate the relative validity of the determinations; hence the catalogue is not a table of selected values. Many experimenters report a series of determinations at several temperatures for each compound. In such cases values for two temperatures have been recorded in the tables. The values reported have been chosen, when possible, to give a mean parachor approximately the mean of all the values given in the reference cited.

No absolute rules can be given for choosing the most valid values beyond those used in the evaluation of any group of data. The excellent correlations obtained between observed and calculated values for many compounds present the opportunity of a reasonable differentiation upon this basis in most cases. While the parachor is not absolutely constant with temperature, the temperature coefficient for non-associated liquids is very small. Consequently, observed values checking well with calculated values and with little or no temperature coefficient may usually be considered superior.

Thomson (see reference 62 on page 585) points out that even the basic values for the paraffins show what he considers to be considerable uncertainty. He uses for an example the different values which have been recorded for *n*-octane from different sources. In Appendix I ten independent parachor values are given for *n*-octane ranging from 347.2 to 351.2, a spread over 1 per cent. However, five observers report values at more than one temperature and with a temperature differential no greater than 0.1 parachor unit in 350. These would appear to be good determinations. The average of these values is 351.86; rounded off to 351.9 this may be considered a reliable value. The maximum deviation of the five determinations from the average is 0.12 per cent. Parachor values for compounds known to be of high purity are probably valid to about this degree (0.1 per cent). Although a number of observers report data with a precision apparently greater than this, a greater accuracy is not usually claimed.

Unfortunately, in many cases the purity of the sample used is not indicated. Where such information is given it should carry considerable weight. If a series of homologs is being considered, the values which give a consistent picture for the whole series should be preferred; that is, values showing a constant increment or a regular change in the increment as the series is extended.

C. Values

Table 26 contains the values for the parachors of many organic compounds. Whenever the temperature is not given in the column headed "surface tension," the value in the first column under this heading was obtained at 20°C., while the value in the second column under this heading was obtained at 30°C. The temperature for which the value of the parachor was calculated is the same as that given for the surface tension, unless otherwise noted. In those cases where the value of the surface tension is given at two temperatures and only one value is given for the parachor, the latter is an average value.

TABLE 26

Parachors of organic compounds

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Hydrocarbons: alkanes				
CH_4	Methane	12.8 (−161.3°)		72.6	(154)
C_2H_6	Ethane	16.25 (−89.1°)	14.48 (−78.8°)	110.5	(125, 207)
C_3H_8	Propane	16.96 (−53.7°)	15.50 (−43.9°)	150.8	(125, 207)
C_4H_{10}	*n*-Butane	12.58 (18.7°)	11.28 (29.7°)	190.3	(28, 143)
C_5H_{12}	*n*-Pentane	15.97		231.0	(161)
		16.82 (13.2°)	16.18 (21.8°)	231.6 232.0	(231)
		15.98		230.7	(252)
		15.97		231.0	(161)
	2-Methylbutane	15.54 (15°)	15.00	230.0	(75, 210)
		14.97		229.7	(252)
C_6H_{14}	*n*-Hexane	17.37 (30°)	16.35 (40°)	270.7 270.8	(161)
				270.1	(189, 207)
		18.43	16.27 (40°)	270.4	(71, 88)
		13.34 (62.5°)		266.8	(76)
		18.42	17.40	270.4	(75, 210)
		18.46 (21.1°)	18.29 (23.5°)	271.5 271.8	(231)
		18.57 (18.5°)	16.26 (41.4°)	271.1 270.7	(231)
	2-Methylpentane	18.41		270.7	(252)
				269.2	(129)
	3-Methylpentane	18.12	17.08	267.9	(161)
		18.10		267.6	(252)
	2,2-Dimethylbutane			266.4	(129)
		16.18		266.4	(254)
	2,3-Dimethylbutane			266.2	(129)
		17.43		266.2	(254)

C_7H_{16}..........	*n*-Heptane	20.31	18.32 (40°)	311.34	311.36	(161)
		20.50 (19.5°)	18.33 (41.2°)	312.1	311.5	(231)
		20.26		310.8		(252)
		19.8	18.32 (40°)	309.3		(107, 207)
		20.28		310.8		(47, 143)
		20.25	19.6 (27°)	310.8	310.8	(129)
	2-Methylhexane	19.17	18.8 (25°)	308.8	309.2	(129)
		19.17		309.1		(43, 161)
		19.17		308.8		(252)
		19.27	18.30	309.6	309.5	(185)
	3-Methylhexane	19.56		306.6		(47, 143)
		19.56		307.3		(43, 161)
		19.82	18.79	307.9	307.7	(185)
	3-Ethylpentane	20.46	19.44	305.4	305.4	(185)
		20.16		304.2		(43, 161)
	2,2-Dimethylpentane	18.03	17.07	306.6	306.5	(185)
		18.05		306.5		(252)
		18.5	17.8	306.5	307.9	(129)
		17.80		305.3		(47, 143)
	2,3-Dimethylpentane	19.8	18.9 (28.2°)	304.1	303.5	(129)
		19.82		304.3		(43, 161)
		19.97	19.98	304.9	304.8	(185)
		19.82		304.1		(252)
	2,4-Dimethylpentane	19.15	17.18	307.6	307.5	(185)
		18.12		307.2		(252)
		18.1	17.9 (25.5°)	307.2	308.4	(129)
		18.12		307.5		(43, 161)
		17.93		305.5		(47, 143)
	3,3-Dimethylpentane	19.45	18.2 (32.8°)	303.5	302.7	(129)
		19.61	18.61	304.3	304.1	(185)
		19.44		303.4		(252)
	2,2,3-Trimethylbutane	18.86		302.5		(252)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Hydrocarbons: alkanes—*Continued*				
	2,2,3-Trimethylbutane—*Continued*	18.6		301.4	(47, 143)
		18.85	17.7 (32.2°)	302.5 302.3	(129)
		18.76	16.81	302.4 301.9	(185)
C_8H_{18}...........	*n*-Octane	21.80	20.75	351.1 351.0	(161)
		21.77		350.3	(93, 143)
		21.31 (15.5°)	18.56 (46.3°)	347.2	(167, 88)
		21.31 (15.5°)		347.4	(76)
		20.75 (30°)	18.82 (50°)	350.96 351.0	(161)
		21.76	20.77	351.2 351.2	(40)
		21.26 (23.5°)	19.66 (40.7°)	350.4 350.5	(231)
		21.71		350.6	(252)
		22.27 (15.0°)		351.0	(75, 210)
		21.7	20.7 (29.4°)	350.6 350.6	(129)
	2-Methylheptane	20.61	19.68	348.8 348.8	(40)
		20.81	19.72	349.4	(161)
			19.52 (34.3°)	348.7	(184, 143)
	3-Methylheptane	21.31	20.34	347.7	(161)
		21.3	19.9 (30.9°)	347.4 345.9	(129)
		20.39		344.7	(222)
		21.19	20.24	347.3 347.4	(40)
			20.34	347.7	(161)
		21.29		347.4	(252)
	4-Methylheptane	21.04	20.08	347.3 347.3	(40)
		21.15	20.09	347.6	(161)
	3-Ethylhexane		20.61	345.0	(161)
		21.54	20.57	345.0 345.0	(40)

	21.62		345.0		(161)
2,2-Dimethylhexane	19.64	18.69	346.1	346.0	(40)
2,3-Dimethylhexane	21.22		344.0		(252)
	21.03	20.06	343.5	343.4	(40)
	21.2	19.55 (37.9°)	344.0	343.9	(129)
	21.22		344.1		(43, 161)
2,4-Dimethylhexane	19.97		345.2		(222)
	19.97		344.9		(43, 161)
	20.08	19.12	345.4	345.3	(40)
2,5-Dimethylhexane	19.67	18.74	347.0	347.1	(40)
	19.80		346.8		(252)
	19.04		343.5		(222)
	19.80		347.2		(43, 161)
	21.95 (0°)		345.5		(93, 143)
	20.24 (15.1°)	17.99 (40.9°)	346.9	347.9	(231)
3,3-Dimethylhexane	20.64	19.72	343.0	343.1	(40)
3,4-Dimethylhexane	21.62	20.70	342.5	342.7	(40)
	21.72 (21.2°)	17.80 (61.9°)	342.9	341.9	(231)
	21.70		342.4		(252)
	21.70		342.6		(43, 161)
3-Ethyl-2-methylpentane	21.54	20.58	338.4	338.2	(40)
3-Ethyl-3-methylpentane	22.00	21.4	340.0	340.3	(129)
	22.0	21.06	344.0	344.2	(40)
	22.02		340.0		(252)
2,2,3-Trimethylpentane	20.69	19.76	340.3	340.3	(40)
	20.80		340.4		(252)
2,2,4-Trimethylpentane	18.80	17.87	343.9	343.8	(40)
	18.82		343.7		(252)
	18.85	19.95	343.7	344.0	(129)
2,3,3-Trimethylpentane	21.62	20.65	339.3	339.1	(40)
2,3,4-Trimethylpentane	21.18	20.23	340.9	340.8	(40)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Hydrocarbons: alkanes—*Continued*					
C_9H_{20}	*n*-Nonane	22.92	21.92	391.1	391.1	(161)
		22.80 (20.6°)	20.79 (41.4°)	391.6	390.3	(231)
		22.77	21.85	390.4	390.6	(185)
		22.91		390.5		(252)
		21.11 (18.8°)	18.88 (42.9°)	386.7	386.6	(231)
		22.0	22.0 (29.4°)	390.5	390.5	(129)
	2,3-Dimethylheptane	—		373.1		(43, 161)
	2,4-Dimethylheptane	20.49		381.1		(43, 161)
		20.49		382.4		(222)
	2,5-Dimethylheptane	21.09		384.9		(43, 161)
		21.09		384.1		(222)
	3,3-Dimethylheptane	23.75	22.83	376.3	376.5	(185)
	2,2,3-Trimethylhexane	21.86	20.98	380.4	380.5	(185)
	2,2,4-Trimethylhexane	20.51	19.67	381.5	381.6	(185)
	2,2,5-Trimethylhexane	20.03	19.16	383.8	384.0	(185)
	2,3,3-Trimethylhexane	22.41	21.49	378.1	378.3	(185)
	2,3,5-Trimethylhexane	21.27	20.37	381.6	381.8	(185)
		21.17		382.9		(222)
	2,4,4-Trimethylhexane	21.17	20.34	379.4	379.9	(185)
	3,3,4-Trimethylhexane	23.27	22.31	378.1	378.2	(185)
	2,2,3,3-Tetramethylpentane	23.39	22.48	372.8	373.0	(185)
	2,2,3,4-Tetramethylpentane	21.98	21.12	375.9	376.1	(185)
	2,2,4,4-Tetramethylpentane	20.37	19.46	378.7	378.6	(185)
	2,3,3,4-Tetramethylpentane	23.31	22.44	373.4	373.6	(185)
$C_{10}H_{22}$..........	*n*-Decane	23.92	22.92	431.2	431.1	(161)

		23.84 (19.0°)	21.90 (41.4°)	430.2	430.3	(231)
		24.41 (15.0°)	23.91 (20.0°)	429.7		(75, 210)
	2,4-Dimethyloctane	21.79		422.9		(43, 161)
		21.79		423.0		(222)
	2,7-Dimethyloctane	22.78 (15.0°)	22.22 (20.0°)	426.9		(75, 210)
		(159.1°)		422.7		(189, 207)
		22.24		427.8		(72, 207)
		22.22		426.4		(43, 161)
		22.85 (16.3°)	18.65 (62.1°)	425.5	424.4	(231)
		21.56 (24.2°)	18.55 (62.1°)	425.5	426.3	(231)
	4,5-Dimethyloctane	23.28 (21.5°)	19.85 (60.0°)	419.7	419.2	(231)
	2,4-Dimethyloctane	23.34 (22.0°)	19.87 (60.5°)	417.3	416.6	(231)
	2,4,6-Trimethylheptane	21.18		422.9		(222)
$C_{11}H_{24}$..........	*n*-Undecane	24.71	23.79	470.6	470.9	(161)
		24.05 (26.3°)	22.73 (40.8°)	470.7	470.5	(231)
	2,4,7-Trimethyloctane	22.26 (26.3°)		461.8		(222)
$C_{12}H_{26}$..........	*n*-Dodecane	25.41 (26.3°)	24.51	510.1	510.8	(161)
		25.53 (18.5°)	23.32 (41.5°)	510.2	509.7	(231)
$C_{13}H_{28}$..........	*n*-Tridecane	25.87 (21.3°)	22.30 (61.9°)	550.7	550.4	(231)
$C_{14}H_{30}$..........	*n*-Tetradecane	26.53 (21.5°)	23.15 (60.2°)	591.3	591.5	(231)
$C_{15}H_{32}$..........	*n*-Pentadecane	26.97 (22.6°)	23.57 (62.0°)	631.1	631.8	(231)
$C_{16}H_{34}$..........	*n*-Hexadecane	27.52 (21.1°)	23.96 (62.1°)	670.6	671.8	(231)
$C_{26}H_{54}$..........	*n*-Hexacosane	24.79 (91.7°)	23.95 (102.2°)	1082		(188, 143)
$C_{32}H_{66}$..........	*n*-Dotriacontane	27.2 (73.2°)	26.4 (83.7°)	1322		(88)
$C_{60}H_{122}$..........	*n*-Hexacontane	24.18 (115.4°)		2480		(188, 143)

Hydrocarbons: cycloalkanes and bicyclic compounds

	5-membered ring				
C_5H_{10}..........	Cyclopentane	23.30 (13.5°)		205	(58)
C_6H_{12}..........	Methylcyclopentane	—		242.8	(105, 207)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
Hydrocarbons: cycloalkanes and bicyclic compounds—*Continued*						
	6-membered ring					
C_6H_{12}	Cyclohexane	23.94 (33.0°)		242.1		(175)
		25.53 (13.5°)		240.1		(58)
		26.9 (10.0°)		239.3		(93, 143)
		24.95	23.75	241.7	241.7	(185)
		16.9 (80.0°)		237.6		(76)
		25.64 (15.0°)	24.99 (20.0°)	241.8		(75, 210)
C_7H_{14}	Methylcyclohexane	24.21 (13.5°)		280		(58)
		24.43 (15.0°)	23.82 (20.0°)	282		(75, 210)
		23.68	22.62	281.6	281.6	(185)
C_8H_{16}	Ethylcyclohexane	25.67	24.57	320.6	320.7	(185)
	1,1-Dimethylcyclohexane	22.14	23.07	318.5	318.4	(185)
				316.1		(105, 207)
	cis-1,2-Dimethylcyclohexane	25.72	24.66	317.4	317.3	(185)
	trans-1,2-Dimethylcyclohexane	24.05	23.09	320.3	320.3	(185)
	1,2-Dimethylcyclohexane	25.53 (13.5°)		319		(58)
	cis-1,3-Dimethylcyclohexane	23.12	22.15	321.3	321.3	(185)
	trans-1,3-Dimethylcyclohexane	24.66	23.66	318.7	318.8	(185)
	1,3-Dimethylcyclohexane	24.31 (13.5°)		321		(58)
	cis-1,4-Dimethylcyclohexane	24.44	23.47	318.8	319.0	(185)
	trans-1,4-Dimethylcyclohexane	23.02	22.00	322.7	322.4	(185)
	1,4-Dimethylcyclohexane	24.06 (13.5°)		321		(58)
C_9H_{18}	*n*-Propylcyclohexane	26.33	25.31	360.4	360.4	(185)
	Isopropylcyclohexane	26.48	25.50	357.0	357.1	(185)
	1,1,3-Trimethylcyclohexane	23.51	22.56	356.9	356.9	(185)
	1,3,4-Trimethylcyclohexane	24.76 (13.5°)		356		(58)

$C_{10}H_{20}$	*n*-Butylcyclohexane	27.03	26.02	400.3	400.3	(185)
	Isobutylcyclohexane	25.84	24.87	397.7	397.7	(185)
	sec-Butylcyclohexane	27.46	26.52	397.4	397.6	(185)
	tert-Butylcyclohexane	26.66	25.71	394.6	394.7	(185)
$C_{12}H_{22}$	Dicyclohexyl	33.24 (15.9°)	30.56 (41.2°)	448.8	448.4	(238)
	7-membered ring					
C_7H_{14}	Cycloheptane	27.84 (13.5°)		278		(58)
C_8H_{16}	Methylcycloheptane	27.12		317		(58)
	8-membered ring					
C_8H_{16}	Cycloöctane	29.90 (13.5°)		314.2		(58)
		30.17 (17.0°)	25.35 (61.2°)	315.8		(186)
C_9H_{18}	Methylcycloöctane	29.2 (13.5°)		353		(58)
	Miscellaneous					
C_8H_{14}	2-Methylbicyclo[1,2,2]heptane	27.93 (20.5°)		296.4		(108)
C_9H_{16}	2-Methylbicyclo[2,2,2]octane	28.28 (40.5°)		329.9		(104)
$C_{10}H_{18}$	Decahydronaphthalene	30.6 (43.5°)	29.8 (51.0°)	371.6	371.7	(128)
	trans-Decahydronaphthalene	29.89	24.82 (70.0°)	371.3	370.1	(193, 113)
	cis-Decahydronaphthalene	32.18	26.82	366.9	365.9	(193, 113)
$C_{16}H_{32}$	Methylcyclopentadecane	32.11 (20.3°)	28.56 (60.9°)	621.3	621.9	(186)
	Hydrocarbons: alkenes and alkadienes					
C_2H_4	Ethylene	15.22 (−97.2°)	13.66 (−88.3°)	99.5		(125, 207)
		17.60 (−106.4°)	16.42 (−100.2°)	100.5	100.4	(252)
		17.66 (−107.0°)	16.10 (−99.3°)	100.5	100.1	(204)
C_3H_4	Allylene	22.61 (−52.6°)	20.95 (−43.9°)	122.9		(125, 207)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Hydrocarbons: alkenes and alkadienes—*Continued*				
C_3H_6	Propylene	18.93 (−62.0°)	17.39 (−51.5°)	139.9	(125, 207)
		2.4 (62.1°)	0.94 (77.8°)	151.2 148.3	(255)
C_5H_{10}	Pentene	(36.8°)		218.2	(189, 207)
	2-Methyl-2-butene	17.26		216.9	(92, 143)
C_6H_{10}	1,5-Hexadiene	(58.4°)		248.2	(189, 207)
		19.42 (14.3°)	16.46 (43.1°)	248.0 248.9	(96)
C_8H_{16}	3-Methyl-2-heptene	22.27		333.7	(222)
	2,4-Dimethyl-4-hexene	21.64		330.6	(222)
	2,5-Dimethyl-2-hexene	21.58		332.6	(222)
C_9H_{18}	2,4-Dimethyl-4-heptene	22.40		372.9	(222)
	2,5-Dimethyl-4-heptene	22.89		373.6	(222)
	2,3,5-Trimethyl-2-hexene	21.64		370.5	(222)
$C_{10}H_{20}$	2,4-Dimethyl-4-octene	23.60		412.0	(222)
	2,4,6-Trimethyl-3-heptene	22.12		413.2	(222)
$C_{11}H_{22}$	2,4,7-Trimethyl-4-octene	23.54		450.3	(222)
	Hydrocarbons: unsaturated cyclic compounds				
	4-membered ring				
C_7H_{12}	Isopropylidenecyclobutane	23.7 (20.3°)		273.4	(108)
	5-membered ring				
C_5H_8	Cyclopentene	23.56 (13.5°)		193	(58)
C_6H_{10}	1-Methyl-1-cyclopentene	25.97		234	(58)
	Methylenecyclopentane	24.27 (20.8°)	21.94 (42.7°)	234.6 236.0	(230)
C_8H_{20}	Dimethylfulvene	31.46		285.2	(108)

	6-membered ring				
C_6H_{10}	Cyclohexene	27.72 (13.5°)		230	(58)
	Methylenecyclohexane	25.96 (17.5°)	23.47 (40.9°)	268.1 269.1	(230)
		25.79		269.6	(108)
	1-Methyl-1-cyclohexene	27.20 (13.5°)		267	(58)
	1-Methyl-3-cyclohexene	26.52		270	(58)
C_8H_{14}	1-Methyl-3-methylenecyclohexane	25.09 (16.3°)	22.54 (42.1°)	310.7 311.2	(230)
	1-Methyl-4-methylenecyclohexane	25.13 (15.9°)	20.68 (60.9°)	309.6 310.5	(230)
	1,4-Dimethyl-1-cyclohexene	25.47 (13.5°)		304.2	(58)
C_9H_{16}	1,3,4-Trimethyl-3-cyclohexene	26.38		345.7	(58)
$C_{13}H_{16}$	Benzalcyclohexane	36.65		441.5	(108)
	7-membered ring				
C_7H_{12}	Cycloheptene	28.28 (13.5°)		266.2	(58)
C_8H_{14}	1-Methyl-1-cycloheptene	28.12		305.2	(58)
	8-membered ring				
C_8H_{14}	Cycloöctene	29.90 (13.5°)		304	(57)
C_9H_{16}	1-Methyl-1-cycloöctene	29.73 (13.5°)		342.3	(57)
	Miscellaneous				
$C_{10}H_{16}$	2-Methylene-*trans*-hexahydrohydrindene	28.71 (21.3°)	24.98 (63.0°)	364.5 365.2	(230)
$C_{11}H_{18}$	2-Methylene-*trans*-decalin	30.81 (20.5°)	26.99 (61.2°)	398.1 398.7	(230)
	Hydrocarbons: alkynes				
C_2H_2	Acetylene	19.28 (−81.8°)	17.16 (−70.9°)	88.6	(125, 207)
C_8H_{14}	1-Octyne	23.12 (23.0°)	21.51 (39.0°)	327.4	(249, 207)
C_9H_{16}	3-Nonyne	26.2		363.8	(221)
$C_{10}H_{18}$	3-Decyne	26.8 (13.8°)		405	(221)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
		Hydrocarbons: alkynes—*Continued*				
$C_{11}H_{12}$	Phenylpropylacetylene	35.3 (16.0°)		382		(221)
$C_{11}H_{20}$	1-Undecyne	27.56 (20.3°)	26.04 (36.6°)	404.5		(249, 207)
$C_{12}H_{14}$	Butylpentylacetylene	27.8 (16.0°)		445		(221)
		33.6 (16.0°)		421		(221)
		Aromatic hydrocarbons				
C_6H_6	Benzene	28.88	29.55 (15.0°)	205.7		(75, 210)
		28.87	27.49	206.1	206.1	(41)
		28.86	27.56	206.0		(93, 143)
		26.41 (40.0°)	24.97 (50.1°)	207.6	207.4	(321)
		20.28 (80.0°)	18.02 (100.0°)	206.3		(166, 207)
		20.28 (80.0°)		204.0		(76)
		(79.9°)		206.1		(189, 207)
C_7H_8	Toluene	28.53	27.32	245.7	245.7	(41)
		28.52	29.10 (15.0°)	245		(75, 210)
		28.43		246.0		(182, 207)
		28.72 (18.7°)	26.01 (41.2°)	245.9	245.3	(232)
		24.94 (50.1°)	24.01 (60.2°)	246.2		(21)
		34.3 (−21.0°)		246.2		(76)
		27.39 (21.2°)	26.73 (27.1°)	246.9		(248, 207)
		—		246.5		(132, 207)
		(109.8°)		245.5		(189, 207)

C_8H_{10}...........	Ethylbenzene	29.04	27.93	284.3	284.4	(41)
		29.20	28.14	284.0		(75, 210)
		28.97 (22.1°)	26.86 (40.5°)	284.5	284.4	(232)
		— (135.9°)		283.0		(189, 207)
				283.8		(132, 207)
		27.20 (40.0°)	24.80 (60.2°)	285.4	285.1	(21)
	o-Xylene	30.03	28.93	282.4	282.5	(41)
		— (141.1°)		283.3		(189, 207)
				283.3		(132, 207)
	m-Xylene	28.63	27.54	284.2	284.3	(41)
		28.63	27.56	284.0		(75, 210)
		28.10 (18.4°)	27.41 (29.4°)	284.6		(248, 207)
		28.75 (8.0°)	23.82 (55.0°)	285.1		(180, 207)
		— (139.2°)		283.8		(189, 207)
				284.3		(132, 207)
	p-Xylene	28.31	27.22	284.5	284.6	(41)
		28.36	27.29	283.8		(75, 207)
		29.1 (25.7°)		287.5		(76)
		— (138.1°)		283.8		(189, 207)
				283.8		(132, 207)
C_9H_8............	Indene	37.4 (28.5°)	36.6 (34°)	290.2	290.1	(128)
		36.99 (30.5°)		284.9		(170)
C_9H_{12}...........	*n*-Propylbenzene	28.99	27.91	323.6	323.7	(41)
		29.01	28.02	323.1		(75, 207)
		29.01 (22.5°)	26.92 (41.3°)	323.5	323.5	(232)
		28.26 (23.6°)	26.39 (41.2°)	323.5	323.1	(232)
		28.71 (20.8°)	26.60 (41.1°)	323.0	323.2	(232)
		— (158.7°)		322.0		(189, 207)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Aromatic hydrocarbons—*Continued*				
C_9H_{12}..........	Isopropylbenzene	28.20	27.17	321.4 321.6	(41)
(*continued*)		28.64 (13.9°)	25.75 (41.2°)	320.8 320.7	(232)
	o-Ethyltoluene	30.20	29.13	319.9 320.1	(41)
	m-Ethyltoluene	29.07	27.97	322.8 322.9	(41)
	p-Ethyltoluene	28.84	27.73	323.3 323.3	(41)
		— (161.8°)		321.7	(189, 207)
	Mesitylene	28.83	27.79	321.9 322.1	(41)
		28.51	25.5 (50°)	320.8	(93, 143)
		30.3 (0.0°)		320.2	(76)
		— (165.0°)		320.5	(189, 207)
				320.8	(132, 207)
	1,2,3-Trimethylbenzene	31.27	30.25	317.6 318.0	(41)
	1,2,4-Trimethylbenzene	29.71	28.67	320.2 320.6	(41)
		29.61	28.61	320.3 320.5	(40)
$C_{10}H_8$..........	Naphthalene	32.03 (80.8°)		312.3	(171)
		32.26 (80.1°)		312.5	(11)
$C_{10}H_{10}$..........	1,2-Dihydronaphthalene	37.6 (35°)	36.6 (45.0°)	324.3 324.7	(128)
$C_{10}H_{12}$..........	Tetrahydronaphthalene	35.5 (28.5°)	32.8 (58.0°)	335.9 336.4	(128)
$C_{10}H_{14}$..........	Hexahydronaphthalene	34.5	31.37	345 346	(39)
		35.46 (21.5°)	32.38 (50°)	334.0 334.0	(39)
	o-Diethylbenzene	30.30	29.25	357.6 357.8	(41)
	m-Diethylbenzene	28.17	28.11	361.0 361.0	(41)
	p-Diethylbenzene	29.00	27.97	361.4 361.5	(41)
	n-Butylbenzene	29.23	28.19	362.8 363.0	(41)
		28.97	26.84 (41.8°)	362.0 361.9	(232)

		29.14 (18.5°)	26.85 (41.5°)	362.3	362.0	(232)
		29.25	28.19	361.7		(75, 210)
		28.10 (40°)	25.81 (60.2°)	361.0	360.3	(21)
	Isobutylbenzene	27.47	26.50	360.2	360.4	(41)
	sec-Butylbenzene	28.53	27.53	359.8	360.1	(41)
	tert-Butylbenzene	28.13	27.14	356.7	356.9	(41)
				360.7		(132, 207)
	Cymene	— (170.2°)		356.9		(189, 207)
	2-Ethyl-1,4-dimethylbenzene	29.59	28.54	355.1	355.1	(40)
	Durene	21.14 (108.5°)		355.6		
$C_{10}H_{16}$	Octahydronaphthalene	32.73	30.22	355.4	358.6	(39)
$C_{10}H_{18}$	Decahydronaphthalene	30.02	27.59	369.4	370.6	(39)
$C_{11}H_{10}$	1-Methylnaphthalene	38.9 (42.5°)		353.8		
$C_{11}H_{16}$	*n*-Amylbenzene	28.99 (25.2°)	27.41 (41.7°)	402.0	401.9	(232)
		29.05 (24.4°)	27.45 (41.1°)	402.0	402.1	(232)
	Amylbenzene	29.65	28.61	402.0		(75, 210)
		28.47 (40°)	26.56 (60.2°)	400.1		(21)
	1,4-Dimethyl-2-propylbenzene	29.13	28.11	395.1	395.1	(40)
	Pentamethylbenzene	23.61 (108.1°)	15.63 (207.4°)	390.0		(45, 143)
$C_{12}H_{10}$	Acenaphthene	31.36 (128.6°)	26.60 (178.7°)	364.1	364.2	(45, 12)
$C_{12}H_{18}$	*n*-Hexylbenzene	29.79 (23.1°)	28.09 (40.1°)	442.2	441.8	(232)
		30.14	29.17	442.0		(75, 210)
	2-Butyl-1,4-dimethylbenzene	29.24	28.44	434.3	434.2	(40)
$C_{13}H_{12}$	Diphenylmethane	38.81 (29.9°)	38.28 (50.0°)	420.5	419.8	(68)
		37.56 (26.0°)		414.5		(73, 207)
		—		419.0		(132, 207)
$C_{13}H_{20}$	2-Amyl-1,4-dimethylbenzene	29.80	28.88	473.7	474.1	(40)
$C_{14}H_{10}$	Phenanthrene	37.24 (100.5°)		414.1		(11)
		36.34 (120.0°)		420.4		(171)
$C_{14}H_{14}$	1,1-Diphenylethane	37.67		449.8		(73, 207)
$C_{14}H_{22}$	2-Hexyl-1,4-dimethylbenzene	29.89	28.98	514.0	514.4	(40)
$C_{15}H_{16}$	Ditolylmethane	35.51		488.0		(73, 207)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Aromatic hydrocarbons—*Continued*					
$C_{15}H_{16}$	Diphenylpropane	37.15		484.6		(73, 207)
$C_{15}H_{22}$	2-Heptyl-1,4-dimethylbenzene	30.15	29.20	554.1	554.2	(40)
$C_{16}H_{24}$	1,4-Dimethyl-2-octylbenzene	30.82	30.06	596.0	594.7	(40)
$C_{19}H_{16}$	Triphenylmethane	32.66 (108.7°)	18.54 (278.7°)	580.2	577.3	(160, 68)
		35.10 (98.6°)	33.15 (117.6°)	586.2	586.2	(69)
	Acetals					
$C_3H_8O_2$	Methylal	21.93 (14.5°)	20.65 (24.2°)	190.4	190.3	(234)
		21.12	19.76	189.8		(75, 210)
$C_4H_{10}O_2$	Dimethylacetal	— (63.0°)		226.0		(189, 207)
		21.60	19.07 (41.3°)	228.1	228.0	(234)
$C_5H_{12}O_2$	Ethylal	21.41 (18.5°)	15.97 (59.7°)	269.2	268.5	(234)
$C_6H_{14}O_2$	Diethylacetal	21.26 (21.8°)	19.05 (41.5°)	307.7	306.9	(234)
		—		305.7		(114, 210)
		— (103.2°)		306.9		(189, 207)
$C_7H_{16}O_2$	*n*-Propylal	23.17 (21.3°)	19.43 (60.0°)	348.3	348.5	(234)
	Isopropylal	20.98 (20.3°)	15.14 (86.3°)	346.0	346.5	(234)
$C_8H_{18}O_2$	Di-*n*-propylacetal	23.09 (20.2°)	20.88 (41.5°)	386.1	386.2	(234)
$C_9H_{20}O_2$	*n*-Butylal	24.74 (17.4°)	18.76 (86.4°)	426.7	427.1	(234)
	Isobutylal	22.57 (21.0°)	16.83 (87.0°)	424.2	424.0	(234)
$C_{10}H_{22}O_2$	Di-*n*-butylacetal	24.26 (22.0°)	22.47 (41.3°)	465.2	465.4	(234)
	Diisobutylacetal	22.21 (22.3°)	20.46 (41.3°)	461.9	462.0	(234)
$C_{11}H_{24}O_2$	*n*-Amylal	25.92 (19.8°)	22.19 (60.8°)	506.5	506.6	(234)
$C_{13}H_{28}O_2$	*n*-Hexylal	27.30 (17.4°)	21.38 (87.0°)	586.5	588.5	(234)

Acids

CH_2O_2	Formic	37.18 (30.0°)	34.65 (50.0°)	94.0	94.5	(178)
		38.1 (9.2°)		92.7		(76)
				93.9		(64)
		37.58	36.49	93.2		(75, 210)
$C_2HCl_3O_2$	Trichloroacetic	27.8 (80.2°)	25.1 (117.5°)	241.3		(95, 143)
$C_2H_2Cl_2O_2$	Dichloroacetic	35.4 (25.7°)	30.3 (80.2°)	203.8		(95, 143)
$C_2H_3ClO_2$	Chloroacetic	33.3 (80.2°)	30.1 (118.5°)	168.3		(95, 143)
$C_2H_4O_2$	Acetic	27.63	24.65 (50.0°)	131.2		(93, 143)
				130.8		(134, 88)
		27.57 (20.1°)	25.36 (42.3°)	131.2	131.4	(239)
		23.46		125.9		(76)
		27.42	26.34 (30.8°)	131.0		(75, 210)
$C_3H_6O_2$	Propionic	26.7	23.7 (50.0°)	169.0		(93, 143)
		26.06 (25.0°)		170.0		(159)
		28.55 (2.5°)	14.9 (140.3°)	168.7		(88)
		27.24 (14.6°)	24.42 (42.1°)	169.2	169.5	(239)
		27.21 (15.0°)	26.70 (20.0°)	169.0		(75, 210)
$C_4H_6O_2$	Crotonic	— —		201.2		(78)
	Vinylacetic	29.46 (14.5°)	22.23 (87.3°)	197.3	197.9	(97)
	Cyclopropanecarboxylic	34.29 (22.4°)	30.13 (60.9°)	191.7	191.9	(99)
$C_4H_8O_2$	Butyric	26.21 (25.0°)		208.6		(159)
		26.26 (22.5°)	24.48 (42.0°)	209.0	209.2	(239)
		28.0 (8.6°)	21.7 (73.2°)	209.1		(88)
	Isobutyric	25.61 (15.1°)	22.96 (41.8°)	207.9	207.8	(239)
		25.2	22.4 (50.0°)	207.8		(93, 143)
$C_5H_8O_2$	Cyclobutanecarboxylic	33.43 (22.8°)	31.38 (40.3°)	228.3	227.8	(99)
$C_5H_8O_3$	Levulinic	39.7 (25.5°)	37.1 (60.1°)	258.6		(95, 143)
$C_5H_{10}O_2$	*n*-Valeric			247.0		(114, 210)
		27.29 (19.2°)	25.06 (41.7°)	248.4	248.2	(239)
	Isovaleric	24.90 (25.0°)		246.3		(159)
		25.55 (19.9°)	23.30 (43.4°)	247.2	247.1	(239)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Acids—*Continued*				
$C_6H_{12}O_2$.........	Caproic	27.49 (25.0°)		288.0	(159)
		26.2 (35.6°)	20.7 (100.8°)	287.2	(88)
$C_7H_{14}O_2$.........	Heptanoic	27.97 (25.0°)		327.2	(159)
$C_8H_{16}O_2$.........	Caprylic	28.34		367.4	(159)
		28.5 (16.1°)	22.8 (79.7°)	365.6	(88)
$C_{10}H_{20}O_2$........	Capric	27.7 (31.9°)	26.9 (50.5°)	447.4	(88)
$C_{11}H_{22}O_2$.........	Undecylenic	30.64 (25.0°)		478.2	(72, 143)
		28.5 (45.0°)	25.0 (88.5°)	532.8	(88)
		— —		522.5 (80.0°)	(112)
$C_{14}H_{28}O_2$........	Myristic	27.0 (76.2°)	25.7 (89.2°)	605.8	(88)
$C_{16}H_{32}O_2$........	Palmitic	28.6 (65.2°)	26.7 (89.2°)	693.2	(88)
		— —		668.0	(112)
$C_{17}H_{34}O_2$.........	Margaric	27.9 (66.9°)	24.4 (112.0°)	733.2	(88)
$C_{18}H_{30}O_2$........	α-Eleostearic	33.42 (50.0°)		741.0	(250)
	β-Eleostearic	31.04 (75.0°)		736.9	(250)
$C_{18}H_{34}O_2$........	2,3-Oleic	27.0 (90.0°)	26.89 (95°)	759.3 763.7	(192)
		— —		738.0	(112)
		27.94 (90°)	27.52 (95°)	765.1 766.9	
	Elaidic	26.56 (90°)	27.52 (95°)	760.4 764.9	(192)
$C_{18}H_{36}O_2$........	Stearic	— —		735.0	(112)
		26.99 (90.0°)	26.42 (95°)	777.8 778.9	
		28.9 (70.0°)	27.7 (87.5°)	778.0	(88)
$C_{22}H_{42}O_2$.........	Erucic	28.56 (90.0°)	27.77 (95°)	932.4 938.9	(192)
$C_{22}H_{42}O_2$.........	Brassidic	27.40 (90.0°)	27.28 (95°)	929.2 934.4	(192)
$C_{22}H_{44}O_2$.........	Behenic	27.77 (90.0°)	37.61 (95°)	950.1 951.4	(192)

Acid halides

$C_4H_4Cl_2O_2$.......	Succinyl chloride	38.75		281.8		(29)
C_7H_5ClO........	Benzoyl chloride			289.8		(190, 143)
$C_8H_4Cl_2O_2$.......	*s*-Phthalyl chloride	44.23 (15°)	36.20 (90°)	372.9	375.3	(54)
	as-Phthalyl chloride	35.88 (90°)		367.8		(54)
$C_8H_4F_2O_2$........	*s*-Phthalyl fluoride	34.63 (50.0°)		315.6		(32)
	as-Phthalyl fluoride	34.45 (50.0°)		315.4		(52)

Acid anhydrides

$C_4H_6O_3$..........	Acetic anhydride	33.14 (15.0°)	29.57 (45.0°)	225.4	226.5	(116)
		32.65	31.22	225.6		(75, 210)
$C_6H_{10}O_3$.........	Propionic anhydride	30.86 (15.0°)	27.52 (45.0°)	301.6	302.6	(116)
$C_8H_4O_3$..........	Phthalic anhydride	39.50 (130.0°)		295.1		(170)
$C_8H_{14}O_3$.........	Butyric anhydride	28.93	26.40 (45.0°)	379.2	380.2	(116)
$C_{12}H_{22}O_3$........	Hexanoic anhydride	28.26	26.04 (45.0°)	536.8	538.0	(116)

Primary alcohols

CH_4O...........	Methanol	—		88.8		(11)
		22.88 (15.2°)		87.9		(239)
		—		88.0	(20°)	(141)
		17.64 (70.0°)		88.2		(76)
		22.55	21.69	88.0		(75, 210)
		— (15°)	— (40.0°)	88.2	88.7	(2)
C_2H_6O...........	Ethanol	— (15°)	— (40.0°)	126.8	127.5	(2)
		—		127.3		(11)
		22.27	21.43	126.8		(93, 143)
		17.97 (80°)	11.34 (140°)	128.8	129.7	(205, 210)
		22.27		126.9		(182, 210)
		22.56 (16.8°)	20.76 (40.3°)	126.5	127.0	(239)
		22.50		126.6		(141)
		20.20 (40.0°)		126.5		(76)
		22.32	21.48	126.6		(75, 210)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Primary alcohols—*Continued*				
C_3H_6O..........	Allyl alcohol	— (15.0°)	— (40.0°)	153.9 154.2	(2)
		—		159.0	(79)
		—		159.3	(78)
		25.68	24.92	153.8	(75, 26)
		25.99 (14.8°)	22.82 (46.4°)	152.7	(165, 11)
		26.01 (17.1°)	23.81 (41.2°)	153.4 153.7	(239)
C_3H_8O..........	1-Propanol	23.91 (17.8°)	21.99 (41.6°)	165.0 165.3	(239)
		—		164.7 (20°)	(141)
		23.70	22.89	164.7	(75, 210)
		21.29 (46.3°)		165.0	(76)
		23.80	22.10 (40.8°)	165.4	(93, 143)
		23.82 (16.4°)	21.29 (46.3°)	165.8	(165, 11)
$C_3H_8O_2$..........	2-Methoxyethanol	20.42 (124.4°)		186.9	(53)
		31.82 (14.9°)	27.25 (61.5°)	186.1 187.3	(239)
$C_4H_{10}O$..........	1-Butanol	24.42 (17.4°)	22.14 (45.7°)	202.9	(167, 11)
		24.57	23.75	203.4	(75, 210)
		22.3		203.4	(141)
		25.76 (16.0°)	23.51 (41.9°)	205.3 205.4	(239)
	2-Methyl-1-propanol	23.25 (15.9°)	21.32 (41.3°)	202.1 202.6	(239)
		22.98	22.11	200.6	(75, 210)
		22.8	22.1	202.1	(93, 143)
$C_4H_{10}O_2$..........	2-Ethoxyethanol	28.46 (24.7°)	26.85 (40.3°)	224.9 224.9	(239)
$C_5H_{12}O$..........	1-Pentanol	21.5		243.3	(141)
		25.60	24.72	243.3	(75, 210)
		26.31 (14.3°)	23.94 (40.9°)	244.2 244.2	(239)
	3-Methyl-1-butanol	24.21 (19.3°)	22.31 (42.3°)	240.8 240.9	(239)
		23.65		241.1	(141)
		24.32	23.44	241.4	(75, 210)

$C_6H_{14}O$..........	1-Hexanol	25.66		278.2	(141)
		24.48	23.61	276.2	(75, 210)
		25.80 (25.0°)	23.50 (55.0°)	282.2	(84)
$C_6H_{14}O$..........	2-Methyl-1-pentanol	24.94 (25.0°)	22.57 (55.0°)	278.0 279.1	(84)
	3-Methyl-1-pentanol	26.28 (5.0°)	18.85 (105°)	277.2 281.1	(82)
	4-Methyl-1-pentanol	25.19 (5.0°)	18.28 (105°)	277.4 282.5	(82)
	2-Ethyl-1-butanol	25.90 (5.0°)	20.13 (85°)	272.4 277.2	(83)
	2,2-Dimethyl-1-butanol	26.01 (5.0°)	19.36 (85°)	274.2 277.2	(83)
$C_6H_{14}O_2$.........	2-*n*-Butoxyethanol	26.62 (17.9°)	23.17 (60.1°)	297.0 297.9	(239)
C_7H_8O..........	Benzyl alcohol	39.0	33.5 (80.0°)	259.6	(93, 143)
		38.30		257.8	(141)
$C_7H_{14}O$..........	*cis*-3-Methylcyclohexanol		28.80	289.25	(56)
	trans-3-Methylcyclohexanol		29.20	292.37	(56)
$C_7H_{16}O$..........	1-Heptanol	25.50		315.5	(141)
		24.42		313.4	(75, 210)
$C_8H_{10}O$..........	2-Phenylethanol	38.65		298.9	(141)
		40.39 (24.5°)	36.67 (59.9°)	303.0 303.3	(239)
$C_8H_{16}O$..........	2-Methyl-1-hepten-2-ol			345.5	(38, 210)
	cis-4-Methylcyclohexylcarbinol	30.11 (30.0°)	30.26	330.9 331.1	(56)
	trans-4-Methylcyclohexylcarbinol	28.89 (30.0°)	28.86	331.5 331.3	(56)
$C_8H_{18}O$..........	1-Octanol	26.71		358.4	(141)
		26.06	25.21	354.4	(75, 210)
		24.58		348.5 (0–50°)	(42)
	6-Methyl-1-heptanol	21.40		342.1 (0–50°)	(42)
	5-Methyl-1-heptanol	25.95		358.6 (0–50°)	(42)
	3-Methyl-1-heptanol	25.74		371.7 (0–50°)	(42)
	2-Methyl-1-heptanol	23.32		356.5 (0–50°)	(42)
$C_9H_{10}O$..........	Cinnamyl alcohol			324.4	(79)
$C_9H_{12}O$..........	3-Phenylpropyl alcohol	38.26		338.0	(141)
	2-Methyl-2-phenylethanol	35.60		331.3	(141)
$C_9H_{18}O$..........	2,5-Dimethyl-1-hepten-2-ol			383.2	(38, 210)
	cis-4-Isopropylcyclohexylcarbinol	30.21 (30.0°)	30.22	404.6 404.6	(56)
	trans-4-Isopropylcyclohexylcarbinol	29.75 (30.0°)	29.80	404.9 405.0	(56)
$C_9H_{20}O$..........	1-Nonanol	26.41		393.6	(141)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Primary alcohols—*Continued*					
$C_{10}H_{18}O$	*d*-Citronellol	27.42		417.5		(141)
				421.7		(38, 210)
	Geraniol	29.7 (40.0°)	27.0 (69°)	417.1	416.3	(128)
		29.57		409.0		(141)
	Nerol	29.9 (39.0°)	29.3 (46.0°)	416.8	416.5	(128)
$C_{10}H_{20}O$	*l*-Rhodinol			421.6		(38, 210)
$C_{10}H_{22}O$	1-Decanol	27.32		435.2		(141)
	Dihydrocitronellol	25.49		426.3		(141)
$C_{11}H_{22}O$	1-Undecen-10-ol	28.53		464.1		(141)
$C_{11}H_{24}O$	1-Undecanol	25.46		474.3		(141)
$C_{12}H_{26}O$	1-Dodecanol	26.06		504.8		(141)
$C_{13}H_{26}O$	Farnesol	30.09		586.1		(141)
	Secondary alcohols					
C_3H_8O	2-Propanol	21.68 (17.1°)	19.59 (41.9°)	164.4	164.4	(239)
		21.35	20.46	164.3		(75, 210)
$C_4H_{10}O$	2-Butanol	23.47	22.62	201.9		(75, 210)
$C_5H_{10}O$	1-Ethylallyl alcohol	— (14°)	— (26°)	228.1	228.0	(78)
	α,γ-Dimethylallyl alcohol	— (14°)	— (61°)	228.9	228.9	(78)
		— (15.0°)	— (40.0°)	230.2	230.4	(2)
	Cyclopentanol	32.06 (21.0°)	28.90 (62°)	216.4	218.3	(230)
$C_6H_{12}O$	Methyl-β-methylallylcarbinol	— (15.0°)	— (40.0°)	268.4	268.6	(2)
	α-Ethyl-γ-methylallyl alcohol or 4-hexen-3-ol	— (15.0°)	— (40.0°)	267.2	267.5	(2)
	Cyclohexanol	33.15 (33.5°)	25.96 (98.0°)	255.5	256.4	(175)
		32.36 (16.2°)	34.5 (20.0°)	254.9		(231, 70, 143)
	cis-dl-3-Methylcyclopentanol	42.77 (28.0°)		280		(60)
	trans-dl-3-Methylcyclopentanol	42.77 (28.0°)		280		(60)
	cis-l-3-Methylcyclopentanol	42.77 (28.0°)		280		(60)
	trans-l-3-Methylcyclopentanol	42.77 (28.0°)		280		(60)

$C_6H_{14}O$..........	2-Hexanol	24.25 (25.0°)	21.68 (55°)	279.6	280.5	(84)
	3-Hexanol	24.04 (25.0°)	21.50 (55°)	277.7	279.0	(84)
	2-Methyl-4-pentanol	22.63 (25.0°)	20.17 (55°)	277.6	278.5	(84)
$C_7H_{12}O$..........	α-Allyl-γ-methylallyl alcohol (1,5-heptadien-4-ol)	(15.0°)	(40.0°)	295.4	295.9	(2)
$C_7H_{14}O$..........	1-*n*-Butylallyl alcohol	—	—	305.9		(79)
	cis-3-Methylcyclohexanol		28.80	289.3		(56)
	trans-3-Methylcyclohexanol	29.18 (30.0°)	29.21	292.3	292.4	(56)
$C_8H_{18}O$..........	2-Octanol	25.83		357.3		(141)
		26.37	24.78 (40.0°)	360.4		(93, 143)
		22.97		350.2	(0–50°)	(42)
	3-Octanol	25.05		358.3	(0–50°)	(42)
	4-Octanol	25.43		356.4	(0–50°)	(42)
	3-Methyl-2-heptanol	25.82		357.2	(0–50°)	(42)
	4-Methyl-2-heptanol	24.53		361.0	(0–50°)	(42)
	5-Methyl-2-heptanol	25.48		360.7	(0–50°)	(42)
	6-Methyl-2-heptanol	24.93		360.8	(0–50°)	(42)
	2-Methyl-3-heptanol	25.51		354.6	(0–50°)	(42)
	4-Methyl-3-heptanol	24.67		363.4	(0–50°)	(42)
	5-Methyl-3-heptanol	24.76		355.4	(0–50°)	(42)
	6-Methyl-3-heptanol	23.74		368.2	(0–50°)	(42)
	3-Methyl-4-heptanol	25.94		352.1	(0–50°)	(42)
$C_9H_{18}O$..........	4-Propylcyclohexanol	31.22		364.5		(55)
$C_{10}H_{14}O$.........	4-Phenyl-2-butanol	35.75		374.9		(141)
$C_{10}H_{18}O$.........	Cyclopentylcyclopentanol	36.01 (22.1°)	32.08 (63.5°)	382.4	382.9	(230)
	Isopulegol	29.52		393.7		(141)
		—		392.2		(38, 210)
$C_{10}H_{20}O$.........	Menthol	22.54 (98.0°)	18.38 (150.0°)	404.7	398.1	(175)
		27.17 (60.0°)		416.1		(34)
$C_{11}H_{24}O$.........	2-Undecanol	27.08		473.1		(141)
$C_{14}H_{20}O$.........	Hexahydrobenzylphenylcarbinol	37.47		499.2		(225)

Tertiary alcohols

	Carbinols					
$C_4H_{10}O$..........	Trimethyl	19.98 (25°)	18.11 (45.0°)	201.3	201.7	(141)
		20.02 (26°)	19.10 (35.0°)	201.0		(75, 210)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Tertiary alcohols—*Continued*					
	Carbinols—*Continued*					
$C_5H_{12}O$..........	Ethyldimethyl	22.27 (25.0°)	20.36 (45.0°)	238.8	239.2	(151)
		22.77	21.84	238.0		(72, 210)
		15.2 (120°)		241.1		(93, 143)
$C_6H_{14}O$..........	Dimethylpropyl	22.58 (25.0°)	20.79 (45.0°)	277.7	277.8	(151)
	Diethylmethyl	24.12 (25.0°)	22.31 (45.0°)	275.6	276.5	(151)
		24.68 (25.0°)	22.92 (45.0°)	276.1	276.8	(81)
	Isopropyldimethyl	23.59 (25.0°)	21.67 (45.0°)	275.1	275.7	(81)
$C_7H_{16}O$..........	Butyldimethyl	23.78 (25.0°)	22.01 (45.0°)	316.9	317.4	(151)
	Ethylmethylpropyl	24.35 (25.0°)	22.60 (45.0°)	314.9	316.1	(151)
	Triethyl	25.20 (25.0°)	23.47 (45.0°)	311.2	312.9	(151)
$C_8H_{18}O$..........	Amyldimethyl	24.74 (25.0°)	22.86 (45.0°)	357.1	357.3	(164)
		25.24		361.1		(42)
	Butylethylmethyl	25.22 (25.0°)	23.33 (45.0°)	353.6	354.1	(164)
		25.71		352.9		(42)
		28.15		363.4		(222)
	Methyldipropyl	24.49 (25.0°)	22.77 (45.0°)	353.8	354.9	(151)
		25.00		353.1		(42)
	Diethylpropyl	25.58 (25.0°)	23.73 (45.0°)	351.2	352.2	(151)
$C_9H_{20}O$..........	Hexyldimethyl	25.45 (25.0°)	23.67 (45.0°)	398.3	398.9	(151)
	Amylethylmethyl	26.06 (25.0°)	24.19 (45.0°)	393.8	394.4	(164)
	Butylmethylpropyl	25.60 (25.0°)	23.65 (45.0°)	392.4	392.5	(164)
	Ethyldipropyl	25.18 (25.0°)	23.72 (45.0°)	389.1	391.5	(151)
$C_{10}H_{22}O$.........	Ethylhexylmethyl	26.15 (25.0°)	24.39 (45.0°)	433.8	434.7	(151)
	Amylmethylpropyl	25.73 (25.0°)	24.04 (45.0°)	431.0	432.2	(164)
	Dibutylmethyl	26.20 (25.0°)	24.23 (45.0°)	430.9	431.1	(164)
	Tripropyl	25.04 (25.0°)	23.44 (45.0°)	427.9	429.6	(151)

$C_{11}H_{16}O$	Benzylethylmethyl	32.91		360.6		(141)
$C_{11}H_{24}O$	Hexylmethylpropyl	26.08 (25.0°)	24.32 (45.0°)	472.8	473.6	(151)
$C_{12}H_{26}O$	Butylhexylmethyl	26.22 (25.0°)	24.43 (45.0°)	511.3	511.6	(151)
	Amylbutylethyl	26.58 (25.0°)	24.80 (45.0°)	506.2	507.6	(164)
$C_{13}H_{28}O$	Amylhexylmethyl	25.69 (25.0°)	25.06 (45.0°)	549.9	552.7	(151)
	Amylbutylpropyl	26.25 (25.0°)	24.64 (45.0°)	545.1	547.0	(164)
$C_{14}H_{30}O$	Amyldibutyl	26.82 (25.0°)	25.04 (45.0°)	584.4	585.6	(164)

Miscellaneous alcohols

$C_{10}H_{18}O$	Linaloöl	27.0 (43.5°)	25.9 (55.8°)	408.9	409.4	(128)
		27.98		408.6		(141)
	Terpineol	31.0 (34.5°)	30.0 (46.0°)	394.1	394.8	(128)
	α-Terpineol, m.p. 21°C.	30.18		367.8		(141)
	α-Terpineol, m.p. 22°C.	28.63		379.2		(141)
	Terpineol (commercial)	28.65		381.0		(141)
$C_{15}H_{28}O$	Nerolidol	28.02		583.5		(141)

Glycols

$C_2H_6O_2$	Ethylene glycol	32.33 (197.4°)		148.9		(53)
$C_3H_8O_2$	Trimethylene glycol	28.30 (214.2°)		189.3		(53)
$C_4H_{10}O_3$	Diethylene glycol	26.28 (244.3°)		248.4		(53)
$C_6H_{14}O_4$	Triethylene glycol	22.45 (278.3°)		350.9		(53)
$C_8H_{18}O_5$	Tetraethylene glycol	18.81 (307.8°)		453.7		(53)
$C_{10}H_{20}O_2$	*dl*-3,8-*m*-Menthanediol	36.8		401.6		(59)
$C_{10}H_{22}O_6$	Pentaethylene glycol	—		555.6		(53)
$C_{12}H_{26}O_2$	3,6-Diethyl-3,6-octanediol	27.12 (70.0°)	26.73 (75.0°)	513.9	514.2	(102)
$C_{12}H_{26}O_7$	Hexaethylene glycol	—		657.4		(53)
$C_{14}H_{30}O_2$	2,11-Dimethyl-2,11-dodecanediol	29.79 (65.0°)	29.39 (70.0°)	620.3	620.7	(102)
$C_{14}H_{30}O_8$	Heptaethylene glycol	—		759.1		(53)
$C_{17}H_{36}O_7$	3,11-Diethyl-3,11-tridecanediol	29.61 (65.0°)	29.31 (70.0°)	722.5	724.1	(102)
$C_{18}H_{38}O_2$	3,12-Diethyl-3,12-tetradecanediol	30.05 (65.0°)	29.63 (70.0°)	765.0	766.0	(102)
$C_{22}H_{46}O_2$	4,13-Dipropyl-4,13-hexadecanediol	28.32 (60.0°)	27.98 (65.0°)	914.5	916.0	(102)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Aldehydes				
$C_5H_{10}O$..........	Isovaleraldehyde	—		237.5	(190, 143)
$C_6H_{12}O_3$.........	Paraldehyde	— (124.1°)		299.0	(189, 207)
		—		298.5	(138, 207)
C_7H_6O..........	Benzaldehyde	37.42 (30.2°)	35.27 (50.0°)	256.2	(136, 207)
		40.04		254.0	(72, 207)
$C_6H_6O_2$..........	*o*-Hydroxybenzaldehyde	41.71 (30.0°)	37.83 (60.2°)	270.1 270.5	(21)
		42.0 (25.0°)	38.2 (51.8°)	267.6 268.3	(196)
	m-Hydroxybenzaldehyde	40.43 (130.4°)	38.11 (150.4°)	275.3 275.4	(21)
	p-Hydroxybenzaldehyde	44.42 (117.0°)	43.71 (127.0°)	275.6 276.3	(24)
		42.71 (130.4°)	41.59 (150.4°)	279.3 278.8	(21)
		45.1 (119.6°)	42.9 (136.7°)	278.3 278.0	(196)
$C_7H_{14}O$..........	*n*-Heptaldehyde	26.58	25.68	318.0	(75, 210)
$C_7H_6O_3$..........	Piperonal	— (43.2°)	— (53.4°)	305.9 307.1	(74)
$C_8H_8O_2$..........	*o*-Methoxybenzaldehyde	39.59 (52.0°)	37.38 (72.0°)	309.4 309.8	(24)
		40.4 (50.8°)	39.7 (79.4°)	312.0	(196)
	p-Methoxybenzaldehyde	43.7 (25.0°)		313.9	(196)
$C_8H_8O_3$..........	*o*-Vanillin	44.7 (50.6°)	39.8 (90.4°)	325.9	(196)
$C_{10}H_{16}O$.........	Citral	31.6 (39.0°)	29.8 (56.0°)	410.2 410.8	(128)
$C_{10}H_{18}O$.........	Citronellal	—		415.2	(38, 210)
	Amides				
CH_3ON	Formamide	59.6 (0.0°)		107.2	(76)
C_2H_5ON.........	Acetamide	38.96 (85.0°)	37.98 (95.0°)	148.0	(223, 207)
C_3H_7ON.........	Propionamide	31.77 (80.0°)	30.88 (90.0°)	181.2	(223, 207)
C_7H_7ON.........	Benzamide	38.06 (130.0°)	37.40 (140.0°)	279.9	(223, 207)
$C_7H_7O_2N$........	Salicylamide	40.35 (140.0°)	39.64 (150.0°)	295.3	(223, 207)
C_8H_9ON.........	Phenylacetamide	33.66 (160.0°)	32.89 (170.0°)	320.2	(223, 207)

Primary amines

CH_5N	Methylamine	26.5 (−49.0°)	23.0 (−20.0°)	95.9		(95, 210)
		19.19 (25°)	17.65 (35.0°)	99.7		(217)
C_2H_7N	Ethylamine	19.21 (25°)	17.82 (35.0°)	139.9		(217)
		21.4 (0.0°)	20.4 (9.9°)	137.4		(95, 143)
$C_2H_8N_2$	Ethylenediamine	41.80 (21.3°)	35.91 (63.1°)	170.4	171.2	(241)
C_3H_7N	Allylamine	24.27 (24.5°)	23.57 (31.1°)	167.4	167.7	(241)
C_3H_9N	*n*-Propylamine	22.21 (19.2°)	20.28 (38.0°)	178.9	180.0	(241)
		21.98	20.81	178.5		(223, 207)
		23.5 (10.0°)	21.2	178.5		(93, 143)
$C_4H_{11}N$	*n*-Butylamine	24.03 (19.2°)	21.70 (40.8°)	218.2	218.7	(241)
		23.81		218.0		(5)
	Isobutylamine	—		216.1		(190, 143)
		22.25 (19.7°)	19.93 (41.4°)	216.3	216.9	(241)
	sec-Butylamine	21.49 (21.0°)	20.91 (27.4°)	217.8	218.2	(241)
$C_5H_{13}N$	*n*-Amylamine	25.20 (20.1°)	22.88 (42.1°)	258.9	259.6	(241)
	Isoamylamine	23.30 (25.3°)	21.57 (43.1°)	257.2	257.4	(241)
	tert-Amylamine	22.4 (0.0°)	20.5 (20.0°)	252.3		(95, 143)
C_6H_6NCl	*o*-Chloroaniline	43.6 (0.0°)		264.5		(76)
C_6H_7N	Aniline	40.10 (50.0°)	37.63 (70.0°)	235.2	235.7	(23)
		44.39 (15.0°)	38.33 (66.0°)	235.7		(206, 210)
		—		232.7		(114, 210)
		42.5 (26.2°)		234.1		(76)
		44.0 (10.0°)	39.4 (50.0°)	234.4		(93, 143)
		39.97 (19.6°)		229.1		(241)
		35.57 (61.3°)		230.2		(241)
$C_6H_{13}N$	Cyclohexylamine	26.92 (13.0°)	22.13 (60.6°)	298.6	299.7	(241)
C_7H_9N	Benzylamine	39.07	37.94	273.7		(223, 207)
		39.82 (21.1°)	34.69 (62.4°)	274.4	274.4	(241)
	o-Toluidine	37.49 (50.0°)	35.18 (70.0°)	272.0	272.4	(23)
		—		269.3		(114, 210)
		43.0 (0.6°)		270.7		(76)
	m-Toluidine	37.73 (25.0°)	35.62 (50.0°)	269.4	271.0	(23)
	p-Toluidine	34.88 (50.0°)	32.80 (70.0°)	270.5	271.3	(23)
		34.60 (50.0°)	29.8 (100.0°)	272.1		(93, 143)
		34.26 (51.0°)	30.29 (93.0°)	272.4		(206, 210)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Primary amines—*Continued*				
$C_8H_{11}N$	2-Amino-1,3-dimethylbenzene	37.91 (25.0°)		307.1	(220)
	4-Amino-1,3-dimethylbenzene	36.49 (25.0°)		306.0	(220)
		36.75 (25.0°)	34.46 (50.0°)	307.2 308.2	(23)
	5-Amino-1,3-dimethylbenzene	36.38 (25.0°)		306.2	(220)
$C_8H_{19}N$	*n*-Octylamine	27.73		376.8	(5)
$C_9H_{17}NO$	4-Amino-4-methoxymethyl-1,6-heptadiene	27.41		402.3	(3)
$C_{10}H_9N$	1-Naphthylamine	47.25 (54.3°)	45.81 (67.5°)	341.0	(12)
	2-Naphthylamine	39.29 (115.8°)	37.91 (130.2°)	341.5 341.8	(12)
$C_{10}H_{19}ON$	4-Amino-4-ethoxymethyl-1,6-heptadiene	28.37		449.5	(3)
$C_{10}H_{21}ON$	4-Amino-4-ethoxymethyl-1-heptene	25.87		450.2	(3)
$C_{10}H_{23}ON$	4-Amino-4-ethoxymethylheptane	24.85		461.6	(3)
$C_{11}H_{21}ON$	4-Amino-4-isopropoxymethyl-1,6-heptadiene	26.70		483.9	(3)
	Secondary amines				
C_2H_7N	Dimethylamine	18.1 (0.0°)	17.7 (5.0°)	136.6	(95, 143)
		16.33 (25.0°)	15.08 (35.0°)	140.3	(217)
$C_4H_{11}N$	Diethylamine	19.28 (25.0°)		217.5	(29)
		19.91 (24.9°)	18.03 (41.0°)	220.3 220.4	(241)
		19.39 (25.0°)	18.20 (34.0°)	219.8	(17)
		23.0 (−21.5°)		212.9	(76)
		20.19		219.2	(5)
$C_6H_{15}N$	Dipropylamine	22.32	21.23	297.3	(223, 207)
		22.54	21.5	297.2	(215, 143)
		23.13 (16.9°)	20.77 (41.3°)	298.8 299.5	(241)
		25.7 (−19.5°)		293.8	(76)
		22.58		298.0	(5)
	Diisopropylamine	20.04 (16.0°)	17.34 (41.5°)	297.1 296.3	(241)

C_7H_9N..........	Methylaniline	40.1 (0.0°)		265.5		(76)
		40.85 (12.2°)	37.72 (40.1°)	272.8	273.5	(241)
$C_8H_{11}N$..........	Ethylaniline	36.79 (20.5°)	34.66 (41.3°)	311.0	311.7	(241)
		37.6 (10.0°)	32.4 (60.0°)	310.4		(93, 143)
$C_8H_{19}N$..........	Di-*n*-butylamine	24.81 (17.7°)	20.71 (60.4°)	378.6	378.6	(241)
		24.50		377.3		(5)
	Diisobutylamine	30.0 (−70.0°)	22.05 (20.0°)	372.1		(93, 143)
		23.5 (0.0°)		371.5		(76)
		22.58 (15.1°)	20.29 (40.8°)	375.7	375.9	(241)
	Di-*sec*-butylamine	23.28 (14.6°)	20.65 (40.9°)	374.4	374.3	(241)
$C_9H_{13}N$..........	*n*-Propylaniline	34.77 (20.9°)	30.84 (61.4°)	348.6	349.8	(241)
$C_{10}H_{15}N$.........	*n*-Butylaniline	33.90 (20.9°)	30.50 (59.9°)	389.1	389.0	(241)
$C_{10}H_{23}N$.........	Di-*n*-amylamine	26.64 (14.1°)	22.40 (60.4°)	457.2	458.8	(241)
	Diisoamylamine	24.73 (14.2°)	22.54 (40.5°)	452.5	453.7	(241)
$C_{12}H_{11}N$.........	Diphenylamine	39.23 (60.0°)	37.77 (75.0°)	402.1		(223, 207)
$C_{12}H_{23}N$.........	Dicyclohexylamine	34.22 (15.1°)	31.75 (40.4°)	478.9	479.4	(241)
$C_{14}H_{15}N$.........	Dibenzylamine	40.68	39.61	485.6		(223, 207)
$C_{20}H_{43}N$.........	Didecylamine	—		845.7		(5)
		Tertiary amines				
C_3H_9N..........	Trimethylamine	20.0 (−32.0°)	17.3 (−4.0°)	177.6		(95, 143)
$C_6H_{15}N$..........	Triethylamine	20.51 (22.3°)	18.46 (42.2°)	296.8	296.5	(241)
		19.99		296.4		(5)
$C_8H_{11}N$..........	Dimethylaniline	36.17 (19.5°)	31.12 (66.3°)	310.4	310.4	(241)
		37.70 (10.0°)	30.39 (75.0°)	311.7		(93, 143)
$C_9H_{12}O_2N_2$.......	*o*-Nitrobenzyldimethylamine	39.29 (25.0°)	38.24	405.3	407.0	(155)
	m-Nitrobenzyldimethylamine	38.96 (25.0°)	38.10	407.9	408.8	(197)
	p-Nitrobenzyldimethylamine	38.78 (25.0°)	38.06	408.8	409.5	(197)
$C_9H_{21}N$..........	Tripropylamine	22.96	22.03	413.6		(223, 207)
		21.5 (25.6°)	18.8 (55.5°)	414.6		(95, 143)
		22.48 (24.5°)	19.28 (60.1°)	414.4	412.9	(241)
		22.85		413.8		(5)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Tertiary amines—*Continued*				
$C_9H_{21}O_3N$........	Trimethoxytriethylamine	30.78		475.5	(5)
$C_{10}H_{15}N$.........	Diethylaniline	34.53 (19.9°)	32.33 (40.9°)	386.7 387.0	(241)
$C_{10}H_{13}ON$.......	Methylphenylaminoacetone	40.21		382.9	(127)
$C_{10}H_{15}N$.........	*N*,*N*-Dimethyl-*m*-2-xylidine	29.74 (25.0°)	24.06 (100.0°)	380.2 388.4	(220)
	N,*N*-Dimethyl-*m*-4-xylidine	30.88 (25.0°)	24.15 (100.0°)	384.8 389.8	(220)
	N,*N*-Dimethyl-*m*-5-xylidine	25.17 (25.0°)	26.73 (100.0°)	391.2 391.3	(220)
$C_{10}H_{19}ON$.......	Methylcyclohexylaminoacetone	32.54		430.7	(127)
$C_{11}H_{15}ON$.......	Methylbenzylaminoacetone	36.17		439.3	(127)
	Ethylphenylaminoacetone	38.27		428.3	(127)
$C_{11}H_{17}N$.........	Benzyldiethylamine	30.10 (18.1°)	27.64 (40.9°)	427.1 426.3	(241)
$C_{12}H_{17}ON$.......	Methyl-*o*-methylbenzylaminoacetone	33.62		471.5	(127)
	Methyl-*p*-methylbenzylaminoacetone	33.48		471.5	(127)
	Ethylbenzylaminoacetone	34.90		476.4	(127)
$C_{12}H_{19}N$.........	Di-*n*-propylaniline	32.79 (22.0°)	30.79 (42.4°)	463.1 463.4	(241)
$C_{12}H_{21}N$.........	Tribenzylamine	33.34 (95.0°)	32.43 (105.0°)	695.7	(223, 207)
$C_{12}H_{27}N$.........	Tri-*n*-butylamine	24.60 (22.9°)	21.36 (61.8°)	531.9 532.2	(241)
		24.64		531.3	(5)
$C_{13}H_{19}ON$.......	*n*-Propylbenzylaminoacetone	32.81		508.1	(127)
$C_{13}H_{20}O_2N_2$......	*o*-Nitrobenzyldipropylamine	33.88 (25.0°)	33.10 (36.5°)	561.4 563.7	(197)
	m-Nitrobenzyldipropylamine	34.01 (25.0°)	33.56 (32.0°)	567.5 567.8	(197)
	p-Nitrobenzyldipropylamine	34.33 (25.0°)	33.11 (35.0°)	562.8 563.9	(197)
$C_{14}H_{21}ON$.......	*n*-Butylbenzylaminoacetone	31.77		545.2	(127)
$C_{14}H_{23}N$.........	Di-*n*-butylaniline	32.82 (15.1°)	28.30 (61.6°)	541.1 540.7	(241)
$C_{15}H_{24}O_2N_2$......	*o*-Nitrobenzyldibutylamine	32.93 (25.0°)	32.09 (35.0°)	635.6 640.1	(197)
	m-Nitrobenzyldibutylamine	32.68 (25.0°)	32.10 (35.0°)	638.3 640.9	(197)
	p-Nitrobenzyldibutylamine	32.47 (25.0°)	31.85 (34.2°)	639.0 637.6	(197)

$C_{15}H_{33}N$	Tri-*n*-amylamine	26.86 (12.1°)	24.41 (41.5°)	650.1	652.2	(241)
	Triisoamylamine	24.85 (14.7°)	22.58 (40.8°)	643.9	643.9	(241)
$C_{15}H_{33}O_3N$	Tripropoxytriethylamine	28.82		707.9		(5)
$C_{16}H_{17}ON$	Benzylphenylaminoacetone	42.37		556.1		(127)
$C_{24}H_{51}N$	Trioctylamine	28.35		1007.2		(5)
$C_{30}H_{63}N$	Tri-*n*-decylamine	29.61		1246.0		(5)
	Amine salts					
$C_2H_8O_3N_2$	Dimethylammonium nitrate	50.38 (69.6°)	49.03 (97.6°)	249.7		(246, 215)
	Ethylammonium nitrate	48.8 (11.0°)	46.2 (56.5°)	235.0	238.8	(215)
		46.09	45.04 (45.2°)	234.9		(246, 215)
$C_4H_{12}O_3N_2$	Diethylammonium nitrate	39.02 (99.6°)	38.56 (109.0°)	324.8		(246, 215)
$C_7H_{10}NCl$	Methylaniline hydrochloride	44.53 (130.0°)	43.50 (140.5°)	348.7	348.9	(215)
$C_8H_{12}NBr$	Dimethylaniline hydrobromide	50.40 (97.0°)	49.00 (118.5°)	409.7	412.3	(246, 215)
$C_8H_{12}NCl$	Ethylaniline hydrochloride	35.82 (173.5°)	35.41 (180.5°)	382.0	382.3	(215)
$C_8H_{13}O_4NS$	Dimethylaniline bisulfate	55.2 (105.5°)	54.0 (126.0°)	467.1	470.0	(215)
$C_{18}H_{30}O_7N_4$	Tetrapropylammonium picrate	41.80 (129.0°)	40.72 (143.5°)	929.0	932.6	(215)
	Azides					
$C_3H_5ON_3$	Azidoacetone	39.33 (18.5°)		220.9		(121)
$C_3H_5O_2N_3$	Methyl azidoacetate	34.11 (19.0°)		277.0		(121)
$C_6H_5N_3$	Phenyl azide	36.66 (21.5°)		267.3		(121)
$C_7H_7N_3$	Benzyl azide	—		316.8		(224)
	o-Tolyl azide	35.73 (22.2°)		306.4		(121)
	p-Tolyl azide	34.78 (22.5°)		307.0		(121)
	Azo compounds					
$C_6H_{10}O_4N_2$	Azoformic acid diethyl ester	33.4 (19.2°)		377.1		(120)
$C_6H_{14}N_2$	2,2′-Azobispropane	18.46 (25.0°)		318.4		(9)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Azo compounds—*Continued*					
$C_8H_{18}N_2$	2,2′-Azobisbutane	21.01 (25.0°)		395.5		(9)
$C_9H_{10}O_2N_2$	Benzeneazoformic acid ethyl ester	38.9 (21.6°)		402.1		(120)
$C_{12}H_6ON_2Cl_4$	Hydroxy-*o*,*o*′-dichloroazobenzene	39.23 (135.0°)		578.1		(13)
$C_{12}H_{10}N_2$	Azobenzene	35.5 (76.9°)		429.5		(120)
$C_{12}H_{10}ON_2$	*m*-Hydroxyazobenzene	39.93 (120.0°)	38.61 (130.0°)	449.1	449.4	(24)
	p-Hydroxyazobenzene	36.60 (157°)	37.35 (160.0°)	446.4		(13)
$C_{13}H_{12}N_2$	*o*-Methylazobenzene	40.5 (25.5°)		463.8		(120)
	m-Methylazobenzene	40.7 (21.7°)		467.3		(120)
$C_{13}H_{12}ON_2$	*o*-Methoxyazobenzene	41.43 (56.5°)	39.42 (75.5°)	486.7	486.9	(24)
	m-Methoxyazobenzene	40.78 (53.0°)	39.96 (62.0°)	486.2	487.2	(24)
	p-Methoxyazobenzene	39.65 (67.0°)	38.46 (78.0°)	484.4	485.1	(24)
$C_{14}H_{14}N_2$	*o*,*o*′-Dimethylazobenzene	35.2 (63.8°)		501.3		(120)
	m,*m*′-Dimethylazobenzene	35.2 (63.9°)		504.6		(120)
$C_{17}H_{14}ON_2$	Benzeneazo-2-naphthol methyl ether	42.30 (83.0°)	40.23 (104.0°)	593.6	594.8	(24)
$C_{18}H_{14}ON_2$	2,4-Benzenebis(azophenol)	37.16 (137°)		664.9		(13)
	Azoxy compounds					
$C_{12}H_5O_7N_5Cl_2$	Trinitro-*m*-dichloroazoxybenzene	38.95 (170.0°)	37.24 (172.0°)	677.7	670.2	(13)
	Trinitro-*m*,*m*′-dichloroazoxybenzene	37.25 (188.0°)		695.0		(13)
$C_{12}H_6ON_2Cl_4$	*o*,*o*,*m*,*m*′-Tetrachloroazoxybenzene	35.24 (150.0°)		587.9		(13)
$C_{12}H_6O_5N_4Cl_2$	*m*-Nitro-*p*-nitro-*m*,*m*′-dichloroazoxybenzene	41.62 (160.0°)	42.32 (164.0°)	668.6	674.1	(13)
$C_{12}H_7O_3N_3Cl_2$	*o*-Nitro-*m*,*m*′-dichloroazoxybenzene	36.00 (117.0°)	36.29 (124.0°)	553.0	557.0	(13)
	p-Nitro-*m*,*m*′-dichloroazoxybenzene	39.06 (148.0°)	39.70 (151.0°)	568.0	569.8	(13)
	o-Nitro-*p*,*p*′-dichloroazoxybenzene	39.53 (140.0°)	38.02 (140.0°)	588.0	578.3	(13)

$C_{12}H_8ON_2Cl_2$	*o,o'*-Dichloroazoxybenzene	38.95 (63.0°)		503.7		(13)
	m,m'-Dichloroazoxybenzene	38.07 (105.0°)		512.3		(13)
	p,p'-Dichloroazoxybenzene	33.62 (159.0°)	32.50 (161.0°)	514.6	503.6	(13)
$C_{12}H_8ON_2Br_2$	*m,m'*-Dibromoazoxybenzene	41.44 (117.0°)	39.92 (120.0°)	536	536	(13)
$C_{12}H_{10}ON_2$	Azoxybenzene	43.44 (51.0°)	40.26 (77.5°)	444.0	444.8	(211)
		37.1 (85.0°)	34.7 (115.0°)	440.2	442.2	(95, 177)
$C_{12}H_{22}O_3N_2$	Ethyl α-azoxyisopropyl ketone	35.88		584.8		(1)
$C_{12}H_{22}O_5N_2$	Ethyl 2-methyl-2-azoxypropionate	33.56		625.8		(1)
$C_{14}H_{14}ON_2$	*o*-Azoxytoluene	40.41 (69.5°)	38.33 (90.5°)	527.9	529.0	(211)
$C_{14}H_{14}O_3N_2$	*p*-Azoxyanisole	40.1 (115.0°)	37.8 (133.5°)	554.6	555.6	(95, 177)
$C_{16}H_{18}O_3N_2$	*p*-Azoxyphenetole	31.6 (142.5°)	30.0 (151.8°)	620.3	618.0	(95, 136)
$C_{16}H_{34}ON_2$	2-Azoxy-2,5-dimethylhexane	28.27		729.2		(1)

Carbohydrates and derivatives

$C_6H_{12}O_6$	Fructose	72.83 (100.0°)	68.64 (130.0°)	360.6	360.8	(172)
	Glucose	71.73 (170.0°)		358.8		(172)
$C_{10}H_{20}O_6$	Tetramethyl-γ-fructose	— (11.4°)	— (31.0°)	501.1	501.1	(74)
$C_{11}H_{22}O_6$	Tetramethyl-γ-fructoside	— (19.2°)	— (36.7°)	537.2	540.6	(74)
$C_{12}H_{22}O_{11}$	Sucrose	62.20 (170.0°)		672.0		(172)
$C_{16}H_{22}O_{11}$	Pentaacetylglucose	25.96 (150.0°)		771.5		(172)
$C_{28}H_{38}O_{19}$	Octaacetylmaltose	30.04 (170.0°)		1339		(172)
	Octaacetylsucrose	36.91 (78.0°)		1331		(172)

Aliphatic diazo compounds

$C_3H_4ON_2$	Diazoacetone	35.4 (19.0°)		191.9		(123)
$C_3H_4O_2N_2$	Methyl diazoacetate	33.3 (25.0°)		207.2		(123)
		35.36	34.86	207.9	211.6	(176)
$C_4H_6O_2N_2$	Ethyl diazoacetate	31.5 (21.0°)		248.3		(123)
		32.05	31.45 (30.5°)	251.2	253.7	(176)
$C_5H_6O_2N_2$	Diazoacetylacetone	38.9 (22.0°)		274.9		(123)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Aliphatic diazo compounds—*Continued*				
$C_5H_6O_3N_2$	Methyl acetyldiazoacetate	35.7 (22.5°)		295.0	(123)
$C_5H_6O_4N_2$	Dimethyl diazomalonate	38.2 (20.5°)		305.4	(123)
$C_5H_8O_2N_2$	*n*-Propyl diazoacetate	28.9	28.32 (28.0°)	306.3 307.0	(176)
$C_6H_{10}O_2N_2$	*n*-Butyl diazoacetate	30.3 (20.3°)		326.0	(123)
$C_7H_{10}O_4N_2$	Diethyl diazomalonate	33.4 (18.0°)		381.6	(123)
$C_7H_{12}O_2N_2$	*n*-Amyl diazoacetate	25.01	21.36 (60.0°)	394.3 394.7	(176)
$C_8H_{12}O_4N_2$	Diethyl diazosuccinate	33.9 (18.0°)		428.4	(123)
	Esters of aliphatic monobasic acids				
$C_2H_4O_2$	Methyl formate	24.64	23.09	138.6	(166, 207)
		24.60 (16.4°)	23.03 (27.8°)	137.7	(137, 207)
$C_3H_5ClO_2$	Methyl chloroacetate	36.24 (12.8°)	29.56 (63.0°)	214.1 214.9	(237)
$C_3H_6O_2$	Ethyl formate	23.56 (22.9°)	21.03 (41.4°)	177.3 177.3	(235)
		— (53.6°)		178.4	(189, 207)
		23.31 (17.0°)	21.23 (34.0°)	177.0	(137, 207)
		15.50 (80.0°)		176.0	(76)
	Methyl acetate	25.17 (21.0°)	22.62 (41.0°)	177.1 177.4	(237)
		— (55.3°)		177.2	(189, 207)
		25.23 (10.0°)	21.93 (34.2°)	176.7	(137, 207)
		25.14 (10.0°)		175.3	(76)
$C_3H_6O_3$	Methyl carbonate	28.46 (25.0°)		196.2	(15)
$C_4H_6O_2$	Vinyl acetate*	23.95	22.54	204.7	(61)
$C_4H_7ClO_2$	Ethyl chloroacetate	31.18 (25.9°)	26.76 (61.9°)	253.5 253.6	(237)

$C_4H_8O_2$..........	*n*-Propyl formate	— (83.0°)		224.4		(189, 207)
		24.01 (17.0°)	22.05 (34.8°)	216.1		(137, 207)
		23.83 (26.1°)	19.94 (61.2°)	216.9	217.2	(237)
	Isopropyl formate	21.63 (25.3°)	19.95 (40.3°)	218.2	218.6	(237)
	Ethyl acetate	23.75 (20.3°)	18.80 (61.4°)	216.0	216.2	(237)
		23.9	20.2 (50.0°)	216.9		(93, 143)
		21.16 (40.0°)	20.10 (50.1°)	216.2	216.8	(21)
		23.75	22.55	215.7		(75, 210)
		23.60	16.32 (80.0°)	217.1		(166, 207)
		— (75.5°)		217.8		(189, 207)
		21.06 (34.6°)	18.08 (60.5°)	215.6		(137, 207)
		16.32 (80.0°)		215.6		(76)
	Methyl propionate	— (79.5°)		215.1		(189, 207)
		25.36 (10.0°)	22.41 (34.7°)	214.9		(137, 207)
		25.37 (10.0°)		213.3		(76)
		25.08 (19.5°)	20.41 (56.9°)	215.3	215.4	(237)
$C_4H_{10}O_3$.........	Methyl orthoformate	27.02	26.01 (25.0°)	250.0	249.0	(86)
$C_5H_7NO_2$........	Ethyl cyanoacetate	34.91 (17.5°)	30.33 (61.0°)	262.1		(248, 143)
$C_5H_8O_2$..........	Allyl acetate	25.40 (28.0°)	21.47 (60.5°)	244.5	244.4	(96)
		— (15°)	— (40°)	245.1	245.4	(2)
	Methyl vinylacetate	27.91 (16.0°)	22.47 (61.3°)	243.3	243.6	(97)
	Methyl crotonate	28.41 (22.9°)	25.98 (41.4°)	245.1	244.2	(96)
$C_5H_9BrO_2$.......	*n*-Propyl bromoacetate	32.10 (19.2°)	24.95 (87.3°)	304.9	306.1	(237)
	Ethyl α-bromopropionate	28.16 (40.8°)	23.29 (86.6°)	301.0	301.1	(237)
$C_5H_9ClO_2$........	*n*-Propyl chloroacetate	30.72 (20.2°)	26.15 (61.4°)	291.8	292.6	(237)
$C_5H_9IO_2$.........	*n*-Propyl iodoacetate	34.76 (17.4°)	27.43 (87.1°)	328.5	330.3	(237)
$C_5H_{10}O_2$.........	*n*-Butyl formate	24.89 (21.3°)	18.17 (86.7°)	256.2	256.6	(235)
	Isobutyl formate	23.98 (18.7°)	21.58 (40.2°)	256.5	256.3	(235)
		— (98.5°)		262.4		(189, 207)
	n-Propyl acetate	22.03 (41.1°)	19.57 (62.0°)	255.3	255.2	(235)
		22.39 (40.0°)	21.20 (50.1°)	257.2	257.0	(21)
		24.84 (10.0°)		253.4		(76)

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* 100 per cent monomer; see reference 61 for various degrees of polymerization.

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Esters of aliphatic monobasic acids—*Continued*					
$C_5H_{10}O_2$........ (*continued*)	*n*-Propyl acetate—*Continued*	— (102.5°)		257.1		(189, 207)
		21.92 (34.6°)	19.25 (60.1°)	255.0		(137, 207)
	Isopropyl acetate	22.14 (21.0°)	17.85 (61.1°)	254.4	254.5	(235)
	Ethyl propionate	24.86 (16.0°)	19.70 (60.1°)	254.4	254.9	(235)
		24.62 (10.0°)		252.3		(16)
		— (99.0°)		255.2		(189, 207)
		24.54 (10.0°)	21.92 (33.9°)	254.4		(137, 207)
		24.27	23.16	254.0		(75, 210)
	Methyl *n*-butyrate	24.24 (27.3°)	22.88 (40.7°)	254.5	254.7	(235)
		— (110.5°)		254.1		(189, 207)
		25.34 (10.0°)	22.61 (34.8°)	254.3		(137, 207)
	Methyl isobutyrate	— (92.4°)		253.1		(189, 207)
		24.15 (10.0°)	21.55 (33.9°)	253.5		(137, 207)
		23.30 (23.7°)	21.37 (40.9°)	253.7	253.6	(235)
$C_5H_{10}O_3$.........	*dl*-Ethyl lactate	29.9	26.8 (50.0°)	268.5		(93, 143)
	Ethyl carbonate	25.70 (25.0°)		274.5		(15)
$C_6H_8O_2$.........	Methyl 3-butyne-1-carboxylate	30.0 (42.6°)	27.52 (63.3°)	272.4	272.4	(98)
$C_6H_{10}O_2$.........	1,3-Dimethylallyl formate	—		281.6		(79)
	Ethyl vinylacetate	26.54 (17.1°)	18.75 (87.2°)	281.9	282.3	(97)
	Allyl propionate	26.89 (15.3°)	19.03 (85.3°)	282.9	282.8	(96)
	Ethyl crotonate	27.23 (20.3°)	22.69 (61.6°)	284.0	283.9	(96)
$C_6H_{10}O_3$.........	Ethyl acetoacetate	—		302.0		(109, 210)
$C_6H_{11}BrO_2$.......	*n*-Butyl bromoacetate	31.30 (26.2°)	27.72 (62.4°)	343.3	344.5	(237)
$C_6H_{11}ClO_2$.......	*n*-Butyl chloroacetate	30.20 (23.9°)	25.99 (62.2°)	331.7	332.3	(237)
$C_6H_{11}IO_2$.......	*n*-Butyl iodoacetate	30.82 (41.5°)	29.08 (61.4°)	367.9	368.6	(237)

$C_6H_{12}O_2$.........	*n*-Amyl formate	25.60 (24.8°)	19.25 (86.7°)	296.9	296.5	(235)
	Isoamyl formate					
	(fermentation alcohol)	25.24 (16.9°)	18.02 (87.8°)	293.9	294.4	(235)
	(synthetic alcohol)	24.64 (23.3°)	20.75 (61.5°)	293.3	293.7	(235)
		—		293.6		(133, 207)
		— (123.5°)		303.8		(189, 207)
		24.69 (10.0°)	22.20 (35.0°)	293.7		(137, 207)
	n-Butyl acetate	25.21 (20.9°)	23.24 (41.0°)	295.6	295.5	(235)
		23.18 (40.0°)	21.96 (50.1°)	296.9	296.3	(21)
	Isobutyl acetate	23.94 (16.9°)	19.26 (61.5°)	293.9	293.6	(235)
		— (112.8°)		300.0		(189, 207)
		—		295.1		(132, 207)
	sec-Butyl acetate	24.46 (12.9°)	19.11 (61.9°)	293.9	293.9	(235)
	tert-Butyl acetate	21.89 (25.3°)	20.17 (41.2°)	291.7	291.3	(235)
	n-Propyl propionate	24.15 (25.8°)	20.40 (61.0°)	293.9	293.9	(235)
		— (121.7°)		295.3		(189, 207)
	Ethyl *n*-butyrate	24.46 (19.9°)	22.32 (40.9°)	293.9	293.8	(235)
		— (118.8°)		293.9		(189, 207)
		24.54		294.2		(183, 207)
		—		293.0		(139, 207)
	Ethyl isobutyrate	20.86 (41.2°)	18.73 (61.4°)	293.1	292.9	(235)
		— (109.9°)		292.9		(189, 207)
	Methyl *n*-valerate	23.58 (40.8°)	21.57 (60.0°)	294.4	294.4	(235)
		— (115.0°)		292.5		(189, 207)
	Methyl isovalerate	24.66 (16.1°)	21.93 (42.0°)	292.6	292.7	(235)
$C_7H_{10}O_2$.........	Ethyl 3-butyne-1-carboxylate	27.88 (41.4°)	25.60 (61.4°)	310.9	311.1	(98)
$C_7H_{12}O_2$.........	1,3-Dimethylallyl acetate	—		321.2		(79)
	Allyl *n*-butyrate	26.23 (19.2°)	21.88 (61.1°)	321.4	322.3	(96)
	n-Propyl vinylacetate	27.00 (13.1°)	22.02 (61.4°)	322.4	322.8	(97)
	n-Propyl crotonate	28.43 (14.1°)	23.36 (61.5°)	324.0	323.9	(96)
$C_7H_{14}O_2$.........	*n*-Hexyl formate	26.65 (22.8°)	20.50 (86.4°)	337.4	337.4	(235)
		23.65 (40.0°)	21.68 (60.2°)	335.9	336.6	(21)
	n-Amyl acetate	25.68	21.60 (61.4°)	335.1	334.9	(235)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Esters of aliphatic monobasic acids—*Continued*				
$C_7H_{14}O_2$........	Isoamyl acetate	24.62 (21.1°)	20.67 (60.8°)	333.0 332.7	(235)
(*continued*)		— (138.9°)		337.1	(189, 207)
		—		331.6	(136, 207)
	n-Butyl propionate	25.94 (15.0°)	18.91 (85.6°)	334.0 333.9	(239)
	Isobutyl propionate	— (137.0°)		331.8	(189, 207)
	n-Propyl *n*-butyrate	22.91 (40.8°)	18.38 (86.9°)	334.1 334.0	(235)
		— (143.5°)		333.8	(189, 207)
	n-Propyl isobutyrate	23.91 (19.1°)	19.48 (61.5°)	332.7 332.0	(235)
		— (134.8°)		332.6	(189, 207)
	Ethyl *n*-valerate	23.00 (41.5°)	18.47 (87.0°)	333.7 333.5	(235)
		— (133.0°)		332.1	(189, 207)
	Ethyl isovalerate	23.46 (23.0°)	19.56 (61.3°)	332.3 331.8	(235)
		23.68		331.9	(72, 207)
	Methyl *n*-hexanoate	26.55 (18.1°)	24.15 (40.9°)	333.2 333.4	(235)
$C_7H_{16}O_3$.........	Ethyl orthoformate	23.93 (17.1°)	21.36 (40.7°)	365.7 365.1	(242)
		23.41 (25.0°)	21.99 (40.0°)	366.7 367.6	(69)
		23.59	23.23 (25.0°)	366.4 367.1	(86)
$C_8H_{12}O_2$........	*n*-Propyl 3-butyne-1-carboxylate	30.10 (18.4°)	22.73 (85.9°)	350.5 351.3	(98)
$C_8H_{13}NO_2$.......	Ethyl *dl*-isopropylcyanoacetate	31.49 (23.3°)	27.60 (61.8°)	373.9 374.8	(226)
$C_8H_{14}O_2$........	α-Ethyl-α-methylallyl acetate	— (15.0°)	— (40.0°)	361.1 361.5	(2)
	n-Butyl vinylacetate	27.29 (13.0°)	22.55 (61.4°)	361.4 362.6	(96)
	n-Butyl crotonate	27.35 (25.3°)	23.72 (61.8°)	363.5 364.0	(96)
$C_8H_{14}O_3$.........	Ethyl dimethylacetoacetate	—		382.3	(131, 207)
$C_8H_{16}O_2$.........	*n*-Hexyl acetate	26.50 (20.2°)	20.01 (87.2°)	375.4 375.7	(235)
	Isoamyl propionate	— (160.5°)		372.1	(189, 207)

	n-Butyl *n*-butyrate	26.11 (16.6°)	19.38 (85.9°)	373.8	374.0	(235)
	n-Butyl isobutyrate	24.86 (16.4°)	20.34 (61.5°)	372.2	372.4	(235)
	Isobutyl butyrate	— (157.0°)		370.5		(189, 207)
	Isobutyl isobutyrate	— (149.0°)		371.8		(189, 207)
	n-Propyl *n*-valerate	— (155.0°)		371.9		(189, 207)
		23.64 (40.9°)	21.67 (61.3°)	373.4	373.8	(235)
	n-Propyl isovalerate	22.46 (40.7°)	20.57 (62.1°)	372.1	372.5	(235)
	Ethyl hexanoate	25.96 (18.4°)	19.52 (85.9°)	373.1	373.6	(235)
	Methyl heptanoate	26.62 (25.0°)	20.35 (87.2°)	373.5	372.9	(235)
$C_9H_{10}O_2$	Methyl phenylacetate	38.44 (18.1°)	30.49 (85.8°)	349.4	350.3	(96)
	Ethyl cinnamate	37.24 (26.0°)	33.62 (60.6°)	416.8	417.9	(96)
$C_9H_{14}O_2$	*n*-Butyl 3-butyne-1-carboxylate	29.28 (22.1°)	25.08 (63.0°)	389.1	390.1	(98)
$C_9H_{16}O_2$	*n*-Amyl crotonate	28.49 (18.3°)	21.94 (87.3°)	403.3	404.3	(96)
	n-Amyl vinylacetate	24.74 (41.8°)	22.84 (61.0°)	401.6	401.5	(96)
$C_9H_{18}O_2$	*n*-Amyl *n*-butyrate	26.58 (16.2°)	20.00 (87.5°)	412.9	414.8	(235)
	Isoamyl *n*-butyrate	25.80 (16.6°)	21.68 (62.1°)	411.3	412.2	(235)
		25.19		410.9		(72, 207)
		—		408.5		(133, 207)
	n-Butyl *n*-valerate	26.36 (18.2°)	19.57 (86.0°)	412.3	413.1	(235)
	Isobutyl *n*-valerate	—		409.4		(133, 207)
	n-Butyl isovalerate	25.55 (16.5°)	21.03 (61.9°)	411.7	411.1	(235)
	Ethyl *n*-heptanoate	25.99 (25.3°)	20.17 (87.0°)	412.8	413.4	(235)
		26.43	25.43	413.3		(75, 210)
	Methyl *n*-octanoate	28.78 (11.6°)	23.84 (61.3°)	413.9	414.7	(235)
$C_{10}H_{10}O_2$	*cis*-Methyl cinnamate	40.17	34.93 (62.0°)	375.2	376.6	(212)
	trans-Methyl cinnamate	37.17 (46.0°)	35.05 (67.0°)	374.1	374.4	(212)
		37.28 (17.6°)	35.77 (32.3°)	383.1		(248, 207)
		—		385.2		(131, 207)
$C_{10}H_{12}O_2$	Ethyl phenylacetate	35.34 (20.0°)	30.72 (61.0°)	387.7	388.4	(96)
	Methyl β-phenylpropionate	38.12 (13.9°)	29.97 (87.1°)	389.1	390.3	(96)
	n-Propyl cinnamate	36.38 (21.4°)	30.19 (85.5°)	455.0	457.0	(96)
$C_{10}H_{18}O_2$	Isoamyl crotonate	27.34 (19.7°)	21.09 (86.9°)	400.8	402.2	(96)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Esters of aliphatic monobasic acids—*Continued*					
$C_{10}H_{18}O_3$........	Ethyl diethylacetoacetate	—		446.2		(131, 207)
$C_{10}H_{20}O_2$........	*n*-Amyl *n*-valerate	26.53 (17.1°)	20.13 (88.1°)	451.3	452.7	(235)
	Ethyl *n*-octanoate	27.94 (14.0°)	20.91 (87.1°)	452.9	453.3	(235)
		26.91	25.97	452.7		(75, 210)
$C_{10}H_{22}O_3$........	*n*-Propyl orthoformate	25.45 (13.4°)	22.78 (41.4°)	482.7	483.1	(242)
		24.61	24.44 (25.0°)	481.2	481.5	(86)
	Isopropyl orthoformate	23.57	22.80 (25.0°)	486.1	483.3	(86)
$C_{11}H_{10}O_2$........	Ethyl phenylpropiolate	—		410.3		(210)
		38.41 (15.6°)	36.37 (35.4°)	375.2		238, 207)
		39.17 (14.2°)	31.77 (85.3°)	410.6	413.4	(98)
$C_{11}H_{12}O_2$........	Ethyl cinnamate	—		417.2		(131, 207)
$C_{11}H_{14}O_2$........	*n*-Propyl phenylacetate	34.21 (20.9°)	30.06 (60.9°)	427.0	427.9	(96)
	Ethyl β-phenylpropionate	32.81 (40.9°)	28.17 (86.7°)	427.3	427.6	(96)
	n-Butyl cinnamate	34.87 (30.9°)	31.70 (61.5°)	494.0	494.7	(96)
$C_{11}H_{22}O_2$........	Methyl *n*-decanoate	28.33 (22.0°)	22.27 (88.1°)	493.1	494.5	(235)
	Ethyl pelargonate	27.57	26.72	439.6		(75, 210)
$C_{12}H_{12}O_2$........	*n*-Propyl phenylpropiolate	37.69 (13.9°)	30.36 (87.0°)	448.3	451.2	(98)
$C_{12}H_{16}O_2$........	*n*-Butyl phenylacetate	33.11 (22.3°)	26.29 (85.2°)	465.1	466.3	(96)
	n-Propyl β-phenylpropionate	33.62 (25.0°)	29.71 (62.7°)	465.7	466.3	(96)
	Isopropyl β-phenylpropionate	32.20 (18.5°)	29.97 (42.0°)	467.4		(248, 207)
$C_{12}H_{20}O_2$........	Methyl 9-decyne-1-carboxylate	33.45 (17.0°)	26.20 (88.7°)	513.0	513.6	(98)
$C_{12}H_{22}O_2$........	Methyl undecylenate	29.18 (28.1°)	26.02 (61.4°)	523.8	524.2	(96)
	Menthol acetate		27.98	500.9		(175)
$C_{12}H_{24}O_2$........	Ethyl *n*-decanoate	28.52 (16.1°)	22.07 (86.6°)	533.4	534.3	(235)
$C_{13}H_{14}O_2$........	*n*-Butyl β-phenylpropionate	33.52 (19.3°)	27.23 (87.4°)			(96)
	n-Butyl phenylpropionate	36.27 (19.3°)	30.11 (86.2°)	485.7	489.2	(98)
	Isobutyl phenylpropionate	34.21 (16.7°)	32.63 (34.6°)	424.7		(248, 207)
		—		487.1		(210)

$C_{13}H_{22}O_2$	Ethyl 9-decyne-1-carboxylate	32.80 (12.3°)	25.02 (88.6°)	551.7	552.0	(98)
$C_{13}H_{24}O_2$	Ethyl *n*-undecylenate	29.61 (16.0°)	23.20 (87.1°)	561.6	563.7	(96)
$C_{13}H_{26}O_2$	*n*-Propyl *n*-decanoate	28.28 (20.1°)	22.38 (88.8°)	573.3	574.6	(235)
	Ethyl *n*-undecylate	28.61 (16.8°)	22.39 (86.4°)	572.6	574.0	(98)
	Methyl *n*-dodecanoate	30.22 (13.4°)	23.64 (86.9°)	574.1	577.1	(235)
$C_{13}H_{26}O_3$	*n*-Hexyl carbonate	27.92 (25.0°)		587.8		(55)
$C_{13}H_{28}O_3$	*n*-Butyl orthoformate	25.92 (17.1°)	23.68 (41.0°)	600.4	600.3	(242)
	Isobutyl orthoformate	23.82	23.61 (25.0°)	597.8	598.7	(86)
$C_{14}H_{24}O_2$	*n*-Propyl 9-decyne-1-carboxylate	31.83 (19.2°)	25.35 (87.2°)	591.2	592.4	(98)
$C_{14}H_{26}O_2$	*n*-Propyl *n*-undecylate	27.41 (42.2°)	23.29 (87.3°)	603.3	603.2	(96)
$C_{14}H_{28}O_2$	*n*-Butyl *n*-decanoate	28.59 (19.0°)	22.65 (87.2°)	612.5	614.4	(235)
	Ethyl *n*-dodecanoate	28.63 (17.1°)	22.49 (88.2°)	611.5	612.9	(235)
$C_{15}H_{28}O_2$	*n*-Butyl *n*-undecylenate	30.03 (16.2°)	23.89 (86.1°)	641.0	643.1	(96)
$C_{15}H_{30}O_2$	*n*-Propyl *n*-dodecanoate	29.48 (13.0°)	25.28 (62.7°)	651.5	654.7	(235)
$C_{16}H_{32}O_2$	Pentadecyl formate	29.38 (35.0°)	26.54 (65.0°)	699.5	700.5	(163)
	Tetradecyl acetate	28.91 (35.0°)	26.03 (65.0°)	698.5	700.5	(163)
	Tridecyl propionate	28.68 (35.0°)	26.13 (65.0°)	697.9	701.8	(163)
	Lauryl butyrate	28.18 (35.0°)	25.41 (65.0°)	695.0	695.5	(163)
	Undecyl valerate	27.71 (35.0°)	25.26 (65.0°)	693.2	694.8	(163)
	Decyl caproate	27.61 (35.0°)	24.95 (65.0°)	693.4	694.6	(163)
	Nonyl heptanoate	27.51 (35.0°)	25.07 (65.0°)	692.1	696.2	(163)
	Octyl caprylate	27.12 (35.0°)	24.65 (65.0°)	690.4	691.0	(163)
	Heptyl pelargonate	27.10 (35.0°)	24.61 (65.0°)	690.5	693.6	(163)
	Hexyl decylate	27.26 (35.0°)	24.56 (65.0°)	691.1	692.2	(163)
	Amyl undecylate	27.25 (35.0°)	24.94 (65.0°)	692.6	693.6	(163)
	Butyl laurate	27.47 (35.0°)	25.21 (65.0°)	692.3	696.2	(163)
		27.26 (40.8°)	25.36 (61.1°)	692.7	692.6	(235)
	Propyl tridecylate	27.89 (35.0°)	25.12 (65.0°)	694.9	696.3	(163)
	Ethyl myristate	28.26 (35.0°)	25.19 (65.0°)	695.4	695.1	(163)
	Methyl pentadecylate	28.38 (35.0°)	26.11 (65.0°)	694.2	697.2	(163)
$C_{16}H_{34}O_3$	Isoamyl orthoformate	25.26	24.83 (25.0°)	713.2	714.6	(86)
$C_{18}H_{32}O_2$	Ethyl palmitate	31.54 (22.0°)	23.46 (110.0°)	783.6	787.9	(48)
$C_{23}H_{46}O_2$	Amyl stearate	—		974.2		(133, 207)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Esters of cyclic structure					
	3-membered ring					
$C_5H_8O_2$	Methyl cyclopropanecarboxylate	30.80	28.10 (40.9°)	236.5	236.3	(99)
$C_6H_{10}O_2$	Ethyl cyclopropanecarboxylate	29.02 (20.9°)	24.22 (61.1°)	275.1	274.7	(99)
$C_7H_{10}O_4$	Methyl cyclopropane-1,1-dicarboxylate	36.03 (23.3°)	31.41 (62.1°)	338.9	339.4	(228)
$C_7H_{12}O_2$	Propyl cyclopropanecarboxylate	29.05 (19.8°)	26.56 (40.7°)	315.4	315.1	(99)
$C_8H_{10}O_4$	Methyl 3-methyl-Δ^2-cyclopropane-1,2-dicarboxylate	35.46 (42.0°)	30.79 (81.0°)	370.3	372.4	(214)
$C_8H_{14}O_2$	Butyl cyclopropanecarboxylate	28.36 (25.8°)	24.60 (62.2°)	354.6	354.4	(99)
$C_9H_{14}O_4$	Ethyl cyclopropane-1,1-dicarboxylate	32.23 (16.2°)	29.33 (41.3°)	416.5	416.4	(99)
		31.28 (25.0°)	26.05 (75.0°)	417.1		(214)
	Ethyl cyclopropane-1,2-dicarboxylate	33.41 (11.0°)	28.92 (54.0°)	420.9	423.4	(214)
$C_9H_{16}O_2$	Amyl cyclopropanecarboxylate	29.61 (15.6°)	27.04 (40.5°)	393.6	393.9	(99)
$C_{10}H_{14}O_4$	Ethyl 3-methyl-Δ^2-cyclopropane-1,2-dicarboxylate (normal)	31.42 (41.5°)	29.12 (62.0°)	450.1	450.2	(214)
	Ethyl 3-methyl-Δ^2-cyclopropane-1,2-dicarboxylate (labile)	33.98 (26.0°)	31.13 (50.0°)	447.5	447.8	(214)
$C_{11}H_{18}O_4$	Ethyl 3,3-dimethylcyclopropane-1,2-dicarboxylate	31.56 (12.0°)	27.10 (54.0°)	491.0	493.7	(214)
	n-Propyl cyclopropane-1,1-dicarboxylate	31.45 (18.7°)	28.75 (40.4°)	494.4	493.5	(99)
$C_{15}H_{22}O_8$	Ethyl cyclopropane-1,1,2,2-tetracarboxylate	29.08 (76.0°)	24.75 (122.0°)	699.0	702.2	(214)
	4-membered ring					
$C_6H_{10}O_2$	Methyl cyclobutanecarboxylate	31.06 (19.3°)	25.77 (61.9°)	273.6	272.9	(99)
$C_7H_{12}O_2$	Ethyl cyclobutanecarboxylate	30.06 (15.1°)	26.76 (40.7°)	313.0	312.1	(99)

$C_7H_{12}O_2$	Ethyl cyclobutanecarboxylate	29.96 (19.5°)	24.10 (70.0°)	309.5	309.8	(214)
$C_8H_{11}O_2N$	Ethyl 1-cyanocyclobutane-1-carboxylate	35.68 (13.5°)	29.26 (69.5°)	358.1	360.1	(214)
$C_8H_{12}O_4$	Methyl cyclobutane-1,1-dicarboxylate	35.12 (20.4°)	32.62 (40.1°)	375.0	374.7	(92)
		35.31	30.36 (62.5°)	374.6	374.8	(228)
$C_8H_{14}O_2$	Propyl cyclobutanecarboxylate	29.45 (17.2°)	24.55 (63.2°)	351.8	352.5	(92)
$C_9H_{16}O_2$	*n*-Butyl cyclobutanecarboxylate	29.87 (15.4°)	27.17 (41.6°)	391.3	391.9	(92)
$C_{10}H_{16}O_4$	Ethyl cyclobutane-1,1-dicarboxylate	32.22 (13.4°)	29.49 (40.2°)	453.1	454.3	(92)
		32.51 (15.0°)	28.70 (49.0°)	453.5	454.4	(214)
$C_{10}H_{18}O_2$	*n*-Amyl cyclobutanecarboxylate	29.84 (16.1°)	27.16 (41.3°)	430.1	430.2	(92)
$C_{12}H_{20}O_4$	*n*-Propyl cyclobutane-1,1-dicarboxylate	30.22 (25.1°)	28.66 (40.4°)	531.3	531.3	(92)
$C_{14}H_{24}O_4$	*n*-Butyl cyclobutane-1,1-dicarboxylate	29.96 (23.9°)	28.46 (40.7°)	607.5	608.9	(92)
	5-membered ring					
$C_6H_{10}O_2$	Cyclopentyl formate	32.20 (15.8°)	29.23 (41.5°)	270.1	270.2	(238)
$C_7H_{12}O_2$	Cyclopentyl acetate	30.67 (20.4°)	25.93 (60.9°)	309.4	309.6	(238)
$C_8H_{14}O_2$	*trans*-*l*-3-Methylcyclopentyl acetate	30.7 (20.5°)		349.		(60)
	cis-*l*-3-Methylcyclopentyl acetate	31.3 (18.5°)		354.		(60)
$C_9H_{14}O_4$	Methyl cyclopentane-1,1-dicarboxylate	35.15 (20.4°)	30.49 (62.2°)	408.2	407.3	(228)
$C_{10}H_{15}O_2N$	Ethyl cyclopentylcyanoacetate	34.99 (17.7°)	30.87 (61.2°)	429.2	429.9	(226)
$C_{11}H_{18}O_4$	Methyl cyclopentane-1,1-diacetate	35.04 (23.4°)	30.91 (61.8°)	483.3	482.0	(229)
$C_{12}H_{18}O_4$	Ethyl cyclopentylidenemalonate	34.00		514.6		(108)
$C_{12}H_{20}O_4$	Methyl 3-methylcyclopentane-1,1-diacetate	32.53 (20.4°)	28.61 (64.6°)	518.5	519.3	(229)
$C_{13}H_{22}O_4$	Ethyl cyclopentane-1,1-diacetate	33.26 (15.7°)	28.66 (62.4°)	561.4	561.4	(229)
$C_{14}H_{24}O_4$	Ethyl 3-dimethylcyclopentane-1,1-diacetate	31.28 (18.2°)	27.41 (62.3°)	598.9	599.4	(229)
	6-membered ring					
$C_7H_{12}O_2$	Cyclohexyl formate	33.02 (13.0°)	29.81 (41.0°)	307.0	307.6	(238)
$C_8H_{14}O_2$	Cyclohexyl acetate	30.42 (32.0°)		347.0		(175)
		31.31 (20.3°)	26.59 (61.5°)	347.0	347.0	(238)
$C_{10}H_{16}O_4$	Methyl cyclohexane-1,1-dicarboxylate	35.53	30.80 (62.5°)	442.2	442.0	(228)
$C_{11}H_{15}NO_2$	Ethyl cyclohexylidenecyanoacetate	38.04 (18.1°)	33.73 (61.8°)	453.6	455.6	(226)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Esters of cyclic structure—*Continued*				
$C_{11}H_{17}NO_2$	Ethyl *dl*-cyclohexylcyanoacetate	35.84 (17.3°)	31.60 (61.8°)	466.8 467.5	(226)
$C_{12}H_{20}O_4$	Methyl cyclohexane-1,1-diacetate	35.54 (23.0°)	31.58 (62.5)	516.9 516.8	(229)
$C_{13}H_{22}O_4$	Methyl 3-methylcyclohexane-1,1-diacetate	33.23 (20.6°)	30.02 (62.9°)	553.7 556.5	(229)
	Methyl 4-methylcyclohexane-1,1-diacetate	33.52 (16.9°)	29.84 (63.9°)	551.2 551.1	(229)
$C_{14}H_{24}O_4$	Ethyl cyclohexane-1,1-diacetate	33.61 (18.6°)	29.30 (63.6°)	595.7 595.3	(229)
$C_{15}H_{24}O_4$	Cyclohexyl malonate	35.83 (30.0°)		620.5	(10)
$C_{15}H_{26}O_4$	Ethyl 3-methylcyclohexane-1,1-diacetate	31.76 (19.4°)	27.83 (62.5°)	632.1 631.9	(229)
	Ethyl 4-methylcyclohexane-1,1-diacetate	31.90 (18.0°)	27.98 (63.2°)	630.7 631.3	(229)
$C_{17}H_{28}O_4$	2-Methyl cyclohexylmalonate		33.77	695.6	(10)
	3-Methyl cyclohexylmalonate		32.11	693.7	(10)
	4-Methyl cyclohexylmalonate		32.10	694.4	(10)
	7-membered ring				
$C_{12}H_{17}NO_2$	Ethyl cycloheptylidenecyanoacetate	37.70 (18.6°)	33.60 (62.0°)	486.7 488.1	(226)
$C_{12}H_{19}NO_2$	Ethyl *dl*-cycloheptylcyanoacetate	35.96 (21.3°)	32.05 (61.8°)	502.3 502.8	(226)
	Esters of miscellaneous ring structures (see also terpene derivatives)				
$C_{13}H_{20}O_2$	Methyl tricycloekasantalate	34.99	33.47	497	(62)
$C_{15}H_{21}NO_2$	Ethyl *trans*-decahydro-2-naphthylidenecyanoacetate	37.37 (21.6°)	33.94 (61.8°)	581.8 582.5	(226)
$C_{15}H_{23}NO_2$	Ethyl *trans*-decahydro-2-naphthylcyanoacetate	36.32 (20.1°)	32.81 (60.8°)	593.9 595.1	(226)
$C_{15}H_{24}O_4$	Methyl *trans*-hexahydrohydrindene-2,2-diacetate	35.50 (21.9°)	31.67 (62.5°)	611.9 611.3	(226)
$C_{16}H_{26}O_4$	Methyl *trans*-decahydronaphthalene-2,2-diacetate	36.71 (17.2°)	32.30 (61.8°)	644.6 644.4	(229)
$C_{17}H_{28}O_4$	Ethyl *trans*-hexahydrohydrindene-2,2-diacetate	33.73 (22.3°)	29.78 (63.2°)	690.2 690.5	(229)
$C_{18}H_{30}O_4$	Ethyl *trans*-decahydronaphthalene-2,2-diacetate	34.54 (18.9°)	30.12 (63.5°)	722.2 722.6	(229)

Esters of dibasic acids

$C_5H_8O_4$..........	Dimethyl malonate	37.92 (15.1°)	31.99 (62.6°)	283.1	283.6	(98)
			35.90	282.5		(99)
		—		283.1		(109, 210)
$C_6H_6O_4$..........	Dimethyl acetylenedicarboxylate	38.48 (15.1°)	29.84 (87.1°)	303.6		(98)
$C_6H_8O_4$..........	Dimethyl maleate	38.11 (21.0°)	33.22 (61.9°)	311.6	312.3	(96)
		37.31 (24.0°)	34.12 (51.0°)	308.4	309.3	(212)
	Dimethyl fumarate	25.67 (106.0°)	22.75 (132.0°)	309.3	308.9	(212)
$C_6H_{10}O_4$.........	Diethyl oxalate	32.34 (17.5°)	27.54 (61.1°)	322.0	323.8	(235)
		31.42 (25.0°)		321.8		(15)
		34.9 (0.0°)		319.9		(76)
		32.22	31.03	322.2		(75, 210)
		—		323.4		(131, 207)
	Dimethyl methylmalonate	34.07 (14.9°)	25.66 (85.9°)	320.0	320.9	(235)
		33.93 (19.0°)	28.41 (64.3°)	321.6	322.0	(228)
		36.26 (22.9°)	31.42 (63.5°)	321.2	321.6	(228)
	Dimethyl succinate	37.11 (17.0°)	24.80 (120.6°)	321.3	322.0	(235)
$C_7H_{10}O_4$.........	Dimethyl citraconate	36.49 (19.3°)	28.25 (87.7°)	349.4	349.4	(96)
		35.69	31.37 (53.0°)	345.5	345.6	(212)
	Dimethyl mesaconate	35.34 (18.9°)	27.59 (85.8°)	344.1	344.9	(96)
		34.68	30.80 (52.0°)	340.8	341.5	(212)
$C_7H_{12}O_4$.........	Dimethyl glutarate	35.91 (22.7°)	31.12 (62.7°)	361.3	361.7	(228)
	Dimethyl dimethylmalonate	30.52 (24.7°)	26.22 (63.2°)	355.8	355.7	(228)
	Dimethyl ethylmalonate	31.75 (25.1°)	27.99 (59.2°)	358.1	359.0	(235)
		32.78 (19.5°)	27.76 (64.0°)	360.0	359.8	(228)
	Diethyl malonate	32.16 (17.0)	27.36 (62.2°)	360.1	362.1	(228)
			30.56	360.4		(39)
		—		362.0		(131, 207)
		31.71	30.49	360.3		(75, 210)
	Dimethyl methylsuccinate	32.75 (25.1°)	28.61 (60.6°)	358.0	357.9	(96)
$C_7H_{14}O_3$.........	Di-*n*-propyl carbonate	26.36 (25.0°)		352.3		(15)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Esters of dibasic acids—*Continued*				
$C_8H_{10}O_4$	Diethyl acetylenedicarboxylate	33.22 (21.7°)	28.97 (61.6°)	383.6 385.0	(98)
$C_8H_{11}ClO_4$	Diethyl chloromaleate	33.33 (26.3°)	30.83 (50.0°)	423.3	(93, 143)
$C_8H_{12}O_4$	Dimethyl allylmalonate	32.66 (19.3°)	27.91 (62.6°)	382.4 384.9	(98)
	Diethyl maleate	33.30 (13.4°)	25.82 (86.6°)	385.6 387.7	(98)
		32.31 (19.8°)	30.08 (41.4°)	387.0	(248, 207)
	Diethyl fumarate	32.16 (15.9°)	24.79 (86.9°)	388.2 390.2	(98)
		31.56 (17.6°)	29.20 (39.6°)	391.2	(248, 207)
		31.59 (17.6°)	29.51 (39.6°)	392.4	(133, 207)
$C_8H_{14}O_4$	Di-*n*-propyl oxalate	29.97 (21.9°)	25.98 (62.0°)	400.9 402.5	(98)
	Diisopropyl oxalate	28.11 (25.1°)	24.03 (62.1°)	405.4 405.8	(98)
	Diethyl methylmalonate	30.33 (16.5°)	25.53 (60.3°)	398.4 398.2	(98)
	Dimethyl ethylmethylmalonate	30.45 (23.5°)	26.09 (62.0°)	391.1 391.7	(228)
	Dimethyl *n*-propylmalonate	31.66 (16.9°)	24.38 (87.1°)	395.4 396.8	(98)
		31.39 (22.1°)	27.24 (62.3°)	397.1 398.3	(228)
	Diethyl succinate	31.00 (28.3°)	25.11 (86.0°)	397.8 399.9	(98)
		31.82 (19.3°)	27.18 (63.4°)	397.4 399.6	(228)
		—		396.2	(109, 210)
	Dimethyl β-methylglutarate	33.25 (24.0°)	29.16 (63.8°)	399.0 398.7	(229)
	Dimethyl adipate	35.32 (23.0°)	30.88 (62.5°)	400.6 401.7	(228)
		36.16 (18.2°)	28.44 (86.7°)	401.4 402.7	(235)
	Di-*n*-propyl acetylenedicarboxylate	31.76 (25.3°)	28.20 (61.7°)	461.0 462.4	(98)
	Diisopropyl acetylenedicarboxylate	30.54 (20.3°)	24.35 (87.5°)	461.9 464.0	(98)
$C_8H_{14}O_5$	Diethyl malate	—		412.4	(133, 143)
$C_8H_{14}O_6$	Diethyl tartrate	37.6 (25.0°)		428.1	(95, 143)
$C_9H_{14}O_4$	Diethyl mesaconate	31.20 (24.1°)	29.19 (41.2°)	423.6 423.8	(96)
	Diethyl citraconate	32.09 (21.1°)	28.02 (60.5°)	426.1 426.3	(96)

$C_9H_{16}O_4$	Diethyl ethylmalonate	29.96 (16.3°)	22.87 (86.7°)	436.7	437.5	(235)
	Diethyl methylsuccinate	29.65 (22.4°)	25.71 (61.0°)	436.1	436.4	(97)
	Dimethyl β,β-dimethylglutarate	31.06 (23.9°)	27.33 (61.8°)	430.9	432.6	(229)
	Diethyl glutarate	32.59 (17.5°)	27.93 (63.1°)	438.4	439.6	(228)
	Dimethyl methyl-*n*-propylmalonate	29.89 (26.0°)	26.08 (64.0°)	431.4	431.2	(228)
	Dimethyl diethylmalonate	30.86 (21.9°)	26.38 (62.0°)	427.1	428.5	(228)
	Di-*n*-propyl malonate		29.22	438.2		(10)
	Diisopropyl malonate		26.97	437.1		(10)
	Dimethyl pimelate	35.84 (17.6°)	31.08 (62.4°)	442.4	443.6	(228)
$C_9H_{18}O_3$	Di-*n*-butyl carbonate	27.07 (25.0°)		423.4		(15)
	Diisobutyl carbonate	24.89 (25.0°)		428.1		(15)
$C_{10}H_{14}O_4$	Diallyl succinate	31.51 (40.9°)	26.70 (87.3°)	454.9	456.0	(96)
$C_{10}H_{16}O_4$	Di-*n*-propyl fumarate	31.22 (18.6°)	24.75 (86.1°)	466.7	469.6	(96)
	Diethyl allylmalonate	29.42 (22.8°)	27.40 (41.5°)	463.0	463.1	(96)
	Di-*n*-propyl maleate	31.53 (26.3°)	27.70 (62.0°)	465.7	465.7	(96)
$C_{10}H_{18}O_4$	Di-*n*-butyl oxalate	28.92 (28.2°)	25.67 (63.3°)	478.6	480.2	(235)
	Di-*n*-propyl malonate	29.54 (15.9°)	22.55 (87.4°)	476.1	476.5	(235)
	Dimethyl *n*-amylmalonate	30.37 (21.4°)	28.54 (40.4°)	473.4	474.1	(96)
	Diethyl *n*-propylmalonate	28.99 (19.9°)	22.40 (87.4°)	475.3	475.9	(235)
	Di-*n*-propyl succinate	31.05 (19.6°)	28.68 (41.4°)	476.5	475.9	(235)
	Diisopropyl succinate	28.30 (18.5°)	22.22 (85.1°)	473.0	475.7	(235)
	Diethyl adipate	32.07 (24.1°)	25.45 (86.7°)	478.9	480.0	(235)
		32.93 (17.0°)	28.06 (63.2°)	520.1	520.3	(228)
	Dimethyl suberate	36.15 (14.5°)	28.43 (86.1°)	482.0	484.0	(235)
	Dimethyl β-ethyl-β-methylglutarate	31.59 (23.9°)	28.03 (62.2°)	466.1	465.9	(229)
	Dimethyl ethyl-*n*-propylmalonate	30.84 (17.0°)	26.16 (62.4°)	468.0	468.3	(228)
	Dimethyl suberate	35.71 (17.4°)	30.66 (64.4°)	483.5	484.0	(228)
$C_{11}H_{18}O_4$	*n*-Propyl citraconate	30.48 (27.8°)	26.95 (62.2°)	502.9	503.2	(96)
	n-Propyl mesaconate	31.30 (16.3°)	24.70 (86.0°)	500.6	503.3	(96)
$C_{11}H_{20}O_4$	Di-*n*-propyl ethylmalonate	29.60 (15.1°)	23.02 (84.8°)	514.7	516.5	(235)
	Di-*n*-propyl methylsuccinate	29.24 (23.0°)	23.44 (86.0°)	513.1	514.9	(96)
	Dimethyl azelate	35.83 (15.6°)	30.63 (63.1°)	523.1	525.2	(228)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Esters of dibasic acids—*Continued*					
$C_{11}H_{20}O_4$	Dimethyl β-methyl-β-*n*-propylglutarate	30.53 (27.3°)	27.31 (62.4°)	506.3	505.5	(229)
(*continued*)	Dimethyl β,β-diethylglutarate	31.47 (23.0°)	28.00 (62.0°)	500.2	501.0	(229)
	Diethyl β,β-dimethylglutarate	29.82 (18.5°)	25.50 (62.7°)	509.9	510.1	(229)
	Dimethyl di-*n*-propylmalonate	29.19 (21.0°)	25.74 (63.2°)	502.9	505.6	(228)
	Di-*n*-butyl malonate		28.61	513.8		(10)
	Diisobutyl malonate		27.02	511.8		(10)
	Diethyl pimelate	32.93 (17.0°)	28.06 (63.2°)	520.1	520.3	(228)
$C_{11}H_{22}O_3$.........	Di-*n*-amyl carbonate	27.39 (25.0°)		508.0		(15)
	Diisoamyl carbonate	25.80 (25.0°)		505.0		(15)
$C_{12}H_{18}O_4$.........	Di-*n*-butyl acetylenedicarboxylate	32.07 (16.0°)	25.81 (85.6°)	537.0	540.7	(98)
$C_{12}H_{20}O_4$.........	Di-*n*-propyl allylmalonate	27.38 (40.6°)	25.24 (61.9°)	541.7	541.6	(96)
	Di-*n*-butyl maleate	29.07 (41.0°)	27.05 (60.4°)	542.3	542.9	(96)
	Diisobutyl maleate	28.69 (21.4°)	23.16 (86.4°)	538.6	540.6	(96)
	Di-*n*-butyl fumarate	31.01 (16.5°)	24.77 (87.4°)	544.2	547.8	(96)
	Diisobutyl fumarate	28.89 (20.3°)	23.09 (87.9°)	542.4	545.3	(96)
$C_{12}H_{22}O_4$........	Di-*n*-amyl oxalate	27.81 (42.0°)	25.88 (62.0°)	558.0	558.1	(235)
	Diisoamyl oxalate	26.38 (41.5°)	24.68 (61.9°)	553.2	554.3	(235)
	Di-*n*-propyl *n*-propylmalonate	28.57 (22.1°)	24.67 (61.5°)	553.1	553.4	(235)
	Di-*n*-butyl methylmalonate	28.81 (19.4°)	22.68 (87.2°)	552.5	554.3	(235)
	Diethyl *n*-amylmalonate	28.90 (19.6°)	24.93 (61.9°)	553.1	553.6	(235)
	Di-*n*-butyl succinate	30.96 (16.7°)	24.42 (87.2°)	554.6	556.0	(235)
	Diisobutyl succinate	28.42 (20.3°)	22.83 (86.9°)	549.8	552.8	(235)
	Dimethyl β-ethyl-β-*n*-propylglutarate	31.46 (19.0°)	27.58 (62.7°)	540.2	540.0	(229)
	Diethyl suberate	32.66 (21.3°)	28.71 (63.6°)	561.7	563.6	(228)
		33.21 (13.5°)	25.93 (88.7°)	560.4	562.7	(235)
	Di-*n*-propyl adipate	32.16 (16.2°)	27.63 (62.4°)	557.2	559.3	(235)
	Diisopropyl adipate	29.66 (17.7°)	25.00 (61.6°)	555.4	555.6	(235)

$C_{13}H_{24}O_4$........	Dimethyl di-*n*-propylglutarate	30.58 (19.5°)	26.46 (63.6°)	576.4	575.3	(229)
	Diisoamyl malonate		27.21	586.9		(10)
	Di-*n*-butyl ethylmalonate	29.19 (16.4°)	24.86 (61.5°)	519.8	591.9	(235)
$C_{13}H_{26}O_3$........	Di-*n*-hexyl carbonate	27.92 (25.0°)		587.8		(15)
$C_{14}H_{16}O_4$........	Diethyl benzylidenemalonate	38.70 (19.8°)	34.42 (61.2°)	560.6	561.2	(226)
$C_{14}H_{18}O_4$........	Diethyl benzylmalonate	35.54 (20.5°)	31.39 (61.2°)	567.9	567.6	(226)
$C_{14}H_{22}O_4$........	Di-*n*-amyl acetylenedicarboxylate	31.45 (18.9°)	25.85 (86.1°)	615.3	619.8	(98)
	Diisoamyl acetylenedicarboxylate	30.26 (25.3°)	25.08 (86.4°)	611.9	615.4	(98)
$C_{14}H_{24}O_4$........	Di-*n*-amyl maleate	31.06 (17.2°)	25.02 (87.3°)	619.9	623.0	(96)
		28.64 (17.4°)	27.70 (28.7°)	613.6		(248, 207)
	Diisoamyl maleate	28.51 (19.3°)	23.71 (86.5°)	610.1	616.3	(96)
		28.44 (24.5°)	23.42 (88.2°)	611.8	616.0	(96)
	Di-*n*-amyl fumarate	31.01 (15.3°)	24.92 (86.6°)	622.4	626.6	(96)
	Diisoamyl fumarate	29.19 (21.8°)	23.86 (87.3°)	618.1	621.9	(96)
		28.93 (24.4°)	23.70 (86.3°)	618.0	619.8	(98)
	Di-*n*-butyl allylmalonate	29.03 (18.1°)	27.13 (41.2°)	618.9	618.6	(96)
$C_{14}H_{26}O_4$........	Di-*n*-butyl *n*-propylmalonate	26.56 (41.1°)	24.82 (61.3°)	630.5	631.2	(235)
	Di-*n*-propyl *n*-amylmalonate	26.83 (40.6°)	25.08 (60.8°)	631.6	632.0	(235)
	Di-*n*-amyl succinate	28.61 (42.0°)	27.07 (60.9°)	633.3	634.8	(235)
		—		621.3		(131, 207)
	Diisoamyl succinate	29.42 (18.6°)	27.79 (41.0°)	628.8	631.4	(235)
		29.44 (24.6°)	24.08 (87.9°)	630.5	632.1	(235)
	Di-*n*-butyl adipate	31.69 (15.9°)	25.35 (87.7°)	634.8	637.7	(235)
	Di-*n*-propyl suberate	32.12 (16.8°)	25.93 (85.4°)	637.5	641.3	(235)
	Diethyl sebacate	32.74 (20.1°)	26.37 (87.1°)	641.1	643.1	(235)
		33.17	28.96 (62.4°)	643.4	643.7	(228)
		31.88 (22.5°)	30.30 (38.7°)	646.9		(249, 207)
$C_{16}H_{30}O_4$........	Di-*n*-butyl *n*-amylmalonate	26.67 (41.3°)	25.00 (60.8°)	708.7	709.3	(235)
	Di-*n*-amyl adipate	29.46 (41.4°)	27.60 (61.4°)	716.0	716.6	(235)
	Diisoamyl adipate	29.99 (22.1°)	24.43 (87.3°)	710.2	713.2	(235)
	Di-*n*-butyl suberate	31.54 (20.5°)	25.70 (86.3°)	716.0	718.3	(235)
	Di-*n*-propyl sebacate	32.26 (20.4°)	26.19 (86.7°)	719.0	721.6	(235)
$C_{19}H_{36}O_4$........	Di-*n*-octyl malonate		28.08	828.7		(10)
$C_{20}H_{38}O_4$........	Diisoamyl sebacate	29.87 (23.5°)	28.87 (35.9°)	877.0		(249, 207)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Esters of fatty acids and glycerol (glycerides)				
$C_{11}H_{22}O_4$	α-Monocaprylin	26.69 (97.3°)		514	(181)
$C_{13}H_{28}O_4$	α-Monocaprin	25.43 (97.3°)		588	(181)
$C_{16}H_{30}O_4$	α-Monolaurin	25.28 (97.3°)		664	(181)
$C_{17}H_{34}O_4$	α-Monomyristin	24.88 (97.3°)		740	(181)
$C_{18}H_{38}O_4$	α-Monopalmitin	25.54 (97.3°)		823	(181)
$C_{21}H_{42}O_4$	α-Monostearin	25.07 (97.3°)		894	(181)
$C_{33}H_{62}O_6$	Tricaprin	27.3 (60.0°)	25.9 (80.0°)	1404 (80.0°)	(100)
		28.3 (70.0°)	27.6 (80.0°)	2134 (80.0°)	(100)
$C_{39}H_{74}O_6$	Trilaurin	27.9 (60.0°)	26.6 (80.0°)	1648 (80.0°)	(100)
$C_{45}H_{88}O_6$	Trimyristin	28.7 (60.0°)	27.2 (80.0°)	1892 (80.0°)	(100)
$C_{51}H_{88}O_6$	Tripalmitin	28.53 (55.7°)	27.85 (65.9°)	2252	(247, 207)
$C_{57}H_{110}O_6$	Tristearin	28.1 (80.0°)		2376	(100)
		28.85 (57.7°)	28.01 (68.8°)	2380	(247, 207)
	Esters of halogenated acids				
$C_3H_3Cl_3O_2$	Methyl trichloroacetate	33.92 (13.3°)	30.60 (41.5°)	285.8 286.5	(242)
$C_3H_4Cl_2O_2$	Methyl dichloroacetate	34.86 (18.0°)	31.95 (41.4°)	252.0 252.2	(242)
$C_3H_5ClO_2$	Ethyl chlorocarbonate	26.53 (15.1°)	22.72 (46.5°)	216.9	(165, 143)
$C_4H_5Cl_3O_2$	Ethyl trichloroacetate	31.36 (15.3°)	30.58 (23.1°)	326.8 327.1	(242)
		30.87		326.1	(36)
		31.2	28.1 (50.0°)	327.6	(93, 143)
$C_4H_5F_3O_2$	Ethyl trifluoroacetate	16.76		241.7	(36)
$C_4H_6Cl_2O_2$	Ethyl dichloroacetate	—		291.7	(190, 143)
		31.34		289.5	(36)
		32.74 (19.9°)	30.06 (41.6°)	292.9 293.0	(242)

$C_4H_6F_2O_2$	Ethyl difluoroacetate	24.60		234.8	(36)
$C_4H_7ClO_2$	Ethyl chloroacetate	—		252.1	(190, 143)
		31.70		252.7	(36)
$C_4H_7FO_2$	Ethyl fluoroacetate	29.35		226.2	(36)
$C_5H_7Cl_3O_2$	*n*-Propyl trichloroacetate	30.75 (17.9°)	27.95 (42.0°)	365.1 365.3	(242)
$C_5H_8Cl_2O_2$	*n*-Propyl dichloroacetate	31.07 (16.5°)	29.75 (29.9°)	329.0 329.8	(242)
$C_6H_8Cl_3O_2$	*n*-Butyl trichloroacetate	30.79 (13.3°)	28.22 (40.8°)	403.4 404.8	(242)
$C_6H_{10}Cl_2O_2$	*n*-Butyl dichloroacetate	30.61 (19.8°)	28.24 (41.6°)	367.3 367.8	(242)
$C_7H_{11}Cl_3O_2$	Isoamyl trichloroacetate	—		443.0	(133, 207)
$C_{10}H_9BrO_2$	Methyl *cis*-α-bromocinnamate	43.41	40.20 (48.0°)	426.4 427.4	(212)
	Methyl *trans*-α-bromocinnamate	45.59	44.32	424.6 425.0	(212)
	Methyl *cis*-β-bromocinnamate	36.04 (66.0°)	34.07 (81.0°)	427.7 427.3	(212)
	Methyl *trans*-β-bromocinnamate	44.79	40.21 (53.0°)	424.7 424.5	(212)

Esters of aromatic acids

$C_8H_8O_2$	Methyl benzoate	37.6	34.2 (50°)	310.4	(93, 143)
		38.32 (15.3°)	29.98 (87.3°)	309.4 310.4	(96)
$C_8H_8O_3$	Methyl salicylate	38.82 (30.0°)	34.95 (60.2°)	323.3 323.3	(21)
		39.1 (25.0°)	33.9 (74.7°)	323.7	(95, 143)
		38.6 (25.0°)	34.9 (58.0°)	321.5 322.6	(196)
	Methyl *m*-hydroxybenzoate	37.77 (100.4°)	34.93 (130.4°)	327.0 328.0	(21)
	Methyl *p*-hydroxybenzoate	35.8 (137.2°)		331.8	(196)
		34.61 (150.4°)	32.47 (174.8°)	332.4 333.2	(21)
$C_9H_6O_2$	Coumarin	41.81 (99.8°)		315.2	(171)
$C_9H_{10}O_2$	Ethyl benzoate	34.6 (25.0°)		347 6	(76)
		34.57 (24.8°)	27.93 (88.1°)	349.3 350.1	(96)
$C_{10}H_{12}O_2$	*n*-Propyl benzoate	33.87 (23.5°)	27.31 (87.6°)	388.3 389.1	(96)
$C_{11}H_{14}O_2$	*n*-Butyl benzoate	33.54 (20.8°)	27.21 (87.5°)	427.0 428.6	(96)
$C_{12}H_{13}NO_4$	1,3-Dimethylallyl *o*-nitrobenzoate	— —		506–509	(79)
	1,3-Dimethylallyl *m*-nitrobenzoate	— —		496.3	(79)
$C_{12}H_{14}O_2$	1,3-Dimethylallyl benzoate	— —		450.5	(79)
$C_{12}H_{14}O_4$	Diethyl phthalate	— —		492.0	(15)
$C_{13}H_{16}O_2$	γ-Methyl-α-ethylallyl benzoate	— (15°)	— (40°)	490.2 490.5	(2)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Esters of inorganic acids				
	Hyponitrites				
$C_4H_{10}N_2O_2$	Ethyl hyponitrite	21.44 (16.0°)		266.5	(90)
$C_6H_{14}N_2O_2$	Propyl hyponitrite	24.94		343.5	(90)
$C_8H_{18}N_2O_2$	Butyl hyponitrite	26.5 (18.0°)		421.7	(90)
	Nitrites				
CH_3NO_2	Methyl nitrite	21.0 (−19.0°)		130.6	(149)
$C_2H_5NO_2$	Ethyl nitrite	16.5 (15.0°)		169.0	(149)
$C_4H_9NO_2$	*n*-Butyl nitrite	20.48 (28.5°)	19.12 (42.5°)	251.6 252.1	(211)
		20.98 (23.6°)	18.87 (41.3°)	251.4 251.1	(242)
$C_5H_{11}NO_2$	*n*-Amyl nitrite	20.47 (41.5°)	18.63 (58.2°)	289.9 289.4	(242)
	Isoamyl nitrite	22.04 (14.0°)	18.06 (56.0°)	286.7 287.7	(211)
$C_6H_{13}NO_2$	*n*-Hexyl nitrite	24.16 (16.3°)	21.62 (42.1°)	329.9 331.0	(242)
	Nitrates				
$C_2H_5NO_3$	Ethyl nitrate	26.52 (30.0°)	25.30 (40.0°)	189.2 189.5	(21)
		—		189.6	(138, 143)
		28.7	20.5 (85.0°)	189.8	(93, 143)
		28.34 (18.3°)	26.64 (31.3°)	189.3 189.3	(242)
$C_3H_5N_3O_9$	Nitroglycerin	51.1 (16.5°)	50.3 (20.5°)	379.6 379.0	(216)
$C_3H_7NO_3$	*n*-Propyl nitrate	27.45 (17.8°)	24.45 (40.9°)	227.7 226.8	(242)
$C_4H_9NO_3$	*n*-Butyl nitrate	28.71 (13.9°)	25.54 (41.8°)	267.9 267.8	(242)
	Borates				
$C_6H_{12}BCl_3O_3$	Tri-2-chloroethyl borate	39.19		488.5	(103)
$C_9H_{15}BCl_6O_3$	Tri(*s*-dichloroisopropyl) borate	43.40		722.6	(103)

	Phosphates					
$C_3H_9O_4P$	Trimethyl phosphate	32.88 (60.9°)	26.06 (120.7°)	286.2	286.3	(243)
$C_6H_{12}Cl_3O_4P$	Tri-2-chloroethyl phosphate	43.83		515.2		(103)
$C_6H_{15}O_4P$	Triethyl phosphate	25.99 (61.7°)	20.72 (121.1°)	399.6	400.7	(243)
$C_9H_{21}O_4P$	Tri-*n*-propyl phosphate	29.46 (16.9°)	20.05 (121.8°)	516.0	515.8	(243)
	Triisopropyl phosphate	25.68 (15.3°)	17.06 (120.4°)	509.4	510.6	(243)
$C_{12}H_{27}O_4P$	Tri-*n*-butyl phosphate	28.15 (16.6°)	20.07 (121.6°)	626.3	631.1	(243)
	Triisobutyl phosphate	26.74 (15.3°)	21.08 (87.3°)	623.0	626.5	(243)
		Aliphatic ethers				
C_2H_4O	Ethylene oxide	28.4 (−5.0°)	24.3 (20.0°)	112.6	112.7	(214)
C_2H_6O	Methyl ether	1.86 (102.5°)	0.78 (115.0°)	136.0	138.9	(255)
C_4H_8O	Ethyl vinyl ether	19.00		199.8		(178)
$C_4H_8O_2$	1,4-Dioxane	22.11 (101.6°)		202.0		(53)
$C_4H_8OCl_2$	2,2-Dichloroethyl ether	37.89 (19.3°)	27.23 (26.1°)	290.7	291.3	(234)
		17.78 (178.8°)		291.6		(53)
$C_4H_{10}O$	Ethyl ether	— (34.6°)		211.9		(189, 207)
		—		209.5		(139, 207)
		16.49	14.05 (40.0°)	211.7		(166, 207)
		16.49		209.8		(76)
		17.06	15.95	211.2		(75, 210)
		17.25 (18.4°)	16.25 (29.4°)	211.5	212.3	(234)
C_5H_8O	Methoxyprene	25.10 (15.0°)		226.5		(157)
$C_5H_{10}O$	Ethyl 2-methylvinyl ether	21.44		239.0		(245)
	n-Propyl vinyl ether	20.62		239.0		(245)
	Isopropyl vinyl ether	18.72		237.8		(245)
$C_5H_{12}O$	*n*-Butyl methyl ether	20.32 (17.0°)	17.79 (40.9°)	250.7	250.4	(234)
	Ethyl propyl ether	—		252.0		(161, 221)
$C_6H_{10}O$	Ethoxyprene	25.29 (15.0°)		267.5		(157)
$C_6H_{12}O$	Cyclopentyl methyl ether	26.75 (16.9°)	25.92 (24.4°)	263.2	263.3	(238)
	2,2-Dimethylvinyl ethyl ether	21.62		278.4		(245)
	n-Butyl vinyl ether	21.95		278.2		(245)
	Isobutyl vinyl ether	20.54		277.6		(245)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Aliphatic ethers—*Continued*				
$C_6H_{14}O$	*n*-Propyl ether	20.53	19.35	290.9	(75, 210)
		20.33 (21.7°)	16.34 (59.0°)	290.4 (mean)	(234)
	Isopropyl ether	18.39 (14.1°)	13.92 (56.7°)	288.9 289.5	(234)
	n-Amyl methyl ether	22.11 (18.0°)	21.49 (24.0°)	290.5 290.7	(234)
	Butyl ethyl ether	21.04 (16.0°)	18.31 (42.3°)	290.7 290.4	(234)
$C_6H_{14}O_3$	Diethyleneglycol dimethyl ether	14.44 (159.8°)		327.4	(53)
C_7H_8O	Anisole	34.57 (18.4°)	32.19 (37.2°)	265.6	(248, 207)
		—		265.6	(139, 207)
		35.22		265.2	(72, 207)
		—		265.7	(180, 207)
		39.3 (−21.0°)		262.9	(76)
$C_7H_{14}O$	Cyclopentyl ethyl ether	26.51 (17.2°)	25.74 (23.7°)	302.9 302.8	(238)
	Isopentyl vinyl ether	22.48		317.7	(245)
	Cyclohexyl methyl ether	28.81 (14.7°)	27.40 (27.4°)	300.7 300.7	(238)
$C_7H_{16}O$	*n*-Hexyl methyl ether	23.46 (17.0°)	19.04 (61.6°)	330.1 330.0	(234)
	n-Amyl ethyl ether	22.12 (19.1°)	17.99 (61.9°)	330.3 330.6	(234)
$C_8H_{10}O$	Benzyl methyl ether	33.77	33.13 (25.0°)	305.1 305.4	(87)
	Phenetole	—		303.5	(180, 207)
		—		303.6	(139, 207)
		32.74		302.8	(72, 207)
$C_8H_{14}O$	Isobutoxyprene	24.51 (15.0°)		345.0	(157)
$C_8H_{16}O$	Cyclohexyl ethyl ether	27.45 (17.3°)	25.25 (40.6°)	338.7 339.1	(238)
	n-Hexyl vinyl ether	24.52		358.3	(245)
$C_8H_{18}O$	Ethyl *n*-hexyl ether	21.00 (42.1°)	19.11 (61.4°)	370.6 369.4	(234)
	n-Butyl ether	20.97 (40.9°)	18.88 (61.8°)	370.9 370.4	(234)
		22.90	21.81	369.9	(75, 210)
$C_8H_{18}O_2$	Diethyleneglycol diethyl ether	26.99 (22.1°)	25.10 (42.1°)	408.9 409.5	(234)
$C_9H_{12}O$	Benzyl ethyl ether	32.82	32.18 (25.0°)	343.7 343.2	(87)

$C_9H_{18}O$	*n*-Butyl 1,3-dimethylallyl ether	—		393.8		(78)
	n-Heptyl vinyl ether	25.45		398.3		(245)
$C_{10}H_{12}O$	Anethole	32.67 (41.4°)	31.26 (55.2°)	363.2		(136, 207)
$C_{10}H_{14}O$	Benzyl *n*-propyl ether	32.15	31.76 (25.0°)	374.9	375.9	(87)
	Benzyl isopropyl ether	30.78	30.46 (25.0°)	374.3	379.0	(87)
$C_{10}H_{22}O$	*n*-Amyl ether	24.76	23.78	449.9		(75, 210)
		25.58 (12.0°)	20.67 (63.8°)	449.7	450.6	(234)
	Isoamyl ether (fermentation alcohol)	23.46 (15.1°)	17.23 (87.3°)	446.3	446.7	(234)
	Isoamyl ether (synthetic alcohol)	22.85 (21.7°)	19.37 (60.3°)	445.8	445.0	(234)
	Isoamyl ether	—		445.7		(106, 143)
	4-Ethoxymethylheptane	22.95		439.4		(3)
		22.95		439.6		(3)
		22.89		439.4		(3)
$C_{10}H_{22}O_5$	Tetraethyleneglycol dimethyl ether	31.71 (41.9°)	29.79 (60.7°)	532.4	532.9	(234)
$C_{11}H_{16}O$	Benzyl *n*-butyl ether	30.92		419.4		(87)
		30.66 (25.0°)		421.0		(87)
	Benzyl isobutyl ether	29.91	29.48 (25.0°)	415.7	416.8	(87)
$C_{12}H_{18}O$	Benzyl isoamyl ether	30.43	29.50 (25.0°)	459.8	458.8	(87)
$C_{12}H_{26}O$	*n*-Hexyl ether	25.41 (25.3°)	20.08 (86.0°)	529.9	530.0	(234)
$C_{13}H_{11}OCl$	2-Chlorobenzyl phenyl ether	41 84 (25 0°)	40.64 (35.0°)	470.8	470.8	(50)
	Benzyl 2-chlorophenyl ether	41.70 (25.0°)	40.63 (35.0°)	480.9	481.4	(50)
$C_{14}H_{30}O$	*n*-Heptyl ether	27.36 (16.2°)	23.27 (62.1°)	610.3	610.7	(234)
$C_{16}H_{34}O$	*n*-Octyl ether	27.25 (25.4°)	24.25 (61.4°)	690.0	691.7	(234)

Aromatic ethers

C_7H_8O	Anisole	35.37 (23.7°)	30.57 (61.5°)	265.6	265.5	(234)
$C_8H_{10}O$	Phenetole	32.85 (22.0°)	30.55 (40.2°)	303.7	303.3	(234)
$C_9H_{10}O$	Allyl phenyl ether	33.44 (25.4°)	31.54 (41.5°)	330.5	330.6	(234)
$C_9H_{12}O$	Phenyl *n*-propyl ether	31.60 (25.8°)	29.86 (41.5°)	341.6	342.0	(234)
	Isopropyl phenyl ether	30.37 (25.2°)	28.58 (40.7°)	341.6	341.4	(234)
$C_{10}H_{14}O$	*n*-Butyl phenyl ether	30.85 (25.4°)	29.44 (40.4°)	380.8	381.2	(234)
$C_{11}H_{16}O$	*n*-Amyl phenyl ether	29.75 (41.3°)	27.93 (60.3°)	421.5	422.0	(234)
$C_{12}H_{18}O$	*n*-Hexyl phenyl ether	30.88 (24.5°)	29.44 (41.3°)	459.8	460.5	(234)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Halogenated ethers: chloro ethers				
$C_5H_{11}OCl$	1-Chloro-2-methoxybutane	—		292.9	(131)
	2-Chloro-3-methoxybutane	—		289.6	(119)
$C_6H_{13}OCl$	1-Chloro-2-ethoxybutane	—		328.9	(119)
	2-Chloro-3-ethoxybutane	—		326.6	(119)
$C_8H_{17}OCl$	2-*n*-Butoxy-1-chlorobutane	—		407.2	(119)
	1-Chloro-2-isobutoxybutane	—		406	(119)
	2-Chloro-3-isobutoxybutane	—		404.9	(119)
$C_9H_{19}OCl$	1-Chloro-2-isopentoxybutane	—		442.8	(119)
	2-Chloro-3-isopentoxybutane	—		444.7	(119)
$C_{10}H_{12}OCl_2$	2-Chloro-3-*o*-chlorophenoxybutane	37.66 (15.0°)		454.4	(117)
	2-Chloro-3-*p*-chlorophenoxybutane	37.88 (15.0°)		455.5	(117)
	1,1-Dichloro-2-phenoxybutane	37.02 (15.0°)		417.7	(117)
	Halogenated ethers: bromo ethers				
C_4H_9BrO	2-Ethoxyethyl bromide	29.51 (21.1°)	27.40 (41.0°)	256.1 256.6	(236)
$C_5H_{11}BrO$	3-Bromo-2-methoxybutane	29.13		299.7	(118)
	1-Bromo-2-methoxybutane	29.36		299.9	(118)
$C_6H_{13}BrO$	1-Bromo-2-ethoxybutane	27.65		336.2	(118)
	2-Bromo-3-ethoxybutane	27.34		338.5	(118)
$C_7H_{15}BrO$	2-Bromo-3-propoxypentane	27.5		376.3	(118)
$C_8H_{17}BrO$	2-Bromo-3-*n*-butoxybutane	27.16		413.6	(118)
	2-Bromo-3-isobutoxybutane	26.52		415.9	(118)
$C_9H_{19}BrO$	2-Bromo-3-isopentoxybutane	27.4		451.8	(118)

Halogenated hydrocarbons: aliphatic monobromides

C_2H_5Br	Bromoethane	—		163.1		(115)
		24.15	22.83	165.7		(75, 210)
		24.16		167.6		(72, 207)
		24.32 (18.8°)	23.60 (25.2°)	165.4	165.4	(236)
		24.32 (16.9°)	23.74 (21.1°)	165.3	165.3	(236)
C_3H_5Br	Allyl bromide	28.01 (11.9°)	24.13 (41.2°)	192.4	192.9	(236)
C_3H_7Br	1-Bromopropane	—		202.1		(115)
		25.85	24.59	205.3		(75, 210)
		26.50 (9.2°)	20.30 (61.5°)	203.0	204.4	(236)
		25.46 (19.4°)	24.87 (25.3°)	203.8	204.1	(236)
	2-Bromopropane	22.90	21.74	205.1		(75, 210)
		23.46 (14.1°)	20.30 (41.2°)	203.4	204.3	(236)
		24.30 (9.8°)	20.29 (40.7°)	206.5	207.0	(236)
		23.56 (15.0°)	20.51 (41.4°)	204.8	205.5	(236)
C_4H_9Br	1-Bromobutane	26.33	25.21	243.5		(75, 210)
		25.73 (26.1°)	23.97 (40.3°)	243.2	242.8	(236)
		26.28 (21.3°)	21.95 (60.6°)	243.7	244.0	(236)
	1-Bromo-2-methylpropane	—		243.8		(114, 210)
		22.53 (41.5°)	20.42 (61.9°)	243.7	244.6	(236)
		25.36 (14.2°)	20.04 (60.4°)	246.6	247.1	(236)
	2-Bromobutane	24.89 (24.8°)	20.44 (60.8°)	243.6	243.5	(236)
		26.23 (10.9°)	20.47 (63.2°)	243.4	244.8	(236)
$C_5H_{11}Br$	1-Bromopentane	27.29	26.06	283.6		(75, 210)
		24.76 (42.4°)	23.05 (60.8°)	282.7	283.3	(236)
		25.07 (42.0°)	22.99 (62.1°)	283.0	282.9	(236)
	1-Bromo-3-methylbutane	25.86	24.79	282.9		(75, 210)
		26.22 (17.1°)	18.74 (87.6°)	281.0	280.2	(236)
		26.57 (15.4°)	19.27 (86.4°)	282.8	282.6	(236)
	2-Bromopentane	26.40 (14.3°)	18.99 (86.5°)	280.7	280.9	(236)
	3-Bromopentane	25.48 (23.3°)	21.94 (61.5°)	281.5	281.9	(236)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Halogenated hydrocarbons: aliphatic monobromides—*Continued*					
$C_6H_{13}Br$........	1-Bromohexane	28.04	26.80	322.8		(75, 210)
		26.46 (28.7°)	23.65 (61.2°)	322.4	323.4	(236)
		28.10 (18.3°)	25.46 (42.1°)	323.0	323.6	(236)
$C_7H_{15}Br$........	1-Bromoheptane	28.56	27.50	363.0		(75, 210)
		28.25 (26.5°)	25.23 (61.8°)	364.1	362.8	(236)
C_8H_9Br........	2-Phenylethyl bromide	39.23 (16.3°)	36.68 (41.1°)	339.9	340.9	(237)
$C_8H_{17}Br$........	1-Bromoöctane	28.89	27.67	402.4		(75, 210)
		27.09 (42.0°)	25.35 (60.7°)	403.7	404.0	(236)
$C_9H_{19}Br$........	1-Bromononane	27.58 (41.8°)	25.62 (63.2°)	443.6	444.2	(236)
$C_{10}H_{21}Br$........	1-Bromodecane	29.09 (26.5°)	27.73 (40.9°)	484.6	484.6	(236)
$C_{11}H_{23}Br$........	1-Bromoundecane	30.06 (21.8°)	26.62 (62.5°)	523.3	524.3	(236)
$C_{12}H_{25}Br$........	1-Bromododecane	30.31 (24.9°)	27.21 (61.2°)	565.3	566.8	(236)
$C_{14}H_{27}Br$........	1-Bromotetradecane	31.26 (19.3°)	27.80 (58.3°)	644.0	645.4	(237)
$C_{16}H_{31}Br$........	1-Bromohexadecane	31.25 (25.3°)	28.00 (61.4°)	725.1	726.2	(237)
	Halogenated hydrocarbons: aliphatic monochlorides					
C_2H_5Cl........	Chloroethane	21.18 (5.0°)	20.58 (10.0°)	151.6		(75, 210)
C_3H_5Cl........	Allyl chloride	24.57 (10.2°)	23.17 (23.8°)	179.6	179.6	(96)
C_3H_7Cl........	1-Chloropropane	— (47.0°)		190.2		(189, 207)
		21.78	20.48	187.0		(75, 210)
		22.78 (12.4°)	19.21 (41.6°)	191.3	192.0	(236)
	2-Chloropropane	19.91 (16.1°)	19.04 (25.6°)	191.9	191.7	(236)
C_4H_9Cl........	1-Chlorobutane	23.66	22.43	230.5		(75, 210)
		23.29 (23.3°)	18.75 (61.0°)	230.5	230.2	(236)
		21.25 (41.0°)	19.14 (61.6°)	230.1	230.3	(236)
	1-Chloro-2-methylpropane	21.99	20.87	228.4		(75, 210)
		19.79 (41.1°)	18.23 (56.5°)	227.9	228.4	(236)
	2-Chlorobutane	21.84 (19.7°)	19.72 (40.5°)	228.9	229.8	(236)
		23.04 (12.7°)	17.60 (60.5°)	230.1	230.5	(236)
	2-Chloro-2-methylpropane	21.35 (0.0°)	18.30 (25.0°)	230.9	229.4	(162)
		19.64 (17.1°)	16.72 (40.6°)	229.7	229.1	(236)

$C_5H_{11}Cl$	1-Chloropentane	25.06	23.77	270.4		(75, 210)
		24.57 (23.0°)	20.38 (62.7°)	270.0	270.4	(236)
		23.79 (19.8°)	21.37 (41.5°)	269.8	269.3	(236)
	1-Chloro-3-methylbutane	23.48		269.8		(72, 207)
		23.52 (18.4°)	21.15 (40.3°)	269.2	269.2	(236)
		23.57 (18.3°)	19.18 (62.6°)	268.5	268.9	(236)
	2-Chloro-2-methylbutane	25.39 (0.0°)	18.67 (50.0°)	269.6	265.4	(162)
		22.75 (17.8°)	18.00 (61.2°)	268.4	267.7	(236)
	2-Chloropentane	23.57 (17.8°)	20.97 (42.0°)	268.3	268.5	(236)
$C_6H_{13}Cl$	1-Chlorohexane	26.21 (20.3°)	19.25 (87.3°)	310.8	309.7	(236)
	2-Chloro-2-methylpentane	22.37 (25.0°)	19.80 (50.0°)	307.6	307.0	(162)
	3-Chloro-3-methylpentane	26.55 (0.0°)	20.93 (50.0°)	306.0	303.9	(162)
C_7H_7Cl	Benzyl chloride	37.46 (20.6°)	29.15 (88.5°)	284.8	284.0	(237)
$C_7H_{11}Cl$	1-Chloro-1-heptyne	26 (17.0°)		321		(221)
$C_7H_{15}Cl$	1-Chloroheptane	26.95 (21.5°)	24.89 (41.6°)	350.5	350.9	(236)
	2-Chloro-2-methylhexane	23.69 (25.0°)	21.15 (50.0°)	346.8	346.2	(162)
	3-Chloro-3-methylhexane	26.88 (0.0°)	24.32 (25.0°)	343.9	343.8	(162)
	2-Chloro-2-ethylpentane	25.46 (25.0°)	22.82 (50.0°)	341.3	340.6	(162)
C_8H_5Cl	1-Chloro-2-phenylacetylene	36.1		297		(221)
$C_8H_{13}Cl$	1-Chloro-1-octyne	26.1		356		(221)
$C_8H_{17}Cl$	1-Chlorooöctane	27.99 (17.9°)	21.39 (87.1°)	390.1	390.5	(236)
	2-Chloro-2-methylheptane	24.54 (25.0°)	21.69 (55.0°)	386.8	386.8	(199)
	3-Chloro-3-methylheptane	23.38 (25.0°)	22.50 (55.0°)	382.6	382.5	(199)
	3-Chloro-3-ethylhexane	28.06 (0.0°)	23.03 (50.0°)	379.5	378.5	(162)
	4-Chloro-4-methylheptane	24.75 (25.0°)	22.41 (50.0°)	383.0	382.9	(162)
$C_9H_{15}Cl$	1-Chloro-1-nonyne	26.0		395		(221)
$C_9H_{19}Cl$	1-Chlorononane	(17.3°)	(61.3°)	431.1	431.0	(236)
	4-Chloro-4-ethylheptane	28.17 (0.0°)	25.76 (25.0°)	418.2	418.2	(162)
	4-Chloro-4-methyloctane	26.00 (25.0°)	23.04 (55.0°)	421.3	421.3	(199)
	3-Chloro-3-methyloctane	26.03 (25.0°)	23.15 (55.0°)	422.3	422.2	(199)
	2-Chloro-2-methyloctane	25.38 (25.0°)	23.00 (50.0°)	427.7	427.5	(162)
$C_{10}H_{21}Cl$	1-Chlorodecane	28.72 (21.8°)	26.81 (42.1°)	471.4	472.3	(236)
	3-Chloro-3-methylnonane	26.37 (25.0°)	24.03 (50.0°)	463.6	463.5	(162)
	5-Chloro-5-methylnonane	26.36 (25.0°)	24.40 (45.0°)	461.0	461.0	(199)
	4-Chloro-4-methylnonane	26.54 (25.0°)	24.66 (45.0°)	461.2	461.3	(199)
	4-Chloro-4-propylheptane	23.58 (50.0°)	21.25 (75.0°)	457.8	456.8	(162)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Halogenated hydrocarbons: aliphatic monochlorides—*Continued*					
$C_{11}H_{23}Cl$	1-Chloroundecane	19.13 (21.3°)	25.55 (61.5°)	511.3	512.4	(236)
	4-Chloro-4-methyldecane	26.50 (25.0°)	24.20 (50.0°)	502.0	501.8	(162)
$C_{12}H_{25}Cl$	1-Chlorododecane	27.17 (41.5°)	23.41 (86.9°)	549.1	550.9	(236)
	3-Chloro-3-ethyldecane	27.19 (25.0°)	25.48 (45.0°)	537.2	537.0	(199)
	5-Chloro-5-methylundecane	27.05 (25.0°)	24.83 (50.0°)	542.3	542.5	(162)
$C_{13}H_{27}Cl$	5-Chloro-5-propyldecane*	27.02 (25.0°)	25.16 (45.0°)	580.9	581.1	(157)
	6-Chloro-6-methyldodecane	27.01 (25.0°)	24.94 (50.0°)	581.5	582.5	(162)
$C_{14}H_{29}Cl$	5-Butyl-5-chlorodecane	27.48 (25.0°)	25.50 (45.0°)	613.7	613.6	(199)
	Halogenated hydrocarbons: aliphatic monofluorides					
C_4H_9F	1-Fluorobutane	17.72		201.5		(36)
	2-Fluorobutane	16.93 (15.0°)		201.0		(36)
$C_5H_{11}F$	1-Fluoropentane	20.06		241.4		(36)
		20.65 (15.4°)	17.61 (41.3°)	241.5	241.4	(237)
$C_6H_{13}F$	1-Fluorohexane	21.83		281.2		(36)
		21.75 (16.9°)	17.29 (61.5°)	281.5	282.5	(237)
	2-Fluorohexane	20.39		279.7		(36)
$C_7H_{15}F$	1-Fluoroheptane	23.07 (16.9°)	18.48 (61.0°)	320.1	320.3	(237)
$C_8H_{17}F$	1-Fluoroöctane	23.92 (20.4°)	19.99 (62.3°)	361.0	361.4	(237)
	Halogenated hydrocarbons: aliphatic monoiodides					
CH_3I	Iodomethane	—		186.5		(115)
		30.14	28.61	146.2		(75, 210)
		31.38 (16.5°)	30.59 (22.9°)	146.8	146.6	(236)
		30.90 (14.1°)	29.76 (22.2°)	146.1	145.8	(236)

C_2H_5I..........	Iodoethane	28.83	27.57	187.0		(75, 210)
		30.4 (0.0°)		184.5		(76)
		29.62 (13.3°)	26.21 (41.1°)	186.1	187.0	(236)
		29.79 (14.4°)	23.85 (61.5°)	187.0	187.8	(236)
C_3H_7I..........	1-Iodopropane	—		264.5		(115)
		29.28	28.27	226.0		(75, 210)
		29.77 (14.5°)	24.23 (60.6°)	225.3	226.1	(236)
		29.22 (14.5°)	21.60 (85.2°)	225.4	226.7	(236)
	2-Iodopropane	25.62 (25.0°)	24.07 (40.9°)	225.9	226.3	(236)
		26.11 (24.5°)	22.13 (61.2°)	227.6	229.1	(236)
C_4H_9I..........	1-Iodobutane	—		303.5		(115)
		29.15	27.90	264.7		(75, 210)
		29.38 (16.9°)	22.12 (86.0°)	264.4	264.6	(236)
		28.39 (22.9°)	24.64 (60.6°)	266.4	267.6	(236)
	1-Iodo-2-methylpropane	27.97	27.04	265.0		(75, 210)
$C_5H_{11}I$..........	1-Iodopentane	28.67 (25.5°)	22.41 (86.7°)	304.7	304.6	(236)
	1-Iodo-3-methylbutane	27.28 (25.0°)	23.75 (61.3°)	302.7	302.7	(236)
		28.40 (21.4°)	22.47 (86.5°)	303.5	305.2	(236)
	2-Iodopentane	28.51 (17.5°)	25.59 (41.2°)	302.4	301.2	(236)
	3-Iodopentane	27.98 (25.1°)	25.87 (41.5°)	302.4	301.6	(236)
$C_6H_{13}I$..........	1-Iodohexane	29.93	29.09	344.1		(75, 210)
		29.62 (24.1°)	23.59 (85.6°)	345.7	345.9	(236)
$C_7H_{15}I$..........	1-Iodoheptane	30.38	29.53	384.5		(75, 210)
		30.56 (18.6°)	26.33 (61.6°)	386.6	386.8	(236)
C_8H_9I..........	2-Phenylethyl iodide	41.31 (14.4°)	33.59 (86.2°)	359.0	360.0	(237)
$C_8H_{17}I$..........	1-Iodoöctane	30.65 (21.0°)	24.63 (86.9°)	425.3	426.4	(236)
$C_{16}H_{33}I$..........	1-Iodohexadecane	32.26 (25.0°)	31.91	748.9		(75, 210)

Halogenated hydrocarbons: aliphatic polyhalides

CBr_3F..........	Tribromofluoromethane	31.68		232.4		(36)
CCl_3F..........	Trichlorofluoromethane	19.05 (15.0°)		192.2		(36)

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* Somewhat impure.

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Halogenated hydrocarbons: aliphatic polyhalides—*Continued*					
CCl_4	Carbon tetrachloride	25.68	18.71 (80.0°)	219.9		(166, 207)
		— (75.2°)		220.0		(199, 207)
		—		218.5		(139, 207)
		26.66		219.8		(72, 207)
		25.53 (30.0°)	23.14 (50.0°)	220.0		(93, 143)
		27.61 (20.1°)	24.58 (40.8°)	221.2	220.5	(242)
		26.76	25.57	219.8		(75, 210)
		25.68		217.4		(76)
$CHBrCl_2$	Bromodichloromethane	31.22 (22.5°)	28.42 (44.0°)	196.8		(249, 207)
$CHBr_3$	Bromoform	45.10 (24.8°)	42.30 (41.7°)	227.8	227.3	(242)
		41.91		222.5		(36)
		41.53		221.9		(93, 143)
$CHCl_3$	Chloroform	27.14		183.4		(182, 207)
		— (60.6°)		183.4		(189, 207)
		—		182.4		(139, 207)
		27.13		183.5		(72, 207)
		27.28	25.89	183.4		(75, 210)
		26.64 (26.2°)	24.67 (40.1°)	183.4	183.4	(242)
CH_2Br_2	Dibromomethane	26.52		143.0		(72, 207)
		27.98 (19.3°)	26.99 (26.9°)	147.5	147.6	(242)
		27.96	26.34	147.6		(75, 210)
$C_2Cl_3F_3$	Trichlorotrifluoroethane	17.75	16.56	244.2		(80)
C_2Cl_4	Tetrachloroethylene	32.8 (10.0°)	31.74 (20.0°)	244.5		(93, 143)
$C_2Cl_4F_2$	Tetrachlorodifluoroethane	22.73 (30.0°)	21.56 (40.0°)	271.9		(80)
C_2HCl_5	Pentachloroethane	34.72	33.58	292.3		(75, 210)
$C_2H_2Br_2F_2$	1,1-Dibromo-2,2-difluoroethane	31.60		228.7		(36)

$C_2H_2Br_4$	s-Tetrabromoethane	48.46 (19.3°)	45.00 (46.0°)	311.0		(249, 207)
		49.67		309.8		(72, 207)
		49.67	46.54 (45.0°)	310.4		(93, 207)
		50.7 (0.0°)		307.9		(76)
$C_2H_2Cl_3F$	1,2,2-Trichloro-1-fluoroethane	29.95		230.1		(36)
$C_2H_2Cl_4$	s-Tetrachloroethane	—		261.0		(114, 210)
		34.88 (22.5°)	32.61 (40.6°)	259.0		(249, 207)
		36.64 (17.2°)	33.54 (40.4°)	257.7	257.8	(242)
$C_2H_3BrF_2$	1-Bromo-2,2-difluoroethane	27.02		182.1		(36)
$C_2H_3Cl_3$	1,1,1-Trichloroethane	25.67 (21.0°)	23.06 (40.9°)	224.8	224.8	(185)
	1,2,2-Trichloroethane	33.57		222.9		(36)
$C_2H_3F_2I$	2,2-Difluoro-1-iodoethane	31.08		203.7		(36)
$C_2H_4Br_2$	1,1-Dibromoethane	34.14 (16.3°)	30.96 (41.2°)	215.2	215.2	(242)
	1,2-Dibromoethane	—		215.7		(139, 207)
		38.71		215.1		(72, 207)
		38.75	37.45	215.5		(93, 143)
		38.91	37.61	213.0		(75, 210)
		38.56 (24.3°)	33.22 (62.0°)	215.3	215.1	(237)
$C_2H_4Cl_2$	1,1-Dichloroethane	24.75	23.62	191.9		(75, 210)
		24.20 (24.3°)	22.17 (41.1°)	187.3	187.9	(242)
		23.4 (35.0°)	20.5 (57.0°)	188.5		(93, 143)
$C_2H_4Cl_2$	1,2-Dichloroethane	24.02 (83.2°)		188.5		(53)
		32.23	30.84	188.3		(72, 210)
		— (83.3°)		189.3		(189, 207)
		— —		189.1		(132, 207)
		34.1 (0.0°)		186.4		(76)
		32.79 (18.4°)	29.49 (41.4°)	188.5	188.7	(237)
$C_3H_5Br_3$	1,2,3-Tribromopropane	45.77 (17.5°)	40.33 (62.0°)	301.7	302.0	(242)
$C_3H_6Br_2$	Propylene dibromide	34.43 (20.7°)	26.63 (88.3°)	253.3	253.2	(237)
	Trimethylene dibromide	41.20 (12.3°)	31.50 (87.4°)	256.4	256.5	(237)
$C_3H_6Cl_2$	Propylene dichloride	29.32 (17.1°)	23.71 (62.3°)	226.4	226.2	(237)
	Trimethylene dichloride	34.45 (15.7°)	28.52 (60.9°)	229.5	229.2	(237)
$C_3H_6I_2$	Trimethylene diiodide	44.02 (19.9°)	38.06 (87.3°)	295.9	299.0	(237)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Halogenated hydrocarbons: aliphatic polyhalides—*Continued*				
$C_7H_5Cl_3$	Trichlorophenylmethane	38.03		353.6	(36)
$C_7H_5F_3$	Trifluorophenylmethane	23.39		270.2	(36)
$C_7H_6Cl_2$	Dichlorophenylmethane	—		320.6	(190, 143)
$C_8H_{12}Cl_2$	5,5-Dichloro-2,2,3-trimethyl-3,4-pentadiene	— (20.0°)		397.4	(145)
$C_8H_{13}ClI_2$	1-Chloro-1,2-diiodo-1-octene	38.1 (18.0°)		507	(221)
$C_8H_{13}Cl_3$	1,1,3-Trichloro-3,4,4-trimethyl-1-pentene	— (18.0°)		445.2	(145)
$C_8H_{16}Cl_2$	2,5-Dichloro-2,5-dimethylhexane	24.13 (70.0°)	23.59 (75.0°)	425.3 425.1	(102)
$C_{10}H_{20}Cl_2$	2,7-Dichloro-2,7-dimethyloctane	26.39 (55.0°)	25.63 (65.0°)	504.0 505.1	(102)
$C_{12}H_{24}Cl_2$	3,6-Dichloro-3,6-diethyloctane	31.32 (25.0°)	29.03 (50.0°)	566.2 566.7	(102)
$C_{13}H_{26}Cl_2$	2,10-Dichloro-2,10-dimethylundecane	30.32 (25.0°)	28.11 (50.0°)	624.3 625.5	(102)
$C_{14}H_{28}Cl_2$	2,11-Dichloro-2,11-dimethyldodecane	30.76 (25.0°)	28.11 (55.0°)	666.0 667.5	(102)
	3,8-Dichloro-3,8-diethyldecane	32.16 (25.0°)	29.84 (50.0°)	649.5 649.8	(102)
$C_{16}H_{32}Cl_2$	4,7-Dichloro-4,7-dipropyldecane	29.85 (25.0°)	27.63 (50.0°)	720.6 721.0	(102)
$C_{17}H_{34}Cl_2$	3,11-Dichloro-3,11-diethyltridecane	32.59 (25.0°)	30.44 (50.0°)	770.0 771.1	(102)
$C_{18}H_{36}Cl_2$	4,9-Dichloro-4,9-dipropylhexadecane	30.72 (25.0°)	28.03 (55.0°)	802.4 802.7	(102)
	3,12-Dichloro-3,12-diethyltetradecane	32.89 (25.0°)	30.70 (50.0°)	811.7 812.9	(102)
$C_{22}H_{44}Cl_2$	4,13-Dichloro-4,13-dipropylhexadecane	31.51 (25.0°)	29.40 (50.0°)	964.9 966.2	(102)
	Halogenated hydrocarbons: halogenated cycloalkanes				
C_5H_9Br	Bromocyclopentane	33.81 (16.9°)	30.82 (40.5°)	258.3 258.1	(238)
C_5H_9Cl	Chlorocyclopentane	31.03 (15.0°)	29.72 (26.6°)	244.3 244.5	(238)
C_5H_9I	Iodocyclopentane	36.80 (14.9°)	33.63 (42.0°)	281.3 281.5	(238)
$C_6H_{11}Br$	Bromocyclohexane	33.55 (23.1°)	29.39 (60.6°)	294.6 294.6	(238)
$C_6H_{11}Cl$	Chlorocyclohexane	32.25 (15.9°)	27.10 (60.9°)	284.6 284.9	(238)
$C_6H_{11}I$	Iodocyclohexane	36.93 (15.2°)	34.13 (40.5°)	317.6 317.8	(238)
$C_7H_{11}F_3$	Trifluoromethylcyclohexane	22.44		305.9	(36)

Halogenated aromatic hydrocarbons

C_6H_4BrCl	*p*-Bromochlorobenzene	33.12 (70.0°)	29.80 (102.0°)	292.5		(206, 207)
C_6H_4BrF	*p*-Bromofluorobenzene	34.4 (21.0°)	29.8 (61.0°)	266.0	266.1	(4)
C_6H_4ClF	*p*-Chlorofluorobenzene	32.7 (15.0°)	26.7 (66.0°)	252.4	253.4	(4)
C_6H_4ClI	*p*-Chloroiodobenzene	37.53 (61.0°)	35.02 (88.0°)	316.4		(206, 207)
$C_6H_4Cl_2$	*m*-Dichlorobenzene	35.6 (25.0°)	30.6 (71.0°)	281.0		(95, 143)
	p-Dichlorobenzene	27.58 (96.0°)	25.44 (117.0°)	279.5		(206, 207)
		36.54 (14.3°)	33.53 (41.8°)	279.3	279.8	(237)
$C_6H_4F_2$	*m*-Difluorobenzene	25.93		222.4		(36)
	p-Difluorobenzene	27.05		222.4		(36)
C_6H_5Br	Bromobenzene	36.34	35.09	257.8		(75, 210)
		—		258.0		(132, 207)
		37.92 (15.0°)	34.92 (42.0°)	260.6		(206, 207)
		36.5 (25.0°)		259.3		(76)
		35.97 (19.0°)	28.16 (86.5°)	257.2	257.0	(96)
C_6H_5Cl	Chlorobenzene	17.67 (150.0°)	12.72 (200.0°)	244.5		(166, 207)
		—		244.9		(139, 207)
		33.08		243.9		(72, 207)
		33.28	32.11	244.1		(75, 210)
		29.6 (50.0°)		244.4		(76)
		33.11 (16.7°)	25.09 (87.6°)	243.1	243.2	(96)
C_6H_5F	Fluorobenzene	28.56 (9.3°)	25.20 (34.5°)	214.5	214.2	(132, 4)
		27.71		215.0		(36)
		27.35 (19.2°)	22.16 (62.1°)	214.4	214.3	(237)
C_6H_5I	Iodobenzene	39.1 (0.0°)		274.1		(76)
		—		280.7		(132, 4)
		41.21 (14.0°)	36.93 (50.0°)	282.3		(206, 207)
		39.38 (18.4°)	34.78 (62.2°)	278.7	279.8	(96)
		37.08 (41.6°)	31.39 (90.0°)	279.5	279.2	(96)
C_7H_7Br	*o*-Bromotoluene	35.85	18.6 (180.0°)	294.3		(93, 143)
	p-Bromotoluene	32.20 (43.0°)	30.54 (60.0°)	296.8		(206, 207)
C_7H_7Cl	*o*-Chlorotoluene	33.44	32.33	280.8		(75, 210)
	p-Chlorotoluene	32.08 (25.0°)	29.38 (50.0°)	283.6		(93, 143)
		32.24 (25.0°)	29.22 (50.0°)	283.6		(206, 207)
		32.90 (18.3°)	25.65 (86.3°)	282.6	282.6	(237)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
Halogenated aromatic hydrocarbons—*Continued*					
C_7H_7F..........	*m*-Fluorotoluene	27.97		253.7	(36)
	p-Fluorotoluene	29.6 (12.0°)	25.6 (46.5°)	255.3 255.6	(4)
		27.93 (23.1°)	20.92 (86.0°)	254.5 253.6	(237)
C_7H_7I..........	*p*-Iodotoluene	35.69 (39.0°)	33.75 (59.0°)	318.6	(206, 207)
$C_{10}H_7Br$..........	1-Bromonaphthalene	44.9 (42.0°)	43.9 (51.0°)	366.2 366.4	(128)
		43.96 (33.4°)	42.13 (50.0°)	362.6 362.6	(12)
		45.26 (16.2°)	40.88 (60.4°)	361.1 361.9	(96)
$C_{10}H_7Cl$..........	1-Chloronaphthalene	42.2 (39.0°)	40.1 (56.5°)	344.8 344.6	(128)
		41.80		353.0	(8)
		43.03 (15.9°)	37.97 (61.0°)	348.8 348.4	(96)
$C_{10}H_7F$..........	1-Fluoronaphthalene	39.7 (15.0°)	36.2 (48.0°)	321.5 322.3	(4)
		39.07 (16.3°)	34.38 (60.5°)	321.4 321.6	(237)
$C_{12}H_8F_2$..........	*p,p'*-Difluorobiphenyl	29.3 (107.0°)	27.9 (124.0°)	394.5 394.9	(4)
Heterocyclic compounds and derivatives: general					
C_4H_3OBr..........	2-Bromofuran	—		212.6	(27)
$C_4H_3O_3N$..........	2-Nitrofuran	—		220.8	(27)
C_4H_4O..........	Furan	—		160.4	(27)
C_4H_4S..........	Thiophene	32.58		189.0	(155)
		33.1	30.1 (40.0°)	189.3	(93, 143)
		36.0 (−19.0°)		185.6	(76)
C_4H_5N..........	Pyrrole	28.80 (29.0°)		166.7	(170)
$C_5H_4O_2$..........	2-Furfural		41.09	210.1	(170)
		— (20.6°)	— (32.4°)	209.5 209.4	(74)
		—		212.9	(138, 207)
		—		212.5	(27)
		43.5 (0.0°)		208.1	(76)

C_5H_5N	Pyridine	37.52 (25.5°)		197.4		(170)
		38.0	35.0 (40.0°)	199.7		(93, 143)
		—		199.8		(139, 207)
		41.1 (−20.5°)		196.6		(76)
C_5H_6O	2-Methylfuran	—		199.8		(27)
$C_5H_6O_2$	2-Furfuryl alcohol					
	Water-soluble	—		216.9		(27)
	Water-insoluble	—		216.2		(27)
$C_5H_{10}O_2$	Tetrahydrofurfuryl alcohol	35.85 (40.7°)	31.20 (87.0°)	241.0	242.1	(239)
$C_5H_{11}N$	Piperidine	29.83 (25.0°)		229		(159)
		34.87 (27.0°)		230.0		(170)
		—		231.5		(136, 207)
		30.20	28.95	232.5		(93, 143)
		30.6 (0.0°)		226.9		(76)
C_6H_8O	2,5-Dimethylfuran	—		240.6		(27)
$C_6H_8O_2$	2-Furfuryl methyl ether	—		260.8		(27)
C_6H_8N	2-Methylpyridine	34.74 (26.0°)		236.3		(170)
$C_6H_{12}N_2$	3,5,5-Trimethylpyrazoline	28.19 (25.0°)		288.4		(9)
$C_7H_8O_3$	Ethyl 2-furoate	—		309.6		(27)
$C_7H_{14}O_2$	Ethyl 2-tetrahydrofurfuryl ether	—		321.3		(27)
C_8H_7N	Indole	37.39 (99.5°)		270.2		(170)
C_9H_7N	Quinoline	44.61 (26.0°)		303.6		(170)
		—		306.4		(139, 207)
		47.0 (0.0°)		305.0		(76)
	Isoquinoline	46.28 (26.8°)		303.8		(170)
C_9H_7ON	8-Hydroxyquinoline	39.68 (98.5°)		322.8		(170)
$C_{10}H_8O_4$	2-Furfuryl 2-furoate	—		398.9		(27)
$C_{10}H_9N$	2-Methylquinoline	40.72 (27.5°)		343.1		(170)
$C_{10}H_{12}O$	α-Clausenan	29.1 (30.0°)	28.2 (50.8°)	381.1	386.8	(168)
	γ-Clausenan	29.92 (30.0°)	29.10 (50.0°)	382.8	388.0	(169)
$C_{10}H_{14}O$	β-Clausenan	27.4 (30.0°)	27.2 (50.0°)	396.8	403.9	(169)
$C_{10}H_{14}N_2$	Nicotine	36.50 (31.2°)		396.3		(170)
$C_{20}H_{24}O_2$	Di-α-clausenan	34.5 (30.0°)	36.1 (50.0°)	704.2	716.7	(168)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Heterocyclic compounds and derivatives: piperidine salts of fatty acids*				
$C_8H_{15}NO$	Piperidine propionate	— (25.0°)		382.6	(159)
$C_9H_{17}NO$	Piperidine butyrate	— (25.0°)		418.5	(159)
$C_{10}H_{19}NO$	Piperidine isovalerate	— (25.0°)		436.6	(159)
$C_{11}H_{21}NO$	Piperidine hexanoate	— (25.0°)		491.7	(159)
$C_{12}H_{23}NO$	Piperidine heptanoate	— (25.0°)		527.9	(159)
$C_{13}H_{25}NO$	Piperidine octanoate	— (25.0°)		568.2	(159)
	Isonitriles				
C_2H_3N	Methyl isonitrile	25.2 (19.0°)		122.1	(123)
C_3H_5N	Ethyl isonitrile	25.6 (7.5°)	24.4 (17.3°)	163.7 163.9	(67)
C_7H_6N	Phenyl isonitrile	35.4 (22.0°)		255.2	(123)
C_8H_7N	*o*-Tolyl isonitrile	35.4 (17.1°)		292.9	(123)
	p-Tolyl isonitrile	35.2		295.5	(123)
C_8H_7NO	*o*-Anisyl isonitrile	42.6 (16.0°)	37.89 (55.5°)	314.1	(123)
	p-Anisyl isonitrile	38.4 (38.1°)		314.5	(123)
		39.4 (31.3°)	38.4 (39.1°)	315.0 315.1	(67)
	Ketones: aliphatic				
C_3H_6O	Acetone	23.27 (16.8°)	22.76 (21.0°)	160.9	(136, 207)
		22.99 (24.80°)		162.1	(152)
		23.70	21.16 (40.0°)	161.5	(93, 143)
		23.13 (21.0°)	21.93	161.7	(180, 207)
		(56.1°)		162.0	(189, 207)
		23.32	22.01	161.5	(25, 210)
		27.9 (−19.5°)		157.9	(76)
		23.40 (26.0°)	21.75 (42.0°)	161.7 161.7	(31)

$C_3H_4Cl_2O$	α,α-Dichloroacetone	31.91		244.1		(72, 207)
C_3H_5ClO	Chloroacetone	35.27		192.7		(72, 207)
$C_4H_6F_2O$	β,β-Difluoroethyl methyl ketone	27.13		234.5		(36)
C_4H_8O	Ethyl methyl ketone	24.6	22.3 (40.0°)	198.8		(93, 143)
		23.97 (24.80°)	21.13 (50.15°)	199.8	200.2	(152)
				198.2		(136, 207)
		22.09 (41.9°)	22.01 (42.01°)	199.7	199.3	(31)
C_5H_8O	Cyclopropyl methyl ketone	30.80 (17.9°)	28.00 (40.9°)	219.8	220.0	(99)
C_5H_{10}	Methyl *n*-propyl ketone	22.41 (24.80°)	21.68 (50.15°)	238.4	238.9	(152)
		24.27 (16.7°)	23.20 (27.1°)	238.0		(138, 201)
		24.98 (16.7°)	23.86 (27.1°)	233.0		(180, 207)
		28.3 (−20.5°)		227.7		(76)
		22.39 (14.3°)	20.06 (62.2°)	238.3	238.3	(31)
	Diethyl ketone	—		236.2		(136, 207)
		24.73 (24.80°)	23.74 (34.85°)	237.3	237.8	(152)
		25.18 (21.0°)	23.00 (40.9°)	237.3	237.5	(31)
$C_6H_{11}O_2Cl$	β-Chloroisopropoxymethyl methyl ketone	34.37		334.1		(201)
$C_6H_{12}O$	*n*-Butyl methyl ketone	25.50 (24.80°)	24.32 (34.85°)	277.8	277.8	(152)
		25.32 (21.1°)	21.27 (61.3°)	277.8	276.9	(31)
	Isobutyl methyl ketone	23.29 (23.7°)	17.25 (87.0°)	277.0	276.0	(31)
	tert-Butyl methyl ketone	15.1 (105.5°)		273.4		(93, 143)
	Ethyl *n*-propyl ketone	25.03 (24.80°)	24.01 (34.85°)	276.2	276.5	(152)
		25.04 (25.0°)	23.28 (42.1°)	277.4	277.1	(31)
$C_7H_{13}O_2Cl$	3-Chloro-1-ethoxypropyl methyl ketone	31.54		372.0		(254)
	β-Chloroisopropoxymethyl ethyl ketone	33.46		371.7		(3)
$C_7H_{14}O$	*n*-Amyl methyl ketone	26.17 (24.80°)	25.02 (34.85°)	318.1	317.9	(152)
		26.20 (24.0°)	22.43 (61.9°)	319.8	318.7	(31)
	n-Butyl ethyl ketone	25.72 (24.80°)	24.69 (34.85°)	315.0	315.2	(152)
		26.30	23.98 (40.9°)	316.1	315.4	(233)
	Di-*n*-propyl ketone	—		314.1		(133, 207)
		25.46 (24.80°)	24.40 (34.85°)	314.9	314.9	(152)
		25.76 (16.2°)	21.31 (62.5°)	314.5	315.2	(31)
$C_8H_{14}O$	2-Methyl-2-hepten-6-one	—		340.7		(38, 210)

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* The values of the parachor are for equimolar concentrations of acid and piperidine. The values given in the reference include those for mixtures of varying weight percentages.

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Ketones: aliphatic—*Continued*				
$C_8H_{15}O_2Cl$.......	3-Chloro-1-ethoxypropyl ethyl ketone	30.44		407.4	(254)
	β-Chloroisopropoxymethyl propyl ketone	31.98		408.6	(201)
$C_8H_{16}O$..........	*n*-Hexyl methyl ketone	—		355.7	(136, 207)
		26.90	25.96	356.8	(75, 210)
		25.57 (22.1°)	22.62 (62.0°)	353.2 356.5	(31)
	n-Amyl ethyl ketone	26.21 (24.80°)	25.22 (34.85°)	354.3 354.6	(152)
		26.82 (19.7°)	24.68 (40.9°)	354.8 354.7	(233)
	n-Butyl *n*-propyl ketone	25.77 (24.8°)	24.85 (34.85°)	354.6 354.9	(152)
$C_8H_{16}O_2$.........	α-(*sec*-Butoxy)ethyl methyl ketone	24.40		368.1	(200)
$C_9H_{17}O_2Cl$.......	Butyl β-chloroisopropoxymethyl ketone	31.49		450.1	(201)
	3-Chloro-1-ethoxypropyl isopropyl ketone	29.91		447.5	(254)
	3-Chloro-1-ethoxypropyl *n*-propyl ketone	30.23		446.8	(254)
$C_9H_{18}O$..........	*n*-Heptyl methyl ketone	24.89 (41.0°)	22.90 (61.5°)	394.4 394.1	(233)
		27.63	26.76	396.8	(75, 210)
	Ethyl *n*-hexyl ketone	27.40 (20.4°)	23.45 (60.7°)	395.0 395.4	(233)
	n-Amyl *n*-propyl ketone	26.30 (24.80°)	25.31 (34.85°)	393.3 393.5	(152)
	Di-*n*-butyl ketone	26.30 (24.80°)	23.85 (50.15°)	394.0 394.6	(152)
		24.68 (41.1°)	22.82 (62.6°)	393.7 394.5	(233)
	Diisobutyl ketone	23.92 (22.0°)	20.52 (61.9°)	391.4 391.6	(31)
$C_9H_{18}O_2$.........	α-(*sec*-Butoxy)ethyl ethyl ketone	25.11		407.1	(200)
$C_{10}H_{19}O_2Cl$......	Amyl β-chloroisopropoxymethyl ketone	31.18		486.0	(201)
	sec-Butyl 3-chloro-1-ethoxypropyl ketone	29.57		482.4	(254)
	3-Chloro-1-ethoxypropyl isobutyl ketone	29.71		487.4	(254)
$C_{10}H_{19}O_2Cl$......	*n*-Butyl 3-chloro-1-ethoxypropyl ketone	30.93		488.9	(254)
$C_{10}H_{20}O$.........	Ethyl *n*-heptyl ketone	26.01 (40.9°)	24.16 (61.3°)	435.7 436.9	(233)
	n-Amyl *n*-butyl ketone	26.56 (24.80°)	25.60 (34.85°)	432.5 432.6	(152)
$C_{10}H_{20}O_2$........	α-(*sec*-Butoxy)ethyl *n*-propyl ketone	24.99		444.8	(200)
	α-(*sec*-Butoxy)ethyl isopropyl ketone	24.65		443.5	(200)

$C_{11}H_{21}O_2Cl$	*n*-Amyl 3-chloro-1-ethoxypropyl ketone	29.42		522.1		(254)
	3-Chloro-1-ethoxypropyl isoamyl ketone	28.37		518.2		(254)
$C_{11}H_{22}O$	Di-*n*-amyl ketone	27.05 (24.80°)	24.78 (50.15°)	471.8	472.9	(152)
		27.40 (19.4°)	23.51 (62.4°)	472.3	472.1	(233)
$C_{11}H_{22}O_2$	α-(*sec*-Butoxy)ethyl *n*-butyl ketone	25.47		484.4		(200)
	α-(*sec*-Butoxy)ethyl isobutyl ketone	24.31		481.3		(200)
	α-(*sec*-Butoxy)ethyl *sec*-butyl ketone	25.18		482.2		(200)
$C_{12}H_{24}O_2$	α-(*sec*-Butoxy)ethyl isoamyl ketone	25.56		524.2		(200)
	n-Amyl α-(*sec*-butoxy)ethyl ketone	25.93		524.3		(200)

Ketones: substituted aminoacetones

$C_5H_{11}ON$	Diethylaminoacetone	27.77		265.7		(126)
$C_7H_{15}ON$	Diethylaminoacetone	26.67		340.6		(126)
$C_9H_{15}ON$	Diallylaminoacetone	28.59		398.6		(126)
$C_9H_{19}ON$	Dipropylaminoacetone	26.69		419.6		(126)
	Diisopropylaminoacetone	27.37		418.6		(126)
$C_{11}H_{23}ON$	Di-*n*-butylaminoacetone	27.20		497.6		(126)
	Diisobutylaminoacetone	28.34		507.4		(126)
$C_{13}H_{27}ON$	Di-*n*-amylaminoacetone	27.49		579.5		(126)
$C_{13}H_{27}ON$	Diisoamylaminoacetone	26.55		573.6		(126)

Ketones: cyclic aliphatic

C_5H_8O	Cyclopentanone	32.98 (23.0°)	28.57 (64.1°)	213.9	214.2	(230)
		34.08 (18.0°)	29.04 (61.6°)	213.9	214.2	(226)
		32.33 (29.0°)		212.3		(170)
$C_6H_{10}O$	3-Methylcyclopentanone	29.59 (21.3°)	25.65 (62.2°)	251.1	252.3	(230)
		30.23	26.41 (60.6°)	251.8	253.1	(227)
	Cyclohexanone	35.23 (20.7°)	29.52 (62.8°)	253.0	251.5	(230)
		33.59 (31.0°)		251.4		(175)
		34.81 (17.3°)	29.84 (61.6°)	251.3	251.4	(226)
		32.33 (45.0°)		253.0		(77, 143)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Ketones: cyclic aliphatic—*Continued*				
$C_7H_{12}O$	2-Methylcyclohexanone	31.83 (22.1°)	27.70 (61.6°)	289.1 289.1	(230)
		31.99	27.78 (61.4°)	288.2 288.3	(244)
		29.61 (45.0°)		289.4	(77)
	3-Methylcyclohexanone	27.17 (60.8°)	25.27 (85.8°)	290.2 290.8	(230)
		31.23	27.04 (63.1°)	290.0 290.3	(244)
		30.39 (32.0°)		289.6	(175)
		28.36 (45.0°)		289.4*	(77)
	3-Methylcyclohexanone	30.65 (23.2°)	37.20 (60.5°)	289.4 289.9	(230)
		31.04	27.05 (62.6°)	289.6 289.6	(244)
		29.91 (45.0°)		290.6*	(77)
	Cycloheptanone	30.17 (61.2°)	27.82 (86.0°)	286.9 287.5	(230)
		35.38 (19.9°)	30.80 (61.6°)	287.9 288.3	(226)
$C_8H_{14}O$	Cycloöctanone	33.45 (45.9°)	32.00 (60.4°)	324.4 323.9	(186)
$C_9H_{14}O$	*trans*-Hexahydro-2-hydrindone	30.81 (64.2°)	28.88 (86.9°)	344.3 344.9	(230)
	trans-2-Decalone	36.31 (18.5°)	32.17 (61.2°)	381.2 382.4	(230)
$C_{16}H_{30}O$	3-Methylcyclopentadecanone	33.23 (35.1°)	31.07 (60.4°)	628.1 628.3	(186)
$C_{17}H_{30}O$	Cyclo-9-heptadecen-1-one	32.77 (60.6°)	31.12 (79.2°)	650.7 650.3	(186)
	Ketones: phorone and derivatives				
$C_9H_{12}OCl_2$	α,α'-Dichlorophorone	30.15 (59.0°)	27.79 (83.0°)	427.6 427.3	(208)
$C_9H_{12}OBr_2$	α,α'-Dibromophorone	35.31 (31.5°)	33.38 (49.5°)	463.2 463.1	(208)
$C_9H_{14}O$	Phorone	30.22 (29.5°)	25.77 (71.0°)	367.8 368.2	(208)
		—		368.5	(46, 143)
$C_{10}H_{15}O_2Br$	α-Bromo-α'-methoxyphorone	32.02 (46.0°)	29.81 (67.0°)	455.6 455.0	(208)
$C_{10}H_{15}O_3Br$	α'-Acetoxy-α-bromophorone	29.45 (80.0°)	25.84 (120.0°)	506.2 506.7	(208)
$C_{11}H_{16}O_3$	α-Acetoxyphorone	32.64 (16.5°)	28.29 (61.5°)	458.3 459.8	(208)
$C_{16}H_{17}O_3Br$	α'-Benzoyloxy-α-bromophorone	33.22 (95.5°)	29.66 (136.0°)	642.0 642.8	(208)

$C_{16}H_{18}O_2Br_2$	α-Bromo-α′-(*p*-bromobenzyloxy)phorone	35.57 (73.5°)	30.63 (131.0°)	683.4	685.3	(208)
$C_{16}H_{18}O_3$	α-Benzyloxyphorone	32.42 (75.0°)	28.81 (117.0°)	582.9	584.4	(208)
$C_{16}H_{19}O_2Br$	α-(*p*-Bromobenzyloxy)phorone	29.99 (115.0°)	27.14 (154.5°)	629.2	631.6	(208)
	Ketones: aromatic and phenyl-substituted					
C_8H_8O	Acetophenone	—		293.8		(138, 207)
		39.8	36.2 (50.0°)	293.8		(93, 143)
		40.1 (24.8°)		295.0		(76)
		39.02 (25.1°)	34.77 (61.0°)	293.2	293.3	(233)
$C_8H_8O_2$	*o*-Hydroxyacetophenone	40.87 (30.0°)	32.45 (100.9°)	307.4	308.0	(21)
	p-Hydroxyacetophenone	38.28 (150.4°)	35.71 (174.8°)	314.4	315.1	(21)
$C_9H_{10}O$	Propiophenone	36.8 (38.5°)	30.8 (93.0°)	331.8	331.4	(128)
		37.22 (22.3°)	35.07 (41.4°)	328.7	328.7	(233)
	Benzyl methyl ketone	37.70 (23.1°)	33.36 (60.7°)	332.7	333.0	(233)
$C_{10}H_{12}O$	Benzyl ethyl ketone	36.66 (19.7°)	32.25 (61.2°)	369.1	369.7	(233)
	Phenyl propyl ketone	34.76 (29.3°)	31.44 (61.4°)	366.7	366.6	(233)
	Methyl 2-phenylethyl ketone	37.28 (26.8°)	33.43 (62.0°)	372.8	373.0	(233)
$C_{11}H_{13}O_2Cl$	β-Chloroisopropoxymethyl phenyl ketone	40.84		461.9		(201)
$C_{11}H_{14}O$	Benzyl *n*-propyl ketone	34.79 (21.3°)	30.68 (60.9°)	405.8	406.6	(233)
	Ethyl 2-phenylethyl ketone	35.83 (28.5°)	34.35 (40.7°)	409.4	409.1	(233)
$C_{12}H_{15}O_2Cl$	Benzyl β-chloroisopropoxymethyl ketone	40.36		504.8		(201)
$C_{12}H_{16}O$	2-Phenylethyl *n*-propyl ketone	34.27 (23.2°)	30.92 (59.9°)	446.3	446.8	(233)
$C_{13}H_{10}O$	Benzophenone	44.18 (19.0°)	40.98 (46.9°)	428.2		(248, 207)
		42.07 (33.5°)	36.05 (89.4°)	425.2		(138, 207)
		40.0 (50.3°)		421.3		(76)
$C_{17}H_{12}OBr_2$	α,α-Dibromodistyryl ketone	40.07 (100.0°)		650.7		(208)
$C_{17}H_{14}O$	Distyryl ketone	38.20 (120.0°)	37.14 (130.0°)	564.2	564.8	(208)

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* Calculated from data given in the reference.

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
Ketones: diketones					
$C_5H_8O_2$	Acetylacetone	30.26 (17.0°)	28.54 (34.0°)	240.7	(131, 207)
		28.50 (39.5°)	24.14 (81.0°)	244.9 245.9	(209)
$C_6H_{10}O_2$	Propionylacetone	30.38 (18.5°)	28.10 (41.0°)	279.1 280.0	(209)
$C_{10}H_{10}O_2$	Benzoylacetone	39.1 (69.0°)	37.1 (89.0°)	381.7 382.8	(209)
$C_{14}H_{10}O_2$	Benzil	34.84 (132.0°)	31.70 (162.0)	481.1 480.0	(54)
$C_{16}H_{14}O_4$	2,2′-Dimethoxybenzil	37.64 (137.5°)	36.22 (155.5°)	596.5 597.2	(54)
Ketones: miscellaneous					
$C_4H_4O_2$	Acetylketene	—		182	(92)
$C_6H_4O_2$	*p*-Benzoquinone	27.94 (150.0°)	26.96 (167.5°)	236.2 237.4	(54)
$C_7H_7O_2$	Toluquinone	33.86 (76.5°)	30.21 (107.5°)	272.3 272.0	(54)
$C_9H_{16}O$	*cis*-Dihydrocamphorone	31.10 (24.5°)		372	(25)
	trans-Dihydrocamphorone	31.20 (24.5°)		373	(25)
$C_{10}H_{14}O$	Carvone	34.4 (31.5°)	28.5 (84.0°)	382.4 380.9	(128)
$C_{10}H_{15}OBr$	Bromocamphor	31.93 (80.0°)	30.19 (96.0°)	423.8 424.2	(175)
$C_{10}H_{16}O$	Carvenone	32.5 (32.0°)	31.8 (41.0°)	396.0 397.1	(128)
	Fenchone	30.11 (33.0°)	23.39 (98.0°)	379.6 377.0	(175)
		28.4 (52.0°)	26.3 (70.0°)	382.3 380.3	(128)
	Pulegone	29.9 (54.5°)	27.8 (74.0°)	390.7 389.0	(128)
	β-Thujone	28.2 (47.0°)	26.9 (60.0°)	391.8 391.3	(128)
$C_{10}H_{18}O$	Menthone	28.3 (44.0°)	26.9 (57.0°)	405.5 404.9	(128)
$C_{11}H_{14}O_3$	Dehydroangustione	36.7		435	(49)
$C_{11}H_{16}O$	*dl*-Angustione	34.9		442	(49)
Methyleneimines					
C_2H_5N	Methyl	30.17 (18.0°)		109.4	(37)
C_3H_7N	Ethyl	29.00 (18.0°)		147.8	(37)

C_4H_9N..........	*n*-Propyl	28.71 (18.0°)		187.0		(37)
	Isopropyl	29.11 (18.0°)		184.2		(37)
$C_5H_{11}N$..........	*n*-Butyl	29.29 (18.0°)		227.0		(37)
	Isobutyl	26.23 (18.0°)		224.4		(37)
$C_6H_{15}N_3$.........	Cyclic methyl	30.17 (18.0°)		328.3		(37)
$C_9H_{21}N_3$.........	Cyclic ethyl	29.00 (18.0°)		443.6		(37)
$C_{12}H_{27}N_3$........	Cyclic *n*-propyl	28.71 (18.0°)		560.9		(37)
	Cyclic isopropyl	29.11 (18.0°)		552.8		(37)
$C_{13}H_{33}N_3$........	Cyclic *n*-butyl	29.29 (18.0°)		680.9		(37)
	Cyclic isobutyl	26.23 (18.0°)		673.4		(37)
Nitriles: aliphatic						
C_2H_3N..........	Acetonitrile	28.73 (16.1°)	26.79 (31.4°)	122.2		(131, 207)
		29.10	27.80	121.6		(75, 210)
		28.40 (26.7°)	26.68 (40.6°)	121.9	121.2	(98)
C_3H_5N..........	Propionitrile	27.25	26.19	160.5		(75, 210)
		26.49 (28.3°)	24.91 (41.3°)	161.3	161.6	(98)
C_4H_5N..........	Allyl cyanide	29.58 (17.1°)	24.63 (62.1°)	186.1	187.5	(98)
C_4H_7N..........	Butyronitrile	27.33	26.24	199.3		(75, 210)
		28.06		201.2		(75, 207)
		26.97	25.88	198.9		(223, 207)
		23.84 (44.9°)	22.65 (56.8°)	199.7		(131, 207)
		26.62 (28.4°)	23.14 (60.1°)	200.2	200.4	(98)
$C_5H_6N_2$.........	Trimethylene dicyanide	45.70 (41.0°)	43.36 (60.6°)	251.8	252.1	(98)
C_5H_9N..........	*n*-Valeronitrile	27.44	26.33	237.4		(75, 210)
		—		236.6		(131, 207)
		27.09 (24.6°)	23.49 (61.6°)	238.4	239.0	(98)
	Isovaleronitrile	26.03		237.3		(72, 207)
		25.93	24.89	237.4		(75, 210)
$C_6H_{11}N$..........	*n*-Capronitrile	27.85	26.99	276.6		(75, 210)
		27.1 (0.0°)		265.3		(76)
		27.12 (28.4°)	24.08 (61.2°)	277.6	278.2	(98)
	Isocapronitrile	26.53	25.61	275.0		(223, 207)
		26.63 (27.1°)	23.15 (61.0°)	276.8	276.5	(98)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Nitriles: aliphatic—*Continued*					
$C_7H_{13}N$..........	*n*-Heptanenitrile	28.39	27.39	316.1		(75, 210)
		25.49 (41.8°)	23.80 (62.5°)	314.9	315.7	(98)
$C_8H_{15}N$..........	*n*-Caprylonitrile	28.67	27.56	356.0		(75, 210)
$C_9H_{17}N$..........	*n*-Nonanenitrile	29.36	28.29	395.2		(75, 210)
	Nitriles: aromatic					
C_7H_5N..........	Benzonitrile	38.43 (27.0°)	34.59 (61.2°)	256.8	252.6	(98)
		—		259.3		(139, 207)
		35.82 (30.0°)	34.60 (40.0°)	255.5		(131, 207)
		38.59	37.51	258.0		(223, 207)
C_8H_7N..........	Phenylacetonitrile	41.36	40.27	293.6		(223, 207)
		41.42 (27.3°)	37.71 (60.0°)	294.1	294.3	(98)
		— —		293.4		(136, 207)
	o-Tolunitrile	35.34 (51.0°)	30.96 (90.0°)	291.4	290.2	(213)
		—		292.9		(131, 207)
		37.84	36.70	292.5		(223, 207)
	m-Tolunitrile	38.20 (18.5°)	31.14 (64.5°)	294.7	295.8	(213)
		—		280.7		(131, 207)
		36.79	35.81	280.0		(223, 207)
	p-Tolunitrile	31.05 (82.5°)	29.84 (96.0°)	294.3	294.7	(213)
		—		295.9		(131, 207)
		36.51 (30.0°)	34.80 (45.0°)	295.2		(223, 207)
	Nitro compounds: aliphatic					
CO_2NCl_3........	Trichloronitromethane	—		236.8		(190, 143)
CO_8N_4..........	Tetranitromethane	30.47	28.98	281.1	280.7	(68)

CHO_6N_3	Trinitromethane	33.98	33.6 (25.0°)	246.5	247.5	(68)
CH_3O_2N	Nitromethane	37.23 (17.3°)	30.88 (60.9°)	132.2	133.1	(242)
		36.97	35.48	132.2		(70, 210)
		36.82		132.1		(72, 207)
		35.78 (25.0°)		132.7		(16)
		—		132.0		(138, 207)
		40.6 (−21.5°)		128.5		(119)
$C_2H_5O_2N$	Nitroethane	32.14 (20.2°)	29.50 (41.3°)	170.7	170.8	(242)
		31.31 (25.0°)		171.0		(16)
		32.2	28.5 (50.0°)	171.2		(93, 143)
$C_3H_7O_2N$	1-Nitropropane	29.28 (25.0°)		208.1		(16)
		30.66 (17.1°)	23.07 (86.7°)	208.8	210.0	(242)
	2-Nitropropane	28.07 (25.0°)		208.3		(16)
		29.08 (21.0°)	26.76 (41.2°)	209.7	209.7	(242)
$C_4H_9O_2N$	1-Nitrobutane	29.20 (25.0°)		247.6		(16)
		29.84 (15.4°)	29.01 (41.6°)	247.1	247.9	(242)
	2-Nitrobutane	28.65 (25.0°)		248.3		(16)
$C_5H_{11}O_2N$	1-Nitropentane	29.55 (17.0°)	22.86 (88.3°)	286.0	287.8	(242)
$C_6H_{13}O_2N$	1-Nitrohexane	29.62 (20.5°)	25.75 (62.5°)	325.8	326.7	(242)
	Nitro compounds: aromatic					
$C_6H_3O_2NCl_2$	2,3-Dichloro-1-nitrobenzene	38.22 (100.0°)		335.8		(144, 219)
	2,4-Dichloro-1-nitrobenzene	37.22 (100.0°)		335.7		(219)
	2,5-Dichloro-1-nitrobenzene	37.10 (100.0°)		336.2		(219)
	2,6-Dichloro-1-nitrobenzene	36.20 (100.0°)		340.1		(219)
	3,4-Dichloro-1-nitrobenzene	37.46 (100.0°)		333.4		(219)
	3,5-Dichloro-1-nitrobenzene	35.57 (100.0°)		334.5		(219)
	1,4-Dichloro-2-nitrobenzene	38.3 (60.5°)	35.3 (95.0°)	335.4		(95, 143)
$C_6H_3O_4N_2Cl$	1-Chloro-2,4-dinitrobenzene	40.7 (114.0°)	32.9 (190.0°)	350.9	351.9	(144)
		43.9 (76.2°)	42.2 (95.0°)	348.1	349.4	(95, 194)
	1-Chloro-3,4-dinitrobenzene	45.1 (40.0°)	44.6 (50.0°)	346.0	347.8	(194)
$C_6H_4O_2NCl$	*o*-Chloronitrobenzene	39.8 (70.5°)	37.23 (91.5°)	299.7	299.9	(213)
	m-Chloronitrobenzene	41.79 (60.5°)	36.27 (90.5°)	300.9	297.8	(213)
	p-Chloronitrobenzene	35.57 (97.0°)	34.18 (111.0°)	300.0		(206, 207)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Nitro compounds: aromatic—*Continued*				
$C_6H_4O_2NBr$	*o*-Bromonitrobenzene	42.12 (67.5°)	40.56 (80.0°)	312.8 313.0	(213)
	m-Bromonitrobenzene	42.45 (63.0°)	40.10 (83.0°)	313.3 313.9	(213)
	p-Bromonitrobenzene	34.58 (132.0°)	31.78 (159.5°)	313.3 313.7	(213)
$C_6H_5O_2N$	Nitrobenzene	44.55 (16.3°)	41.42 (40.9°)	263.6 263.9	(242)
		43.35	42.17	262.1	(75, 210)
		39.63 (57.0°)	35.92 (90.0°)	264.5	(206, 207)
		43.38		262.5	(72, 207)
		—		264.1	(136, 207)
		43.9	40.2 (50.0°)	264.5	(93, 143)
		42.5 (26.0°)		262.5	(76)
$C_6H_5O_3N$	Nitrophenol (see phenols)				
$C_7H_7O_2N$	*o*-Nitrotoluene	41.46		297.7	(72, 207)
		38.69 (44.5°)	34.70 (79.0°)	300.9 301.9	(213)
	m-Nitrotoluene	41.36	36.37 (64.0°)	299.4 300.9	(213)
		40.99		297.0	(72, 207)
	p-Nitrotoluene	37.15 (54.0°)		301.6	(11)
		37.41 (56.0°)	34.82 (77.0°)	302.8	(206, 207)
$C_7H_7O_3N$	*o*-Nitroanisole	45.70 (26.0°)	41.93 (55.0°)	319.4 320.1	(24)
		45.9 (25.0°)	42.3 (57.4°)	321.0	(196)
	p-Nitroanisole	41.6 (68.4°)	39.1 (94.8°)	321.8 323.3	(196)
$C_{10}H_7O_2N$	1-Nitronaphthalene	43.31 (61.5°)		363.3	(11)
	Nitroso compounds				
$C_2H_6ON_2$	Nitrosodimethylamine	38.73 (16.3°)	30.10 (86.8°)	183.3 184.7	(242)
		37.21	35.99	183.8	(138, 207)
		38.97	37.73	184.8	(223, 207)
$C_4H_{10}ON_2$	Nitrosodiethylamine	33.40 (16.4°)	30.86 (41.8°)	259.6 260.5	(142)
		32.81	31.82	260.3	(223, 207)

$C_6H_{14}ON_2$	Nitrosodi-*n*-propylamine	31.69 (19.1°)	29.59 (41.9°)	337.0	377.8	(242)
$C_7H_8ON_2$	*N*-Nitrosomethylaniline	44.96	43.75	313.6		(223, 207)
		45.32 (18.8°)	40.39 (60.9°)	312.4	313.6	(241)
$C_8H_{10}ON_2$	*N*-Nitrosoethylaniline	42.29 (12.3°)	38.91 (42.4°)	349.8	350.9	(241)
$C_8H_{18}ON_2$	Nitrosodi-*n*-butylamine	30.60 (17.3°)	28.46 (42.0°)	412.1	413.6	(242)

Oximes and derivatives

C_2H_5ON	Acetaldoxime	30.1 (35.0°)	25.1 (80.0°)	145.4		(93, 143)
$C_7H_{15}ON$	Heptaldoxime	25.37 (54.60°)	23.83 (76.78°)	343.7		(44, 143)
C_8H_9ON	*N*-Methyl ether of *anti*-benzaldoxime	38.62 (122.0°)	34.53 (163.0°)	325.4	327.0	(211)
	O-Methyl ether of *anti*-benzaldoxime	32.20 (55.5°)	30.13 (73.0°)	324.4	324.6	(211)
$C_8H_{17}ON$	Hexyl methyl ketoxime	29.06	28.14	375.2		(75, 210)
$C_9H_{19}ON$	Heptyl methyl ketoxime	29.87	28.86	414.6		(75, 210)
$C_{10}H_{17}ON$	Camphor oxime	25.35 (130.0°)	24.45 (145.0°)	402.8	402.4	(175)

Phenols

$C_6H_5O_3N$	*o*-Nitrophenol	41.91 (45.2°)		273.5		(7)
		42.3 (50.0°)		274.7		(196)
		35.34 (100.9°)	31.66 (130.4°)	274.9	275.0	(21)
	m-Nitrophenol	44.6 (108.8°)	43.5 (118.5°)	282.9	283.6	(196)
		39.25 (150.4°)	38.16 (174.8°)	282.3	283.1	(21)
	p-Nitrophenol	44.71 (114.0°)		280.8		(11)
		46.1 (121.0°)		283.2		(196)
		43.15 (150.4°)	41.31 (174.8°)	286.0	288.9	(21)
C_6H_6O	Phenol	37.92 (41.0°)		220.2		(11)
		37.74 (50.0°)	33.35 (90.0°)	222.0	222.7	(23)
		37.8 (49.6°)	29.1 (131.6°)	222.3	224.6	(196)
		40.9	39.88	221.3		(93, 143)
		37.0 (41.2°)		218.2		(76)
C_7H_8O	*o*-Cresol	36.21 (41.4°)	34.66 (55.0°)	257.5		(17, 11)
		40.3 (14.0°)		258.8		(191)
	m-Cresol	33.01 (55.4°)	29.31 (98.7°)	257.1		(17, 11)
		39.6 (14.0°)		261.0		(191)
	p-Cresol	39.2 (14.0°)		260.2		(191)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Phenols—*Continued*				
$C_{10}H_8O$	1-Naphthol	40.02 (98.0°)		329.4	(171)
		38.88 (100.5°)	37.16 (116.8°)	363.2 326.4	(12)
	2-Naphthol	35.14 (144.5°)	33.70 (161.0°)	328.6 329.0	(12)
$C_{10}H_{12}O_2$	Eugenol	37.18		398.1	(55)
	Isoeugenol	39.60		379.7	(55)
	Carvacrol	31.6 (41.0°)	29.7 (62.0°)	370.2 370.5	(128)
	Dihydroeugenol	35.12		390.4	(55)
	2-(Chlorobenzyl)phenol	43.24 (25.0°)	42.62 (35.0°)	463.2 463.4	(50)
$C_{13}H_{11}OCl$	4-Benzyl-2-chlorophenol	43.72 (25.0°)	42.70 (35.0°)	473.0 473.8	(50)
$C_{16}H_{18}O_2$	*o*-Hydroxy-1,1-diphenylbutane	37.36 (25.0°)	36.74 (35.0°)	532.8 535.0	(50)
$C_{19}H_{15}OBr$	4-Benzyl-6-bromo-2-phenylphenol	43.24 (35.0°)	42.54 (50.0°)	648.3 651.9	(50)
	6-Benzyl-4-bromo-2-phenylphenol	43.73 (35.0°)	42.62 (50.0°)	627.2 628.8	(50)
$C_{19}H_{16}O$	4-Benzyl-2-phenylphenol	43.78 (25.0°)	43.09 (35.0°)	595.7 597.2	(50)
	6-Benzyl-2-phenylphenol	43.70 (25.0°)	42.84 (35.0°)	599.0 599.9	(50)
$C_{21}H_{20}O$	4,6-Dibenzyl-2-methylphenol	42.39 (25.0°)	41.80 (35.0°)	669.2 671.3	(50)
	2,6-Dibenzyl-3-methylphenol	39.34 (25.0°)	38.88 (35.0°)	658.7 659.6	(50)
	2,6-Dibenzyl-4-methylphenol	40.62 (25.0°)	40.12 (35.0°)	663.4 665.3	(50)
	Molecular compounds of phenol and amines				
$C_{12}H_{13}ON$	Phenol·aniline	39.17 (50.0°)	34.90 (90.0°)	454.9 457.9	(23)
$C_{13}H_{15}ON$	Phenol·*o*-toluidine	38.12 (50.0°)	33.53 (90.0°)	492.2 494.2	(23)
	Phenol·*m*-toluidine	36.67 (50.0°)	34.49 (70.0°)	490.6 491.5	(23)
	Phenol·*p*-toluidine	34.11 (70.0°)	32.18 (90.0°)	490.5 492.2	(23)
$C_{14}H_{17}ON$	Phenol·4-amino-1,3-dimethylbenzene	35.76 (50.0°)	33.65 (70.0°)	526.3 527.4	(23)

Silicon compounds

$C_6H_{18}OSi_2$	Hexamethyldisiloxane	15.7		423		(51)
		14.82 (25.0°)		420.2		(91)
$C_8H_{16}Cl_4O_4Si$	Tetra(2-chloroethoxy)silane	39.56		647.9		(103)
$C_8H_{24}O_2Si_3$	Octamethyltrisiloxane	16.05 (25.0°)		580.14		(91)
		16.96		585		(51)
$C_8H_{24}O_4Si_4$	Tetramer of $(CH_3)_2SiO$	17.37 (25.0°)		637		(89)
$C_{10}H_{30}O_3Si_4$	Decamethyltetrasiloxane	16.52 (25.0°)		737.4		(91)
		17.60		745		(51)
$C_{10}H_{30}O_5Si_5$	Pentamer of $(CH_3)_2SiO$	17.42 (25.0°)		794		(89)
$C_{12}H_{20}Cl_8O_4Si$	Tetra(2-chloro-1-chloromethylethoxy)silane	42.28		946.6		(103)
$C_{12}H_{36}O_4Si_5$	Dodecamethylpentasiloxane	18.10		906		(51)
		17.08 (25.0°)		900.06		(91)
$C_{12}H_{36}O_6Si_6$	Hexamer of $(CH_3)_2SiO$	17.61 (25.0°)		948		(91)
$C_{14}H_{42}O_5Si_6$	Tetradecamethylhexasiloxane	17.42 (25.0°)		1059.5		(91)
		18.45		1067		(51)
$C_{14}H_{42}O_7Si_7$	Heptamer of $(CH_3)_2SiO$	18.30 (25.0°)		1110		(89)
$C_{16}H_{48}O_6Si_7$	Hexadecamethylheptasiloxane	17.61 (25.0°)		1217.3		(91)
		18.60		1215		(51)
$C_{18}H_{54}O_7Si_8$	Octadecamethyloctasiloxane	18.03 (25.0°)		1381.1		(91)
		18.82		1385		(51)
$C_{20}H_{60}O_8Si_9$	Nonamer of trimethylsiloxane	19.24		1554		(51)
$C_{26}H_{78}O_{11}Si_{12}$	Dodecamer of trimethylsiloxane	19.56		2040		(51)
$C_{36}H_{108}O_{16}Si_{17}$	Heptadecamer of trimethylsiloxane	19.87		2852		(51)

Sulfur compounds: sulfides

C_2H_6S	Dimethyl sulfide	24.96 (12.9°)	24.64 (17.3°)	163.0	163.0	(243)
C_3H_8S	Ethyl methyl sulfide	25.62 (16.5°)	22.20 (41.3°)	201.8	202.0	(243)
$C_4H_4Cl_4S$	2-Chloroethyl 1,2,2-trichlorovinyl sulfide	42.0	41.2 (25.0°)	374.4	374.0	(142)
$C_4H_5Cl_3S$	2-Chloroethyl 1,2-dichlorovinyl sulfide	40.9	39.9	338.3	339.1	(142)
$C_4H_6Cl_4S$	2-Chloroethyl 1,2,2-trichloroethyl sulfide	—		377.4		(142)
$C_4H_7Cl_3S$	2-Chloroethyl 1,2-dichloroethyl sulfide	—		341.9		(142)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Sulfur compounds: sulfides—*Continued*					
$C_4H_8Cl_2S$........	2,2′-Dichlorodiethyl sulfide	42.3 (19.0°)	41.8 (22.5°)	318.6	318.0	(130)
C_4H_9ClS........	2-Chloroethyl ethyl sulfide	32.2 (21.5°)	32.2 (22.5°)	277.2	277.5	(130)
$C_4H_{10}S$..........	Diethyl sulfide	25.0 (17.5°)	24.5 (20.5°)	240.4	239.8	(130)
		22.19		239.1		(8)
		25.85 (13.5°)	20.54 (61.5°)	241.1	241.9	(243)
$C_5H_{12}S$..........	*n*-Butyl methyl sulfide	26.15 (21.0°)	18.84 (91.3°)	280.1	280.0	(243)
	Isobutyl methyl sulfide	24.92 (20.7°)	20.74 (63.3°)	279.6	279.6	(243)
	tert-Butyl methyl sulfide	23.95 (19.0°)	19.05 (62.8°)	277.9	278.0	(243)
C_6H_7NS.........	Methyl 2-pyridyl sulfide	41.0 (25.0°)		286		(30)
$C_6H_{14}S$..........	*n*-Butyl ethyl sulfide	26.60 (18.9°)	24.29 (41.1°)	320.5	320.0	(243)
	tert-Butyl ethyl sulfide	21.41 (43.0°)	17.08 (87.5°)	317.7	316.6	(243)
	Di-*n*-propyl sulfide	26.72 (16.4°)	19.49 (86.7°)	319.1	318.8	(243)
	Diisopropyl sulfide	24.31 (9.5°)	16.83 (86.2°)	317.6	318.1	(243)
C_7H_8S..........	Methyl phenyl sulfide	40.31 (20.4°)	35.30 (60.3°)	295.5	296.0	(240)
C_7H_9NS.........	Ethyl 2-pyridyl sulfide	37.7 (25.0°)		323		(30)
$C_8H_{10}S$..........	Ethyl phenyl sulfide	36.89 (22.5°)	34.60 (40.5°)	334.3	334.4	(240)
$C_8H_{18}S$..........	Di-*n*-butyl sulfide	27.40 (18.3°)	20.94 (87.8°)	397.6	400.0	(243)
	Diisobutyl sulfide	23.00 (41.1°)	18.87 (88.2°)	395.1	395.7	(243)
	Di-*sec*-butyl sulfide	26.55 (12.0°)	25.39 (25.2°)	394.6	395.4	(243)
$C_9H_{12}S$..........	Phenyl *n*-propyl sulfide	35.36 (19.9°)	33.13 (40.6°)	371.0	371.7	(240)
	Isopropyl phenyl sulfide	33.86 (17.4°)	31.13 (41.1°)	372.1	371.8	(240)
$C_{10}H_{14}S$.........	*n*-Butyl phenyl sulfide	32.31 (41.0°)	28.04 (86.5°)	409.9	411.2	(240)
$C_{10}H_{22}S$.........	Di-*n*-amyl sulfide	28.05 (17.3°)	21.98 (86.9°)	476.0	478.1	(243)
	Diisoamyl sulfide	22.37 (62.0°)	17.64 (121.8°)	473.0	473.0	(243)
$C_{11}H_{16}S$.........	*n*-Amyl phenyl sulfide	31.96 (41.6°)	27.87 (86.6°)	448.8	450.1	(240)
$C_{12}H_{10}S$.........	Diphenyl sulfide	42.54 (16.4°)	35.85 (86.4°)	426.1	429.3	(243)
$C_{12}H_{18}S$.........	*n*-Hexyl phenyl sulfide	41.61 (40.7°)	36.23 (85.1°)	523.1	523.8	(240)
$C_{12}H_{26}S$.........	Di-*n*-hexyl sulfide	28.00 (25.3°)	24.84 (62.3°)	556.0	556.9	(243)
$C_{14}H_{30}S$.........	Di-*n*-heptyl sulfide	29.27 (20.2°)	23.81 (87.7°)	637.0	639.4	(243)
$C_{16}H_{34}S$.........	Di-*n*-octyl sulfide	30.28 (21.7°)	26.25 (61.1°)	719.0	717.3	(243)

Sulfur compounds: disulfides

$C_2H_6S_2$	Dimethyl disulfide	34.87 (14.1°)	28.40 (62.3°)	213.6	214.1	(243)
$C_4H_{10}S_2$	Diethyl disulfide	31.19 (17.3°)	24.05 (86.2°)	290.5	291.5	(243)
		23.71		287.6		(8)
$C_6H_{14}S_2$	Di-*n*-propyl disulfide	30.68 (18.8°)	23.87 (87.3°)	368.1	369.0	(243)
$C_6H_{14}S_2$	Diisopropyl disulfide	28.60 (18.4°)	22.24 (86.4°)	367.8	368.3	(243)
$C_8H_{18}S_2$	Di-*n*-butyl disulfide	31.01 (15.5°)	24.42 (86.3°)	446.8	448.3	(243)
	Diisobutyl disulfide	28.29 (17.1°)	22.25 (86.2°)	442.2	444.3	(243)
	Di-*tert*-butyl disulfide	27.33 (17.5°)	21.22 (87.9°)	440.9	440.8	(243)
$C_{10}H_{22}S_2$	Di-*n*-amyl disulfide	29.72 (18.5°)	21.38 (120.7°)	522.0	525.6	(243)
	Diisoamyl disulfide	29.08 (13.4°)	20.39 (120.2°)	518.5	522.9	(243)
$C_{12}H_8Br_2S_2$	4,4′-Dibromodiphenyl disulfide	40.33 (115.0°)	38.51 (136.0°)	575.3	576.1	(14)
$C_{12}H_8Cl_2S_2$	4,4′-Dichlorodiphenyl disulfide	41.90 (76.2°)	39.38 (102.3°)	550.1	550.7	(14)
$C_{12}H_{10}S_2$	Diphenyl disulfide	39.03 (79.1°)	37.29 (96.8°)	477.6	478.5	(14)
$C_{14}H_{22}N_2O_4S_2$	2,2′-Dinitrodibenzyl disulfide	43.53 (125.0°)	42.25 (140.0)	665.3	666.5	(14)
$C_{14}H_{14}O_2S_2$	4,4′-Dimethoxydiphenyl disulfide	38.86 (89.7°)	36.23 (117.0°)	665.5	667.4	(14)
$C_{14}H_{14}S_2$	4,4′-Dimethyldiphenyl disulfide	39.00 (51.2°)	37.30 (69.3°)	552.5	553.1	(114)
	Dibenzyl disulfide	37.43 (88.0°)	35.26 (112.5°)	556.7	558.1	(14)
$C_{20}H_{14}S_2$	2,2′-Dinaphthyl disulfide	36.98 (115.0°)	36.24 (169.0°)	689.5	692.1	(14)

Sulfur compounds: polysulfides

$C_4H_{10}S_3$	Ethyl trisulfide	24.22		335.3		(8)
	Ethyl tetrasulfide	24.54		406.4		(8)
	Ethyl pentasulfide	23.89		449		(8)

Sulfur compounds: sulfites

$C_2H_6O_3S$	Dimethyl sulfite	34.23 (17.8°)	25.46 (87.9°)	219.1	219.1	(243)
$C_4H_{10}O_3S$	Diethyl sulfite	35.96 (19.3°)	29.18 (86.2°)	292.5	294.3	(243)
		29.25 (22.9°)	22.52 (85.9°)	297.6	297.5	(243)
		27.15 (40.0°)	24.56 (70.3°)	297.3	299.7	(21)
		28.28 (21.0°)	26.23 (40.6°)	299.7		(248, 143)
$C_6H_{14}O_3S$	Di-*n*-propyl sulfite	28.87 (18.9°)	19.35 (121.3°)	374.4	376.2	(243)
	Diisopropyl sulfite	23.36 (18.6°)	20.01 (87.4°)	374.2	374.7	(243)
$C_8H_{18}O_3S$	Di-*n*-butyl sulfite	28.92 (19.0°)	24.96 (62.4°)	452.1	452.9	(243)
	Diisobutyl sulfite	27.58 (15.2°)	18.20 (122.4°)	449.5	451.3	(243)
$C_{10}H_{22}O_3S$	Di-*n*-amyl sulfite	29.27 (16.0°)	20.43 (122.3°)	530.0	533.4	(243)
	Diisoamyl sulfite	28.28 (15.5°)	22.14 (87.0°)	525.2	526.2	(243)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Sulfur compounds: thiosulfites				
$C_2H_6O_2S_2$	Methyl thiosulfite	32.88 (18.0°)	32.45 (25.0°)	252.7 254.3	(202)
$C_4H_{10}O_2S_2$	Ethyl thiosulfite	30.56 (18.0°)	29.53 (25.0°)	332.7 332.4	(202)
$C_6H_{14}O_2S_2$	*n*-Propyl thiosulfite	29.78 (18.0°)	29.16 (25.0°)	408.9 408.7	(202)
$C_8H_{18}O_2S_2$	*n*-Butyl thiosulfite	29.47 (18.0°)	28.82 (25.0°)	485.1 485.6	(202)
	Sulfur compounds: sulfates				
$C_2H_6O_4S$	Dimethyl sulfate	39.50 (15.1°)	31.25 (86.5°)	237.0 238.9	(243)
		40.12 (18.0°)	35.46 (55.0°)	237.7 238.9	(211)
$C_4H_{10}O_4S$	Diethyl sulfate	34.02 (14.9°)	23.72 (120.7°)	314.9 317.4	(243)
		31.28 (40.0°)	28.66 (70.3°)	315.3 317.3	(21)
		32.54 (32.5°)	30.86 (48.0°)	313.5 314.2	(21)
$C_6H_{14}O_4S$	Di-*n*-propyl sulfate	32.73 (13.3°)	22.92 (120.1°)	390.3 393.4	(243)
$C_8H_{18}O_4S$	Di-*n*-butyl sulfate	31.77 (13.6°)	22.38 (120.6°)	467.9 470.7	(243)
	Sulfur compounds: sulfur dioxide addition compounds				
$C_6H_{15}NO_2S$	SO_2·triethylamine	36.91 (10.0°)	34.82 (25.0°)	386.1 380.0	(19)
$C_8H_{11}NO_2S$	SO_2·dimethylaniline	42.97 (5.0°)	39.37 (25.0°)	405.4 (mean)	(18)
$C_9H_{27}NO_2S$	SO_2·tri-*n*-propylamine	29.96 (21.7°)	27.73 (40.0°)	488.4 488.8	(94)
	Sulfur compounds: sulfones and sulfoxides				
C_6H_7NOS	Methyl 2-pyridyl sulfoxide	48.0 (25.0°)		306	(30)
$C_6H_7NO_2S$	Methyl 2-pyridyl sulfone	49.5 (25.0°)		327	(30)
C_7H_9NOS	Ethyl 2-pyridyl sulfoxide	42.7 (25.0°)		344	(30)
$C_7H_9NO_2S$	Ethyl 2-pyridyl sulfone	45.4 (25.0°)		356	(30)
$C_7H_{16}O_4S_2$	Sulfonal	32.20 (154.5°)	30.54 (169.5°)	466.1 464.4	(52)
$C_8H_{10}O_2S$	Benzyl methyl sulfone	33.93 (164.5°)	32.22 (184.0°)	369.8 370.3	(52)
$C_8H_{16}O_4S_2$	Trional	33.39 (110.0°)	32.20 (123.5°)	493.4 494.0	(52)
$C_{12}H_{10}O_2S$	Diphenyl sulfone	37.77 (137.5°)	35.97 (157.0°)	465.6 466.5	(52)
$C_{13}H_{12}O_2S$	Benzyl phenyl sulfone	35.40 (153.5°)	32.38 (184.0°)	503.5 503.6	(52)

Sulfur compounds: sulfonyl halides

$C_6H_5FO_2S$	Benzenesulfonyl fluoride	37.98 (17.5°)	33.13 (60.4°)	297.5	298.2	(237)
$C_6H_5ClO_2S$	Benzenesulfonyl chloride	37.48 (70.3°)	34.67 (100.9°)	329.9	332.0	(21)
		42.70 (24.9°)	38.75 (60.3°)	329.3	329.7	(237)
$C_7H_7ClO_2S$	*p*-Toluenesulfonyl chloride	30.64 (130.4°)	28.88 (150.4°)	372.0	373.2	(21)
		35.54 (74.0°)	31.82 (103.5°)	368.6	367.0	(52)
$C_7H_7FO_2S$	*o*-Toluenesulfonyl fluoride					
	Cyclic	36.05 (30.5°)		333.6		(32)
	Acyclic	35.91 (30.5°)		333.4		(32)
	p-Toluenesulfonyl fluoride	33.04 (60.0°)		338.5		(32)

Sulfur compounds: thiocyanates

C_2H_3NS	Methyl thiocyanate	34.78 (42.5°)	32.44 (60.9°)	168.5	169.6	(242)
		38.18 (24.0°)		170.2		(156)
		—		168.6		(190, 211)
C_3H_5NS	Ethyl thiocyanate	33.99 (14.4°)	32.53 (27.2°)	206.8	207.2	(242)
		—		209.1		(211)
		35.32 (17.6°)	31.79 (46.4°)	210.7		(165, 211)
C_4H_7NS	*n*-Propyl thiocyanate	30.48 (41.5°)	25.82 (86.8°)	247.1	248.2	(242)
C_5H_9NS	*n*-Butyl thiocyanate	29.96 (40.4°)	25.80 (85.1°)	285.7	287.4	(242)
C_7H_5NS	Phenyl thiocyanate	42.51 (23.6°)		307.3		(156)
$C_{16}H_{34}N_2S$	Triisoamylammonium thiocyanate	29.34 (80.0°)	28.89 (90.0°)	761.6		(246, 215)

Sulfur compounds: isothiocyanates

C_3H_5NS	Ethyl isothiocyanate	33.31 (16.4°)	30.50 (41.3°)	209.4	210.1	(242)
		31.87 (18.4°)	28.85 (46.0°)	211.7		(131, 211)
		35.02 (18.4°)		211.5		(56)
C_4H_5NS	Allyl isothiocyanate	31.53 (18.4°)		231.4		(56)
		33.97 (21.0°)	26.80 (85.6°)	236.9	238.2	(242)
		33.52 (18.4°)	30.37 (46.0°)	232.4		(131, 211)
C_5H_9NS	Isobutyl isothiocyanate	31.34 (11.2°)		281.6		(56)
C_7H_5NS	Phenyl isothiocyanate	38.40 (38.8°)	30.96 (109.2°)	304.1		(131, 211)
		42.51 (23.5°)		305.4		(56)

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Sulfur compounds: xanthates				
$C_5H_{10}OS_2$	Diethyl xanthate	34.33 (19.2°)	31.90 (41.9°)	335.4 335.6	(242)
$C_7H_{14}OS_2$	Ethyl *S*-*n*-butyl xanthate	30.61 (42.3°)	26.67 (86.1°)	412.8 414.2	(242)
	n-Butyl *S*-ethyl xanthate	30.71 (40.9°)	26.71 (84.8°)	412.6 413.8	(242)
	Di-*n*-propyl xanthate	32.76 (20.9°)	30.81 (40.8°)	412.5 413.1	(242)
$C_9H_{18}OS_2$	Di-*n*-butyl xanthate	31.45 (24.9°)	28.00 (60.9°)	489.7 489.9	(242)
	Sulfur compounds: miscellaneous				
CBr_4S	Thiocarbonyl tetrabromide	47.74		316.4	(20)
CCl_4S	Thiocarbonyl tetrachloride	35.02		266.1	(20)
CS_2	Carbon disulfide	32.25	30.79	143.6	(75, 210)
		33.58 (19.4°)	29.41 (46.1°)	144.7	(165, 211)
		31.38		142.9	(75, 211)
		— —		143.6*	(139, 211)
					(132, 211)
$C_4H_{10}O_2S$	Thiodiglycol	53.8	53.4 (20.5°)	279.9 279.4	(130)
$C_4H_{10}O_3S$	Ethyl ethanesulfonate	35.15 (17.6°)	31.93 (49.7°)	295.8	(248, 143)
$C_5H_{12}S_4$	Methyl orthothiocarbonate	36.0 (70.0°)		419.0	(7)
C_6H_6OS	Methyl 2-thienyl ketone		44.5	281.9	(101)
$C_8H_{10}O_3S$	Methyl *p*-toluenesulfonate	38.63 (70.3°)	35.56 (100.9°)	392.5 393.5	(21)
$C_9H_{12}O_2S$	Ethyl *p*-toluenesulfinate	38.48 (18.0°)	37.03 (32.0°)	409.4 410.3	(158)
$C_9H_{12}O_3S$	Ethyl *p*-toluenesulfonate	39.18 (53.5°)	37.62 (70.0°)	431.5 432.3	(52)
	Terpenes and related compounds†				
$C_9H_{18}O$	*trans*-Dihydrocryptol	30.03 (30.0°)	30.05	366.7_3	(56)
	cis-Dihydrocryptol	29.72 (30.0°)	29.76	363.9_4	(56)
$C_{10}H_{14}O$	Piperitenone	38.02 (19.4°)		381.3	(148)

$C_{10}H_{16}$	*dl*-Δ⁴-Carene	26.06 (22.6°)		358.4		(148)
	Camphene	24.87 (50.0°)		359.9		(108)
		23.36 (75.0°)	20.97 (95.0°)	351.1	353.1	(175)
	l-Camphene	25.8 (59.0°)	24.2 (70.0°)	365.9	364.0	(178)
	dl-Limonene	27.45 (33.5°)	21.41 (97.0°)	365.3	364.9	(175)
	l-Limonene	25.8 (55.0°)	24.5 (73.0°)	375.2	376.4	(128)
	m-Menthadiene (−)	32.4		379		(59)
	dl-*m*-Menthadiene	32.5		378		(58)
	α-Pinene	26.13 (33.0°)	19.97 (97.0°)	358.3	357.2	(175)
	α-*l*-Pinene	27.05 (30.0°)	24.60 (54.0°)	365.0	364.4	(128)
	α-*d*-Pinene	26.50 (34.5°)	24.60 (53.5°)	364.8	365.1	(128)
	Savinene	26.5 (40.6°)	23.5 (72.0°)	373.7	373.4	(128)
	Silvestrene	30.1 (−20.0°)		357.9		(76)
$C_{10}H_{16}O$	Piperitone	30.43 (22.6°)		383.8		(148)
	Pulegone	31.48 (19.5°)		384.4		(148)
$C_{10}H_{18}$	Menthene	27.30 (67.0°)	20.75 (93.0°)	384.8	383.2	(128)
	m-Menthene (+)	28.7 (25.0°)		391		(59)
	dl-*m*-Menthene	28.7 (25.0°)		391		(59)
	l-Pinane	26.4 (43.0°)	24.2 (66.0°)	374.8	374.3	(128)
	Sabinane	28.4 (42.0°)	23.2 (57.0°)	386.2	385.1	(128)
$C_{10}H_{18}O$	*dl*-Isomenthone	28.87 (30.0°)	28.92	401.1_1	401.2_7	(56)
	l-Menthone	28.39 (30.0°)	28.30	401.1_7	400.9_9	(56)
	Eucalyptol	27.5 (40.0°)	26.3 (48.0°)	389.4	387.8	(128)
$C_{10}H_{18}O_2$	2,3-Epoxy-2,6-dimethyl-7-octen-6-ol	27.53	24.39 (60.0°)	410.3	412.9	(147)
$C_{10}H_{20}$	*dl*-*m*-Menthane	29.8 (25.0°)		406		(59)
	l-*m*-Menthane	29.5 (25.0°)		405		(59)
	trans-*p*-Menthane	24.49 (30.0°)	24.48	397.8_0	397.8_3	(56)
	cis-*p*-Menthane	24.82 (30.0°)	24.86	395.5_0	395.5_7	(56)
$C_{11}H_{20}O_2$	*cis*-Dihydrocryptyl acetate	28.73 (30.0°)	28.70	458.1_0		(56)
	trans-Dihydrocryptyl acetate	28.74 (30.0°)	28.71	459.9_8		(56)
$C_{12}H_{20}O_2$	*dl*-Bornyl acetate	29.24		463.3		(124)
		29.74 (32.0°)	23.37 (97.0°)	468.8		(175)
	dl-Isobornyl acetate	29.06		462.8		(124)

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* The mean value obtained from two references giving data on the surface tension.

† See also alcohols, aldehydes, and ketones.

TABLE 26—*Continued*

FORMULA	NAME	SURFACE TENSION		PARACHOR		REFERENCES
		20°C.	30°C.			
	Terpenes and related compounds*—*Continued*					
$C_{12}H_{22}O_2$	*l*-Menthyl acetate	27.73 (30.0°)	27.77	496.7		(56)
	dl-Isomenthyl acetate	26.33 (30.0°)	28.35	495.4		(56)
	dl-Neomenthyl acetate	27.64 (30.0)	27.61	498.1		(56)
	dl-Neoisomenthyl acetate	27.86 (30.0°)	27.82	498.3		(56)
$C_{13}H_{18}$	Ionene	35.46		453.8		(140)
$C_{13}H_{20}$	Allylcamphene	30.05		462.2		(108)
$C_{13}H_{20}O$	α-Ionone	32.45 (17.5°)	28.35 (60.5°)	491.1	492.1	(146)
	β-Ionone	34.41 (11.0°)	29.68 (60.0°)	489.0	490.9	(146)
$C_{13}H_{24}O$	Dihydro-α-ionol	31.06 (18.0°)	27.60 (60.0°)	501.9	505.1	(146)
	Dihydro-β-ionol	32.33 (12.8°)		502.7		(146)
$C_{13}H_{26}O$	Tetrahydroionol	31.18 (12.8°)	27.13 (60.0°)	509.4	511.6	(146)
$C_{14}H_{22}O$	Methyl-α-ionone	32.94 (12.0°)	28.27 (60.5°)	525.0	526.3	(146)
$C_{14}H_{26}O$	Dihydromethyl-α-ionol	30.98 (15.6°)	27.43 (61.0°)	534.7	539.4	(146)
$C_{14}H_{28}O$	Tetrahydromethylionol	32.05 (10.2°)	27.85 (60.0°)	546.8	551.1	(146)
$C_{15}H_{18}$	Guaiazulene	35.11 (23.0°)	30.23 (80.0°)	496.8	497.8	(187)
		35.09	30.04 (79.0°)	496.4	498.1	(187)
	Elomazulene	35.13 (19.0°)	30.19 (79.0°)	495.5	496.5	(187)
	Chamazulene	36.62 (19.0°)	31.63 (80.0°)	494.0	492.1	(187)
$C_{15}H_{26}O_2$	Dihydro-α-ionol acetate	29.46 (21.5°)	25.93 (59.5°)	591.1	590.6	(146)
	Dihydro-β-ionol acetate	29.45 (22.5°)	26.20 (59.5°)	590.8	592.0	(146)
$C_{16}H_{20}$	Phenylcamphene	33.98		522.2		(108)
$C_{16}H_{28}O_2$	Dihydromethyl-α-ionol acetate	29.19 (23.0°)	25.83 (59.5°)	625.3	625.7	(141)
$C_{17}H_{20}O_2$	"Camphor benzoate"	28.78 (94.0°)	29.09 (97.0°)	594.8	594.6	(175)
$C_{17}H_{22}$	Benzylidenecamphene		34.76		563.3	(108)

Thiols and thiophenols

	Thiols					
C_2H_6S..........	Ethanethiol	24.30 (9.4°)	23.59 (17.2°)	162.0	161.7	(240)
		—		162.9		(131, 211)
		23.63 (2.0°)	21.62 (16.7°)	159.6	159.0	(165, 198)
C_3H_8S..........	1-Propanethiol	24.32 (23.5°)	22.20 (40.8°)	202.4	202.3	(240)
	2-Propanethiol	22.25 (17.1°)	19.55 (40.1°)	201.5	202.0	(240)
$C_4H_{10}S$..........	1-Butanethiol	25.57 (21.9°)	21.08 (60.9°)	241.5	241.1	(240)
	2-Methyl-1-propanethiol	24.29 (16.4°)	22.03 (41.5°)	239.0	240.4	(240)
	1,1-Dimethylethanethiol	20.69 (18.4°)	18.25 (40.9°)	240.4	240.2	(240)
$C_5H_{12}S$..........	1-Pentanethiol	24.25 (41.1°)	19.80 (87.3°)	281.0	281.5	(240)
	3-Methyl-1-butanethiol	25.45 (19.7°)	23.62 (41.1°)	278.7	280.0	(240)
$C_6H_{14}S$..........	1-Hexanethiol	28.10 (14.3°)	25.38 (40.8°)	320.8	321.2	(240)
C_7H_8S..........	Phenylmethanethiol	39.26 (18.5°)	37.96	293.6	294.1	(198)
$C_7H_{16}S$..........	1-Heptanethiol	27.86 (16.0°)	25.14 (40.9°)	359.7	358.8	(240)
$C_8H_{18}S$..........	1-Octanethiol	26.06 (40.8°)	22.37 (86.5°)	399.4	401.4	(240)
	Thiophenols					
C_6H_5ClS........	p-Chlorothiophenol	36.80 (60.0°)	34.52 (80.0°)	291.1	291.2	(198)
C_6H_5BrS........	p-Bromothiophenol	35.34 (100.0°)	33.79 (116.5°)	304.8	305.0	(198)
C_6H_6S..........	Thiophenol	39.19 (16.9°)	36.89 (35.0°)	257.5		(248, 211)
		39.27 (18.9°)	36.42 (41.1°)	256.0	255.9	(240)
		38.46 (16.9°)	36.31 (35.0°)	256.4		(131, 211)
		37.67 (25.5°)	33.58 (58.0°)	253.9	255.7	(131, 198)
C_7H_8S..........	p-Methylthiophenol	32.48 (64.4°)	31.65 (80.1°)	293.3	294.1	(198)
$C_8H_{10}OS$........	p-Methoxy-*m*-methylthiophenol	36.48 (44.6°)	35.51 (59.7°)	346.5	348.0	(198)

Compounds not elsewhere classified

	Anilides					
C_7H_7NO........	Formanilide	39.04 (60.0°)	37.73 (75.0°)	273.5		(223, 207)
C_8H_9NO........	Acetanilide	35.24 (120.0°)	34.34 (130.0°)	321.8		(223, 207)
$C_9H_{11}NO$........	*N*-Methylacetanilide	32.09 (105.0°)	31.15 (115.0°)	354.2		(223, 207)
$C_{10}H_{13}NO$	*N*-Ethylacetanilide	34.27 (60.0°)	32.73 (75.0°)	398.5		(223, 207)

* See also alcohols, aldehydes, and ketones.

TABLE 26—*Concluded*

FORMULA	NAME	SURFACE TENSION		PARACHOR	REFERENCES
		20°C.	30°C.		
	Compounds not elsewhere classified—*Continued*				
	Azines				
$C_6H_{12}N_2$	Dimethylketazine	26.02 (25.0°)		302.2	(9)
$C_8H_{16}N_2$	Methylethylketazine	26.11 (25.0°)		379.8	(9)
$C_{16}H_{16}N_2O_2$	*p*-Methoxybenzalazine	32.1 (171.0°)	31.2 (180.5°)	607.1 612.4	(95, 177)
	Boron compounds (see also esters)				
$C_3H_8BF_3O$	Borontrifluoride methyl ethyl ether	30.80 (25.0°)		256.2	(111)
$C_6H_{15}B$	Boron triethyl	19.87 (30.0°)		305.46	(110)
	Carbamates				
$C_3H_7NO_2$	Ethyl carbamate	31.47 (60.0°)	30.01 (75.0°)	202.2	(223, 207)
$C_4H_9NO_2$	Ethyl *N*-methylcarbamate	29.80 (40.9°)	25.92 (86.1°)	242.9 244.9	(241)
$C_5H_{11}NO_2$	Ethyl *N*-ethylcarbamate	30.27 (21.1°)	26.29 (61.3°)	281.1 281.7	(241)
$C_9H_{11}NO_2$	Ethyl phenylcarbamate	36.04 (60.0°)	34.65 (75.0°)	375.6	(223, 207)
	Epoxides				
C_2H_4O	Ethylene oxide	28.4 (−5.0°)	24.3 (20.0°)	112.6 112.7	(214)
C_3H_5OCl	Epichlorohydrin	38.13 (12.5°)	32.86 (50.5°)	193.6 193.9	(214)
$C_8H_{17}O$	Epoxy-1,4-octane	27.26 (14.0°)		340.8	(153)
	Epoxy-1,5-octane	26.65 (14.0°)		338.1	(153)
$C_9H_{19}O$	Epoxy-1,4-nonane	27.84 (14.0°)		379.8	(153)
	Epoxy-1,5-nonane	27.72 (14.0°)		377.9	(153)

	Hydrazine derivatives					
$C_6H_8N_2$	Phenylhydrazine	45.55	44.31	255.7		(223, 207)
		42.75	42.11	255.9		(131, 207)
		— —		257.1		(210)
$C_6H_{16}N_2$	*s*-Diisopropylhydrazine	23.91 (25.0°)		327.1		(9)
$C_8H_{20}N_2$	*s*-Di-*sec*-butylhydrazine	24.52 (25.0°)		400.8		(9)
	Hydrazones					
$C_6H_{14}N_2$	Acetone isopropylhydrazone	25.60 (25.0°)		313.7		(9)
$C_{10}H_{16}N_2$	Ethyl methyl ketone *sec*-butylhydrazone	25.33 (25.0°)		387.6		(9)
$C_{12}H_{10}N_2O$	*o*-Benzoquinone phenylhydrazone	35.79 (100.0°)	34.14 (120.0°)	442.9	444.0	(24)
$C_{16}H_{12}N_2O$	1,2-Naphthoquinone 1-phenylhydrazone	36.60 (150.0°)	35.93 (160.5°)	545.5	546.5	(24)
	Miscellaneous					
CO	Carbon monoxide	— —		61.6		(210)
$COCl_2$	Carbonyl chloride	— —		151.6		(143)
CO_2	Carbon dioxide	— —		77.5		(210)
		9.21 (−24.3°)		80.6		(76)
C_4H_9NO	Morpholine	37.5		215.7		(33)
$C_4H_5NO_2$	Succinimide	45.20 (126.0°)		206.7		(170)
$C_6H_4N_2O$	Benzfurazan	35.54 (80.0°)	34.13 (90.5°)	252.3	252.1	(66)
$C_6H_4N_2O_2$	Benzfurazan oxide	44.14 (80.0°)	40.55 (110.5°)	273.8	274.6	(66)
$C_7H_6N_2O_2$	4-Methylbenzfurazan oxide	38.13 (100.5°)	37.03 (108.0°)	312.0	311.3	(66)
$C_7H_{17}NO_2$	Diethylammonium propionate	31.45 (25.0°)		376.4		(29)
$C_9H_{15}NO_6$	Ethyl nitrilotricarboxylate	34.82 (18.9°)	32.65 (40.2°)	496.8	497.9	(241)
$C_{12}H_{10}Se$	Phenyl selenide	39.88 (61.0°)	33.33 (121.3°)	445.5	443.8	(243)
$C_{20}H_{44}IN$	Tetraisopentylammonium iodide	26.40 (99.5°)	25.98 (109.5°)	895.5		(246, 215)

APPENDIX II

TABLE 27

Typical parachor determinations in solution

FORMULA	COMPOUND	SOLVENT	T	MOLE-FRACTION OF SOLUTE	γ^*	P^*	REFERENCES
		Hydrocarbons					
			°C.				
C_6H_{12}	Cyclohexane	Benzene	25.0	0.2963	26.41	240.9	(65)
				0.4508	25.84	240.9	
C_8H_{10}	*m*-Xylene	Benzene	25.0	0.3969	28.00	286.3	(65)
				0.6918	28.11	285.6	
				1.0000	30.45	285.1	
$C_{10}H_8$	Naphthalene	Benzene	30–32	0.04650	28.89	311.1	(171)
				0.08569	29.12	312.7	
		Carbon tetrachloride	30–32	0.05480	26.66	312.6	(171)
				0.08872	27.10	311.1	
		Chloroform	30–32	0.03461	27.46	338.1	(171)
				0.06218	27.35	333.4	
$C_{14}H_{10}$	Anthracene	Nitrobenzene	30–32	0.01091	42.96	419.1	(171)
				0.01177	42.83	416.5	
		Acids					
CH_2O_2	Formic acid	Water	30.0	0.0202†	65.71	93.3	(135, 88)
				0.2813†			
				1.0000	35.28		
$C_2H_4O_2$	Acetic acid	Benzene	25.0	0.279	28.08	133.5	(65)
				0.820	27.78	132.1	
		Ethanol	25.0	0.2262	24.06	133.5	(65)
				0.5550	26.07	131.9	
				1.0000	28.52	132.2	

Alcohols

C_2H_6O	Ethanol	Benzene	25.0	0.237	27.38	125.5	(65)
				0.564	25.00	126.0	
				1.000	21.90	126.0	
$C_{10}H_{10}O$	Menthol	Nitrobenzene	40	0.081	33.59	360	(34)
				0.238	31.45	392	

Carbohydrates

$C_6H_{12}O_6$	Fructose	Pyridine	32 ± 1	0.01806	35.91	342.6	(172)
				0.03217	36.46	329.6	
				1.00	—	358.0‡	
		Water	32 ± 1	0.004930	71.78	359.2	(172)
				0.01203	72.73	349.1	
			19.4	0.02134	—	315.3	(74)
				0.03035	—	326.3	
$C_6H_{12}O_6$	Glucose	Pyridine	32 ± 1	0.01153	35.72	355.4	(172)
				0.01536	35.74	351.9	
				1.00	—	360.0‡	
		Water	32 ± 1	0.006582	71.60	361.4	(172)
				0.01196	72.21	343.6	
			19.4	0.01779	—	365.4	(74)
				0.09262	—	399.4	
$C_{12}H_{22}O_{11}$	Maltose	Pyridine	32 ± 1	0.01854	83.87	593.3	(172)
				0.02252	84.91	577.3	
				1.00	—	663.0‡	
		Water	32 ± 1	0.002098	71.13	667.3	(172)
				0.005448	71.96	664.5	
	Sucrose	Pyridine	32 ± 1	0.004318	35.21	555.8	(172)
				0.005301	35.63	528.3	
				1.00	—	664.0‡	
		Water	32 ± 1	0.003629	71.98	666.8	(172)
				0.007638	73.10	663.7	
			19.4	0.005643	—	613.0	(74)
				0.007226	—	550.8	

TABLE 27—*Concluded*

FORMULA	COMPOUND	SOLVENT	T	MOLE-FRACTION OF SOLUTE	γ^*	P^*	REFERENCES
		Esters					
			°C.				
$C_4H_8O_2$	Ethyl acetate	Acetic acid	25.0	0.1273	27.49	216.0	(65)
				0.5429	25.21	216.5	
				1.0000	23.42	216.1	
		Carbon tetrachloride	25.0	0.1755	25.59	215.4	(65)
				0.4758	24.39	216.0	
$C_9H_6O_2$	Coumarin	Benzene	30–32	0.04542	28.24	314.8	(171)
				0.1234	29.45	297.4	
		Chloroform	30–32	0.05693	26.99	312.6	(171)
				0.1111	28.69	315.1	
		Halogen compounds					
CCl_4	Carbon tetrachloride	Benzene	25.0	0.3419	27.69	219.2	(65)
				0.7326	26.98	220.2	
				1.0000	26.20	219.5	
$CHCl_3$	Chloroform	Benzene	25.0	0.2474	27.78	182.4	(65)
				0.9020	26.53	183.2	
				1.0000	26.73	183.4	
			25.0	0.2068	28.06	184.7	(65)
				0.4892	27.32	183.5	
				1.0000	26.43	183.0	
		Ketones					
C_3H_6O	Acetone	Acetic acid	25.0	0.2909	27.79	160.8	(65)
				0.6183	26.14	160.2	
				1.0000	22.72	161.1	
		Benzene	25.0	0.2993	26.82	159.5	(65)
				0.7034	24.52	160.6	

		Ethanol	25.0	0.4508	22.85	162.4	(65)
				0.6874	22.63	161.1	
				1.0000	23.07	161.4	
C_8H_8O	Acetophenone	Benzene	25.0	0.1538	29.94	284.7	(65)
				0.4668	32.63	287.4	
		Nitro compounds					
CH_3NO_2	Nitromethane	Benzene	25.0	0.2327	29.14	128.0	(65)
				0.5594	30.04	128.9	
				1.0000	35.80	131.8	
$C_6H_5NO_2$	Nitrobenzene	Benzene	25.0	0.2129	30.26	249.0	(65)
				0.4822	33.15	253.7	
				1.0000	42.87	262.5	
		Carbon tetrachloride	25.5	0.2246	28.35	249.5	(65)
				0.6551	34.54	256.2	
				1.0000	43.25	263.0	
		Phenols					
$C_{10}H_8O$	1-Naphthol	Ethyl acetate	30–32	0.02453	23.22	331.7	(171)
				0.1237	25.17	308.1	
		Pyridine	30–32	0.02983	36.40	335.4	(171)
				0.03927	35.71	333.6	
$C_{10}H_{14}O$	Thymol	Acetic acid	40.0	0.176	26.64	375	(34)
			60.0	0.176	25.14	379	
		Nitrobenzene	40.0	0.176	36.16	373	(34)
				0.229	37.4	386	
		Ether					
$C_4H_{10}O$	Ethyl ether	Benzene	25.0	0.2356	24.53	203.7	(65)
				0.7464	18.49	208.8	
				1.0000	16.47	211.0	

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* γ is the surface tension of the solution; P is the parachor of the solute, assuming a mole-fraction relationship.

† Mole-fraction calculated from the weight per cent values given in the reference.

‡ Value of parachor obtained by extrapolation of experimental values.

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