The fact that the nitrogen atoms have different polarity is proven from the ionization constants of ammonia and hydrazine, the former gives $K_b^{25°} = 1.87 \times 10^{-5}$ while for the latter we have $K_b^{25°} = 3 \times 10^{-6}$. From the previous work upon polarity it is evident that the second NH_2 radical in hydrazine behaves as a negative group, since it reduces the ionization of ammonia. The fact that when two like atoms combine one must be positive while the other is negative was first suggested by W. A. Noyes[1] from the reaction between chlorine and ammonia.

In the case of negative aldehydes and ketones, the less positive the substituted ammonia which adds, the more chance that it will give a stable hydroxy addition product. The work of R. S. Curtiss[2] upon the substituted amine addition products of dimethyl mesoxalate bears out this deduction. He has been able to isolate in the hydroxyl form addition products of the above ester with aniline ($\phi = 107$) and urea ($\phi = 72.2$), while attempts to isolate a similar compound with ammonia ($\phi = 211.4$) have failed.

Similarly, with aldehydes and ketones possessing an excess of positivity within the molecule, it should be easier to isolate the hydroxy addition products of substituted ammonias the more positive the substituted ammonia.

URBANA, ILL.,
April 21, 1911.

[CONTRIBUTION FROM THE CHEMICAL LABORATORY OF THE UNIVERSITY OF ILLINOIS.]

APPLICATION OF POLARITY MEASURED IN TERMS OF A LOGARITHMIC FUNCTION OF THE IONIZATION CONSTANT. II. SCALE OF COMBINED INFLUENCE OF SUBSTITUTION IN ORGANIC COMPOUNDS.

BY C G. DERICK.

Received May 15, 1911.

Michael,[3] following the idea of van't Hoff that the atoms in a molecule act upon each other through direct union (through space) or indirectly through intermediate atoms, states[4] "if we number a certain atom in any fatty compound with a normal carbon chain by the figure 1, our present knowledge of the combined mutual influence between this atom and the others in the molecule is expressed by the following scale of combined influence, the number indicating the degree of removal and the extent of influence decreasing in the order given: 2–3–5–6–4–7–(9–10–11)–8. It is to be strongly emphasized that the effect of any atom in the position 2 or 3 is *far greater* than that of any similar atom less closely connected,

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[1] THIS JOURNAL, 23, 460 (1901).

[2] *Ibid.*, 31, 1053 (1909).

[3] *J. prakt. Chem.*, [2] 60, 331; *Ber.*, 39, 2138, 2780; 40, 141.

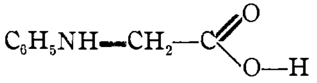
[4] THIS JOURNAL, 32, 999 (1910).

and in the case of atoms farther removed, the influence must be largely direct (*i. e.*, spatial)."

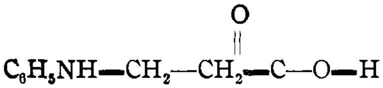
B. Flürscheim[1] has also studied the effect of substitution of radicals into a molecule upon a given atom. He attributes this effect to three factors: polarity of the substituent, the amount of affinity which the substituent requires (the quantitative factor), and stearic hindrance. Not having an accurate measure of these factors, he arbitrarily assigns them certain values and then proceeds to test his hypotheses, which he illustrates thus: "If we have, for example, an unsaturated atom (or group) substituting hydrogen in the α-position the carbon atom will be more strongly bound by it; this leads to a reduction of the force with which the α-(carbon) atom binds the carbonyl carbon atom, to a stronger linking between the latter and oxygen and therefore to a weakening of the bond between oxygen and hydrogen. The following examples illustrate this case. Although aniline is a base, anilinoacetic acid ($K = 0.000038$) is stronger than acetic acid ($K = 0.0000186$).

"On the other hand, an unsaturated atom substituting hydrogen in the β-position must have exactly the opposit effect—it takes up a greater amount of the affinity of the β-carbon than does hydrogen; the amount of affinity with which the β-carbon can bind the α-carbon is thereby lessened and the strength of the linking between the latter and the carbonyl carbon is increased. That between the latter and oxygen diminished, and the bond between oxygen and hydrogen is strengthened. β-Anilinopropionic acid ($k = 0.000004$) is weaker than propionic acid ($k = 0.000013$)."

Graphically, he would represent the above facts as follows:



$C_6H_5NH-CH_2-C\begin{matrix}\nearrow O \\ \searrow O-H\end{matrix}$ Anilinoacetic acid.



$C_6H_5NH-CH_2-CH_2-\overset{\overset{O}{\|}}{C}-O-H$ β-Anilinopropionic acid.

The relative thickness of the bonds shows, qualitatively, the relative strength of the union. He assumes that weak chemical union favors ionizations.

It is interesting to note that he did not test these conclusions beyond the β-position in the above case. According to his theory γ-anilino substituted acids should have K_a greater than K_a for the β-isomers. He calls the halogens "unsaturated" atoms and shows how, in the case of the *o*-, *m*-, and *p*-halogen benzoic acids, his theory applies. Yet reference to Table II will show that it does not hold in a single case for the halogen-substituted open-chain acids. He overlooks the fact that radicals

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[1] *J. Chem. Soc.*, 95, 718 (1909).

are amphoteric by confusing this property with his quantitative factor. The illustrations are the exception rather than the rule. Finally Flürscheim needlessly confuses the problem. The direct and indirect influences

TABLE I.—A LOGARITHMIC FUNCTION OF THE IONIZATION CONSTANT AS A MEASURE OF THE DIRECT AND INDIRECT INFLUENCES OF RADICALS UPON THE MOLECULE.

Name.[1]	K$^{25°}$.	Log K.	1000/Log. K.
cis-α,α′-Methylallylsuccinic acid	2.33 10^{-4}	—3.632	275.2
trans-α,α′-Methylallylsuccinic acid	2.43 10^{-4}	—3.613	277.0
cis-α,α′-Ethylallylsuccinic acid	3.59 10^{-4}	—3.444	290.4
trans-α,α′-Ethylallylsuccinic acid	2.69 10^{-4}	—3.569	280.0
cis-α,α′-Dimethylsuccinic acid	1.24 10^{-4}	—3.906	256.0
trans-α,α′-Dimethylsuccinic acid	1.93 10^{-4}	—3.714	269.0
Methyl *cis*-α,α′-dimethylsuccinate	4.55 10^{-5}	—4.341	219.7
Methyl *trans*-α,α′-dimethylsuccinate	6.05 10^{-5}	—4.217	237.3
cis-α,α′-Diethylsuccinic acid	2.01 10^{-4}	—3.696	270.5
trans-α,α′-Diethylsuccinic acid	2.45 10^{-4}	—3.611	277.0
cis-α,α′-Dipropylsuccinic acid	4.9 10^{-4}	—3.308	302.0
trans-α,α′-Dipropylsuccinic acid	2.5 19^{-4}	—3.602	277.7
cis-α,α′-Diisopropylsuccinic acid	2.3 10^{-3}(?)	—2.637(?)	379.0(?)
trans-α,α′-Diisopropylsuccinic acid	1.08 10^{-4}	—3.966	250.0
Methyl *cis*-α,α′-diisopropylsuccinate	1.15 10^{-4}	—3.938	254.0
Methyl *trans*-α,α′-diisopropylsuccinate	1.24 10^{-4}	—3.906	256.0
cis-α,α′-Dimethylglutaric acid	5.2 10^{-4}	—4.283	233.5
trans-α,α′-Dimethylglutaric acid	5.9 10^{-4}	—4.228	236.5
cis-β-Methylglutaric acid	1.29 10^{-4}	—3.888	257.8
trans-β-Methylglutaric acid	1.39 10^{-4}	—3.856	259.2
cis-α,γ-Tricarballylic acid	5.45 10^{-4}	—3.262	306.5
trans-α,γ-Tricarballylic acid	4.45 10^{-4}	—3.351	298.0
Maleic acid	1.2 10^{-2}	—1.921	521.0
Fumaric acid	9.0 10^{-4}	—3.044	328.4
cis-Hexahydroterephthalic acid	3.0 10^{-5}	—4.523	221.0
trans-Hexahydroterephthalic acid	4.56 19^{-5}	—4.341	230.4
cis-Hexahydrophthalic acid	4.4 10^{-5}	—4.356	229.7
trans-Hexahydrophthalic acid	6.2 10^{-5}	—4.207	237.8
cis-Pentamethylenedicarboxylic acid (1,2)	1.58 10^{-4}	—3.801	263.2
trans-Pentamethylenedicarboxylic and (1,2)	1.16 10^{-4}	—3.936	253.7
cis-Pentamethylenedicarboxylic acid (1,3)	5.4 10^{-5}	—4.267	234.2
trans-Pentamethylenedicarboxylic acid (1,3)	5.0 10^{-5}	—4.301	231.6
cis-Tetramethylenedicarboxylic acid (1,2)	6.6 10^{-5}	—4.179	239.0
trans-Tetramethylenedicarboxylic acid (1,2)	2.8 10^{-5}	—4.552	219.7
cis-Trimethylenedicarboxylic acid (1,2)	4.0 10^{-4}	—3.399	294.0
trans-Trimethylenedicarboxylic acid (1,2)	2.06 10^{-4}	—3.686	271.2
trans-Tartaric acids:			
d-Tartaric acid	9.7 10^{-4}	—3.012	331.8
l-Tartaric acid	9.7 10^{-4}	—3.012	331.8
r-Tartaric acid	9.7 10^{-4}	—3.012	331.8
cis-Tartaric acid (i) (*meso*) Tartaric acid	6.0 10^{-4}	—3.221	310.4

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[1] In this table *cis* refers to *cis*-form of geometric isomers or to *meso*-form of optical isomers. Similarly *trans* refers to *trans*-form of geometric isomers or *d*, *l* and *r* optical isomers.

mentioned by van't Hoff are sufficient to account for all the phenomena the former mentions. Flürscheim's quantitative factor is a confusion of the amphoteric nature of radicals with van't Hoff's indirect factor of influence. The stearic hindrance factor fails to include the full meaning of the direct spatial factor as van't Hoff stated it. Lack of a quantitative measure of the factors under discussion has led both Michael and Flürscheim to wrong conclusions, as will be developed more fully later.

The question immediately suggests itself, What shall be a measure of these influences? Table I shows that —1000/logarithm of K may be taken as such a measure. (Polarity as defined in the last paper = — 1000/log K.) The table shows clearly that the ionization constant will measure, relatively, the combined influence of the direct and indirect factors of a substituent upon the rest of the molecule as expressed in the given group which ionizes. For example, in each case of *cis-trans*-isomerism of the unsaturated dicarboxylic acids, the same number and kinds of atoms intervene between the carboxyl radicals of each isomer, so that if the ionization constant was not affected by the direct space influence of atoms, each isomer ought to have the same ionization constant *due to the same indirect influence.* Table I shows that this is not the case, nor has a single example been found in which the *cis* and *trans* isomers have the same ionization constant. Hence the difference in the ionization constants of *cis* and *trans* isomers must be attributed to the direct space influence of the radical, as Ostwald first noted. It becomes clear, therefore, *that some function of the ionization constant may be taken as a relative measure of the combined direct and indirect influences of radicals upon a given atom or molecule.*

Since each atom in the molecule exerts a direct and indirect influence upon the ionization, as Table II will show, the ionization constant for a given ionizing group expresses the resultant of the combined influence of the direct and indirect factors of every atom in the molecule. Table II will show that the combined influence of hydrogen or an alkyl radical is very small, and their substitution into a given molecule has little effect upon the ionization and therefore their combined influence (direct and indirect) is very small. (See the paraffin monocarboxylic acid and their monoolefin derivatives No. B and No. A, I). In the case of the other atoms the combined direct and indirect influences may be very great (see paraffin dicarboxylic acids). To determine the combined influence of the direct and indirect factors for a given radical, we must substitute it into a given acid and note the effect in the change of the ionization constant. Since the ionization constant of the unsubstituted acid expresses the combined influence of all the atoms in the molecule, the change in the ionization constant produced by substituting a given group for hydrogen will express the value of the combined direct and indirect influences of the substituent. By varying the position of the substituent with reference to the ionizing group the combined direct and indirect influences of the substituent with reference to the ionizing group may be determined. A correction for the hydrogen displaced should be applied, but since it is so small it may be safely neglected without appreciably changing the relative results desired.

The method of application of this measure of the scale of combined influence of the direct and indirect influence of substituents will be illustrated by the following. Supposing it is desired to test the relative scale of combined influence for chlorine when substituted in different positions of a normal fatty acid, say butyric acid. In Table II (No. A, II, III, and IV) will be found the logarithms of the ionization constants for butyric and the chloro-substituted butyric acids. First determin the ratio of the combined direct and indirect influences of the atoms in the substituted and unsubstituted acids, thus α-chlorobutyric acid: butyric acid = —1000/log K (α-chlorobutyric): —1000/log K (butyric) = log K (butyric)/log K (α-chlorobutyric) = —4.807/—2.857 = 1.682/1.

β-Chlorobutyric acid: butyric acid = (—4.807) : (—4.049) = 1.186 : 1

γ-Chlorobutyric acid: butyric acid = (—4.807) : (—4.523) = 1.062 : 1

δ-Chlorobutyric acid: valerianic acid = (—4.796) : (—4.690) = 1.022 : 1

Subtracting the combined influence of the other atoms in the molecule (which is equal to the logarithm of the ionization constant of butyric acid and equal to one in the above ratio, neglecting the effect of the displaced hydrogen) we have:

$$\alpha\text{-factor} = 1.682 - 1 = 0.682$$
$$\beta\text{-factor} = 1.186 - 1 = 0.187$$
$$\gamma\text{-factor} = 1.062 - 1 = 0.062$$
$$\delta\text{-factor} = 1.022 - 1 = 0.022$$

Therefore the relative scale of the combined direct and indirect actions of chlorine in the α-, β-, γ- and δ-positions as measured by the carboxyl group in the α-position is:

$$\alpha : \beta : \gamma : \delta = 0.682 : 0.186 : 0.062 : 0.022^{1}$$

Thus it is evident that the scale for the combined influence for a given radical may be measured for at least one type of chemical reaction and Michael's "scale of combined influence" may be tested as well as the conclusions drawn by Flürscheim.

To understand Michael's scale of combined influence it is better to translate his nomenclature into that commonly employed by the organic chemist. One illustration will suffice to show the relation, namely, γ-bromocaproic acid:

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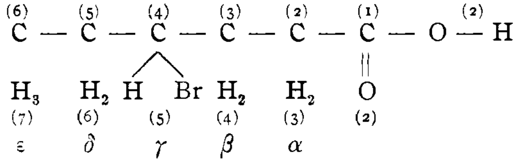
[1] The regularity in these ratios will be treated later.



Thus in the γ-position, the carbon is in position (4) and the bromine in position (5) with respect to the carbonyl carbon in position (1). In Table II the first column gives Michael's nomenclature and the last column the factor corresponding to the combined influence of the direct and indirect actions of the given radical for the given position.

It is evident from Tables I and II that no general "scale of combined influence" for all atoms in a molecule upon a given atom can be stated. The order of such a scale of combined influence for water solution is dependent upon polarity as well as external conditions of temperature and pressure. Taking into consideration polarity we may make certain general statements, namely:

1. That in open-chain compounds possessing normal chains, if the substituent is negative then the scale of combined influence for a given negative group in position (1) is 2, 3, 4, 5, 6, 7, 8, 9, etc.; *i. e.*, greatest when the negative substituent is in position 2 and decreases, proportional to the number of carbon atoms intervening. For example, the scale of combined influence for chlorine as measured by the carboxyl group in position (1) is $3 : 4 : 5 : 6 = \alpha : \beta : \gamma : \delta = 0.680 : 0.189 : 0.063 : 0.024$. A notable exception to this rule is that of the unsaturated acids containing a double union. The order of influence in this case has been fully developed by the author in a previous paper.[1] In this case the maxi. mum effect is produced in (3) not (2) as in all other cases.

2. That in all cases except where the substituent is of great negativity the effect of the substitution of negative radicals upon a given negative radical in position (1) has fallen to a constant value by the γ-position (5 in the above scale) which is approximately that of the corresponding unsubstituted acid. A slight residual effect is always present so that the ionization of the substituted acid never completely falls to that of the corresponding unsubstituted acid.

3. When the substituent is positive and the group in position (1) is also positive no general rule for the scale of combined influence is possible. However, if both positive groups are amine (—NH_2), then the order of influence of one amine group upon the other in position (1) is 2, 3, 4, 5, 6, etc., the minimum effect being in position (2), and the effect increasing as the number of carbon atoms intervening between the amine groups are increased. The case of the dicarboxylic paraffin acids offers the anal-

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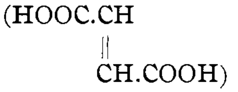
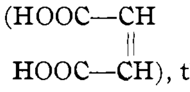
[1] THIS JOURNAL, **32**, 1339 (1910).

ogous example where both groups are negative and of the same kind, but an exact opposite order of influence is obtained (see tables), the maximum effect being in position (2) and decreasing, proportional to the number of carbon atoms intervening between the two carboxyl groups.

4. That in the case of ring compounds no general scale of combined influence can be stated. In the case of the halogen-substituted benzoic acids, it is interesting to notice that in the ortho position the order of influence of the halogens is Br > I > Cl, while in the meta position Cl > Br > I as in the case of all normal chain halogen acids for the halogens in any similar position. The order of influence of the halogenated benzoic acids is not general for other substituted benzoic acids even though the substituent is more "unsaturated" as Flürscheim would lead us to believe.

5. Michael further states that the effect of any atom in the position 2 or 3 (α) is far greater than that of any similar atom less closely connected, and in the case of atoms farther removed, the influence must be largely direct, *i. e.*, spatial. He implies that the spatial influence of groups is always less than the direct influence of a group in position 3 (α). This is not necessarily true and depends upon the relative negativity or positivity of the substituent. For example, malonic acid has the ionization constant 1.63×10^{-3} at 25°. It has a carboxyl in position 3 (α) which acts mainly indirectly through the α carbon atom upon the other carboxyl group. In furmaric acid  $\begin{matrix}(\text{HOOC.CH}\\ \|\\ \text{CH.COOH})\end{matrix}$ we have a carboxyl group in position 4 (β), which acts mainly indirectly through two carbon atoms, doubly bound, upon the carboxyl group in position 1; its ionization constant at 25° is 9×10^{-4}. In the isomeric maleic acid  $\begin{matrix}(\text{HOOC—CH}\\ \|\\ \text{HOOC—CH})\end{matrix}$, the same indirect influence is present as in fumaric acid, yet its ionization constant at 25° is 1.2×10^{-2}, due to the greater direct spatial influence of the carboxyl group. But the ionization constant of maleic acid is greater than that of malonic acid in spite of the fact that in the latter the carboxyl group is in position 3 (α). Hence it is evident that the direct spatial influence of a carboxyl group in position 4 (β) may be greater than the indirect influence of the same group in position 3. Again it is evident that no general conclusions as to the "scale of combined influence can be drawn, but a logarithmic function of the ionization constant may be used to determine this scale in any given case under discussion.

6. For other conclusions see "Affinitätmessungen an schwachen Säuren und Basen," by H. Lundén, page 77.

7. Lactone and anhydride formations.

TABLE II—A. ORDER OF EFFECT OF NEGATIVE SUBSTITUENTS IN A NORMAL ALIPHATIC COMPOUND UPON A GIVEN NEGATIVE RADICAL (CARBOXYL RADICAL).

Name.	Formula.	Ka.	Log K.	Factors.
I. Double Union:				
2[2] Δ¹-Pentenic acid	$C_2H_5.CH = CH.CO_2H$	1.48 10^{-5}	—4.830	—0.007[1]
3 Δ²-Pentenic acid	$CH_3CH = CHCH_2CO_2H$	3.35 10^{-5}	—4.475	+0.0095
4 Δ³-Pentenic acid	$CH_2 = CH.(CH_2)_2CO_2H$	2.09 10^{-5}	—4.680	+0.024
2 Δ¹-Hexenic acid	$C_3H_7.CH = CHCO_2H$	1.89 10^{-5}	—4.724	+0.0395
3 Δ²-Hexenic acid	$C_2H_5CH = CH_2CO_2H$	2.64 10^{-5}	—4.578	+0.057
4 Δ³-Hexenic acid	$CH_3CH = CH(CH_2)_2CO_2H$	1.74 10^{-6}	—4.758	+0.018
5 Δ⁴-Hexenic acid	$CH_2 = CH.(CH_2)_3CO_2H$	1.91 10^{-5}	—4.718	+0.026
II. Chlorine:				
3 α-Chlorobutyric acid	$C_2H_5CHClCO_2H$	1.39 10^{-3}	—2.857	0.680
4 β-Chlorobutyric acid	$CH_3CHOCH_2CO_2H$	8.94 10^{-5}	—4.049	0.187
5 γ-Chlorobutyric acid	$CH_2Cl.(CH_2)_2CO_2H$	3.0 10^{-5}	—4.523	0.063
6 δ-Chlorovalerianic	$CH_2Cl(CH_2)_3CO_2H$	2.04 10^{-5}	—4.690	0.023
III. Bromine:				
3 α-Bromoacetic acid	$CH_2Br.CO_2H$	1.38 10^{-3}	—2.860	0.655
4 β-Bromopropionic acid	$CH_2Br.CH_2CO_2H$	9.8 10^{-5}	—4.009	0.210
5 γ-Bromobutyric acid	$CH_2Br(CH_2)_2CO_2H$	2.6 10^{-5}	—4.585	0.047
6 δ-Bromovalerianic acid	$CH_2Br(CH_2)_3CO_2H$.	1.91 10^{-5}	—4.719	0.017
IV. Iodine:				
3 α-Iodoacetic acid	CH_2ICO_2H	7.5 10^{-4}	—3.125	0.515
4 β-Iodopropionic acid	$CH_2ICH_2OCO_2H$	9.0 10^{-5}	—4.046	0.167
5 γ-Iodobutyric acid	$CH_2I(CH_2)_2CO_2H$	2.3 10^{-6}	—4.638	0.035
6 δ-Iodovalerianic acid	$CH_2I(CH_2)_3CO_2H$	1.71 10^{-5}	—4.767	0.008

[1] A minus value for these factors mean that the substituting group decreases the hydrogen ionization of the unsubstituted acid instead of increasing the same. These calculations were made using the slide rule, but are accurate enough for the purpose of this article.

[2] The column refers to the nomenclature used by Michael.

V. Hydroxyl:

3	α-Hydroxyacetic	CH_2OHCO_2H	$1.5\ 10^{-4}$	—3.824	0.238
4	β-Hydroxypropionic ...	$CH_2OH.CH_2CO_2H$	$3.1\ 10^{-5}$	—4.509	0.073
5	γ-Hydroxybutyric acid.	$CH_2OH.(CH_2)CO_2H$	$1.93\ 10^{-5}$	—4.714	0.018

VI. Carboxyl.

2	Oxalic acid	$HOOC.COOH$	$1.00\ 10^{-1}$	—1.000	2.670
3	Carboxyacetic acid.....	$HO_2CCH_2CO_2H$	$1.64\ 10^{-3}$	—2.785	0.710
4	β Carboxypropionic acid	$HO_2C(CH_2)_2CO_2H$	$6.7\ 10^{-5}$	—4.174	0.160
5	γ-Carboxybutyric acid..	$HO_2C(CH_2)_3CO_2H$	$4.7\ 10^{-5}$	—4.328	0.111
6	δ-Carboxyvalerianic acid	$HO_2C(CH_2)_4CO_2H$	$3.7\ 10^{-5}$	—4.432	0.083
7	ε-Carboxycaproic acid..	$HO_2C(CH_2)_5CO_2H$	$3.23\ 10^{-5}$	—4.491	0.076
8	ζ-Carboxyeonanthic acid	$HO_2C(CH_2)_6CO_2H$	$2.99\ 10^{-5}$	—4.524	0.069
9	η-Carboxycaprylic acid..	$HO_2C(CH_2)_7CO_2H$	$2.5\ 10^{-5}$	—4.602	0.053
10	θ-Carboxypelargonic acid	$HO_2C(CH_2)_8CO_2H$	$2.38\ 10^{-5}$	—4.624	0.072

VII. Carboxyethyl.

3	Carboxyethylacetic acid.	$C_2H_5OOC.CH_2CO_2OH$	$4.51\ 10^{-4}$	—3.346	0.407
4	β-Carboxyethylpropionic	$C_2H_5O_2C.(CH_2)_2CO_2H$	$3.02\ 10^{-5}$	—4.520	0.072
8	ζ-Carboxyethyleonanthic	$C_2H_5O_2C(CH_2)_6CO_2H$	$1.46\ 10^{-5}$	—4.836	0.000
10	θ-Carboxyethylpelargonic	$C_2H_5O_2C(CH_2)_8CO_2H$	$1.43\ 10^{-5}$	—4.845	—0.003

VIII. Phenyl.

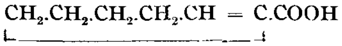
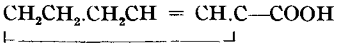
3	Phenylacetic acid......	$C_6H_5CH_2CO_2H$	$5.02\ 10^{-5}$	—4.276	0.107
4	β-Phenylpropionic acid.	$C_6H_5(CH_2)_2CO_2H$	$2.3\ 10^{-5}$	—4.637	0.043

B.—ORDER OF EFFECT OF POSITIVE SUBSTITUENTS IN A NORMAL ALIPHATIC COMPOUND UPON A GIVEN NEGATIVE RADICAL (CARBOXYL GROUP).

I. Methyl.

2	Methylformic acid......	$CH_3.CO_2H$	$1.86\ 10^{-5}$	—4.731	—0.226
3	Methylacetic acid......	$CH_3CH_2CO_2H$	$1.45\ 10^{-5}$	—4.839	—0.022
3	α-Methylpropionic acid.	$CH_3CH(CH_3)CO_2H$	$1.60\ 10^{-5}$	—4.796	+0.008
4	β-Methylbutyric acid...	$CH_3.CH(CH_3).CH_2CO_2H$	$1.70\ 10^{-5}$	—4.770	+0.006
5	γ-Methylvalerianic acid.	$CH_3CH(CH_3)_2CO_2H$	$1.44\ 10^{-5}$	—4.842	—0.015
2	Methylformic acid.....	CH_3COOH	$1.86\ 10^{-5}$	—4.731	—0.226

TABLE II (*Continued*).

Name.	Formula.	Ka.	Log K.	Factors.
3 Methylacetic acid......	$CH_3CH_2CO_2H$	1.45 10^{-5}	—4.839	—0.022
4 β-Methylpropionic acid.	$CH_3(CH_2)_2CO_2H$	1.56 10^{-5}	—4.807	—0.004
5 γ-Methylbutyric acid...	$CH_3(CH_2)_3CO_2H$	1.60 10^{-5}	—4.796	0.000
6 δ-Methylvalerianic acid	$CH_3(CH_2)_4CO_2H$	1.45 10^{-5}	—4.839	0.000
7 ε-Methylcaproic acid....	$CH_3(CH_2)_5CO_2H$	1.46 10^{-5}	—4.842	—0.001
8 ζ-Methyleonanthic acid.	$CH_3(CH_2)_6CO_2H$	1.44 10^{-5}	—4.951	—0.024
C.—ORDER OF EFFECT OF NEGATIVE SUBSTITUENTS IN A NORMAL ALIPHATIC COMPOUND UPON A GIVEN POSITIVE RADICAL (AMINE GROUP).				
I. Phenyl:		K_b		
2 Phenylamine..........	$C_6H_5NH_2$	4.6 10^{-10}	—9.337	—0.4935
3 Phenylmethylamine....	$C_6H_5CH_2NH_2$	2.4 10^{-5}	—4.619	—0.2849
D.—ORDER OF EFFECT OF POSITIVE SUBSTITUENTS IN A NORMAL ALIPHATIC COMPOUND UPON A GIVEN POSITIVE RADICAL (AMINE GROUP).				
I. Amine:[1]		K_b		
2 Hydrazine............	$NH_2–NH_2(NH_2–NH_3OH)$	3. 10^{-6}	—5.523	—0.144
4 β-aminoethylamine.....	$NH_2–CH_2CH_2NH_2$	8.5 10^{-5}	—4.071	—0.202
5 γ-aminopropylamine....	$NH_2(CH_2)_3NH_2$	3.5 10^{-4}	—3.456	—0.028
6 δ-aminobutylamine.....	$NH_2(CH_2)_4NH_2$	5.1 10^{-4}	—3.293	...
7 ε-aminopentylamine....	$NH_2(CH_2)_5NH_2$	7.3 10^{-4}	—3.137	...
II. Methyl:				
2 Methylamine..........	CH_3NH_2	5.0 10^{-4}	—3.301	0.433
3 α-Methylethylamine....	$CH_3CH(CH_3)NH_2$	5.3 10^{-4}	—3.276	—0.008
4 β-Methylpropylamine...	$CH_3CH(CH_3)CH_2NH_2$	3.1 10^{-4}	—3.509	—0.052
E.—ORDER OF EFFECT OF NEGATIVE SUBSTITUENTS UPON A GIVEN NEGATIVE RADICAL (CARBOXYL GROUP) IN THE RING.				
I. Double union:		K_a		
2 Δ¹-Tetrahydrobenzoic acid	 $CH_2.CH_2.CH_2.CH_2.CH = C.COOH$	2.21 10^{-5}	—4.656	—0.107
3 Δ²-Tetrahydrobenzoic acid	 $CH_2CH_2.CH_2CH = CH.C—COOH$	3.05 10^{-5}	—4.516	—0.079

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[1] Amine substituent is apparently functionating with its amphoteric negative nature until ε-amino pentylamine.

II. Chlorine:				
4 *o*-Chlorobenzoic acid....	CH = CH — CH = CH.C(Cl) = C.COOH	$1.32\ 10^{-3}$	—2.880	0.445
5 *m*-Chlorobenzoic acid...	CH = CH.CH = C(Cl).CH = CCOOH	$1.55\ 10^{-3}$	—2.810	0.480
6 *p*-Chlorobenzoic acid....	CH = CH.C(Cl) = CHCH = CCOOH	$9.3\ 10^{-5}$	—4.032	0.03
III. Bromine:				
4 *o*-Bromobenzoic acid...	CH = CH.CH = CH.C(Br) = C.COOH	$1.45\ 10^{-3}$	—2.839	0.466
5 *m*-Bromobenzoic acid..	CH = CH.CH = C(Br).CH = C.COOH	$1.37\ 10^{-3}$	—2.863	0.452
6 *p*-Bromobenzoic acid...	CH = CH.C (Br) = CH.CH = C.COOH	...	.....	.....
IV. Iodine:				
4 *o*-Iodobenzoic acid.....	CH = CH — CH = CH.C(I) = C COOH	$1.37\ 10^{-3}$	—2.863	0.452
m-Iodobenzoic acid....	CH = CH.CH = C(I).CH = C.COOH	$1.6\ 10^{-4}$	—3.796	0.05
V. Hydroxyl:				
4 *o*-Hydroxybenzoic acid.	CH = CH.CH = CH.C(OH) = C .COOH	$1.04\ 10^{-3}$	—2.983	0.394
5 *m*-Hydroxybenzoic acid	CH = CH.CH = C(CH).CH = C COOH	$8.33\ 10^{-5}$	—4.079	0.018
6 *p*-Hydroxybenzoic acid.	CH = CH.C(OH) = CH.CH = C COOH	$2.9\ 10^{-5}$	—4.538	—0.103
VI. Carboxyl:				
4 *o*-Carboxybenzoic acid.	CH = CH.CH = CH.C(CO_2H) =CCO_2H	$1.21\ 10^{-3}$	—2.917	0.425
5 *m*-Carboxybenzoic acid	CH = CH.CH = C(CO_2H).CH = CCO_2H	$2.9\ 10^{-4}$	—3.462	0.176

TABLE II (*Continued*).

Name.	Formula.	K*a*.	Log K.	Factors.
6 *p*-Carboxybenzoic acid..	$\mathrm{CH = CH.CH(CO_2H) = CH.CH = CCO_2H}$	$1.5 \quad 10^{-4}$	—3.398	0.087
VII. Nitro:				
4 *o*-Nitrobenzoic acid.....	$\mathrm{CH = CH.CH = CH.C(NO_2) = C.CO_2H}$	$6.3 \quad 10^{-3}$	—2.199	0.892
5 *m*-Nitrobenzoic acid....	$\mathrm{CH = CH.CH = C(NO_2)CH = C\ CO_2H}$	$3.45 \quad 10^{-4}$	—3.462	0.201
6 *p*-Nitrobenzoic acid....	$\mathrm{CH = CH.C(NO_2) = CH.CH = CCO_2H}$	$4.0 \quad 10^{-4}$	—3.398	0.224
E.—ORDER OF EFFECT OF POSITIVE SUBSTITUENTS UPON A GIVEN NEGATIVE RADICAL (CARBOXYL GROUP) IN THE RING.				
I. Amine.		K_a		
4 *o*-Aminobenzoic acid....	$\mathrm{CH = CH.CH : CH.C(NH_2) : C.CO_2H}$	$1.06 \quad 10^{-5}$	—4.975	—0.164
5 *m*-Aminobenzoic acid...	$\mathrm{CH : CH.CH : C(NH_2).CH : C.CO_2H}$	$1.63 \quad 10^{-5}$	—4.788	—0.132
6 *p*-Aminobenzoic acid...	$\mathrm{CH = CH.C(NH_2) = CH.CH = C.CO_2H}$	$1.21 \quad 10^{-5}$	—4.917	—0.123
or				
4 *o*-Anilinosulfonic acid...	$\mathrm{CH = CH.CH = CH.C(NH_2) = C.SO_3H}$	$3.3 \quad 10^{-3}$	—2.482	...
5 *m*-Anilinosulfonic acid.	$\mathrm{CH = CH.CH = C(NH_2).CH = C.SO_3H}$	$1.85 \quad 10^{-4}$	—3.733	...
6 *p*-Anilinosulfonic acid..	$\mathrm{CH = CH.C(NH_2) = CH.CH = C.SO_3H}$	$5.81 \quad 10^{-4}$	—3.318[6]	...
II. (*N*)-Methylamine:				
4 (*N*)-Methyl-*o*-aminobenzoic acid...........	$\mathrm{CH = CH.CH = CH.C(NHCH_3) = C\ CO_2H}$	$4.6 \quad 10^{-6}$	—5.337	—0.222
5 (*N*)-Methyl-*m*-aminobenzoic acid...........	$\mathrm{CH = CH.CH = C(NHCH_3).CH = CCO_2H}$	$8.0 \quad 10^{-6}$	—5.196	—0.200

6 (*N*)-Methyl -*p*-aminobenzoic acid	$CH = CH.C(NHCH_3) = CH.CH = C.CO_2H$	9.2	10^{-6}	—5.036	—0.175
III. Dimethylamine:					
4 (*N*)-Dimethyl-*o*-aminobenzoic acid.........	$CH = CH.CH = CH.C[N(CH_3)_2] = C.CO_2H$	2.1	10^{-9}	—8.678	—0.521
5 (*N*)-Dimethyl-*m*-aminobenzoic acid.........	$CH = CH.CH = C[N(CH_3)_2].CH = C.CO_2H$	8.0	10^{-6}	—5.096	—0.184
6 (*N*)-Dimethyl-*p*-aminobenzoic acid.........	$CH = CH.C[N(CH_3)_2] = CH.CH = C.CO_2H$	9.4	10^{-6}	—5.027	—0.173
IV Methyl:					
4 *o*-Toluic acid..........	$CH = CH.CH = CH.C(CH_3) = C.CO_2H$	1.25	10^{-4}	—3.903	0.065
5 *m*-Toluic acid..........	$CH = CH.CH = C(CH_3).CH = C.CO_2H$	5.1	10^{-5}	—4.293	—0.033
6 *p*-Toluic acid..........	$CH = CH.C(CH_3) = CH.CH = C.CO_2H$	5.1	10^{-5}	—4.293	—0.033
V. Ring *N*:					
4 *α*-Pyridine carboxylic acid	$CH = CH.CH = CH.C(CO_2H) = N$	3.0	10^{-6}	—5.522	—0.248
5 *β*-Pyridine carboxylic acid	$CH = CH.CH = C(CO_2H.CH = N$	1.4	10^{-5}	—4.852	—0.144
6 *γ*-Pyridine carboxylic acid	$CH = CH.C(CO_2H) = CH.CH = N$	1.1	10^{-5}	—4.959	—0.161

F.—ORDER OF EFFECT OF NEGATIVE SUBSTITUENTS UPON A GIVEN POSITIVE RADICAL (AMINE GROUP) IN THE RING.

		K_b			
I. Carboxyl:					
4 *o*-Aminobenzoic acid....	$CH = CH.CH = CH.C(CO_2H) = C.NH_2$	1.38	10^{-12}	—11.860	—0.213
5 *m*-Aminobenzoic acid...	$CH = CH.CH = C(CO_2H).CH = C.NH_2$	1.22	10^{-1}	—10.913	—0.144
4 (*N*)-Methyl *o*-aminobenzoic acid............	$CH = CH.CH = CH-C(CO_2H) = C.NHCH_3$	8.55	10^{-13}	—11.632	—0.326

TABLE II (*Continued*).

Name.	Formula.	K*a*.	Log K.	Factors.
6 *p*-Aminobenzoic acid..	$CH = CH.C(CO_2H) = CH.CH = C.NH_2$	$2.33\ 10^{-12}$	—12.068	—0.197
5 (*N*)-Methyl-*o*-aminobenzoic acid..........	$CH = CH.CH = C(CO_2H).CH = C.NHCH_3$	$1.10\ 10^{-11}$	—10.959	—0.258
6 (*N*)-Methyl-*p*-aminobenzoic acid..........	$CH = CH.C(CO_2H) = CH.CH = C.NHCH_3$	$1.52\ 10^{-12}$	—11.818	—0.312
II. Nitro:				
4 ε-Nitraniline..........	$CH = CHCH = CH.C(NO_2) = C.NH_2$	$1.0\ 10^{-14}$	—14.000	—0.333
5 *m*-Nitraniline..........	$CH = CH.CH = C(NO_2.CH = C.NH_2$	$4.0\ 10^{-12}$	—11.398	—0.180
6 *p*-Nitraniline..........	$CH = CH.C(NO_2) = CH.CH = C.NH_2$	$1.0\ 10^{-12}$	—12.000	—0.222

G.—ORDER OF EFFECT OF POSITIVE SUBSTITUENTS UPON A GIVEN POSITIVE RADICAL (AMINE GROUP AND RING NITROGEN) IN THE RING.

Name.	Formula.	K*a*.	Log K.	Factors.
I. Methyl:				
4 ε-Toluidine..........	$CH = CH.CH = CH.C(CH_3) = C.NH_2$	$3.3\ 10^{-10}$	—9.482	—0.016
5 *m*-Toluidine..........	$CH = CH.CH = C(CH_3).CH = C.NH_2$	$6.0\ 10^{-10}$	—9.222	+0.013
6 *p*-Toluidine..........	$CH = CH.C(NH_3) = CH.CH = C.NH_2$	$2.0\ 10^{-9}$	—8.699	+0.073
4 α-Picoline..........	$CH = CH.CH = CH.C(CH_3) = N$	$3.0\ 10^{-8}$	—7.523	0.147
5 β-Picoline..........	$CH = CH.CH = C(CH_3).CH = N$	$1.0\ 10^{-8}$	—8.000	0.079
6 γ-Picoline..........	$CH = CH.C(CH_3) = CH.CH = N$	$1.0\ 10^{-8}$	—8.000	0.079

Michael[1] finds the best support of his "scale of combined influence," (1)–2–3–5–6–4–7(9–10–11)–8, in lactone and anhydride formations. He attributes the cause of the same to the fact that halogen, hydroxyl or carboxyl attached to the γ- or δ-carbon exerts a greater space or direct action upon the α-carboxyl then when the same radicals are attached to the β, ε, ζ, η, etc., carbons. Therefore in his "scale of combined influence" positions 5 and 6 are of greater influence than 4, 7 (9–10–11) and 8.

In Table I it was shown that a logarithmic function of K could be used as a measure of this direct influence of radicals as well as of their indirect influence. If this is true, the ionization constants of the γ- or δ-halogen, hydroxyl or carboxyl substituted normal monobasic paraffin acids should be greater than that of the β-substituted isomeric acids. This must be true unless the excess of indirect influence of the β-position over that of the same substituent in the γ- and δ-position is sufficiently great to compensate for the greater direct influence of the latter position which Michael assumes. In Table II will be found the factors of combined influence (direct or indirect) by which the conclusions drawn by Michael may be tested. The combined influence of the direct and indirect actions of halogen, hydroxyl and carboxyl radicals for β-, γ-, and δ-positions (4, 5 and 6 in terms of nomenclature employed by Michael) are as follows:

Chlorine $\beta : \gamma : \delta = 0.187 : 0.063 : 0.023$
Bromine $\beta : \gamma : \delta = 0.210 : 0.047 : 0.017$
Iodine $\beta : \gamma : \delta = 0.167 : 0.035 : 0.008$
Hydroxyl $\beta : \gamma : \delta = 0.073 : 0.018 : \ldots.$
Carboxyl $\beta : \gamma : \delta = 0.160 : 0.111 : 0.083$

In no case, is the combined influence of the direct and indirect actions for these groups less in the β-position than in either the γ- or δ-. This is opposite to the conclusions drawn by Michael. Obviously, we must look further for the reason of lactone and anhydride formations in the paraffin series.

[Contribution from the Chemical Laboratory of the University of Illinois.]

APPLICATION OF POLARITY MEASURED IN TERMS OF A LOGARITHMIC FUNCTION OF THE IONIZATION CONSTANT. III. CORRELATION OF CHEMICAL STRUCTURE WITH IONIZATION.

By C. G. Derick.

Received May 17, 1911.

A. Determination of Structure from Ionization.

Many attempts have been made to use the ionization constant to determine the structure of organic compounds. Many interesting conclu-

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[1] *J. prakt. Chem.*, [2] 60, 335 (1899).