pared by the first method (*via* the imidic ester hydrochloride). The melting point in each case was 168–169.5° and was at variance with the reported value 130–132°.[11,26]

(c) **From the Amidine.**—In analogy to the synthesis of 2-(hydroxymethyl)-imidazoline,[15] 0.607 g. (0.0025 mole) of carvacryloxyacetamidine hydrochloride and 0.165 g. (0.00275 mole) of ethylenediamine were refluxed in ethanol solution for six hours, 0.2 cc. of 4.5 *N* methanolic hydrogen chloride was added and the solution left in the refrigerator overnight. After working up as in (a), there was obtained 0.15 g. (22%) of 2-(carvacryloxymethyl)-imidazoline hydrochloride, m. p. 175–176°, which gave no depression in melting point when mixed with a sample of this substance prepared according to method (a).

Summary

It has been shown that aryloxyacetonitriles can be obtained in good yield by condensation of phenols with chloroacetonitrile.

Treatment of the nitriles with ethanolic hydrogen chloride led to a series of ethyl aryloxyacetimidate hydrochlorides. The imidic esters were converted with ammonia to the amidines and with primary and secondary amines to the corresponding unsymmetrically N-alkylated amidines.

A number of 2-(aryloxymethyl)-imidazolines have been prepared by effecting ring closure of the imidic ester or the amidine hydrochlorides with ethylenediamine. The imidazolines could be obtained also by condensation of the phenol with 2-(chloromethyl)-imidazoline hydrochloride.

Preliminary results on the pharmacological properties of the amidines and imidazolines have been summarized, and have indicated that the usual dialkylaminoalkyl side chain of spasmolytics can be replaced by other radicals.

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(26) In a private communication from the author, we have been informed that the compound of m. p. 130–132° contained water and that the anhydrous material melted at 168–170° in agreement with our findings.

[CONTRIBUTION FROM THE EASTERN REGIONAL RESEARCH LABORATORY,[1] PHILADELPHIA 18, PA.]

Electronic Interpretation of the Reaction of Olefins with Organic Per-acids

BY DANIEL SWERN

Numerous investigators have shown that, under similar experimental conditions, the rate of reaction of olefins with organic per-acids is dependent on the structure of the unsaturated compounds. This is illustrated in Tables I and II, in which specific reaction rates are given for the reaction of various olefins with peracetic and perbenzoic acids. In the majority of published papers, however, kinetic studies have not been reported, and the oxidation reactions have merely been described as slow or rapid (sometimes violent), or not taking place.

No explanation for this difference in reaction rates has been proposed by earlier workers, although certain empirical rules have been established. Thus, the reaction is either slowed down considerably or does not take place when carboxyl, carboalkoxy, aldehydo or keto groups are either attached to or are in close proximity to the double bond,[2] such as is the case in cinnamic acid and its esters,[2,3] maleic, fumaric and crotonic acids and their esters, and α,β-pentenoic and hexenoic acids.[3,4] Aliphatic mono-olefins with terminal double bonds also react slowly,[5a,6] whereas substitution of the hydrogen atoms attached to the double bond by alkyl groups increases the reaction rate considerably,[5b,7] and phenyl groups usually have only a mildly accelerating effect.[5a,8] Also, in the oxidation of isoprene, the double bond to which the methyl group is attached is attacked first[9,10]; in the oxidation of 2-methyl-2,3-butadiene (a substituted allene), geraniol, linalyl acetate and citral, the double bond to which both methyl groups are attached is attacked first[2b,10]; and in the oxidation of methyl 2,4-hexadienoate the double bond farther from the carbomethoxy group is attacked first.[11]

On the basis of stereochemical considerations alone, it is surprising that olefins with terminal double bonds react much more slowly with per-acids than olefins which contain alkyl groups directly attached to the double bond. In fact, ethylene, which contains no groups which might prevent ready access of the per-acid to the double bond, would be expected to react rapidly with per-acids, yet just the reverse is true. The majority of the specific reaction rates shown in Tables I and II, as well as the empirical rules and preferential reactions discussed above, fit into a logical pattern if one applies to them the electronic interpretations

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(1) One of the laboratories of the Bureau of Agricultural and Industrial Chemistry, Agricultural Research Administration, United States Department of Agriculture. Article not copyrighted.

(2) (a) Bodendorf, *Arch. Pharm.*, **268**, 491 (1930); (b) Prileschajew, *J. Russ. Phys.-Chem. Soc.*, **44**, 613 (1912).

(3) Böeseken and de Graaff, *Rec. trav. chim.*, **41**, 199 (1922); Böeseken, *ibid.*, **45**, 838 (1926).

(4) Braun, THIS JOURNAL, **51**, 228 (1929); **52**, 3185, 3188 (1930).

(5) (a) Stuurman, *Proc. Acad. Sci. Amsterdam*, **38**, 450 (1935); (b) Thesis, Delft (1936).

(6) (a) Swern, Billen and Scanlan, THIS JOURNAL, **68**, 1504 (1946); (b) Findley, Swern and Scanlan, *ibid.*, **67**, 412 (1945).

(7) Böeseken and Stuurman, *Proc. Acad. Sci. Amsterdam*, **39**, 2 (1936); *Rec. trav. chim.*, **56**, 1034 (1937); Böeseken and Hanegraaff, *ibid.*, **61**, 69 (1942).

(8) (a) Böeseken and Blumberger, *Rec. trav. chim.*, **44**, 90 (1925); (b) Böeseken and Elsen, *ibid.*, **48**, 363 (1929).

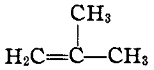
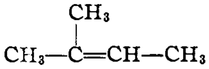
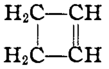
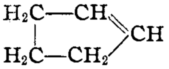
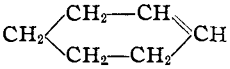
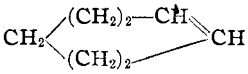
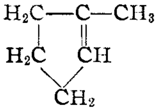
(9) Pummerer and Reindel, *Ber.*, **66**, 335 (1933).

(10) Böeseken, van Asperen, Cauchy, Maters and Ottenhoff, *Rec. trav. chim.*, **54**, 657 (1935).

(11) Heinanen, *Suomen Kennistilehti*, **11B**, 2 (1938); *C. A.*, **32**, 2903.

TABLE I

SPECIFIC REACTION RATES (k) FOR THE REACTION OF ALIPHATIC AND ALICYCLIC OLEFINS WITH PERACETIC ACID IN ACETIC ACID SOLUTION

Olefin	Structural formula	t, °C.	$k \times 10^3$[a]
Ethylene[5a]	$H_2C=CH_2$	25.8	0.19
Propylene[5a]	$H_2C=CH-CH_3$	25.8	4.2
1-Pentene[5a]	$H_2C=CH-(CH_2)_2-CH_3$	25.8	4.3
1-Octene[6a]	$H_2C=CH-(CH_2)_5-CH_3$	25	5.0
1-Decene[6a]	$H_2C=CH-(CH_2)_7-CH_3$	25	4.7
Methyl hendecenoate[6b]	$H_2C=CH-(CH_2)_8-COOCH_3$	25	4.1
Oleic acid[16]	$CH_3-(CH_2)_7-CH=CH-(CH_2)_7-COOH$ (*cis*)	18	36
		25.8	67 (estd.)
Elaidic acid[16]	$CH_3-(CH_2)_7-CH=CH-(CH_2)_7-COOH$ (*trans*)	18	33
		25.8	59 (estd.)
Ricinoleic acid[16]	$CH_3-(CH_2)_5-CH(OH)-CH_2-CH=CH-(CH_2)_7-COOH$ (*cis*)	18	26
		25.8	46 (estd.)
Ricinelaidic acid[16]	$CH_3-(CH_2)_5-CH(OH)-CH_2-CH=CH-(CH_2)_7-COOH$ (*trans*)	18	16
		25.8	28 (estd.)
2-Methyl-1-propene[5a]	 $H_2C=C(CH_3)-CH_3$	25.8	92
2-Butene[5a]	$CH_3-CH=CH-CH_3$	25.8	93
2-Pentene[5a]	$CH_3-CH=CH-CH_2-CH_3$	25.8	95
2-Hexene[5b]	$CH_3-CH=CH-(CH_2)_2-CH_3$	25.8	99
3-Hexene[5b]	$CH_3-CH_2-CH=CH-CH_2-CH_3$	25.8	129
3-Heptene[7]	$CH_3-CH_2-CH=CH-(CH_2)_2-CH_3$	25.8	110
4-Nonene[7]	$CH_3-(CH_2)_2-CH=CH-(CH_2)_3-CH_3$	25.8	105
2-Methyl-2-butene[5a]	 $CH_3-C(CH_3)=CH-CH_3$	25.8	1240
Cyclobutene[5b]		25.8	20.4
Cyclopentene[5a]		25.8	195
Cyclohexene[5a]		25.8	129
Cycloheptene[7]		25.8	175
1-Methylcyclopentene[5a]		25.8	2220

[a] Time in minutes, concentration in moles per liter.

of organic reactions developed by Lewis[12] and Lucas,[13] and, in recent years, by numerous English workers, notably Ingold, Lapworth and Robinson.[14]

Olefins are nucleophilic substances, and alterations in structure which increase the electron density of the ethylenic system, and thereby increase its nucleophilic properties, result in an increase in the rate of reaction of the olefin with electrophilic substances. This is a fundamental postulate of the English school. Thus, in the reaction of olefins with bromine, it has been observed that the successive substitution of electron-releasing groups, such as methyl, for the hydrogen atoms attached to the double bond causes an increase in reaction velocity.[14] This is explained on the assumption that the electron-releasing groups, by increasing the electron density of the ethylenic system, increase its nucleophilic properties and thereby cause a more rapid attack by the electrophilic (electron-poor) bromine ion $\left(:\overset{..}{\underset{..}{\mathrm{Br}}}\right)^{+}$.[14] Conversely, the introduction of electron-attracting groups, such as carboxyl, causes a reduction in reaction rate because of the effect of such groups in diminishing the nucleophilic properties of the

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[12] Lewis, "Valence and Structure of Atoms and Molecules," (The Chemical Catalog Co.), Reinhold Publ. Corp., New York, N. Y., 1923.

[13] Lucas, THIS JOURNAL, **46**, 2475 (1924); **47**, 1459 (1925); **48**, 1827 (1926); **51**, 2718 (1929).

[14] For an excellent discussion of the contributions of the English workers, and for previous literature, see Remick, "Electronic Interpretations of Organic Chemistry," John Wiley & Sons, Inc., N. Y., 1943, especially pp. 52, 55, 69, 117, 129, 187 and 416.

TABLE II

SPECIFIC REACTION RATES (k) FOR THE REACTION OF OLEFINS CONTAINING AROMATIC GROUPS WITH PERACETIC ACID IN ACETIC ACID SOLUTION AND WITH PERBENZOIC ACID IN CHLOROFORM OR CARBON TETRACHLORIDE SOLUTION

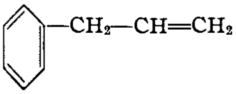
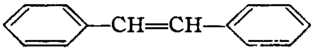
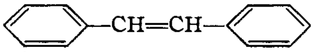
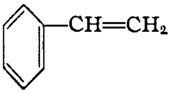
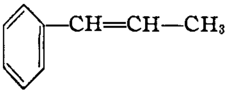
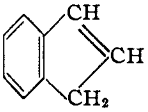
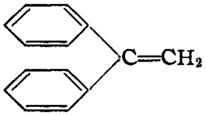
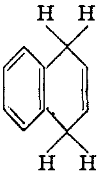
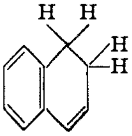
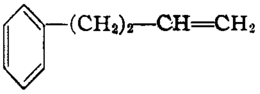
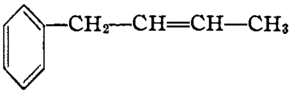
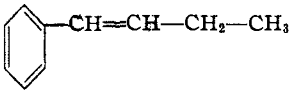
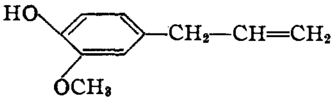
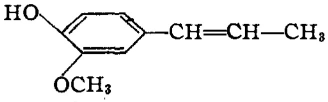
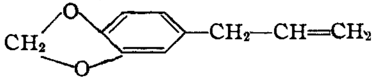
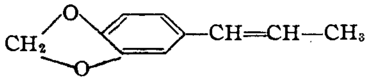
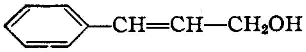
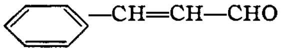
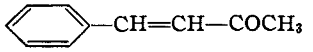
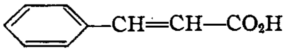
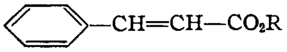
Olefin	Structural formula	Peracetic acid		Perbenzoic acid	
		t, °C.	$k \times 10^3$[a]	t, °C.	$k \times 10^3$[b]
Allylbenzene[5a,8a]		25.8	1.9	25–30	6–15
Stilbene[5a,8a]	 (*trans*)	25.8	6.7	25–30	18
Isostilbene[5a,8a]	 (*cis*)	25.8	11.1	15–16	9
Styrene[5a,8a]		25.8	11.2	25–30	35
1-Phenyl-1-propene[5a,8a]		25.8	46	25–30	110–190
Indene[5a]		25.8	47	...	.....
1,1-Diphenylethylene[5a]		25.8	48	...	.....
1,4-Dihydronaphthalene[5a]		25.8	37	...	.....
1,2-Dihydronaphthalene[5a]		25.8	230	...	.....
1-Phenyl-3-butene[8a]		..	...	15–16	8–9
1-Phenyl-2-butene[8a]		..	...	15–16	10
1-Phenyl-1-butene[8a]		..	...	15–16	80
Eugenol[17]		..	...	0	2.2
Isoeugenol[17]		..	...	0	127
Safrole[17]		..	...	0	1.3
Isosafrole[17]		..	...	0	148

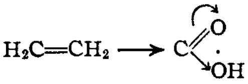
TABLE II (*Concluded*)

Olefin	Structural formula	Peracetic acid t, °C.	Peracetic acid $k \times 10^{3a}$	Perbenzoic acid t, °C.	Perbenzoic acid $k \times 10^{3a}$
Cinnamyl alcohol[2a]	 —CH=CH—CH$_2$OH	..	...	20	202.5
Cinnamaldehyde[2a]	 —CH=CH—CHO	..	...	20	4.7
1-Phenyl-2-acetylethylene[2a]	 —CH=CH—COCH$_3$	..	...	20	2.5
Cinnamic acid[2a]	 —CH=CH—CO$_2$H	..	...	20	0.13
Alkyl cinnamates[2a]	 —CH=CH—CO$_2$R	..	...	20	.13

[a] Time in minutes, concentration in moles per liter.

double bond. These electron shifts are illustrated below.

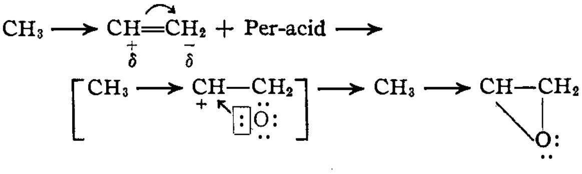
$CH_3 \longrightarrow CH{=}CH_2$ Increased nucleophilic properties



$H_2C{=}CH_2 \longrightarrow C\overset{O}{\underset{OH}{\lt}}$ Decreased nucleophilic properties

The concept that an increase or decrease in electron density of the ethylenic system results in an increase or decrease in the nucleophilic properties of the double bond may be employed to explain successfully the differences in reaction rates of the vast majority of olefins with per-acids.

Although the actual structure of organic per-acids, usually written as R—CO$_3$H, is not known, the peroxide oxygen must be loosely bound in the molecule, since it is given up so readily under a wide variety of reaction conditions. For the purpose of the subsequent discussion, it is sufficient to assume that in the per-acid molecule, the peroxide oxygen is electrophilic and is readily released from the per-acid in the presence of a nucleophilic group such as the double bond.[15] The reaction of an olefin, such as propylene, with a per-acid may be represented in the following way



The oxirane compound may or may not be the final product, depending upon its stability, the reaction conditions, the per-acid employed, etc.[6b] In the reaction of an olefin such as crotonic acid with a per-acid, the reaction proceeds slowly because the powerful electron-attracting properties of the carboxyl group reduce the nucleophilic properties of the double bond, and, therefore, the tendency for the peroxide oxygen to detach itself from the per-acid is diminished.

This proposed electronic mechanism may be applied, without exception, to explain the differences in the reaction rates of the aliphatic olefins, shown in Table I. If the specific reaction rate of ethylene with peracetic acid is taken as the standard for comparison, ($k \times 10^3 = 0.19$ at 25.8°, Table 1), it will be seen that the substitution of one electron-releasing group (methyl, *n*-propyl, *n*-hexyl, *n*-octyl) for one hydrogen atom increases the reaction rate about twenty-four times, from 0.19 to about 4.5. The substitution of two such groups (methyl-methyl, methyl-ethyl, methyl-*n*-propyl, ethyl-ethyl, ethyl-*n*-propyl, *n*-propyl-*n*-butyl) for any two of the hydrogen atoms of ethylene increases the specific reaction rate about five hundred and forty times, from 0.19 to 92 to 129, with the majority of specific reaction rates falling between 92 and 99. The substitution of three electron-releasing groups increases the specific reaction rate about six thousand five hundred times from 0.19 to about 1240, and the substitution of four electron-releasing groups yields a compound, tetramethylethylene, whose specific reaction rate with peracetic acid at 25.8° is too high to be measured.[7] This increase in reaction rate is a striking illustration of the influence of electron-releasing alkyl groups on nucleophilic activity.

The octadecenoic acids[16] shown in Table I (oleic, elaidic, ricinoleic and ricinelaidic acids) may be assumed to be ethylene with two of the hydrogen atoms replaced by alkyl groups, and, therefore, their specific reaction rates should be at least 92 at 25.8°. The specific reaction rates are considerably lower, however, and it must be assumed that, in oleic and elaidic acids, the field effect of the electron-attracting carboxyl group reduces the nucleophilic properties of the double bond, resulting in lower specific reaction rates. In ricinoleic and ricinelaidic acids, the electron-attracting properties of the neighboring hydroxyl group, in addition to the field effect of the carboxyl group, reduce the nucleophilic properties of the double bond still further, and this is reflected in even lower specific reaction rates. Steric factors may account for the difference in specific reaction rates of the *cis* and *trans* isomers. In methyl hendecenoate (undecylenate), however, the field effect is only a minor factor, since the specific reaction rate of this compound is only slightly lower than that of the other terminally unsaturated compounds.

The failure of maleic and fumaric acids and

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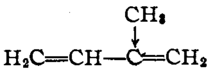
(15) The reactions of hydrogen peroxide and organic per-acids with sulfides to yield sulfoxides and sulfones and with amines to yield amine oxides also support the assumption that the peroxide oxygen in these oxidants is electrophilic.

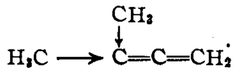
(16) Smit, *Rec. trav. chim.*, **49**, 686 (1930).

their esters[3] to react with perbenzoic and peracetic acids is not unexpected, since the nucleophilic properties of the double bond are considerably reduced by the combined action of two powerful electron-attracting groups. One such group in the molecule, such as in crotonic, isocrotonic, α,β-pentenoic and α,β-hexenoic acids, causes a marked reduction in the reaction rate, about one to three months' reaction time being required.[4] It is not surprising that Böeseken reported that crotonic acid and ethyl crotonate do not react with perbenzoic acid.[3] Although olefins which contain either a carbonyl or a hydroxymethyl group attached to the double bond suffer a decrease in reaction rate,[2a] the effect of these groups acting singly is not nearly so marked as that of the carboxyl group,[2a] which may be considered to consist of both these groups acting simultaneously.

The preferential oxidation of one double bond in the di-unsaturated compounds referred to earlier is in line with the theory. In the hydrocarbons isoprene and 2-methyl-2,3-butadiene, one of the double bonds has increased nucleophilic properties conferred on it because of the electron-releasing effect of the methyl group (or groups), and it is attacked at a more rapid rate.

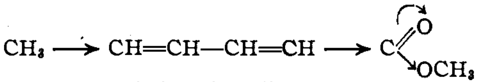

$H_2C{=}CH{-}\overset{CH_3}{\overset{\downarrow}{C}}{=}CH_2$

Isoprene

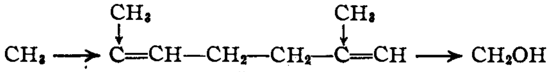

$H_3C \longrightarrow \overset{CH_3}{\overset{\downarrow}{C}}{=}C{=}CH_2$

2-Methyl-2,3-butadiene

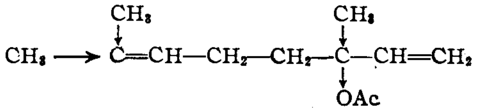
In methyl 2,4-hexadienoate, two effects are operative. The double bond in the 4,5-position, which is preferentially oxidized, has increased nucleophilic properties because of the methyl group attached to it, whereas the double bond in the 2-position has decreased nucleophilic properties because of the carbomethoxy group. In geraniol, linalyl acetate and citral, the double bond to which both methyl groups are attached is preferentially oxidized because of a large increase in its nucleophilic properties, whereas the nucleophilic properties of the other double bond are probably affected very little, if at all, because of the compensating effects of the methyl group and either the hydroxymethyl, acetoxy or aldehydo group.


$CH_3 \longrightarrow CH{=}CH{-}CH{=}CH \longrightarrow C\genfrac{}{}{0pt}{}{/\!\!/ O}{\searrow OCH_3}$

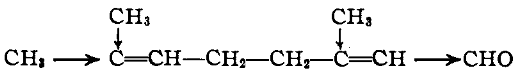
Methyl 2,4-hexadienoate


$CH_3 \longrightarrow \overset{CH_3}{\overset{\downarrow}{C}}{=}CH{-}CH_2{-}CH_2{-}\overset{CH_3}{\overset{\downarrow}{C}}{=}CH \longrightarrow CH_2OH$

Geraniol


$CH_3 \longrightarrow \overset{CH_3}{\overset{\downarrow}{C}}{=}CH{-}CH_2{-}CH_2{-}\underset{\underset{OAc}{\downarrow}}{\overset{CH_3}{\overset{\downarrow}{C}}}{-}CH{=}CH_2$

Linalyl acetate


$CH_3 \longrightarrow \overset{CH_3}{\overset{\downarrow}{C}}{=}CH{-}CH_2{-}CH_2{-}\overset{CH_3}{\overset{\downarrow}{C}}{=}CH \longrightarrow CHO$

Citral

The specific reaction rates of the alicyclic olefins (Table I) follow no definite pattern, with the exception of 1-methylcyclopentene, which reacts much more rapidly than the other alicyclic olefins. This is in line with the earlier discussion.

When olefins which contain aromatic groups are examined (Table II) the picture is not so clear-cut, especially when more than one phenyl group is present in the molecule. In general, the phenyl group acts as an electron-release group, but not infrequently the reverse is true.[14] Thus, it is evident that the phenyl group acts as an electron-release group in styrene and 1-phenyl-1-propene, since their specific reaction rates with peracetic acid are greater than that of ethylene and propylene, respectively. In allylbenzene, however, the phenyl group appears to act as a mild electron-attracting group, since this compound has a lower specific reaction rate than propylene. The electron-attracting effect of phenyl is less than the electron-releasing effect of $-CH_2-$, since allylbenzene has a higher specific reaction rate than ethylene. Also, one is tempted to conclude that the electron-releasing effect of the phenyl group is greater than that of the alkyl group because the specific reaction rate of styrene with peracetic acid is greater than that of propylene. Comparison of the specific reaction rate of 1-phenyl-1-propene (1-phenyl-2-methylethylene) with that of 2-butene (1,2-dimethylethylene), however, leads to the opposite conclusion.

The combined electron-release effects of two phenyl groups are always less than that of two methyl groups but greater than that of one methyl group. This is shown by comparing the specific reaction rate of 1,1-diphenylethylene with that of 2-methyl-1-propene (1,1-dimethylene) and propylene, and that of the stilbenes (1,2-diphenylethylenes) with that of 2-butene (1,2-dimethylethylene) and propylene. In olefins which contain two phenyl groups, the influence of one phenyl group on the electron-releasing or electron-attracting properties of the other phenyl group is not known. Perhaps the introduction of additional phenyl groups in the olefin molecule increases the amount of resonance by increasing the number of contributing forms, thereby increasing the stability of the entire molecule.

The specific reaction rate of indene with peracetic acid is the same as that of 1-phenyl-1-propene. Since these two compounds are somewhat similar structurally (each contains a completely conjugated double-bond system, and an alkyl and an aryl substituent attached to the ethylenic system), this is not unexpected. 1,2-Dihydronaphthalene, however, which differs from indene only in that it consists of two six-membered rings instead of one six-membered and one five-membered ring, has a specific reaction rate about five times as great as that of indene, and about two and a half times as great as that of most aliphatic dialkylethylenes (Table I). No explanation is offered for this marked increase in reaction rate. In 1,4-dihydronaphthalene, the phenyl group must be exerting an electron-attracting effect, since this compound has a much lower specific reaction rate with peracetic acid than 2-butene, its aliphatic structural analog. The phenyl group appears to act as an electron-attracting group when it is separated from the double bond by a methylene group (see also allylbenzene), and electron-releasing when it is directly attached to the ethylenic system.

With the exception of crotonaldehyde[2a] ($k \times 10^3 = 0.76$ at 20°), no data on specific reaction rates could be found for the reaction of perbenzoic acid with aliphatic olefins, for comparison with olefins containing aromatic groups. Since it was pointed out earlier, however, that the phenyl group in allylbenzene exerts an electron-attracting effect, it would be expected that the specific reaction rate of this compound with perbenzoic acid would be less than that of styrene, in which the phenyl group exerts an electron-releasing effect. In 1-phenyl-1-propene, the phenyl group is again exerting an electron-releasing effect, as manifested by the marked increase in specific reaction rate as compared with that of allylbenzene. Also, the marked increase in specific reaction rate of 1-phenyl-1-propene as compared with that of styrene, is due to the presence of two electron-releasing groups in the molecule. In the case of the three isomeric phenylbutenes, it was pointed out by Bőeseken and Blumberger[8a] that the speed of oxidation increases as the double bond approaches the benzene ring, although no explanation was offered for this phenomenon. It would be expected that 1-phenyl-1-butene would have a greater specific reaction rate than its isomers, since this compound contains two electron-releasing groups, namely, a phenyl group directly attached to the ethylenic system and an alkyl group. In 1-phenyl-2-butene, the phenyl group is separated from the double bond by a methylene group and, as previously pointed out, a phenyl group in such a position exerts an electron-attracting effect which operates in opposition to the electron-releasing effects of the methylene and methyl groups (net effect = 1 + electron-releasing groups). In 1-phenyl-3-butene the phenyl group is probably too far from the double bond to exert an appreciable effect, and the methyl group is the only group affecting the nucleophilic properties of the double bond (net effect = 1 electron-releasing group). On the basis of this reasoning, 1-phenyl-2-butene should and does have a slightly higher specific reaction rate than 1-phenyl-3-butene.

The slow rates of reaction of 1-phenyl-2-acetylethylene,[2a] safrole,[8b,17] and eugenol,[2a,17] and the more rapid rates of reaction of anethole,[8b] 1,3-diphenylpropene,[8b] isosafrole,[8b,17] and isoeugenol[2a,17] with per-acids, follow from the earlier discussion in this paper. Although it has been reported that cinnamic acid and methyl cinnamate do not react with perbenzoic acid,[2b,3] they do react,[2a] but at such low rates that for all practical purposes no reaction occurs. In these compounds the phenyl group should exert an electron-releasing effect which counteracts, in part, the strong electron-attracting effect of the carboxyl or carbomethoxy group, resulting in a situation analogous to that of crotonic acid and related compounds, in which an alkyl group is present instead of a phenyl group.[4] Cinnamyl alcohol has been reported to react with perbenzoic acid at a normal rate,[2a] and probably does so because the electron-releasing phenyl group is able to compensate for the electron-attracting effect of the hydroxyl group. It should be pointed out, however, that the rate of reaction of olefins with perbenzoic acid is often markedly affected by the age and method of preparation of the per-acid,[8b] as well as by the solvent employed.[17] For these reasons, conclusions drawn from perbenzoic acid oxidations must often be accepted with reservation.

The reaction of olefins with other organic per-acids, such as performic,[6] percamphoric,[18] perfuroic[19] and monoperphthalic acids,[20] has not been studied extensively, and specific reaction rates are not available. Although percamphoric, perfuroic and monoperphthalic acids would not be expected to differ fundamentally from perbenzoic acid in their reactivity with variously substituted olefins, and the limited amount of experimental evidence available is consistent with this conclusion, performic acid gives results which differ substantially from those obtained with peracetic acid.[6] Thus, performic acid appears to react rapidly with oleic acid and related compounds[21] as well as with compounds which contain a terminal double bond,[6] provided that the reactions are carried out in a homogeneous solution.

By the application of the principles discussed here, it is possible to predict with a considerable degree of accuracy, especially in the aliphatic series, the specific reaction rate of the peracetic acid oxidation of an olefin of known structure, and suitable reaction conditions readily can be devised. In addition, valuable information regarding the structure of an olefin may be obtained by determining its specific reaction rate with peracetic acid. Also, a determination of the specific reaction rate of a mixture of olefins, such as those obtained from dehydration, dehalogenation, dehydrohalogenation and olefin polymerization reactions,[22] may yield much information regarding the positions of the double bonds.

Acknowledgment.—The author wishes to express his appreciation to Thomas W. Findley,

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(17) Meerwein, *J. prakt. Chem.*, **113**, 9 (1926).

(18) Milas and Cliff, THIS JOURNAL, **55**, 352 (1933).

(19) Milas and McAlevy, *ibid.*, **56**, 1219 (1934).

(20) Böhme, *Ber.*, **70**, 379 (1937).

(21) Swern, Billen, Findley and Scanlan, THIS JOURNAL, **67**, 1786 (1945).

(22) *Chem. Eng. News*, **24**, 772 (1946); Saffer and Johnson, paper delivered at the meeting of the American Chemical Society, Chicago, Illinois, September, 1946.

John T. Scanlan and Waldo C. Ault, for their constructive criticism during the preparation of this article.

Summary

An electronic interpretation of the reaction of olefins with organic per-acids is proposed. This is based on the assumption that the peroxide oxygen in per-acids is electrophilic, and is readily released in the presence of a nucleophilic group, such as the double bond. When electron-releasing groups are attached to, or are in close proximity to, the double bond, the reaction rate is increased because of the increased electron density of the ethylenic system, which results in an increase in the nucleophilic properties of the double bond; when electron-attracting groups are present, the reaction rate is decreased because of a decrease in the nucleophilic properties of the double bond.

The preferential oxidation of one of the double bonds in certain di-unsaturated compounds, such as isoprene, 2-methyl-2,3-butadiene, geraniol, linalyl acetate and citral is explained on the basis of an increase in the nucleophilic properties of one of the double bonds as a result of electron-releasing substituents. In methyl 2,4-hexadienoate, the 4,5-double bond, which is preferentially oxidized, has increased nucleophilic properties because of the electron-releasing methyl group attached to it, whereas the 2,3-double bond has decreased nucleophilic properties because of the electron-attracting carbomethoxy group.

Although only a small amount of experimental work is available on the use of performic acid as an oxidizing agent, it appears to react rapidly with olefins which contain one as well as two electron-releasing groups attached to the ethylenic system, whereas a slow reaction would be expected with those olefins which contain only one such group.

PHILADELPHIA 18, PA. RECEIVED FEBRUARY 3, 1947

[CONTRIBUTION FROM THE DEPARTMENT OF CHEMISTRY, UNIVERSITY OF COLORADO]

The Preparation of Some Monosubstituted Derivatives of Pyrrole by the Mannich Reaction

BY WERNER HERZ, KARL DITTMER AND STANLEY J. CRISTOL

As a part of a program of synthesis and biological investigation of a number of compounds related to important biological materials, it was decided to study β-(2-pyrrole)-alanine. Since gramine, 3-dimethylaminomethylindole, and its quaternary salts have been used for the synthesis of *dl*-tryptophan,[1] it was hoped that dimethylaminomethylpyrrole would react in the same manner to give β-(2-pyrrole)-alanine. With this in mind we investigated the application of the Mannich reaction to the synthesis of various derivatives of aminomethylpyrrole. These derivatives were obtained by treating an excess of pyrrole with a solution of the various amine hydrochlorides in formalin under conditions analogous to those applied in the synthesis of gramine. Applying these conditions we found that 2-(dimethylaminomethyl)-pyrrole could be prepared in good yield by treating pyrrole with dimethylamine hydrochloride and formalin. The hydrochlorides of other secondary amines, such as diethylamine, piperidine and morpholine, were employed in the same manner.

Under the conditions used in these experiments the hydrochlorides of the primary amines, methylamine and ethylamine, condensed readily with pyrrole and formaldehyde to give the corresponding 2-(alkylmethyl)-pyrroles, although in much lower yield.

During the preparation of this manuscript a paper by Bachman and Heisey[2] appeared which describes the results obtained by the use of the Mannich reaction with nitrogenous five-atom ring systems. These workers did not employ the procedure described in this paper, but added pyrrole to a solution of the amine in formalin, so that an excess of the formaldehyde–amine complex was present. Under these conditions they were unable to obtain products from primary amines, although the yields reported by them for the Mannich reaction of pyrrole with morpholine or piperidine are higher than the yields obtained by us.

Bachman and Heisey also stated that with dimethyl- or diethylamine colorless high-boiling liquids were obtained to which they assigned the structure of 2,5-bis-(dialkylaminomethyl)-pyrroles, although the Ehrlich test[3] was positive. The compounds isolated by us from the same reactions are low-melting solids, identified as the monosubstituted 2-(dialkylaminomethyl)-pyrroles.[4]

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[1] Snyder and Smith, THIS JOURNAL, **66**, 350 (1944); Albertson, Archer and Suter, *ibid.*, **66**, 500 (1944); *ibid.*, **67**, 36 (1945); Howe, Zambito, Snyder and Tishler, *ibid.*, **67**, 38 (1945).

[2] Bachman and Heisey, *ibid.*, **68**, 2496 (1946).

[3] Fischer-Orth, "Die Chemie des Pyrrols," Vol. I, Akademische Verlagsgesellschaft, Leipzig, 1934, p. 66.

[4] When informed of our results, Dr. Bachman in a private communication reported the following: The structures of 2,5-bis-(dimethylaminomethyl)-pyrrole and 2,5-bis-(diethylaminomethyl)-pyrrole were assigned solely on the basis of analytical data. These data are however about equally satisfactory for the corresponding monosubstituted pyrroles, whose calculated N-values lie within 0.7 of those for the disubstituted pyrroles. A re-examination of the two compounds by titration with standard acid has shown them to be the monosubstituted pyrroles and identical with the compounds described in this paper.