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Studies on the Proton Magnetic Resonance Spectra in Aliphatic Systems. IV.[1] Interpretation of Substituent Effect on the Chemical Shift and Coupling Constant for Substituted Ethylene Derivatives

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Introduction

Recently, numerous nuclear magnetic resonance parameters of substituted ethylene derivatives have been presented in the recent literature,[3] and Yonezawa, *et al.*[4] have investigated on the origin of the coupling constant from the quantum chemical viewpoint, but the results of which showed unfavorable agreement with those of the observed ones.

In our previous work,[5] the ^1H chemical shifts and coupling constants for substituted aromatics and heteroaromatics have been arranged with respect to the substituent effect by the agencies of substituent constants σ_i and σ_π,[6] and the compatible conclusions have been secured among above parameters and quantum chemical treatment.

In this work, the nuclear magnetic resonance parameters of substituted ethylene derivatives have been examined with respect to the above substituent constants, as the pretreatment of the quantum chemical approach.

TABLE I. ^1H Chemical Shifts of Monosubstituted Ethylene Derivatives (ppm refered to Me_4Si)[7]

Substituent R	δA	$\Delta\delta$A	δB	$\Delta\delta$B	δC	$\Delta\delta$C
Me[10i]	4.88	+0.41	4.96	+0.33	5.73	−0.44
C_6H_5[a]	5.21	+0.08	5.71	−0.42	6.69	−1.40
OMe[a]	3.90	+1.39	4.04	+1.25	6.43	−1.14
CO_2Et 10[g]	5.82	−0.53	6.38	−1.09	6.20	−0.91
F[a]	4.03	+1.26	4.37	+0.92	6.17	−0.88
Cl[a]	5.44	−0.15	5.52	−0.23	6.30	−1.01
Br[a]	6.03	−0.74	5.88	−0.59	6.49	−1.20
CN[a]	6.05	−0.76	5.91	−0.62	5.53	−0.24
H[b]	5.29		5.29		5.29	

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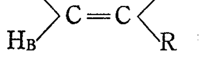
1) Part III: Y. Sasaki and M. Suzuki, *Chem. Pharm. Bull.* (Tokyo), **18**, 32 (1970).
2) Location: *Toneyama 6–5, Toyonaka, Osaka.*
3) "Advances in Magnetic Resonance," Vol. 1, ed. by J.S. Waugh Academic Press. New York and London, 1965, p. 195.
4) T. Yonezawa, I. Morishima, M. Fujii and H. Kato, *Bull. Chem. Soc. Japan*, **40**, 487 (1967); *ibid.*, **42**, 1248 (1969).
5) Y. Sasaki and M. Suzuki, *Chem. Pharm. Bull.* (Tokyo), **17**, 1090, 1104 (1969).
6) Y. Yukawa and Y. Tsuno, *J. Chem. Soc. Japan.* (*Pure Chemistry Section*), **86**, 873 (1965).
7) *a*) C.N. Banwell and N. Sheppard, *Mol. Phys.*, **3**, 351 (1960); *b*) G.S. Reddy and J.H. Goldstein, *J. Am. Chem. Soc.*, **83**, 2045 (1961).



Results and Discussion

^{1}H Chemical Shifts of Monosubstituted Ethylene Derivatives

The ^{1}H chemical shifts data$^{7)}$ of this series summarised in Table I have been shown to be linear with substituent constant σ_π (*cf.* Fig. 1).

This fact suggests that the π-electronic effect is the dominant factor in determining the magnitude of ^{1}H chemical shift, and, moreover, the simple sum of an excess shift $\Delta\delta$ from ethylene reference (*cf.* Table I) have been proved reliable in the estimation of the ^{1}H chemical shift for disubstituted ethylene derivatives.$^{8)}$ (*cf.* Table II and III).

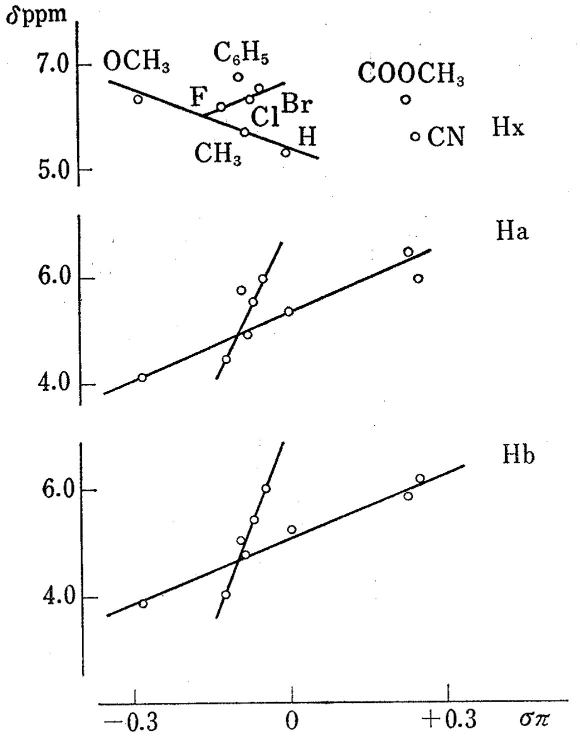


Fig. 1

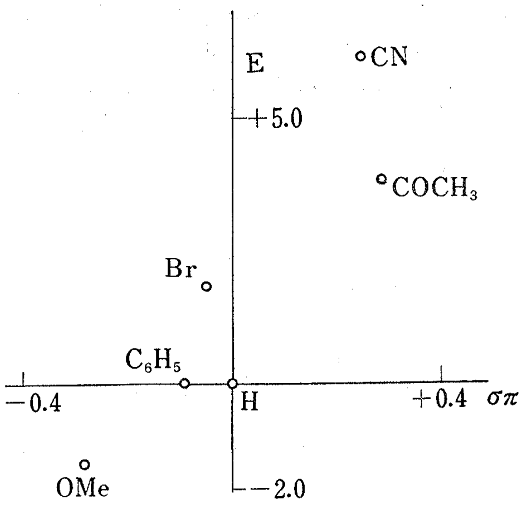


Fig. 2

Table II. Observed and Calculated ^{1}H Chemical Shifts of 2-Substituted Propene-1 (ppm)$^{8)}$

Substituent	$\delta A_{obs.}$	$\delta A_{calcd.}$	$\delta B_{obs.}$	$\delta B_{calcd.}$
Alkyl	4.80	4.33	4.63	4.33
C_6H_5	5.02	4.77	5.28	5.39
CO_2Me	5.49	5.38	6.04	5.86
CO_2H	5.72	5.38	6.30	5.86
Cl	5.08	5.00	5.08	5.00
Br	5.53	5.59	5.33	5.36
CN	5.76	5.61	5.72	5.39

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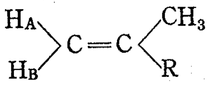
8) L.M. Jackman and R.H. Wiley, *J. Chem. Soc.*, **1960**, 2881.



$$\begin{matrix} H_A \\ H_B \end{matrix} \!> C{=}C <\! \begin{matrix} CH_3 \\ R \end{matrix}$$

Table III. The Differential Chemical Shifts ($\delta\Delta=\delta_{cis}-\delta_{trans}$ ppm) for *cis*/*trans* Pairs of 1,2-Disubstituted Olefines CHR=CHR[8)]

Substituent	Me	Cl	Br	CO_2Me
$\delta\Delta_{obs.}$	−0.03	−0.08	−0.38	+0.53
$\delta_{calcd.}$				
cis	4.30	6.45	7.23	6.73
trans	4.38	6.53	7.07	7.29
$\delta\Delta_{calcd.}$	−0.08	−0.08	−0.15	+0.46

Electric Field of Monosubstituted Ethylene Derivatives

In our previous study,[9)] π-electronic contribution of ^1H chemical shift for Me-R series have been shown to be comparable with the magnitude of electric field E, afforded by the next equation (1),

$$E=\mu/\alpha \qquad (1)$$

where μ=dipole moment
α=polarizability

And, in this work, α is also estimated from the Clausius–Mosotti's equation (2), namely

$$n^2-1/n^2+2\cdot M/d=4/3\pi N\cdot\alpha \qquad (2)$$

where n=refractive index
M=molecular weight
d=density
N=Avogadro's number 6.023×10^{23}

The E values of the monosubstituted ethylene derivatives thus obtained are proved to be comparable with σ_π (*cf.* Fig 2).

These results cited above suggest that an electric field given by the π-electronic effect from the substituent group in an ethylene framework is in fact the dominat factor in determining the magnitude of the ^1H chemical shift (*cf.* Table IV).

Coupling Constants for Monosubstituted Ethylene Derivatives

The numerous reliable data[10a–l)] on the coupling constants for monosubstituted ethylene derivatives have been arranged with respect to σ_i–0.5 σ_π, and divided into two parts-namely, 67% π-electronic and 33% σ-electronic contributions (*cf.* Fig. 3, Table V).

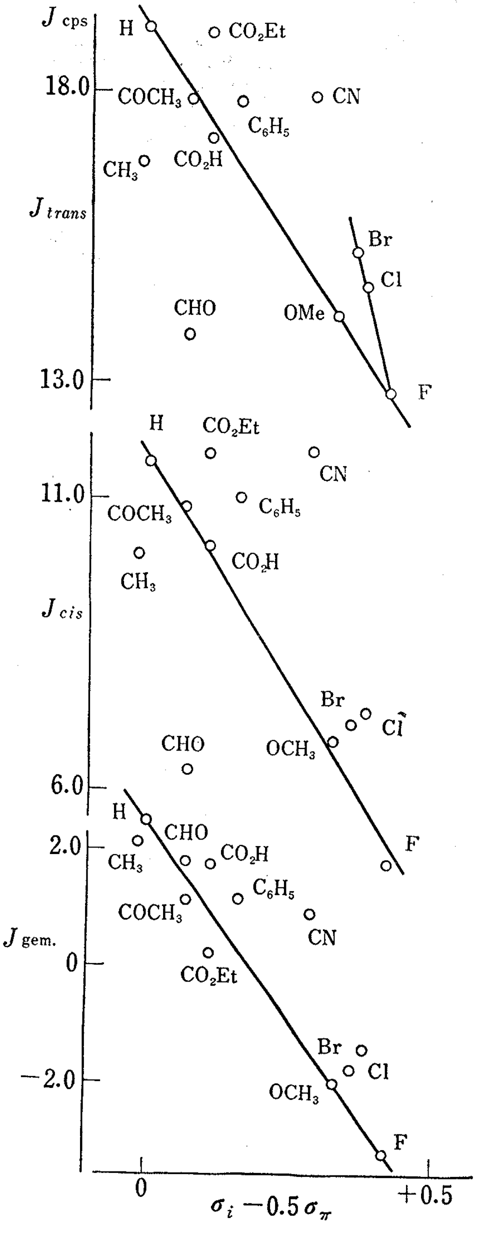


Fig. 3

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9) Y. Sasaki and M. Suzuki, *Chem. Pharm. Bull.* (Tokyo), 17, 2049 (1969).

Table IV. Polarizability $\alpha \times 10^{-23}$ cm³ and $E \times 10^{5}$ esu/cm² of Monosubstituted Ethylene Derivatives

Substituent	α	μDebye	E
OEt	0.87	1.27	1.46
C_6H_5	1.44	0	0
COMe	0.79	3.00	3.8
Br	0.74	1.42	1.92
CN	0.64	3.89	6.08

Table V. Coupling Constants (cps) of Monosubstituted Ethylene Derivatives[10]

Substituent	$J_{gem.}$	i	π	J_{cis}	i	π	J_{trans}	i	π
H[a,b,c]	+2.5	1.7	0.8	11.6	7.8	3.8	19.1	12.8	6.3
COMe[d]	1.1	0.7	0.4	10.8	7.2	3.6	17.8	11.9	5.9
CHO[e]	1.7	1.2	0.7	6.3	4.2	2.1	13.8	9.2	4.6
CN[f]	0.9	0.6	0.3	11.8	7.9	3.9	17.9	12.0	5.9
CO_2Et[g]	0.24	0.2	0.1	11.7	7.8	3.9	19.0	12.7	6.3
CO_2H[h]	1.7	1.1	0.6	10.2	6.8	3.4	17.2	11.5	5.7
C_6H_5[i]	1.1	0.7	0.4	11.0	7.4	3.6	17.8	11.9	5.9
F[j]	−3.2	−2.1	−1.1	4.7	3.1	1.6	12.8	8.6	4.2
Cl[j]	−1.4	−0.9	−0.5	7.3	4.9	2.4	14.6	9.8	4.8
Br[k]	−1.8	−1.2	−0.6	7.1	4.8	2.3	15.2	10.2	5.0
OMe[l]	−2.2	−1.3	−0.9	7.0	4.7	2.3	14.1	9.4	4.7
Me[i]	+2.1	1.4	0.7	10.0	6.7	3.3	16.8	11.3	5.5

Table VI. J_{cis} Values of Disubstituted Ethylene Derivatives (cps)[11]

R_1	R_2	$J_{calcd.}$	$J_{obs.}$
Me	CO_2Me	8.6	11.4[a]
C_6H_5	COMe	10.4	11.5[b]
F	F	2.2	2.0[c]
F	Br	3.9	3.5[d]
F	Me	5.8	5.2[e]
Cl	Cl	5.8	5.2[f]
CO_2Et	CO_2Et	11.8	11.9[f]
C_6H_5	CHO	7.6	7.7[g]
Me	CHO	6.9	7.9[h]
$C_{10}H_{21}$	OMe	7.4	6.4[i]

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10) *a*) R.M. Lynden-Bell and N. Sheppard, *Proc. Roy. Soc.* (London), **A269**, 385 (1962);*b*) G.S. Reddy and J.H. Goldstein, *J. Mol. Spectry.*, **8**, 475 (1962);*c*) D.M. Graham and C.E. Halloway, *Can. J. Chem.*, **41**, 2114 (1963);*d*) S. Castellano and J.S. Waugh, *J. Chem. Phys.*, **37**, 1951 (1962);*e*) T. Schaefer, *J. Chem. Phys.*, **36**, 2235 (1962);*f*) R.T. Hobgood Jr., R.E. Mayo and J.H. Goldstein, *J. Chem. Phys.*, **39**, 2501 (1963);*g*) Y. Arata, H. Shimizu and S. Fujiwara, *J. Chem. Phys.*, **36**, 1951 (1962);*h*) S. Castellano and J.S. Waugh, *J. Chem. Phys.*, **34**, 295 (1961);*i*) A.A. Bothner-By and C. Naar-Colin, *J. Am. Chem. Soc.*, **83**, 231 (1961);*j*) C.N. Banwell and N. Sheppard, *Discus. Faraday Soc.*, **34**, 115 (1962);*k*) T. Schaefer and W.G. Schneider, *Can. J. Chem.*, **38**, 2066 (1960);*l*) R.T. Hobgood Jr., G.S. Reddy and J.H. Goldstein, *J. Phys. Chem.*, **67**, 110 (1963).

11) *a*) R.R. Fraser, *Can. J. Chem.*, **38**, 549 (1960); R.R. Fraser and D.E. McGreer, *Can. J. Chem.*, **39**, 505 (1961);*b*) H.S. Gutowsky, M. Karplus and D.M. Grant, *J. Chem. Phys.*, **31**, 1278 (1959);*c*) T.D. Coyle, S.L. Stafford and F.G. Astone, *J. Chem. Soc.*, **1961**, 743; G.W. Flynn, M. Matsushima and J.D. Baldeschwieler, *J. Chem. Phys.*, **38**, 2295 (1963);*d*) A. Demiel, *J. Org. Chem.*, **27**, 3500 (1962);*e*) R.A. Beaudet and J.D. Baldeschwieler, *J. Mol. Spectry.*, **9**, 30 (1962);*f*) N. Muller, *J. Chem. Phys.*, **37**, 2729 (1962);*g*) E.O. Bishop and R.E. Richards, *Mol. Phys.*, **3**, 114 (1961);*h*) S. Gronowitz and R.A. Hoffman, *Arkiv Kemi.*, **16**, 471 (1960);*i*) H.R. Warner and W.E.M. Lands, *J. Am. Chem. Soc.*, **85**, 60 (1963);*j*) v.J. Kowalewski and D.G. deKowalewski, *J. Chem. Phys.*, **33**, 1794 (1960);*k*) R.W. Fessenden and J.S. Waugh, *J. Chem. Phys.*, **31**, 996 (1959);*l*) E.B. Whipple, J.H. Goldstein and L. Mandell, *J. Am. Chem. Soc.*, **82**, 3010 (1960).

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Table VII. J_{trans} Values of Disubstituted Ethylene Derivatives (cps)[11]

R_1	R_2	$J_{calcd.}$	$J_{obs.}$
C_6H_5	CHO	16.7	15.6[g]
Me	CO_2Et	14.9	15.4[j]
Me	CHO	15.7	15.5[h]
F	F	6.5	9.5[c]
Br	F	8.9	11.0[d]
Me	F	10.5	11.1[e]
Cl	Cl	10.1	12.2[f]
CO_2Et	CO_2Et	15.3	15.5[f]
C_6H_5	Me	15.5	15.6[k]
Me	CO_2H	14.9	14.9[j]
$C_{10}H_{21}$	OMe	11.8	12.5[i]

Table VIII. $J_{gem.}$ Values of Disubstituted Ethylene Derivatives (cps)[11]

R_1	R_2	$J_{calcd.}$	$J_{obs.}$
Me	Br	2.2	2.0[l]
Me	Cl	1.8	1.3[l]
Me	CHO	2.2	1.5[l]
Me	CO_2Me	1.3	1.8[8]
Me	COMe	1.4	0.7[8]

Coupling Constants of Disubstituted Ethylene Derivatives

In this section, the observed coupling constants[11a–m] of disubstituted ethylene derivatives are compared with those of calculated values estimated from the data summarised in Table V, and it is concluded that J_{trans} and $J_{gem.}$ are expressed in the form of $J_{C_2H_4}+\sum\Delta J_i+\sum\Delta J_\pi$, whereas J_{cis} is $J_{C_2H_4}+\sum\Delta J_i$ (*cf.* Table VI, VII, VIII).

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An Alternative Synthesis of (±)-Dehydrogriseofulvin by Enzymic Phenolic Oxidation by Homogenized Potato Peelings[1] (Studies on the Syntheses of Heterocyclic Compounds. CCCLIII[2])

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(Received March 10, 1970)

(+)-Griseofulvin (IV) was first isolated from the mycellium of *penicillium griseofulvum*.[4] It was subsequently shown to be a metabolic product of many species of *penicillia*.[5] Barton

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[1] Preliminary Communication was reported in *Chem. Comm.*, **1969**, 131, by T. Kametani, S. Hibino, and S. Takano.

[2] Part CCCLII: T. Kametani, F. Satoh, H. Agui, K. Ueki, K. Kigasawa, M. Hiiragi, H. Ishimaru, and S. Horie, *Chem. Pharm. Bull.* (Tokyo), **18**, 1161 (1970).

[3] Location: *Aobayama, Sendai.*

[4] A.B. Oxford, H. Raestrick, and P. Simonart, *Biochem. J.*, 33, 240 (1939).

[5] M.W. Miller, "The Pfizer Handbook of Microbial Metabolites," McGraw-Hill Book Co., Inc., New York, 1961, p. 207.