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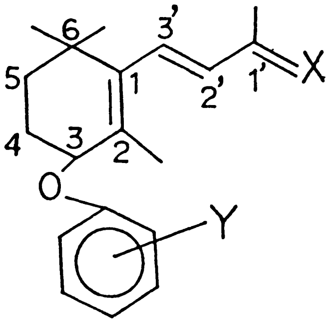
SYNTHESES AND SPECTRAL CHANGES OF β-IONONE DERIVATIVES BEARING A CARBOXYL GROUP ISOLATED FROM π-CONJUGATED SYSTEM

Masato NANASAWA* and Hiroyoshi KAMOGAWA
Department of Apllied Chemistry, Faculty of Engineering, Yamanashi University, Takeda, Kofu 400

β-Ionone derivatives bearing an o- or p-carboxyphenoxy substituent at the 3-position were synthesized. The iminium salt having an o-carboxyl group absorbs at a shorter wavelength, while under alkaline conditions λ_{max} shifts to a longer wavelength presumably on account of the electrostatic attraction between the carboxylate anion and the positive charge.

The absorption maxima of the bacteriorhodopsin or visual pigments are observed over a wide range of 500-570 nm, although the protonated retinylidene butylamine in methanol absorbs at 440 nm. On the basis of molecular orbital calculations$^{1)}$ and synthetic model compounds,$^{2)}$ it is proposed that the bathochromic shift is caused by the electrostatic effect of polar or charged groups in the vicinity of the chromophore. Recently the structure of the bacteriorhodopsin was established;$^{3)}$ Asp$_{96}$ is a likely candidate for a point charge close to the β-ionone ring of retinal bound to Ly$_{41}$.

In this communication, we present the first model compounds bearing a charged



X=O;
Y= H(1), o-COOMe(2), o-COOH(3), o-COO$^-$ HN$^+$ O(4),
p-COOMe(5), p-COOH(6), p-COO$^-$ HN$^+$ O(7).
X=$^+$N ;
ClO$_4^-$
Y=H(8), o-COOMe(9), o-COOH(10), p-COOMe(11),
p-COOH(12).

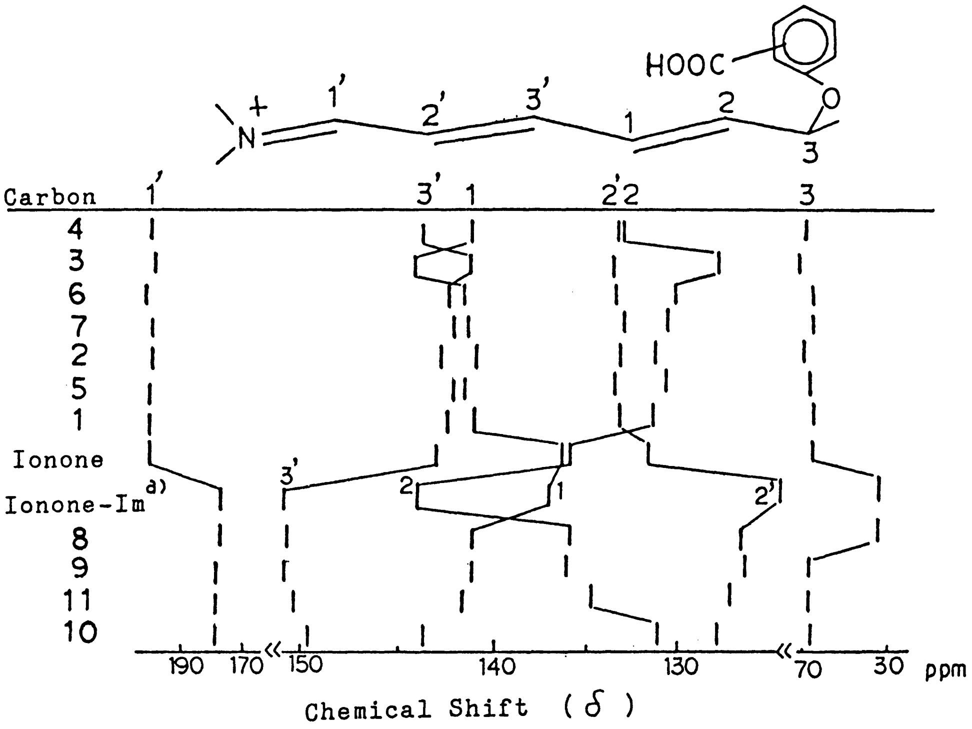


Fig. 1. Schematic Presentation of ^{13}C-NMR Spectra of β-Ionone Derivatives (In $CDCl_3$ approximately 20 wt%). a) β-Ionone iminium salt.

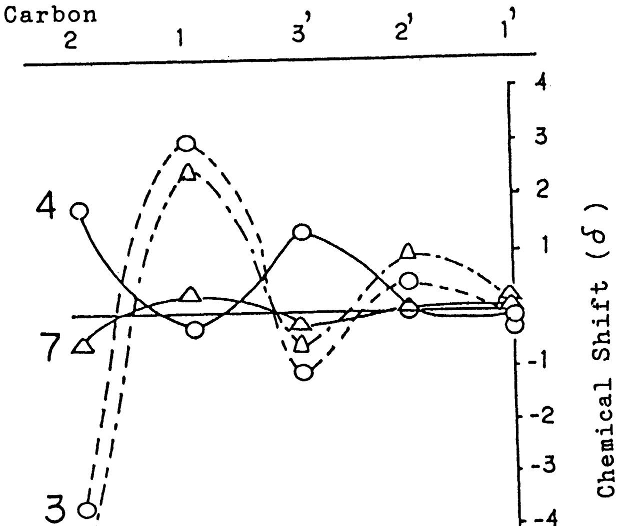


Fig. 2. The Magnitude of Carbon Chemical Shift against 3-Phenoxy-β-ionone and Its Iminium Salt.

Table 1.

Absorption Maxima of β-Ionone Derivatives

	λ_{max} a)		
		Et_3N b)	CF_3COOH b)
Ionone-Im	351 nm	351 nm	350 nm
8	332	332	332.5
9	332.5	332.5	332
10	320	341.5	321
11	330	329.5	330.5
12	330.5	330.5	330.5

a) In $CHCl_3$ (10^{-4} mol/l). b) After the addition of five equivalents to a solution of iminium salt in $CHCl_3$.

group attached to the β-ionone ring and discuss their electrostatic interaction by UV and ^{13}C-NMR spectra. β-Ionone derivatives having a phenoxyl group at the 3-position were synthesized by the reaction with 3-bromo-β-ionone and sodium methoxycarbonylphenoxide.[4)] The resulting reaction products exhibited 3-H signals at 4.50 (axial) and 4.65 (equatorial) ppm. Recrystallization from petroleum ether affords an axial substituted product (3-H: lower field), in which 2-Me group is on opposite side of the ring.[5)] The corresponding iminium salts (**8** - **12**) were prepared with pyrrolidine perchlorate in ethanol[6)] and recrystallized from isopropyl alcohol.[7)] The electronegative substituent at the 3-position leads to an upfield shift of C-2 signal and downfield shifts of C-1 and C-2′ as shown in Fig.1.[8)] This electron distribution is contrary to that of β-ionone iminium salt (Ionone-Im) in which the positive charge on the nitrogen atom is delocalized on C-2 and C-3′; consequently the λ_{max} of **8** shifts by approximately 20 nm to shorter wavelength than that of Ionone-Im[9)] (Table 1).

Since there is no difference in chemical shift of olefinic carbons among **1**, **5**, **6**, and **7**,[10)] the inductive effect of the carboxyl group is screened from the π-conjugated system with the intervention of four atoms (one oxygen and three carbon atoms). ^{13}C-NMR spectrum of **3** suggests that π-electrons in the conjugated double bonds are further concentrated on C-2 and C-3′. o-Carboxyl group at the axial aromatic ring attached to the 3-position can be close to the 1-2 double bond on the basis of a space filling molecular model; the electrostatic interaction such as π-complexation might exist between the carboxyl proton and π-electrons. This diminishes the distribution of the positive charge on C-2 and C-3′, thence **10** absorbs at shorter wavelength by about 10 nm than **12**.[2e)]

The electron density on olefinic carbons in **4**, on the other hand, is inverse to those of **3** or **10** (Fig.2) due to the electrostatic interaction between π-electrons and the carboxylate anion located near the 1-2 double bond. Since iminium salts are gradually hydrolyzed under alkaline or acidic conditions, it was impossible to determine their ^{13}C-NMR spectra. The λ_{max} of **10** shifts by 21.5 nm to longer wavelength immediately after the deprotonation by adding triethylamine (Table 1). The bathochromic shift is caused by the electrostatic attraction between the carboxylate anion and the charged iminium polyene,[11, 12)] and this attraction promotes the delocalization of the positive charge on the nitrogen atom along the conjugated double bonds.[1)] These models indicate that the terminal charge effectively changes the absorption maxima of ionylidene iminium polyene, and this also would produce large spectroscopic shifts on the natural system in which the positive charge is able to be delocalized over five conjugated double bonds.

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7) Satisfactory elemental analyses and supporting spectral date were obtained. NMR date: **2**, ^{1}H-NMR($CDCl_3$) δ= 1.03, 1.10(6H, 6-Me_2), 1.3-1.7(m, 4H, 4,5-H_2), 1.83(s, 3H, 2-Me), 2.15(s, 3H, 1'-Me), 3.80(s, 3H, Me-ester), 4.50(d, 1H, 3-H), 6.0(d, 1H,J=16Hz, 2'-H), 6.7-7.7(m, 5H, 3'-H, ArH)ppm. ^{13}C-NMR($CDCl_3$), δ=18.7 (2-Me), 24.3(4), 27.3,27.4(6-Me_2), 28.7(5), 29.0(1'-Me), 34.7(6), 77.3(3), 115.2 (o-C), 120.5(p-C), 122.3(o-$\underline{C}$-COO), 131.3(2), 133.1(m-C), 133.3(2'), 140.9(1), 142.5(3'), 157.7(3-0-C), 167.1($\underline{C}$OOMe), 198.3(1')ppm. **10**, ^{1}H-NMR($CDCl_3$), δ=1.16 (s, 6H, 6-Me_2), 1.3-1.8(m, 4H, 4,5-H_2), 1.95(s, 3H, 2-Me), 2.10(s, 4H, pyrrolidine β-CH_2), 2.60(s, 3H, 1'-Me), 4.06(s, 4H, pyrrolidine α-CH_2), 4.90(s, 1H, 3-H), 6.60(d, 1H, J=16Hz, 2'-H), 7.1, 7.9(ArH), 7.58(d, J=16Hz, 3'-H)ppm. **12**, ^{13}C-NMR(DMSO d-6), δ=126.3(2'), 132.7(2), 141.2(1), 149.3(3'), 173.6(1')ppm.

8) δ-values for each compounds were determined in a conventional manner. Assignments of C-1 and C-2 were made by comparison to the date described in the following literatures; E.Breitmaier, G.Haas, and W.Voelter, "Atlas of Carbon-13 NMR Date," Heyden & Son Ltd., (1976); J.Shriver, E.W.Abrahamson, and G.D. Mateescu, J. Am. Chem. Soc., 98, 2407 (1976).

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10) λ_{max}($CHCl_3$): **1**, 280, 287^{sh}; **2**, 288; **3**, 282; **4**, 285; **5**, 265, 280^{sh}; **6**, 264, 278^{sh}; **7**, 264, 278^{sh} nm.

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12) Intramolecular ionic interaction might be entropically more favorable than the internal one. This decreases the effect of a counterion (ClO_4^-) to pull the positive charge to the nitrogen atom, and induces a bathochromic shift.

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