Bull. Chem. Soc. Jpn., 76, 2051–2052 (2003) 2051

A Facile Preparation and Properties of (2*E*,4*E*,6*E*,8*E*)-1-(3-Guaiazulenyl)-3,7-dimethyl-9-(2,6,6-trimethyl-1-cyclohexen-1-yl)-2,4,6,8-nonatetraen-1-ylium Hexafluorophosphate

Masaru Nakamura, Masato Sasaki,
Hideko Takekuma, Toshie Minematsu,[†]
and Shin-ichi Takekuma[*]

Department of Applied Chemistry, Faculty of Science and Engineering, Kinki University,
3-4-1 Kowakae, Higashi-Osaka 577-8502

†School of Pharmaceutical Sciences, Kinki University,
3-4-1 Kowakae, Higashi-Osaka 577-8502

Received January 21, 2003; E-mail: takekuma@apch.kindai.ac.jp

Reactions of guaiazulene (**1**) with all-*trans*- and 13-*cis*-retinals (**2a** and **2b**) in methanol in the presence of hexafluorophosphoric acid at −10 °C for 1 h afforded the title monocarbocation compound **3** in 87–91% yield, respectively.

In previous papers, we reported an efficient preparation, the molecular and crystal structures, and the characteristic chemical and electrochemical properties of mono- and dicarbocation compounds stabilized by a 3-guaiazulenyl group.[1–6] These products can be readily obtained by the reactions of guaiazulene (**1**) with the corresponding aromatic aldehyde compounds in acetic acid (and methanol) in the presence of hexafluorophosphoric acid (and tetrafluoroboric acid), respectively. On the other hand, the chemistry on retinals has been studied to a considerable extent, and the physical and chemical properties, the biological activities, and the functions for those molecules have been well documented. As a series of basic studies on the creation of novel functional materials possessing a 3-guaiazulenyl group and their potential utility, our interest has been focused on the reactions of **1** with commercially available all-*trans*- and 13-*cis*-retinals (**2a** and **2b**) in methanol in the presence of hexafluorophosphoric acid, giving the title monocarbocation compound, (2*E*,4*E*,6*E*,8*E*)-1-(3-guaiazulenyl)-3,7-dimethyl-9-(2,6,6-trimethyl-1-cyclohexen-1-yl)-2,4,6,8-nonatetraen-1-ylium hexafluorophosphate (**3**), respectively. We now wish to report on our detailed studies of a facile preparation as well as the spectroscopic and electrochemical properties of the new compound **3**, with a delocalized π-electron system, compared with those of (3-guaiazulenyl)phenylmethylium hexafluorophosphate (**4**)[5] (Chart 1).

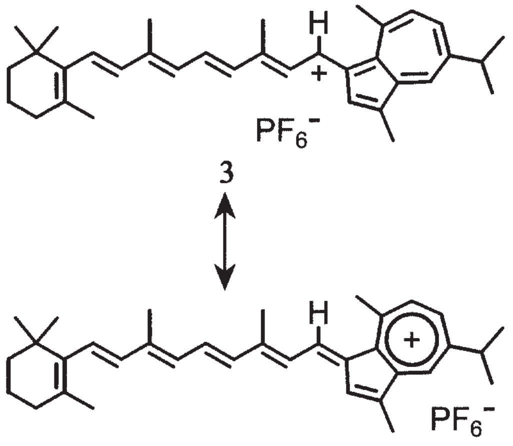

Chart 1. Structural formulas.

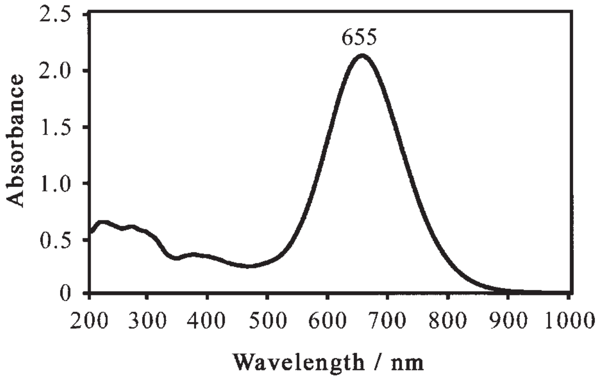

Fig. 1. The UV/vis spectrum of **3** in acetonitrile. Concentration of **3**: 0.020 g/L (31.8 µmol/L). Length of the cell: 1 cm.

Compound **3** was prepared by the following procedure. To a solution of guaiazulene (**1**) (9 mg, 45 µmol) in methanol (1 mL) was added a solution of all-*trans*-retinal (**2a**) (10 mg, 35 µmol) in methanol (2 mL) containing hexafluorophosphoric acid (60% aqueous solution, 0.2 mL). The mixture was stirred at −10 °C for 1 h under aerobic conditions, giving a precipitation of a dark-blue solid of **3**. The thus-obtained crude product was carefully washed with diethyl ether, and recrystallized from *o*-dichlorobenzene–hexane (1:5, v/v) to provide pure **3** as stable crystals (19–20 mg, 87–91% yield). Similarly, the reaction of **1** with 13-*cis*-retinal (**2b**) under the same reaction conditions as **2a** afforded **3** in 87–91% yield, owing to the rearrangement from **2b** to **2a**. Instumental analyses of **3** were carried out according to procedures described before.[1–6] Compound **3** was dark-blue needles, mp > 120 °C [decomp., determined by thermal analysis (TGA and DTA)]. The UV/vis spectrum [λ_{max} (CH_3CN) nm (log ε)] appeared at 222 (4.30), 271 (4.27), 374 (4.03), and 655 (4.82), as shown in Fig. 1, whose characteristic absorption band, based on the formation of the (2*E*,4*E*,6*E*,8*E*)-1-(3-guaiazulenyl)-3,7-dimethyl-9-(2,6,6-trimethyl-1-cyclohexen-1-yl)-2,4,6,8-nonatetraen-1-ylium moiety, with a delocalized π-electron system, appeared at the absorption maximum (λ_{max} 655 nm, log $\varepsilon = 4.82$). The IR (KBr) spectrum showed two specific bands based on the counter anion (PF_6^-) at ν_{max} 837 and 555 cm^{-1}, which coincided with those of (3-guaiazulenyl)phenylmethylium hexafluorophosphate (**4**).[5] The MALDI-TOF-MS spectrum [2-(4-hydroxyphenylazo)benzoic acid matrix] showed only an ion

Published on the web October 15, 2003; DOI 10.1246/bcsj.76.2051

peak at m/z 466 ($[\mathrm{M} - \mathrm{PF_6} + \mathrm{H}]^+$, 100%). The molecular formula $C_{35}H_{45}$ for the monocarbocation unit was determined by the exact FAB-MS spectrum (3-nitrobenzyl alcohol matrix; Found: m/z 465.3537; Calcd for $C_{35}H_{45}$: $[\mathrm{M} - \mathrm{PF_6}]^+$, m/z 465.3521). An elemental analysis confirmed the molecular formula $C_{35}H_{45}F_6P$ [Found: H, 7.56; C, 66.71%. Calcd for $C_{35}H_{47}F_6OP$ ($C_{35}H_{45}F_6P{\bullet}H_2O$): H, 7.54; C, 66.86%.]. The 500 MHz ^{1}H NMR (CD_3CN) spectrum showed signals based on the 3-guaiazulenyl group at $\delta = 1.43$ (6H, d, $J = 6.9$ Hz, $(C\underline{H}_3)_2CH$-7′), 2.54 (3H, s, Me-1′), 3.29 (3H, s, Me-4′), 3.41 (1H, sept, $J = 6.9$ Hz, $Me_2C\underline{H}$-7′), 8.12 (1H, s, H-2′), 8.23 (1H, dd, $J = 11.2$, 1.7 Hz, H-6′), 8.25 (1H, d, $J = 11.2$ Hz, H-5′), and 8.50 (1H, d, $J = 1.7$ Hz, H-8′), and signals based on the (2*E*,4*E*,6*E*,8*E*)-3,7-dimethyl-9-(2,6,6-trimethyl-1-cyclohexen-1-yl)-2,4,6,8-nonatetraen-1-ylium moiety at $\delta =$ 1.08 (6H, s, *gem*-Me$_2$-6″), 1.507 (1H, dd, $J = 6.0$, 3.0 Hz, Ha-5″), 1.512 (1H, dd, $J = 6.0$, 3.0 Hz, Hb-5″), 1.65 (1H, dddd, $J = 6.0$, 6.0, 6.0, 6.0 Hz, Ha-4″), 1.65 (1H, dddd, $J = 6.0$, 6.0, 3.0, 3.0 Hz, Hb-4″), 1.78 (3H, s, Me-2″), 2.09 (2H, dd, $J = 6.0$, 6.0 Hz, CH_2-3″), 2.13 (3H, s, Me-7), 2.39 (3H, s, Me-3), 6.35 (1H, d, $J = 16.0$ Hz, H-8), 6.44 (1H, d, $J = 11.8$ Hz, H-6), 6.59 (1H, d, $J = 16.0$ Hz, H-9), 6.74 (1H, d, $J = 14.6$ Hz, H-4), 7.34 (1H, d, $J = 12.9$ Hz, H-2), 7.49 (1H, dd, $J = 14.6$, 11.8 Hz, H-5), and 8.68 (1H, d, $J = 12.9$ Hz, HC^+-1), whose signals were carefully assigned using the H–H COSY and NOESY techniques and, further, a computer-assisted simulation analysis (the software: gNMR developed by Adept Scientific plc) on a DELL Dimension XPS T500 personal-computer with a Pentium Ⅲ processor. The 125 MHz ^{13}C NMR (CD_3CN) spectrum exhibited the following thirty-three carbon signals assigned by the HMQC and HMBC techniques: δ 166.1 (C-7′), 161.1 (C-3), 158.0 (C-8a′), 155.8 (C-4′), 150.7 (C-3a′), 147.1 (C-5′), 147.0 (C-7), 145.6 (HC^+-1), 143.5 (C-6′), 142.2 (C-1′), 139.2 (C-8′), 139.0 (C-2′), 138.7 (C-1″), 138.5 (C-5), 137.9 (C-8), 137.8 (C-3′), 137.4 (C-4), 133.2 (C-2″), 133.1 (C-9), 132.1 (C-6), 131.2 (C-2), 40.5 (C-5″), 39.8 ($Me_2\underline{C}H$-7′), 35.0 (C-6″), 34.0 (C-3″), 29.4 (Me-4′), 29.3 (*gem*-Me$_2$-6″), 23.9 ($(\underline{C}H_3)_2CH$-7′), 22.1 (Me-2″), 19.8 (C-4″), 14.5 (Me-3), 13.9 (Me-1′), and 13.4 (Me-7). The chemical shifts (δ, ppm) for the proton and carbon signals of the HC^+-1 carbenium-ion center of **3** (8.68 for ^{1}H NMR; 145.6 for ^{13}C NMR) showed up-field shifts, respectively, comparared with those of the HC^+-α carbenium-ion center of **4** (8.78 for ^{1}H NMR; 149.6 for ^{13}C NMR).[5] These spectroscopic data and an elemental analysis for **3** led to the molecular structure, (2*E*,4*E*,6*E*,8*E*)-1-(3-guaiazulenyl)-3,7-dimethyl-9-(2,6,6-trimethyl-1-cyclohexen-1-yl)-2,4,6,8-nonatetraen-1-ylium hexafluorophosphate, with a delocalized π-electron system.

Further, we have been interested in a comparative study of the electrochemical behavior of **3** and (3-guaiazulenyl)phenylmethylium hexafluorophosphate (**4**)[5] under the same electrochemical conditions. The electrochemical behavior of **3** was therefore measured by means of CV and DPV (Potential/V vs SCE) in CH_3CN containing 0.1 M $[n\text{-}Bu_4N]PF_6$ as a supporting electrolyte. As a result, the potential based on a one-electron reduction of the HC^+-1 carbenium-ion center of **3** appeared at −0.24 (E_{pc}, irreversible) V by CV (corresponding to −0.19 (E_p) V by DPV), generating the corresponding radical species ($HC^\bullet$-1), as shown in Fig. 2, which indicated that **3** was slightly susceptible to one-electron reduction compared with that of **4** [−0.29 (E_{pc}, irreversible) V by CV (corresponding to −0.20 (E_p) V by DPV)].[5]

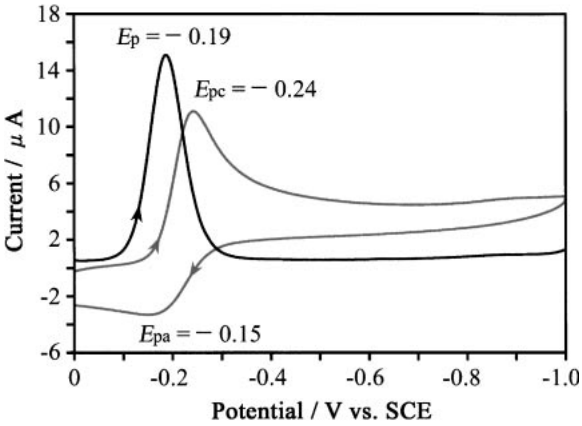

Fig. 2. Cyclic and differential pulse voltammograms of **3** (3.0 mg, 4.8 μmol) in CH_3CN (10 mL) containing 0.1 M $[n\text{-}Bu_4N]PF_6$ at a glassy carbon (ID: 3 mm) and platinum wire served as the working and auxiliary electrodes; scan rates 100 mV s^{-1} at 25 °C under argon, respectively. For comparative purposes, the oxidation potential using ferrocene as a standard material showed +0.42 (E_p) V by DPV and +0.40 ($E_{1/2}$) V by CV under the same electrochemical conditions as **3**.

This work was partially supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Culture, Sports, Science, and Technology.

References

1 S. Takekuma, M. Sasaki, H. Takekuma, and H. Yamamoto, *Chem. Lett.*, **1999**, 999.

2 S. Takekuma, S. Takata, M. Sasaki, and H. Takekuma, *Tetrahedron Lett.*, **42**, 5921 (2001).

3 S. Takekuma, M. Tanizawa, M. Sasaki, T. Matsumoto, and H. Takekuma, *Tetrahedron Lett.*, **43**, 2073 (2002).

4 M. Sasaki, M. Nakamura, G. Hannita, H. Takekuma, T. Minematsu, M. Yoshihara, and S. Takekuma, *Tetrahedron Lett.*, **44**, 275 (2003).

5 M. Sasaki, M. Nakamura, T. Uriu, H. Takekuma, T. Minematsu, M. Yoshihara, and S. Takekuma, *Tetrahedron*, **59**, 505 (2003).

6 M. Nakatsuji, Y. Hata, M. Sasaki, H. Takekuma, M. Yoshihara, T. Minematsu, and S. Takekuma, *Tetrahedron*, submitted for publication.