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First isolation of selenabenzenes stabilised by two electron-withdrawing groups at the 2- and 6-positions

Tadashi Kataoka,* Eiji Honda, Tatsunori Iwamura, Tetsuo Iwama and Shin-ichi Watanabe

Gifu Pharmaceutical University, 6-1 Mitahora-higashi 5-chome, Gifu 502-8585, Japan

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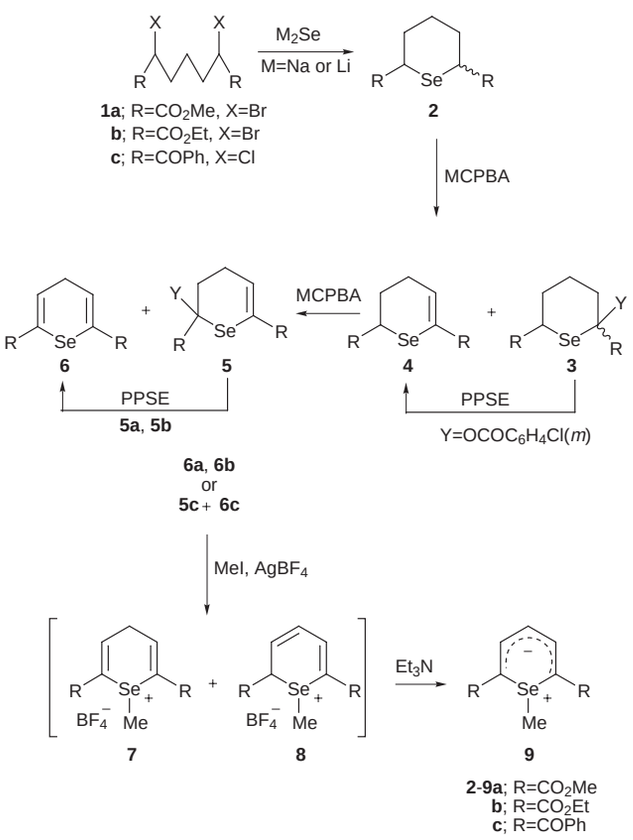
Selenabenzenes with two electron-withdrawing groups at 2,6-positions 9a–c were isolated and stable at room temperature and underwent the thermal rearrangement giving 2- and 4-methylselenines 13 and 14 and the oxygenation reaction giving dienone 15 and selenin-4-one 16.

In the course of our studies on selenabenzenes,[1,2] we had attempted to isolate monocyclic selenabenzene derivatives with one electron-withdrawing group. We confirmed the generation of them at −30 °C in an NMR tube, but could not isolate them as stable compounds at room temperature.[3] Therefore, we made a plan to introduce two electron-withdrawing groups at the 2- and 6-positions. This paper describes the synthesis and reactions of monocyclic selenabenzenes having two electron-withdrawing groups such as an ester or a benzoyl group at the 2- and 6-positions.

The synthetic route to the selenabenzenes is shown in Scheme 1. Selenanes having electron-withdrawing groups at the 2- and 6-positions **2a–c** were prepared by the ring closure of dihalo compounds **1a–c** with sodium or lithium selenide. Selenanes **2a–c** were treated with *m*-chloroperbenzoic acid (MCPBA) in order to construct a C–C double bond between the 2- and 3-positions. This oxidation reaction gave the Pummerer type products **3a–c** and **4a–c**. Undesired benzoates **3a–c** were converted into the desired dihydroselenines **4a–c** by treatment with polyphosphoric acid trimethylsilyl ester (PPSE)[4] which is a good reagent for dehydration under neutral conditions.[3] Similar treatments led the dihydroselenines **4a**, **b** to 4*H*-selenines **6a**, **b**, whereas the benzoyl derivative **5c** could not be converted into **6c**. Methylation of **6a**, **b** with MeI–$AgBF_4$ afforded mixtures of the isomeric selenonium salts **7a**, **b** and **8a**, **b**. Deprotonation of the mixtures of the selenonium salts with triethylamine afforded selenabenzenes **9a**, **b**. The benzoyl-substituted selenabenzene **9c** was prepared by methylation and the successive deprotonation of a mixture of compounds **5c** and **6c** because the isolation of the 4*H*-selenine **6c** and the selenonium salts **7c**, **8c** were difficult. The selenabenzenes **9a–c** were stable in the atmosphere at room temperature and could be purified by silica-gel PLC.



Scheme 1

Table 1 Spectroscopic data for selenabenzenes **9a–c**

	9a	9b	9c
δ_H (3,5)	7.39 (d)	7.40 (d)	7.20 (d)
δ_H (4)	5.23 (t)	5.21 (t)	5.18 (t)
J/Hz	8.8	8.8	8.8
δ_C (2,6)	83.4	83.9	102.3
δ_C (3,5)	139.2	139.1	141.8
δ_C (4)	101.0	100.7	103.1
δ_{Se}	310	311	289
IR (C=O)	1660	1640	1540

Characteristic signals of the ^1H and ^{13}C NMR and IR spectra for the selenabenzenes **9a–c** are shown in Table 1. In the ^1H NMR spectra the H(4) signals of **9a–c** appeared at about δ 5.2 and were at higher field than that of 2-(*p*-bromobenzoyl)-1-methylthiabenzene **11** at δ 5.58,[5] and much higher than those of benzene protons. The H(3,5) signals of **9a–c** at δ 7.20–7.40 were at lower field than the H(3) signals of 2-(*p*-bromobenzoyl)-1,4,5-trimethylselenabenzene **12** at δ 6.39[3] and the thiabenzene **11** at δ 6.90.[5] In the ^{13}C NMR spectrum, the C(2,6) and C(3,5) signals of **9c** at δ 102.3 and 141.8 were at lower field than the C(2) and C(3) signals of **12** at δ 85.1 and 127.6, respectively. The broad and very strong absorption bands of the ester carbonyl (**9a, b**) and the benzoyl (**9c**) groups appeared at 1640–1660 and 1540 cm^{-1}, respectively, lower frequencies than normal by 60–80 cm^{-1}. These observations indicate that these selenabenzenes are stabilised by contribution of the enol canonical structure **C** in Fig. 1 and two electron-withdrawing groups delocalise the negative charge as shown in structure **10**. The difference in the chemical shifts between C(3,5) and C(4) is attributable to the difference in the electron density at the 3,5- and 4-positions.

Scheme 2 shows reactions of the selenabenzenes **9b** and **9c**. Selenabenzene **9b** was refluxed in benzene for 2.5 h to give an inseparable mixture of 2-methyl-2*H*-selenine **13** and 4-methyl-4*H*-selenine **14** in 58% yield with a ratio of **13/14** = 1.1. Oxygenation of the selenabenzene **9c** was conducted in methanol for 1 week under an oxygen atmosphere to give (*Z*,*Z*)-

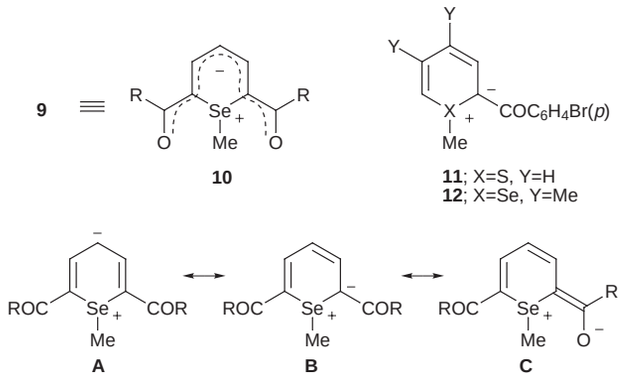
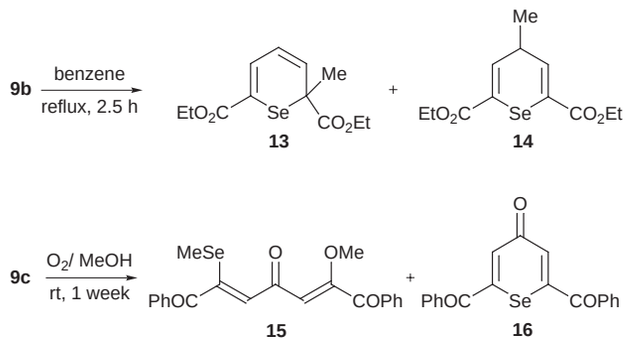


Fig. 1



Scheme 2

1,5-dibenzoyl-1-methoxy-5-methylselenopenta-1,4-dien-3-one **15** (20%) and 1,5-dibenzoyl-4*H*-selenin-4-one **16** (36%). The dienone **15** and the selenin-4-one **16** would be produced by oxygenation of C(4) of **9c** and the subsequent cleavage of the C(1)–Se bond or the subsequent demethylation of the Se–methyl group, respectively, due to attack of methanol. In the ^{1}H NMR spectrum of **15**, the two olefinic signals, the H(2) and H(4) signals, appeared at δ 5.70 and 7.24 and the two methyl signals, the SeMe and OMe signals, appeared at δ 1.88 and 3.81. In the ^{13}C NMR spectrum of **15**, four olefinic carbon signals and three carbonyl signals were observed. These NMR spectral data and other analytical data supported the structure of **15**. A nuclear Overhauser effect (NOE) enhancement was observed between the H(2) signal at δ 5.70 and the doublet signal at δ 7.95 due to H(2′,6′) of the 1-benzoyl group and between the H(4) signal at δ 7.24 and the doublet signal at δ 8.04 due to H(2′,6′) of the 5-benzoyl group. This indicates that the geometry of **15** is the (*Z*,*Z*) configuration. The preparation of **9a** and reactions of **9b**, **c** are given as an example. Further study of the selenabenzenes **9a**–**c** will be described in a full paper.

Experimental

Synthesis of dimethyl 1-methyl-1λ^4-selenabenzene-2,6-dicarboxylate (9a)

A mixture of dimethyl 4*H*-selenine-2,6-dicarboxylate **6a** (261 mg, 1 mmol), iodomethane (0.4 cm^3, 6 mmol) and silver tetrafluoroborate (324 mg, 1.5 mmol) in dichloromethane (15 cm^3) was stirred for 2 h at 0 °C. The precipitate was filtered off and washed with dichloromethane. The filtrate and the washing were combined and concentrated to dryness. Triethylamine (0.6 cm^3, 4 mmol) was added to a solution of the residue, a mixture of 1-methyl-2,6-bis(methoxycarbonyl)-4*H*-seleninium tetrafluoroborate (**7a**) and 1-methyl-2,6-bis(methoxycarbonyl)-2*H*-seleninium tetrafluoroborate (**8a**), in ethanol (15 cm^3) at 0 °C with stirring. The reaction mixture was stirred for 5 h at 0 °C and then water was added to it. The whole was extracted with dichloromethane. The extracts were dried ($MgSO_4$) and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using hexane–ethyl acetate (5:1) to give dimethyl 1-methyl-1λ^4-selenabenzene-2,6-dicarboxylate (**9a**) (203 mg, 74%), dark red oil (Found: C, 43.6; H, 4.4; $C_{10}H_{12}O_4Se$ requires C, 43.48; H, 4.35%); ν_{max}(film)/cm^{-1} 1660 (ester C=O); δ_H (400 MHz; $CDCl_3$) 2.14 (3 H, s, SeMe), 5.23 (1 H, t, *J* 9, 4-H), 3.80 (6 H, s, OMe × 2), 7.39 (2 H, t, *J* 9, 3- and 5-H); δ_C (100 MHz; $CDCl_3$) 26.6 (q), 52.0 (q), 83.4 (s), 101.0 (d), 139.2 (d), 165.8 (s); δ_{Se} (76 MHz; $CDCl_3$) 310; *m*/*z* (EI) 276 (M$^+$, 10%), 261 (100).

Diethyl 2-methyl-2*H*-selenine-2,6-dicarboxylate 13

Yellow oil; ν_{max}(film)/cm^{-1} 1720 (ester C=O); δ_H (400 MHz; $CDCl_3$) 1.30 (3 H, t, *J* 7, CH_2CH_3), 1.33 (3 H, t, *J* 7, CH_2CH_3), 1.71 (3 H, s, SeMe), 4.24 (2 H, q, *J* 7, CH_2CH_3), 4.28 (2 H, q, *J* 7, CH_2CH_3), 5.93 (1 H, d, *J* 11, 3-H), 6.17 (1 H, dd, *J* 7 and 11, 4-H), 7.36 (1 H, d, *J* 7, 5-H); δ_C (100 MHz; $CDCl_3$) 13.9 (q), 14.1 (q), 26.6 (q), 44.1 (s), 61.5 (t), 62.1 (t), 124.7 (s), 125.4 (d), 128.1 (d), 129.0 (d), 165.1 (s), 172.4 (s); δ_{Se} (76 MHz; $CDCl_3$) 350; *m*/*z* (EI) 304.0217 ($C_{12}H_{16}O_4Se$ requires 304.0213), 304 (M$^+$, 10%), 231 (100).
Compound **13** was isolated.

Diethyl 4-methyl-4*H*-selenine-2,6-dicarboxylate 14

δ_H (400 MHz; $CDCl_3$) 1.33 (6 H, t, *J* 7, CH_2CH_3), 1.33 (3 H, d, *J* 7, Me), 3.23 (1 H, tq, *J* 4 and 7, 4-H), 4.28 (4 H, q, *J* 7, CH_2CH_3), 6.94 (2 H, d, *J* 4, 3- and 5-H); δ_C (100 MHz; $CDCl_3$) 14.1 (q), 19.0 (q), 35.7 (d), 61.7 (t), 123.9 (s), 136.9 (d), 163.9 (s). These data were picked up from the NMR spectra of a mixture of **13** and **14**.

(*Z*,*Z*)-1,5-Dibenzoyl-1-methoxy-5-methylselenopenta-1,4-dien-3-one 15

Red oil; ν_{max}(film)/cm^{-1} 1660, 1620, 1600 (C=O); δ_H (400 MHz; $CDCl_3$) 1.88 (3 H, s, SeMe), 3.81 (3 H, s, OMe), 5.70 (1 H, s, 2-H), 7.24 (1 H, s, 4-H), 7.50–7.53 (4 H, m, aromatic), 7.63–7.65 (2 H, m, aromatic), 7.95 (2 H, d, *J* 7, aromatic), 8.04 (2 H, d, *J* 7, aromatic); δ_C (100 MHz; $CDCl_3$) 6.6 (q), 59.5 (q), 112.6 (d), 123.7 (d), 128.9 (d), 129.0 (d), 129.9 (d), 134.4 (d), 134.5 (d), 135.2 (s), 158.5 (s), 160.4 (s), 186.3 (s), 191.6 (s), 193.1 (s); δ_{Se} (76 MHz; $CDCl_3$) 379; *m*/*z* (EI) 414.0359 ($C_{21}H_{18}O_4Se$ requires 414.0370), 314 (M$^+$, 6%), 105 (100).

2,6-Dibenzoyl-4*H*-selenin-4-one 16

Colorless needles, mp 145–156 °C (from methanol) (Found: C, 62.1; H, 3.2; $C_{19}H_{12}O_3Se$ requires C, 62.1; H, 3.3%); ν_{max}(KBr)/cm^{-1} 1610, 1650 (C=O); δ_H (400 MHz; $CDCl_3$) 7.55 (4 H, t, *J* 7, aromatic), 7.56 (2 H, s, 3- and 5-H), 7.69 (2 H, t, *J* 7, aromatic), 7.83 (4 H, d, *J* 7, aromatic); δ_C (100 MHz; $CDCl_3$) 129.0 (d), 129.9 (d), 134.0 (s), 134.4 (s), 136.4 (d), 136.5 (d), 154.3 (s), 193.3 (s); δ_{Se} (76 MHz; $CDCl_3$) 462; *m*/*z* (EI) 368 (M$^+$, 25%), 105 (100).

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