Rearrangement of *cis*- and *trans*-2-Methyl-3-(substituted phenyl)-1,2,3,4-tetrahydroisoquinolinium 2-Methylides

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Sommelet–Hauser and Stevens rearrangements of α-arylcycloammonium *N*-methylides provide convenient methods for the ring enlargement of cyclic amines.[1] The former increases the ring by three carbons, while the latter results in a one-carbon increase. We have reported that ylide formation by the fluoride ion-induced desilylation of *N*-methyl-*N*-[(trimethylsilyl)methyl]-α-phenylcycloammonium salts is suitable for ring enlargement because a single ylide is formed quantitatively in nonbasic media.[2] Although *cis*- and *trans*-isomers might be formed in the syntheses of these ammonium salts, the relationship between the type of ylide rearrangement and the configuration of the ammonium salts has not been determined due to the difficulty in isolating the isomers. We previously showed in the study of 2-methyl-1-phenyl-2-isoindolinium 2-methylides that the *cis*-isomers led mainly to Sommelet–Hauser rearrangement products while the *trans*-isomers afforded exclusively Stevens products.[3] In this paper, we describe the rearrangement of *cis*- and *trans*-isomers of 2-methyl-3-(4-substituted phenyl)-1,2,3,4-tetrahydroisoquinolinium 2-methylides **4**.

2-Methyl-2-[(trimethylsilyl)methyl]-3-(4-substituted phenyl)-1,2,3,4-tetrahydroisoquinolinium iodides **3a–d** were prepared starting from 3-(4-substituted phenyl)-1,2,3,4-tetrahydroisoquinolines **1a–d**, and their geometric isomers were separated by recrystallization (Scheme 1). The major isomer of **3a** was assigned the *trans*-configuration on the basis of an X-ray crystallographic analysis.[4] The major isomers of **3b–d** were also assigned the *trans*-configuration by comparing the chemical shifts of the trimethylsilyl groups (*cis* < *trans*) in their respective ^{1}H NMR spectra (Table 1).[5]

Reaction of *cis*-**3a–d** with cesium fluoride in DMF at room temperature for 3 h gave (*E*)-1-(4-substituted phenyl)-2-[2-[(dimethylamino)methyl]phenyl]ethylenes (*E*)-**8a–d** (intramolecular Hofmann degradation products) in high yields, without contamination by any of the other isomerization products (entries 1–4, Table 2).

Similar treatment of *trans*-**3a,b** primarily gave (*Z*)-3-substituted 6-methyl-4a,5,6,7-tetrahydro-12*H*-dibenzo[*c*,*g*]azonines (*Z*)-**5a,b** ([2,3] sigmatropic rearrangement products), accompanied by small amounts of 4-(4-substituted phenyl)-2-methyl-2,3,4,5-tetrahydro-1*H*-2-benzazepines **7a,b** (Stevens rearrangement products), as well as the Hofmann degradation products (*E*)-**8a,b** and (*Z*)-**8a,b** (entries 6 and 8). From the reaction of *trans*-**3c**, a mixture of the two geometric isomers of the sigmatropic rearrangement product, (*E*)-**5c** and (*Z*)-**5c**, was formed (entry 11). When the reactions were quenched after 0.5 h, no significant changes of the product ratios were observed for *trans*-**3a,b** (compare entry 5 with entry 6 and 7 with 8), but the ratio of (*E*)-**5c** to (*Z*)-**5c** was reversed for *trans*-**3c**, especially at 0 °C (compare entries 9 and 10 with entry 11).

We reported earlier that the stability of [2,3] sigmatropic rearrangement products (isotoluenes) of benzylammonium methylides increases with the electron-donating ability of the substituents on the conjugated

Scheme 1

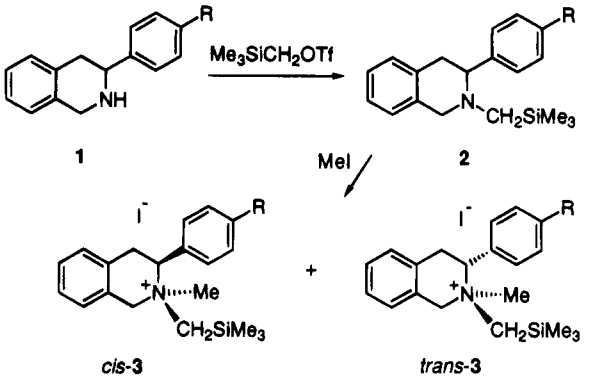


Table 1. 2-Methyl-2-[(trimethylsilyl)methyl]-3-(4-substituted phenyl)-1,2,3,4-tetrahydroisoquinolinium Iodides 3

3	R	yield, %	ratio of *cis*:*trans*	^{1}H NMR ($CDCl_3$), δ (CH_3Si) *cis*	*trans*
3a	H	96	38:62	0.20	0.33
3b	Me	94	44:56	0.19	0.33
3c	OMe	93	39:61	0.19	0.33
3d	CF_3	97	39:61	0.22	0.34

Table 2. Reaction of *cis*-3 and *trans*-3 with CsF at Room Temperature

entry	salt	reaction time, h	total yield, %	% of product[a] (*E*)-**5**	(*Z*)-**5**	**6**	**7**	(*E*)-**8**	(*Z*)-**8**
1	*cis*-**3a**	3	80	0	0	0	0	100	0
2	*cis*-**3b**	3	84	0	0	0	0	100	0
3	*cis*-**3c**	3	80	0	0	0	0	100	0
4	*cis*-**3d**	3	87	0	0	0	0	100	0
5	*trans*-**3a**	0.5	55	0	84	0	3	2	11
6	*trans*-**3a**	3	69	0	84	0	3	2	11
7	*trans*-**3b**	0.5	53	0	84	0	3	3	10
8	*trans*-**3b**	3	74	0	84	0	10	3	3
9	*trans*-**3c**	0.5	61	45	41	0	3	3	8
10	*trans*-**3c**	0.5[b]	62	77	16	0	1	0	6
11	*trans*-**3c**	3	53	17	72	0	5	0	6
12	*trans*-**3d**	0.5	89	0	56	16	24	3	1
13	*trans*-**3d**	3	84	0	10	44	42	3	1
14	*trans*-**3d**	72	89	0	0	57	39	2	2

[a] Determined from the proton ratios of ^{1}H NMR. [b] The reaction was carried out at 0 °C.

(1) (a) Nakai, T.; Mikami, K. *Yuki Gosei Kagaku Kyokaishi* **1980**, *38*, 381. (b) Hesse, M. *Ring Enlargement in Organic Chemistry*; VCH: Weinheim, 1991; p 83.

(2) (a) Shirai, N.; Sumiya, F.; Sato, Y.; Hori, M. *J. Org. Chem.* **1989**, *54*, 836. (b) Sumiya, F.; Shirai, N.; Sato, Y. *Chem. Pharm. Bull.* **1991**, *39*, 36. (c) Kitano, T.; Shirai, N.; Sato, Y. *Synthesis* **1991**, 996. (d) Kitano, Y.; Shirai, N.; Sato, Y. *Chem. Pharm. Bull.* **1992**, *40*, 768. (d) Kitano, T.; Shirai, N.; Motoi, M.; Sato, Y. *J. Chem. Soc., Perkin Trans. 1* **1992**, 2851. (e) Sato, Y.; Shirai, N.; Machida, Y.; Ito, E.; Yasui, T.; Kurono, Y.; Hatano, K. *J. Org. Chem.* **1992**, *57*, 6711.

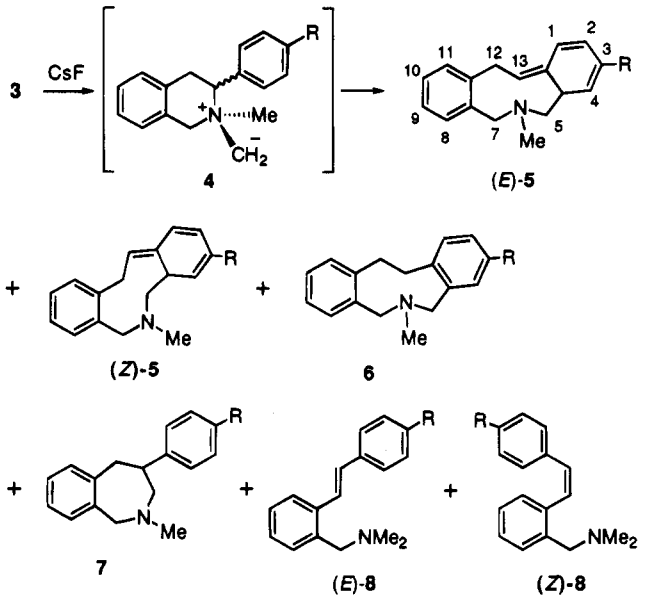
(3) Sakuragi, A.; Shirai, N.; Sato, Y.; Kurono, Y.; Hatano, K. *J. Org. Chem.* **1994**, *59*, 148.

(4) The authors have deposited atomic coordinates for *trans*-**3a** and (*Z*)-**5a** with the Cambridge Crystallographic Data Centre. The coordinates can be obtained, on request, from the Director, Cambridge Crystallographic Data Centre, 12 Union Road, Cambridge, CB2 1EZ, UK.

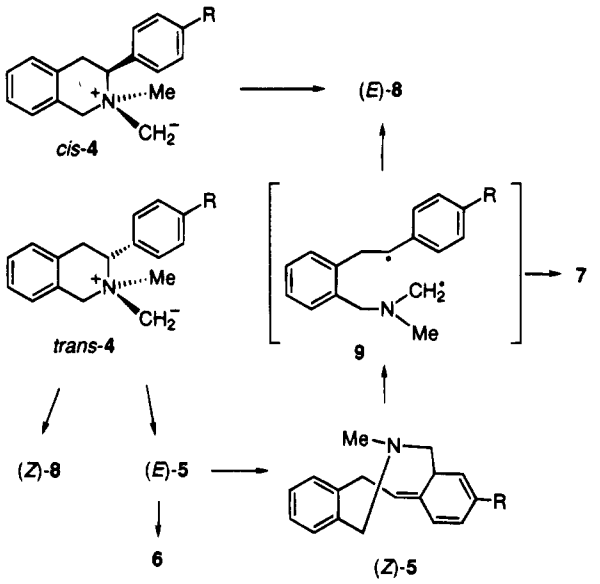
(5) A similar relationship in ^{1}H NMR spectroscopy was observed by Sato et al. in studies on *cis*- and *trans*-2-methyl-1-phenyl-2-[(trimethylsilyl)methyl]-1,2,3,4-tetrahydroisoquinolinium iodides[2e] and *cis*- and *trans*-2-methyl-1-phenyl-2-[(trimethylsilyl)methyl]isoindolinium iodides.[3]

0022-3263/95/1960-4272$09.00/0

Scheme 2



Scheme 3



triene bonds; e.g., 3-methoxy-5-[(dimethylamino)methyl]-6-methylene-1,3-cyclohexadiene was stable at room temperature.[2,6]

Methoxy-substituted (*E*)-**5c** may be more stable than (*E*)-**5a,b**, which were not detected. *Trans*-ylides (*trans*-**4**) initially rearranged to give (*E*)-**5**, followed by isomerization to (*Z*)-**5**. This isomerization may occur by a suprafacial [1,5] shift of the C5 carbon from the C4a to the C1 carbon (Scheme 3). Light-induced conversion from an (*E*)- to a (*Z*)-olefin is unlikely because no change in the ratio was observed when the reaction of *trans*-**3c** was carried out in the dark.

The reaction of a 4-(trifluoromethyl)phenyl-substituted analogue, *trans*-**3d**, gave the following three main products after 0.5 h: (*Z*)-**5d**, 3-(trifluoromethyl)-6-methyl-6,7,12,13-tetrahydro-5*H*-dibenzo[*c*,*g*]azonine (**6d**) (Sommelet–Hauser rearrangement product), and 4-[4-(trifluoromethyl)phenyl]-2-methyl-2,3,4,5-tetrahydro-1*H*-2-benzazepine (**7d**) (Stevens rearrangement product) (entry 12).

(6) Shirai, N.; Watanabe, Y.; Sato, Y. *J. Org. Chem.* **1990**, *55*, 2767.

Prolonged reaction time resulted in a decrease in the amount of (*Z*)-**5d** and an increase in **6d** and **7d** (compare entries 12–14). We initially thought that (*Z*)-**5d** was slowly converted to both **6d** and **7d**. However, when isolated (*Z*)-**5d** was again dissolved in DMF and allowed to stand for 72 h, a 4:93:3 ratio of **6d**, **7d**, and (*E*)-**8d** was formed. Thus, the main isomerization product from (*Z*)-**5d** was not **6d** but **7d**. The increasing yield of **6d** with reaction time may be a result of the aromatization of (*E*)-**5d**, which remains in the reaction mixture, although we could not confirm its presence.

Aromatization of (*E*)-**5** or (*Z*)-**5** to **6** requires an antarafacial hydrogen shift. This shift may be allowed in (*E*)-**5** but is difficult in (*Z*)-**5** because the hydrogen must pass through the inside of the nine-membered ring. Thus, diradical intermediate **9** may be formed by homolysis of the C–C bond of (*Z*)-**5**, and it may then change to **7** by radical recombination and to **8** by hydrogen abstraction.

In conclusion, a [2,3] sigmatropic migration predominantly occurred on *trans*-ylides (*trans*-**4**) to give the isotoluene intermediates (*E*)-**5**, which were aromatized to the Sommelet–Hauser products **6** or converted to the Stevens products **7** and the Hofmann products (*E*)-**8** via isomerization to (*Z*)-**5**. These pathways are similar to the formation of Stevens rearrangement products and olefins from benzylammonium alkylides[7] and 1-methyl-2-phenylpiperidinium 1-methylides.[2a] With *cis*-ylides (*cis*-**4**), however, an intramolecular Hofmann degradation giving (*E*)-**8** was the single pathway.

Experimental Section

All reactions were carried out in N_2. DMF was dried by distillation from BaO under reduced pressure. CsF was dried over P_2O_5 at 170 °C under reduced pressure. ^1H NMR spectra were recorded at 270, 400, or 500 MHz. Distillation of the products was performed by using a Büchi Kugelrohr distillation apparatus. All melting points and boiling points are uncorrected.

3-(4-Substituted phenyl)-2-[(trimethylsilyl)methyl]-1,2,3,4-tetrahydroisoquinolines 2a–d. General Procedure. A mixture of 3-phenyl- (**1a**), 3-(4-methylphenyl)- (**1b**), 3-(4-methoxyphenyl)- (**1c**), or 3-[4-(trifluoromethyl)phenyl]-1,2,3,4-tetrahydroisoquinoline **1d** (48 mmol) and (trimethylsilyl)methyl triflate (11.3 g, 48 mmol) in CH_2Cl_2 (150 mL) was stirred at room temperature for 3 h. The mixture was poured into 5% NaOH (300 mL) and extracted with diethyl ether (3 × 150 mL). The extract was washed with water, dried ($MgSO_4$), and concentrated under reduced pressure. The products were chromatographed on silica gel columns (hexane/ethyl acetate) and distilled under reduced pressure.

3-Phenyl-2-[(trimethylsilyl)methyl]-1,2,3,4-tetrahydroisoquinoline (2a): yield 11.2 g (79%); bp 110–111 °C (0.55 mmHg); IR (film) 2959, 1742, 1370, 1290, 1252, 1225, 1030, 847 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.03 (s, 9 H), 1.54 (d, 1 H, J = 14.4 Hz), 2.11 (d, 1 H, J = 14.4 Hz), 2.96 (dd, 1 H, J = 16.5, 4.5 Hz), 3.09 (dd, 1 H, J = 16.5, 9.5 Hz), 3.53 (dd, 1 H, J = 9.5, 4.5 Hz), 3.55 (d, 1 H, J = 15.7 Hz), 4.04 (d, 1 H, J = 15.7 Hz), 7.04–7.08 (m, 2 H), 7.14–7.15 (m, 2 H), 7.25–7.28 (m, 1 H), 7.32–7.34 (m, 4 H). Anal. Calcd for $C_{19}H_{25}NSi$: C, 77.23; H, 8.53; N, 4.74. Found: C, 77.36; H, 8.47; N, 4.67.

3-(4-Methylphenyl)-2-[(trimethylsilyl)methyl]-1,2,3,4-tetrahydroisoquinoline (2b): yield 11.7 g (79%); bp 140–142 °C (0.60 mmHg); IR (film) 2953, 2762, 1514, 1422, 1372, 1248, 1098, 856, 743 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.03 (s, 9 H), 1.53 (d, 1 H, J = 14.5 Hz), 2.12 (d, 1 H, J = 14.5 Hz), 2.34 (s, 3 H), 2.97–3.07 (m, 2 H), 3.45–3.50 (m, 1 H), 3.53 (d, 1 H, J = 15.7 Hz), 4.03 (d, 1 H, J = 15.7 Hz), 7.01–7.06 (m, 2 H), 7.12–7.23 (m, 6 H). Anal.

(7) Tanaka, T.; Shirai, N.; Sugimori, J.; Sato, Y. *J. Org. Chem.* **1992**, *57*, 5034.

Calcd for $C_{20}H_{27}NSi$: C, 77.61; H, 8.79; N, 4.53. Found: C, 77.38; H, 8.63; N, 4.46.

3-(4-Methoxyphenyl)-2-[(trimethylsilyl)methyl]-1,2,3,4-tetrahydroisoquinoline (2c): yield 12.7 g (81%); bp 145–150 °C (0.55 mmHg); IR (film) 2953, 2764, 1611, 1512, 1248, 1175, 1039, 858, 835, 743 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.03 (s, 9 H), 1.53 (d, 1 H, J = 14.1 Hz), 2.10 (d, 1 H, J = 14.1 Hz), 2.97 (dd, 1 H, J = 16.6, 4.3 Hz), 3.07 (dd, 1 H, J = 16.6, 9.0 Hz), 3.49 (m, 1 H), 3.55 (d, 1 H, J = 15.8 Hz), 3.81 (s, 3 H), 4.02 (d, 1 H, J = 15.8 Hz), 6.86–6.89 (m, 2 H), 7.03–7.07 (m, 2 H), 7.12–7.15 (m, 2 H), 7.23–7.28 (m, 2 H). Anal. Calcd for $C_{20}H_{27}NOSi$: C, 73.79; H, 8.36; N, 4.30. Found: C, 73.76; H, 8.31; N, 4.42.

3-[4-(Trifluoromethyl)phenyl]-2-[(trimethylsilyl)methyl]-1,2,3,4-tetrahydroisoquinoline (2d): yield 13.9 g (79%); bp 130–132 °C (0.55 mmHg); IR (film) 2955, 2766, 1618, 1418, 1327, 1250, 1165, 1127, 1067, 843, 743 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.03 (s, 9 H), 1.55 (d, 1 H, J = 14.2 Hz), 2.03 (d, 1 H, J = 14.2 Hz), 2.99–3.03 (m, 2 H), 3.55 (d, 1 H, J = 15.5 Hz), 3.52–3.60 (m, 1 H), 4.02 (d, 1 H, J = 15.5 Hz), 7.04–7.06 (m, 2 H), 7.13–7.19 (m, 2 H), 7.42–7.45 (m, 2 H), 7.56–7.59 (m, 2 H). Anal. Calcd for $C_{20}H_{24}F_3NSi$: C, 66.08; H, 6.66; N, 3.85. Found: C, 66.14; H, 6.73; N, 3.89.

2-Methyl-3-[4-substituted phenyl]-2-[(trimethylsilyl)-methyl]-1,2,3,4-tetrahydroisoquinolinium Iodides 3a–d. General Procedure. A solution of **2** (30 mmol) and iodomethane (21.3 g, 150 mmol) in MeCN (300 mL) was heated at 50 °C for 24 h. The solvent was removed in vacuo to give crude **3**. The yields and *cis*:*trans* ratios are listed in Table 1. Both isomers were isolated by repeated recrystallization from a mixture of acetone and ether.

***cis*-3a**: yield 2.8 g (21%); mp 205–207 °C; IR (Nujol) 1498, 1257, 849, 766, 730 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.20 (s, 9 H), 2.82 (s, 2 H), 3.37 (dd, 1 H, J = 18.8, 5.0 Hz), 3.40 (s, 3 H), 3.66 (dd, 1 H, J = 18.8, 11.2 Hz), 4.35 (d, 1 H, J = 15.5 Hz), 5.98 (d, 1 H, J = 15.5 Hz), 6.02 (dd, 1 H, J = 11.2, 5.3 Hz), 7.14 (d, 1 H, J = 7.9 Hz), 7.27 (d, 1 H, J = 7.9 Hz), 7.31–7.33 (m, 1 H), 7.36–7.39 (m, 1 H), 7.50–7.56 (m, 3 H), 7.91 (bs, 2 H). Anal. Calcd for $C_{20}H_{28}INSi$: C, 54.91; H, 6.45; N, 3.20. Found: C, 54.89; H, 6.39; N, 3.35.

***trans*-3a**: yield 2.2 g (17%); mp 228–229 °C; IR (KBr) 3034, 1499, 1456, 1254, 848, 770, 721 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.33 (s, 9 H), 3.13 (s, 3 H), 3.15 (d, 1 H, J = 14.5 Hz), 3.51 (dd, 1 H, J = 18.8, 6.3 Hz), 3.64 (dd, 1 H, J = 18.8, 7.3 Hz), 3.94 (d, 1 H, J = 14.5 Hz), 4.31 (d, 1 H, J = 15.2 Hz), 5.36 (d, 1 H, J = 15.2 Hz), 5.95 (t, 1 H, J = 6.8 Hz), 7.18 (d, 1 H, J = 6.9 Hz), 7.28–7.53 (m, 6 H), 7.74 (bs, 2 H). Anal. Calcd for $C_{20}H_{28}INSi$: C, 54.91; H, 6.45; N, 3.20. Found: C, 54.69; H, 6.45; N, 3.20.

***cis*-3b**: yield 2.7 g (20%); mp 142–145 °C; IR (KBr) 3032, 2953, 1615, 1499, 1460, 1256, 849, 770, 734 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.19 (s, 9 H), 2.41 (s, 3 H), 2.77 and 2.79 (AB-q, 2 H, J = 14.1 Hz), 3.36 (dd, 1 H, J = 18.9, 5.3 Hz), 3.39 (s, 3 H), 3.62 (dd, 1 H, J = 18.9, 11.5 Hz), 4.34 (d, 1 H, J = 15.4 Hz), 5.96 (dd, 1 H, J = 11.5, 5.3 Hz), 5.98 (d, 1 H, J = 15.4 Hz), 7.14 (d, 1 H, J = 7.3 Hz), 7.23–7.39 (m, 5 H), 7.76 (bs, 2 H). Anal. Calcd for $C_{21}H_{30}INSi$: C, 55.87; H, 6.70; N, 3.10. Found: C, 56.17; H, 6.85; N, 2.75.

***trans*-3b**: yield 2.4 g (18%); mp 189–191 °C; IR (KBr) 2949, 1618, 1501, 1460, 1256, 853, 754 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.33 (s, 9 H), 2.39 (s, 3 H), 3.10 (s, 3 H), 3.15 (d, 1 H, J = 14.8 Hz), 3.49 (dd, 1 H, J = 18.7, 7.4 Hz), 3.68 (dd, 1 H, J = 18.7, 6.1 Hz), 3.92 (d, 1 H, J = 14.8 Hz), 4.30 (d, 1 H, J = 15.3 Hz), 5.35 (d, 1 H, J = 15.3 Hz), 5.89 (m, 1 H), 7.18 (d, 1 H, J = 7.0 Hz), 7.23–7.29 (m, 3 H), 7.32–7.42 (m, 2 H), 7.53 (bs, 2 H). Anal. Calcd for $C_{21}H_{30}INSi$: C, 55.87; H, 6.70; N, 3.10. Found: C, 56.24; H, 6.88; N, 2.78.

***cis*-3c**: yield 1.8 g (13%); mp 168–170 °C; IR (KBr) 2955, 1611, 1516, 1462, 1263, 1184, 1154, 1032, 843, 639 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.19 (s, 9 H), 2.75 (s, 2 H), 3.30 (s, 3 H), 3.35 (dd, 1 H, J = 18.8, 5.4 Hz), 3.61 (dd, 1 H, J = 18.8, 11.1 Hz), 3.86 (s, 3 H), 4.35 (d, 1 H, J = 15.6 Hz), 5.69 (d, 1 H, J = 15.6 Hz), 5.72 (m, 1 H), 7.01 (dd, 2 H, J = 7.6, 1.4 Hz), 7.13 (d, 1 H, J = 7.6 Hz), 7.24–7.39 (m, 3 H), 7.75 (bs, 2 H). Anal. Calcd for $C_{21}H_{30}INOSi$: C, 53.96; H, 6.46; N, 3.00. Found: C, 53.83; H, 6.40; N, 2.89.

***trans*-3c**: yield 2.2 g (16%); mp 209–210 °C; IR (KBr) 1611, 1516, 1460, 1262, 1190, 1026, 856, 768 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.33 (s, 9 H), 3.08 (s, 3 H), 3.13 (d, 1 H, J = 14.8 Hz), 3.48 (dd, 1 H, J = 18.7, 7.4 Hz), 3.60 (dd, 1 H, J = 18.7, 6.1 Hz), 3.84 (s, 3 H), 3.90 (d, 1 H, J = 14.8 Hz), 4.27 (d, 1 H, J = 15.2 Hz), 5.29 (d, 1 H, J = 15.2 Hz), 5.92 (m, 1 H), 6.95 (d, 2 H, J = 8.6 Hz), 7.17 (d, 1 H, J = 7.5 Hz), 7.31 (d, 1 H, J = 11.7 Hz), 7.34–7.42 (m, 2 H), 7.65 (bs, 2 H). Anal. Calcd for $C_{21}H_{30}INOSi$: C, 53.96; H, 6.46; N, 3.00. Found: C, 53.88; H, 6.35; N, 2.62.

***cis*-3d**: yield 2.9 g (19%); mp 154–156 °C; IR (KBr) 2959, 1329, 1260, 1171, 1125, 1069, 843 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.22 (s, 9 H), 2.85 (s, 2 H), 3.42 (dd, 1 H, J = 18.6, 5.4 Hz), 3.45 (s, 3 H), 3.67 (dd, 1 H, J = 18.6, 11.1 Hz), 4.37 (d, 1 H, J = 15.4 Hz), 5.97 (d, 1 H, J = 15.4 Hz), 6.30 (dd, 1 H, J = 11.1, 5.4 Hz), 7.15 (d, 1 H, J = 6.9 Hz), 7.29–7.42 (m, 3 H), 7.78 (d, 2 H, J = 8.3 Hz), 8.14 (bs, 2 H). Anal. Calcd for $C_{21}H_{27}F_3INSi$: C, 49.90; H, 5.38; N, 2.77. Found: C, 50.15; H, 5.51; N, 2.95.

***trans*-3d**: yield 2.7 g (18%); mp 174–175 °C; IR (KBr) 1620, 1460, 1329, 1258, 1169, 1123, 1069, 849, 766 cm^{-1}; ^1H NMR ($CDCl_3$) δ 0.34 (s, 9 H), 3.15 (d, 1 H, J = 14.5 Hz), 3.16 (s, 3 H), 3.53 (dd, 1 H, J = 18.8, 7.4 Hz), 3.64 (dd, 1 H, J = 18.8, 6.6 Hz), 4.00 (d, 1 H, J = 14.5 Hz), 4.28 (d, 1 H, J = 15.2 Hz), 5.38 (d, 1 H, J = 15.2 Hz), 6.30 (m, 1 H), 7.18 (d, 1 H, J = 7.5 Hz), 7.29 (1 H, d, J = 8.6 Hz), 7.32–7.42 (m, 2 H), 7.73 (d, 2 H, J = 7.7 Hz), 8.00 (bs, 2 H). Anal. Calcd for $C_{21}H_{27}F_3INSi$: C, 49.90; H, 5.38; N, 2.77. Found: C, 49.95; H, 5.55; N, 2.76.

Reaction of 3 with Cesium Fluoride. General Procedure. Ammonium salt **3a–d** (1 mmol) was placed in a 30 mL flask equipped with a magnetic stirrer and a test tube which was connected to the flask by a short piece of rubber tubing. CsF (0.76 g, 5 mmol) was placed in the test tube. The apparatus was dried under reduced pressure and was flushed with N_2. DMF (10 mL) was added to the flask by syringe, and then CsF was added from the test tube. The mixture was stirred for 0.5 or 3 h at room temperature (or 0 °C). The reaction mixture was poured into water and extracted with ether. The ethereal extract was washed with water, dried ($MgSO_4$), and concentrated under reduced pressure to give a mixture of (*E*)- and (*Z*)-isomers of 3-substituted 6-methyl-4a,5,6,7-tetrahydro-12*H*-dibenzo[*c*,*g*]azonine (*E*)-**5**, (*Z*)-**5**, 3-substituted 6-methyl-6,7,12,13-tetrahydro-5*H*-dibenzo[*c*,*g*]azonine **6**, 4-(4-substituted phenyl)-2-methyl-2,3,4,5-tetrahydro-2-benzazepine **7**, and (*E*)- and (*Z*)-isomers of 1-(4-substituted phenyl)-2-[2-[(dimethylamino)methyl]phenyl]-ethylenes (*E*)-**8** and (*Z*)-**8**. The products were separated on silica gel columns (hexane/ethyl acetate = 6:1 to 1:1). Compounds **6**, **7**, (*E*)-**8**, and (*Z*)-**8** were distilled under reduced pressure. The ratios were determined on the basis of the proton ratios of ^1H NMR of the ethereal extracts (Table 2).

(*Z*)-5a: mp 84–86 °C; IR (KBr) 3029, 2946, 2832, 1447, 1038, 860, 752, 718, 652 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.27 (s, 3 H), 2.42 (dd, 1 H, J = 12.8, 10.6 Hz), 2.59 (dd, 1 H, J = 12.8, 4.9 Hz), 3.22 (dd, 1 H, J = 13.4, 5.5 Hz), 3.54 (d, 1 H, J = 14.1 Hz), 3.77 (d, 1 H, J = 14.1 Hz), 4.01 (m, 1 H), 4.15 (m, 1 H), 5.65–5.78 (m, 2 H), 5.82 (m, 2 H), 5.95–6.05 (ddd, 1 H, J = 9.2, 5.6, 1.0 Hz), 7.04 (d, 1 H, J = 6.9 Hz), 7.12–7.23 (m, 3 H); UV λ_{max}^{hexane} 312 nm (ϵ 10 100). Anal. Calcd for $C_{17}H_{19}N$: C, 86.03; H, 8.07; N, 5.90. Found: C, 85.94; H, 8.12; N, 5.90. The stereochemistry was confirmed by X-ray crystallographic analysis.[4]

7a: bp 120–123 °C (1.0 mmHg); IR (film) 2920, 1451, 1047, 702, 619 cm^{-1}; NMR ($CDCl_3$) δ 2.36 (s, 3 H), 2.93 (d, 1 H, J = 14.1 Hz), 3.04–3.18 (m, 3 H), 3.38–3.45 (m, 1 H), 3.72 (d, 1 H, J = 14.3 Hz), 4.15 (d, 1 H, J = 14.3 Hz), 7.11–7.19 (m, 4 H), 7.21–7.25 (m, 3 H), 7.31–7.35 (m, 2 H). Anal. Calcd for $C_{17}H_{19}N$: C, 86.03; H, 8.07; N, 5.90. Found: C, 86.06; H, 8.29; N, 5.91.

(*E*)-8a: bp 125–127 °C (1.0 mmHg); IR (film) 3025, 2940, 2816, 2768, 2361, 1495, 1451, 1022, 760 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.21 (s, 6 H), 3.43 (s, 2 H), 6.93 (d, 1 H, J = 16.5 Hz), 7.21–7.31 (m, 4 H), 7.36 (m, 2 H), 7.53 (m, 2 H), 7.54 (d, 1 H, J = 16.5 Hz), 7.65 (d, 1 H, J = 7.7 Hz). Anal. Calcd for $C_{17}H_{19}N$: C, 86.03; H, 8.07; N, 5.90. Found: C, 86.04; H, 8.28; N, 5.86.

(*Z*)-8a: bp 125–127 °C (1.0 mmHg); IR (film) 2972, 2814, 2766, 1447, 1026, 781 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.24 (s, 6 H), 3.42 (s, 2 H), 6.62 (d, 1 H, J = 12.2 Hz), 6.80 (d, 1 H, J = 12.2 Hz), 7.07–7.17 (m, 7 H), 7.23 (td, 1 H, J = 7.5, 1.5 Hz), 7.40 (d, 1 H, J = 7.5 Hz). Anal. Calcd for $C_{17}H_{19}N$: C, 86.03; H, 8.07; N, 5.90. Found: C, 86.04; H, 8.27; N, 5.88.

(*Z*)-5b (an undistillable waxy oil): IR (film) 3017, 2936, 2832, 2785, 1449, 1042, 868, 748 cm^{-1}; ^1H NMR ($CDCl_3$) δ 1.78 (s, 3 H), 2.26 (s, 3 H), 2.37 (dd, 1 H, J = 12.5, 10.6 Hz), 2.55 (dd, 1 H, J = 12.5, 5.0 Hz), 3.20 (dd, 1 H, J = 14.5, 5.9 Hz), 3.51 (d, 1 H, J = 13.9 Hz), 3.75 (d, 1 H, J = 13.9 Hz), 3.93 (m, 1 H), 4.15 (m,

1 H), 5.50 (d, 1 H, J = 5.5 Hz), 5.60 (d, 1 H, J = 9.5 Hz), 5.73 (ddd, 1 H, J = 11.5, 5.9, 1.0 Hz), 5.98 (d, 1 H, J = 9.5 Hz), 7.03 (d, 1 H, J = 7.2 Hz), 7.09–7.22 (m, 3 H); UV λ_{max}^{hexane} 310 nm (ϵ 9 400).

7b: mp 58–60 °C; IR (KBr) 2922, 1514, 1451, 1115, 1051, 808, 750, 625, 530 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.34 (s, 3 H), 2.35 (s, 3 H), 2.91 (d, 1 H, J = 13.4 Hz), 2.97–3.06 (m, 2 H), 3.14 (d, 1 H, J = 9.8 Hz), 3.39 (dd, 1 H, J = 14.0, 10.4 Hz), 3.71 (d, 1 H, J = 14.0 Hz), 4.13 (d, 1 H, J = 14.0 Hz), 7.10–7.19 (m, 8 H). Anal. Calcd for $C_{18}H_{21}NO$: C, 86.01; H, 8.42; N, 5.57. Found: C, 85.98; H, 8.58; N, 5.54.

(*E*)-8b: bp 140 °C (0.6 mmHg); IR (film) 2942, 2814, 2764, 1698, 1512, 1456, 1022, 804, 750 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.28 (s, 6 H), 2.36 (s, 3 H), 3.51 (s, 2 H), 6.98 (d, 1 H, J = 16.3 Hz), 7.17 (d, 2 H, J = 7.3 Hz), 7.19–7.30 (m, 3 H), 7.42 (d, 2 H, J = 8.2 Hz), 7.55 (d, 1 H, J = 16.3 Hz), 7.63–7.65 (m, 1 H). Anal. Calcd for $C_{18}H_{21}NO$: C, 86.01; H, 8.42; N, 5.57. Found: C, 85.96; H, 8.54; N, 5.46.

(*Z*)-8b: bp 140 °C (0.6 mmHg); IR (film) 2940, 2814, 2764, 1512, 1454, 1022, 750 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.25 (s, 6 H), 2.26 (s, 3 H), 3.43 (s, 2 H), 6.57 (d, 1 H, J = 12.4 Hz), 6.74 (d, 1 H, J = 12.4 Hz), 6.96 (s, 4 H), 7.08–7.26 (m, 3 H), 7.41 (d, 1 H, J = 6.9 Hz). Anal. Calcd for $C_{18}H_{21}NO$: C, 86.01; H, 8.42; N, 5.57. Found: C, 85.78; H, 8.51; N, 5.67.

(*E*)-5c (the presence was confirmed on the ^{1}H NMR spectrum of the mixture, but isolation was impossible because of its instability at room temperature): ^{1}H NMR ($CDCl_3$) δ 1.98 (dd, 1 H, J = 12.8, 9.2 Hz), 2.41 (s, 3 H), 2.68 (dd, 1 H, J = 12.8, 5.5 Hz), 2.78 (d, 1 H, J = 12.8 Hz), 2.94 (m, 1 H), 3.40–3.45 (m, 1 H), 3.42 (d, 1 H, J = 12.8 Hz), 3.57 (s, 3 H), 4.09 (dd, 1 H, J = 14.7, 12.2 Hz), 4.94 (dd, 1 H, J = 6.1, 2.4 Hz), 5.67 (dd, 1 H, J = 12.2, 1.8 Hz), 5.91 (d, 1 H, J = 9.8 Hz), 6.62 (d, 1 H, J = 9.8 Hz), 6.99 (dd, 1 H, J = 7.3, 1.2 Hz), 7.12–7.24 (m, 3 H).

(*Z*)-5c (an undistillable waxy oil): IR (film) 2936, 2832, 1651, 1447, 1416, 1221, 1171, 789, 752 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.25 (s, 3 H), 2.40 (dd, 1 H, J = 12.6, 10.7 Hz), 2.55 (dd, 1 H, J = 12.6, 4.8 Hz), 3.23 (dd, 1 H, J = 13.1, 5.2 Hz), 3.56 (s, 3 H), 3.73 (d, 1 H, J = 11.9 Hz), 3.82 (d, 1 H, J = 11.9 Hz), 4.02 (m, 1 H), 4.19 (m, 1 H), 4.68 (dd, 1 H, J = 5.4, 2.0 Hz), 5.60 (dd, 1 H, J = 9.7, 2.0 Hz), 5.74 (dd, 1 H, J = 11.1, 5.2 Hz), 6.04 (d, 1 H, J = 9.7 Hz), 7.03 (d, 1 H, J = 6.8 Hz), 7.12–7.24 (m, 3 H); UV λ_{max}^{hexane} 315 nm (ϵ 5300). Anal. Calcd for $C_{18}H_{21}NO$: C, 80.86; H, 7.92; N, 5.24. Found: C, 80.77; H, 8.07; N, 5.19.

7c: mp 84–87 °C; IR (Nujol) 1609, 1512, 1248, 1181, 1051, 1030, 820, 766 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.36 (s, 3 H), 2.93 (d, 1 H, J = 14.1 Hz), 3.04–3.18 (m, 3 H), 3.38–3.45 (m, 1 H), 3.72 (d, 1 H, J = 14.3 Hz), 3.80 (s, 3 H), 4.15 (d, 1 H, J = 14.3 Hz), 7.11–7.19 (m, 4 H), 7.21–7.25 (m, 3 H), 7.31–7.35 (m, 1 H). Anal. Calcd for $C_{18}H_{21}NO$: C, 80.86; H, 7.92; N, 5.24. Found: C, 80.77; H, 8.10; N, 5.20.

(*E*)-8c: bp 135 °C (1.5 mmHg); IR (film) 2940, 2814, 2766, 1607, 1512, 1462, 1250, 1175, 1034, 820, 750 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.28 (s, 6 H), 3.49 (s, 2 H), 3.83 (s, 3 H), 6.89–6.92 (m, 2 H), 6.96 (d, 1 H, J = 15.9 Hz), 7.19–7.21 (m, 1 H), 7.25–7.29 (m, 2 H), 7.45–7.49 (m, 3 H), 7.63 (d, 1 H, J = 7.3 Hz). Anal. Calcd for $C_{18}H_{21}NO$: C, 80.86; H, 7.92; N, 5.24. Found: C, 80.87; H, 8.10; N, 5.15.

(*Z*)-8c: bp 130 °C (1.3 mmHg); IR (film) 2942, 2814, 2766, 1607, 1510, 1460, 1254, 1177, 1034, 835, 752 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.23 (s, 6 H), 3.41 (s, 2 H), 3.74 (s, 3 H), 6.62 (d, 1 H, J = 12.2 Hz), 6.80 (d, 1 H, J = 12.2 Hz), 7.07–7.17 (m, 6 H), 7.23 (td, 1 H, J = 7.5, 1.5 Hz), 7.40 (d, 1 H, J = 7.5 Hz). Anal. Calcd for $C_{18}H_{21}NO$: C, 80.86; H, 7.92; N, 5.24. Found: C, 80.61; H, 8.06; N, 5.17.

(*Z*)-5d (an undistillable waxy oil): IR (KBr) 2834, 2801, 1345, 1327, 1289, 1165, 1107, 1065, 882, 768, 604 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.27 (s, 3 H), 2.43 (dd, 1 H, J = 12.9, 10.4 Hz), 2.67 (dd, 1 H, J = 12.9, 5.0 Hz), 3.26 (dd, 1 H, J = 14.5, 5.9 Hz), 3.56 (d, 1 H, J = 13.9 Hz), 3.77 (d, 1 H, J = 13.9 Hz), 4.06–4.15 (m, 2 H), 5.78 (d, 1 H, J = 9.7 Hz), 5.84 (dd, 1 H, J = 11.6, 5.4 Hz), 6.15 (d, 1 H, J = 9.7 Hz), 6.29 (d, 1 H, J = 4.9 Hz), 7.05 (d, 1 H, J = 6.6 Hz), 7.12–7.25 (m, 3 H); UV λ_{max}^{hexane} 310 nm (ϵ 10 500).

6d: mp 89–90 °C; IR (KBr) 2960, 1335, 1169, 1111, 1082, 831, 762 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.58 (s, 3 H), 2.94–3.02 (m, 4 H), 3.37 (s, 2 H), 3.42 (s, 2 H), 7.17–7.36 (m, 5 H), 7.50 (d, 1 H, J = 7.9 Hz), 7.58 (s, 1 H). Anal. Calcd for $C_{18}H_{18}F_3N$: C, 70.80; H, 5.94; N, 4.59. Found: C, 70.56; H, 6.10; N, 4.54.

7d: mp 65–66 °C; IR (KBr) 1618, 1420, 1325, 1163, 1136, 1113, 1049, 822, 752 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.38 (s, 3 H), 2.93 (d, 1 H, J = 13.9 Hz), 3.09–3.16 (m, 3 H), 3.39–3.46 (m, 1 H), 3.77 (d, 1 H, J = 14.3 Hz), 4.18 (d, 1 H, J = 14.3 Hz), 7.12–7.14 (m, 1 H), 7.17–7.21 (m, 3 H), 7.34 (d, 2 H, J = 8.0 Hz), 7.59 (d, 2 H, J = 8.0 Hz). Anal. Calcd for $C_{18}H_{18}F_3N$: C, 70.80; H, 5.94; N, 4.59. Found: C, 70.67; H, 6.24; N, 4.40.

(*E*)-8d: bp 125–126 °C; IR (film) 2818, 2770, 1645, 1325, 1165, 1125, 1067, 822, 754 cm^{-1}; ^{1}H NMR ($CDCl_3$) δ 2.31 (s, 6 H), 3.56 (s, 2 H), 7.03 (d, 1 H, J = 16.1 Hz), 7.24–7.34 (m, 3 H), 7.61 (s, 4 H), 7.65 (d, 1 H, J = 7.7 Hz), 7.73 (d, 1 H, J = 16.1 Hz). Anal. Calcd for $C_{18}H_{18}F_3N$: C, 70.80; H, 5.94; N, 4.59. Found: C, 70.92; H, 5.92; N, 4.69.

(*Z*)-8d (not isolated, the presence was confirmed by characteristic vinyl-H peaks on the ^{1}H NMR spectrum of the mixture): ^{1}H NMR ($CDCl_3$) δ 6.67 (d, 1 H, J = 12.2 Hz), 6.99 (d, 1 H, J = 12.2 Hz).

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