N_2 was treated sequentially with cyclohexanone (49.0 mg, 0.5 mmol, 1.0 equiv) in chloroform (0.5 mL) and pyrrolidine (36.0 mg, 0.5 mmol, 1.0 equiv). Active 4-Å molecular sieves (ca. 0.2 g) were added, and the reaction mixture was warmed at 45 °C (32 h). Chromatography (SiO_2, 50% ether–pentane eluant) afforded 44.0 mg (66.5 mg theoretical, 66%) of pure 5,6,7,8-tetrahydroisoquinoline as a light yellow oil identical in all respects with authentic material.[3]

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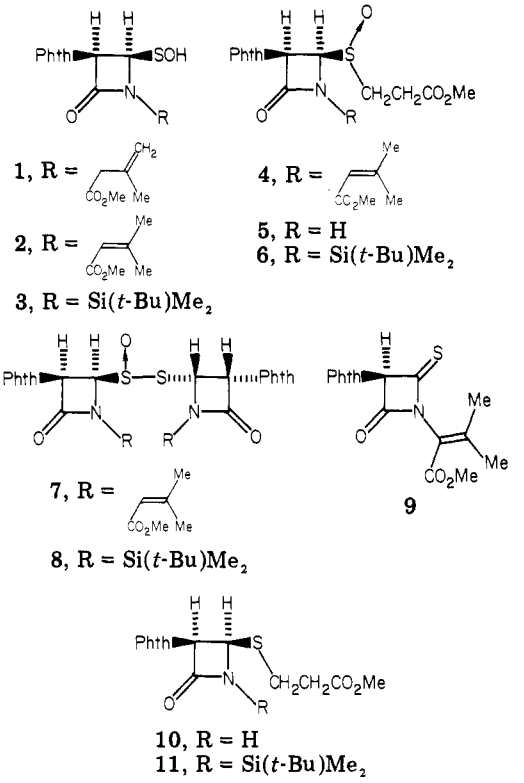
Registry No. 3a, 290-38-0; **3b,** 6498-02-8; **3c,** 80375-59-3; cyclopentanone, 120-92-3; cycloheptanone, 502-42-1; 3-pentanone, 96-22-0; cyclohexanone, 108-94-1; 1-cyclohexylethanone, 823-76-7; 1-cyclopentylethanone, 6004-60-0; 1-(3-hydroxycyclopentyl)ethanone, 80375-60-6; 6,7-dihydro-5*H*-2-pyridine, 533-35-7; 6,7,8,9-tetrahydro-5*H*-cyclohepta[*c*]pyridine, 71579-81-2; 4-ethyl-3-methylpyridine, 20815-29-6; 5,6,7,8-tetrahydroisoquinoline, 36556-06-6; 4-cyclohexylpyridine, 13669-35-7; ethyl 4-ethyl-3-methyl-2-pyridinecarboxylate, 80375-61-7; 3-(dimethoxymethyl)-4-ethyl-5-methylpyridine, 80375-62-8; 4-cyclopentyl-3-(dimethoxymethyl)pyridine, 80375-63-9; *cis*-3-(dimethoxymethyl)-4-(3-hydroxycyclopentyl)-pyridine, 80375-64-0; *trans*-3-(dimethoxymethyl)-4-(3-hydroxycyclopentyl)pyridine, 80375-65-1.

Chart I[a]



[a] Phth = phthalimido.

Thermally Stable Sulfenic Acid: (3*R*,4*R*)-1-(*tert*-Butyldimethylsilyl)-3-phthalimido-2-oxoazetidine-4-sulfenic Acid

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Except for a few sulfenic acids deriving from anthraquinone[1] and from uracyl,[2] which are stabilized by intramolecular hydrogen bonding, sulfenic acids have been considered as highly reactive and elusive compounds. Evidence for the formation of *tert*-butylsulfenic acid in the thermolysis of di-*tert*-butyl sulfoxide was provided by NMR and IR spectral data and by its chemical derivatization in situ.[3] Some aliphatic and aromatic sulfenic acids were produced by flash vacuum pyrolysis of sufoxides and isolated at −196 °C but underwent a spontaneous self-condensation to the corresponding thiolsulfinate on warming to ambient temperature.[4] Various sulfenic acids have been reported as reactive transient species in a wide variety of chemical reactions[5] and biological transformations.[6] Their isolation, except in the very special instances and conditions described above, was unsuccessful until 1974, when the Lilly group reported the isolation of the 2-oxoazetidine-4-sulfenic acids 1 and 2 in crystalline forms at room temperature.[7]

These compounds are not stable in solution: the sulfenic acid 1 (Chart I) underwent a spontaneous annelation to a penicillin sulfoxide, thus reverting the electrocyclic process by which it was originally obtained, while the sulfenic acid 2 underwent a self-condensation to the corresponding thiosulfinate 7.[8] In a previous paper from this laboratory the conversion of the β-lactam sulfoxide 4 into the 4-thioxo-2-azetidinone 9 was described.[9] This transformation which occurred at 100 °C in nonpolar organic solvents involved the generation of the sulfenic acid 2, followed by its spontaneous condensation to the thiosulfinate 7 which afforded the thioxo compound 9. We now describe the synthesis of the sulfenic acid 3 which was found to exhibit an unusually high thermal stability.

Attempts to prepare the silyl derivative 6 by treatment of the β-lactam sulfoxide 5[10] with *tert*-butyldimethylsilyl chloride and triethylamine in DMF resulted in decomposition of the β-lactam. The sulfoxide 5 was therefore reduced quantitatively (trifluoroacetic anhydride and sodium iodide)[11] to the sulfide 10 which was converted to the *N*-silyl derivative 11 (90%).

Oxidation of the sulfide 11 (*m*-chloroperbenzoic acid, methylene dichloride −40 °C) afforded the β-lactam sulf-

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0022-3263/82/1947-0897$01.25/0

oxide **6** as a mixture of two diastereoisomers from which the major isomer was obtained in a pure crystalline form (67%).

Heating the sulfoxide **6** in benzene at 60 °C for 24 h afforded the 2-oxoazetidine-4-sulfenic acid **3**: 79%; mp 170–172 °C; $[\alpha]^{26}_D$ −118.3° (*c* 0.4, $CHCl_3$). The structure of this compound was determined by its spectral data and elemental microanalysis and then corroborated by converting it quantitatively to the sulfoxide **6** by treating it with methyl acrylate either for 10 min at 60 °C or for 2 h at ambient temperature.

The sulfenic acid **3** is remarkably stable: no decomposition was detected after storage for more than 6 months at 0 °C or after being heated in benzene at 80 °C for 24 h. However, it decomposed upon being heated in xylene at 130 °C. The high stability of this particular sulfenic acid seems to derive from steric hindrance due to the bulky *tert*-butyldimethylsilyl group which prevents its self-condensation into the thiosulfinate **8**.

Experimental Section

NMR data were determined on an 80-MHz Varian FT-80A or a 90-MHz Bruker FT-HFX-10 spectrometer. For other general experimental details see ref 10.

(3*R*,4*R*)-4-[[2-(Methoxycarbonyl)ethyl]thio]-3-phthalimido-2-azetidinone (10). To an ice-cold mixture of the (*R*)- and the (*S*)-sulfoxides **5** (160 mg, 0.5 mmol, 2:1 ratio, respectively)[10] and NaI (200 mg, 1.3 mmol) in acetone (2.5 mL) was added a solution of trifluoroacetic anhydride (0.3 mL, 2.2 mmol) in acetone (6 mL) dropwise during 30 min. To the residue obtained after evaporation was added water (20 mL), and the product was extracted with chloroform, washed with a 1 N solution of sodium thiosulfate (15 mL) and with brine, dried, and evaporated to give the sulfide **10**: 150 mg (98%); mp 126–128 °C (after trituration with ether); IR ($CHCl_3$) 3420, 1790, 1775, 1740 (sh), 1730 cm^{-1}; NMR (80 MHz, $CDCl_3$) δ 2.72 (m, $SCH_2CH_2CO_2$), 3.61 (s, OMe), 5.15 (d, *J* = 4.7 Hz, 4-H), 5.63 (dd, *J* = 4.7, 1.0 Hz, 3-H), 6.53 (br, NH), 7.83 (m, Phth); high-resolution mass spectrum, calcd for $C_{15}H_{14}N_2O_5S$ *m/e* 334.0623, found *m/e* 334.0626; *m/e* 334 (M^+), 291 (M^+ − NH=C=O), 247 (M^+ − $SCH_2CH_2CO_2CH_3$), 187 (PhthCH=C=O^+).

(3*R*,4*R*)-1-(*tert*-Butyldimethylsilyl)-4-[[2-(methoxycarbonyl)ethyl]thio]-3-phthalimido-2-azetidinone (11). To a solution of the sulfide **10** (1.5 g, 4.5 mmol) in DMF (20 mL) were added *tert*-butyldimethylsilyl chloride (800 mg, 5.3 mmol) and triethylamine (2 mL, 14.5 mmol). After being stirred for 15 min at room temperature, the reaction mixture was poured into benzene–ethyl acetate (1:1, 150 mL) and washed with water and with brine. The organic solution was dried, and the residue obtained after evaporation was chromatographed on a short silica gel column (toluene–ethyl acetate, 3:1) to give the title compound **11**: 1.8 g (90%); mp 98–99 °C (from benzene–hexane); $[\alpha]^{26}_D$ −90.0° (*c* 0.9, $CHCl_3$); IR ($CHCl_3$) 1785, 1755, 1730 cm^{-1}; NMR (80 MHz, $CDCl_3$) δ 0.35 and 0.36 (2 s, $SiMe_2$), 1.06 (s, *t*-Bu), 2.59 (m, $SCH_2CH_2CO_2$), 3.51 (s, OMe), 4.94 (d, *J* = 4.9 Hz, azetidine H), 5.63 (d, *J* = 4.9 Hz, azetidine H), 7.82 (m, Phth); high-resolution mass spectrum, calcd for $C_{21}H_{28}SiN_2O_5S$ *m/e* 448.1487, found *m/e* 448.1517; *m/e* 448 (M^+), 391 (M^+ − C_4H_9), 361 (M^+ − $CH_2CH_2CO_2CH_3$), 329 (M^+ − $SCH_2CH_2CO_2CH_3$), 291 (M^+ − *t*-Bu(Me_2)SiN=C=O).

(3*R*,4*R*)-1-(*tert*-Butyldimethylsilyl)-4-[[2-(methoxycarbonyl)ethyl]sulfinyl]-3-phthalimido-2-azetidinone (6). To a stirred solution of the sulfide **11** (1.25 g, 2.8 mmol) in CH_2Cl_2 (100 mL) at −40 °C was added a solution of *m*-chloroperbenzoic acid (500 mg, 87%, 2.5 mmol) in CH_2Cl_2 (100 mL) during 90 min. The solution was washed with aqueous $NaHCO_3$, water, and with brine, dried, and evaporated. The residue contained two isomers of the sulfoxide **6** (TLC and NMR). The reaction mixture was unstable on a silica gel plate. The major isomer of **6** was isolated by crystallization from benzene–hexane: 870 mg (67%); mp 136–138 °C; IR ($CHCl_3$) 1785 (sh), 1770, 1730 cm^{-1}; NMR (90 MHz, $CDCl_3$) δ 0.37 and 0.41 (2 s, Me_2Si), 1.08 (s, *t*-Bu), 2.7–2.8 (m, $S(O)CH_2CH_2CO_2$), 3.67 (s, OMe), 4.67 (d, *J* = 5.3 Hz, azetidine H), 5.81 (d, *J* = 5.3 Hz, azetidine H), 7.79 (m, Phth). Anal. Calcd for $C_{21}H_{28}N_2O_6SSi$: C, 54.29; H, 6.07; N, 6.03. Found: C, 54.03; H, 5.88; N, 6.12.

The mother liquor contained a mixture of the two isomeric sulfoxides. For minor isomer of **6** (ca. 20%): NMR δ 1.12 (s, *t*-Bu), 3.38 (s, OMe), 4.77 (d, *J* = 5.3 Hz, azetidine H), 5.68 (d, *J* = 5.3 Hz, azetidine H).

(3*R*,4*R*)-1-(*tert*-Butyldimethylsilyl)-3-phthalimido-2-oxoazetidine-4-sulfenic Acid (3). The sulfoxide **6** (100 mg, 0.2 mmol, major isomer) was heated in benzene (25 mL) at 60 °C for 24 h. The solvent was evaporated, and the residue was crystallized (from benzene–hexane) to give the sulfenic acid **3**: 64 mg (79%); small colorless crystals; mp 170–172 °C dec; $[\alpha]^{26}_D$ −118.3° (*c* 0.4, $CHCl_3$); IR (KBr) 3250 (br), 1785 (sh), 1730 cm^{-1}; NMR (80 MHz, $CDCl_3$) δ 0.39 and 0.43 (2 s, $SiMe_2$), 1.05 (s, *t*-Bu), 4.55 (br s, SOH), 5.20 (d, *J* = 5.3 Hz, azetidine H), 5.81 (d, *J* = 5.3 Hz, azetidine H), 7.83 (m, Phth); high-resolution mass spectrum, calcd for $C_{17}H_{22}N_2O_4SSi$ *m/e* 378.1069, found *m/e* 378.1070; *m/e* 378 (M^+), 361 (M^+ − OH), 329 (M^+ − SOH), 321 (M^+ − C_4H_9), 221 (m^+ − *t*-BuMe$_2$SiN=C=O), 203 (PhthCH=C=S^+), 187 (PhthCH=C=O^+). Anal. Calcd for $C_{17}H_{22}N_2O_4SSi$: C, 53.94; H, 5.86; N, 7.40; S, 8.47. Found: C, 54.20; H, 6.01; N, 7.28; S, 8.75.

Reaction of the Sulfenic Acid 3 with Methyl Acrylate. A solution of the sulfenic acid **3** (20 mg, 0.059 mmol) in methyl acrylate (1 mL) was heated at 60 °C for 10 min. The solvent was evaporated to afford the sulfoxide **6** (quantitative, 2:1 mixture of two isomers). A similar result was obtained when the reaction was performed at ambient temperature for 2 h.

Colorflammine and Berbacolorflammine, Two New Orange-Colored Bis[benzylisoquinoline] Alkaloids from *Pycnarrhena longifolia*

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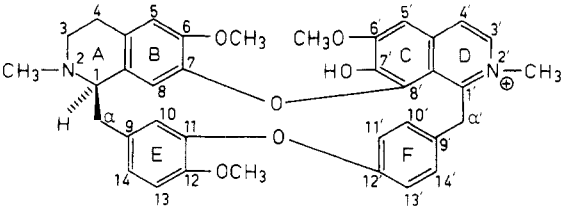
In continuation of our research on Indonesian medicinal plants we studied the alkaloids from a chloroform fraction of *Pycnarrhena longifolia*. In a previous communication the identification of some tertiary bis[benzylisoquinoline] alkaloids, i.e., obaberine, homoaromaline, limacine, aromoline, krukovine, and daphnoline, in a toluene fraction and of some quaternary alkaloids, i.e., magnoflorine and pycnarrhine, in an aqueous fraction were described.[1]

Besides the tertiary alkaloids already found in the toluene fraction, two orange-colored alkaloids were typical for the chloroform fraction. This report describes the isolation and structure elucidation of these two new bis[benzylisoquinoline] alkaloids.

In neutral methanol colorflammine **1** showed UV ab-



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sorption maxima at 439, 333, 292, and 233 nm. Basification did not give shifts and acidification with dilute hydrochloric acid led to a colorless solution with UV maxima at

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