at 25 °C for 12 h. The workup and purification as described above in method A gave (95%) acid **16** as a white solid: 520 mg, mp 346 °C dec; ^{1}H NMR (Me_2SO-d_6) δ 1.82–2.40 (m, C*H*, CH_2, 63 H), 4.45 (bs, OH, 9 H, exchanged with D_2O), 6.28 (bs, NH, 4 H); ^{13}C NMR (Me_2SO-d_6) δ 29.6 (γ-CH), 30.2 ($NHCCH_2CH_2COOH$), 31.0, 32.4 ($NHCCH_2CH_2CONH$), 37.8 (δ-CH_2), 40.1 (β-CH_2), 42.5 (α-C), 58.0 ($NHCCH_2CH_2CONH$), 58.4 ($NHCCH_2CH_2COOH$), 177.6 (COOH), 179.8 (CONH); IR (KBr) 3360, 3340–2600, 2900, 1744, 1690, 1245, 1090 cm^{-1}. Anal. Calcd for $C_{51}H_{76}O_{22}N_4$: C, 55.83; H, 6.98; N, 5.11. Found: C, 55.71; H, 7.04; N, 4.98.

Acknowledgment. We thank the National Science Foundation (DMR 86-00929; 89-06792) and the donors of the Petroleum Research Foundation, administered by the American Chemical Society, for partial support of this research.

Registry No. 1, 711-01-3; 2, 136586-90-8; 3b, 36949-72-1; 4b, 136586-91-9; 5b, 136586-92-0; 6, 136586-93-1; 7, 136586-94-2; 8, 136586-95-3; 9, 136586-96-4; 10, 136586-97-5; 11, 136586-98-6; 12, 136586-99-7; 13, 136587-00-3; 14, 136587-01-4; 15, 136587-02-5; 16, 136587-03-6; $H_2NC(CH_2OH)_3$, 77-86-1; $MeSO_2Cl$, 124-63-0; $HC(CO_2Et)_3$, 6279-86-3; $O_2NC(CH_2CH_2CH_2OAc)_3$, 129918-72-5; $MeNO_2$, 75-52-5; *t*-BuOC(O)CH=CH_2, 1663-39-4; 1-adamantanecarbonyl chloride, 2094-72-6; 1-(2-hydroxymethyl)-adamantane, 6240-11-5; triton B, 100-85-6.

Notes

Synthesis of the Highly Oxygenated Quassinoid Shinjulactone D

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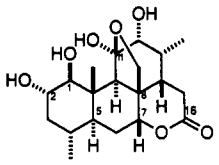
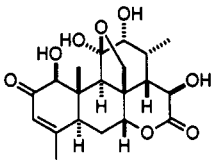
Shinjulactone D (1) belongs to a group of highly oxygenated quassinoids isolated from *Ailanthus altissima* Swingle.[1] The C(8), C(11) bridged hemiketal structural unit present in shinjulactone D is common to a large number of quassinoids (cf. glaucarubolone, 2). The role, if any, that this functional arrangement plays in the observed pharmacological properties[2] (e.g. antitumor activity) of quassinoids remains unclear. We detail below the first synthesis of shinjulactone D which confirms the structural assignment for 1 which was based on ^{1}H NMR and ^{13}C NMR measurements recorded by Takahashi and coworkers in 1983.[1]

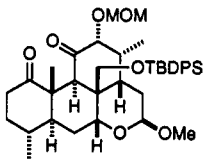


1



2

The synthesis of shinjulactone D commences with the known tetracyclic compound 3 which served as a key intermediate in a recently completed total synthesis of chaparrinone.[3] With the necessary functionality already present in ring C of 3 for construction of the C(8), C(11) bridged hemiketal unit, the primary task was elaboration of the vicinal trans-diol arrangement in ring A. Toward this end tetracyclic dione 3 was selectively converted (88%) into silyl enol ether 4 by employing lithium hexamethyldisilazide. The selective formation of 4 was anticipated due to the fact that the C(9) proton is extremely hindered. The trans-diequatorial arrangement of the vicinal C(1), C(2) diol was realized via hydroboration of the less hindered α face of the silyl enol ether.[4] Thus addition of diborane in tetrahydrofuran to 4 provided in 72% yield tetracyclic diol 5. Protection of the C(1), C(2) diol as its cyclic carbonate followed by selective hydrolysis of the protected lactone and subsequent oxidation at C(16) provided crystalline tetracyclic lactone 6, mp 188–189 °C.



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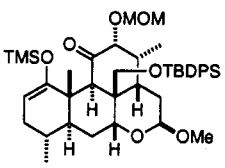

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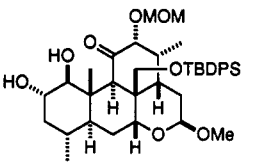

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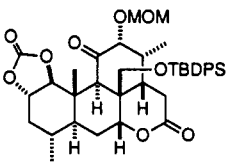
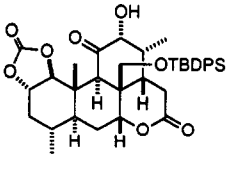
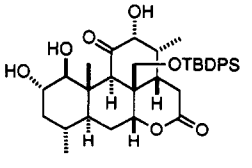


6

Completion of the synthesis of shinjulactone D was realized by a three-step process. Trimethylsilyl iodide induced cleavage of the C(12) methoxymethyl ether afforded (90%) ketol 7, mp 208–210 °C, which upon treatment with potassium carbonate in methanol–tetrahydrofuran (1:1) generated crystalline tetracyclic triol 8 in 87% yield.



7



8

Exposure of 8 to tetra-*n*-butylammonium fluoride in tetrahydrofuran provided crystalline racemic shinjulactone D whose spectral properties (IR, ^{1}H NMR, ^{13}C NMR) were identical with spectra kindly provided by Professor Tak-

(1) Ishibashi, M.; Furuno, T.; Tsuyuki, T.; Takahashi, T.; Matsushita, K. *Chem. Pharm. Bull.* **1983**, *31*, 2179–2181. Furuno, T.; Ishibashi, M.; Noara, H.; Murae, T.; Hirota, H.; Tsuyuki, T.; Takahashi, T. *Bull. Chem. Soc. Jpn.* **1984**, *57*, 2484–2489.

(2) (a) Cassady, J. M.; Suffness, M. In *Anticancer Agents Based on Natural Product Models*; Academic Press: New York 1980; pp 254–267. (b) Polonsky, J. Chemistry and Biological Activity of the Quassinoids. In *The Chemistry and Chemical Taxonomy of the Rutales*; Waterman, P. G., Grundon, M. F., Eds.; Academic Press: New York, 1983; p 247.

(3) Gross, R. S.; Grieco, P. A.; Collins, J. L. *J. Am. Chem. Soc.* **1990**, *112*, 9436–9437.

(4) Klein, J.; Levene, R.; Dunkelblum, E. *Tetrahedron Lett.* **1972**, 2845–2848.

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ahashi. The synthesis of 1 thus confirms the structural assignment for 1, which was based solely on ^1H NMR and ^{13}C NMR measurements.

Experimental Section

Infrared (IR) spectra were taken as a solution in chloroform or as KBr pellets. Absorption intensities are indicated as strong (s), medium (m), or weak (w). Elemental analyses were performed by Robertson Laboratories, Inc., Madison, NJ, and Galbraith Laboratories, Inc., Knoxville, TN. Melting points are uncorrected. Reactions were monitored by thin-layer chromatography (TLC) using E. Merck precoated silica gel 60 F-254 (0.25 mm thickness) plates. The plates were visualized by immersion in a *p*-anisaldehyde solution and warming on a hotplate. E. Merck silica gel 60 (230–400 mesh) was used for flash chromatography.

All solvents are reagent grade unless otherwise stated. Anhydrous solvents were dried immediately before use. Dichloromethane, acetonitrile, hexamethyldisilazane, and chlorotrimethylsilane were distilled from calcium hydride. Methanol was distilled from magnesium metal and a trace of iodine. Diethyl ether and tetrahydrofuran were freshly distilled from benzophenone ketyl.

(1β,2α,12α,16β)-20-(*tert*-Butyldiphenylsiloxy)-1,2-dihydroxy-16-methoxy-12-(methoxymethoxy)picrasan-11-one (5). To 158 μL (0.75 mmol) of anhydrous hexamethyldisilazane dissolved in 1.0 mL of anhydrous tetrahydrofuran at 0 °C under argon was added dropwise 466 μL (0.75 mmol) of a 1.6 M solution of *N*-butyllithium in hexanes. After being stirred at 0 °C for 30 min, the solution of lithium hexamethyldisilazide (LHMDS) was added dropwise to 332 mg (0.50 mmol) of **3** dissolved in 5.7 mL of anhydrous tetrahydrofuran cooled to −78 °C. After being stirred at −78 °C for 30 min, the reaction mixture was warmed to 0 °C and stirred for 30 min. Upon recooling to −78 °C, the enolate was treated in a dropwise fashion with a premixed solution of 191 μL (1.50 mmol) of anhydrous chlorotrimethylsilane and 209 μL (1.50 mmol) of anhydrous triethylamine. After being stirred at −78 °C for 15 min and at 0 °C for 15 min, the reaction mixture was applied directly to a chromatography column containing 75 g of flash silica gel. Elution with hexanes–ether (4:1) provided 324 mg (88%) of silyl enol ether **4** as an oil which was used directly in the next reaction.

A solution of 324 mg (0.441 mmol) of the above silyl enol ether dissolved in 8.5 mL of anhydrous tetrahydrofuran was treated at −23 °C in a dropwise fashion with 441 μL (0.441 mmol) of a 1.0 M solution of diborane in tetrahydrofuran. After 15 min at −23 °C and 30 min at 0 °C, an additional 441 μL (0.441 mmol) of a 1.0 M solution of diborane in tetrahydrofuran was added, and stirring was continued for 15 min. The intermediate organoborane was oxidized at 0 °C by adding, successively, 1.93 mL of a 3.0 N aqueous sodium hydroxide solution and 1.93 mL of a 30% aqueous hydrogen peroxide solution. After being warmed to room temperature and stirred for 4 h, the reaction mixture was diluted with 10 mL of water and 10 mL of diethyl ether. The aqueous layer was extracted with diethyl ether (4 × 10 mL), and the combined organic layers were dried over anhydrous magnesium sulfate, filtered, and concentrated in vacuo. Purification on 60 g of flash silica gel and elution with hexanes–ethyl acetate (1:1) followed by ethyl acetate provided 216 mg (72%) of **5** as a clear oil: R_f 0.16 (hexanes–ethyl acetate, 1:1); IR ($CHCl_3$) 3620–3420 (m), 3075 (w), 3005 (m), 2955 (s), 2935 (s), 2900 (s), 2880 (m), 1702 (m), 1587 (w), 1459 (m), 1425 (m), 1390 (m), 1363 (m), 1354 (m), 1287 (m), 1258 (m), 1250–1195 (m), 1150 (m), 1112 (s), 1057 (s), 1029 (s), 1007 (m), 969 (m), 951 (m), 924 (m), 903 (m), 819 (m), 696 (m) cm^{-1}; ^1H NMR (300 MHz, $CDCl_3$) δ 7.70–7.50 (m, 4 H), 7.50–7.30 (m, 6 H), 4.79 (d, 1 H, J = 2.7 Hz), 4.67 and 4.52 (AB quartet, 2 H, J = 6.3 Hz), 4.06 (t, 1 H, J = 3.0 Hz), 3.70 (d, 1 H, J = 11.3 Hz, $^1/_2$ of AB quartet), 3.57 (d, 1 H, J = 3.3 Hz), 3.61–3.50 (m, 1 H), 3.52 (s, 1 H), 3.45–3.33 (unresolved, 1 H, $^1/_2$ of AB quartet), 3.37 (s, 3 H), 3.36 (s, 3 H), 3.07 (d, 1 H, J = 5.0 Hz), 3.00–2.80 (m, 2 H), 2.66 (br s, 1 H), 2.33 (dt, 1 H, J = 14.2, 3.3 Hz), 2.26–2.08 (m, 1 H), 1.95–1.72 (m, 3 H), 1.45–0.75 (m, 4 H), 1.08 (s, 9 H), 1.02 (d, 3 H, J = 7.2 Hz), 0.91 (s, 3 H), 0.81 (d, 3 H, J = 5.4 Hz); high-resolution MS (CI) calcd for $C_{39}H_{57}O_8Si$ (M + 1) m/e 681.3824, found 681.3824; calcd for $C_{39}H_{56}O_8Si$ (M) m/e 680.3746, found 680.3775.

(1β,2α,12α)-20-(*tert*-Butyldiphenylsiloxy)-1,2-dihydroxy-12-(methoxymethoxy)picrasane-11,16-dione 1,2-Carbonate (6). To a solution of 216 mg (0.32 mmol) of diol **5** in 6 mL of anhydrous dichloromethane at 0 °C was added 257 mg (1.59 mmol) of 1,1′-carbonyldiimidazole followed by 388 mg (3.17 mmol) of 4-(dimethylamino)pyridine. After being stirred at 0 °C for 12.5 h and at room temperature for 1.5 h, the reaction contents were applied directly to 70 g of flash silica gel. Elution with hexanes–ethyl acetate (3:1) provided 224 mg (100%) of cyclic carbonate.

A solution of the above carbonate in 4.6 mL of tetrahydrofuran at room temperature was treated with 2.3 mL of a 10% aqueous hydrochloric solution. After being stirred for 42.5 h, the reaction mixture was neutralized with solid sodium bicarbonate and diluted with 10 mL of water and 10 mL of diethyl ether. The aqueous layer was extracted with diethyl ether (4 × 10 mL), and the combined organic layers were dried over anhydrous magnesium sulfate, filtered, and concentrated in vacuo, giving rise to crude lactol which was dissolved in 7.4 mL of anhydrous dichloromethane containing 65 mg (0.79 mmol) of sodium acetate and 867 mg of Celite and treated at 0 °C with 205 mg (0.951 mmol) of pyridinium chlorochromate in one portion. After the mixture was stirred at 0 °C for 15 min and room temperature for 1.25 h, an additional 205 mg (0.951 mmol) of pyridinium chlorochromate was added. Upon being stirred for 5 h, the reaction contents were filtered through silica gel–sand and washed successively with ethyl acetate. The filtrate was concentrated in vacuo, and the crude product was chromatographed on 50 g of flash silica gel. Elution with hexanes–ethyl acetate (2:1) provided 174 mg (79%) of **6** as a white solid: R_f 0.23 (hexanes–ethyl acetate, 2:1); IR ($CHCl_3$) 3080 (w), 3040 (w), 2975 (m), 2950 (m), 2905 (m), 2870 (m), 1807 (s), 1725 (s), 1463 (m), 1427 (m), 1374 (m), 1330 (w), 1302 (m), 1278 (m), 1240 (m), 1193 (m), 1155 (m), 1114 (s), 1104 (s), 1083 (s), 1039 (s), 1020 (s), 973 (m), 933 (m), 835 (m), 827 (m) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.58–7.37 (m, 10 H), 4.59 (br s, 1 H), 4.57 and 4.47 (AB quartet, 2 H, J = 6.4 Hz), 4.25 (dt, 1 H, J = 11.3, 4.3 Hz), 3.76 and 3.49 (AB quartet, 2 H, J = 11.5 Hz), 3.69 (d, 1 H, J = 3.3 Hz), 3.63 (d, 1 H, J = 11.3 Hz), 3.46–3.36 (m, 1 H), 3.31 (s, 3 H), 3.14 (s, 1 H), 2.84–2.73 (m, 2 H), 2.20–2.11 (m, 2 H), 1.71 (dt, 1 H, J = 15.2, 2.8 Hz), 1.52–1.42 (m, 1 H), 1.38 (q, 1 H, J = 11.7 Hz), 1.28–0.80 (m, 2 H), 1.09 (d, 3 H, J = 7.0 Hz), 1.06 (s, 9 H), 1.01 (s, 3 H), 0.92 (d, 3 H, J = 6.4 Hz); ^{13}C NMR (125 MHz, $CDCl_3$) δ 205.64, 170.52, 154.27, 135.61, 135.42, 132.14, 131.95, 130.35, 128.07, 96.06, 91.55, 84.87, 78.33, 61.85, 56.07, 48.55, 44.83, 43.95, 38.28, 36.81, 34.38, 33.94, 28.68, 27.98, 26.95, 24.83, 19.23, 18.85, 13.45, 12.27. An analytical sample was prepared by recrystallization from diethyl ether, mp 188–189 °C. Anal. Calcd for $C_{39}H_{50}O_9Si$: C, 67.80; H, 7.29. Found: C, 67.89; H, 7.30.

(1β,2α,12α)-20-(*tert*-Butyldiphenylsiloxy)-1,2,12-trihydroxypicrasane-11,16-dione 1,2-Carbonate (7). A solution of 534 mg (3.56 mmol) of sodium iodide in 3.6 mL of anhydrous acetonitrile at room temperature was treated with 452 μL (3.56 mmol) of anhydrous chlorotrimethylsilane. After being stirred for 30 min, the resulting 1.0 M solution of iodotrimethylsilane was added dropwise to 164 mg (0.237 mmol) of methoxymethyl ether **6** dissolved in 4.9 mL of anhydrous acetonitrile cooled to −23 °C. The reaction mixture was stirred at −23 °C for 20 min and at 0 °C for 20 min. Upon being warmed to room temperature and stirred for 2.5 h, the reaction was quenched by the addition of 8 mL of a saturated aqueous sodium thiosulfate solution and diluted with 10 mL of water and 20 mL of diethyl ether. The aqueous layer was extracted with diethyl ether (3 × 20 mL), and the combined organic layers were dried over anhydrous magnesium sulfate, filtered, and concentrated in vacuo. The crude residue was chromatographed on 30 g of flash silica gel. Elution with hexanes–ethyl acetate (1:1) provided 138 mg (90%) of α-ketol **7** as a white solid: R_f 0.17 (hexanes–ethyl acetate; 2:1); IR ($CHCl_3$) 3630–3200 (w), 3080–3000 (w), 2970 (m), 2940 (m), 2900 (m), 2860 (m), 1810 (s), 1726 (s), 1591 (w), 1463 (m), 1429 (m), 1377 (m), 1350 (w), 1339 (w), 1330 (w), 1301 (m), 1282 (m), 1260 (m), 1241 (m), 1190 (m), 1168 (m), 1152 (w), 1111 (s), 1106 (s), 1074 (s), 1037 (s), 1005 (m), 983 (m), 936 (w), 907 (w), 834 (w), 820 (w), 790 (w), 699 (m) cm^{-1}; ^1H NMR (500 MHz, $CDCl_3$) δ 7.59–7.37 (m, 10 H), 4.57 (br s, 1 H), 4.24 (dt, 1 H, J = 11.3, 4.3 Hz), 3.80 (d, 1 H, J = 11.3 Hz), 3.78 (t, 1 H, J = 3.4 Hz), 3.73 and 3.47 (AB quartet, 2 H, J = 11.4 Hz), 3.63 (br d, 1 H, J = 3.4 Hz), 3.53 (dd, 1 H, J

= 20.4, 14.7 Hz), 3.35 (s, 1 H), 2.84–2.72 (m, 2 H), 2.20–2.08 (m, 2 H), 1.69 (dt, 1 H, J = 15.2, 2.5 Hz), 1.48–1.35 (m, 2 H), 1.27–0.80 (m, 2 H), 1.12 (d, 3 H, J = 7.0 Hz), 1.06 (s, 9 H), 0.97 (s, 3 H), 0.91 (d, 3 H, J = 5.9 Hz); ^{13}C NMR (125 MHz, $CDCl_3$) δ 208.24, 170.76, 154.93, 135.64, 135.46, 132.23, 132.13, 130.29, 128.07, 128.01, 91.51, 80.27, 78.29, 62.05, 47.81, 44.85, 43.82, 38.20, 36.70, 34.61, 33.94, 28.70, 28.17, 26.96, 24.86, 19.25, 18.82, 13.20, 12.21. An analytical sample was prepared by recrystallization from diethyl ether, mp 208–210 °C. Anal. Calcd for $C_{37}H_{46}O_8Si$: C, 68.70; H, 7.17. Found: C, 68.59; H, 7.13.

(1β,2α,12α)-20-(*tert*-Butyldiphenylsiloxy)-1,2,12-trihydroxypicrasane-11,16-dione (8). A solution of 128 mg (0.20 mmol) of cyclic carbonate 7 in 3.6 mL of methanol and 3.6 mL of tetrahydrofuran was treated at ambient temperature with 27 mg (0.20 mmol) of potassium carbonate. After 1 h, the reaction was acidified with 500 μL of a 10% aqueous hydrochloric acid solution. After being stirred for 30 min, the reaction contents were filtered through a pad of silica gel and washed successively with chloroform–methanol (9:1). The filtrate was concentrated in vacuo, and the product was chromatographed on 30 g of flash silica gel. Elution with chloroform–methanol (92:8) provided 107 mg (87%) of triol 8, which was recrystallized from acetone, mp 227–229.5 °C: R_f 0.18 (ethyl acetate); IR (KBr) 3524 (s), 3344 (s), 3255 (m), 3073 (w), 3048 (w), 2961 (s), 2939 (s), 2902 (m), 2858 (m), 1720 (s), 1693 (s), 1590 (w), 1474 (m), 1429 (m), 1390 (m), 1364 (m), 1342 (m), 1286 (m), 1268 (m), 1244 (m), 1226 (m), 1199 (w), 1165 (w), 1112 (s), 1065 (s), 1041 (s), 1019 (m), 993 (m), 959 (w), 943 (w), 928 (w), 822 (m), 803 (m), 772 (m), 743 (m), 703 (s), 689 (m), 618 (m) cm^{-1}; ^{1}H NMR (500 MHz, C_5D_5N) δ 8.13 (d, 1 H, J = 4.5 Hz), 7.81–7.73 (m, 4 H), 7.55–7.42 (m, 6 H), 5.73 (br s, 1 H), 5.32 (br s, 1 H), 5.05 (br s, 1 H), 4.24 (dd, 1 H, J = 17.7, 11.7 Hz), 4.20 and 4.01 (AB quartet, 2 H, J = 11.5 Hz), 4.12 (t, 1 H, J = 3.6 Hz), 4.04 (s, 1 H), 3.96–3.87 (m, 1 H), 3.35 (br d, 1 H, J = 8.4 Hz), 3.14–3.01 (m, 2 H), 2.41–2.32 (m, 1 H), 2.05 (dt, 1 H, J = 12.7, 4.0 Hz), 1.87 (d, 1 H, J = 13.4 Hz), 1.50–1.06 (m, 4 H), 1.37 (s, 3 H), 1.22 (d, 3 H, J = 6.9 Hz), 1.13 (s, 9 H), 0.75 (d, 3 H, J = 6.9 Hz); ^{13}C NMR (125 MHz, C_5D_5N) δ 213.39, 170.66, 136.14, 136.00, 135.81, 133.19, 133.14, 130.64, 130.60, 128.51, 128.45, 123.79, 86.34, 82.16, 79.05, 70.16, 62.85, 48.31, 46.03, 44.00, 43.22, 41.80, 35.88, 35.68, 29.05, 28.26, 27.12, 26.11, 19.63, 19.45, 13.86, 12.23; high-resolution MS (CI) calcd for $C_{32}H_{39}O_7Si$ (M – C_4H_9) m/e 563.2466, found 563.2477.

(±)-Shinjulactone D (1). To a solution of 97 mg (0.16 mmol) of silyl ether 8 dissolved in 3.1 mL of anhydrous tetrahydrofuran at room temperature was added 3.12 mL (3.12 mmol) of a 1.0 M solution of tetra-*n*-butylammonium fluoride in tetrahydrofuran. After being stirred for 3 h, the reaction contents were filtered through a pad of flash silica gel and washed successively with chloroform–methanol (9:1). The filtrate was concentrated in vacuo, and the resulting solid was chromatographed on 30 g of flash silica gel. Elution with ethyl acetate–methanol (8:1) afforded 54 mg (90%) of (±)-shinjulactone D, which upon recrystallization from acetone provided fine needles, mp 277–280 °C: R_f 0.29 (chloroform–methanol, 9:1); IR (KBr) 3500 (s), 3411 (s), 3261 (m), 2971 (m), 2933 (m), 2883 (m), 2786 (m), 2593 (w), 1725 (s), 1505 (m), 1470 (m), 1436 (m), 1409 (m), 1385 (m), 1343 (w), 1324 (m), 1293 (m), 1262 (m), 1235 (m), 1216 (m), 1177 (m), 1131 (w), 1081 (m), 1046 (s), 1011 (m), 984 (m), 961 (m), 945 (m), 918 (w), 884 (w), 857 (w), 795 (w), 764 (w), 718 (w), 633 (w), cm^{-1}; ^{1}H NMR (500 MHz, C_5D_5N) δ 6.87 (br d, 1 H, J = 4.5 Hz), 4.40 (br s, 1 H), 4.13 and 3.70 (AB quartet, 2 H, J = 8.1 Hz), 4.09–4.01 (m, 1 H), 3.95 (t, 1 H, J = 4.5 Hz), 3.58 (d, 1 H, J = 8.3 Hz), 3.27 (dd, 1 H, J = 18.5, 14.4 Hz), 2.95 (s, 1 H), 2.81 (dd, 1 H, J = 18.5, 5.5 Hz), 2.46–2.37 (m, 1 H), 2.08 (dt, 1 H, J = 12.7, 4.4 Hz), 1.94 (br d, 1 H, J = 14.5 Hz), 1.87 (dt, 1 H, J = 14.4, 5.5 Hz), 1.70 (t, 1 H, J = 14.4 Hz), 1.64 (s, 3 H), 1.59–1.49 (m, 1 H), 1.41 (t, 1 H, J = 11.7 Hz), 1.26 (q, 1 H, J = 12.2 Hz), 1.06 (d, 3 H, J = 6.8 Hz), 0.81 (d, 3 H, J = 5.9 Hz); ^{13}C NMR (125 MHz, C_5D_5N) δ 170.65, 110.90, 85.31, 79.70, 79.19, 71.75, 70.05, 46.53, 46.47, 44.19, 43.37, 42.90, 41.59, 31.70, 30.60, 29.01, 26.78, 20.10, 13.30, 11.61; high-resolution MS (CI) calcd for $C_{20}H_{31}O_7$ (M + 1) m/e 383.2070, found 383.2083; calcd for $C_{20}H_{29}O_6$ (M + 1 – H_2O) m/e 365.1965, found 365.1945.

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Approximate Absolute Rate Constants for the Reactions of Tributyltin Radicals with Aryl and Vinyl Halides

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Introduction

Rate constants of atom (and group) transfer reactions to tributyltin radicals are of fundamental interest in radical chemistry,[2] and they are also important in synthesis planning.[3] Such rate constants are used to determine at what concentrations a radical precursor will be reactive enough to propagate a good chain and to anticipate whether an atom or group transfer reaction will be faster or slower than other possible competing reactions. A large body of both absolute and relative rate data exists for tin radical abstractions of groups bonded to sp^3-hybridized carbon atoms.[2] In contrast, while it is well known that bromides and iodides bonded to sp^2-hybridized carbon atoms are useful radical precursors,[4] very little is known about the relative reactivity of these precursors. This absence of data threatened to impede several of our projects, so we undertook a brief study to determine the rate constants for bromine abstraction by tributyltin radical from a representative series of aryl and vinyl bromides and one aryl iodide. Finally, we provide illustrative applications of these rate constants to synthesis problems.

Results

Relative reactivities were measured by competition reactions of a known standard (R^2–Y) with a given radical precursor (R^1–X), as outlined in Scheme I. We selected

Scheme I

$$R^1\text{–}X + R^2\text{–}Y \xrightarrow{Bu_3SnH} R^1\text{–}H + R^2\text{–}H + Bu_3SnX(Y)$$

$$R^1\text{–}X + Bu_3Sn^\bullet \xrightarrow{k_X} R^{1\bullet} + Bu_3SnX$$

$$R^{1\bullet} + Bu_3SnH \rightarrow R^1\text{–}H + Bu_3Sn^\bullet$$

$$R^2\text{–}Y + Bu_3Sn^\bullet \xrightarrow{k_Y} R^{2\bullet} + Bu_3SnY$$

$$R^{2\bullet} + Bu_3SnH \rightarrow R^2\text{–}H + Bu_3Sn^\bullet$$

R^2–Y = 1-bromooctane, benzyl chloroacetate, or 4-bromoanisole

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