Preparation of $\alpha$-Sulfenyl Enones by Thermal Fragmentation of $\beta$-Sulfenyl Enol Triflates.

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Supporting Information

General experimental details: All reactions were performed in flamed-dried glassware under an atmosphere of nitrogen. Concentrations were performed under reduced pressure (ca. 50 mm) with a rotary evaporator. THF and PhMe were dried according to published procedures. Acetonitrile and PhH were distilled from CaH$_2$. Methylthiomethylsulfone was prepared according to the published procedure. All other reagents and solvents were purchased at highest commercial quality and used as received.

Instrumentation and chromatography: 400 or 500 MHz $^1$H and 100 or 125 MHz $^{13}$C NMR spectra were obtained using Bruker FT-NMR spectrometers. Chemical shifts are reported in ppm relative to residual protiated solvent. Multiplicity is reported according to the appearance of the spectra peak and is indicated as follows: s (singlet); d (doublet); t (triplet); q (quartet); m (multiplet); dd (doublet of doublets); dt (doublet of triplets); td (triplet of doublets). IR spectra were obtained either using a Perkin–Elmer 1600 Series FT-IR spectrometer or a React-IR (thin films deposited from CH$_2$Cl$_2$ or CDCl$_3$). Column chromatography was performed with Siliacycle 43–60 µm silica gel; the eluent used is reported in parentheses. Analytical thin-layer chromatography (TLC) was performed on precoated glass-backed plates (Merck Kieselgel 60 F$_{254}$).

An important note: The $\beta$-sulfenyl enol triflates described herein are quite unstable as neat oils (typical half-life ca. 30 min at rt); therefore they were used either directly upon purification or stored as solutions in pentane (ca. 0.1 M) at −20 °C. Compound 26 is insoluble in pentane and was stored as a solution in 20% Et$_2$O–pentane (ca. 0.1 M) at −20 °C.

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2 Scholz, D. Synthesis, 1983, 944–945. Note: A serious explosion occurred when preparing MeSO$_2$SMe using the procedure published in this reference. It is strongly urged to prepared this reagent by other means or purchase it from commercial sources.
General Procedure for Preparing β-Methylthio Enol Triflates.

Preparation of 7. A solution of 2-(methylthio)cyclohexanone (5) (1.00 g, 6.49 mmol) in THF (20 mL) was added drop-wise by cannula to a solution of KHMDS (1.66 g, 8.32 mmol) in THF (70 mL) at –78 °C. The resulting solution was maintained for 20 min at –78 °C before a solution of PhNTf₂ (2.72 g, 7.63) in THF (10 mL) was added drop-wise by cannula. The reaction was maintained at –78 °C for an additional 20 min and then quenched by pouring the cold solution into 1 N HCl (100 mL). The resulting suspension was extracted with Et₂O (2 × 100 mL). The ethereal solution was washed with saturated aqueous NaHCO₃ (1 × 100 mL) and brine (1 × 100 mL), dried over anhydrous MgSO₄ and concentrated. Purification of the resulting oil by column chromatography (pentane to 98:2 pentane-Et₂O) gave triflate 7 (1.82 g, 95%) as a clear, colorless oil: IR (film) 2937, 2866, 1655, 1415, 1207, 1033 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 2.34–2.40 (m, 4H), 2.26 (s, 3H), 1.69–1.80 (m, 4H); ¹³C NMR (125 MHz, CDCl₃) δ 144.1, 127.0, 118.3 (q, J = 317.9 Hz), 28.54, 28.47, 22.6, 22.3, 13.7; MS (FAB+) m/z 276.0107 (276.0102 calcd for C₈H₁₁F₃O₃S₂, M⁺).

Preparation of 8. Utilizing the procedure described for 7, 2-benzyl-6-(methylthio)cyclohexanone (6) (3.63 g, 15.5 mmol) in THF (20 mL) was deprotonated with a solution of KHMDS (3.70 g, 18.6 mmol) in THF (150 mL) and triflated with a solution of PhNTf₂ (6.08 g, 17.0 mmol) in THF (20 mL). The reaction was worked-up in the standard way and the product was purified by column chromatography (98:2 pentane-Et₂O) to give triflate 8 (4.53 g, 80% yield) as a clear, colorless oil: IR (film) 2339, 1443, 1420, 1214, 1130, 872 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.29 (t, J = 7.2 Hz, 2H), 7.22 (t, J = 7.4 Hz, 1H), 7.13 (d, J = 7.2 Hz, 2H), 4.16 (dd, J = 13.6, 3.4 Hz, 1H), 2.74–2.76 (m, 1H), 2.48 (dd, J = 13.6, 10.6 Hz, 1H), 2.36–2.41 (m, 2H), 2.27 (s, 3H), 1.59–1.71 (m, 3H), 1.48–1.51 (m, 1H); ¹³C NMR (125 MHz, CDCl₃) δ 146.5, 138.7, 129.12, 129.08, 128.4, 126.4, 118.4 (q, J = 318.1 Hz), 40.2, 37.8, 29.1, 27.0, 19.5, 13.7; MS (CI/NH₃) m/z 366.0578 (366.0571 calcd for C₁₅H₁₇F₃O₃S₂, M⁺).

Preparation of triflate 12. Utilizing the procedure described for 7, 2-methylthio-4-(tert-butyl)cyclohexanone (11) (600 mg, 2.99 mmol) in THF (10 mL) was deprotonated with a solution of KHMDS (716 mg, 3.59 mmol) in THF (30 mL) and triflated with a solution of PhNTf₂ (1.18 g, 3.29 mmol) in THF (10 mL). The reaction was worked-up in the standard way and the product was purified by column chromatography (98:2 pentane-Et₂O) to give triflate 12 (980 mg, 98% yield) as a clear, colorless oil: IR (film) 2964, 2872, 1417, 1208, 1143, 865 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 2.37–2.47 (m, 3H), 2.26 (s, 3H), 2.07–2.15 (m, 1H), 1.92–1.96 (m, 1H), 1.32–1.42 (m, 2H), 0.91 (s, 9H); ¹³C NMR (100 MHz, CDCl₃) δ 144.4, 126.9, 117.8 (q, J = 317.9 Hz), 44.0, 32.2, 30.2, 29.2, 27.1, 24.0, 13.8; MS (CI/NH₃) m/z 332.0728 (332.0728 calcd for C₁₂H₁₉F₃O₃S₂, M⁺).

Prepared by the method described in reference 2.
Preparation of triflate 15. Utilizing the procedure described for 7, 2-(methylthio)cycloheptanone\(^3\) (1.00 g, 6.32 mmol) in THF (20 mL) was deprotonated with a solution of KHMS (1.51 g, 7.58 mmol) in THF (70 mL) and triflated with a solution of PhNTf\(_2\) (2.48 g, 6.95 mmol) in THF (10 mL). The reaction was worked-up in the standard way and the product was purified by column chromatography (98:2 pentane-Et\(_2\)O) to give triflate 14 (1.80 g, 98% yield) as a clear, colorless oil: IR (film) 2929, 1641, 1417, 1206, 1141, 861 cm\(^{-1}\); \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta 2.53–2.55\) (m, 2H), 2.47–2.49 (m, 2H), 2.25 (s, 3H), 1.72–1.76 (m, 2H), 1.62–1.67 (m, 4H); \(^13\)C NMR (125 MHz, CDCl\(_3\)) \(\delta 149.0, 131.9, 118.4\) (q, \(J = 318.8\) Hz), 33.1, 31.1, 30.5, 25.6, 24.3, 14.9; MS (GC–MS, CI/isobutane) \(m/z\) 290.0265 (290.0258 calcd for C\(_9\)H\(_{13}\)F\(_3\)O\(_3\)S\(_2\), M\(^+\)).

General Procedure for the Preparation of \(\alpha\)-Phenylthio-Enol Triflates.

Preparation of 21. Solid KHMS (103 mg, 0.52 mmol) was added in one portion to a stirred solution of 2-benzyl-6-(phenylthio)cyclohexanone (20)\(^4\) (128 mg, 0.43 mmol) in THF (5 mL) at –78 °C. The resulting solution was maintained at –78 °C for 20 min before adding 2-[N,N-bis(trifluoromethylsulfonyl)amino]-5-chloropyridine (186 mg, 0.48 mmol) in one portion. The reaction was maintained at –78 °C for 1 h and then quenched by pouring the cold solution into 1 N HCl (20 mL) and diluting with Et\(_2\)O (30 mL). The resulting layers were separated and the organic phase was washed with 1 N NaOH (1 × 20 mL), H\(_2\)O (1 × 20 mL), and brine (1 × 20 mL), dried over anhydrous MgSO\(_4\) and concentrated. The resulting oil was purified by column chromatography (98:2 hexanes-Et\(_2\)O) to give 21 (138 mg, 75%) as a clear, colorless oil: IR (film) 2934, 2864, 1417, 1208, 1139, 872 cm\(^{-1}\); \(^1\)H NMR (500 MHz, C\(_6\)D\(_6\)) \(\delta 7.29–7.32\) (m, 2H), 7.00–7.12 (m, 5H), 6.91–6.95 (m, 3H), 3.05 (dd, \(J = 13.6, 3.6\) Hz, 1H), 2.76–2.83 (m, 1H), 2.27 (dd, \(J = 13.6, 10.3\) Hz, 1H), 1.83–1.89 (m, 1H), 1.73–1.79 (m, 1H), 1.19–1.25 (m, 1H), 1.00–1.14 (m, 2H), 0.90–0.95 (m, 1H); \(^13\)C NMR (125 MHz, C\(_6\)D\(_6\)) \(\delta 149.0, 139.2, 133.8, 132.1, 129.9, 129.7, 129.3, 129.2, 128.7, 127.1, 119.5\) (q, \(J = 317.5\) Hz), 41.3, 38.4, 30.9, 27.6, 20.1; MS (CI/NH\(_3\)) \(m/z\) 428.0731 (428.0728 calcd for C\(_{20}\)H\(_{19}\)F\(_3\)O\(_3\)S\(_2\), M\(^+\)).

Preparation of Triflate 18. Utilizing the procedure described for 21, 2-(phenylthio)cyclopentanone (23)\(^4\) (400 mg, 2.08 mmol) in THF (40 mL) was deprotonated with KHMS (500 mg, 2.50 mmol) and triflated with 2-[N,N-bis(trifluoromethylsulfonyl)amino]-5-chloropyridine (900 mg, 2.30 mmol). The reaction was worked-up in the standard way and the product was purified by column chromatography (95:5 hexanes-Et\(_2\)O) to give triflate 18 (591 mg, 88% yield) as a clear, colorless oil: IR (film) 2961, 2860, 1648, 1420, 1208, 1139 cm\(^{-1}\); \(^1\)H NMR (500 MHz, C\(_6\)D\(_6\)) \(\delta 7.19–7.23\) (m, 2H), 6.90–6.94 (m, 3H), 2.20–2.24 (m, 2H), 1.85–1.89 (m, 2H), 1.20–1.26 (m, 2H); \(^13\)C NMR (125 MHz, C\(_6\)D\(_6\)) \(\delta 146.5, 133.2, 132.0, 129.7, 128.5, 126.8, 119.5\) (q, \(J = 318.8\) Hz), 32.5, 31.8, 19.9; MS (CI/NH\(_3\)) \(m/z\) 324.0100 (324.0102 calcd for C\(_{12}\)H\(_{11}\)F\(_3\)O\(_2\)S\(_2\), M\(^+\)).

Preparation of Triflate 26. Utilizing the procedure described for 7, 2-methylthio-1,4-cyclohexandione-4-ethylene ketal\(^5\) (378 mg, 1.13 mmol) in THF (3 mL) was deprotonated with KHMDS (270 mg, 1.36 mmol) in THF (11 mL) and triflated with a solution of PhNTf\(_2\) (444 mg, 1.24 mmol) in THF (3 mL). The reaction was worked-up in the standard way and the product was purified by column chromatography (80:20 hexanes-Et\(_2\)O) to give triflate 20 (370 mg, 98\% yield) as colorless oil: IR (film) 2922, 2852, 1659, 1416, 1209, 852 cm\(^{-1}\); \(^1\)H NMR (400 MHz, CDCl\(_3\)) \(\delta 4.01–4.05 (m, 4H), 2.57–2.61 (m, 4H), 2.28 (s, 3H), 1.93 (t, \(J = 6.5\) Hz, 2H); \(^1\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 143.1, 124.4, 118.3 (q, J = 254.0\) Hz), 106.5, 64.8, 38.5, 31.1, 26.8, 13.7; MS (CI/isobutane) \(m/z\) 334.0156 (334.0156 calcd for C\(_{10}\)H\(_{13}\)F\(_3\)O\(_5\)S\(_2\), M\(^+\)).

Preparation of Triflate 30. Utilizing the procedure described for 7, 2-(methylthio)testosterone-18-(\(t\)-butyldimethylsilyl)ether\(^5\) (463 mg, 1.03 mmol) in THF (7 mL) was deprotonated with a solution of KHMDS (2.5 mL, 1.23 mmol, 0.5 M PhMe) and triflated with a solution of PhNTf\(_2\) (442 mg, 1.23 mmol) in THF (5 mL). The reaction was worked-up in the standard way and the product was purified by column chromatography (99:1 hexanes-Et\(_3\)N) to give triflate 19 (404 mg, 68\% yield) as a slightly orange oil: IR (film) 2928, 2855, 1422, 1211, 1142 cm\(^{-1}\); \(^1\)H NMR (500 MHz, C\(_6\)D\(_6\)) \(\delta 5.53 (s, 1H), 3.44 (t, \(J = 8.3\) Hz, 1H), 2.30 (d, \(J = 16.4\) Hz, 1H), 2.08 (d, \(J = 16.4\) Hz, 1H), 1.92–1.95 (m, 1H), 1.81 (s, 3H), 1.72 (dt, \(J = 12.2, 3.0\) Hz, 1H), 1.25–1.55 (m, 6H), 1.03–1.55 (m, 4H), 1.03 (s, 9H), 0.81 (s, 3H), 0.74 (s, 3H), 0.57–0.65 (m, 3H), 0.10 (s, 3H), 0.09 (s, 3H); \(^1\)C NMR (125 MHz, C\(_6\)D\(_6\)) \(\delta 149.9, 141.8, 121.4, 119.2 (q, J = 320.0\) Hz), 114.2, 82.0, 54.3, 50.1, 43.4, 42.3, 38.9, 37.6, 36.1, 31.2, 30.7, 30.2, 26.1, 23.7, 21.4, 18.3, 17.1, 13.9, 11.6, –4.3, –4.6.

Preparation of Triflate 28. Utilizing the procedure described for 7, (\(R\))-2-(methylthio)pulegone\(^5\) (210 mg, 1.06 mmol) in THF (7 mL) was deprotonated with a solution of KHMDS (2.54 mL, 1.27 mmol, 0.5 M PhMe) and triflated with a solution of PhNTf\(_2\) (454 mg, 1.27 mmol) in THF (5 mL). The reaction was worked-up in the standard way and the product was purified by column chromatography (99:1 hexanes-Et\(_3\)N) to give triflate 20 (273 mg, 78\% yield) as slightly orange oil: IR (film) 2930, 2864, 1417, 1206, 1139, 883 cm\(^{-1}\); \(^1\)H NMR (400 MHz, C\(_6\)D\(_6\)) \(\delta 2.22–2.27 (m, 1H), 2.06–2.12 (m, 2H), 1.76 (s, 3H), 1.73 (s, 3H), 1.48–1.53 (m, 1H), 1.40 (s, 3H), 1.09–1.15 (m, 1H), 0.89 (d, \(J = 7.0\) Hz, 3H); \(^1\)C NMR (100 MHz, CDCl\(_3\)) \(\delta 144.0, 135.4, 132.0, 123.9, 118.4 (q, J = 318.8\) Hz), 33.7, 30.8, 26.2, 23.2, 21.6, 19.1, 15.1.

General Procedure for Preparing α-Sulfenyl Enones Using DMSO as Solvent. Preparation of Enone 9. A solution of triflate 7 (950 mg, 3.44 mmol), 2,6-lutidine (552 mg, 0.60 mL, 5.15 mmol) and DMSO (35 mL) was heated at 80 °C for 10 h. The reaction was then cooled to rt and diluted with Et₂O (75 mL). The resulting solution was washed successively with 1N HCl (1 × 75 mL), saturated aqueous NaHCO₃ (1 × 75 mL) and brine (1 × 75 mL). This solution was dried over anhydrous MgSO₄ and concentrated. Purification of the residue by column chromatography (80:20 pentane-Et₂O) gave enone 9 (383 mg, 78% yield) as a clear, colorless oil. Analytical data for 22 matched that previously reported.⁶

Preparation of Enone 10. Utilizing the procedure described for the preparation of 9, a solution of triflate 8 (1.21 g, 3.29 mmol), 2,6-lutidine (530 mg, 0.57 mL, 4.94 mmol) and DMSO (33 mL) was heated at 80 °C for 6 h. The reaction was worked-up in the standard way and the product was purified by column chromatography (95:5 pentane-Et₂O) to give enone 10 (680 mg, 89% yield) as a clear, colorless oil: IR (film) 3026, 2918, 1671, 1332, 1150 cm⁻¹; ¹H NMR (500 MHz, CDCl₃) δ 7.27–7.30 (m, 2H), 7.15–7.25 (m, 3H), 6.46 (dd, J = 5.23, 2.15 Hz, 1H), 3.38 (dd, J = 13.7, 3.9 Hz, 1H), 2.63–2.66 (m, 1H), 2.43–2.59 (m, 2H), 2.20 (s, 3H), 1.94–2.02 (m, 1H), 1.62–1.74 (m, 1H); ¹³C NMR (125 MHz, CDCl₃) δ 197.1, 139.6, 138.3, 137.2, 129.1, 128.3, 126.0, 48.8, 35.3, 27.0, 26.1, 13.7; MS (GC-MS, EI) m/z 232.0922 (232.0922 calcd for C₁₄H₁₆O₃S, M⁺).

Preparation of Enone 13. Utilizing the procedure described for the preparation of 9, a solution of triflate 12 (540 mg, 1.62 mmol), 2,6-lutidine (260 mg, 0.28 mL, 2.43 mmol) and DMSO (16 mL) was heated at 80 °C for 10 h. The reaction was worked-up in the standard way and the product was purified by column chromatography (80:20 pentane-Et₂O) to give enone 13 (261 mg, 81% yield) as a clear, colorless oil: IR (film) 2961, 2872, 1679, 1343 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 6.60 (s, 1H), 2.64 (dt, J = 16.4, 3.6 Hz, 1H), 2.40 (td, J = 16.8, 5.2 Hz), 2.21–2.28 (m, 4H), 2.07–2.10 (m, 1H), 1.69–1.73 (m, 1H), 0.98 (s, 9H); ¹³C NMR (100 MHz, CDCl₃) δ 196.0, 142.3, 137.7, 48.2, 38.0, 33.3, 27.3, 24.2, 13.9; MS (EI) m/z 198.1079 (198.1078 calcd for C₁₁H₁₈O₃S, M⁺).

Preparation of Enone 16. Utilizing the procedure described for the preparation of 9, a solution of triflate 15 (1.00 g, 3.44 mmol), 2,6-lutidine (550 mg, 0.60 mL, 5.15 mmol) and DMSO (35 mL) was heated at 80 °C for 10 h. The reaction was worked-up in the standard way and the product was purified by column chromatography (80:20 pentane-Et₂O) to give enone 16 (444 mg, 83% yield) as a clear, colorless oil: IR (film) 2925, 2862, 1669, 1456 cm⁻¹; ¹H NMR (400 MHz, CDCl₃) δ 6.42 (t, J = 6.6 Hz, 6 Oki, M.; Kobayashi, K. Bull. Chem. Soc. Jpn., 1970, 43, 1223–1229.
Preparation of Enone 19. A solution of 2-(methylthio)cyclopentanone (17)\(^1\) (1.00 g, 7.60 mmol) in THF (10 mL) was added drop-wise by cannula to a solution of KHMDS (1.84 g, 9.21 mmol) in THF (80 mL) at –78 °C. The resulting solution was maintained for 20 min at –78 °C before a solution of PhNTf\(_2\) (3.01 g, 8.45 mmol) in THF (10 mL) was then added drop-wise by cannula. The reaction was maintained for an additional 20 min at –78 °C and then quenched by pouring the cold solution into 1 N HCl (100 mL). The resulting suspension was extracted with Et\(_2\)O (2 × 150 mL). The ethereal solution was washed with saturated aqueous NaHCO\(_3\) (1 × 100 mL) and brine (1 × 100 mL), dried over anhydrous MgSO\(_4\) and concentrated (vacuum ca. 30 mmHg, complete removal of residual solvent leads to rapid decomposition) to give 18 as a crude brown oil which was used without further purification. Partial analytical data of 18 for the purpose of identification: \(^1\)H NMR (500 MHz, CDCl\(_3\)) \(\delta\) 2.64–2.69 (m, 2H), 2.57–2.60 (m, 2H), 2.30 (s, 3H), 2.02–2.08 (m, 2H); MS (FAB+) m/z 261.9940 (261.9945 calcd for C\(_7\)H\(_9\)F\(_3\)O\(_3\)S\(_2\), M\(^+\)).

The crude triflate 18 was then combined with 2,6-lutidine (1.22 g, 1.34 mL, 11.4 mmol) and dissolved in DMSO (76 mL). The resulting solution was heated at 80 °C for 2 h. Reaction was then cooled to rt and diluted with Et\(_2\)O (75 mL). This solution washed successively with 1N HCl (1 × 75 mL), saturated aqueous NaHCO\(_3\) (1 × 75 mL) and brine (1 × 75 mL), dried over anhydrous MgSO\(_4\) and concentrated. Purification of the residue by column chromatography (80:20 pentane-Et\(_2\)O) gave enone 19 (364 mg, 37% yield) as a clear, colorless oil: Analytical data matched previously reported data.

Preparation of Enone 22. Utilizing the procedure described for the preparation of 9, a solution triflate 21 (138 mg, 0.32 mmol) and 2,6-lutidine (51.7 mg, 56 µL, 0.48 mmol) in DMSO (3 mL) was heated at 80 °C for 24 h. The reaction was worked-up in the standard way and the product was purified by column chromatography (92:8 pentane-Et\(_2\)O) to give enone 22 (48 mg, 51% yield) as a colorless solid: IR (film) 2926, 2860, 1675, 1146 cm\(^{-1}\); \(^1\)H NMR (500 MHz, C\(_6\)D\(_6\)) \(\delta\) 7.48–7.51 (m, 2H), 7.32–7.44 (m, 5H), 7.24–7.28 (m, 3H), 6.51 (t, \(J = 4.3\) Hz, 1H), 3.44 (dd, \(J = 13.7, 3.9\) Hz, 1H), 2.70–2.76 (m, 1H), 2.65 (dd, \(J = 13.7, 9.6\) Hz, 1H), 2.32–2.48 (m, 2H), 2.01–2.07 (m, 1H), 1.70–1.79 (m, 1H); \(^13\)C NMR (125 MHz, C\(_6\)D\(_6\)) \(\delta\) 196.3, 144.3, 139.6, 137.3, 133.7, 132.4, 129.4, 129.2, 128.2, 126.2, 49.1, 35.4, 27.1, 26.4; MS (Cl/Na\(_2\)) m/z 294.1081 (294.1078 calcd for C\(_{19}\)H\(_{18}\)OS, M\(^+\)).

Preparation of Enone 25. Utilizing the procedure described for the preparation of 9, a solution triflate 24 (217 mg, 0.67 mmol), 2,6–lutidine (108 mg, 0.12 mL, 1.00 mmol) and DMSO (7 mL) was heated at 80 °C for 24 h. The reaction was worked-up in the standard way and the product was purified by column chromatography (80:20 pentane-Et\(_2\)O) to give enone 25 (80 mg, 80% yield) as a clear, colorless oil. Analytical data matched

Preparation of Enone 27. A solution of triflate 26 (536 mg, 1.60 mmol), 2,6-lutidine (202 mg, 220 µL, 1.89 mmol) and MeCN (84 mL) was heated to 75 °C for 48 h. The reaction was then cooled to rt and concentrated to give a crude oil. The product was purified by column chromatography (66:33:1 hexanes-EtOAc-Et$_3$N) to give enone 27 (189 mg, 59%): IR (film) 2922, 1660, 1592, 1440, 1290, 1074 cm$^{-1}$; $^1$H NMR (500 MHz, CDCl$_3$) δ 6.04 (s, 1H), 4.01–4.11 (m, 4H), 2.73 (t, $J$ = 6.4 Hz, 2H), 2.21 (t, $J$ = 6.1 Hz, 2H), 2.20 (s, 3H); $^{13}$C NMR (125 MHz, CDCl$_3$) δ 195.1, 141.8, 133.7, 105.0, 65.0, 35.3, 32.9, 13.2; MS (GC-MS/EI) m/z 200.0510 (200.0507 calcd for C$_9$H$_{12}$O$_3$S, M$^+$).

Preparation of Enone 29. A solution of triflate 28 (285 mg, 861 µmol), 2,6-lutidine (110 mg, 120 µL, 1.03 mmol) and MeCN (45 mL) was heated to 82 °C for 24 h. The reaction was then cooled to rt and concentrated to give a crude oil. The product was purified by column chromatography (hexanes) to give enone 29 (138 mg, 82%): IR (film) 2961, 2888, 1687, 1592, 1117, 1029 cm$^{-1}$; $^1$H NMR (500 MHz, CDCl$_3$) δ 2.61 (t, $J$ = 6.1 Hz, 1H), 2.44 (t, $J$ = 6.2 Hz, 1H), 2.22 (s, 3H), 2.21 (s, 3H), 2.06 (s, 3H), 1.84 (s, 3H); $^{13}$C NMR (125 MHz, CDCl$_3$) δ 187.3, 161.9, 142.5, 134.0, 129.1, 33.9, 27.0, 23.6, 22.8, 22.4, 17.3; MS (CI/isobutane) m/z 196.0921 (196.0922 calcd for C$_{11}$H$_{16}$OS, M$^+$).

Preparation of Enone 31. A solution of triflate 30 (217 mg, 374 µmol), 2,6-lutidine (110 mg, 120 µL, 1.03 mmol) and MeCN (45 mL) was heated to 82 °C for 24 h. The reaction was then cooled to rt and concentrated to give a crude oil. The product was purified by column chromatography (99:1 hexanes-Et$_3$N) to give enone 31 (111 mg, 67%): IR (film) 2934, 2855, 1652, 884 cm$^{-1}$; $^1$H NMR (500 MHz, C$_6$D$_6$) δ 6.24 (s, 1H), 6.17 (s, 3H), 3.40 (t, $J$ = 8.3 Hz), 1.86–1.92 (m, 1H), 1.87 (s, 3H), 1.74–1.80 (m, 1H), 1.67 (dt, $J$ = 12.4, 3.7 Hz, 1H), 1.43–1.50 (m, 2H), 1.36–1.40 (m, 1H), 1.25–1.33 (m, 2H), 1.10–1.16 (m, 1H), 1.02–1.10 (m, 1H), 1.02 (s, 9H), 0.80 (s, 3H), 0.71–0.77 (m, 1H), 0.74 (s, 3H), 0.56–0.62 (m, 2H), 0.44–0.50 (m, 2H), 0.10 (s, 3H), 0.08 (s, 3H); $^{13}$C NMR (125 MHz, CDCl$_3$) δ 182.0, 167.7, 143.1, 138.1, 123.1, 81.9, 53.0, 49.6, 44.4, 43.6, 37.0, 35.5, 33.3, 32.3, 31.1, 26.1, 23.7, 22.9, 19.0, 18.3, 13.3, 11.6, –4.3, –4.7; MS (CI/isobutane) m/z 446.2667 (446.2675 calcd for C$_{26}$H$_{42}$O$_2$SSi, M$^+$).

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Kinetic Studies: A. Determination of kinetic order in 2,6-lutidine (pseudo-first order conditions with excess 2,6-lutidine). A standard solution (soln. #1) of triflate 8 was prepared by dissolving 8 (1.390 ± 0.005 g, 3.798 ± 0.014 mmol) in anhydrous DMSO (total volume of 20.0 ± 0.2 mL, 0.190 ± 0.003 M). This solution was used immediately after preparation. The reaction solutions were prepared by combining the stock solution of 8 (1.00 ± 0.01 mL), naphthalene (2 mL, ca. 0.1 M in DMSO) and the indicated amount of 2,6-lutidine in a volumetric flask and diluting to 10.00 ± 0.02 mL with DMSO. The reaction solutions (2 mL) were then transferred to a flame-dried vial containing a magnetic stir bar and N₂ inlet. These vials were then heated in an oil bath at 70 ± 1 °C. Prior to heating and then at regular intervals thereafter (1 h) aliquots (ca. 50 µL) were removed from each reaction, cooled and diluted with hexanes. These samples were analyzed by HPLC (Alltima, 5 micron silica gel column, 1% i-PrOH-hexanes as eluent, UV-vis detection at 240 nm) to determine the concentration of 8, using the naphthalene as an internal standard. Sampling was continued through ca. 6 half-lives; control experiments demonstrated that the composition of the samples did not detectably change over the course to the HPLC analyses. The results of these experiments are summarized in Table S1. The dependence of the observed rate constant \(k_{\text{obs}} = -3.3 \times 10^{-5} \pm 3.9 \times 10^{-6} \text{[2,6-lutidine]} \text{mM}^{-1} \text{s}^{-1} + 1.6 \times 10^{-1} \pm 2.3 \times 10^{-3} \text{s}^{-1}\) is consistent with the reaction being zero order in 2,6-lutidine.

<table>
<thead>
<tr>
<th>Run</th>
<th>[substrate] (mM)</th>
<th>volume of 2,6-lutidine (mL)</th>
<th>[2,6-lutidine] (mM)</th>
<th>(k_{\text{obs}} \times 10) (s(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19.0 ± 0.5</td>
<td>0.25 ± 0.01</td>
<td>215 ± 2</td>
<td>1.46 ± 0.02</td>
</tr>
<tr>
<td>2</td>
<td>19.0 ± 0.5</td>
<td>0.50 ± 0.01</td>
<td>430 ± 4</td>
<td>1.45 ± 0.02</td>
</tr>
<tr>
<td>3</td>
<td>19.0 ± 0.5</td>
<td>0.75 ± 0.01</td>
<td>645 ± 6</td>
<td>1.35 ± 0.02</td>
</tr>
<tr>
<td>4</td>
<td>19.0 ± 0.5</td>
<td>1.00 ± 0.01</td>
<td>860 ± 9</td>
<td>1.26 ± 0.04</td>
</tr>
</tbody>
</table>

Table S1.

![Figure S1. Left: Typical logarithmic plot of [8] vs. time (Run # 1, Table S1). Right: \(k_{\text{obs}}\) vs. [2,6-lutidine].](image)
B. Determination of kinetic order in 8 (pseudo-first order conditions with excess 2,6-lutidine). A standard solution (soln. #2) of triflate 8 was prepared by dissolving 8 (1.035 ± 0.005 g, 2.824 ± 0.014 mmol) in anhydrous DMSO (total volume of 15.0 ± 0.15 mL, 0.189 ± 0.003 M). This solution was used immediately upon preparation. The reaction solutions were prepared by combining the indicated volume of soln. #2 (see Table S2), 2,6-lutidine (1.00 ± 0.01 mL) and naphthalene (2 mL, ca. 0.1 M in DMSO) to a volumetric flask and diluting to 10.00 ± 0.02 mL with DMSO. The kinetic analysis was then performed as described in section A. The results of these experiments are summarized in Table S2. The observed dependence of the initial rate upon the concentration of 8 is consistent with the reaction being first order in 8 (see Figure S2).

<table>
<thead>
<tr>
<th>Run</th>
<th>volume of soln. #2 (mL)</th>
<th>[substrate] (mM)</th>
<th>[2,6-lutidine] (mM)</th>
<th>Initial rate x 10³ (mM/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>1.00 ± 0.01</td>
<td>18.9 ± 0.4</td>
<td>860 ± 9</td>
<td>2.20 ± 0.25</td>
</tr>
<tr>
<td>6</td>
<td>2.00 ± 0.02</td>
<td>37.8 ± 0.8</td>
<td>860 ± 9</td>
<td>4.40 ± 0.41</td>
</tr>
<tr>
<td>7</td>
<td>3.00 ± 0.03</td>
<td>56.7 ± 1.2</td>
<td>860 ± 9</td>
<td>6.56 ± 0.82</td>
</tr>
<tr>
<td>8</td>
<td>4.00 ± 0.04</td>
<td>75.6 ± 1.6</td>
<td>860 ± 9</td>
<td>8.62 ± 0.78</td>
</tr>
</tbody>
</table>

Table S2.

Figure S2. Left: Typical plot of [8] vs. time (Run # 5, Table S2). Right: Plot of initial rate vs [8].
13C spectrum with 1H decoupling

OTf
SMe

C₈H₁₁F₃O₃S₂
Exact Mass: 276.0102
Mol. Wt.: 276.2983

125 MHz CDCl₃
$^{13}$C spectrum with $^1$H decoupling

$C_{15}H_{17}F_3O_7S_2$

Exact Mass: 366.0571

Mol. Wt.: 366.4209

125 MHz CDCl$_3$
Current Data Parameters

USER             watson
NAME           DAW3130c
EXPNO                 1
PROCNO                1

F2 - Acquisition Parameters
Date_          20010822               Time              21.14
INSTRUM          drx400
PROBHD     5 mm QNP  1H
PULPROG          zgdc30
TD                65536               SOLVENT           CDCl3
NS                   64
DS                    2               SWH           25125.629 Hz
FIDRES         0.383387 Hz
AQ            1.3042164 sec
RG               2896.3
DW               19.900 usec          DE                 4.50 usec
TE                300.0 K
D1           0.10000000 sec           D11          0.03000000 sec

============ CHANNEL f1 =============
NUC1                13C
P1                10.12 usec          PL1                0.00 dB
SFO1        100.6232933 MHz

============ CHANNEL f2 =============
CPDPRG2         waltz16
NUC2                 1H
PCPD2            100.00 usec
PL2               17.00 dB            PL12              17.00 dB
SFO2        400.1320000 MHz

F2 - Processing parameters
SI                65536
SF          100.6127747 MHz
WDW                  EM
SSB                   0               LB                 0.30 Hz
GB                    0
PC                 1.00

1D NMR plot parameters
CX                22.80 cm
F1P             180.731 ppm
F1             18183.88 Hz            F2P               0.998 ppm
F2               100.38 Hz
PPMCM           7.88305 ppm/cm
HZCM          793.13599 Hz/cm

Exact Mass: 332.0728Mol. Wt.: 332.4047

$\text{C}_{9}\text{H}_{13}\text{F}_{3}\text{O}_{2}\text{S}_{2}$

Exact Mass: 290.0258
Mol. Wt.: 290.3249

500 MHz
CDCl$_3$
OTf

SMe

C₉H₁₃F₃O₃S₂

Exact Mass: 290.0258
Mol. Wt.: 290.3249

125 MHz CDCl₃

CDCl₃
$\text{OTf-SMe}$

Exact Mass: 261.9945
Mol. Wt.: 262.2718

500 MHz CDCl$_3$
C_{20}H_{19}F_{3}O_{3}S_{2}

Exact Mass: 428.0728
Mol. Wt.: 428.4903

500 MHz
C_{6}D_{6}
$^{13}$C spectrum with $^1$H decoupling
### Current Data Parameters

- **USER**: hansa
- **NAME**: DA03175h
- **PROCNO**: 1

#### F2 - Acquisition Parameters
- **Date**: 20011218
- **Time**: 17.47
- **INSTRUM**: gn500
- **PROBHD**: 5 mm broadban
- **PULPROG**: zg30
- **TD**: 65536
- **SOLVENT**: CDCl3
- **NS**: 8
- **DS**: 2
- **SWH**: 8012.820 Hz
- **FIDRES**: 0.122266 Hz
- **AQ**: 4.0894966 sec
- **RG**: 203.2
- **DW**: 62.400 usec
- **DE**: 6.00 usec
- **TE**: 300.0 K
- **D1**: 0.10000000 sec

#### F2 - Processing parameters
- **SI**: 32768
- **SF**: 500.0299993 MHz
- **WDW**: EM
- **SSB**: 0
- **LB**: 0.30 Hz
- **GB**: 0
- **PC**: 4.00

### 1H NMR spectrum

- **Exact Mass**: 324.0102
- **Mol. Wt.**: 324.3411

- **500 MHz C6D6**

---

**Supporting Information**

Hynes, Nasser, Overman and Watson, Dec. 21, 2001
$^{13}$C spectrum with $^1$H decoupling

\[ \text{C}_{12} \text{H}_{14} \text{F}_2 \text{O}_3 \text{S}_2 \]

Exact Mass: 324.0102
Mol. Wt.: 324.3411

125 MHz
$^{6}$D$_6$
Supporting Information Hynes, Nasser, Overman and Watson, Dec. 21, 2001

Exact Mass: 334.0156
Mol. Wt.: 334.3344

$\text{C}_{10}H_{13}F_{3}O_{5}S_{2}$

$\text{CDCl}_3$

100 MHz

Carbon

$137.5$

$69.7$

$31.1$

$38.4$

$69.7$

$92.2$

$106.4$

$96.1$

$10.4$

$55.6$

$60.0$

$12.4$

$143.0$

$76.7$

$100.0$

$77.2$

$120.0$

$180.0$

ppm

$\text{O}^+\text{H}^+\text{F}_{3}\text{O}_{5}\text{S}_{2}$

$\text{CoH}_5\text{F}_{3}\text{O}_{5}\text{S}_{2}$

Exact Mass: 334.0156
Mol. Wt.: 334.3344

$\text{CDCl}_3$

100 MHz
Supporting Information

Hynes, Nasser, Overman and Watson, Dec. 21, 2001

C_{50}H_{55}O_{2}S_{2}N_{2}P_{2}

Exact Mass: 580.2324
Mol. Wt.: 580.8406

500 MHz
Exact Mass: 580.2324
Mol. Wt.: 580.8406

125 MHz

$\text{C}_27\text{H}_{43}\text{F}_3\text{O}_4\text{S}_2\text{Si}$

Supporting Information Hynes, Nasser, Overman and Watson, Dec. 21, 2001
Supporting Information

Hynes, Nasser, Overman and Watson, Dec. 21, 2001

Exact Mass: 330.0571
Mol. Wt.: 330.3888

C_{12}H_{17}F_{3}O_{5}S_{2}

400 MHz
C_{6}D_{6}
$\text{C}_{12}\text{H}_{17}\text{F}_3\text{O}_2\text{S}_2$

Exact Mass: 330.0571
Mol. Wt.: 330.3888

$125$ MHz
$\text{CDCl}_3$
$^{13}$C spectrum with $^1$H decoupling

Bn
\[
\text{O} \quad \begin{array}{c}
\text{C} \\
\text{14} \\
\text{H} \\
\text{16} \\
\text{OS} \\
\end{array}
\]

$^{13}$C spectrum with $^1$H decoupling

C$_{14}$H$_{16}$OS
Exact Mass: 232.0922
Mol. Wt.: 232.3422

125 MHz
CDCl$_3$
Supporting Information

Hynes, Nasser, Overman and Watson, Dec. 21, 2001

C₈H₁₂OS
Exact Mass: 156.0609
Mol. Wt.: 156.2463

400 MHz
CDCl₃
Supporting Information

Hynes, Nasser, Overman and Watson, Dec. 21, 2001

OSMe

C₆H₈OS

Exact Mass: 156.0609
Mol. Wt.: 156.2463

100 MHz
CDCl₃
Supporting Information

Hynes, Nasser, Overman and Watson, Dec. 21, 2001

Current Data Parameters

USER                watson
NAME                DAW3119c
EXPNO               1
PROCNO              1

F2 - Acquisition Parameters
Date_          20010817               Time              17.50
INSTRUM          omega500
PROBHD        5 mm broadband
PULPROG          zgdc30
TD                65536               SOLVENT           CDCl3
NS                  399
DS                    2               SWH           30303.031 Hz
FIDRES         0.462388 Hz
AQ            1.0813940 sec
RG               7298.2
DW               16.500 usec          DE                 4.50 usec
TE                300.0 K
D1           0.25000000 sec           D11          0.03000000 sec

============ CHANNEL f1 =============
NUC1                13C
P1                11.00 usec          PL1               -3.00 dB
SFO1        125.7942048 MHz

============ CHANNEL f2 =============
CPDPRG2         waltz16
NUC2                 1H
PCPD2             80.00 usec
PL2              120.00 dB            PL12              14.80 dB
SFO2        500.2230013 MHz

F2 - Processing parameters
SI                65536
SF          125.7804267 MHz
WDW                  EM
SSB                   0               LB                 0.30 Hz
GB                    0
PC                 1.00

1D NMR plot parameters
CX                22.80 cm
F1P             211.424 ppm
F1             26592.95 Hz            F2P              -0.303 ppm
F2               -38.11 Hz
PPMCM           9.28625 ppm/cm
HZCM         1168.02893 Hz/cm

Bn
O
SPh
C
19
H
18
OS

Exact Mass: 294.1078 Mol. Wt.: 294.4116

125MHz CDCl3
Supporting Information
Hynes, Nasser, Overman and Watson, Dec. 21, 2001

Exact Mass: 200.0507
Mol. Wt.: 200.2558

400 MHz
CDCl₃
Supporting Information Hynes, Nasser, Overman and Watson, Dec. 21, 2001

Exact Mass: 200.0507
Mol. Wt.: 200.2558

$\text{C}_{9}\text{H}_{12}\text{O}_3\text{S}$

$\nu$
Supporting Information

Hynes, Nasser, Overman and Watson, Dec. 21, 2001

\[
\text{C}_{26}\text{H}_{42}\text{O}_{2}\text{Si}
\]
Exact Mass: 446.2675
Mol. Wt.: 446.7620

500 MHz
\[\text{CDCl}_3\]

MeS
Me
OTBS

\[
\begin{align*}
\text{Exact Mass: 446.2675} \\
\text{Mol. Wt.: 446.7620}
\end{align*}
\]
Supporting Information

Hynes, Nasser, Overman and Watson, Dec. 21, 2001

Exact Mass: 446.2675
Mol. Wt.: 446.7620

125MHz CDCl₃