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JO011178M

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**Thallium Trinitrate Mediated Oxidation of
3-Alkenols: Ring Contraction vs Cyclization**

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Supporting Information

General procedure for the preparation of the 3-alkenols.^{1,2} 2-Cyclohex-1-enyl-ethanol (4a):³ To a stirred suspension of Zn^4 (3.92 g, 60.0 mmol), benzene (50 mL), cyclohexanone (5.39 g, 55.0 mmol) and iodine (one crystal) was added ethyl 2-bromoacetate (6.43 mL, 58.0 mmol). The mixture was refluxed for 2.5 h (**CAUTION!** a vigorous reflux is observed in the beginning) and 10% aqueous H_2SO_4 was added at 0 °C. The aqueous phase was extracted with ethyl acetate (twice) and

the combined organic phases were washed with brine and dried over anhydrous MgSO_4 . The solvent was removed under reduced pressure to give **1a** (9.52 g, 51.2 mmol, 93%). When necessary, the hydroxy-esters was separated from the unreacted starting materials by distillation.

To a stirred solution of the hydroxy-ester **1a** (9.30 g, 50.0 mmol) in anhydrous Et_2O (50 mL) at 0°C was added SOCl_2 ⁵ (4.74 mL, 65.0 mmol) and dry pyridine (10 drops). The mixture was stirred for 48 h at room temperature and saturated aqueous NaHCO_3 was added. The aqueous phase was extracted with ethyl acetate (three times) and the combined organic phases were washed with brine (twice) and dried over anhydrous MgSO_4 . The solvent was removed under reduced pressure and the crude product was distilled ($52\text{--}53^\circ\text{C}$, 0.30 mmHg) to afford a 3:7 mixture (by GC and ^1H NMR) of α,β - and β,γ -unsaturated esters (6.38 g, 38.0 mmol).

The mixture of the esters mentioned above (6.38 g, 38.0 mmol) was dissolved in ethanol (38 mL). To this solution, 10% aqueous NaOH (38 mL) was added dropwise at 10°C . The mixture was stirred for 20 minutes at 30°C and water was added. The aqueous phase was extracted with ether (three times) and the combined organic phases were washed with brine (twice) and dried over anhydrous MgSO_4 . The solvent was removed under reduced pressure to give the α,β -unsaturated ester **2a** (1.34 g, 7.98 mmol, 16% from **1a**). Concentrated HCl was added to the aqueous phase, which was extracted with ether (three times). The new combined organic phases were washed with brine (twice) and dried over anhydrous MgSO_4 . The solvent was removed under reduced pressure to give the β,γ -unsaturated acid **3a**

(3.43 g, 24.5 mmol, 49% from **1a**), which was submitted to the next step without purification.

To a stirred suspension of LiAlH_4 (1.37 g, 36.0 mmol) in anhydrous THF (24 mL) at 0°C was added dropwise a solution of the acid **2a** (3.36 g, 24.0 mmol) in anhydrous THF (24 mL). The mixture was stirred for 5 h at room temperature and water was carefully added dropwise followed by 10% aqueous H_2SO_4 . The aqueous phase was extracted with ethyl acetate (twice) and the combined organic phases were washed with brine and dried with anhydrous MgSO_4 . The solvent was removed under reduced pressure and the crude product was purified by flash chromatography (hexanes:AcOEt 7:3 as eluent), affording **4a**³ (2.57 g, 20.4 mmol, 85%) as a viscous colorless oil. ^1H NMR (300 MHz, CDCl_3) δ 1.52-1.67 (m, 4H), 1.77 (br s, OH), 1.92-2.04 (m, 4H), 2.21 (t, $J=6.3$ Hz, 2H), 3.66 (t, $J=6.3$ Hz, 2H), 5.51-5.54 (m, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 22.4, 22.9, 25.3, 28.1, 41.2, 60.3, 124.3, 134.1.

The 3-alkenols **4b-f** and **8** were prepared following the general procedure described above, starting from the corresponding cycloketone and bromoester (see Scheme 2).

2-Cyclohex-1-enyl-propan-1-ol (4b):⁶ viscous colorless oil; ^1H NMR (300 MHz, CDCl_3) δ 0.99 (d, $J=6.9$ Hz, 3H), 1.54-1.66 (m, 4H, OH), 1.89-2.05 (m, 4H), 2.26 (sextet, $J=6.9$ Hz, 1H), 3.43-3.51 (m, 2H), 5.52-5.54 (m, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 15.4, 22.7, 22.9, 25.2, 25.3, 43.9, 65.4, 123.3, 138.6.

2-(4-Methyl-cyclohex-1-enyl)-ethanol (4c): viscous colorless oil; IR (film) 3348, 2908, 1455, 1435, 1044 cm^{-1} ; ^1H NMR (300 MHz, CDCl_3) δ 0.95 (d, $J=6.3$ Hz, 3H), 1.16-1.29 (m, 1H), 1.54-1.74 (m, 3H, OH), 1.96-2.11 (m, 3H), 2.21 (t, $J=6.3$ Hz, 2H), 3.65 (t, $J=6.3$ Hz, 2H), 5.47-5.49 (m, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 21.7, 28.2, 28.4, 31.2, 33.9, 40.8, 60.3, 123.8, 133.8; MS m/z (%) 140 (16, M^+), 122 (15), 107 (52), 93 (100), 79 (66), 67 (91), 55 (55). The compound was mentioned in the literature⁷ with no characterization and analytical data.

2-(4-*tert*-Butyl-cyclohex-1-enyl)-ethanol (4d):⁸ viscous colorless oil; ^1H NMR (300 MHz, CDCl_3) δ 0.86 (s, 9H), 1.07-1.31 (m, 2H), 1.68-1.91 (m, 2H, OH), 1.99-2.09 (m, 3H), 2.22 (t, $J=6.3$ Hz, 2H), 3.66 (t, $J=6.3$ Hz, 2H), 5.52-5.53 (br s, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 24.2, 26.9, 27.2, 29.6, 32.2, 40.6, 44.2, 60.3, 124.5, 133.9.

2-(4-Methyl-cyclohex-1-enyl)-propan-1-ol (4e): viscous colorless oil; IR (film) 3371, 2922, 1456, 1032 cm^{-1} ; ^1H NMR (500 MHz, CDCl_3) δ 0.95 (d, $J=6.2$ Hz, 3H), 0.98 e 1.00 (d, $J=3.8$ Hz, d, $J=3.8$ Hz, 3H), 1.16-1.26 (m, 1H), 1.57-1.75 (m, 3H, OH), 1.91-2.12 (m, 3H), 2.24-2.31 (m, 1H), 3.43-3.50 (m, 2H), 5.49-5.50 (m, 1H); ^{13}C NMR (125 MHz, CDCl_3) δ 15.2/15.7, 21.7/21.8, 25.1/25.6, 28.6/28.7, 31.1/31.3, 33.8/33.9, 43.5/43.6, 65.4/65.5, 122.7/122.9, 138.2/138.3; MS m/z (%) 154 (9.3, M^+), 136 (10), 123 (88), 107 (24), 95 (27), 81 (100), 67 (46), 55 (27); HRMS Calcd for $\text{C}_{10}\text{H}_{12}\text{O}_2$: 154.1357; Found: 154.1324.

2-(4-*tert*-Butyl-cyclohex-1-enyl)-propan-1-ol (4f): viscous colorless; IR (film) 3355, 2958, 1469, 1364, 1037, 1024 cm^{-1} ; ^1H NMR (300 MHz, CDCl_3) δ 0.87 (s, 9H), 0.98 e 1.00 (d, $J=3.0$ Hz, d, $J=3.0$ Hz, 3H), 1.07-1.29 (m, 2H), 1.42 (br s, OH), 1.67-2.01 (m, 5H), 2.26-2.32 (m, 1H), 3.44-3.48 (m, 2H), 5.53-5.55 (m, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 15.1/15.8, 24.2/24.3, 26.5, 26.8/26.9, 27.2, 32.2, 43.3/43.4, 44.4, 65.4, 123.5/123.7, 138.3/138.5; MS m/z (%) 196 (1.9, M^+), 155 (43), 137 (6.0), 115 (41), 109 (11), 98 (75), 81 (33), 67 (24), 57 (100); Anal. Calcd. for $\text{C}_{10}\text{H}_{18}\text{O}$: C, 79.53%; H, 12.32%; Found: C, 79.50%; H, 11.95%.

2-Cyclohept-1-enyl-ethanol (8):⁹ viscous colorless oil; ^1H NMR (300 MHz, CDCl_3) δ 1.44-1.52 (m, 4H), 1.71-1.78 (m, 2H, OH), 2.08-2.15 (m, 4H), 2.24 (t, $J=6.2$ Hz, 2H), 3.63 (t, $J=6.2$ Hz, 2H), 5.66 (t, $J=6.4$ Hz, 1H); ^{13}C NMR (75 MHz, CDCl_3) δ 26.9, 27.4, 28.4, 32.5, 32.6, 43.4, 60.2, 129.6, 140.8.

Reaction of 2-(4-methyl-cyclohex-1-enyl)-ethanol (4c) with TTN in MeOH.
To a stirred solution of **4c** (0.468 g, 3.34 mmol) in MeOH (20 mL) at 0°C was added $\text{TTN} \cdot 3\text{H}_2\text{O}$ (1.48 g, 3.34 mmol). The reagent promptly dissolved. The mixture was stirred for 3 minutes and an abundant precipitation was observed. The resulting suspension was filtered through a silica gel pad (70-230 Mesh, ca. 10 cm), using CH_2Cl_2 as eluent. The filtrate was then washed with water followed by brine (twice) and dried over anhydrous MgSO_4 . The solvent was removed under reduced pressure and the crude product was purified by flash chromatography

(CH₂Cl₂:AcOEt 9:1 as eluent) affording **5c** (0.166 g, 1.06 mmol, 32%) as a colorless oil.

Reaction of 2-cyclohept-1-enyl-ethanol (8) with TTN in MeOH. A mixture of **8** (0.241 g, 1.72 mmol), MeOH (10 mL) and TTN.3H₂O (0.764 g, 1.72 mmol) was stirred for 2 minutes at 0°C, following the procedure described above. Purification by flash chromatography (gradient elution, 0-50% AcOEt in hexanes) gave **9** (0.125 g, 0.801 mmol, 46%) as a colorless oil.

Reaction of 2-(4-methyl-cyclohex-1-enyl)-ethanol (4c) with TTN in 35% aqueous HClO₄. To a stirred solution of **4c** (0.412 g, 2.94 mmol) in 35% aqueous HClO₄ (9 mL) was added TTN.3H₂O (1.57 g, 3.53 mmol), which promptly dissolved. The mixture was stirred for 15 minutes at room temperature and water was added. The mixture was extracted with CH₂Cl₂ (three times) and the combined organic phases were washed with brine (twice) and dried over anhydrous MgSO₄. The solvent was removed under reduced pressure and the crude product was purified by flash chromatography (gradient elution, 0-50% AcOEt in hexanes) affording **6c** (0.266 g, 1.71 mmol, 58%) as a colorless oil.

Reaction of 2-(4-*tert*-butyl-cyclohex-1-enyl)-ethanol (4d) with TTN in 35% aqueous HClO₄. A mixture of **4d** (0.366 g, 2.01 mmol), 35% aqueous HClO₄ (6 mL) and TTN.3H₂O (1.07g, 2.40 mmol) was stirred for 15 minutes at room temperature, following the procedure described above. Purification by flash

chromatography (gradient elution 0-50% AcOEt in hexanes) gave **6d** (0.275 g, 1.39 mmol, 69%) as a white solid.

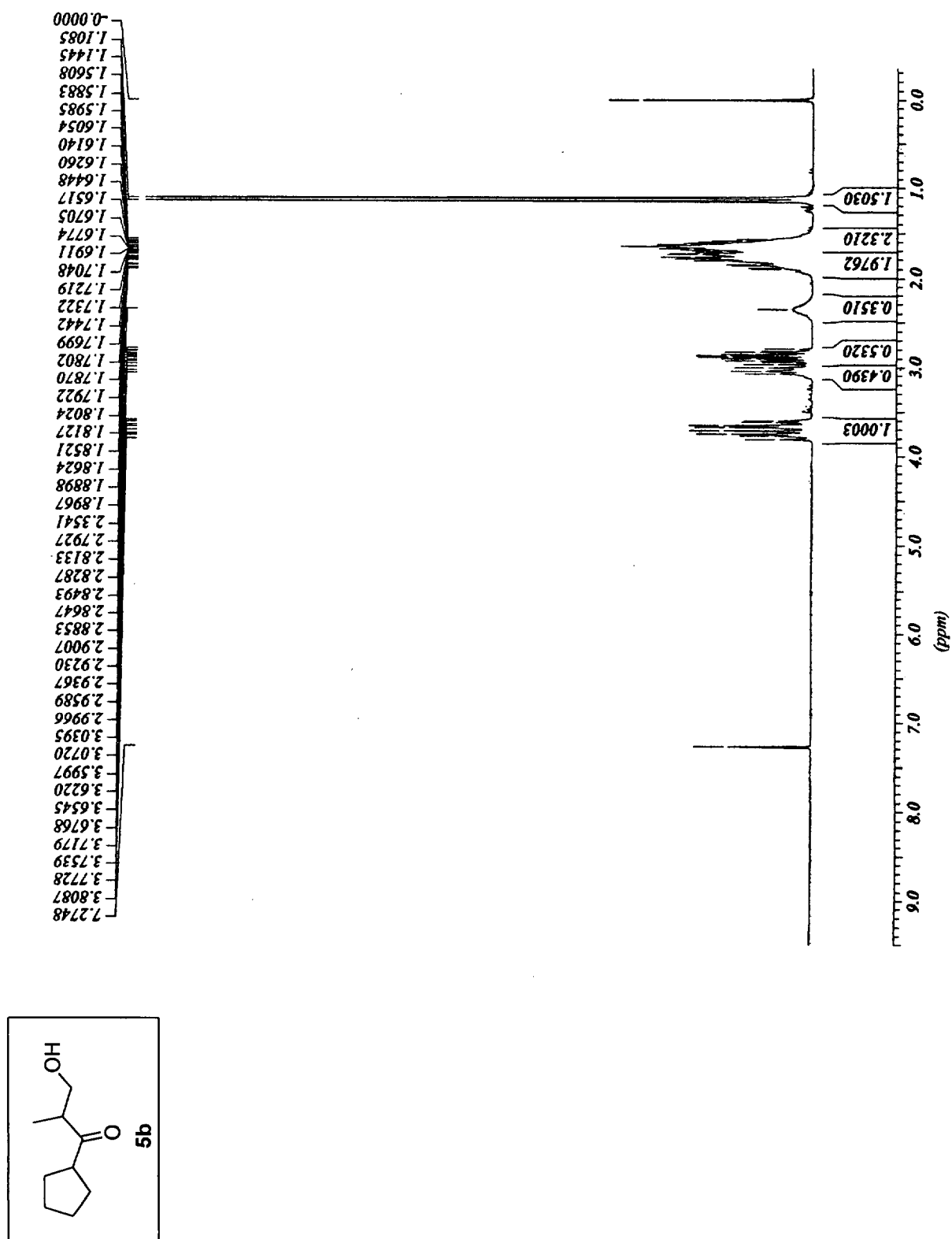


Figure S1. ¹H NMR spectrum of **5b** (CDCl₃, 200MHz, TMS, δ ppm).

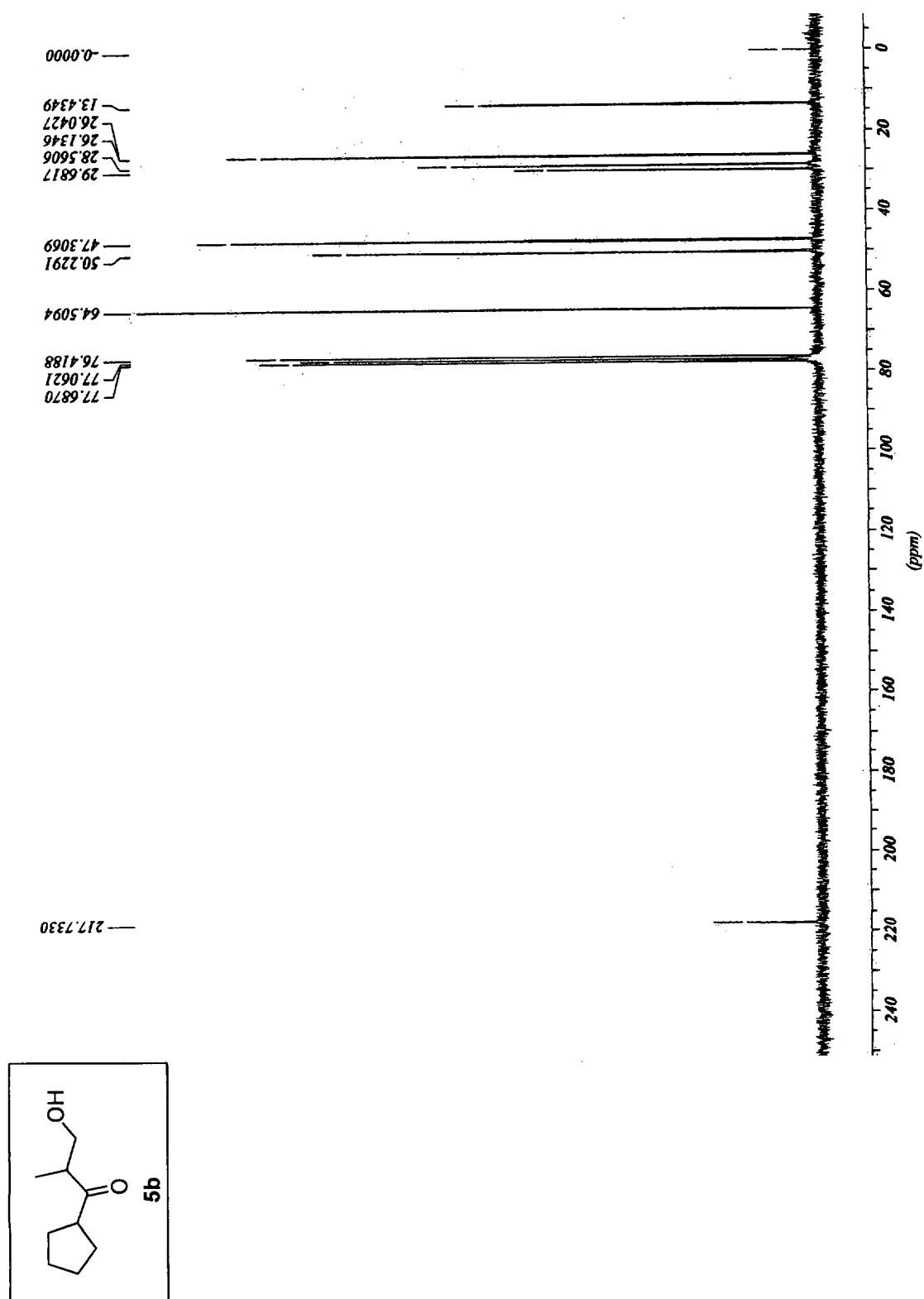


Figure S2. ¹³C NMR spectrum of **5b** (CDCl₃, 50MHz, TMS, δ ppm).

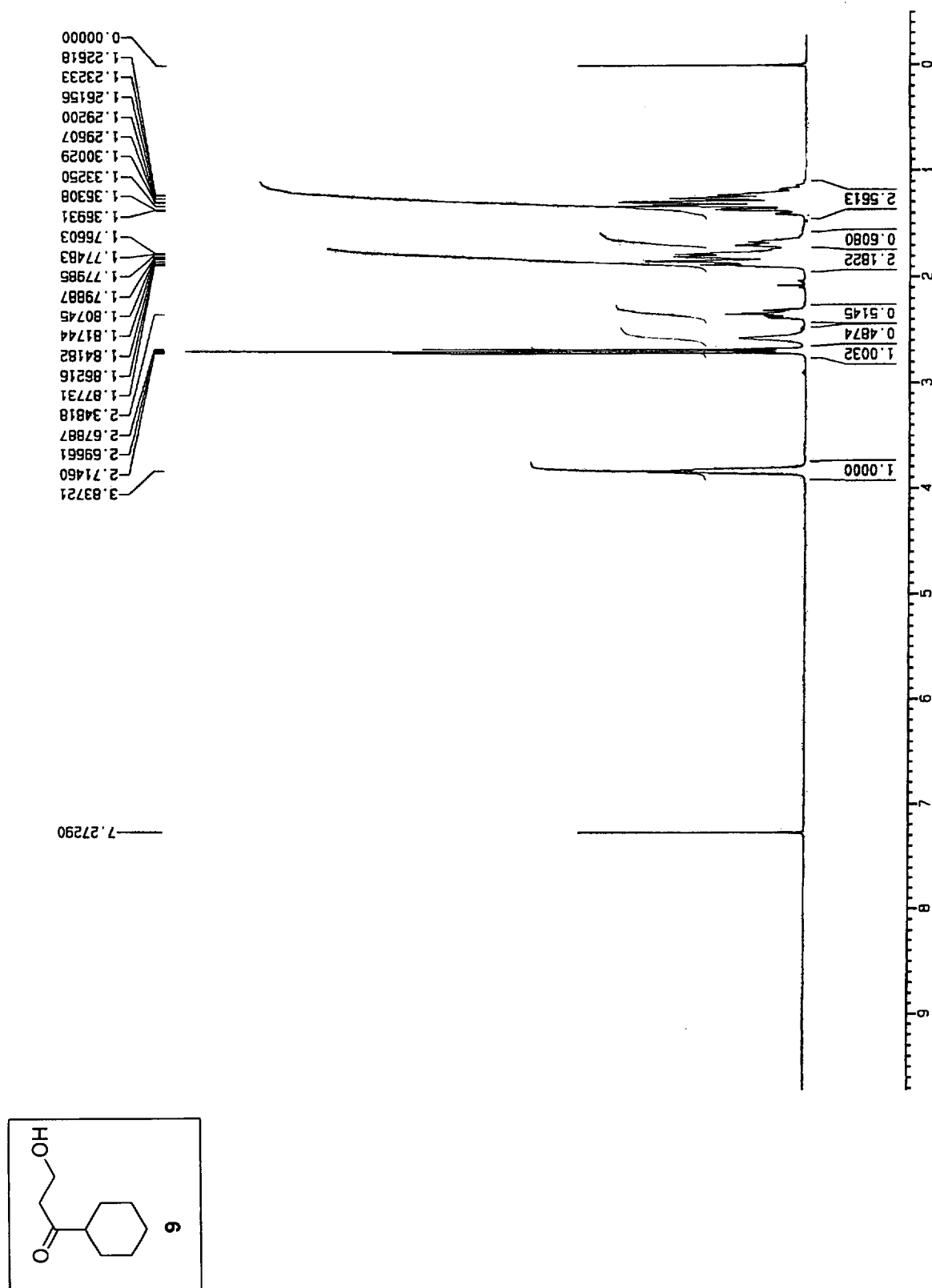


Figure S3. ¹H NMR spectrum of **9** (CDCl₃, 300MHz, TMS, δ ppm).

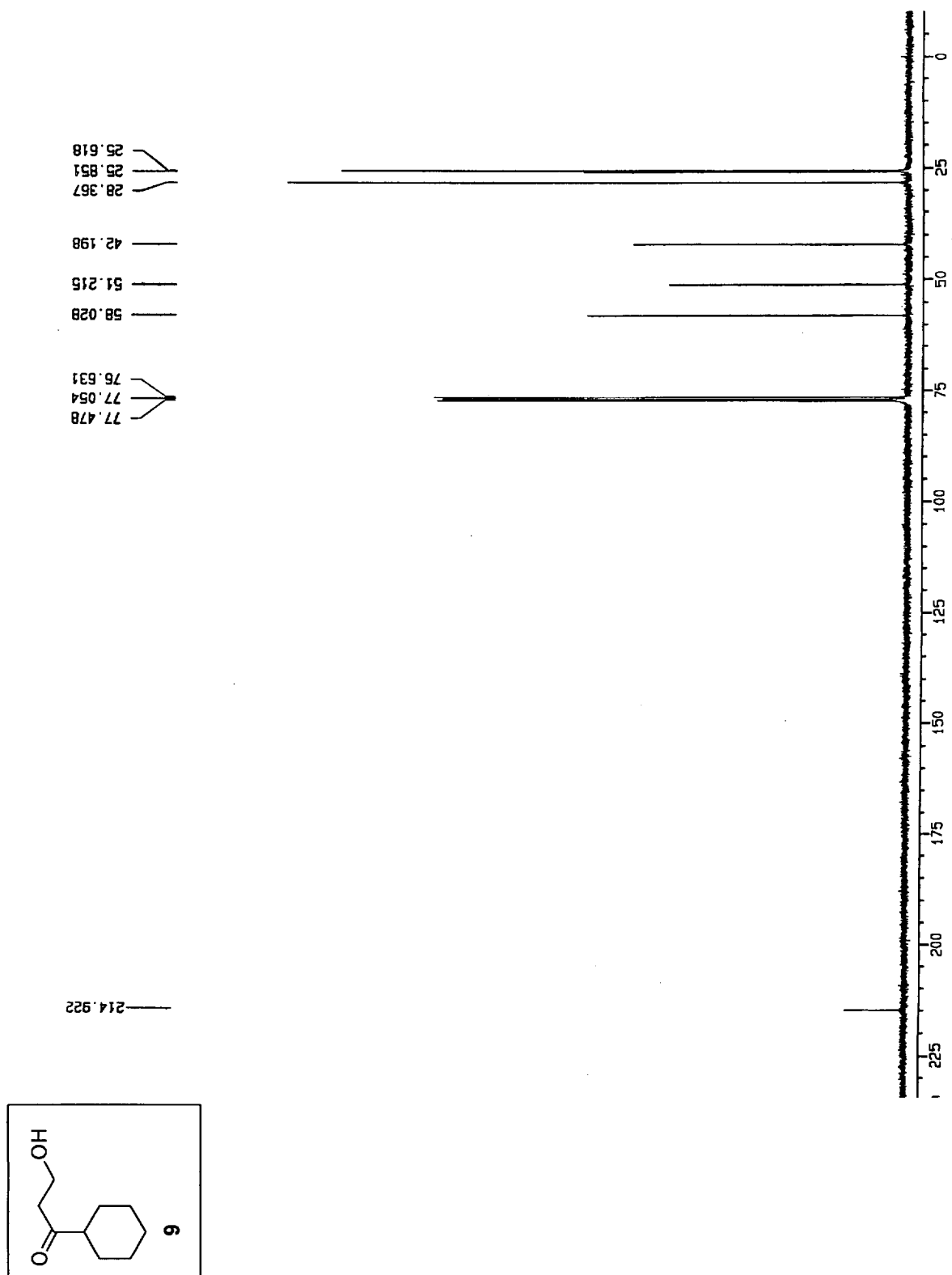


Figure S4. ¹³C NMR spectrum of **9** (CDCl₃, 75MHz, TMS, δ ppm).

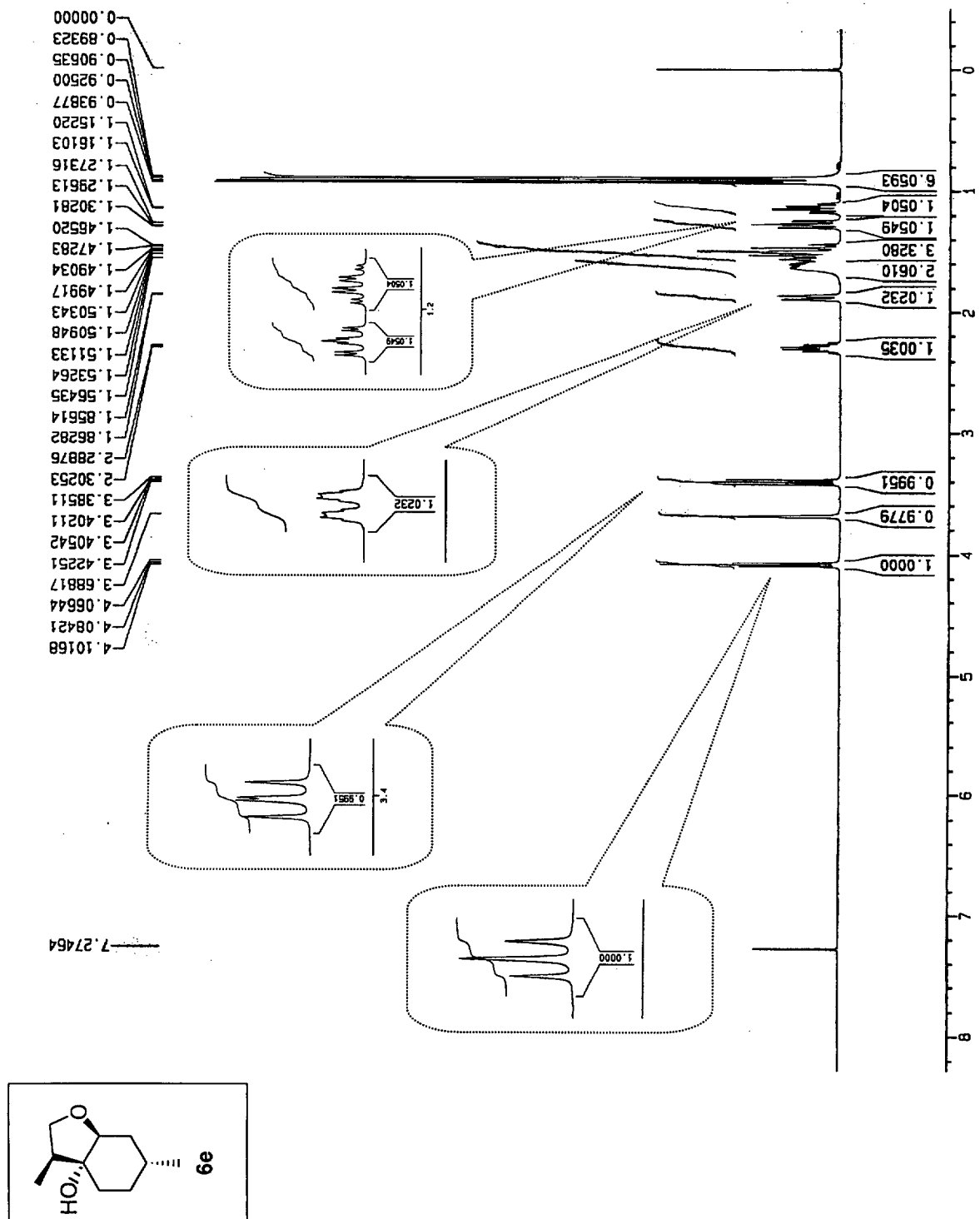


Figure S5. ¹H NMR spectrum of **6e** (CDCl₃, 500MHz, TMS, δ ppm).

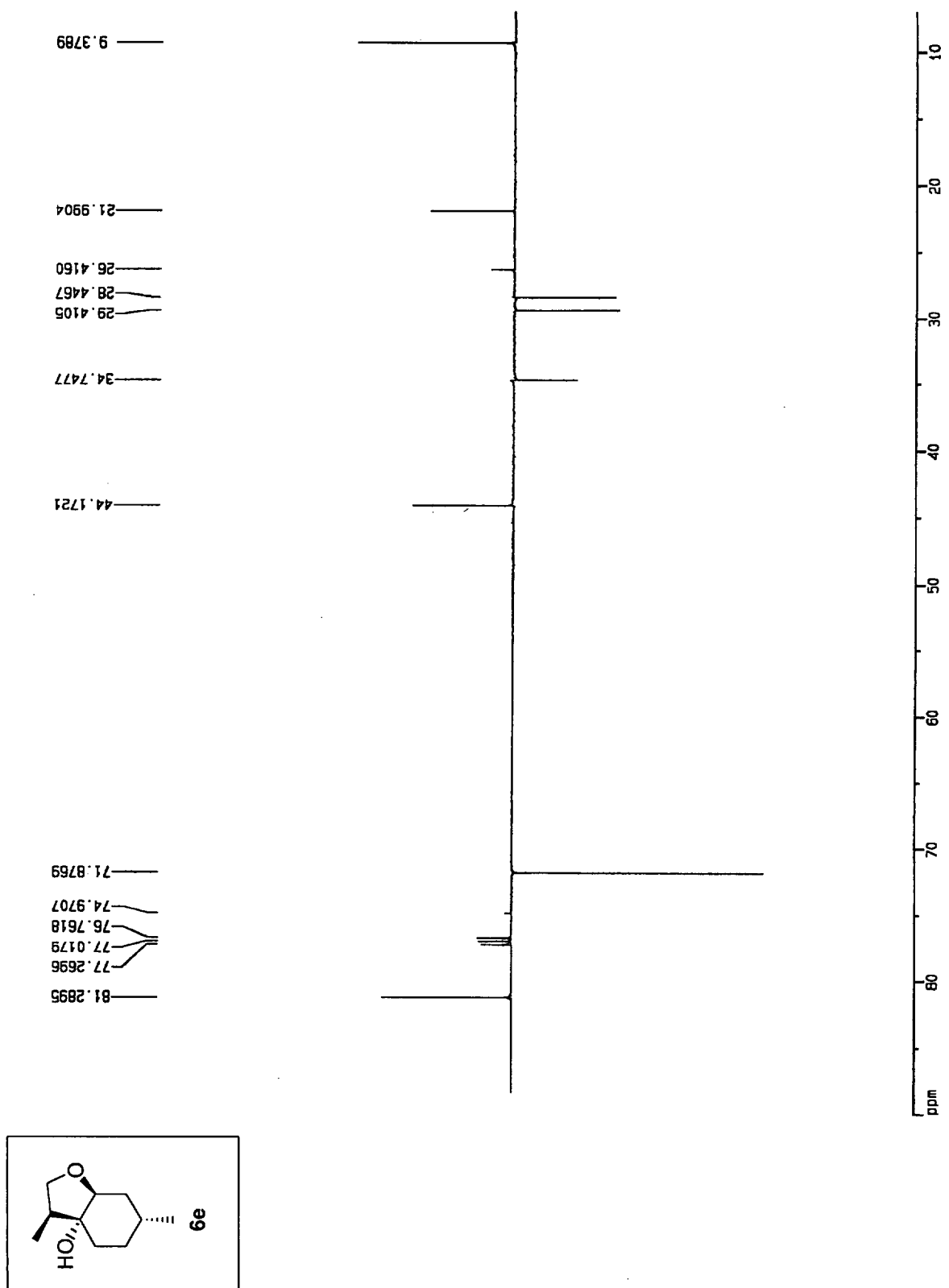


Figure S6. ¹³C NMR (PENDANT) spectrum of **6e** (CDCl₃, 125MHz, TMS, δ ppm).

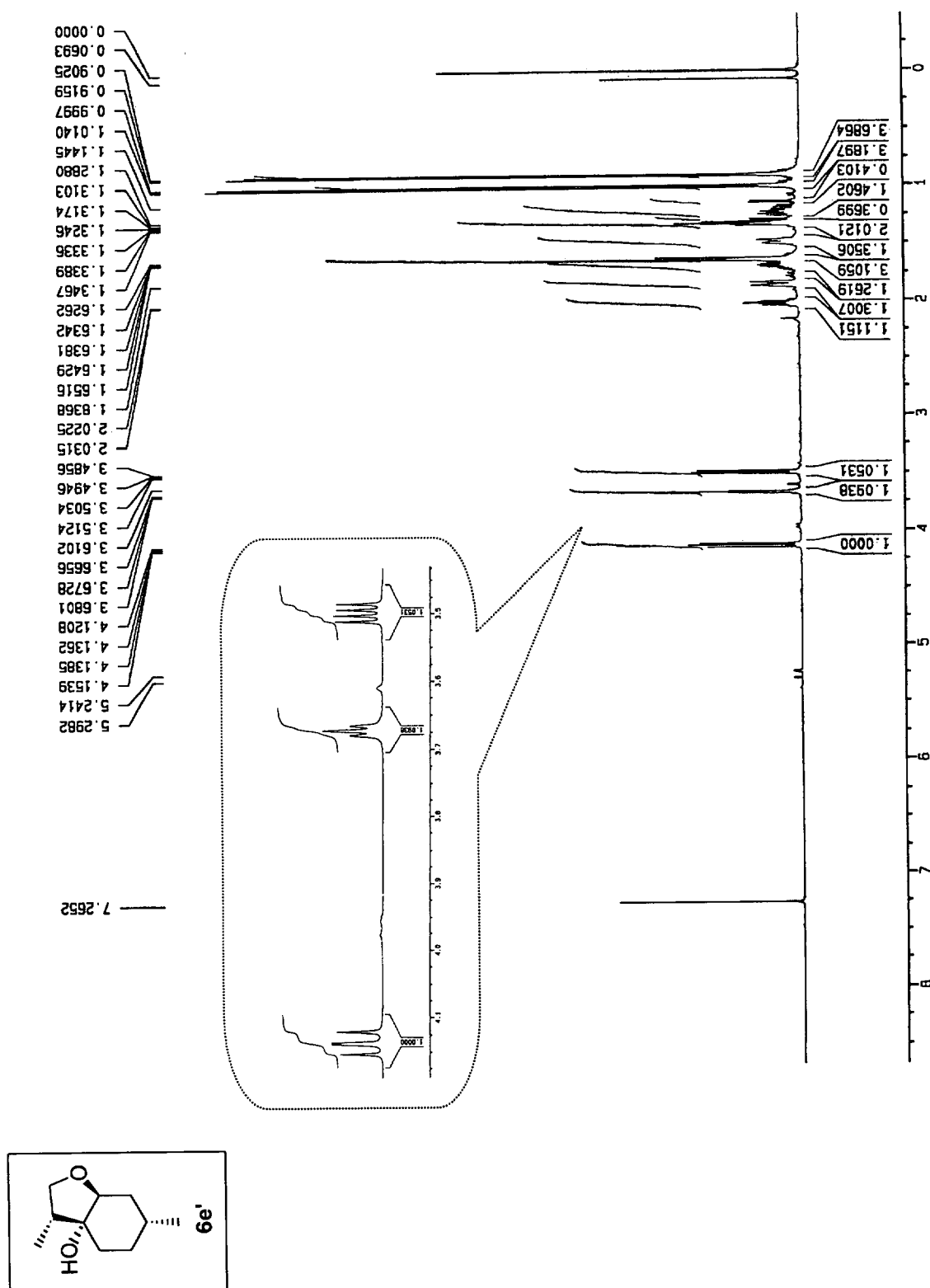


Figure S7. ¹H NMR spectrum of **6e'** (CDCl₃, 500MHz, TMS, δ ppm).

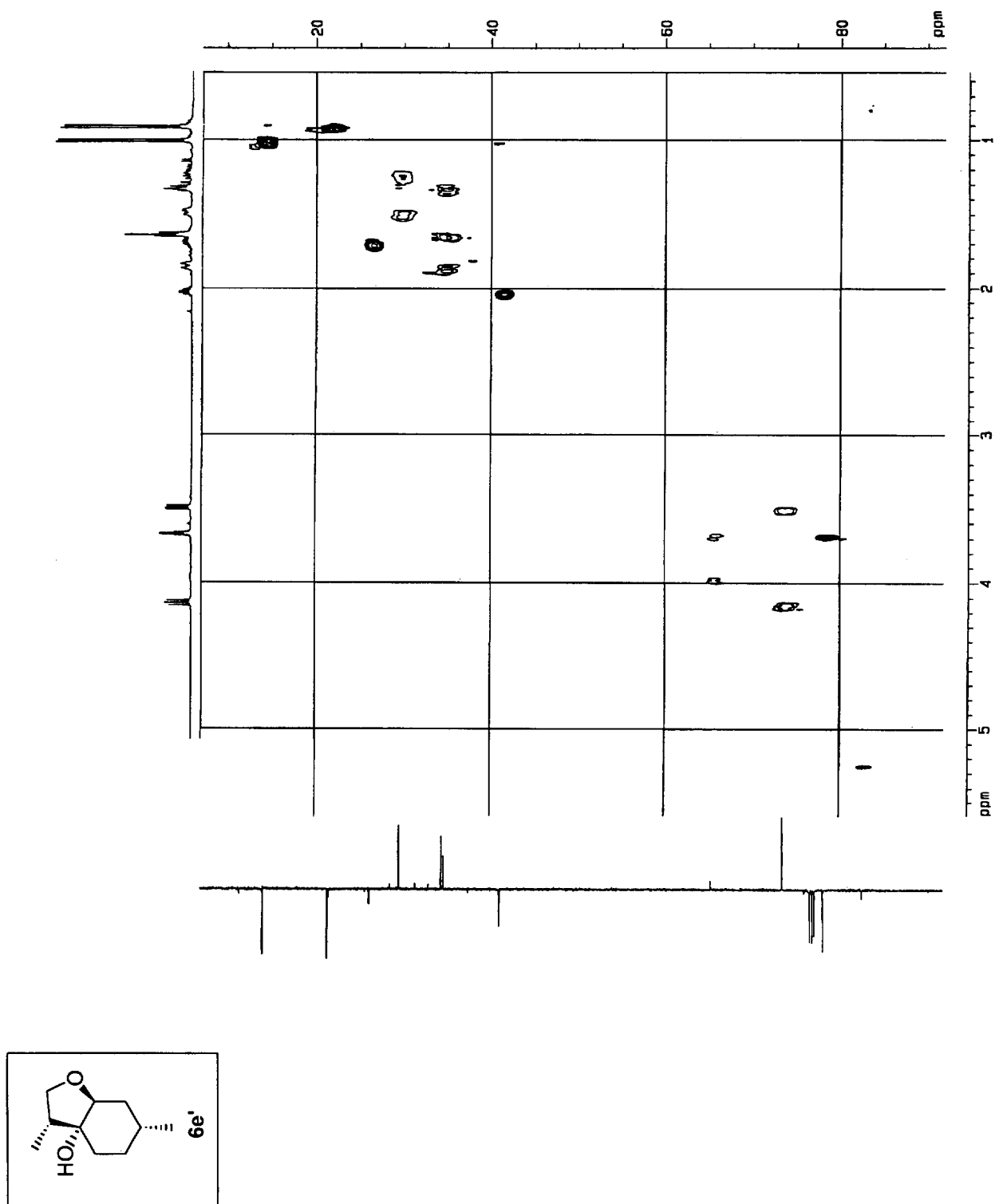


Figure S8. HSQC spectrum of **6e'** (CDCl_3 , 500MHz, TMS, δ ppm).

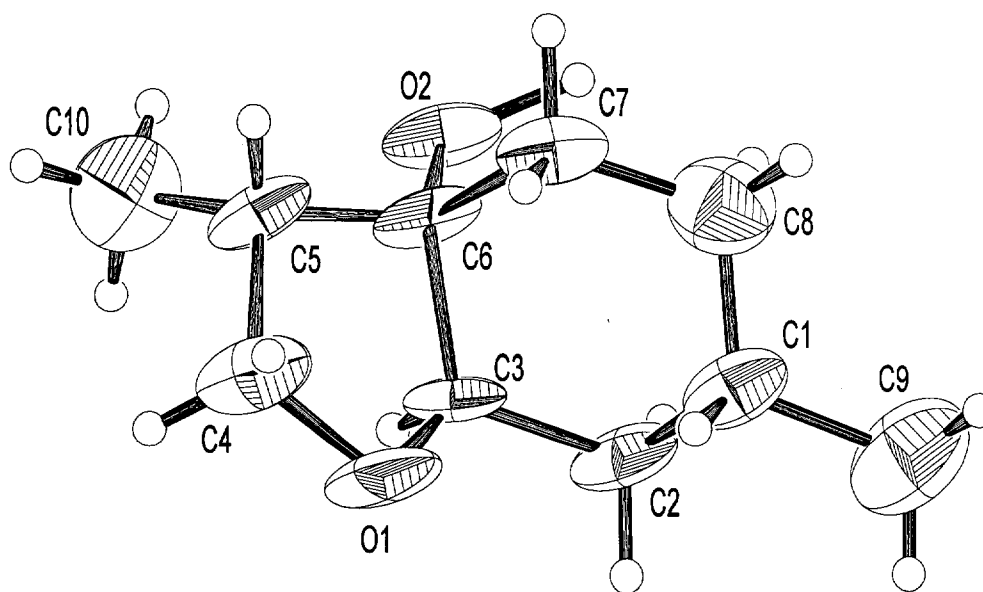


Figure S9. ORTEP diagram of the X-ray crystal structure of **6e'**.

Crystal data and structure refinement.

| | |
|---------------------------------------|---|
| Empirical formula | C10 H18 O2 |
| Formula weight | 170.24 |
| Temperature | 293(2) K |
| Wavelength | 0.71073 Å |
| Crystal system, space group | monoclinic, P21 |
| Unit cell dimensions | $a = 5.8358(9) \text{ Å}$ ($\angle = 90^\circ$) $b = 9.285(1) \text{ Å}$ ($\angle = 96.96(1)^\circ$) $c = 9.343(1) \text{ Å}$ ($\angle = 90^\circ$) |
| Volume | 502.52(11) Å ³ |
| Z, Calculated density | 2, 1.125 Mg/m ³ |
| Absorption coefficient | 0.076 mm ⁻¹ |
| F(000) | 188 |
| Crystal size | 0.10 x 0.10 x 0.04 mm |
| (θ range for data collection) | 2.20 to 24.95° |

| | |
|--------------------------------|-------------------------------------|
| Limiting indices | -6=h=6, 0=k=10, 0=l=10 |
| Reflections collected / unique | 890 / 837 [R(int) = 0.0176] |
| Refinement method | Full-matrix least-squares on F2 |
| Data / restraints / parameters | 837 / 1 / 111 |
| Goodness-of-fit on F2 | 1.065 |
| Final R indices [I>2sigma(I)] | R1 = 0.0655, wR2 = 0.1734 |
| R indices (all data) | R1 = 0.1244, wR2 = 0.2066 |
| Largest diff. peak and hole | 0.244 and -0.362 e. Å ⁻³ |

Atomic coordinates (x 104) and equivalent isotropic displacement parameters (Å² x 103). U(eq) is defined as one third of the trace of the orthogonalized U_{ij} tensor.

| | x | y | z | U(eq) |
|-------|----------|----------|----------|-------|
| O(1) | 343(6) | 2396(6) | 8522(6) | 67(2) |
| O(2) | 6021(6) | 3689(5) | 8393(5) | 56(1) |
| C(1) | 4245(8) | 2613(7) | 8296(7) | 47(2) |
| C(2) | 4445(10) | 1598(7) | 7039(8) | 56(2) |
| C(3) | 3768(12) | 2268(9) | 5586(9) | 67(2) |
| C(4) | 1344(11) | 2832(8) | 5449(8) | 58(2) |
| C(5) | 1140(11) | 3970(7) | 6590(8) | 55(2) |
| C(6) | 1949(8) | 3426(7) | 8085(8) | 49(2) |
| C(8) | 1526(12) | 1436(10) | 9586(9) | 72(2) |
| C(9) | 4086(10) | 1777(8) | 9684(8) | 55(2) |
| C(10) | 4997(14) | 2534(10) | 11026(9) | 76(2) |
| C(11) | 461(15) | 3419(13) | 3943(10) | 93(3) |

Bond lengths [Å] and angles [deg].

| | |
|------------|-----------|
| O(1)-C(6) | 1.433(8) |
| O(1)-C(8) | 1.447(9) |
| O(2)-C(1) | 1.434(7) |
| C(1)-C(2) | 1.521(9) |
| C(1)-C(9) | 1.524(10) |
| C(1)-C(6) | 1.530(7) |
| C(2)-C(3) | 1.502(11) |
| C(3)-C(4) | 1.500(9) |
| C(4)-C(5) | 1.516(11) |
| C(4)-C(11) | 1.539(10) |
| C(5)-C(6) | 1.506(9) |
| C(8)-C(9) | 1.519(9) |
| C(9)-C(10) | 1.479(10) |

| | |
|-----------------|----------|
| C(6)-O(1)-C(8) | 109.4(5) |
| O(2)-C(1)-C(2) | 110.9(4) |
| O(2)-C(1)-C(9) | 114.8(5) |
| C(2)-C(1)-C(9) | 111.1(6) |
| O(2)-C(1)-C(6) | 106.2(5) |
| C(2)-C(1)-C(6) | 110.7(5) |
| C(9)-C(1)-C(6) | 102.6(5) |
| C(3)-C(2)-C(1) | 113.9(6) |
| C(4)-C(3)-C(2) | 111.3(5) |
| C(3)-C(4)-C(5) | 109.7(6) |
| C(3)-C(4)-C(11) | 114.2(6) |
| C(5)-C(4)-C(11) | 110.5(6) |
| C(6)-C(5)-C(4) | 112.1(6) |
| O(1)-C(6)-C(5) | 110.3(5) |
| O(1)-C(6)-C(1) | 103.1(5) |
| C(5)-C(6)-C(1) | 117.2(5) |
| O(1)-C(8)-C(9) | 107.3(6) |
| C(10)-C(9)-C(8) | 113.6(6) |
| C(10)-C(9)-C(1) | 115.3(6) |
| C(8)-C(9)-C(1) | 102.5(5) |

Anisotropic displacement parameters ($\text{\AA}^2 \times 10^3$). The anisotropic displacement factor exponent takes the form: $-2 \left(h^2 a^{*2} U_{11} + \dots + 2 h k a^* b^* U_{12} \right)$

| | U11 | U22 | U33 | U23 | U13 | U12 |
|-------|-------|-------|--------|--------|--------|--------|
| O(1) | 18(2) | 74(4) | 104(4) | 19(3) | -9(2) | 0(2) |
| O(2) | 21(2) | 43(3) | 99(3) | -12(3) | -6(2) | -10(2) |
| C(1) | 15(3) | 40(4) | 80(5) | -6(4) | -16(3) | 3(3) |
| C(2) | 30(3) | 40(4) | 94(5) | -11(4) | -5(3) | 4(3) |
| C(3) | 61(4) | 52(4) | 86(6) | -5(5) | 5(4) | 6(4) |
| C(4) | 36(3) | 50(4) | 84(5) | 12(4) | -13(3) | 0(3) |
| C(5) | 37(3) | 41(4) | 86(5) | 20(4) | -2(3) | 11(3) |
| C(6) | 19(3) | 41(4) | 86(5) | -5(4) | 1(3) | 6(3) |
| C(8) | 42(4) | 66(5) | 105(6) | 24(5) | -4(4) | -2(4) |
| C(9) | 30(3) | 42(4) | 85(5) | 7(4) | -21(3) | 0(3) |
| C(10) | 80(5) | 63(5) | 80(5) | 0(5) | -4(4) | -12(5) |
| C(11) | 87(6) | 89(7) | 96(7) | 15(6) | -19(4) | 6(6) |

Hydrogen coordinates (x 104) and isotropic displacement parameters ($\text{\AA}^2 \times 10^3$)

| | x | y | z | U(eq) |
|--------|-------|------|-------|-------|
| H(2O) | 6612 | 3635 | 7185 | 67 |
| H(2A) | 6027 | 1264 | 7090 | 67 |
| H(2B) | 3473 | 765 | 7136 | 67 |
| H(3A) | 4818 | 3051 | 5445 | 80 |
| H(3B) | 3897 | 1555 | 4840 | 80 |
| H(4) | 337 | 2029 | 5645 | 70 |
| H(5A) | 2053 | 4803 | 6390 | 66 |
| H(5B) | -457 | 4273 | 6545 | 66 |
| H(6) | 2040 | 4241 | 8755 | 58 |
| H(8B) | 1247 | 442 | 9299 | 87 |
| H(8A) | 977 | 1582 | 10515 | 87 |
| H(9) | 4933 | 870 | 9636 | 65 |
| H(10A) | 6531 | 2871 | 10948 | 113 |
| H(10B) | 5031 | 1883 | 11827 | 113 |
| H(10C) | 4019 | 3338 | 11175 | 113 |
| H(11A) | 1332 | 4259 | 3750 | 140 |
| H(11B) | -1141 | 3669 | 3908 | 140 |
| H(11C) | 641 | 2696 | 3231 | 140 |

References

- (1) For a review concerning Reformatsky Reaction, see: Rathke, M.W. In *Organic Reactions*; Dauben, W.G., Ed.; John Wiley & Sons: New York, 1975; Vol. 22, p 423; and references cited therein.
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- (3) (a) Benkeser R.A.; Arnold, Jr., C.; Lambert, R.F.; Thomas, O.H. *J. Am. Chem. Soc.* **1955**, *77*, 6042; (b) Barluenga, J.; Alvarez, F.; Concellon, J.M.; Yus, M. *Synthesis* **1986**, 654.
- (4) Zinc powder was activated by washing several times with 10% aqueous HCl, water, saturated aqueous HgCl₂, water, ethanol and acetone. The zinc obtained was then dried in an oven (ca. 120 °C) and stored in a desiccator.
- (5) Thionyl chloride was distilled from linseed oil (50 g of SOCl₂/20 g of linseed oil).
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