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# A Palladium-Catalyzed Vinylcyclopropane (3+2) Cycloaddition Approach to the Melodinus Alkaloids

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**A Palladium-Catalyzed Vinylcyclopropane (3 + 2) Cycloaddition Approach to the Melodinus Alkaloids**

Alexander F. G. Goldberg and Brian M. Stoltz\*

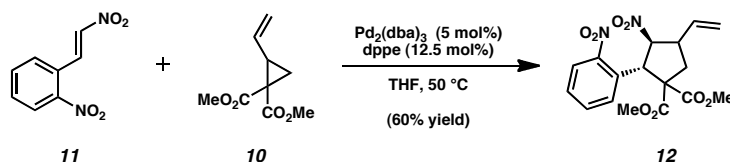
*The Warren and Katherine Schlinger Laboratory for Chemistry and Chemical Engineering, Division of Chemistry and Chemical Engineering, California Institute of Technology, 1200 East California Boulevard, MC 101-20, Pasadena, CA 91125, USA*

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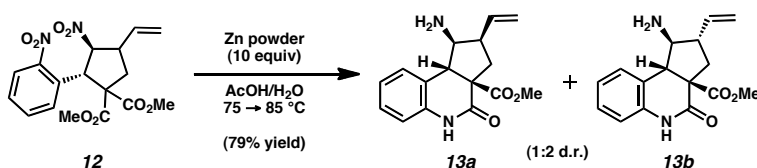
**Materials and Methods.** Unless stated otherwise, reactions were performed in flame-dried glassware under an argon or nitrogen atmosphere using dry, deoxygenated solvents (distilled or passed over a column of activated alumina).<sup>1</sup>  $\beta$ -2-dinitrostyrene is commercially available from Sigma-Aldrich for \$123.50/5g but may be prepared according to the method of Solomonovici and Blumberg.<sup>2</sup> Vinylcyclopropane **10** was prepared in one step according to the method of Parsons and Johnson.<sup>3</sup> Commercially obtained reagents were used as received with the exception of *trans*-cinnamaldehyde, which was purified by bulb-to-bulb distillation before use. Reaction temperatures were controlled by an IKAmag temperature modulator. Thin-layer chromatography (TLC) was performed using E. Merck silica gel 60 F254 precoated plates (0.25 mm) and visualized by UV fluorescence quenching, potassium permanganate, or anisaldehyde staining. SiliaFlash P60 Academic Silica gel (particle size 0.040-0.063 mm) was used for flash chromatography. <sup>1</sup>H and <sup>13</sup>C NMR spectra were recorded on a Varian 400 (at 400 MHz and 100 MHz, respectively) or on a Varian Mercury 300 (at 300 MHz) and are reported relative to CHCl<sub>3</sub> ( $\delta$  7.26 & 77.16 respectively). Data for <sup>1</sup>H NMR spectra are reported as follows: chemical shift ( $\delta$  ppm) (multiplicity, coupling constant (Hz), integration). IR spectra were recorded on a Perkin Elmer Paragon 1000 Spectrometer and are reported in frequency of absorption (cm<sup>-1</sup>). HRMS were acquired using an Agilent 6200 Series TOF with an Agilent G1978A Multimode source in electrospray ionization (ESI), atmospheric pressure chemical ionization (APCI) or mixed (MM) ionization mode.

## Experimental Procedures



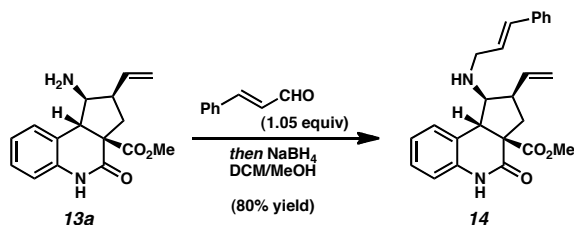
**Cyclopentane 12.** To a flame-dried schlenk-tube was added  $\text{Pd}_2(\text{dba})_3$  (147 mg, 0.160 mmol) and dppe (147 mg, 0.369 mmol). The schlenk-tube was evacuated and backfilled with argon twice. In a separate, flame-dried, conical flask, THF was sparged with argon for 20 minutes. After this period, THF (25 mL) was added to the schlenk-tube, and the resulting purple solution was heated at 40 °C until the solution became bright orange, at which point, the solution was allowed to cool to ambient temperature. To a separate, flame-dried conical flask was added  $\beta$ -2-dinitrostyrene (**11**) (575 mg, 2.96 mmol, 1 equiv), THF (5 mL) and vinylcyclopropane **10** (500  $\mu\text{L}$ , 2.96 mmol, 1 equiv). The latter solution was transferred via cannula to the schlenk tube, and the reaction mixture became red. The solution was heated to 40 °C and stirred for 14 hours. Upon completion, the reaction mixture was concentrated *in vacuo* and purified by flash chromatography (100 mL  $\text{SiO}_2$ , 10:1 $\rightarrow$ 5:1 hexanes:ethyl acetate), yielding a yellow solid which was further purified by trituration with diethyl ether to afford **12** (670.9 mg, 60% yield), a white solid, as a mixture of diastereomers, **12a** (major) and **12b** (minor):  $R_f$  = 0.17 (3:1 hexanes:ethyl acetate);  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ , **12a**)  $\delta$  7.89–7.84 (m, 1H), 7.60–7.52 (m, 1H), 7.49–7.41 (m, 1H), 7.40–7.35 (m, 1H), 5.90 (dtd,  $J$  = 18.2, 8.8, 8.0 Hz, 1.4 Hz, 1H), 5.53 (d,  $J$  = 10.7 Hz, 1H), 5.33–5.19 (m, 2H), 5.10 (td,  $J$  = 10.5, 1.4 Hz, 1H), 3.85–3.76 (m, 1H) 3.75 (app d,  $J$  = 1.4 Hz, 3H), 3.27 (app d,  $J$  = 1.5 Hz, 3H), 2.76–2.67 (m, 1H), 2.65–2.56 (m, 1H);  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ , **12b**)  $\delta$  7.89–7.84 (m, 1H),

7.60–7.52 (m, 1H), 7.49–7.41 (m, 1H), 7.40–7.35 (m, 1H), 5.76–5.61 (m, 2H), 5.43 (ddd,  $J = 8.7, 7.1, 1.3$  Hz, 1H), 5.33–5.19 (m, 2H), 3.71 (app d,  $J = 1.6$  Hz, 3H), 3.42–3.30 (m, 1H), 3.34 (app d,  $J = 1.4$  Hz, 3H), 2.79 (ddd,  $J = 13.7, 6.9, 1.3$  Hz, 1H), 2.39 (ddd,  $J = 13.8, 10.6, 1.4$  Hz, 1H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  170.5, 170.4, 170.0, 169.9, 134.7, 132.9, 132.5, 132.4, 130.6, 129.5, 129.4, 129.2, 125.4, 125.4, 120.3, 119.4, 94.9, 93.4, 64.7, 62.9, 53.7, 53.5, 52.9, 52.8, 48.2, 46.6, 46.3, 38.6, 37.4; IR (NaCl/film) 3002, 2955, 1733, 1557, 1532, 1436, 1358, 1282, 1263, 1219, 1173, 932  $\text{cm}^{-1}$ ; HRMS (MM: ESI-APCI)  $m/z$  calc'd for  $\text{C}_{17}\text{H}_{19}\text{N}_2\text{O}_8$   $[\text{M}+\text{H}]^+$ : 379.1136, found 379.1144.



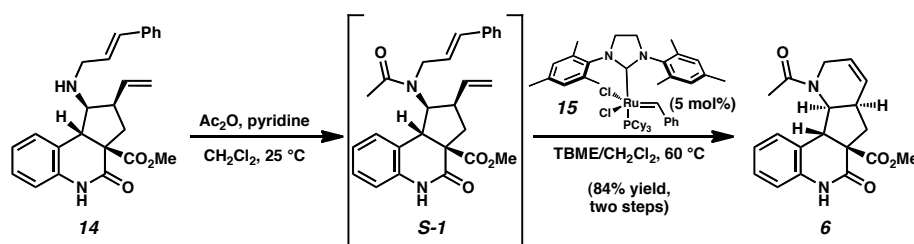
**Lactams 13a and 13b.** A suspension of cyclopentane **12** (5.2206 g, 13.8 mmol, 1 equiv) in acetic acid (85% in  $\text{H}_2\text{O}$ , 70 mL, 0.2 M) was stirred in an open flask, heated in a 75 °C oil bath until completely homogeneous. Zinc powder (9.0130 g, 138 mmol, 10 equiv) was added to the heated solution in portions, maintaining an internal temperature lower than 90 °C. Vigorous bubbling is observed over the course of the zinc addition. Upon completion of the addition, the temperature was allowed to stabilize at 75 °C and the reaction progress was monitored by TLC. Upon consumption of starting material, the flask was removed from the oil bath and allowed to cool to room temperature, during which time, white solids precipitate from solution. The heterogeneous mixture is filtered through celite, and washed with 100 mL of ethyl acetate. The solution was basified with saturated  $\text{NaHCO}_3(\text{aq})$  and solid  $\text{Na}_2\text{CO}_3$ . The phases were separated and the aqueous phase was extracted exhaustively with ethyl acetate. The combined organics were

washed with saturated  $\text{NaHCO}_3(\text{aq})$  and brine, dried over sodium sulfate, filtered and evaporated in vacuo. The crude product was purified by flash chromatography (800 mL  $\text{SiO}_2$ , 150:1:0.25  $\text{CHCl}_3$ : $\text{MeOH}$ : $\text{Et}_3\text{N}$ ) to afford **13a** (1.7434 g, 44% yield) as a white solid and a 3.5:1 mixture of **13b**:**13a** (1.3768g, 35% yield) which could be repurified under the same conditions to yield **13b** as a single diastereomer. **13a**:  $R_f = 0.30$  (10:1 chloroform:methanol);  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  9.12 (s, 1H), 7.22–7.11 (m, 2H), 7.01–6.95 (m, 1H), 6.81 (d,  $J = 8.3$  Hz, 1H), 5.59 (ddd,  $J = 16.8, 10.0, 8.4$  Hz, 1H), 5.15–4.98 (m, 2H), 3.54 (s, 3H), 3.05 (d,  $J = 10.8$  Hz, 1H), 2.77 (dd,  $J = 14.3, 9.8$ , 1H), 2.67 (t,  $J = 10.4$  Hz, 1H), 2.50 (dd,  $J = 14.3, 9.2$  Hz), 2.44–2.31 (m, 1H);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  171.4, 169.2, 138.2, 134.4, 121.7, 127.4, 122.5, 120.6, 116.0, 114.8, 61.2, 54.6, 54.6, 52.2, 50.0, 36.33; IR (NaCl/film) 3233, 1734, 1675, 1595, 1496, 1383, 1248, 919, 758  $\text{cm}^{-1}$ ; HRMS (MM: ESI-APCI)  $m/z$  calc'd for  $\text{C}_{16}\text{H}_{19}\text{N}_2\text{O}_3$   $[\text{M}+\text{H}]^+$ : 287.1390, found 287.1392. **13b**:  $R_f = 0.26$  (10:1 chloroform:methanol);  $^1\text{H}$  NMR (500 MHz,  $\text{CDCl}_3$ )  $\delta$  8.89 (s, 1H), 7.23–7.04 (m, 2H), 6.97 (t,  $J = 7.5$  Hz, 1H), 6.80 (d,  $J = 7.9$  Hz, 1H), 5.86 (dt,  $J = 18.1, 9.5$  Hz, 1H), 5.21–5.08 (m, 2H), 3.55 (s, 3H), 3.03 (m, 3H), 2.76 (dt,  $J = 14.3, 7.6$  Hz, 1H), 2.37 (dd,  $J = 13.9, 4.8$  Hz, 1H);  $^{13}\text{C}$  NMR (125 MHz,  $\text{CDCl}_3$ )  $\delta$  172.2, 169.5, 137.5, 135.6, 128.8, 128.3, 123.5, 122.4, 117.9, 115.8, 60.3, 56.5, 54.8, 53.2, 45.2, 37.2; IR (NaCl/film) 3210, 3074, 1730, 1672, 1595, 1496, 1384, 1272, 1250, 1213, 924, 758  $\text{cm}^{-1}$ ; HRMS (MM: ESI-APCI)  $m/z$  calc'd for  $\text{C}_{16}\text{H}_{19}\text{N}_2\text{O}_3$   $[\text{M}+\text{H}]^+$ : 287.1390, found 287.1393.



**Cinnamyl amine 14.** A flame-dried schlenk tube was charged with primary amine **13a** (200.6 mg, 0.70 mmol, 1 equiv), and CH<sub>2</sub>Cl<sub>2</sub> (1.4 mL, 0.5M). To this suspension, at ambient temperature (21 °C) was added freshly distilled *trans*-cinnamaldehyde (92 µL, 0.73 mmol, 1.05 equiv). After three minutes, the mixture becomes completely homogeneous. The progress of the reaction was monitored by TLC (imine R<sub>f</sub> = 0.47, 10:1 chloroform:methanol), and after consumption of the primary amine was observed (approximately one hour), the solution was cooled to 0 °C in an ice bath, and methanol (7 mL) was added. The solution was stirred for one minute, sodium borohydride (34.9 mg, 0.91 mmol, 1.3 equiv) was added in one portion under high flow of argon, and vigorous bubbling was observed. The schlenk tube was removed from the ice bath, and after 5 minutes, LCMS indicated complete consumption of the imine. After an additional 10 minutes of stirring, the solution was cooled again to 0 °C, and water (1 mL) was added dropwise. The reaction mixture was concentrated *in vacuo*, partitioned between diethyl ether (20 mL) and water (5 mL), and the phases were separated. The aqueous phase was extracted with diethyl ether (2 x 15 mL), then the combined organics were washed with brine (5 mL), dried over Na<sub>2</sub>SO<sub>4</sub>, filtered, and concentrated *in vacuo*. The crude material was purified by flash chromatography (30 mL SiO<sub>2</sub>, 3:1 → 1:1 hexanes:ethyl acetate) to afford **14** (225.2 mg, 80% yield) as a white solid: R<sub>f</sub> = 0.46 (1:1 hexanes:ethyl acetate); <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) δ 8.87 (s, 1H), 7.23–7.06 (m, 7H), 6.97 (t, *J* = 7.4 Hz, 1H), 6.77 (d, *J* = 7.7 Hz, 1H), 6.20 (d, *J* = 15.9 Hz, 1H), 6.02–5.88 (m, 2H), 5.18–5.08 (m,

2H), 3.53 (s, 3H), 3.34 (d,  $J = 10.5$  Hz, 1H), 3.26 (dd,  $J = 13.7, 6.5$  Hz, 1H), 3.06 (dd,  $J = 14.2, 6.2$  Hz, 1H), 3.01–2.92 (m, 2H), 2.89–2.76 (m, 1H), 2.38 (dd,  $J = 14.2, 4.6$  Hz, 1H) 1.30 (br s, 1H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  172.2, 169.6, 137.8, 137.1, 135.6, 131.0, 129.4, 128.6, 128.3, 128.2, 127.4, 126.3, 123.5, 122.4, 117.1, 115.7, 65.6, 56.5, 53.2, 52.2, 50.0, 43.8, 37.5; IR (NaCl/film) 3207, 3060, 1733, 1677, 1596, 1494, 1384, 1247, 1104,  $753\text{ cm}^{-1}$ ; HRMS (MM: ESI-APCI)  $m/z$  calc'd for  $\text{C}_{25}\text{H}_{27}\text{N}_2\text{O}_3$   $[\text{M}+\text{H}]^+$ : 403.2016, found 403.2018.



**Tetracycle 6.** An oven-dried scintillation vial was charged with secondary amine **14** (60.3 mg, 0.150 mmol, 1 equiv) and sealed with a screw-cap fitted with a teflon septum. Dichloromethane (0.3 mL) was added, followed by acetic anhydride (71  $\mu\text{L}$ , 77 mg, 0.75 mmol, 5 equiv), then pyridine (0.12 mL, 118 mg, 1.5 mmol, 10 equiv). The vial was lowered into a  $25\text{ }^\circ\text{C}$  oil bath and stirred for 14 hours. Over the course of the reaction, a white precipitate formed. Upon completion, the reaction mixture was diluted with diethyl ether (2 mL) and the precipitate was collected by filtration, washed further with diethyl ether and air-dried to afford crude acetamide **S-1** (58.9 mg, 88% crude yield) which was used without further purification in the next reaction.<sup>4</sup>

A flame-dried schlenk bomb was charged with crude **S-1** (58.9 mg, 0.133 mmol, 1 equiv) and Grubbs 2nd generation catalyst (**15**) (5.8 mg, 0.0068 mmol, 0.05 equiv). The bomb was evacuated and backfilled with argon three times. In a separate, flame-dried conical flask, a 1:1 mixture of dichloromethane and *tert*-butyl methyl ether was degassed by



sparging with argon for 20 minutes, then 2.7 mL of this solvent mixture was added to the schlenk bomb under high argon flow. The bomb was sealed and heated in a 60 °C oil bath, and the heterogeneous mixture was stirred for 100 minutes, monitoring by LCMS. Upon completion, the reaction mixture was concentrated in vacuo, and the residue was triturated with toluene to yield tetracycle **6** (45.1 mg, 95% yield, 84% over two steps), in greater than 95% purity, as a grey solid which exists as a 3:1 mixture of rotomers in chloroform:  $R_f = 0.26$  (10:1  $\text{CHCl}_3$ :MeOH);  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ )  $\delta$  8.32 (br s, 0.33H), 8.19 (br s, 1H), 7.29–7.23 (m, 1H), 7.23–7.17 (m, 0.33H), 7.03 (td,  $J = 7.5, 1.2$  Hz, 1H), 6.98–6.91 (m, 1.33H), 6.87–6.77 (m, 1.66H), 5.83–5.70 (m, 2.66H), 5.16 (dd,  $J = 11.9, 7.8$  Hz, 0.33H), 4.75–4.66 (m, 1H), 4.16–3.98 (m, 1.66H), 3.64–3.56 (m, 5.66H), 3.48 (d,  $J = 11.9$  Hz, 0.33H), 3.23–3.13 (m, 1.33H), 2.89 (br s, 1H), 2.80 (br s, 0.33 H), 2.35 (dd,  $J = 14.4, 3.3$  Hz, 1H), 2.27 (dd,  $J = 14.3, 3.3$  Hz, 0.33 H), 1.99 (s, 1H), 1.28 (s, 3H);  $^{13}\text{C}$  NMR (100 MHz,  $\text{CDCl}_3$ )  $\delta$  172.1, 171.5, 170.3, 169.8, 169.0, 168.8, 135.7, 135.4, 130.6, 129.2, 128.9, 128.5, 128.4, 127.9, 124.2, 123.2, 121.8, 121.1, 120.6, 120.4, 116.0, 115.6, 60.9, 55.6, 55.5, 54.7, 53.5, 53.3, 47.3, 46.7, 41.6, 38.0, 37.1, 34.6, 33.8, 34.6, 33.8, 22.1, 20.7; IR (NaCl/film) 3215, 2917, 1734, 1680, 1639, 1624, 1597, 1493, 1430, 1372, 1271, 1246, 1214, 1115, 758  $\text{cm}^{-1}$ ; HRMS (MM: ESI-APCI)  $m/z$  calc'd for  $\text{C}_{19}\text{H}_{21}\text{N}_2\text{O}_4$   $[\text{M}+\text{H}]^+$ : 341.1496, found 341.1498.

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## References

- (1) Pangborn, A. B.; Giardello, M. A.; Grubbs, R. H.; Rosen, R. K.; Timmers, F. J. *Organometallics* **1996**, *15*, 1518–1520.
- (2) Solomonovici, A.; Blumberg, S. *Tetrahedron* **1966**, *22*, 2505–2509.
- (3) Parsons, A. T.; Campbell, M. J.; Johnson, J. S. *Org. Lett.* **2008**, *10*, 2541–2544.
- (4) A crude  $^1\text{H}$  NMR spectrum (500 MHz, DMSO) of the acetamide intermediate, which exists as a 3:1 mixture of rotomers in solution, can be found on page S17.

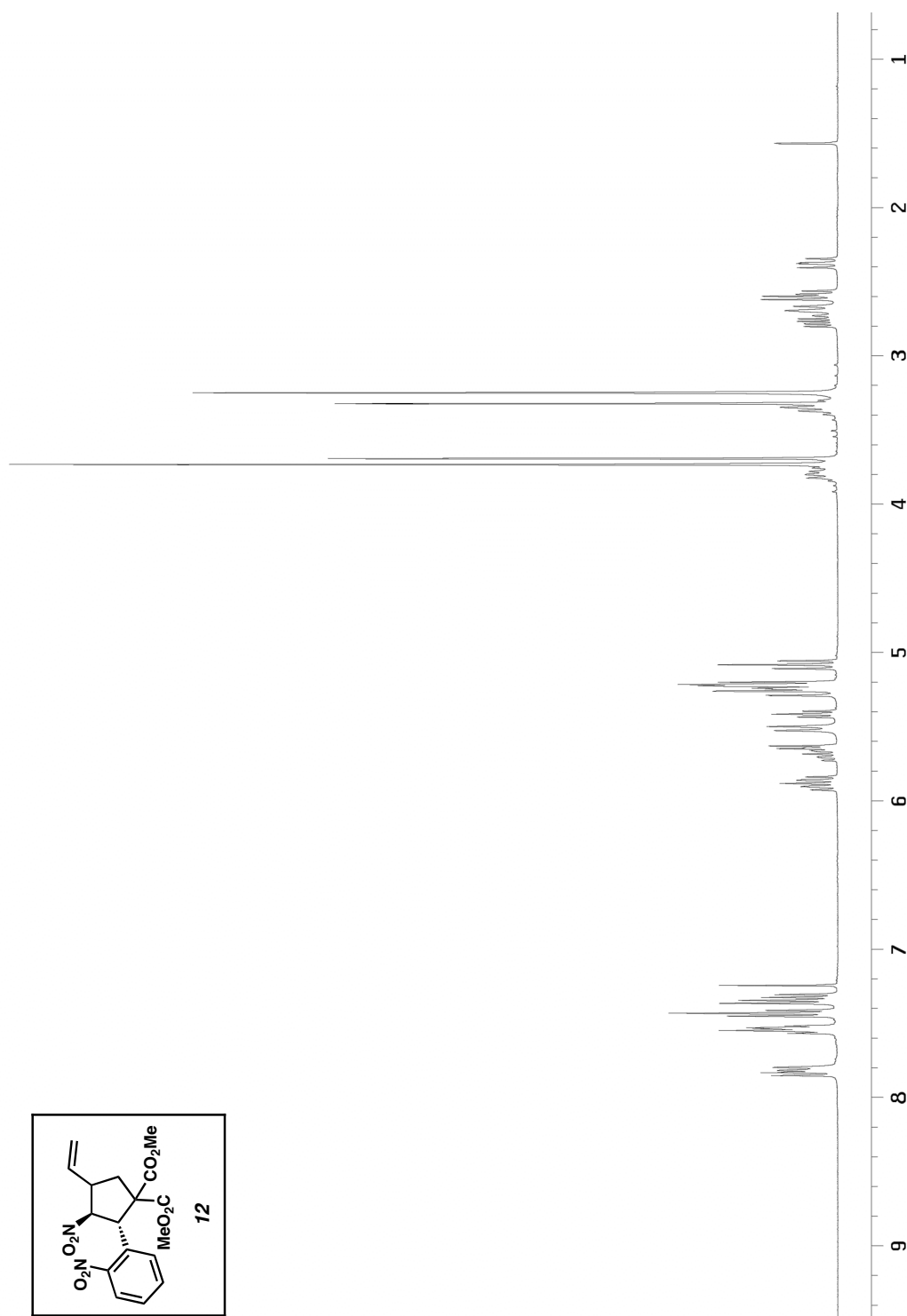


Figure I.1 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of compound **12**.

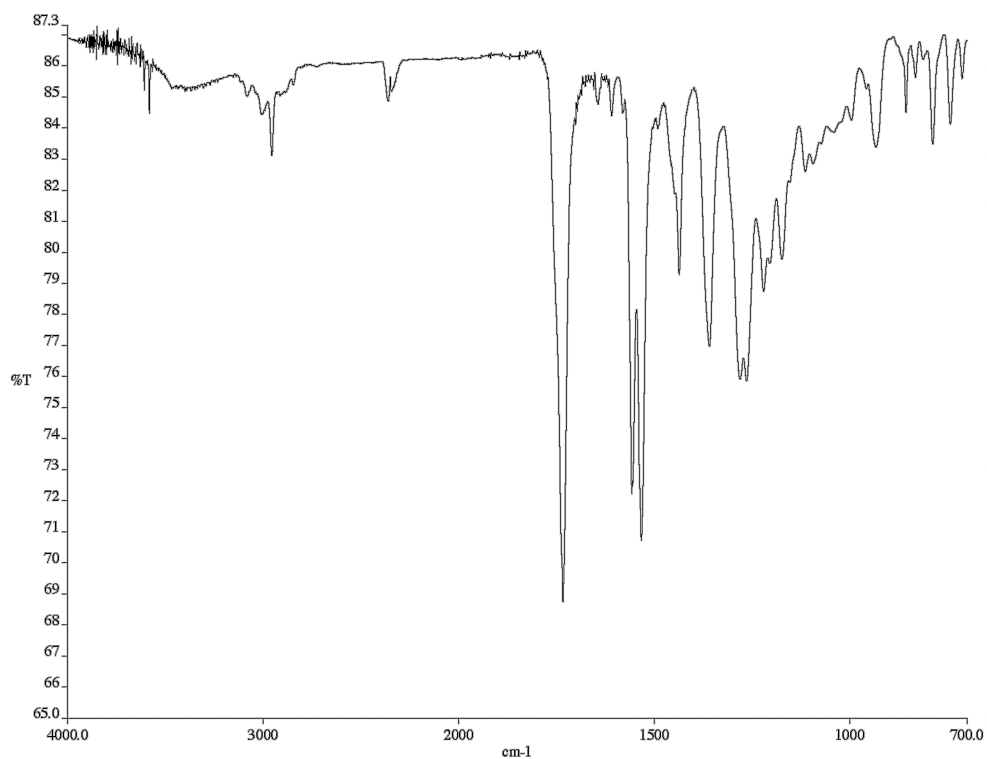


Figure 1.2 Infrared spectrum (thin film/NaCl) of compound **12**.

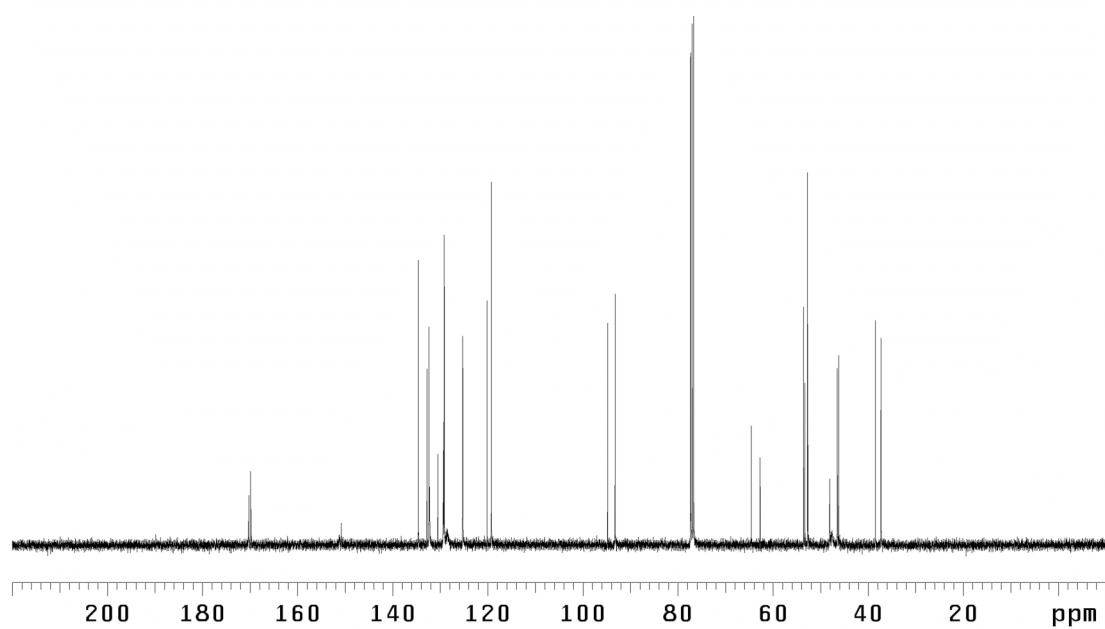


Figure 1.3 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of compound **12**.

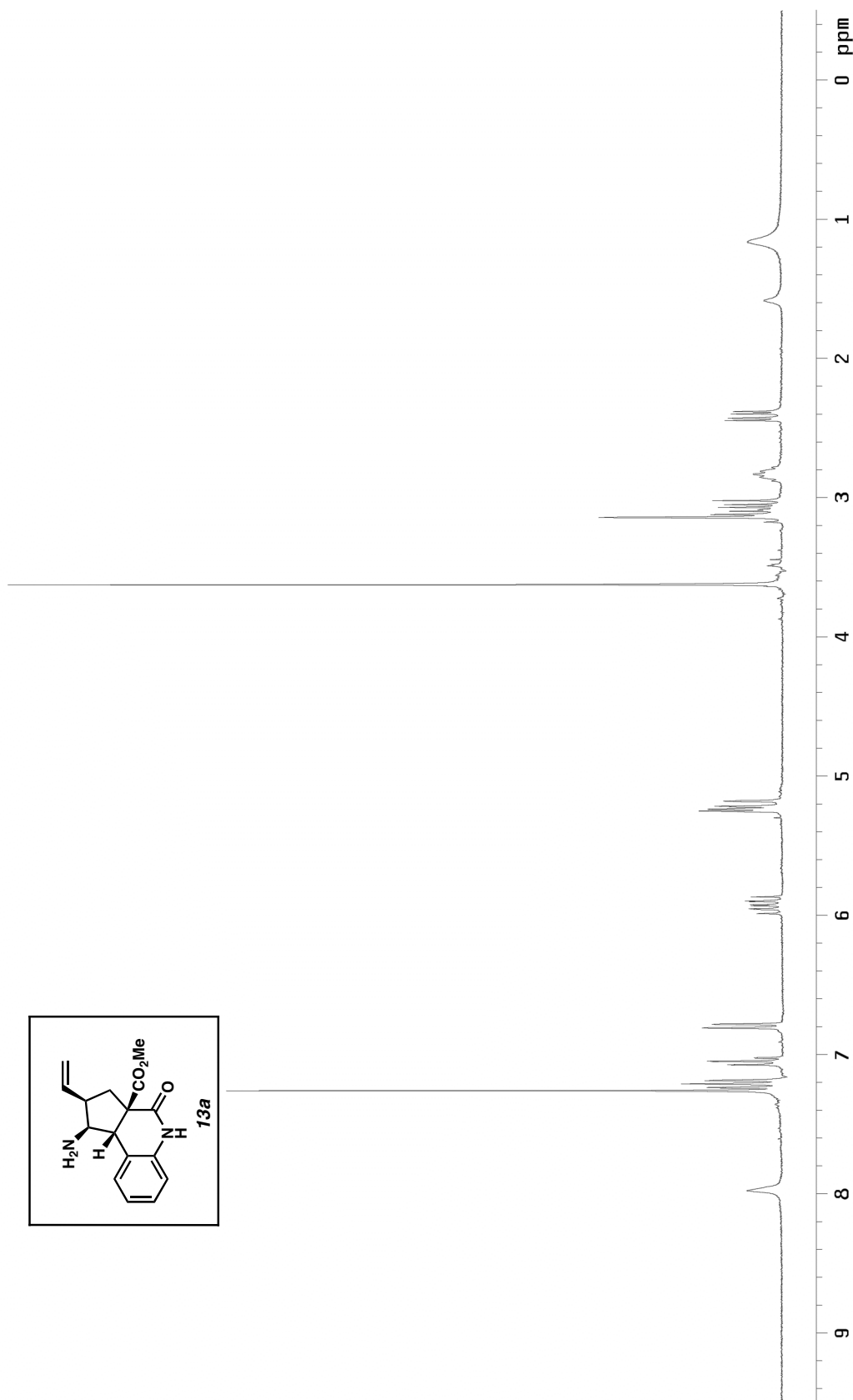


Figure 2.1  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) of compound **13a**.

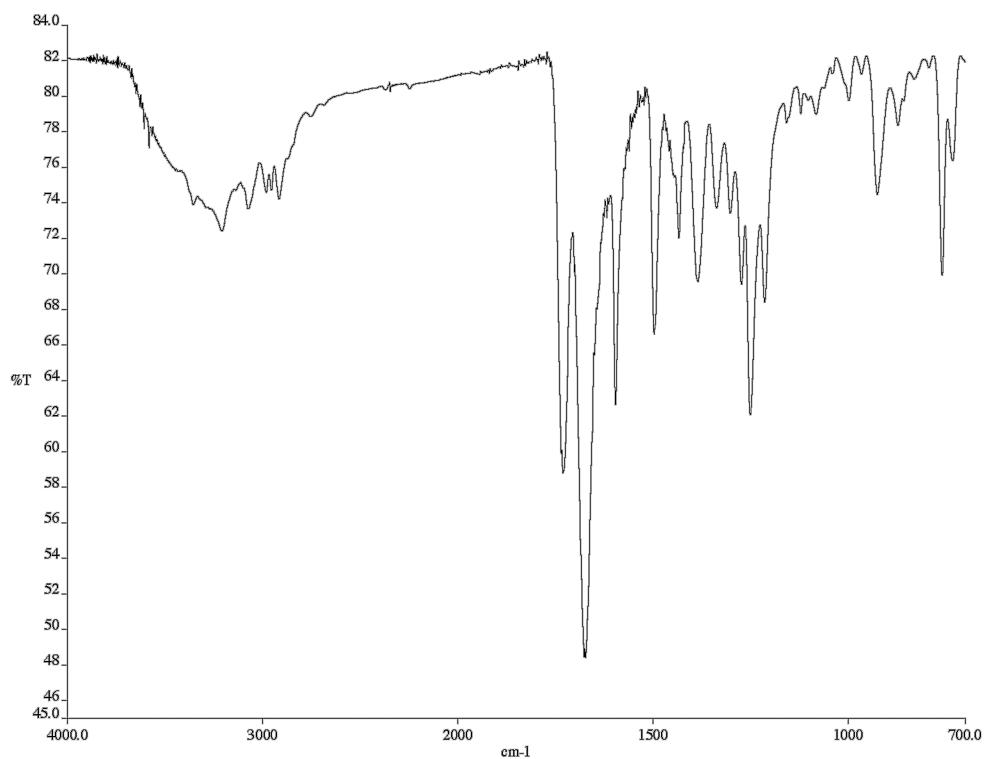


Figure 2.2 Infrared spectrum (thin film/NaCl) of compound **13a**.

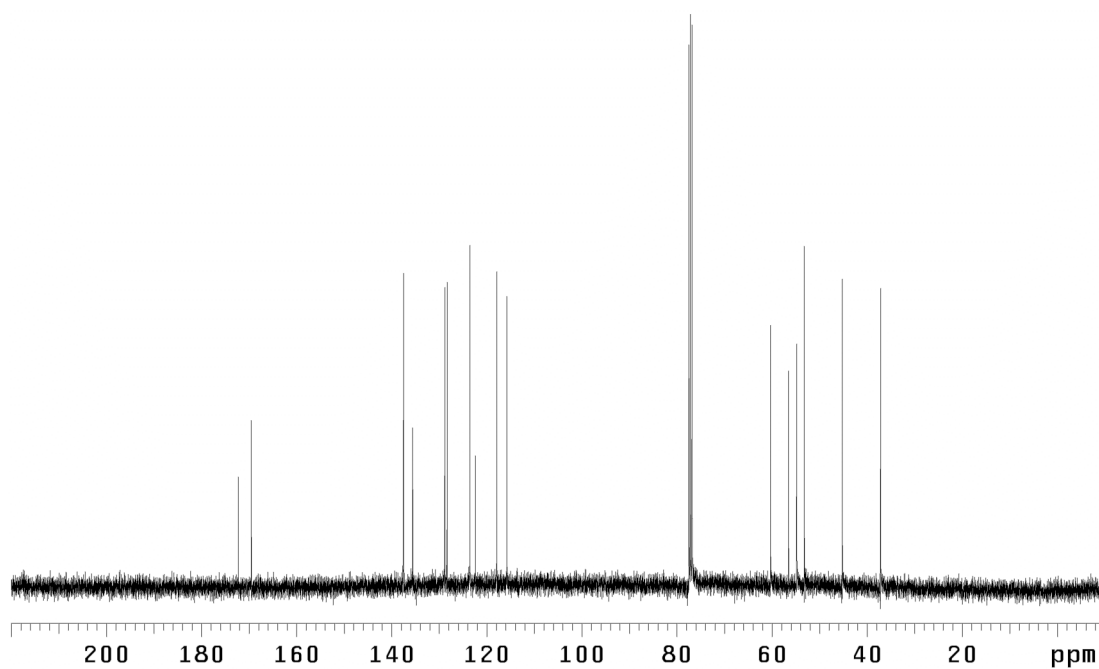


Figure 2.3 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of compound **13a**.

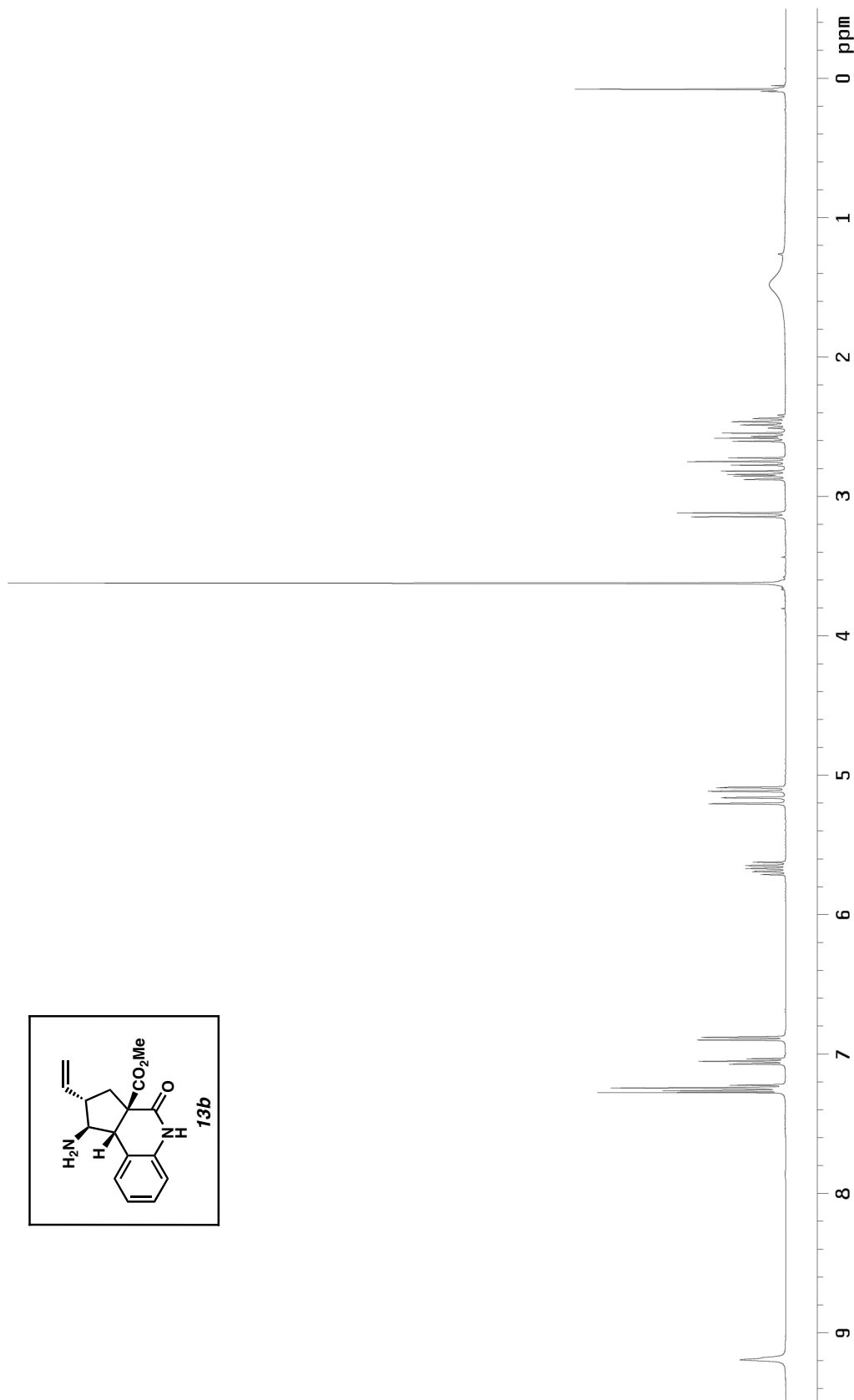


Figure 3.1 <sup>1</sup>H NMR (400 MHz, CDCl<sub>3</sub>) of compound **13b**.

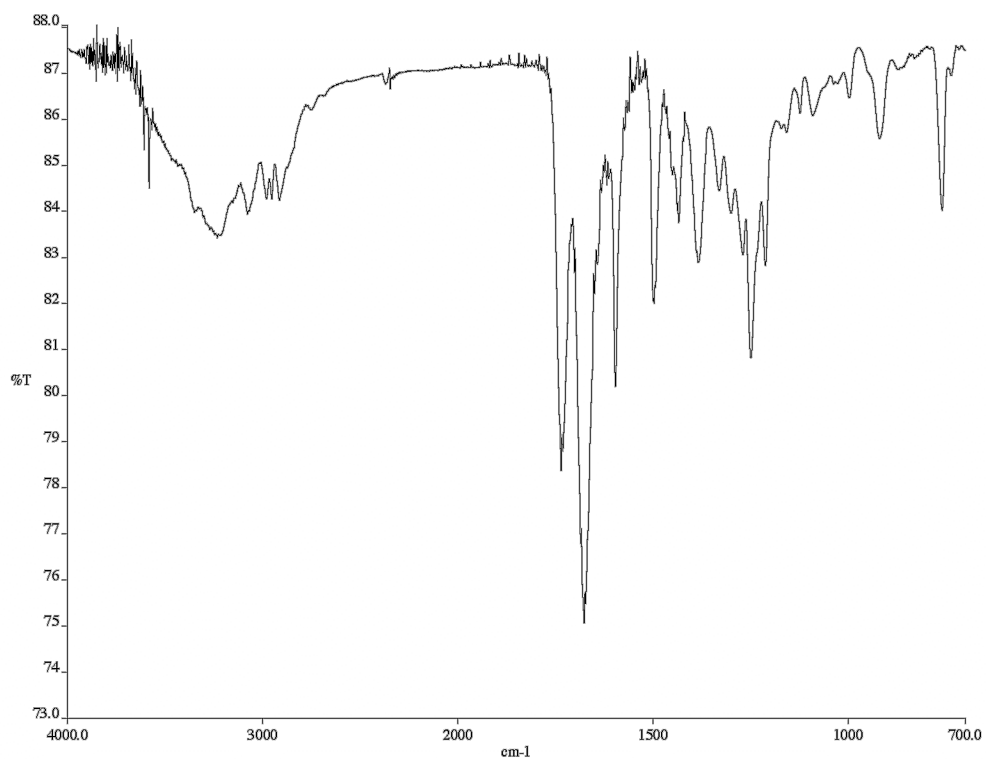


Figure 3.2 Infrared spectrum (thin film/NaCl) of compound **13b**.

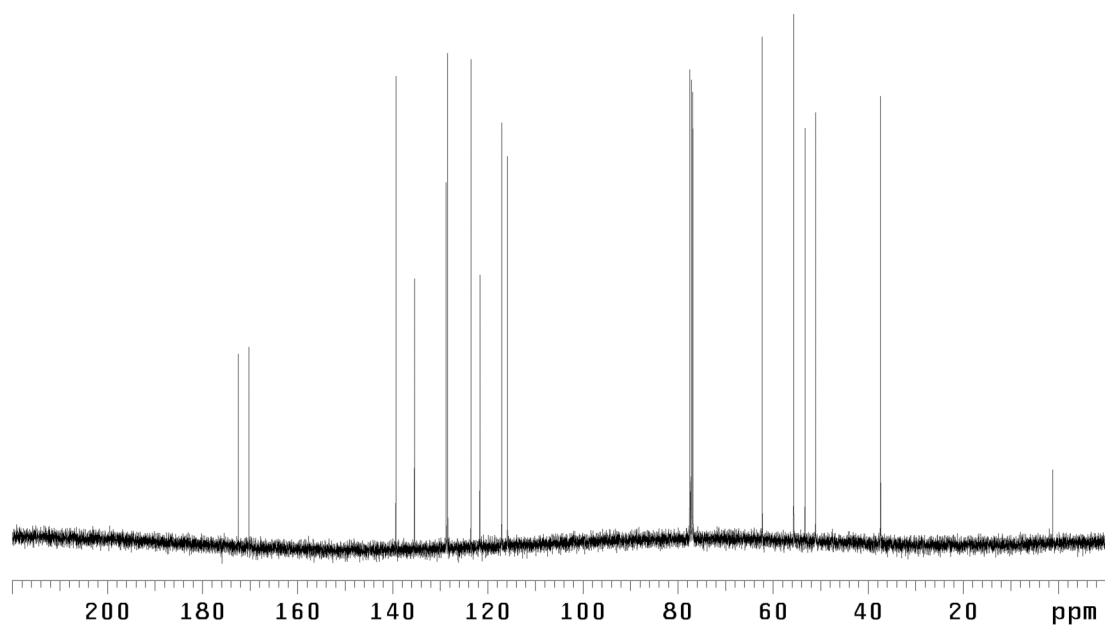


Figure 3.3 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of compound **13b**.

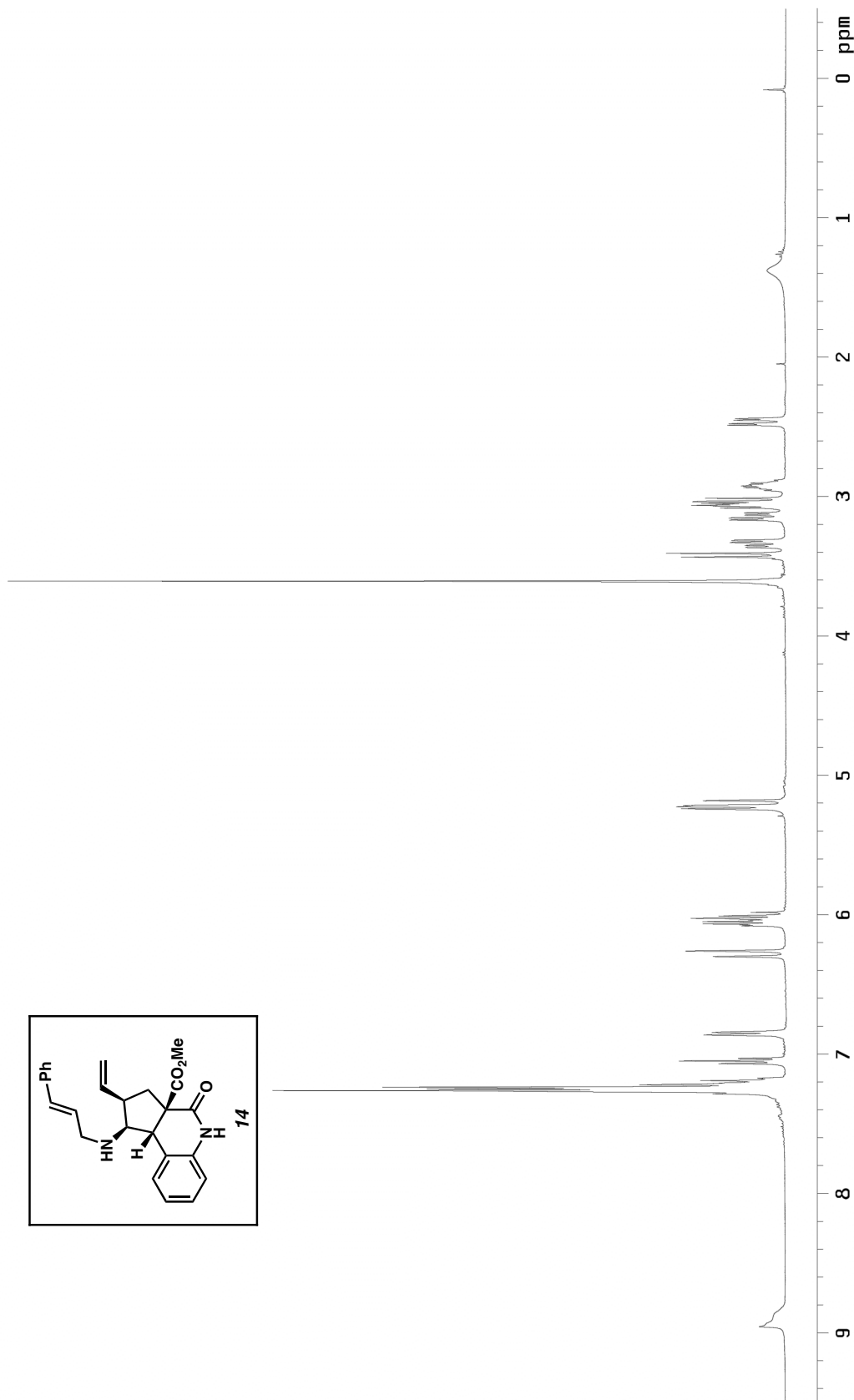


Figure 4.1  $^1\text{H}$  NMR (400 MHz,  $\text{CDCl}_3$ ) of compound **14**.



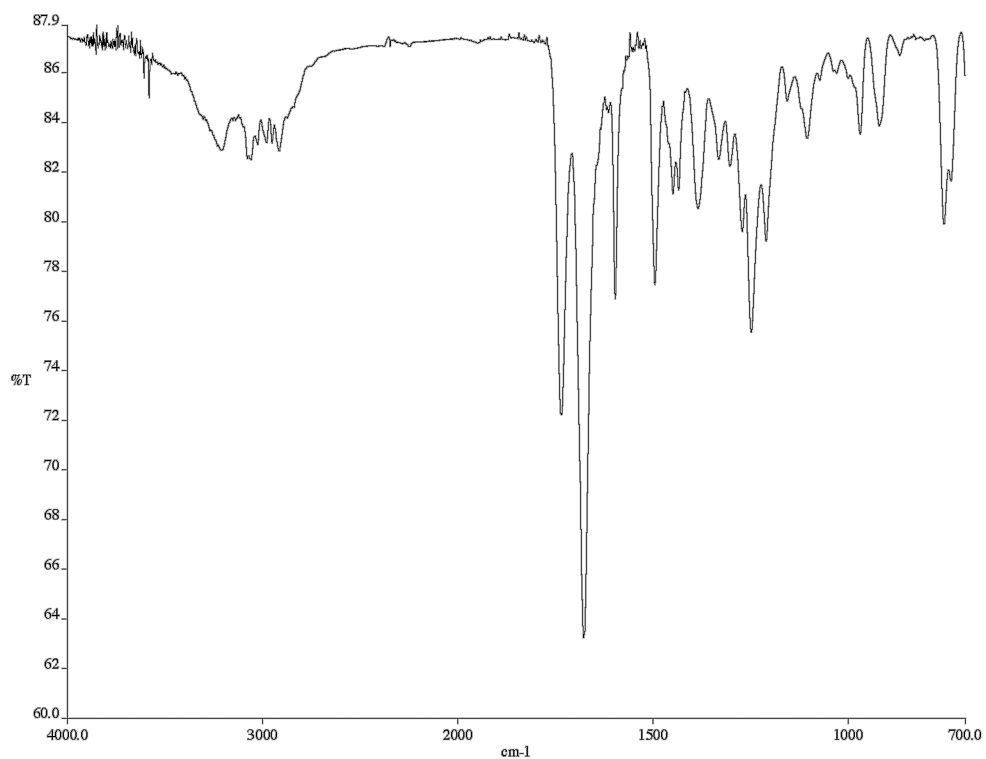


Figure 4.2 Infrared spectrum (thin film/NaCl) of compound **14**.

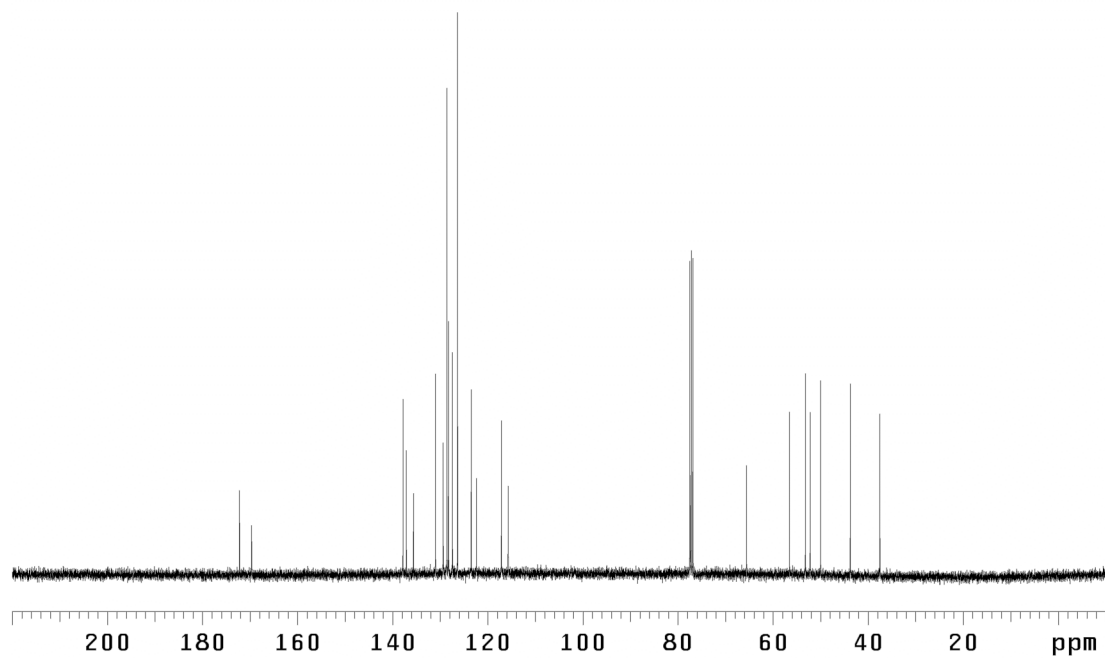


Figure 4.3 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of compound **14**.

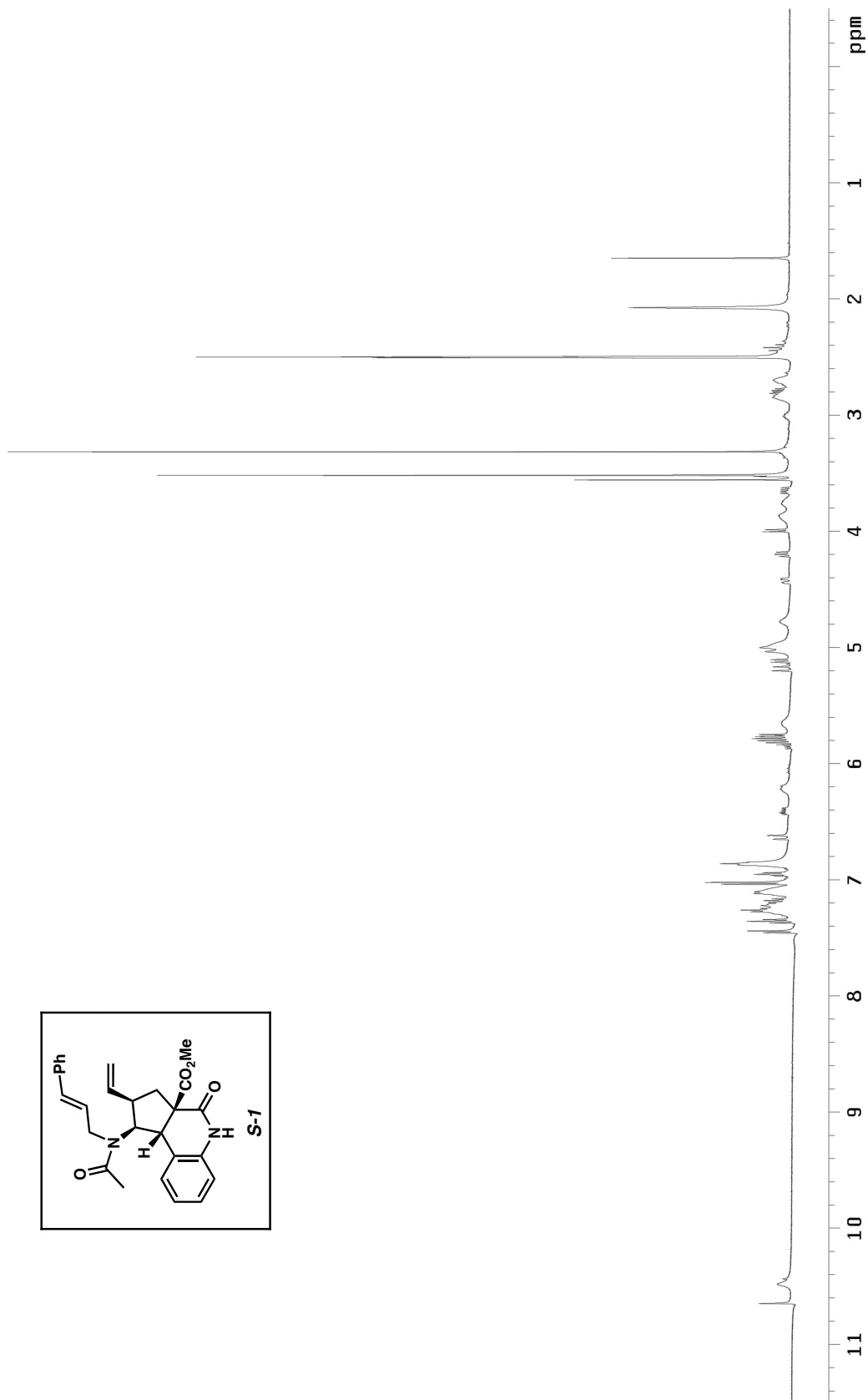


Figure S-1.1 <sup>1</sup>H NMR (500 MHz, d<sub>6</sub>-DMSO) of crude compound S-1

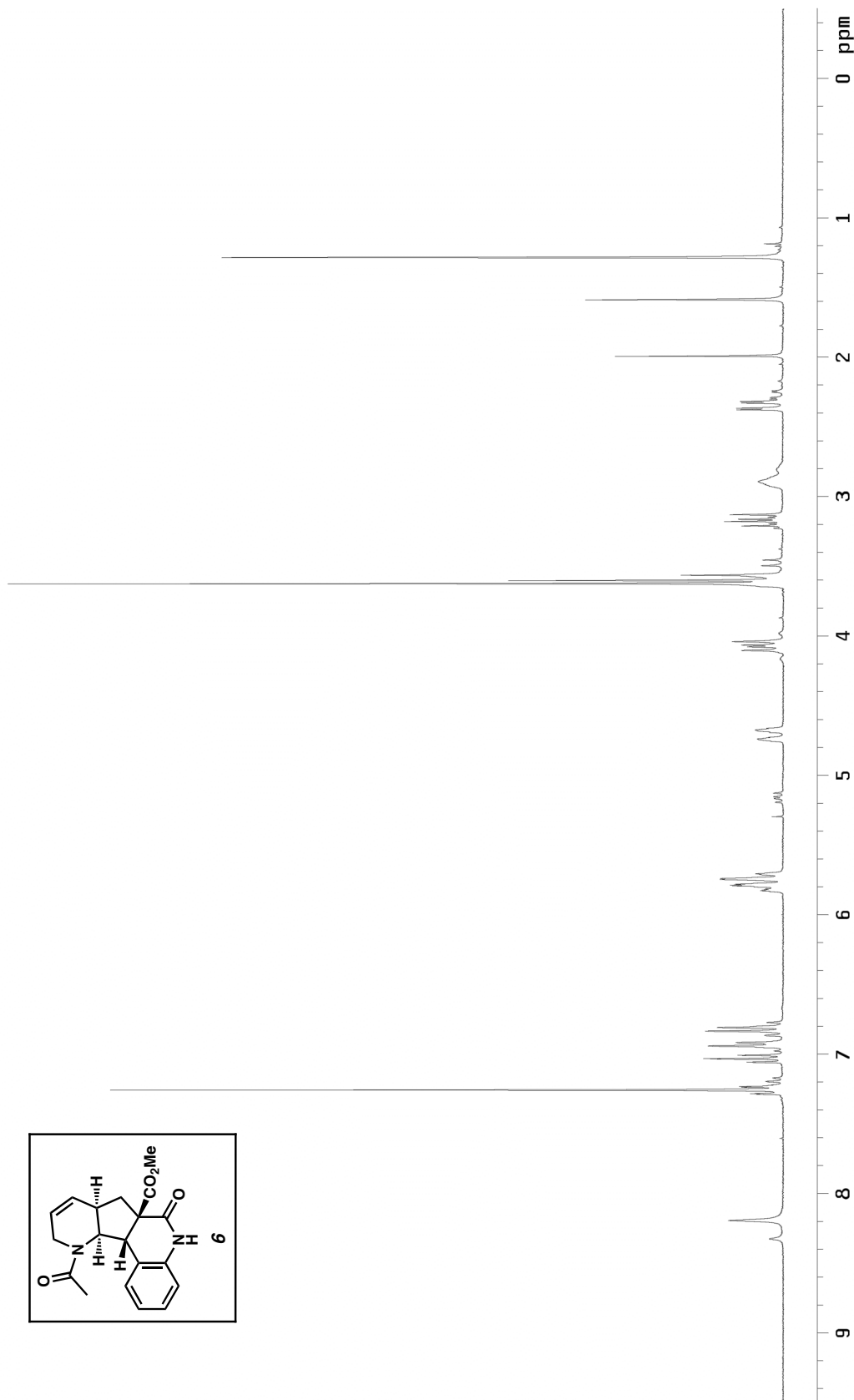


Figure 6.1  $^1\text{H}$  NMR (300 MHz,  $\text{CDCl}_3$ ) of compound **6**.

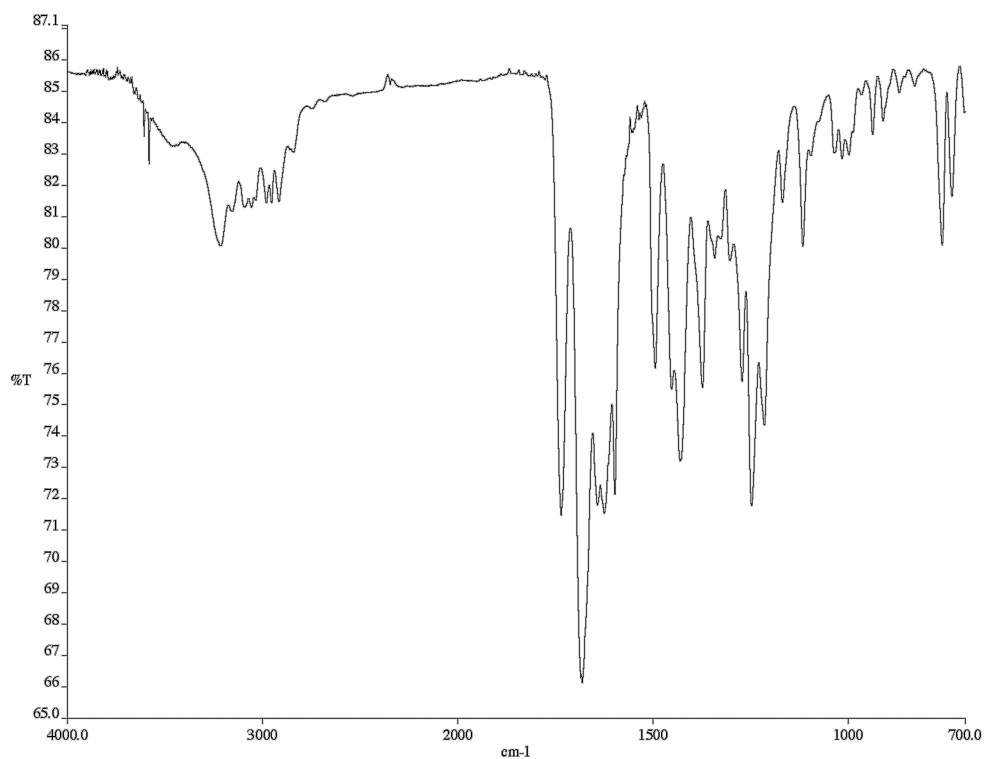


Figure 6.1 Infrared spectrum (thin film/NaCl) of compound **6**.

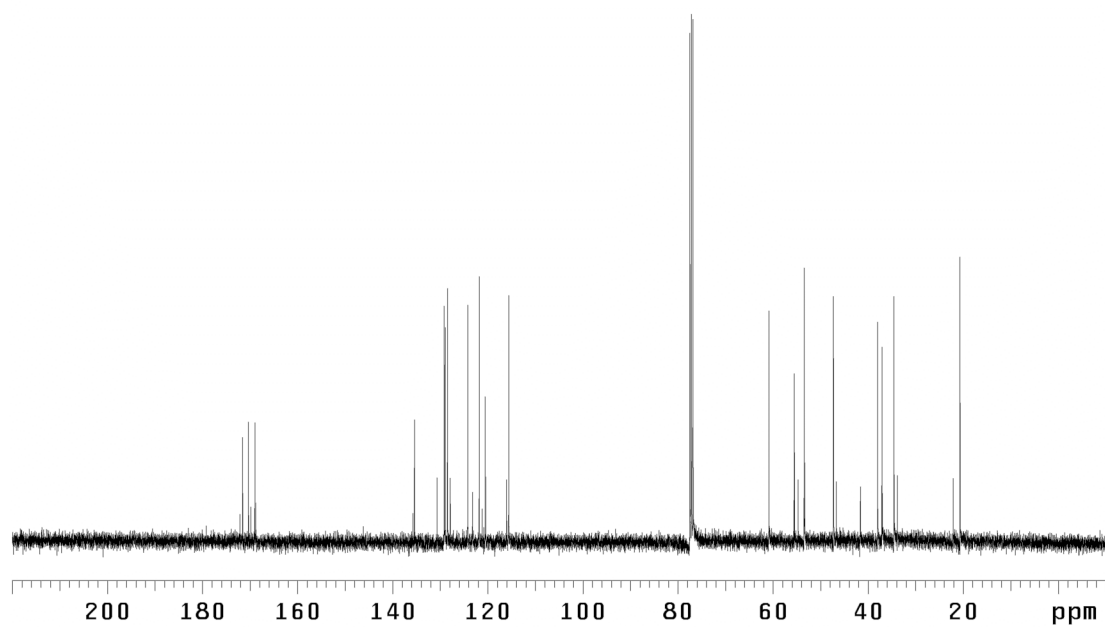
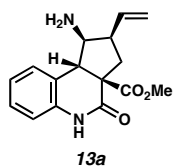


Figure 6.3 <sup>13</sup>C NMR (100 MHz, CDCl<sub>3</sub>) of compound **6**.

## Crystal Structure Analysis of:



By Michael W. Day

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Table 1. Crystal data

Figures Minimum overlap

Table 2. Atomic Coordinates

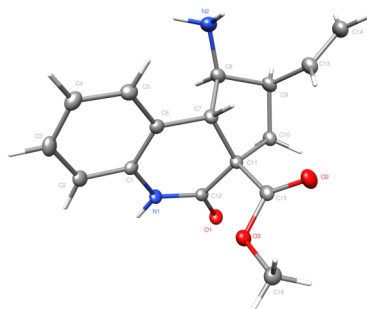
Table 3. Full bond distances and angles

Table 4. Anisotropic displacement parameters

Table 5. Hydrogen atomic coordinates

Table 6. Hydrogen bond distances and angles

Table 7. Observed and calculated structure factors (available upon request)



**Table 1. Crystal data and structure refinement for AFG03 (CCDC 820779).**

Empirical formula	C <sub>16</sub> H <sub>18</sub> N <sub>2</sub> O <sub>3</sub>
Formula weight	286.32
Crystallization Solvent	Dichloromethane/hexane
Crystal Habit	Column
Crystal size	0.36 x 0.19 x 0.19 mm <sup>3</sup>
Crystal color	Colorless

**Data Collection**

Type of diffractometer	Bruker SMART 1000	
Wavelength	0.71073 Å MoK $\alpha$	
Data Collection Temperature	100(2) K	
$\theta$ range for 8222 reflections used in lattice determination	2.71 to 36.32°	
Unit cell dimensions	a = 7.6777(3) Å b = 9.1864(3) Å c = 10.8584(4) Å	$\alpha$ = 71.309(2)° $\beta$ = 69.829(2)° $\gamma$ = 75.7590(10)°
Volume	673.01(4) Å <sup>3</sup>	
Z	2	
Crystal system	Triclinic	
Space group	P-1	
Density (calculated)	1.413 Mg/m <sup>3</sup>	
F(000)	304	
Data collection program	Bruker SMART v5.630	
$\theta$ range for data collection	2.07 to 36.35°	
Completeness to $\theta$ = 36.35°	98.4 %	
Index ranges	-12 $\leq$ h $\leq$ 12, -15 $\leq$ k $\leq$ 15, -18 $\leq$ l $\leq$ 18	
Data collection scan type	$\omega$ scans at 10 settings	
Data reduction program	Bruker SAINT-Plus v7.66A	
Reflections collected	24459	
Independent reflections	6449 [ $R_{\text{int}}$ = 0.0431]	
Absorption coefficient	0.099 mm <sup>-1</sup>	
Absorption correction	None	
Max. and min. transmission	0.9815 and 0.9654	

**Table 1 (cont.)****Structure solution and Refinement**

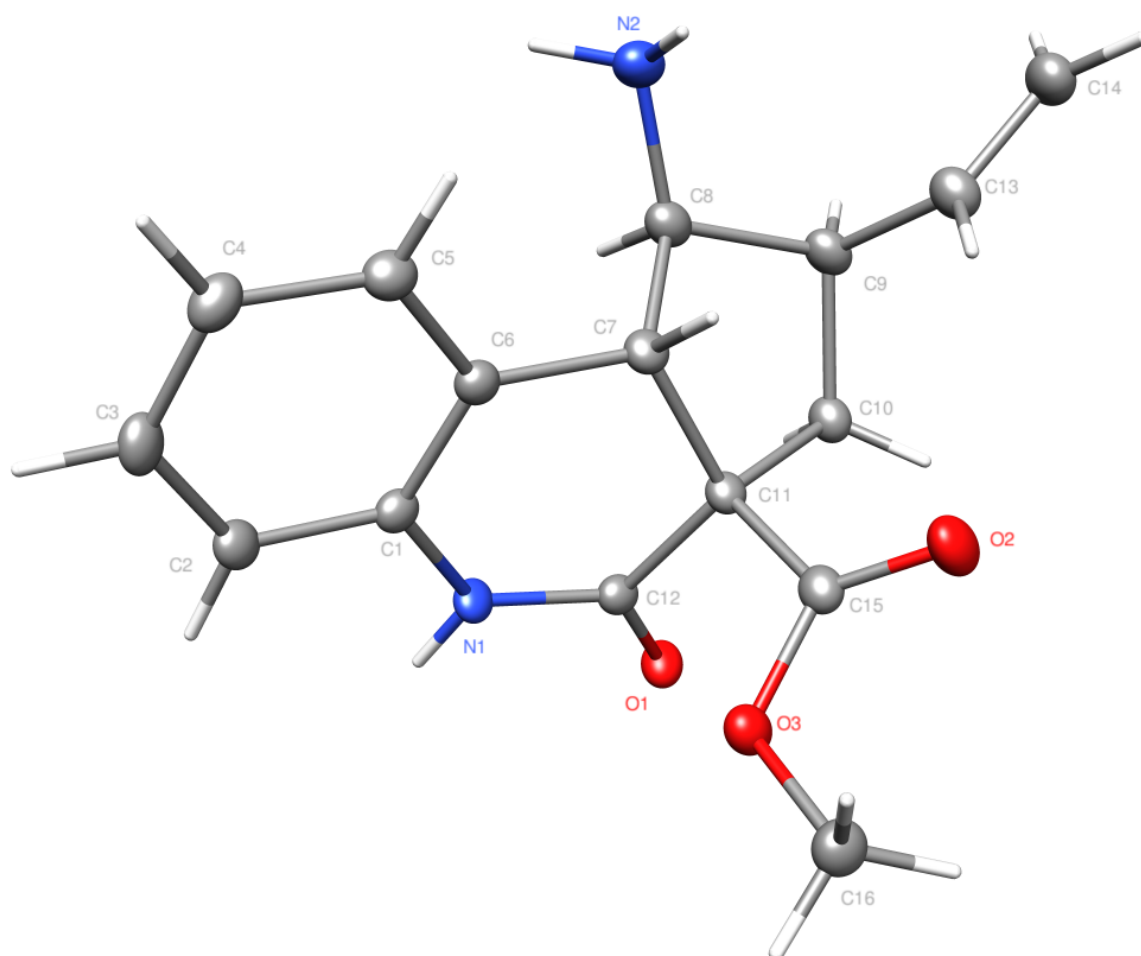
Structure solution program	SHELXS-97 (Sheldrick, 2008)
Primary solution method	Direct methods
Secondary solution method	Difference Fourier map
Hydrogen placement	Difference Fourier map
Structure refinement program	SHELXL-97 (Sheldrick, 2008)
Refinement method	Full matrix least-squares on $F^2$
Data / restraints / parameters	6449 / 0 / 262
Treatment of hydrogen atoms	Unrestrained
Goodness-of-fit on $F^2$	2.646
Final R indices [ $I > 2\sigma(I)$ , 4636 reflections]	$R1 = 0.0623$ , $wR2 = 0.0933$
R indices (all data)	$R1 = 0.0829$ , $wR2 = 0.0954$
Type of weighting scheme used	Sigma
Weighting scheme used	$w = 1/\sigma^2(F_o^2)$
Max shift/error	0.001
Average shift/error	0.000
Largest diff. peak and hole	0.666 and -0.395 e.Å <sup>-3</sup>

**Special Refinement Details**

Crystals were mounted on a glass fiber using Paratone oil then placed on the diffractometer under a nitrogen stream at 100K.

Refinement of  $F^2$  against ALL reflections. The weighted R-factor ( $wR$ ) and goodness of fit ( $S$ ) are based on  $F^2$ , conventional R-factors ( $R$ ) are based on  $F$ , with  $F$  set to zero for negative  $F^2$ . The threshold expression of  $F^2 > 2\sigma(F^2)$  is used only for calculating R-factors(gt) etc. and is not relevant to the choice of reflections for refinement. R-factors based on  $F^2$  are statistically about twice as large as those based on  $F$ , and R-factors based on ALL data will be even larger.

All esds (except the esd in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell esds are taken into account individually in the estimation of esds in distances, angles and torsion angles; correlations between esds in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell esds is used for estimating esds involving l.s. planes.





**Table 2. Atomic coordinates ( $\times 10^4$ ) and equivalent isotropic displacement parameters ( $\text{\AA}^2 \times 10^3$ ) for AFG03 (CCDC 820779).  $U(\text{eq})$  is defined as the trace of the orthogonalized  $U^{ij}$  tensor.**

	x	y	z	$U_{\text{eq}}$
O(1)	4408(1)	7089(1)	4178(1)	19(1)
O(2)	7024(1)	9577(1)	237(1)	26(1)
O(3)	6615(1)	7073(1)	1117(1)	19(1)
N(1)	7276(1)	5626(1)	3956(1)	16(1)
N(2)	10859(2)	9851(1)	3092(1)	24(1)
C(1)	9253(1)	5399(1)	3465(1)	15(1)
C(2)	10235(2)	3896(1)	3734(1)	18(1)
C(3)	12183(2)	3662(1)	3300(1)	20(1)
C(4)	13148(2)	4913(1)	2592(1)	20(1)
C(5)	12157(2)	6406(1)	2289(1)	19(1)
C(6)	10199(2)	6674(1)	2726(1)	15(1)
C(7)	9129(2)	8291(1)	2420(1)	16(1)
C(8)	9097(2)	9371(1)	3279(1)	20(1)
C(9)	7562(2)	10747(1)	2922(1)	19(1)
C(10)	6011(2)	9897(1)	2999(1)	18(1)
C(11)	7013(1)	8352(1)	2576(1)	14(1)
C(12)	6129(2)	6970(1)	3640(1)	15(1)
C(13)	8229(2)	11823(1)	1535(1)	22(1)
C(14)	8438(2)	13284(2)	1290(1)	26(1)
C(15)	6863(2)	8427(1)	1186(1)	16(1)
C(16)	6494(2)	7061(2)	-190(1)	21(1)

**Table 3. Bond lengths [Å] and angles [°] for AFG03 (CCDC 820779).**

O(1)-C(12)	1.2396(13)	C(6)-C(1)-N(1)	120.01(10)
O(2)-C(15)	1.2129(13)	C(3)-C(2)-C(1)	119.60(10)
O(3)-C(15)	1.3331(13)	C(3)-C(2)-H(2)	121.6(8)
O(3)-C(16)	1.4571(14)	C(1)-C(2)-H(2)	118.7(8)
N(1)-C(12)	1.3493(14)	C(2)-C(3)-C(4)	120.27(11)
N(1)-C(1)	1.4101(14)	C(2)-C(3)-H(3)	118.2(7)
N(1)-H(1)	0.894(14)	C(4)-C(3)-H(3)	121.5(7)
N(2)-C(8)	1.4532(15)	C(3)-C(4)-C(5)	119.80(11)
N(2)-H(2A)	0.874(16)	C(3)-C(4)-H(4)	119.3(8)
N(2)-H(2B)	0.923(16)	C(5)-C(4)-H(4)	120.8(8)
C(1)-C(2)	1.3935(15)	C(4)-C(5)-C(6)	121.02(11)
C(1)-C(6)	1.3990(14)	C(4)-C(5)-H(5)	121.5(8)
C(2)-C(3)	1.3881(16)	C(6)-C(5)-H(5)	117.5(8)
C(2)-H(2)	0.958(12)	C(5)-C(6)-C(1)	118.25(10)
C(3)-C(4)	1.3862(17)	C(5)-C(6)-C(7)	121.02(10)
C(3)-H(3)	0.963(12)	C(1)-C(6)-C(7)	120.72(9)
C(4)-C(5)	1.3918(16)	C(6)-C(7)-C(8)	116.70(9)
C(4)-H(4)	0.941(14)	C(6)-C(7)-C(11)	114.37(9)
C(5)-C(6)	1.3954(15)	C(8)-C(7)-C(11)	104.20(9)
C(5)-H(5)	0.949(13)	C(6)-C(7)-H(7)	107.1(8)
C(6)-C(7)	1.5046(15)	C(8)-C(7)-H(7)	105.8(7)
C(7)-C(8)	1.5555(16)	C(11)-C(7)-H(7)	108.1(7)
C(7)-C(11)	1.5630(14)	N(2)-C(8)-C(9)	113.55(10)
C(7)-H(7)	1.000(13)	N(2)-C(8)-C(7)	117.56(10)
C(8)-C(9)	1.5509(16)	C(9)-C(8)-C(7)	102.10(9)
C(8)-H(8)	1.005(12)	N(2)-C(8)-H(8)	108.3(7)
C(9)-C(13)	1.5060(16)	C(9)-C(8)-H(8)	107.3(7)
C(9)-C(10)	1.5433(16)	C(7)-C(8)-H(8)	107.4(7)
C(9)-H(9)	0.980(13)	C(13)-C(9)-C(10)	111.69(10)
C(10)-C(11)	1.5665(15)	C(13)-C(9)-C(8)	113.01(10)
C(10)-H(10A)	0.948(12)	C(10)-C(9)-C(8)	101.94(9)
C(10)-H(10B)	0.995(12)	C(13)-C(9)-H(9)	109.3(7)
C(11)-C(15)	1.5308(15)	C(10)-C(9)-H(9)	112.2(7)
C(11)-C(12)	1.5333(14)	C(8)-C(9)-H(9)	108.5(7)
C(13)-C(14)	1.3213(17)	C(9)-C(10)-C(11)	107.07(9)
C(13)-H(13)	1.001(14)	C(9)-C(10)-H(10A)	113.9(7)
C(14)-H(14A)	0.955(14)	C(11)-C(10)-H(10A)	109.5(7)
C(14)-H(14B)	0.968(14)	C(9)-C(10)-H(10B)	109.0(7)
C(16)-H(16A)	0.990(13)	C(11)-C(10)-H(10B)	108.6(7)
C(16)-H(16B)	0.938(13)	H(10A)-C(10)-H(10B)	108.6(10)
C(16)-H(16C)	0.944(14)	C(15)-C(11)-C(12)	109.43(9)
		C(15)-C(11)-C(7)	107.53(8)
C(15)-O(3)-C(16)	115.23(9)	C(12)-C(11)-C(7)	114.40(9)
C(12)-N(1)-C(1)	125.72(9)	C(15)-C(11)-C(10)	110.87(9)
C(12)-N(1)-H(1)	116.1(9)	C(12)-C(11)-C(10)	110.03(9)
C(1)-N(1)-H(1)	118.1(9)	C(7)-C(11)-C(10)	104.48(8)
C(8)-N(2)-H(2A)	111.6(10)	O(1)-C(12)-N(1)	121.40(10)
C(8)-N(2)-H(2B)	111.6(9)	O(1)-C(12)-C(11)	120.58(9)
H(2A)-N(2)-H(2B)	106.0(14)	N(1)-C(12)-C(11)	118.01(9)
C(2)-C(1)-C(6)	121.00(10)	C(14)-C(13)-C(9)	125.48(12)
C(2)-C(1)-N(1)	118.99(10)	C(14)-C(13)-H(13)	120.0(8)

C(9)-C(13)-H(13)	114.5(8)	O(3)-C(16)-H(16A)	110.0(8)
C(13)-C(14)-H(14A)	119.3(8)	O(3)-C(16)-H(16B)	107.2(8)
C(13)-C(14)-H(14B)	122.8(8)	H(16A)-C(16)-H(16B)	108.9(11)
H(14A)-C(14)-H(14B)	117.8(11)	O(3)-C(16)-H(16C)	109.2(8)
O(2)-C(15)-O(3)	123.70(10)	H(16A)-C(16)-H(16C)	112.1(11)
O(2)-C(15)-C(11)	123.68(10)	H(16B)-C(16)-H(16C)	109.3(11)
O(3)-C(15)-C(11)	112.57(9)		

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**Table 4. Anisotropic displacement parameters ( $\text{\AA}^2 \times 10^4$ ) for AFG03 (CCDC 820779). The anisotropic displacement factor exponent takes the form:  $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$**

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{23}$	$U^{13}$	$U^{12}$
O(1)	135(4)	188(4)	200(4)	-10(3)	-24(3)	-30(3)
O(2)	364(5)	196(4)	198(4)	13(3)	-101(4)	-86(4)
O(3)	230(4)	166(4)	166(4)	-23(3)	-69(3)	-42(3)
N(1)	132(4)	148(4)	154(4)	6(3)	-27(3)	-38(3)
N(2)	243(5)	230(5)	277(6)	-18(4)	-111(5)	-80(4)
C(1)	131(5)	176(5)	124(5)	-31(4)	-36(4)	-24(4)
C(2)	186(5)	172(5)	156(5)	-16(4)	-55(4)	-29(4)
C(3)	204(6)	191(6)	178(5)	-36(4)	-66(4)	26(4)
C(4)	130(5)	257(6)	193(6)	-63(4)	-35(4)	2(4)
C(5)	155(5)	209(6)	189(5)	-37(4)	-28(4)	-49(4)
C(6)	143(5)	168(5)	152(5)	-38(4)	-45(4)	-25(4)
C(7)	135(5)	160(5)	165(5)	-13(4)	-22(4)	-42(4)
C(8)	215(6)	178(5)	193(6)	-28(4)	-59(4)	-51(4)
C(9)	219(6)	163(5)	193(5)	-50(4)	-38(4)	-41(4)
C(10)	157(5)	161(5)	187(5)	-38(4)	-28(4)	-15(4)
C(11)	120(5)	142(5)	146(5)	-18(4)	-19(4)	-31(4)
C(12)	152(5)	160(5)	126(5)	-20(4)	-39(4)	-40(4)
C(13)	202(6)	185(6)	227(6)	-39(4)	-35(4)	-34(4)
C(14)	269(7)	199(6)	314(7)	-16(5)	-124(5)	-49(5)
C(15)	128(5)	158(5)	183(5)	-35(4)	-29(4)	-15(4)
C(16)	244(6)	218(6)	173(6)	-46(4)	-72(5)	-37(5)

**Table 5. Hydrogen coordinates (  $\times 10^4$ ) and isotropic displacement parameters ( $\text{\AA}^2 \times 10^3$ ) for AFG03 (CCDC 820779).**

	x	y	z	$U_{\text{iso}}$
H(1)	6719(19)	4828(16)	4556(14)	29(4)
H(2)	9539(17)	3045(15)	4204(13)	21(3)
H(2A)	11470(20)	10154(18)	2232(16)	40(4)
H(2B)	11660(20)	9042(19)	3473(16)	43(4)
H(3)	12833(17)	2615(15)	3504(12)	18(3)
H(4)	14470(20)	4737(15)	2302(14)	29(4)
H(5)	12784(18)	7277(15)	1776(13)	26(4)
H(7)	9747(18)	8815(15)	1456(13)	24(3)
H(8)	8599(16)	8819(14)	4261(12)	14(3)
H(9)	7155(17)	11335(14)	3609(13)	19(3)
H(10A)	5241(16)	10483(14)	2433(12)	15(3)
H(10B)	5202(16)	9630(13)	3954(12)	14(3)
H(13)	8473(18)	11360(15)	762(14)	28(4)
H(14A)	8124(19)	13735(16)	2033(14)	32(4)
H(14B)	8860(19)	13939(16)	381(14)	28(4)
H(16A)	5459(19)	7866(15)	-436(13)	24(3)
H(16B)	6227(18)	6081(16)	-92(13)	22(3)
H(16C)	7662(19)	7209(15)	-849(14)	25(4)

**Table 6. Hydrogen bonds for AFG03 (CCDC 820779) [Å and °].**

D-H...A	d(D-H)	d(H...A)	d(D...A)	<(DHA)
N(1)-H(1)...O(1)#1	0.894(14)	2.029(14)	2.9217(12)	175.5(13)
N(2)-H(2A)...O(2)#2	0.874(16)	2.483(16)	3.3366(15)	165.7(13)
N(2)-H(2B)...O(1)#3	0.923(16)	2.576(16)	3.4855(13)	168.5(13)

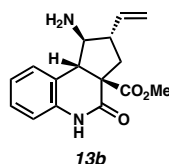
Symmetry transformations used to generate equivalent atoms:

#1 -x+1,-y+1,-z+1

#2 -x+2,-y+2,-z

#3 x+1,y,z

## Crystal Structure Analysis of:



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Contents

Table 1. Crystal data

Figures Minimum overlap

Table 2. Atomic Coordinates

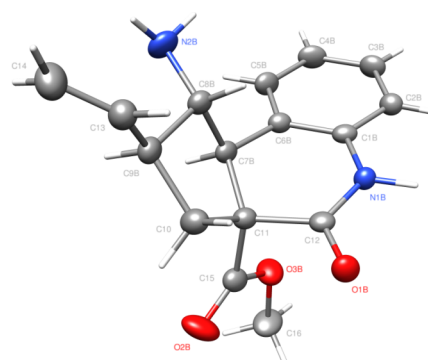
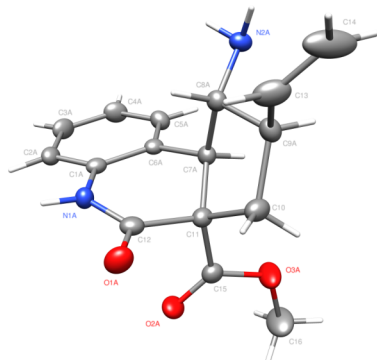
Table 3. Full bond distances and angles

Table 4. Anisotropic displacement parameters

Table 5. Hydrogen atomic coordinates

Table 6. Hydrogen bond distances and angles

Table 7. Observed and calculated structure factors (available upon request)



AFG02

**Note:** The crystallographic data have been deposited in the Cambridge Database (CCDC). The deposition number is 820778."

**Table 1. Crystal data and structure refinement for AFG02 (CCDC 820778).**

Empirical formula	C <sub>16</sub> H <sub>18</sub> N <sub>2</sub> O <sub>3</sub>
Formula weight	286.32
Crystallization Solvent	Dichloromethane/hexane
Crystal Habit	Plate
Crystal size	0.43 x 0.40 x 0.08 mm <sup>3</sup>
Crystal color	Colorless

**Data Collection**

Type of diffractometer	Bruker SMART 1000	
Wavelength	0.71073 Å MoK $\alpha$	
Data Collection Temperature	100(2) K	
$\theta$ range for 9885 reflections used in lattice determination	2.42 to 28.07°	
Unit cell dimensions	a = 19.947(2) Å b = 13.3646(15) Å c = 11.2796(13) Å	$\alpha = 90^\circ$ $\beta = 105.507(2)^\circ$ $\gamma = 90^\circ$
Volume	2897.5(6) Å <sup>3</sup>	
Z	8	
Crystal system	Monoclinic	
Space group	P2(1)/c	
Density (calculated)	1.313 Mg/m <sup>3</sup>	
F(000)	1216	
Data collection program	Bruker SMART v5.630	
$\theta$ range for data collection	1.06 to 29.00°	
Completeness to $\theta = 29.00^\circ$	92.1 %	
Index ranges	-26 $\leq$ h $\leq$ 26, -17 $\leq$ k $\leq$ 17, -15 $\leq$ l $\leq$ 15	
Data collection scan type	$\omega$ scans at 5 settings	
Data reduction program	Bruker SAINT-Plus v7.66A	
Reflections collected	44322	
Independent reflections	7100 [ $R_{\text{int}} = 0.0500$ ]	
Absorption coefficient	0.092 mm <sup>-1</sup>	
Absorption correction	None	
Max. and min. transmission	0.9927 and 0.9617	



**Table 1 (cont.)****Structure solution and Refinement**

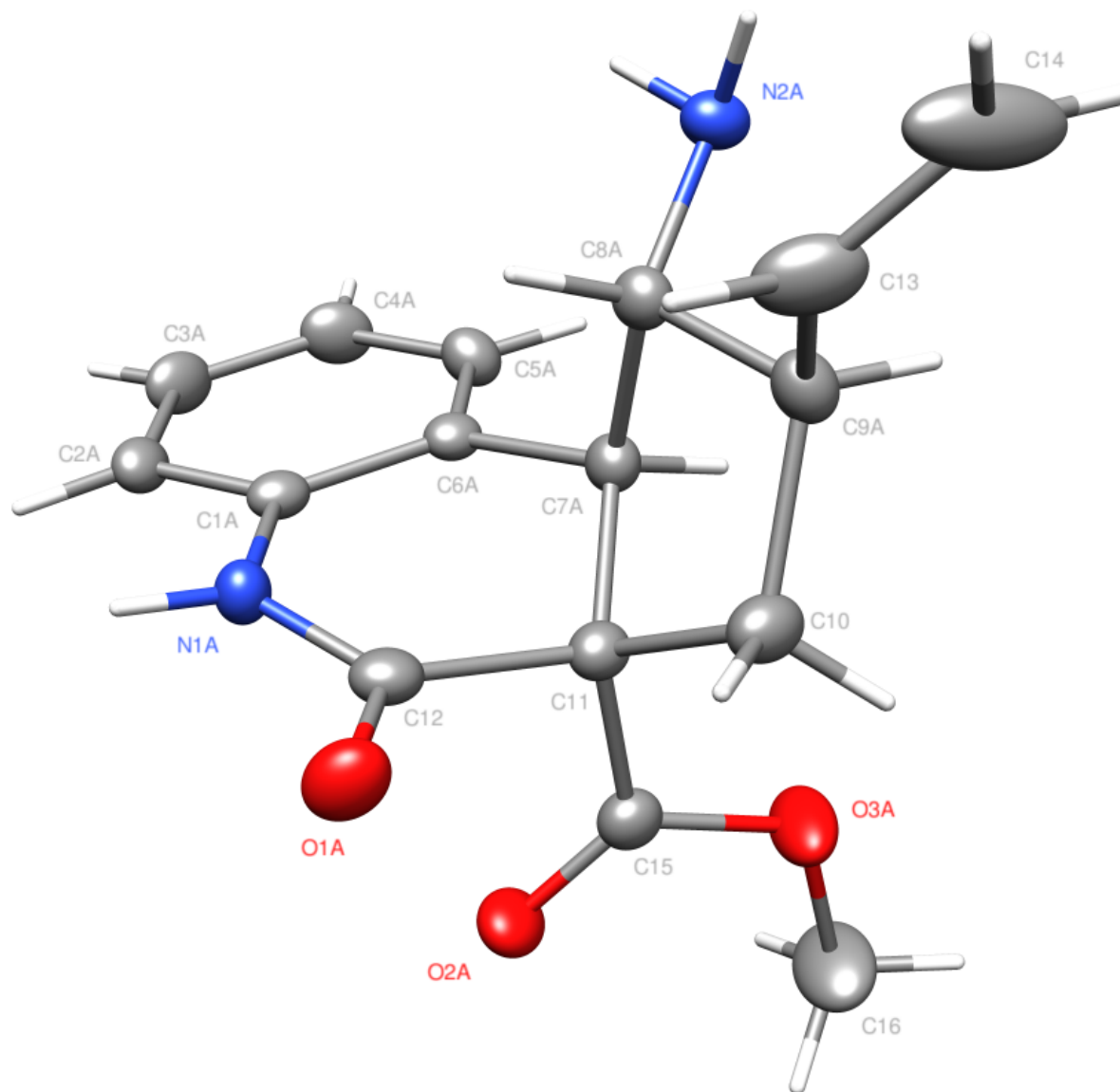
Structure solution program	SHELXS-97 (Sheldrick, 2008)
Primary solution method	Direct methods
Secondary solution method	Difference Fourier map
Hydrogen placement	Difference Fourier map
Structure refinement program	SHELXL-97 (Sheldrick, 2008)
Refinement method	Full matrix least-squares on $F^2$
Data / restraints / parameters	7100 / 0 / 523
Treatment of hydrogen atoms	Unrestrained
Goodness-of-fit on $F^2$	2.160
Final R indices [ $I > 2\sigma(I)$ , 5019 reflections]	$R1 = 0.0507$ , $wR2 = 0.0645$
R indices (all data)	$R1 = 0.0748$ , $wR2 = 0.0664$
Type of weighting scheme used	Sigma
Weighting scheme used	$w = 1/\sigma^2(F_o^2)$
Max shift/error	0.001
Average shift/error	0.000
Largest diff. peak and hole	0.362 and -0.287 e.Å <sup>-3</sup>

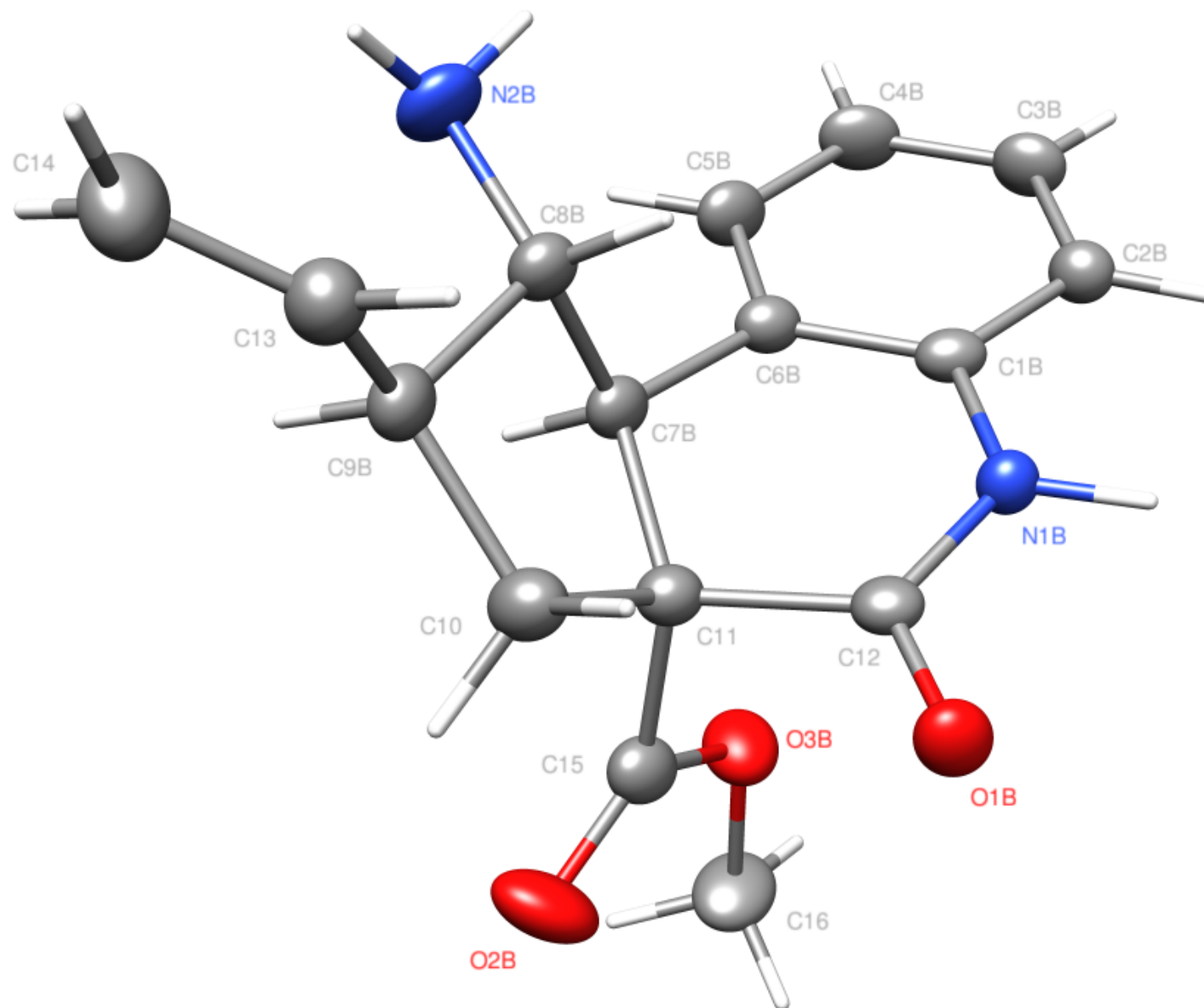
**Special Refinement Details**

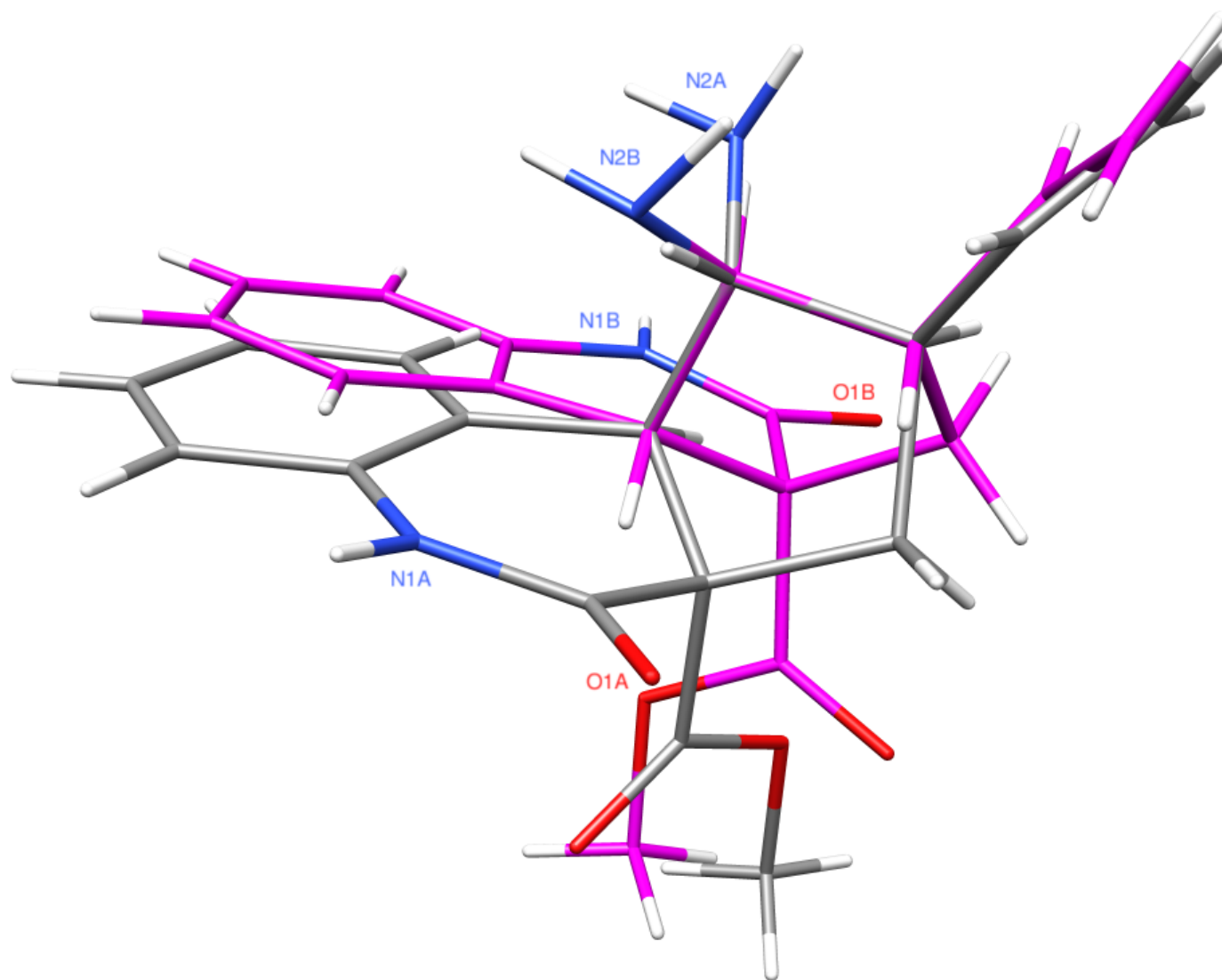
Crystals were mounted on a glass fiber using Paratone oil then placed on the diffractometer under a nitrogen stream at 100K.

Refinement of  $F^2$  against ALL reflections. The weighted R-factor ( $wR$ ) and goodness of fit ( $S$ ) are based on  $F^2$ , conventional R-factors ( $R$ ) are based on  $F$ , with  $F$  set to zero for negative  $F^2$ . The threshold expression of  $F^2 > 2\sigma(F^2)$  is used only for calculating R-factors(gt) etc. and is not relevant to the choice of reflections for refinement. R-factors based on  $F^2$  are statistically about twice as large as those based on  $F$ , and R-factors based on ALL data will be even larger.

All esds (except the esd in the dihedral angle between two l.s. planes) are estimated using the full covariance matrix. The cell esds are taken into account individually in the estimation of esds in distances, angles and torsion angles; correlations between esds in cell parameters are only used when they are defined by crystal symmetry. An approximate (isotropic) treatment of cell esds is used for estimating esds involving l.s. planes.







**Table 2. Atomic coordinates ( $\times 10^4$ ) and equivalent isotropic displacement parameters ( $\text{\AA}^2 \times 10^3$ ) for AFG02 (CCDC 820778).  $U_{eq}$  is defined as the trace of the orthogonalized  $U^{ij}$  tensor.**

	x	y	z	$U_{eq}$
O(1A)	6702(1)	965(1)	10260(1)	30(1)
O(2A)	5913(1)	-380(1)	7880(1)	29(1)
O(3A)	6207(1)	438(1)	6371(1)	40(1)
N(1A)	5544(1)	1226(1)	9712(1)	21(1)
N(2A)	5566(1)	3969(1)	7309(1)	22(1)
C(1A)	4910(1)	1456(1)	8853(1)	18(1)
C(2A)	4287(1)	1269(1)	9137(1)	22(1)
C(3A)	3667(1)	1512(1)	8294(1)	27(1)
C(4A)	3665(1)	1922(1)	7172(2)	28(1)
C(5A)	4288(1)	2101(1)	6890(1)	23(1)
C(6A)	4918(1)	1880(1)	7728(1)	18(1)
C(7A)	5609(1)	2116(1)	7503(1)	19(1)
C(8A)	5924(1)	3121(1)	8029(1)	20(1)
C(9A)	6683(1)	3049(1)	7979(1)	22(1)
C(10A)	6869(1)	1925(1)	8123(2)	26(1)
C(11A)	6188(1)	1377(1)	8134(1)	20(1)
C(12A)	6171(1)	1172(1)	9462(1)	22(1)
C(13A)	7153(1)	3721(1)	8882(2)	32(1)
C(14A)	7450(1)	4528(1)	8569(3)	54(1)
C(15A)	6091(1)	375(1)	7477(1)	23(1)
C(16A)	6124(1)	-490(2)	5675(2)	50(1)
O(1B)	9130(1)	9861(1)	5062(1)	29(1)
O(2B)	8139(1)	9887(1)	7206(1)	45(1)
O(3B)	9269(1)	9904(1)	8214(1)	36(1)
N(1B)	10085(1)	9132(1)	6282(1)	22(1)
N(2B)	9194(1)	5996(1)	7029(1)	38(1)
C(1B)	10439(1)	8525(1)	7274(1)	22(1)
C(2B)	11161(1)	8550(1)	7645(1)	26(1)
C(3B)	11516(1)	7954(1)	8606(1)	29(1)
C(4B)	11153(1)	7340(1)	9203(2)	33(1)
C(5B)	10430(1)	7324(1)	8825(1)	30(1)
C(6B)	10065(1)	7911(1)	7857(1)	23(1)
C(7B)	9289(1)	7838(1)	7351(1)	24(1)
C(8B)	9075(1)	6972(1)	6433(1)	27(1)
C(9B)	8305(1)	7173(1)	5848(2)	28(1)
C(10B)	8283(1)	8303(1)	5632(2)	31(1)
C(11B)	8929(1)	8747(1)	6584(1)	24(1)
C(12B)	9393(1)	9284(1)	5913(1)	22(1)
C(13B)	8014(1)	6569(1)	4712(2)	33(1)
C(14B)	7622(1)	5776(1)	4621(2)	47(1)
C(15B)	8714(1)	9570(1)	7353(1)	29(1)
C(16B)	9139(1)	10740(1)	8951(2)	42(1)

**Table 3. Bond lengths [Å] and angles [°] for AFG02 (CCDC 820778).**

O(1A)-C(12A)	1.2239(15)	C(1B)-C(2B)	1.3877(18)
O(2A)-C(15A)	1.1996(15)	C(1B)-C(6B)	1.3878(18)
O(3A)-C(15A)	1.3307(16)	C(2B)-C(3B)	1.378(2)
O(3A)-C(16A)	1.4539(19)	C(2B)-H(2B)	0.963(12)
N(1A)-C(12A)	1.3544(16)	C(3B)-C(4B)	1.384(2)
N(1A)-C(1A)	1.4057(16)	C(3B)-H(3B)	0.924(12)
N(1A)-H(1A)	0.877(14)	C(4B)-C(5B)	1.390(2)
N(2A)-C(8A)	1.4642(17)	C(4B)-H(4B)	0.996(13)
N(2A)-H(2A2)	0.878(14)	C(5B)-C(6B)	1.3835(19)
N(2A)-H(2A3)	0.950(14)	C(5B)-H(5B)	0.958(13)
C(1A)-C(2A)	1.3868(18)	C(6B)-C(7B)	1.5015(19)
C(1A)-C(6A)	1.3936(17)	C(7B)-C(8B)	1.5351(19)
C(2A)-C(3A)	1.3823(19)	C(7B)-C(11B)	1.5521(19)
C(2A)-H(2A)	0.968(12)	C(7B)-H(7B)	1.020(12)
C(3A)-C(4A)	1.378(2)	C(8B)-C(9B)	1.5252(19)
C(3A)-H(3A)	0.953(11)	C(8B)-H(8B)	1.039(12)
C(4A)-C(5A)	1.3832(19)	C(9B)-C(13B)	1.494(2)
C(4A)-H(4A)	0.945(13)	C(9B)-C(10B)	1.529(2)
C(5A)-C(6A)	1.3878(18)	C(9B)-H(9B)	1.001(13)
C(5A)-H(5A)	0.941(11)	C(10B)-C(11B)	1.558(2)
C(6A)-C(7A)	1.4997(18)	C(10B)-H(10C)	0.992(14)
C(7A)-C(8A)	1.5328(18)	C(10B)-H(10D)	1.061(15)
C(7A)-C(11A)	1.5427(18)	C(11B)-C(12B)	1.5233(18)
C(7A)-H(7A)	0.938(11)	C(11B)-C(15B)	1.5307(19)
C(8A)-C(9A)	1.5334(18)	C(13B)-C(14B)	1.304(2)
C(8A)-H(8A)	0.975(11)	C(13B)-H(13B)	1.017(15)
C(9A)-C(13A)	1.487(2)	C(14B)-H(14C)	1.009(16)
C(9A)-C(10A)	1.5448(19)	C(14B)-H(14D)	1.028(18)
C(9A)-H(9A)	0.929(12)	C(16B)-H(16D)	1.006(15)
C(10A)-C(11A)	1.5453(19)	C(16B)-H(16E)	1.000(16)
C(10A)-H(10A)	0.949(13)	C(16B)-H(16F)	1.011(15)
C(10A)-H(10B)	0.966(13)		
C(11A)-C(15A)	1.5177(18)	C(15A)-O(3A)-C(16A)	115.42(13)
C(11A)-C(12A)	1.5333(18)	C(12A)-N(1A)-C(1A)	125.33(13)
C(13A)-C(14A)	1.323(2)	C(12A)-N(1A)-H(1A)	116.4(9)
C(13A)-H(13A)	0.972(13)	C(1A)-N(1A)-H(1A)	118.3(9)
C(14A)-H(14A)	0.99(2)	C(8A)-N(2A)-H(2A2)	110.6(9)
C(14A)-H(14B)	0.958(17)	C(8A)-N(2A)-H(2A3)	112.2(8)
C(16A)-H(16A)	0.984(16)	H(2A2)-N(2A)-H(2A3)	102.5(12)
C(16A)-H(16B)	0.945(18)	C(2A)-C(1A)-C(6A)	120.81(13)
C(16A)-H(16C)	0.977(16)	C(2A)-C(1A)-N(1A)	119.86(13)
O(1B)-C(12B)	1.2332(15)	C(6A)-C(1A)-N(1A)	119.33(12)
O(2B)-C(15B)	1.1911(16)	C(3A)-C(2A)-C(1A)	119.39(14)
O(3B)-C(15B)	1.3395(17)	C(3A)-C(2A)-H(2A)	121.8(7)
O(3B)-C(16B)	1.4563(18)	C(1A)-C(2A)-H(2A)	118.8(7)
N(1B)-C(12B)	1.3454(17)	C(4A)-C(3A)-C(2A)	120.60(15)
N(1B)-C(1B)	1.4098(17)	C(4A)-C(3A)-H(3A)	119.6(7)
N(1B)-H(1B)	0.984(15)	C(2A)-C(3A)-H(3A)	119.7(7)
N(2B)-C(8B)	1.4569(18)	C(3A)-C(4A)-C(5A)	119.74(15)
N(2B)-H(2B2)	0.944(17)	C(3A)-C(4A)-H(4A)	118.2(8)
N(2B)-H(2B3)	1.006(19)	C(5A)-C(4A)-H(4A)	122.1(8)

C(4A)-C(5A)-C(6A)	120.88(14)	C(15B)-O(3B)-C(16B)	115.53(13)
C(4A)-C(5A)-H(5A)	121.6(7)	C(12B)-N(1B)-C(1B)	126.00(13)
C(6A)-C(5A)-H(5A)	117.5(7)	C(12B)-N(1B)-H(1B)	115.0(9)
C(5A)-C(6A)-C(1A)	118.56(13)	C(1B)-N(1B)-H(1B)	118.7(9)
C(5A)-C(6A)-C(7A)	123.09(13)	C(8B)-N(2B)-H(2B2)	111.7(11)
C(1A)-C(6A)-C(7A)	118.29(12)	C(8B)-N(2B)-H(2B3)	104.7(10)
C(6A)-C(7A)-C(8A)	114.80(11)	H(2B2)-N(2B)-H(2B3)	112.9(14)
C(6A)-C(7A)-C(11A)	113.34(11)	C(2B)-C(1B)-C(6B)	121.21(13)
C(8A)-C(7A)-C(11A)	101.70(11)	C(2B)-C(1B)-N(1B)	119.00(13)
C(6A)-C(7A)-H(7A)	109.6(7)	C(6B)-C(1B)-N(1B)	119.78(13)
C(8A)-C(7A)-H(7A)	107.1(7)	C(3B)-C(2B)-C(1B)	119.80(15)
C(11A)-C(7A)-H(7A)	109.9(7)	C(3B)-C(2B)-H(2B)	121.2(7)
N(2A)-C(8A)-C(7A)	112.03(11)	C(1B)-C(2B)-H(2B)	119.0(7)
N(2A)-C(8A)-C(9A)	111.57(12)	C(2B)-C(3B)-C(4B)	119.97(15)
C(7A)-C(8A)-C(9A)	103.79(11)	C(2B)-C(3B)-H(3B)	120.0(8)
N(2A)-C(8A)-H(8A)	111.9(7)	C(4B)-C(3B)-H(3B)	120.0(8)
C(7A)-C(8A)-H(8A)	107.7(7)	C(3B)-C(4B)-C(5B)	119.63(15)
C(9A)-C(8A)-H(8A)	109.5(7)	C(3B)-C(4B)-H(4B)	120.6(8)
C(13A)-C(9A)-C(8A)	112.64(12)	C(5B)-C(4B)-H(4B)	119.7(8)
C(13A)-C(9A)-C(10A)	115.17(13)	C(6B)-C(5B)-C(4B)	121.26(15)
C(8A)-C(9A)-C(10A)	105.56(11)	C(6B)-C(5B)-H(5B)	118.1(8)
C(13A)-C(9A)-H(9A)	108.2(8)	C(4B)-C(5B)-H(5B)	120.6(8)
C(8A)-C(9A)-H(9A)	106.8(7)	C(5B)-C(6B)-C(1B)	118.13(14)
C(10A)-C(9A)-H(9A)	108.1(7)	C(5B)-C(6B)-C(7B)	122.38(13)
C(9A)-C(10A)-C(11A)	105.98(11)	C(1B)-C(6B)-C(7B)	119.26(13)
C(9A)-C(10A)-H(10A)	112.4(8)	C(6B)-C(7B)-C(8B)	112.21(12)
C(11A)-C(10A)-H(10A)	109.9(8)	C(6B)-C(7B)-C(11B)	115.94(12)
C(9A)-C(10A)-H(10B)	111.1(8)	C(8B)-C(7B)-C(11B)	102.14(11)
C(11A)-C(10A)-H(10B)	111.2(8)	C(6B)-C(7B)-H(7B)	109.4(7)
H(10A)-C(10A)-H(10B)	106.4(11)	C(8B)-C(7B)-H(7B)	107.4(7)
C(15A)-C(11A)-C(12A)	106.60(11)	C(11B)-C(7B)-H(7B)	109.2(7)
C(15A)-C(11A)-C(7A)	110.96(11)	N(2B)-C(8B)-C(9B)	112.24(13)
C(12A)-C(11A)-C(7A)	110.81(11)	N(2B)-C(8B)-C(7B)	112.46(13)
C(15A)-C(11A)-C(10A)	114.37(11)	C(9B)-C(8B)-C(7B)	103.05(12)
C(12A)-C(11A)-C(10A)	110.02(12)	N(2B)-C(8B)-H(8B)	112.5(6)
C(7A)-C(11A)-C(10A)	104.15(11)	C(9B)-C(8B)-H(8B)	107.8(7)
O(1A)-C(12A)-N(1A)	121.61(13)	C(7B)-C(8B)-H(8B)	108.2(7)
O(1A)-C(12A)-C(11A)	121.19(13)	C(13B)-C(9B)-C(8B)	113.00(13)
N(1A)-C(12A)-C(11A)	117.20(12)	C(13B)-C(9B)-C(10B)	114.15(13)
C(14A)-C(13A)-C(9A)	123.67(19)	C(8B)-C(9B)-C(10B)	103.03(12)
C(14A)-C(13A)-H(13A)	119.8(8)	C(13B)-C(9B)-H(9B)	109.4(7)
C(9A)-C(13A)-H(13A)	116.6(8)	C(8B)-C(9B)-H(9B)	104.5(7)
C(13A)-C(14A)-H(14A)	124.0(13)	C(10B)-C(9B)-H(9B)	112.3(7)
C(13A)-C(14A)-H(14B)	116.5(11)	C(9B)-C(10B)-C(11B)	106.44(12)
H(14A)-C(14A)-H(14B)	119.5(16)	C(9B)-C(10B)-H(10C)	111.1(8)
O(2A)-C(15A)-O(3A)	123.49(13)	C(11B)-C(10B)-H(10C)	109.8(8)
O(2A)-C(15A)-C(11A)	124.74(13)	C(9B)-C(10B)-H(10D)	109.6(8)
O(3A)-C(15A)-C(11A)	111.73(12)	C(11B)-C(10B)-H(10D)	107.0(8)
O(3A)-C(16A)-H(16A)	109.5(10)	H(10C)-C(10B)-H(10D)	112.8(12)
O(3A)-C(16A)-H(16B)	104.6(11)	C(12B)-C(11B)-C(15B)	104.11(11)
H(16A)-C(16A)-H(16B)	112.8(15)	C(12B)-C(11B)-C(7B)	113.14(11)
O(3A)-C(16A)-H(16C)	109.5(10)	C(15B)-C(11B)-C(7B)	113.85(12)
H(16A)-C(16A)-H(16C)	106.8(14)	C(12B)-C(11B)-C(10B)	109.70(12)
H(16B)-C(16A)-H(16C)	113.6(15)	C(15B)-C(11B)-C(10B)	111.03(12)

C(7B)-C(11B)-C(10B)	105.12(11)	O(2B)-C(15B)-O(3B)	124.10(14)
O(1B)-C(12B)-N(1B)	121.49(13)	O(2B)-C(15B)-C(11B)	125.52(15)
O(1B)-C(12B)-C(11B)	119.52(13)	O(3B)-C(15B)-C(11B)	110.37(13)
N(1B)-C(12B)-C(11B)	118.97(13)	O(3B)-C(16B)-H(16D)	108.7(9)
C(14B)-C(13B)-C(9B)	126.38(18)	O(3B)-C(16B)-H(16E)	102.4(9)
C(14B)-C(13B)-H(13B)	120.7(9)	H(16D)-C(16B)-H(16E)	117.4(13)
C(9B)-C(13B)-H(13B)	112.9(8)	O(3B)-C(16B)-H(16F)	111.0(9)
C(13B)-C(14B)-H(14C)	117.8(10)	H(16D)-C(16B)-H(16F)	104.4(12)
C(13B)-C(14B)-H(14D)	119.9(10)	H(16E)-C(16B)-H(16F)	113.0(13)
H(14C)-C(14B)-H(14D)	122.0(14)		

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**Table 4. Anisotropic displacement parameters ( $\text{\AA}^2 \times 10^4$ ) for AFG02 (CCDC 820778). The anisotropic displacement factor exponent takes the form:  $-2\pi^2 [h^2 a^{*2} U^{11} + \dots + 2 h k a^* b^* U^{12}]$**

	$U^{11}$	$U^{22}$	$U^{33}$	$U^{23}$	$U^{13}$	$U^{12}$
O(1A)	253(6)	371(7)	237(6)	-16(5)	14(5)	87(5)
O(2A)	349(6)	203(6)	340(6)	-11(5)	151(5)	-42(5)
O(3A)	730(8)	230(6)	323(7)	-81(5)	306(6)	-52(6)
N(1A)	236(7)	231(7)	176(7)	22(6)	75(6)	28(6)
N(2A)	235(8)	169(7)	260(7)	-7(6)	66(6)	-6(6)
C(1A)	191(8)	137(7)	206(8)	-36(6)	40(6)	1(6)
C(2A)	278(9)	173(8)	245(9)	-15(7)	112(7)	-24(7)
C(3A)	211(9)	257(9)	359(10)	-34(8)	112(8)	-40(7)
C(4A)	198(9)	274(9)	334(10)	-11(8)	10(8)	-2(7)
C(5A)	279(9)	203(8)	207(9)	7(7)	44(7)	-25(7)
C(6A)	205(8)	129(7)	202(8)	-32(6)	59(6)	-10(6)
C(7A)	228(8)	188(8)	161(8)	-3(6)	63(7)	1(6)
C(8A)	233(8)	194(8)	163(8)	2(7)	55(7)	4(7)
C(9A)	226(8)	222(9)	206(8)	27(7)	55(7)	-15(7)
C(10A)	232(9)	221(9)	338(10)	-20(8)	112(8)	8(7)
C(11A)	205(8)	176(8)	213(8)	-15(6)	73(6)	0(6)
C(12A)	253(9)	158(8)	237(9)	-19(7)	51(7)	22(7)
C(13A)	235(9)	288(10)	381(11)	-83(8)	-17(8)	55(8)
C(14A)	224(10)	263(11)	1040(20)	-139(13)	28(12)	-15(8)
C(15A)	214(8)	235(9)	241(9)	-3(7)	69(7)	31(7)
C(16A)	862(19)	309(12)	416(13)	-147(10)	319(13)	-61(12)
O(1B)	262(6)	314(6)	272(6)	94(5)	53(5)	48(5)
O(2B)	376(7)	523(8)	461(7)	-28(6)	106(6)	209(6)
O(3B)	371(7)	321(7)	408(7)	-122(5)	149(6)	-33(5)
N(1B)	212(7)	210(7)	226(7)	33(6)	54(6)	5(6)
N(2B)	411(10)	219(8)	492(10)	91(7)	91(8)	14(7)
C(1B)	263(9)	184(8)	203(8)	-19(6)	46(7)	39(7)
C(2B)	248(9)	242(9)	273(9)	-7(7)	66(7)	4(7)
C(3B)	228(9)	308(10)	290(9)	-1(8)	8(8)	46(8)
C(4B)	355(10)	328(10)	257(9)	54(8)	18(8)	98(8)
C(5B)	362(10)	266(9)	280(9)	74(7)	124(8)	38(8)
C(6B)	258(9)	206(8)	231(8)	4(7)	72(7)	26(7)
C(7B)	268(9)	203(8)	275(9)	48(7)	110(7)	10(7)
C(8B)	278(9)	202(9)	337(10)	32(7)	101(8)	2(7)
C(9B)	271(9)	234(9)	365(10)	11(8)	120(8)	-32(7)
C(10B)	248(9)	237(10)	431(11)	0(8)	47(8)	5(7)
C(11B)	242(8)	201(8)	277(9)	15(7)	79(7)	22(7)
C(12B)	244(9)	174(8)	238(9)	-29(7)	55(7)	21(7)
C(13B)	266(10)	279(10)	449(11)	-18(8)	99(8)	-21(8)
C(14B)	375(11)	426(12)	656(15)	-141(11)	227(11)	-88(9)
C(15B)	316(10)	266(9)	298(9)	61(7)	118(8)	29(8)
C(16B)	580(14)	312(11)	432(12)	-127(9)	232(12)	-18(10)

**Table 5. Hydrogen coordinates (  $\times 10^4$ ) and isotropic displacement parameters ( $\text{\AA}^2 \times 10^3$ ) for AFG02 (CCDC 820778).**

	x	y	z	$U_{\text{iso}}$
H(1A)	5539(7)	1098(10)	10472(13)	34(5)
H(2A2)	5783(7)	4531(10)	7573(13)	34(5)
H(2A3)	5119(7)	4079(10)	7431(12)	38(5)
H(2A)	4299(6)	966(9)	9922(11)	16(4)
H(3A)	3237(6)	1368(9)	8474(11)	15(4)
H(4A)	3231(7)	2080(9)	6620(12)	31(4)
H(5A)	4301(6)	2378(9)	6130(11)	16(4)
H(7A)	5564(5)	2131(8)	6654(11)	9(3)
H(8A)	5908(6)	3154(8)	8884(11)	11(3)
H(9A)	6693(6)	3246(9)	7194(11)	15(4)
H(10A)	7040(6)	1680(9)	7471(12)	29(4)
H(10B)	7229(7)	1801(9)	8872(12)	27(4)
H(13A)	7228(7)	3553(10)	9747(13)	36(5)
H(14A)	7393(10)	4747(16)	7705(19)	113(10)
H(14B)	7747(9)	4902(13)	9228(15)	66(6)
H(16A)	6398(8)	-1022(13)	6186(15)	61(6)
H(16B)	6281(9)	-339(12)	4975(17)	70(6)
H(16C)	5637(9)	-701(12)	5475(15)	59(6)
H(1B)	10359(8)	9538(11)	5853(14)	56(5)
H(2B2)	9672(9)	5832(13)	7271(16)	73(7)
H(2B3)	8911(9)	5518(14)	6404(17)	88(7)
H(2B)	11404(6)	8983(9)	7218(11)	18(4)
H(3B)	11996(7)	7978(9)	8865(12)	25(4)
H(4B)	11405(7)	6906(9)	9899(12)	31(4)
H(5B)	10172(7)	6897(10)	9223(12)	33(4)
H(7B)	9067(6)	7713(9)	8053(11)	19(4)
H(8B)	9335(6)	7055(8)	5755(11)	18(4)
H(9B)	8070(6)	6974(9)	6494(12)	29(4)
H(10C)	7851(7)	8599(10)	5759(13)	43(5)
H(10D)	8346(7)	8456(11)	4745(14)	52(5)
H(13B)	8177(7)	6812(11)	3980(14)	52(5)
H(14C)	7503(8)	5535(12)	5387(16)	67(6)
H(14D)	7481(9)	5385(13)	3807(17)	86(7)
H(16D)	8958(8)	11320(12)	8388(14)	52(5)
H(16E)	9600(8)	10826(12)	9569(15)	60(6)
H(16F)	8750(8)	10579(11)	9338(14)	51(5)

**Table 6. Hydrogen bonds for AFG02 (CCDC 820778) [ $\text{\AA}$  and  $^\circ$ ].**

D-H...A	d(D-H)	d(H...A)	d(D...A)	$\angle(\text{DHA})$
N(1A)-H(1A)...N(2A)#1	0.877(14)	2.060(14)	2.9300(18)	171.0(13)
N(2A)-H(2A3)...O(2A)#2	0.950(14)	2.120(14)	3.0283(17)	159.6(12)
N(1B)-H(1B)...O(1B)#3	0.984(15)	1.820(16)	2.7986(15)	172.3(13)
N(2B)-H(2B2)...O(3B)#4	0.944(17)	2.630(17)	3.4707(18)	148.6(14)

Symmetry transformations used to generate equivalent atoms:

#1  $x, -y+1/2, z+1/2$

#2  $-x+1, y+1/2, -z+3/2$

#3  $-x+2, -y+2, -z+1$

#4  $-x+2, y-1/2, -z+3/2$