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Gas Phase Fragmentation of *N,N*-Ditosyl-2-aminodiphenylamine to Phenazine

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Abstract

N,N-Ditosyl-2-aminodiphenylamine was prepared by the tosylation of 2-aminodiphenylamine with tosylchloride in dichloromethane. Unwanted isomers owing to the tosylation of the diarylamine were not formed. This compound was fully characterized by IR, UV/Vis, NMR, *m/z*, and mp, including an X-Ray single crystal structure determination. It was fragmented in an Atmospheric Solids Analysis Probe (ASAP) mass spectrometer showing a series of fragments down to phenazine.

Keywords: smashing; fragmentation; gas phase; phenazine; tosylation

1. Introduction

We recently reported the syntheses and crystal structures of a family of di-, tri- and tetra-tosylated amines [1] and related tosylation chemistry [Figure 1] [2–18]. These molecules form readily at room temperature in dichloromethane (DCM) solution in the presence of triethylamine, Et_3N. Compound **2**, formed using three molar equivalents of tosyl chloride, was not expected as the benzylic amine is more nucleophilic. It is however more hindered, which presumably accounts for the structure. This paper reports the synthesis and characterization of a new, similar, ditosylated amine **7** and its fragmentation to phenazine and other products in an Atmospheric Solids Analysis Probe (ASAP) mass spectrometer.

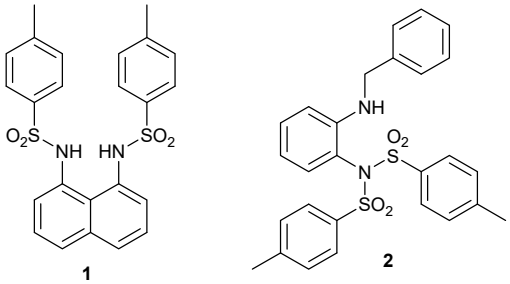


Figure 1. *Cont.*

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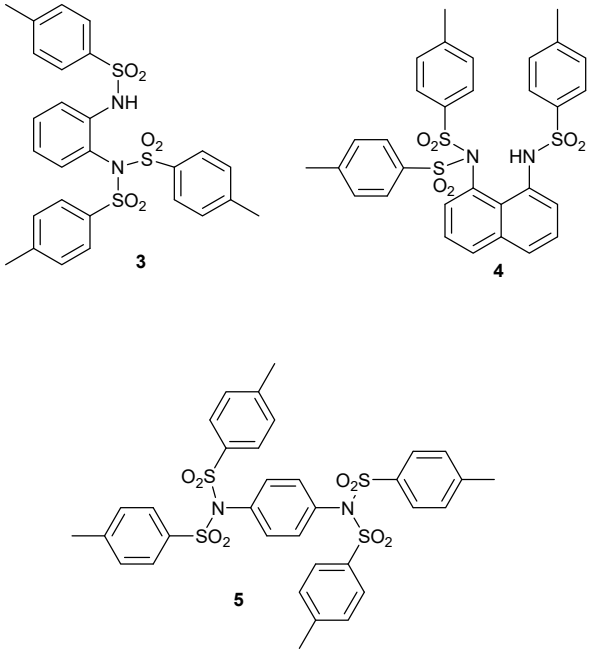


Figure 1. Tosylated amines prepared previously by us [1] and others [2,7].

2. Discussion

2-Aminodiphenylamine **6** was reacted with tosyl chloride (2 equiv) in DCM at rt to give compound **7** (Figure 2). The steric bulk of the ditosylated primary amine was expected to prevent tosylation of the diphenylamine as in compound **2**. It is also less nucleophilic because of conjugation of the amine to two phenyl rings. Compound **7** was isolated in 68% yield as a white crystalline solid. It was fully characterized by IR, UV/Vis, NMR, *m/z* and mp (see experimental section and Supplementary section for NMR). The IR shows sulphonamide peaks at 1378 and 1158 cm^{-1}. The proton NMR has the correct ratios of hydrogens adding up to 23H, and 15C in the carbon 13 NMR. Overlapping resonances make interpretation difficult. There is however a doublet at 7.88 ppm for four hydrogens on the tolyl ring. The literature [19] shows that diphenylamine does tosylate under mild conditions to give *N*-tosyldiphenylamine, but we found that all the compounds used (diphenylamine, tosyl chloride and any products) had identical R_f values and the product was not isolated. Pyridine is unsuitable here because it only mono-tosylates, rather than ditosylates, aromatic primary amines [1,2,7]. Presumably the ditosylate does form but hot pyridine decomposes it. This understanding enabled us to make compounds **1**–**5** [1].

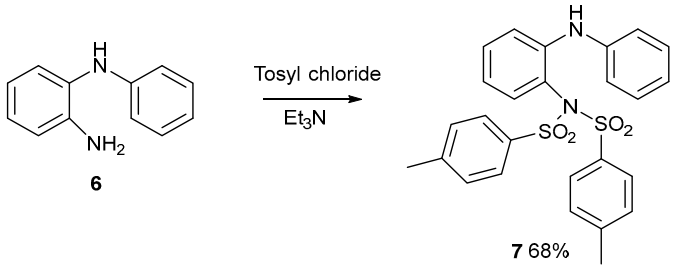


Figure 2. Synthesis of *N*,*N*-ditosylated-2-aminodiphenylamine **7**.

The crystal structure of compound **7** shows that the asymmetric unit contains two molecules, *A* containing C1 (Figure 3) and *B* containing C27. In the *A* molecule, the dihedral angles between the C1–C6 benzene ring and the pendant C7–C12, C13–C18 and C20–C25 rings are 44.91 (13), 45.44 (12) and 40.29 (13)°, respectively. The bond–angle sum at N1 is

359.1°, indicative of sp^2 hybridization, but the presumed orientation of the unhybridized *p* orbital is not well aligned to overlap with the π-system of the C1–C6 ring and the C1—N1 bond length is relatively long at 1.446 (3) Å. The closest acceptor atom to the N2—H1n moiety is O1 at 2.70 Å, which must correspond at best to an extremely weak intramolecular hydrogen bond. In molecule *B*, the N4—H2n grouping has a slightly different orientation and the closest acceptor atom, O5, is some 2.53 Å away, but overall, the *A* and *B* molecules have very similar conformations (Figure 4). In the extended structure of compound **7**, various weak C—H···O hydrogen bonds link the molecules into a three-dimensional network.

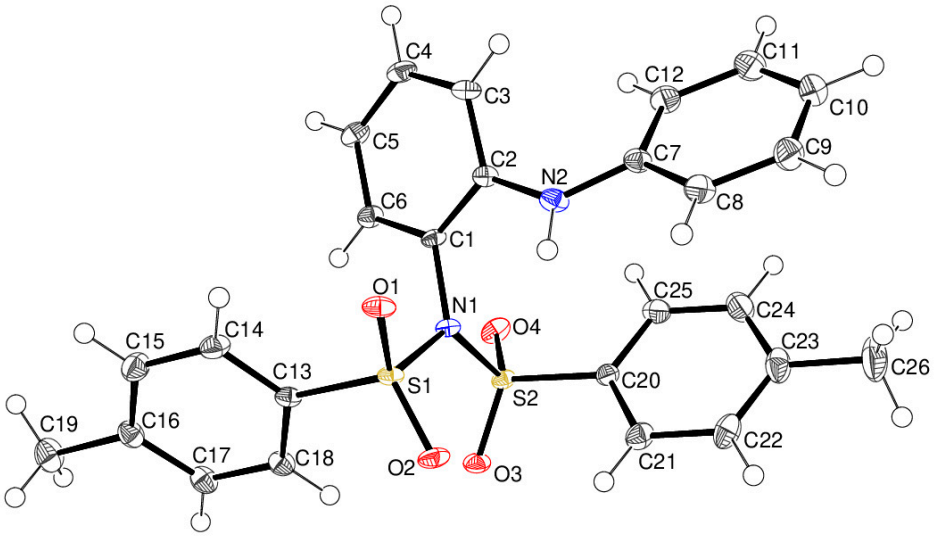


Figure 3. The molecular structure of molecule *A* of compound **7** showing 50% displacement ellipsoids. Nitrogen (N) is blue, Oxygen (O) is red and Sulfur (S) is yellow.

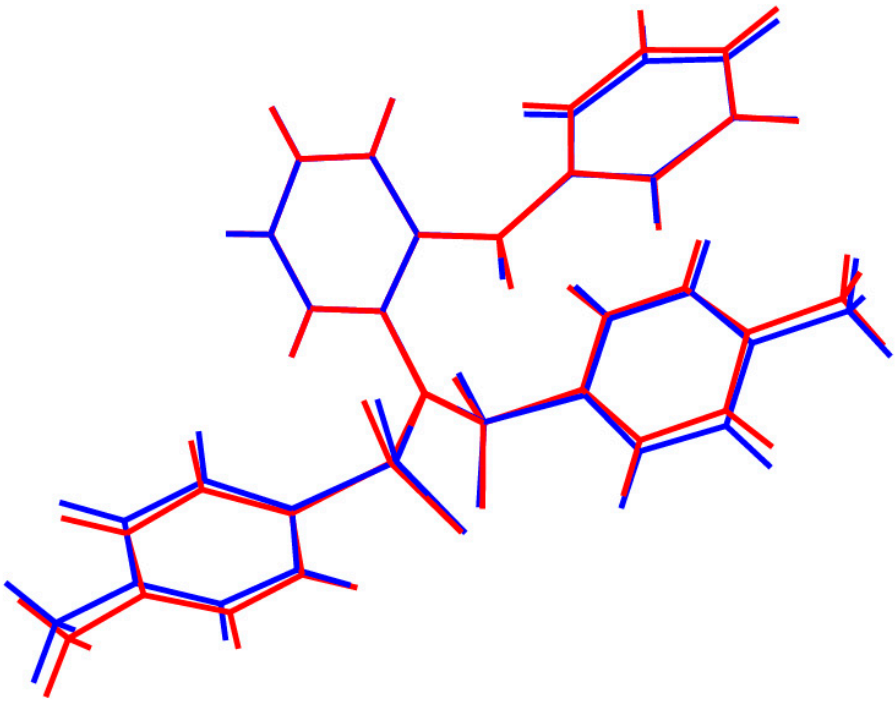


Figure 4. Overlay plot of the *A* (red) and *B* (blue) molecules of compound **7**. The conformation of *B* has been inverted from that in the asymmetric unit.

Gas-Phase Fragmentation of Compound **7**

N,N-Ditosyl-2-aminodiphenylamine **7** gave a strong molecular ion at 493 [M+H] in the ASAP mass spectrum (Figure 5). The ion was then isolated and fragmented in a high-

resolution accurate mass (HRAM) ASAP mass spectrum (Figure 6) [20,21]. Suggested molecular formulae for these ions are drawn on the mass spectrum and possible structures are drawn in Figure 7. The ions are all M + H. The molecular ion initially loses $ArSO_2$ giving ion **8**, which then loses either OH or O and H to give ion **9**. This loses SO to give ion **10**, which then loses C_7H_8 to form the phenazine ion **11** [22,23]. The initial fragmentations are strong, but the final fragmentations are weaker as a percentage of the molecular ion (Figure 6).

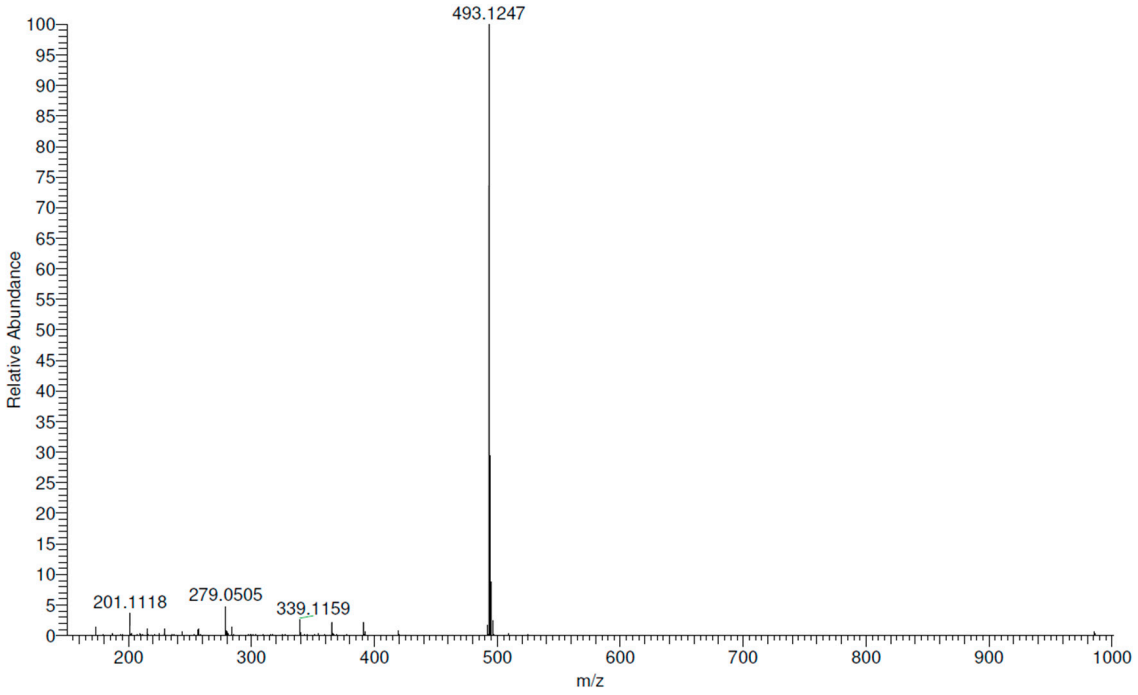


Figure 5. ASAP mass spectrum of compound **7** showing an [M+H] molecular ion [$C_{26}H_{24}N_2O_4S_2$].

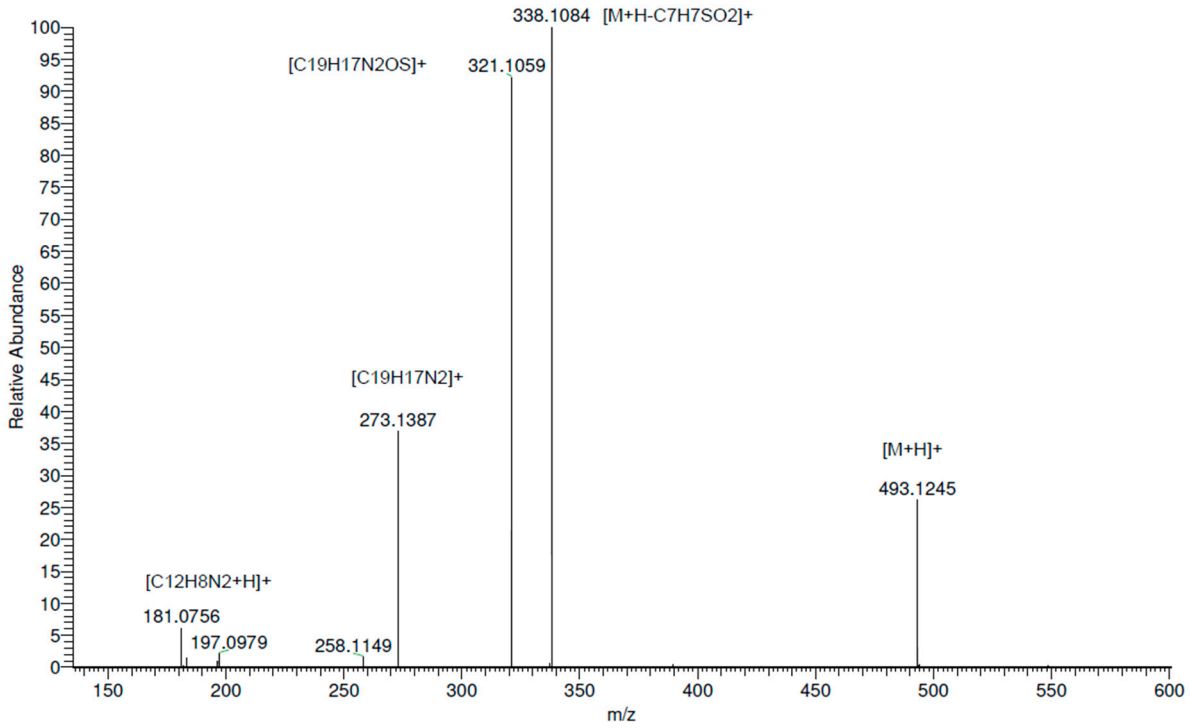


Figure 6. HRAM ASAP-MS/MS fragmentation spectra of compound **7**.

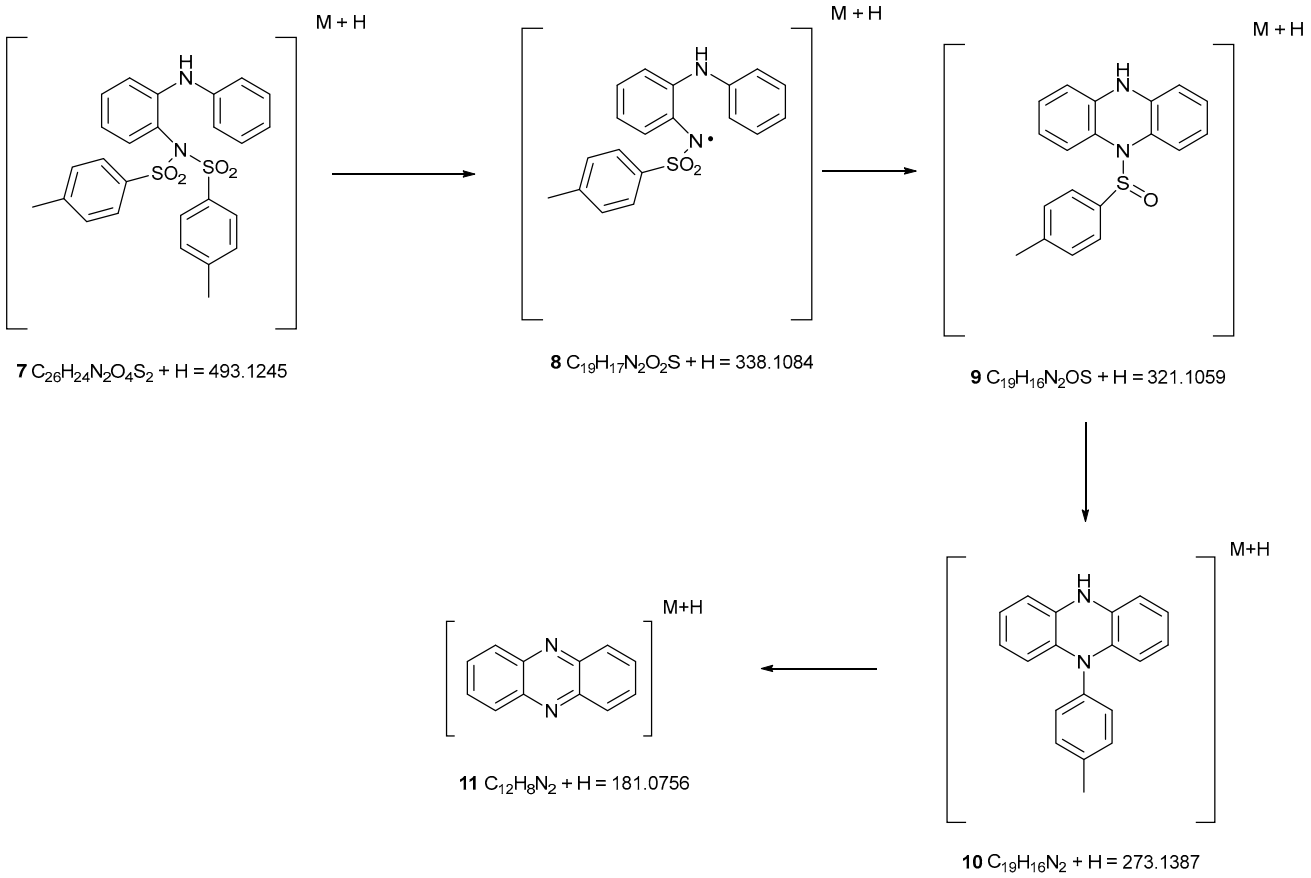


Figure 7. Proposed structures for the HRAM ASAP-MS/MS fragmentation spectra of compound **7** to give phenazine **11**.

3. Conclusions

Future work is anticipated to be the synthesis and fragmentation of larger systems by the same methods and to observe the fragments. The synthesis of *N*,*N*-ditosyl-2-aminodiphenylamine is straightforward without the formation of unwanted isomers. It is also freely soluble in dichloromethane.

4. Experimental

4.1. General Procedure

IR spectra were recorded on a Diamond Anvil Fourier transform infrared (FTIR) spectrometer. Ultraviolet (UV) spectra were recorded using a PerkinElmer (Waltham, MA, USA) Lambda 25 UV-Vis spectrometer with EtOH as the solvent. The term sh means shoulder. ^{1}H and ^{13}C nuclear magnetic resonance (NMR) spectra were recorded at 400 and 100.5 MHz, respectively, using a Varian (Macquarie Park, Australia) 400 spectrometer. Chemical shifts, δ, are given in ppm and were measured by performing a comparison with the residual solvent. Coupling constants, *J*, are given in Hz. High-resolution mass spectra were obtained at the University of Wales, Swansea, using an Atmospheric Solids Analysis Probe (ASAP) (Positive mode) Instrument: Xevo (Bellevue, WA, USA) G2-S ASAP. Melting points were determined on a Kofler (Zug, Switzerland) hot-stage microscope.

N,*N*-Ditosyl-2-aminodiphenylamine

2-Aminodiphenylamine (300 mg, 1.63 mmol) in DCM (30 mL) was treated with tosyl chloride (622 mg, 3.27 mmol) and Et_3N (330 mg, 3.27 mmol). After stirring for 18 h at room temperature, the mixture was extracted with water (200 mL), dried over $MgSO_4$, filtered

and evaporated. A column was set up with silica in DCM. The product in DCM/light petrol (25:75) was loaded and tosyl chloride was eluted with DCM/light petrol (25:75). DCM/light petrol (50:50) then eluted the *title compound* (545 mg, 68%) as colorless crystals, m.p. 166–167 °C. ^{1}H NMR (400 MHz; $CDCl_3$) 2.41 (6H, s), 6.08 (1H, s, NH), 6.77–6.85 (2H, m), 6.89 (2H, d, J = 8.0), 6.97 (1H, t, 8.0), 7.24 (8H, m, 7.20–7.39) and 7.88 (4H, d, J = 8.0); ^{13}C NMR (100.1 MHz; $CDCl_3$) 21.5, 118.5, 118.6, 120.6, 121.6, 123.2, 128.8, 129.2, 129.6, 131.2, 133.2, 136.3, 141.9, 143.3 and 145.4; IR (ATR diamond) (cm^{-1}) 2987 w, 2900 w, 1593 s, 1515 s, 1378 s, 1360 s, 1158 s, 1082 s, 950 w, 915 s, 868 s, 813 s, 742 s, 729 s, 687 w, 659 s, 595 w and 546 s; UV/Vis (EtOH): λ_{max} (ε) = 280 (282), 235 nm (708 mol^{-1} dm^3 cm^{-1}); HRMS (ASAP Orbitrap) *m/z* calcd. for CHNO + H^+: 493.1250; found: 493.1247 100%; HRAM ASAP-MS/MS 493.1245 (M^+), 338.1084 (M+H − $C_7H_7SO_2$)$^+$, 321.1059 ($C_{19}H_{17}N_2OS$)$^+$, 273.1387 ($C_{19}H_{17}N_2$)$^+$ and 181.0756 ($C_{12}H_8N_2$ +H)$^+$.

The crystal structure of **7** was routinely solved by dual-space methods using *SHELXT* [24] and the structural model was completed and optimized by refinement against $|F|^2$ with *SHELXL*-2019 [25]. The N-bound hydrogen atoms were located in difference maps, and their positions were freely refined; the C-bound H atoms were placed in idealized locations (C-H = 0.95–0.98 Å depending on hybridization) and refined as riding atoms. The methyl groups were allowed to rotate, but not to tip, to best fit the electron density. The constraint U_{iso}(H) = 1.2U_{eq}(carrier) or 1.5U_{eq}(methyl carrier) was applied in all cases. Full details of the structure and refinement are available in the deposited cif.

Crystal data for **7** $C_{26}H_{24}N_2O_4S_2$ (colorless plate 0.28 × 0.20 × 0.03 mm), M_r = 492.59, triclinic, space group $P\bar{1}$ (No. 2), a = 9.32141 (11) Å, b = 11.0707 (2) Å, c = 22.7468 (4) Å, α = 94.8247 (15)°, β = 96.4331 (12)°, γ = 90.4214 (12)°, V = 2323.96 (6) Å^3, Z = 4, T = 100 K, Mo Kα radiation, λ = 0.71073 Å, μ = 0.266 mm^{-1}, ρ_{calc} = 1.408 g cm^{-3}, 54,576 reflections measured ($3.6 \leq 2\theta \leq 61.0°$), 14,159 unique ($R_{Int}$ = 0.050), $R(F)$ = 0.067 [10967 reflections with $I > 2\sigma(I)$], $wR(F^2)$ = 0.180 (all data), $\Delta\rho_{min,max}$ (e Å^{-3}) = −0.66, +1.29, CCDC deposition number 2487823.

Supplementary Materials: The following supporting information can be downloaded online. NMR data for compound **7**.

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Conflicts of Interest: The authors declare no conflicts of interest.

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