SUPPORTING INFORMATION

The Effect of Structure on Nitroxide EPR Spectral Linewidth

Scott R. Burks,[†,¶] Mallory A. Makowsky,[‡] Zachary A. Yaffe,[‡] Chad Hoggle,[‡] Pei Tsai,[†,‡] Sukumaran Muralidharan,[†] Michael K. Bowman,[§] Joseph P.Y. Kao,[†,¶], and Gerald M. Rosen,*[,†,‡]

† Center for Biomedical Engineering and Technology, University of Maryland, Baltimore, MD, 21201 and Center for EPR Imaging In Vivo Physiology, University of Maryland, Baltimore, MD 21201

¶ Department of Physiology, University of Maryland School of Medicine, Baltimore, MD 21201

‡ Department of Pharmaceutical Sciences, University of Maryland School of Pharmacy, Baltimore, MD 21201

§ Department of Chemistry, The University of Alabama, Tuscaloosa, AL 35487

Table of Contents **Page**

Table 1. Crystal data and structure refinement for nitroxide **7** 2

Table 2. Atomic coordinates and equivalent isotropic atomic displacement parameters for nitroxide **7** 3

Table 3. Anisotropic atomic displacement parameters for nitroxide **7** 3

Table 4. Hydrogen atom coordinates and isotropic atomic displacement parameters for nitroxide **7** 4

Table 5. Site occupancy factors that deviate from unity for nitroxide **7** 4

Table 6. Bond lengths, valence and torsion angles for nitroxide **7** 5

Quantum chemical coordinates for nitroxide **5** 6

Quantum chemical coordinates for nitroxide **6** 7

Quantum chemical coordinates for nitroxide **7** 8

Quantum chemical coordinates for nitroxide **8** 9

Table 1. Crystal data and structure refinement for nitroxide **7**

Empirical formula	$C_{12}H_{20}NO_3$	
Formula weight	226.29	
Temperature	250(2) K	
Wavelength	0.71073 Å	
Crystal size	$0.53 \times 0.50 \times 0.40$ mm^3	
Crystal habit	orange bulk	
Crystal system	Monoclinic	
Space group	$P2_1/c$	
Unit cell dimensions	a = 7.7657(7) Å	α = 90°
	b = 15.5387(14) Å	β = 109.5925(10)°
	c = 11.2639(10) Å	γ = 90°
Volume	1280.5(2) Å^3	
Z	4	
Density, ρ_{calc}	1.174 g/cm^3	
Absorption coefficient, μ	0.084 mm^{-1}	
F(000)	492 $\bar{e}$	
Diffractometer	Bruker Smart Apex II CCD area detector	
Radiation source	fine-focus sealed tube, MoKα	
Detector distance	5.800 cm	
Detector resolution	11.2 pixels/mm	
Total frames	1830	
Frame size	512 pixels	
Frame width	-0.30°	
Exposure per frame	45 sec	
Total measurement time	25.9 hours	
Data collection method	ω scans	
θ range for data collection	2.32 to 25.00°	
Index ranges	$-9 \le h \le 9$, $-18 \le k \le 18$, $-13 \le l \le 13$	
Reflections collected	9232	
Independent reflections	2268	
Observed reflection, I>2σ(I)	1909	
Coverage of independent reflections	100.0 %	
Variation in check reflections	0 %	
Absorption correction	Semi-empirical from equivalents SADABS (Sheldrick, 1996)	
Max. and min. transmission	0.967 and 0.914	
Structure solution technique	direct	
Structure solution program	SHELXS-97 (Sheldrick, 1990)	
Refinement technique	Full-matrix least-squares on F^2	
Refinement program	SHELXL-97 (Sheldrick, 1997)	
Function minimized	$\Sigma w(F_o^2 - F_c^2)^2$	
Data / restraints / parameters	2268 / 0 / 161	
Goodness-of-fit on F^2	1.000	
Δ/σ_{max}	0.000	
Final R indices: R_1, I>2σ(I)	0.0488	
wR_2, all data	0.0970	
R_{int}	0.0220	
R_{sig}	0.0216	
Weighting scheme	$w = 1/[\sigma^2(F_o^2)+(0.005P)^2+0.9535P]$, $P = [\max(F_o^2,0)+2F_o^2]/3$	
Largest diff. peak and hole	0.439 and -0.157 $\bar{e}$/Å^3	

$R_1 = \Sigma||F_o|-|F_c||/\Sigma|F_o|$, $wR2 = [\Sigma w(F_o^2 - F_c^2)^2/\Sigma w(F_o^2)^2]^{1/2}$

Table 2. Atomic coordinates and equivalent* isotropic atomic displacement parameters ($Å^2$) for nitroxide **7**

Atom	*x/a*	*y/b*	*z/c*	U_{eq}
O1	0.6610(2)	0.38706(11)	0.89383(14)	0.0741(5)
N1	0.5555(2)	0.35818(10)	0.78880(14)	0.0468(4)
C2	0.3837(2)	0.40869(12)	0.72710(19)	0.0484(5)
C2A	0.4312(3)	0.49318(14)	0.6750(2)	0.0685(7)
C2B	0.2963(3)	0.42736(15)	0.8258(2)	0.0652(6)
C3	0.2518(2)	0.35544(12)	0.61889(18)	0.0475(5)
C4	0.3469(2)	0.31039(12)	0.54149(18)	0.0441(4)
C5	0.4927(3)	0.25126(12)	0.61718(18)	0.0488(5)
C6	0.6412(2)	0.29927(13)	0.71939(18)	0.0486(5)
C6A	0.7623(3)	0.35100(16)	0.6627(2)	0.0672(6)
C6B	0.7577(3)	0.23421(15)	0.8149(2)	0.0681(6)
C7	0.3122(3)	0.32013(12)	0.41688(18)	0.0479(5)
C8	0.1776(2)	0.37773(12)	0.33009(17)	0.0434(4)
O8	0.0882(2)	0.43324(10)	0.35579(13)	0.0633(4)
O9	0.1677(2)	0.35998(9)	0.21150(13)	0.0609(4)
C9	0.0499(3)	0.41343(16)	0.11337(19)	0.0699(7)

* U_{eq} is defined as one third of the trace of the orthogonalized U_{ij} tensor.

Table 3. Anisotropic atomic displacement parameters* ($Å^2$) for nitroxide **7**

Atom	U_{11}	U_{22}	U_{33}	U_{23}	U_{13}	U_{12}
O1	0.0580(9)	0.0932(12)	0.0558(9)	-0.0184(9)	-0.0012(7)	0.0092(9)
N1	0.0388(8)	0.0507(9)	0.0459(9)	-0.0006(7)	0.0076(7)	0.0034(7)
C2	0.0427(10)	0.0430(10)	0.0575(12)	0.0043(9)	0.0143(9)	0.0073(8)
C2A	0.0667(15)	0.0466(12)	0.0866(17)	0.0065(12)	0.0182(13)	-0.0006(11)
C2B	0.0612(13)	0.0678(15)	0.0663(14)	-0.0059(12)	0.0208(11)	0.0159(11)
C3	0.0350(9)	0.0480(11)	0.0561(12)	0.0046(9)	0.0107(8)	0.0020(8)
C4	0.0376(9)	0.0401(10)	0.0542(11)	-0.0031(8)	0.0147(8)	-0.0059(8)
C5	0.0474(10)	0.0449(10)	0.0554(12)	0.0016(9)	0.0190(9)	0.0029(9)
C6	0.0403(10)	0.0531(11)	0.0536(11)	0.0006(9)	0.0173(9)	0.0029(9)
C6A	0.0503(12)	0.0763(16)	0.0804(16)	-0.0046(13)	0.0289(12)	-0.0097(11)
C6B	0.0547(13)	0.0720(15)	0.0718(15)	0.0056(12)	0.0134(11)	0.0210(11)
C7	0.0431(10)	0.0450(10)	0.0543(12)	-0.0028(9)	0.0145(9)	0.0021(8)
C8	0.0386(10)	0.0420(10)	0.0463(11)	-0.0038(8)	0.0097(8)	-0.0028(8)
O8	0.0658(9)	0.0604(9)	0.0605(9)	0.0002(7)	0.0168(7)	0.0180(8)
O9	0.0636(9)	0.0651(9)	0.0474(8)	-0.0012(7)	0.0097(7)	0.0130(7)
C9	0.0735(15)	0.0787(16)	0.0447(12)	0.0041(11)	0.0029(11)	0.0196(13)

* The anisotropic atomic displacement factor exponent takes the form: $-2\pi^2 [h^2a^{*2}U_{11} + ... + 2hka^*b^*U_{12}]$

Table 4. Hydrogen atom coordinates and isotropic atomic displacement parameters ($Å^2$) for nitroxide **7**

Atom	*x/a*	*y/b*	*z/c*	U_{iso}
H2A1	0.5193	0.5250	0.7425	0.075(6)
H2A2	0.3213	0.5274	0.6399	0.075(6)
H2A3	0.4832	0.4807	0.6097	0.075(6)
H2A4	0.3633	0.4970	0.5856	0.075(6)
H2A5	0.5612	0.4946	0.6882	0.075(6)
H2A6	0.3993	0.5413	0.7184	0.075(6)
H2B1	0.2718	0.3736	0.8610	0.060(5)
H2B2	0.1826	0.4582	0.7874	0.060(5)
H2B3	0.3785	0.4622	0.8923	0.060(5)
H2B4	0.2834	0.4891	0.8328	0.060(5)
H2B5	0.3727	0.4045	0.9064	0.060(5)
H2B6	0.1767	0.4005	0.8015	0.060(5)
H3A	0.1901	0.3127	0.6545	0.058(4)
H3B	0.1581	0.3937	0.5643	0.058(4)
H5A	0.5474	0.2220	0.5615	0.055(4)
H5B	0.4387	0.2073	0.6564	0.055(4)
H6A1	0.6862	0.3869	0.5949	0.074(4)
H6A2	0.8327	0.3118	0.6299	0.074(4)
H6A3	0.8448	0.3870	0.7273	0.074(4)
H6B1	0.8581	0.2639	0.8767	0.090(5)
H6B2	0.8059	0.1916	0.7715	0.090(5)
H6B3	0.6830	0.2060	0.8572	0.090(5)
H7	0.3822	0.2861	0.3811	0.068(7)
H9A	-0.0752	0.4074	0.1117	0.076(6)
H9B	0.0580	0.3959	0.0327	0.076(6)
H9C	0.0875	0.4730	0.1295	0.076(6)
H9D	0.1221	0.4435	0.0709	0.076(6)
H9E	-0.0111	0.4550	0.1499	0.076(6)
H9F	-0.0407	0.3778	0.0531	0.076(6)

Table 5. Site occupancy factors that deviate from unity for nitroxide **7**

Atom	sof	Atom	sof	Atom	sof
H2A1	0.93(3)	H2A2	0.93(3)	H2A3	0.93(3)
H2A4	0.07(3)	H2A5	0.07(3)	H2A6	0.07(3)
H2B1	0.86(2)	H2B2	0.86(2)	H2B3	0.86(2)
H2B4	0.14(2)	H2B5	0.14(2)	H2B6	0.14(2)
H9A	0.75(3)	H9B	0.75(3)	H9C	0.75(3)
H9D	0.25(3)	H9E	0.25(3)	H9F	0.25(3)

Table 6. Bond lengths (Å), valence and torsion angles (°) for nitroxide **7**

O1-N1	1.2736(19)	N1-C6	1.497(2)	N1-C2	1.502(2)
C2-C2B	1.512(3)	C2-C2A	1.533(3)	C2-C3	1.543(3)
C3-C4	1.492(3)	C4-C7	1.346(3)	C4-C5	1.485(3)
C5-C6	1.523(3)	C6-C6A	1.530(3)	C6-C6B	1.532(3)
C7-C8	1.471(3)	C8-O8	1.202(2)	C8-O9	1.341(2)
O9-C9	1.439(2)				
O1-N1-C6	116.12(14)	O1-N1-C2	116.14(15)	C6-N1-C2	124.00(15)
N1-C2-C2B	107.93(16)	N1-C2-C2A	109.53(16)	C2B-C2-C2A	110.00(18)
N1-C2-C3	109.67(15)	C2B-C2-C3	109.91(17)	C2A-C2-C3	109.78(17)
C4-C3-C2	112.66(15)	C7-C4-C5	121.04(17)	C7-C4-C3	126.24(17)
C5-C4-C3	112.72(16)	C4-C5-C6	111.66(16)	N1-C6-C5	109.74(14)
N1-C6-C6A	109.87(16)	C5-C6-C6A	110.93(17)	N1-C6-C6B	107.34(16)
C5-C6-C6B	109.08(17)	C6A-C6-C6B	109.81(17)	C4-C7-C8	127.63(18)
O8-C8-O9	122.87(17)	O8-C8-C7	128.00(18)	O9-C8-C7	109.12(16)
C8-O9-C9	117.14(16)				
O1-N1-C2-C2B	-47.4(2)	C6-N1-C2-C2B	155.33(17)	O1-N1-C2-C2A	72.4(2)
C6-N1-C2-C2A	-84.9(2)	O1-N1-C2-C3	-167.09(16)	C6-N1-C2-C3	35.6(2)
N1-C2-C3-C4	-42.5(2)	C2B-C2-C3-C4	-160.97(17)	C2A-C2-C3-C4	77.9(2)
C2-C3-C4-C7	-121.0(2)	C2-C3-C4-C5	58.3(2)	C7-C4-C5-C6	118.40(19)
C3-C4-C5-C6	-60.9(2)	O1-N1-C6-C5	164.37(17)	C2-N1-C6-C5	-38.3(2)
O1-N1-C6-C6A	-73.4(2)	C2-N1-C6-C6A	83.9(2)	O1-N1-C6-C6B	45.9(2)
C2-N1-C6-C6B	-156.75(17)	C4-C5-C6-N1	47.6(2)	C4-C5-C6-C6A	-74.0(2)
C4-C5-C6-C6B	164.92(17)	C5-C4-C7-C8	-177.88(17)	C3-C4-C7-C8	1.4(3)
C4-C7-C8-O8	8.9(3)	C4-C7-C8-O9	-171.64(18)	O8-C8-O9-C9	2.9(3)
C7-C8-O9-C9	-176.56(17)				

nitroxide **5** Coordinates in Angstroms

Atom	X	Y	Z
O	-0.05384	-0.31617	0.087824
N	0.02212	0.087926	1.30304
C	1.352987	0.010823	1.982535
C	-1.22598	0.605345	1.945856
C	-1.43167	2.071499	1.510083
H	-1.41982	2.130241	0.418717
H	-2.39556	2.445275	1.869941
H	-0.64925	2.73095	1.897381
C	-2.40765	-0.24715	1.458464
H	-2.25757	-1.30048	1.712478
H	-3.32975	0.097826	1.936207
H	-2.51481	-0.17186	0.376331
C	2.439798	0.358245	0.95359
H	2.279526	1.359081	0.542272
H	3.421815	0.333586	1.43585
H	2.428183	-0.35299	0.127656
C	1.563217	-1.43171	2.489343
H	0.854604	-1.69936	3.278799
H	1.430978	-2.13036	1.659237
H	2.574795	-1.55218	2.889998
C	-1.10155	0.482661	3.477098
H	-1.93818	0.985169	3.971125
H	-1.16643	-0.57689	3.761098
C	1.396989	1.028669	3.138894
H	2.301139	0.888595	3.738454
H	1.456075	2.044568	2.724186
C	0.194961	1.011106	4.069949
O	0.266474	1.397	5.219966

nitroxide **6** Coordinates in Angstroms

Atom	X	Y	Z
O	-0.05328	-0.35322	0.094177
N	0.026856	0.082646	1.298472
C	1.351455	0.002294	1.985076
C	-1.21281	0.612137	1.952013
C	-1.40222	2.093501	1.561294
H	-1.35805	2.19144	0.472942
H	-2.38052	2.447421	1.902675
H	-0.64643	2.740235	2.01039
C	-2.40627	-0.2071	1.436614
H	-2.2725	-1.27089	1.65348
H	-3.32219	0.136619	1.927123
H	-2.51494	-0.09445	0.357768
C	2.443515	0.344256	0.958837
H	2.295233	1.350063	0.55531
H	3.426681	0.302866	1.438131
H	2.42046	-0.36072	0.127639
C	1.564542	-1.4387	2.496012
H	0.842609	-1.71561	3.269098
H	1.454986	-2.13719	1.662189
H	2.570248	-1.55157	2.914584
C	-1.08294	0.417999	3.47508
H	-1.93545	0.890221	3.973222
H	-1.15159	-0.65461	3.685625
C	1.375393	1.041181	3.120808
H	2.33123	0.954217	3.651896
H	1.356498	2.038686	2.669554
C	0.199883	0.967806	4.116698
H	0.468306	0.305492	4.95335
O	-0.10276	2.27021	4.630562
H	0.700845	2.622065	5.037047

nitroxide **7** Coordinates in Angstroms

Atom	X	Y	Z
O	-0.02347	-0.43094	0.091969
N	0.030316	0.036384	1.285756
C	1.352772	0.030769	1.978097
C	-1.21828	0.584405	1.894119
C	-1.3967	2.053829	1.45177
H	-1.33949	2.11531	0.361695
H	-2.37575	2.427449	1.769267
H	-0.63513	2.714627	1.873858
C	-2.40376	-0.24299	1.37332
H	-2.27314	-1.30214	1.611788
H	-3.32767	0.109015	1.842499
H	-2.49399	-0.14979	0.291117
C	2.433553	0.43758	0.964915
H	2.241906	1.440914	0.572601
H	3.414964	0.435617	1.449169
H	2.44719	-0.258	0.12569
C	1.628828	-1.39549	2.495047
H	0.918334	-1.69151	3.272284
H	1.54861	-2.10286	1.665758
H	2.637538	-1.46245	2.915535
C	-1.15207	0.446452	3.431054
H	-1.99094	0.992079	3.868666
H	-1.32862	-0.60426	3.694986
C	1.312741	1.055878	3.129822
H	2.259004	1.010713	3.677717
H	1.262008	2.059979	2.68785
C	0.148447	0.875673	4.075824
C	0.33862	1.078688	5.394786
H	1.327967	1.361793	5.742776
C	-0.6173	0.995769	6.515906
O	-0.32471	1.297108	7.657912
O	-1.85217	0.540405	6.174089
C	-2.78506	0.450142	7.263044
H	-3.70686	0.062849	6.829
H	-2.41079	-0.22546	8.035798
H	-2.95435	1.43279	7.710051

nitroxide **8** Coordinates in Angstroms

Atom	X	Y	Z
O	-0.00145	0.080137	-0.0047
N	0.002214	0.030535	1.277361
C	1.321498	0.00066	1.974462
C	-1.30858	0.029574	1.992211
C	-1.80765	1.484238	2.134455
H	-1.80661	1.965732	1.152993
H	-2.82984	1.496658	2.526586
H	-1.18425	2.076507	2.809467
C	-2.31327	-0.76603	1.143662
H	-1.95408	-1.78411	0.968884
H	-3.27222	-0.82013	1.668188
H	-2.46177	-0.28926	0.174855
C	2.281052	0.946564	1.237033
H	1.894223	1.969995	1.235191
H	3.256841	0.944063	1.732462
H	2.404682	0.629787	0.201426
C	1.870482	-1.43992	1.932739
H	1.248425	-2.13055	2.509386
H	1.901479	-1.78593	0.896426
H	2.884923	-1.47563	2.34312
C	-1.15535	-0.66474	3.362549
H	-2.07784	-0.52761	3.930069
H	-1.08034	-1.74757	3.197255
C	1.123356	0.49354	3.422579
H	2.076791	0.426237	3.955705
H	0.868599	1.561257	3.384186
C	0.042092	-0.23821	4.184254
C	0.217699	-0.47828	5.499344
H	1.136867	-0.14846	5.974502
C	-0.67691	-1.13881	6.464393
O	-0.42838	-1.22893	7.65179
O	-1.81882	-1.66561	5.938129
H	-2.28743	-2.05652	6.694906