residues in the loops were also identified, although there is little interresidue contact in the loop structure to permit specific assignments. In this approach, the correct identification of the H2′,2″ geminal proton pair is critical. This can be easily achieved in our case, for the 31-mer DNA sequence, by observing well-resolved strong H2′–H2″[10] and moderate H3′–H2′ and H3′–H2″ cross peaks on the same spectral plane (right panel of Figure 1). A major complication in data analysis arises from the presence of the so-called "cross-talk" cross peaks[2c] due to the resolution limitation of the 3D data set (Figure 1a,b). These ambiguities can be removed in most cases by comparing the relative intensities of these cross peaks and the spectral patterns in adjacent planes.

The strategy to assign DNA resonances through 3D NOE–*J* connectivities shown herein uses H1′ planes along the ω3 dimension in the NOESY–TOCSY spectrum and H2′,2″ to base proton connectivities observed on these H1′ planes. The assignment is assisted by spectral regions of H2′–H2″ and H3′–H2′,2″ on the ω3 = H1′ planes. The NOE connectivities observed on the H1′ planes exhibit enhanced clarity and a characteristic correlation pattern. By contrast, the H2′,2″ to base proton NOE cross peaks of a large DNA molecule in a 2D data set are often too crowded to be of primary use, and the cross peaks in H2′–H2″ and H3′–H2′,2″ regions are extensively overlapped. The H5 planes of the cytidine residues provide well-resolved sequential connectivities of the H6 with the H2′,2″ protons for the intra- and interresidues,[8] permitting verification of the assignments made at the corresponding H1′ planes.[10] Other spectral regions are helpful in verifying the assignments. 3D proton–proton NMR spectroscopy presents great potential in the studies of increasingly larger DNA molecules as illustrated by its application to the proton assignment of this 31-mer DNA triplex.[10] The assignment strategy used in this work should be applicable to the interpretation of 3D TOCSY–NOESY data and could also be extended to the resonance assignments of ribonucleotide sequences.

Acknowledgment. This work was supported in part by NIH Grant GM34504 to D.P.

Spectroscopic Characterization of the Peroxide Intermediate in the Reduction of Dioxygen Catalyzed by the Multicopper Oxidases

James L. Cole,† David P. Ballou,‡ and Edward I. Solomon*,†

Department of Chemistry, Stanford University Stanford, California 94305
Department of Biological Chemistry The University of Michigan, Ann Arbor, Michigan 48109
Received June 14, 1991

The multicopper oxidases (laccase, ascorbate oxidase, and ceruloplasmin)[1] catalyze the four-electron reduction of dioxygen to water. These enzymes contain type 1 (blue), type 2 (normal), and type 3 (coupled binuclear) copper centers. We have previously demonstrated that N_3^- binds to laccase and ascorbate oxidase as a bridging ligand between the type 2 site and one of the type 3 coppers, thereby defining a novel trinuclear copper cluster.[2] A recent X-ray structure of ascorbate oxidase supports this cluster model.[3] The reduced trinuclear site in a type 1 Hg^{2+}-substituted

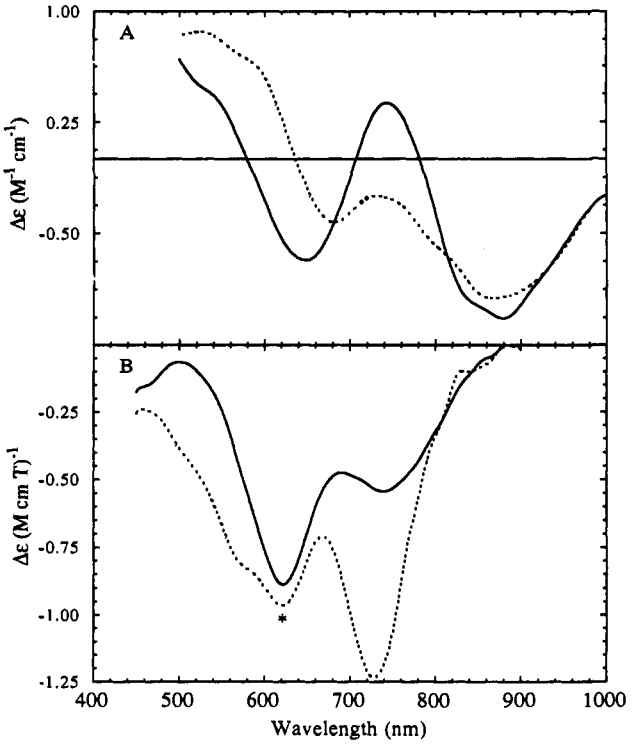


Figure 1. Ligand-field spectra of the T1Hg laccase intermediate. (A) Room temperature CD: (—), oxygen intermediate; (···), fully oxidized enzyme. [T1Hg] = 0.419 mM, [O_2] = 0.45 mM in 100 mM potassium phosphate, pH 7.4. The spectrum of the intermediate was recorded 1.5 min after oxygenation. At pH 7.4, $t_{1/2}$ for decay of the intermediate is ~1 h. Conditions: scan speed, 200 nm/min; time constant, 0.25 s. (B) MCD at 4.2 K and 7 T: (—), oxygen intermediate; (···), fully oxidized enzyme. [T1Hg] = 0.476 mM. The sample was reduced in 200 mM potassium phosphate, pH 7.4, and reoxidation was initiated by addition of an equal volume of O_2-saturated glycerol. The intermediate sample was frozen in liquid nitrogen after 3 min. The negative band at 614 nm (*) is associated with a ≤5% contaminant of native laccase.

laccase derivative (T1Hg) is reoxidized by dioxygen,[4] indicating that the trinuclear center represents the minimal structural unit capable of reducing dioxygen. In the course of these studies, we detected an intermediate in the reaction of T1Hg with dioxygen. Here we provide evidence that two electrons are transferred from the type 3 coppers to dioxygen, generating a peroxide intermediate. Stopped-flow data indicate that this species represents a precursor to the intermediate observed[5] upon reoxidation of native laccase. The absorption spectrum of the laccase peroxide intermediate is strikingly different from that of oxyhemocyanin, and it is suggested that the laccase intermediate contains a μ-1,1 hydroperoxide that bridges one of the oxidized type 3 coppers and the reduced type 2 copper.

For MCD and CD studies, T1Hg laccase[6] was reduced by anaerobic dialysis against 5 mM sodium dithionite in 100 mM

† Stanford University.
‡ The University of Michigan.

(1) (a) Malkin, R.; Malmström, B. G. *Adv. Enzymol.* **1970**, *33*, 177. (b) Malmström, B. G.; Andréasson, L.-E.; Reinhammar, B. In *The Enzymes*; Boyer, P. D., Ed.; Academic: New York, 1975; Vol. XII. (c) Fee, J. A. *Struct. Bonding (Berlin)* **1975**, *23*, 1–60. (d) Solomon, E. I. In *Copper Proteins*; Spiro, T. G., Ed.; Wiley-Interscience; New York, 1981; pp 41–108. (e) Solomon, E. I.; Penfield, K. W.; Wilcox, D. E. *Struct. Bonding (Berlin)* **1983**, *53*, 1.

(2) (a) Allendorf, M. D.; Spira, D. J.; Solomon, E. I. *Proc. Natl. Acad. Sci. U.S.A.* **1985**, *82*, 3063–3067. (b) Spira-Solomon, D. J.; Allendorf, M. D.; Solomon, E. I. *J. Am. Chem. Soc.* **1986**, *108*, 5318–5328. (c) Cole, J. L.; Clark, P. A.; Solomon, E. I. *J. Am. Chem. Soc.* **1990**, *112*, 9534–9548. (d) Cole, J. L.; Avigliano, L.; Morpurgo, L.; Solomon, E. I. *J. Am. Chem. Soc.*, in press.

(3) (a) Messerschmidt, A.; Rossi, A.; Ladenstein, R.; Huber, R.; Bolognesi, M.; Gatti, G.; Marchesini, A.; Petruzzelli, R.; Finazzi-Agrò, A. *J. Mol. Biol.* **1989**, *206*, 513–529. (b) Messerschmidt, A.; Huber, R. *Eur. J. Biochem.* **1990**, *187*, 341–352.

(4) Cole, J. L.; Tan, G. O.; Yang, E. K.; Hodgson, K. O.; Solomon, E. I. *J. Am. Chem. Soc.* **1990**, *112*, 2243–2249.

(5) (a) Andréasson, L.-E.; Brändén, R.; Reinhammar, B. *Biochim. Biophys. Acta* **1976**, *438*, 370–379. (b) Andréasson, L.-E.; Reinhammar, B. *Biochim. Biophys. Acta* **1979**, *568*, 145–156. (c) Reinhammar, B. *Chem. Scr.* **1985**, *25*, 172–176.

(6) *Rhus vernificera* laccase was isolated[7] from the acetone powder (Saito and Co., Osaka, Japan) to a purity ratio A_{280}/A_{614} of 14.5–15.5, as modified in ref 8. The T1Hg derivative of laccase was prepared according to published procedures[9] as modified in ref 4 using a hollow fiber dialysis unit (Spectrum Medical Instruments, Los Angeles).

(7) Reinhammar, B. *Biochim. Biophys. Acta* **1970**, *205*, 35–47.

(8) Spira-Solomon, D. J.; Solomon, E. I. *J. Am. Chem. Soc.* **1987**, *109*, 6421–6432.

(9) Morie-Bebel, M. M.; Morris, M. C.; Menzie, J. L.; McMillin, D. R. *J. Am. Chem. Soc.* **1984**, *106*, 3677–3678.

0002-7863/91/1513-8544$02.50/0

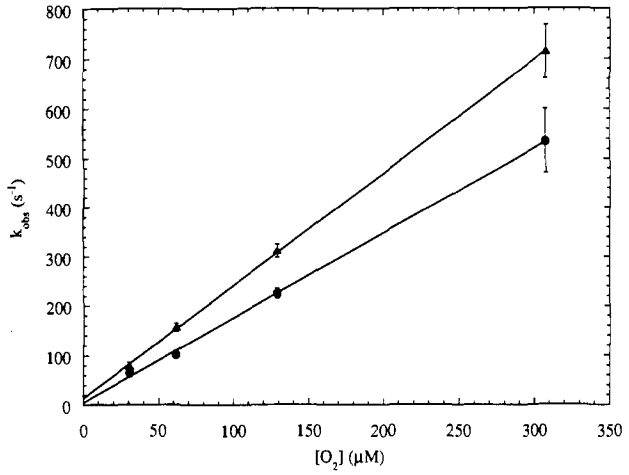


Figure 2. The dependence on dioxygen concentration of the oxidation of T1Hg and native laccase. The oxidation of T1Hg laccase (▲) was monitored at 340 and 470 nm, and the oxidation of native laccase (●) was monitored at 614 and 360 nm. Formation of the intermediates was pseudo first order. The error bars indicate 1 standard deviation. The final reaction solution contained either 10 μM (T1Hg) or 5 μM (native) enzyme in 100 mM potassium phosphate, pH 7.4, and variable [O_2] at 3 °C. Path length = 2 cm. Defined [O_2] was achieved by equilibrating buffer with an appropriate O_2/N_2 gas mixture.

potassium phosphate, pH 7.4. Low-temperature MCD[2b] and anaerobic stopped-flow[10] measurements were performed as previously described.

CD spectra in the ligand-field region (500–1000 nm) allow us to assign the oxidation state of the type 3 coppers as only Cu^{2+} can have d → d transitions. The T1Hg oxygen intermediate and oxidized enzyme exhibit similar negative CD bands at ~900 nm (Figure 1A), assigned as a d → d transition of one of the type 3 coppers (type 3_β).[2c] The intermediate also exhibits a broad positive feature at 500–550 nm and bands at (−) 645 and (+) 745 nm (Figure 1A, solid). The 500–550- and 645-nm features correspond to analogous d → d transitions in the oxidized enzyme spectrum at 500–550 and 680 nm associated with the type 3_α Cu^{2+}.[2c] Thus, both type 3 coppers are oxidized in the intermediate, and the differences between the spectra of the intermediate and oxidized enzyme likely reflect distortion of the type 3_α Cu^{2+} by the bound oxygen species.

The low-temperature MCD spectrum in the ligand-field region defines the oxidation state of the type 2 copper. Oxidized T1Hg contains a band at 730 nm (Figure 1B, dashed), which has been assigned as a d → d transition of the paramagnetic type 2 Cu^{2+}.[2c] This feature is eliminated in the MCD spectrum of the T1Hg oxygen intermediate (Figure 1B, solid), indicating that the type 2 copper is reduced.[11] Thus, upon oxygenation of reduced T1Hg, two electrons are transferred from the type 3 site to dioxygen, generating a peroxide-level intermediate.

Figure 2 shows that the formation kinetics of the intermediate in T1Hg exhibits a linear dependence on [O_2] with a second-order rate constant of 2.2×10^6 M^{-1} s^{-1}. The y intercept is close to 0, indicating that formation of the intermediate is essentially irreversible. The rate constant for native laccase is 1.7×10^6 M^{-1} s^{-1} (Figure 2),[12] indicating that the absence of the type 1 Cu^{1+} does not substantially affect the kinetics of the reaction of the reduced trinuclear site with dioxygen. The rate-limiting step is then the oxidation of the type 3 coppers to form the bound peroxide intermediate. In native laccase oxidation of the type 1 and type

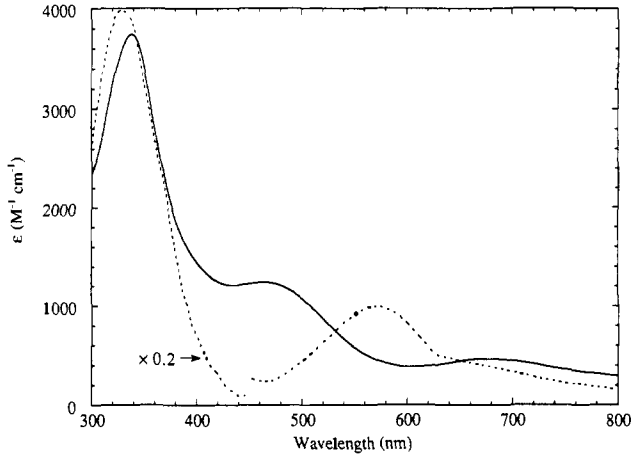
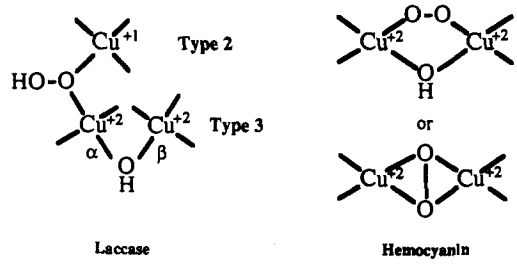


Figure 3. Comparison of the absorption spectra of the peroxide intermediate in T1Hg laccase and oxyhemocyanin: (—), T1Hg laccase; (···), oxyhemocyanin. The T1Hg laccase spectrum was recorded 8 min after reaction of reduced enzyme with 1 equiv of dioxygen. The spectrum of fully oxidized enzyme has been subtracted. [T1Hg] = 0.632 mM. The oxyhemocyanin spectrum is from ref 13a. Note that the amplitude scale for oxyhemocyanin is reduced 5-fold in the region from 300 to 450 nm.

Scheme I



3 coppers is observed to occur simultaneously. Thus, in native laccase, electron transfer from the type 1 copper to the trinuclear site must occur rapidly (k > 1000 s^{-1}) and the native laccase intermediate represents at least a one electron more reduced species than the T1Hg peroxide intermediate. Note that the decay of the T1Hg intermediate correlates with the formation of the type 2 EPR signal associated with the fully oxidized derivative.[4]

The absorption spectrum of the T1Hg oxygen intermediate (Figure 3, solid) contains bands at 340 and 470 nm assigned as O_2^{2-} → type 3 Cu^{2+} CT and a weak band at 670 nm assigned as type 3 d → d. The absorption spectrum of oxyhemocyanin, which reversibly binds dioxygen, is included in Figure 3. In oxyhemocyanin, peroxide bridges a binuclear copper site in either an end-on cis μ-1,2 or a side-on μ-η^2:η^2 geometry.[13] Since the spectra are quite different, peroxide must bind differently to T1Hg. In particular, the O_2^{2-} → Cu^{2+} CT intensity in laccase is ~5-fold weaker than in oxyhemocyanin and ~3-fold weaker than in a trans μ-1,2 bridging peroxide model complex,[14] indicating that the peroxide likely binds to only one laccase type 3 Cu^{2+}.[15] Previous ligand binding studies of type 2 depleted laccase (T2D) demonstrated that, in contrast to hemocyanin, exogenous ligands do not bridge the laccase type 3 site.[8] The T1Hg intermediate spectrum is also not consistent with a terminal peroxide binding mode, since a terminal model complex shows no O_2^{2-} → Cu^{2+} CT at energies above 500 nm.[16] However, in Cu^{2+} hydroperoxide complexes,

(10) Beaty, N. B.; Ballou, D. P. *J. Biol. Chem.* **1981**, *256*, 4611–4618.
(11) EPR measurements indicate ~20% oxidized enzyme to be present in samples of the T1Hg oxygen intermediate. Thus, the weak 730-nm MCD intensity in the spectrum of the intermediate is associated with this fraction of oxidized T1Hg derivative.
(12) The rate of reaction of native laccase is about 3-fold lower than previously reported[5a] because the present experiments were performed at 3 °C whereas the previous work was performed at 25 °C. We obtain comparable rates at 25 °C.

(13) (a) Eickman, N. C.; Himmelwright, R. S.; Solomon, E. I. *Proc. Natl. Acad. Sci. U.S.A.* **1979**, *76*, 2094–2098. (b) Ross, P. K.; Solomon, E. I. *J. Am. Chem. Soc.* **1991**, *113*, 3246–3259. (c) Kitajima, N.; Fujisawa, K.; Moro-oka, Y. *J. Am. Chem. Soc.* **1989**, *111*, 8975–8976.
(14) Jacobson, R. R.; Tyeklar, Z.; Farooq, A.; Karlin, K. D.; Liu, S.; Zubieta, J. *J. Am. Chem. Soc.* **1988**, *110*, 3690–3692.
(15) Further evidence against a type 3 bridging geometry in laccase is the absence of a perturbation of the type 3_β d → d feature in the intermediate (Figure 1A), and spectroscopic data which indicate that the bound peroxide in the intermediate does not prevent azide binding to the type 3_β copper (Cole, J. L.; Solomon, E. I.; unpublished results).

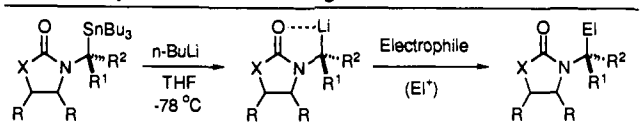
$HO_2^{2-} \rightarrow Cu^{2+}$ CT is observed at higher energies (340–500 nm)[17] due to the strong bonding interaction of the proton with the peroxide π^* orbital. The fact that the reduced type 3 site in T2D does not react with dioxygen[4,18] indicates a major role for the type 2 site in catalysis, and we propose that a μ-1,1 hydroperoxide bridges one of the oxidized type 3 and the reduced type 2 coppers in the laccase oxygen intermediate (Scheme I, left). A type 2–type 3 bridging mode has been defined by low-temperature MCD studies of N_3^- binding to the fully oxidized trinuclear copper site.[2]

In contrast to hemocyanin (Scheme I, right), protonation of the bound peroxide in laccase is expected to lead to irreversible binding and promote further reduction to water. Furthermore, we have observed that exogenous ligands bridge mixed valent (Cu^{2+}–Cu^{1+}) binuclear sites with an unusually high affinity,[19] suggesting that bridging to the reduced type 2 copper stabilizes the oxygen intermediate in T1Hg laccase. An attractive feature of this model is that μ-1,1 hydroperoxide cobalt complexes[20] have been demonstrated to be most reactive in further reduction to water.[21]

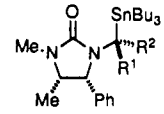
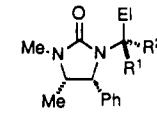
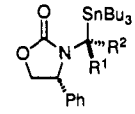
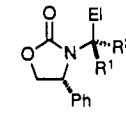
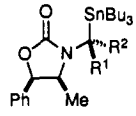
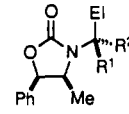
Acknowledgment. This research was supported by grants from the National Institutes of Health (E.I.S., Grant AM31450; D.P.B., GM20877).

(16) Pate, J. E.; Cruse, R. W.; Karlin, K. D.; Solomon, E. I. *J. Am. Chem. Soc.* **1987**, *109*, 2624–2630.
(17) (a) Ghosh, P.; Tyeklar, Z.; Karlin, K. D.; Jacobson, R. R.; Zubieta, J. *J. Am. Chem. Soc.* **1987**, *109*, 6889–6891. (b) Karlin, K. D.; Ghosh, P.; Cruse, R. W.; Farooq, A.; Gultneh, Y.; Jacobson, R. R.; Blackburn, N. J.; Strange, R. W.; Zubieta, J. *J. Am. Chem. Soc.* **1988**, *110*, 6769–6780. (c) Sorrell, T. N.; Vankai, V. A. *Inorg. Chem.* **1990**, *29*, 1687–1692.
(18) (a) LuBien, C. D.; Winkler, M. E.; Thamann, T. J.; Scott, R. A.; Co, M. S.; Hodgson, K. O.; Solomon, E. I. *J. Am. Chem. Soc.* **1981**, *103*, 7014–7016. (b) Kau, L.-S.; Spira-Solomon, D. J.; Penner-Hahn, J. E.; Hodgson, K. O.; Solomon, E. I. *J. Am. Chem. Soc.* **1987**, *109*, 6433–6442.
(19) Westmoreland, T. D.; Wilcox, D. E.; Baldwin, M. J.; Mims, W. B.; Solomon, E. I. *J. Am. Chem. Soc.* **1989**, *111*, 6106–6123.
(20) (a) Mori, M.; Weil, M. A. *J. Am. Chem. Soc.* **1967**, *89*, 6769–6780. (b) Thewalt, U.; Marsh, R. A. *J. Am. Chem. Soc.* **1967**, *89*, 6364–6365. (c) Davies, R.; Sykes, A. G. *J. Chem. Soc. A* **1968**, 2840–2847.
(21) Davies, R.; Stevenson, M. G.; Sykes, A. G. *J. Chem. Soc. A* **1970**, 1261–1266.

Table I. Reactions of Chiral Nitrogen-Substituted Carbanions Generated by Tin–Lithium Exchange



a: R^1=Me, R^2=H b: R^1=H, R^2=Me c: R^1=Et, R^2=H d: R^1=H, R^2=Et e: R^1=iPr, R^2=H

Entry	Stannane	Electrophile	Product(s)	El	Ratio[a]	Yield (%)[b]
						
1	**1a**	DCl/D_2O	**5a**	D	–	63
2	**1c**	DCl/D_2O	**5c**	D	–	72
3	**1e**	DCl/D_2O	**5e**	D	–	82
4	**1a**	Bu_3SnCl	**1a**	$SnBu_3$	–	46
5	**1b**	Bu_3SnCl	**1a** + **1b**	$SnBu_3$	1:2.4[c]	44
6	**1a**	Bu_3SnCl/TMEDA	**1a**	$SnBu_3$	–	48
7	**1b**	Bu_3SnCl/TMEDA	**1a**	$SnBu_3$	–	48
8	**1c**	Bu_3SnCl	**1c**	$SnBu_3$	–	62
9	**1e**	Bu_3SnCl	**1e**	$SnBu_3$	–	67
10	**1c**	cyclohexanone	**6c**	$C(OH)(CH_2)_5$	–	78
11	**1c**	PhCHO	**7c**	CH(OH)Ph	1.7:1[d]	88
12	**1c**	iPrCHO	**8c**	CH(OH)iPr	1.5:1[d]	91
13	**1c**	$ClCO_2Et$	**9c** + **9d**	CO_2Et	12:1	83
						
14	**2a**	PhCHO	**10a**	CH(OH)Ph	1:1[d]	69
15	**2b**	PhCHO	**10a**	CH(OH)Ph	1:1[d]	76
						
16	**3a**	Bu_3SnCl	**3b**	$SnBu_3$	–	52
17	**3b**	Bu_3SnCl	**3b**	$SnBu_3$	–	76
18	**3a**	PhCHO	**11b**	CH(OH)Ph	1:1[d]	50
19	**3b**	PhCHO	**11b**	CH(OH)Ph	1:1[d]	82
20	**3a**	cyclohexanone	**12b**	$C(OH)(CH_2)_5$	–	39
21	**3b**	cyclohexanone	**12b**	$C(OH)(CH_2)_5$	–	32

[a] A dash (–) indicates that only one product was detected by 300-MHz ^1H NMR. [b] Yields of isolated, purified materials. [c] Ratio after 15 min at −78 °C. See Figure 1 for ratios at other times. [d] Mixture of erythro and threo isomers, which were not assigned.

Stereochemical Studies on Chiral, Nonconjugated, Nitrogen-Substituted Carbanions Generated by Tin–Lithium Exchange

William H. Pearson* and Aline C. Lindbeck

Department of Chemistry, The University of Michigan Ann Arbor, Michigan 48109-1055

Received June 27, 1991

Nitrogen-substituted carbanions have been widely studied and have become useful intermediates for the synthesis of amines and their derivatives.[1] Chiral, conjugated versions of these carbanions have seen considerable research activity.[2-5] While several stereochemical studies have been reported on racemic, nonconjugated anions,[6-11] Walborsky[12] and Gawley[4c] have published the only examples of chiral, *nonracemic*, nonconjugated, nitrogen-substituted carbanions. Both cases involve cyclic systems, where small-ring strain[12,13] or conformational considerations[4c] affect the configuration of the carbanion. The configurational stability of acyclic nitrogen-substituted carbanions has not been studied, and there have been no reports on the generation of chiral, nonracemic,

(1) (a) Beak, P.; Zajdel, W. J.; Reitz, D. B. *Chem. Rev.* **1984**, *84*, 471–523. (b) Beak, P.; Reitz, D. B. *Chem. Rev.* **1978**, *78*, 275.
(2) (a) Highsmith, T. K.; Meyers, A. I. In *Advances in Heterocyclic Natural Product Synthesis*; Pearson, W. H., Ed.; JAI: Greenwich, 1990; Vol. 1, pp 95–135. (b) Meyers, A. I. *Aldrichimica Acta* **1985**, *18*, 59.
(3) Roder, H.; Helmchen, G.; Peter, E.-M.; Peters, K.; von Schnering, H.-G. *Angew. Chem., Int. Ed. Engl.* **1984**, *23*, 898.
(4) (a) Gawley, R. E.; Rein, K.; Chemburkar, S. *J. Org. Chem.* **1989**, *54*, 3002–3004. (b) Rein, K.; Goicoechea-Pappas, M.; Anklekar, T. V.; Hart, G. C.; Smith, G. A.; Gawley, R. E. *J. Am. Chem. Soc.* **1989**, *111*, 2211–2217. (c) Gawley, R. E.; Hart, G. C.; Bartolotti, L. J. *J. Org. Chem.* **1989**, *54*, 175–181.
(5) Häner, R.; Olano, B.; Seebach, D. *Helv. Chim. Acta* **1987**, *70*, 1676–1693.
(6) (a) Seebach, D.; Wykypiel, W.; Lubosch, D.; Kalinowski, H.-O. *Helv. Chim. Acta* **1978**, *61*, 3100–3102. (b) Renger, B.; Kalinowski, H.-O.; Seebach, D. *Chem. Ber.* **1977**, *110*, 1866–1878. (c) Seebach, D.; Enders, D. *Angew. Chem., Int. Ed. Engl.* **1975**, *14*, 15.
(7) Fraser, R. R.; Grindley, T. B.; Passannanti, S. *Can. J. Chem.* **1975**, *53*, 2473–2480.
(8) Lyle, R. E.; Saavedra, J. E.; Lyle, G. G.; Fribush, H. M.; Marshall, J. L.; Lijinsky, W.; Singer, G. M. *Tetrahedron Lett.* **1976**, 4431–4434.
(9) (a) Beak, P.; Lee, W. K. *J. Org. Chem.* **1990**, *55*, 2578–2580. (b) Beak, P.; Zajdel, W. J. *J. Am. Chem. Soc.* **1984**, *106*, 1010.
(10) (a) Meyers, A. I.; Edwards, P. D.; Rieker, W. F.; Bailey, T. R. *J. Am. Chem. Soc.* **1984**, *106*, 3270–3276. (b) Shawe, T. T.; Meyers, A. I. *J. Org. Chem.* **1991**, *56*, 2751–2755.
(11) Sanner, M. A. *Tetrahedron Lett.* **1989**, *30*, 1909–1912.
(12) (a) Periasamy, M. P.; Walborsky, H. M. *J. Am. Chem. Soc.* **1977**, *99*, 2631. (b) Walborsky, H. M.; Periasamy, M. P. *J. Am. Chem. Soc.* **1974**, *96*, 3711.
(13) Seebach has studied a chiral, nonracemic, configurationally stable 2-lithioaziridine.[5] Even though the anion is substituted by a thioester, the small ring prevents epimerization.

0002-7863/91/1513-8546$02.50/0