

# Aggregation and C–N Rotation of the Lithium Salt of *N,N*-Dimethyldiphenylacetamide

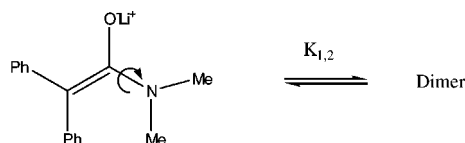
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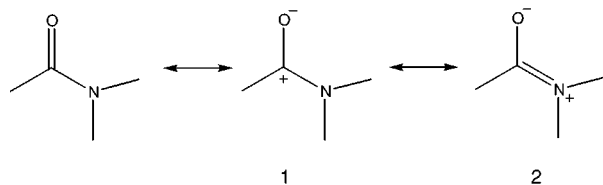
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## ABSTRACT

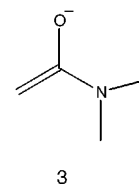


Two methyl <sup>1</sup>H NMR signals for the Li salt of *N,N*-dimethyldiphenylacetamide are observed at low temperature and assigned to the monomer and dimer. From line shape analysis, the dimerization constant ( $K_{1,2}$ ) is  $40 \pm 10 \text{ M}^{-1}$  at 200 K ( $\Delta G^\circ = 1.5 \text{ kcal mol}^{-1}$ ,  $\Delta H^\circ = 0.8 \text{ kcal mol}^{-1}$ ,  $\Delta S^\circ = 12 \text{ eu}$ ) and the activation parameters are  $\Delta H^\ddagger = 5.5 \text{ kcal mol}^{-1}$  and  $\Delta S^\ddagger = -18 \text{ eu}$ . The C–N bond rotation is too fast to observe on the NMR time scale, indicating a rotation barrier of less than  $10 \text{ kcal mol}^{-1}$ .

The magnitude and origin of the hindered amide C–N rotation has long been of interest. Experimentally, the activation energy is 17–20 kcal/mol.<sup>1</sup> This relatively high rotation barrier has been associated with conjugation of the amide nitrogen with the carbonyl group, but the relative roles of resonance structures **1** and **2** have recently been the subject of considerable controversy.<sup>2</sup> In all of these interpretations,



the important resonance structure **3** in the corresponding amide enolate ion is expected to reduce the importance of amide conjugation, and accordingly, the barrier to C–N bond rotation should substantially decrease. As part of our recent studies of the aggregation and basicities of several lithium



salts of amide enolates in THF solution,<sup>3</sup> we have studied the variable temperature NMR of the lithium enolate of *N,N*-dimethyldiphenylacetamide.

*N,N*-Dimethyldiphenylacetamide<sup>4</sup> (7.3 mg) and LiTMS (3.4 mg) were dissolved in THF-*d*<sub>8</sub> (0.3 g), and the solution was transferred to a Teflon valve-sealed tube (J. Young roto-

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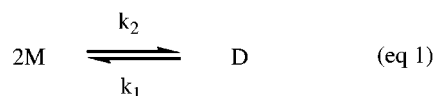
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(4) The compound is used as in ref 3.

tite from WILMAD). A more dilute solution was prepared by adding 0.6 g of THF- $d_8$  to the above solution. The temperature was calibrated using methanol chemical shifts.<sup>5</sup> All manipulations were carried out in a glovebox under an argon atmosphere. The  $^1\text{H}$  NMR spectra were taken at various temperatures using a Bruker AMX-300 MHz.

The line shape analysis was made using a standard diagonalization program in the Mathematica suite to solve the  $2 \times 2$  matrix in eq 2. The natural line width (1.5 Hz) was obtained from the rapid exchange peak at room temperature.



At equilibrium,  $k_2[\text{M}]^2 = k_1[\text{D}]$

$$\begin{bmatrix} i2\pi(\nu - \nu_M) - 1/T - k_2[\text{M}] & k_2[\text{M}] \\ k_1 & i2\pi(\nu - \nu_D) - 1/T - k_1 \end{bmatrix} \begin{bmatrix} e^{\text{M}} \\ e^{\text{D}} \end{bmatrix} = i\text{C} \begin{bmatrix} 1 \\ 1 \end{bmatrix} \quad (\text{eq 2})$$

in which  $\nu$  = horizontal axis of spectrum;  $\nu_M$  and  $\nu_D$  = shifts (Hz) of Me's in two species;  $1/T = \pi d\nu$ ;  $d\nu$  = width at half-height of peak unperturbed by exchange; and  $\text{abs}(\nu) = -\text{Im}([\text{M}]e^{\text{M}} + 2[\text{D}]e^{\text{D}})$ . The resulting rate constants,  $k_1$  and  $k_2$ , are summarized in Table 1.

**Table 1.** Rate Constants,  $k_1$  and  $k_2$ , Obtained from Line Shape Analysis

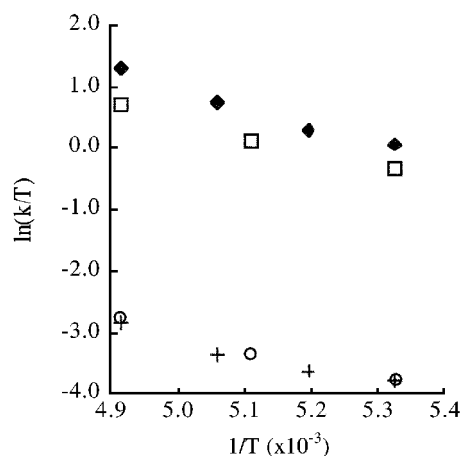
	$T$ (K)	$k_1$ ( $\text{s}^{-1}$ )	$k_2$ ( $\text{s}^{-1} \text{M}^{-1}$ )
0.03 M	203.5	13.2	422
	195.7	7	224
	187.8	4.4	136
0.09 M	203.5	12	750
	197.7	7	425
	192.5	5.2	261
	187.8	4.3	204

The  $^1\text{H}$  NMR spectrum of  $N,N$ -dimethyldiphenylacetamide in THF- $d_8$  shows two signals for methyl protons at room temperature. As with other  $N,N$ -dimethyl amides, the C–N rotation barrier is high enough to observe two sets of methyl protons. The  $^1\text{H}$  NMR spectrum of the Li enolate of  $N,N$ -dimethyldiphenylacetamide has averaged phenyl protons and showed a sharp singlet for the methyl protons at room temperature. For the 0.09 M solution of the Li enolate, line broadening was observed for the phenyl signals at 0 °C and for methyl signals at –65 °C. At –90 °C, two peaks were shown for methyl protons with a 12 Hz chemical shift difference and an integration ratio of 2:1. This integration ratio suggests that these NMR absorptions come not from two different methyls of the amide but from a monomer and

dimer. The latter hypothesis requires that this ratio change with concentration.

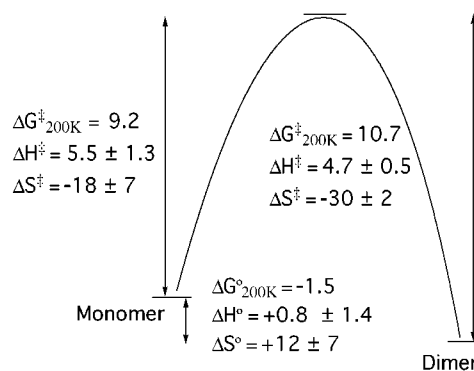
For the 0.03 M solution, the decoalescence temperature is –70 °C and two separate peaks were observed at –85 °C. The NMR integration ratio is 1:1, and the chemical shift separation is 11 Hz. This change shows that the downfield peak corresponds to the monomer. The NMR integration of the two independent samples gives the dimerization constant,  $K_{1,2} = [\text{dimer}]/[\text{monomer}]^2 = 33 \text{ M}^{-1}$  at –85 to –90 °C.

From line shape analysis, the interconversion rate constants (Table 1) and activation parameters of monomer to dimer of  $N,N$ -dimethyldiphenylacetamide enolate were obtained. A plot of  $\ln(k/T)$  vs  $1/T$  in Figure 1, where  $k$  is  $k_1$  or  $k_2$ ,



**Figure 1.** Eyring plot for rate constants  $k_1$  ( $\blacklozenge$  0.03 M,  $+$  0.09 M) and  $k_2$  ( $\square$  0.03 M,  $\circ$  0.09 M).

gives the activation parameters for the dimerization;  $\Delta H^\ddagger$  and  $\Delta S^\ddagger$  are calculated from the slope and the intercept, respectively. These results are summarized in Figure 2.  $\Delta H^\circ$  is relatively small; dimerization is primarily an entropy-driven process with an entropy change comparable to that for a lithium enolate.<sup>6</sup> The dimerization constant  $K_{1,2}$



**Figure 2.** Schematic diagram of energy states of monomer, transition state, and dimer (in  $\text{kcal mol}^{-1}$  and eu).

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extrapolated to room temperature is  $75 \text{ M}^{-1}$  and is consistent with results reported earlier.<sup>3</sup> In that study, UV measurements at low concentration showed only monomer and  $K$  was estimated to be  $<100 \text{ M}^{-1}$ .

The C–N rotation barrier of Li enolate could not be deduced since it is too fast to be measured by NMR. The rapid rotation even at low temperature indicates a rotation barrier of less than  $10 \text{ kcal mol}^{-1}$ . This result is consistent

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(6) Streitwieser, A.; Wang; D. Z.; *J. Am. Chem. Soc.* **1999**, *121*, 6213–9.

with ab initio computations<sup>7</sup> and indicates that the lone pair on nitrogen is not significantly conjugated with the carbonyl group as symbolized in resonance structure **3**.

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