t-Butylsulfinyl Phenylmethyl Carbanion. Conformation in Nonpolar Solvent

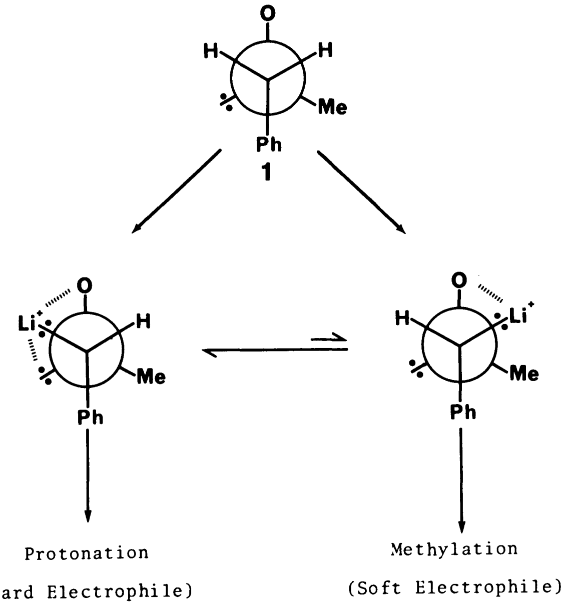
Atsuyoshi Ohno,* Masato Higaki, and Shinzaburo Oka
Institute for Chemical Research, Kyoto University, Uji, Kyoto 611

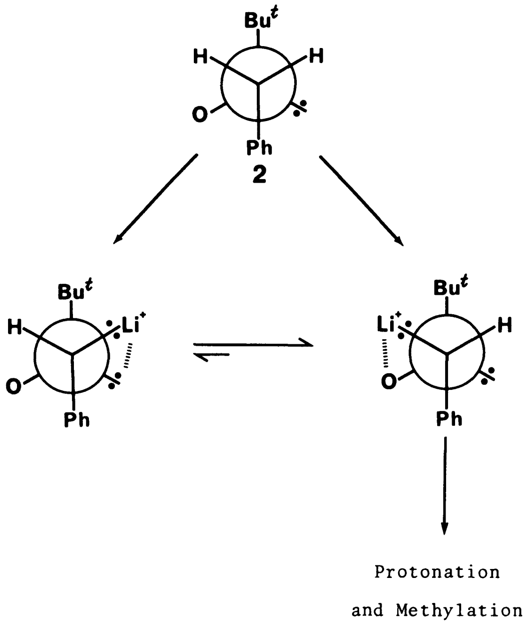
(Received December 24, 1987)

^{1}H NMR spectra were studied for a carbanion derived from *t*-butyl phenylmethyl sulfoxide in tetrahydrofuran. It has been concluded that the conformation of the carbanion in solution is the same as that in a crystal. The carbanion exists in two diastereomeric dimeric forms in the presence of an equivalent amount of countercation, but it becomes a monomer when excess base exists in the solution.

A recent report on neutron diffraction crystallography on *t*-butyl phenylmethyl sulfoxide[1)] casted a doubt on the configurations and reactivities of α-sulfinyl carbanions so far accepted.[2)] Stereochemistry of the reaction from an α-sulfinyl carbanion changes irregularly depending on the property of attacking electrophile and the steric bulk of substituent on the sulfur atom as well as on the polarity of solvent.[2–4)]

Reinvestigation of stereochemistry of the products derived from α-sulfinyl carbanions made us propose[5)] that 1) the major conformation of the carbanion is determined primarily by steric bulk of the substituents on the sulfur and the carbanionic carbon atom, then 2) a conformation is preferred so that the countercation of the carbanion can maintain a maximum interaction with a lone pair on the sulfinyl oxygen. 3) An interaction between the countercation and the sulfinyl lone pair exerts a minor effect. Since solvent-separated and dissociated ion pairs become popular in polar solvents, the importance of the role of the countercation decreases in such solvents. 4) Hard electrophiles such as water and a carbonyl compound attack the carbanion from its hard face; the attacking reagent interacts with the countercation initially and the population of a particular conformation of the carbanion controls the steric course of the reaction. 5) A soft electrophiles such as an alkyl halide, on the other hand, prefer to attack the carbanion from its soft face; the carbanion lone pair anti to the lone pair on the sulfinyl sulfur becomes more polarizable due to an α-effect.[6)] The reaction courses are illustrated in Scheme 1 for the protonations and methylations of carbanions derived from (*S*)-methyl phenylmethyl sulfoxide (*S*-**1**) and (*R*)-*t*-butyl phenylmethyl sulfoxide (*R*-**2**). It is important to note that the *R*,*S*-notation appears different in methyl and *t*-butyl phenylmethyl sulfoxides because of definition.





Although the proposal described above can explain the reactions of α-sulfinyl carbanions sufficiently, we have had no information on the conformation of the carbanion in solution. In order to obtain further insight into the conformation, we studied ^{1}H NMR spectroscopy of **2** in tetrahydrofuran (THF) and the results will be described in this paper. The hybridization of carbanionic carbon in α-sulfenyl, sulfinyl, and sulfonyl carbanions was extensively studied by Chassaing and Marquet by means of ^{13}C and ^{1}H NMR spectroscopies.[7,8)]

Results and Discussion

When 1.2 equivalent amounts of butyllithium was added to a solution of racemic mixture of **2** in tetrahydrofuran-d_8 (THF-d_8) at −100 °C, two ^{1}H

NMR signals for the benzylic proton appeared as singlets of approximately equal intensity at δ 3.34 and 3.36 in addition to signals for the aromatic protons at 5.86 (t, para), 6.11 and 6.13 (two doublets, ortho), 6.53 (q, meta), and 6.79 (d, ortho). The spectrum is shown in Fig. 1a and hereafter this solution will be called as the standard system. As shown in Fig. 1b, however, when the same solution with optically pure *R*-**2** instead of racemic **2** was subjected to the ^{1}H NMR spectroscopy, the benzylic proton resulted in only one singlet at δ 3.34 and the doublets for ortho-protons at δ 6.11 and 6.13 converged into a single doublet at δ 6.11.

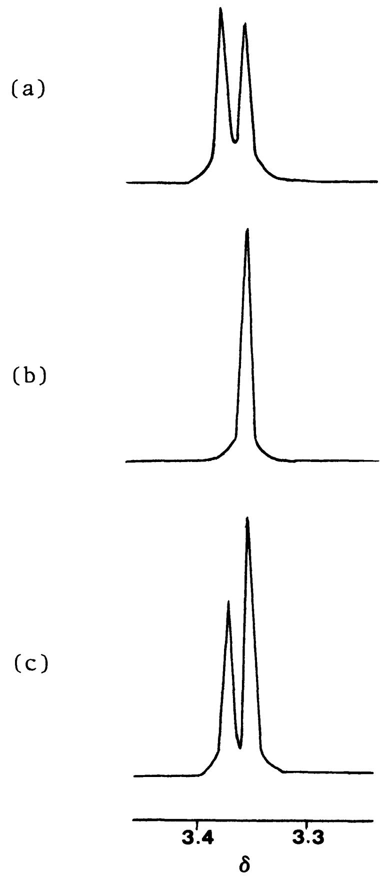
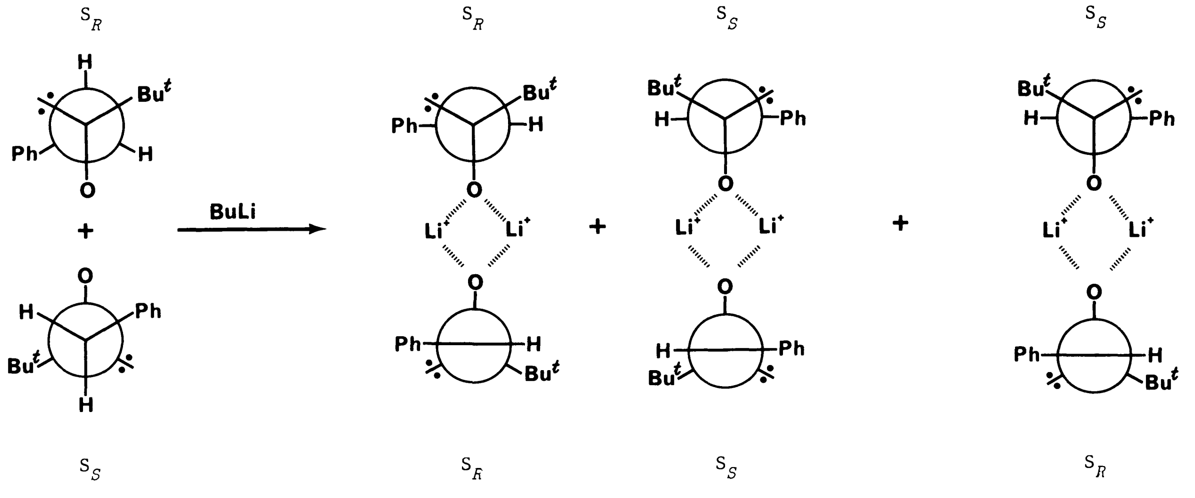


Fig. 1. ^{1}H NMR spectra of a benzylic proton of (a) racemic, (b) optically pure *R*-, and (c) 55% optically pure *R*-lithium salt of *t*-butylsulfinyl phenylmethyl carbanion in THF at −100 °C.

The appearance of two singlets from the racemic system suggests the existence of two or more diastereomeric isomers. Since optically pure **2** shows only one singlet and two doublets for the benzylic proton and for the two ortho-protons, respectively, and since it has been confirmed that the abstraction of a benzylic proton in **2** by a base results in highly diastereospecific carbanion thermodynamically,[5] there is no doubt that the two singlets observed for the benzylic proton in racemic **2** is *not* due to diastereomerism of benzylic protons with respect to the chirality on a single sulfur. That is, the spectra indicate that the lithiated carbanions produced from racemic **2** in THF are dimerized[9] to form *dl* (S_RS_R and S_SS_S)- and meso (S_RS_S)-isomers (**3** and **4**, respectively), whereas those from *R*-**2** can dimerize to only one S_RS_R form. That 2-methylbutyllithium displays two ^{1}H NMR signals (quartets) for α-protons in diastereomeric hexamers has been documented as well.[10]

Although the dimer of the carbanion from 1-phenylethyl phenyl sulfoxide has been known in crystalline state[11] and the possibility of its existence in a solution was suggested,[7,8] the present result is the first one to confirm that the carbanion from **2** prefers to be in dimeric form even in a solution. It is known that benzylic carbanion tends to exist as a monomeric ion pair with a lithium cation.[12–14] The preference of the dimeric form in the present benzylic carbanion with the bridge of lithium ions seems to suggest that the coordination of lithium ion onto the lone pair of sulfinyl oxygen is more important interaction than the coordination onto the lone pair on the benzylic carbon.[7,8,15] The present result suggests that the negative charge induced on the carbanion on the



2 **3** **4**

abstraction of a benzylic proton delocalizes largely onto the sulfinyl oxygen as well as on the phenyl group and the conformation of this benzylic carbon may be close to planar, in accord with the result reported previously.[7,8)]

The coalescence temperature of two singlets (−40 °C) elucidates that free energy of activation for intermolecular exchange of the carbanion is 51 kJ mol^{-1}, which is almost equivalent to 56 kJ mol^{-1} for 2-methylbutyllithium.[15)] Thus, the present result indicates that the SO···Li interaction in the dimer of sulfinyl carbanions is reasonably strong.

Figure 1c shows a spectrum obtained from the solution with *R*-**2** in 55% optical purity. The ratio in intensities of two singlets at δ 3.34 and 3.36 is 6:4, which is almost equivalent to the ratio of 7.5:4 calculated for the ratio in abandance of *dl*- and meso-dimers assuming random pairing of the carbanions. Thus, although thermodynamic stabilities of *dl*- and meso-dimers are equivalent in solution within experimental error, the X-ray crystallography predicted that the carbanion from a racemic mixture of 1-phenylethyl phenyl sulfoxide crystallizes as the meso-dimer.[11)]

Not only the qualitative similarity in the dimeric form, but also the similarity in the conformation of individual (monomeric) carbanion can be seen between the carbanions in the solid and liquid phases; a nuclear Overhouser effect observed for the carbanion in THF at −50 °C by irradiating the signal from the methyl protons showed 13.5% increase in the intensity of the signal for the benzylic proton, whereas the effect was only 4.7% in the spectrum from the mother species, **2**.[5)] This result indicates that the benzylic proton in the carbanion is set in more proximity to the *t*-butyl group than that in the original sulfoxide **2**. Thus, the conformations of carbanions derived from *S*- and *R*-**2** in THF are those shown in **3** and **4** in accord with that elucidated by X-ray crystallography.[11)]

The discussion described above has been developed on the basis of assumption that the carbanion is in dimeric form in THF and not in tetramer or higher aggregate. The validity of this assumption can be tested experimentally. No change in the spectrum was observed when two equivalent amounts of *N,N,N′,N′*-tetramethylethylenediamine was added to the standard system, in contrast to the observation on butyllithium, where the presence of tetrameric aggregate is suggested.[12)] Since the free energy of activation for ligand exchange in α-sulfinyl and alkyl carbanions are similar, the present observation indicates that the α-sulfinyl carbanion chelated by lithium cations are not in tetrameric or higher aggregation.[12)] Instead, the sulfinyl oxygen in the dimeric form coordinates onto the lithium cation quite strongly so that the other chelating reagent can only substitute the solvent molecule on the lithium ion without destroying the dimeric form into monomers.

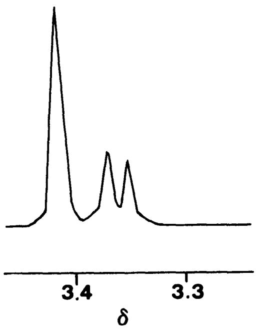


Fig. 2. ^{1}H NMR spectrum of a benzylic proton of racemic, *t*-butylsulfinyl phenylmethyl carbanion with one more equivalent excess butyllithium in THF at −100 °C.

When one more equivalent amount of butyllithium was added to the standard system, however, another singlet appeared at δ 3.40 as the signal from the benzylic proton at the sacrifice of intensities of signals from protons in the dimers. The appearance of the singlet is accompanied by the appearance of another pair of four signals from the aromatic protons (Fig. 2). That is, all the benzylic protons in the solution become magnetically equivalent by forming a new species, which means that the dimeric carbanions dissociate into monomers in the presence of excess base, or more precisely, butyllithium substituted to a half portion of the dimer forming a sulfinylalkyl mixed aggregate.

Experimental

Instruments. ^{1}H NMR spectra were recorded at 400 MHz on a JEOL GX-400 Fourier Transform NMR Spectrometer with a low-temperature equipment. δ-Values in ppm were internally related to that of the residual α-protons (δ 3.5) in the THF-d_8 solvent. The optical purity was measured on a Perkin-Elmer 241 Polarimeter. Elemental analyses were performed with a Yanako MT-3 Elemental Analyzer and gave satisfactory results for all compounds used.

Materials. (S_R)-*t*-butyl phenylmethyl sulfoxide was prepared according to the literature procedure.[16)] Tetrahydrofuran-d_8 and a hexane solution of butyllithium were obtained from a commercial source.

Preparation of α-Sulfinyl Carbanion. An NMR sample tube containing 4.9 mg (0.025 mmol) of *t*-butyl phenylmethyl sulfoxide was sealed by a rubber stopper under atmosphere of nitrogen, then 700 μl of THF-d_8 was poured into the tube through a syringe. The solution was cooled to an appropriate temperature under a streem of nitrogen in order to keep the pressure inside the tube atmospheric. Since 3.57 mM dm^{-3} water was detected on the ^{1}H NMR spectrum of the solution, 1.6 μl of butyllithium in hexane was added to the solution in order to quench all the water molecule present. Then 1.2 equivalent amounts of butyllithium in hexane (19.2 μl, 0.03 mmol) was added to this solution through a syringe.

Measurement of Nuclear Overhauser Effect. The lithiated *t*-butylsulfinyl phenylmethyl carbanion (**2**) in THF-d_8 was kept at −50 °C. Irradiation on the methyl protons in the *t*-butyl group led to the enhancement in the intensity of signal from the benzylic proton in the difference NOE experiment.

References

1) Y. Iitaka, A. Itai, N. Tomioka, Y. Kodama, K. Ichikawa, K. Nishihata, M. Nishio, M. Izumi, and K. Doi, *Bull. Chem. Soc. Jpn.*, **59**, 2801 (1986).

2) T. Durst, R. Viau, and M. R. McClory, *J. Am. Chem. Soc.*, **93**, 3077 (1971).

3) J. E. Baldwin, R. E. Hacker, and R. M. Scott, *J. Chem. Soc., Chem. Commun.*, **1969**, 1415.

4) T. Durst, R. R. Fraser, M. R. McClory, R. B. Swingle, R. Viau, and Y. Y. Wigfield, *Can. J. Chem.*, **48**, 2148 (1970).

5) K. Nakamura, M. Higaki, S. Adachi, S. Oka, and A. Ohno, *J. Org. Chem.*, **52**, 1414 (1987).

6) J. O. Edwards and R. G. Pearson, *J. Am. Chem. Soc.*, **84**, 16 (1962).

7) G. Chassaing and A. Marquet, *Tetrahedron*, **34**, 1399 (1978).

8) G. Chassaing and A. Marquet, *J. Organomet. Chem.*, **232**, 293 (1982).

9) Although we do not know the molecularity in this aggregation at present, the evidence obtained from a solution with *N,N,N′,N′*-tetramethylethylenediamine elucidates the dimeric form, which will be discussed later.

10) G. Fraenkel, W. E. Beckenbaugh, and P. P. Yang, *J. Am. Chem. Soc.*, **98**, 6878 (1976).

11) M. Marsch, W. Massa, K. Harms, G. Baum, and G. Boche, *Angew. Chem., Int. Ed. Engl.*, **25**, 1011 (1986).

12) D. Seebach, R. Hässig, and J. Gabriel, *Helv. Chim. Acta*, **66**, 308 (1983).

13) R. Waack, M. A. doran, E. B. Baker, and G. A. Olah, *J. Am. Chem. Soc.*, **88**, 1057 (1969).

14) L. D. McKeever and R. Waack, *J. Organomet. Chem.*, **28**, 145 (1971).

15) C. Näjera, M. Yvs, R. Hässig, and D. Seebach, *Helv. Chim. Acta*, **67**, 1100 (1984).

16) M. Axelrod, P. Bickart, J. Facobus, M. M. Green, and K. Mislow, *J. Am. Chem. Soc.*, **90**, 4835 (1968).