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The Determination of the Enantiomeric Purity of Methyl *p*-Tolyl Sulfoxide by Means of an NMR Shift Reagent

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The NMR method for determining the enantiomeric excess of amines and alcohols employs a chiral complex of europium, tris[3-(*tert*-butylhydroxymethylene)-*d*-camphorato]europium(III) (**1**).[1] The NMR shift of oxiranes and sulfoxides has also been recorded.[2–4] We have independently been engaged in the same subject of research and wish to record the NMR shifts of optically-resolved sulfoxides as well as the analytical practice, neither of which has yet been described. A modified method of preparing **1** is also described.

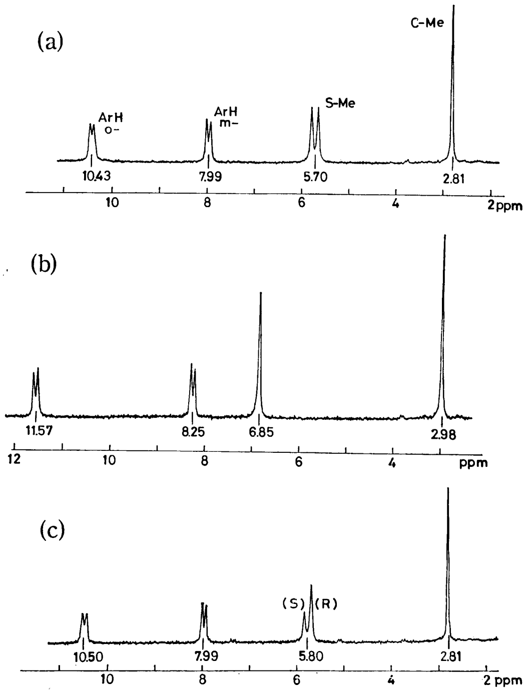

Fig. 1. Spectra of (a) (±)-methyl *p*-tolyl sulfoxide (**2**) (0.091 mmol) in CCl_4 (0.4 m*l*) containing the shift reagent, **1** (0.030 mmol), (b) (+)-(R)-**2** (0.91 mmol), CCl_4 (0.4 m*l*), **1** (0.026 mmol), and (c) partially resolved sulfoxide, **2** (1.04 mmol), CCl_4 (0.5 m*l*), **1** (0.032 mmol).

Figure 1a shows a spectrum of a carbon tetrachloride solution of (±)-methyl *p*-tolyl sulfoxide (**2**) and **1** (3.0: 1.0 mol ratio). The separation of the enantiotopic methyl singlets was 0.14 ppm. A mixture of the optically-pure (+)-(R)-methyl *p*-tolyl sulfoxide (**2**) ($[\alpha]_D$ +145.5°, *c* 0.40, acetone) and **1** (3.5: 1.0 mol ratio) exhibited the NMR spectrum shown in Fig. 1b, only one S-methyl singlet being observed. The NMR spectrum of partially-resolved sulfoxide **2** ($[\alpha]_D$ +47.9°, *c* 1.06, acetone, 33% calculated optical purity) in the presence of **1** is given in Fig. 1c. Obviously, the S-methyl protons of (R)-**2** resonate at a higher field than their counterparts in (S)-**2**. The overlapping methyl peak areas in Fig. 1c were separated by means of the Brace method.[5] Each peak was cut out and weighed. The values gave an enantiomeric ratio of 1.0/2.0 or a 33% enantiomeric excess. The absolute rotation of methyl *p*-tolyl sulfoxide was calculated to be 144° (lit. 145.5° [6a]).

The NMR method is naturally applicable to further sulfoxides. The S-methyl singlet of methyl phenyl sulfoxide resonating at the higher field in a carbon tetrachloride solution has been shown to arise from

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[1] G. M. Whitesides and D. W. Lewis, *J. Amer. Chem. Soc.*, **92**, 6979 (1970).

[2] H. L. Goering, J. N. Eikenberry, and G. S. Koermer, *ibid.*, **93**, 5913 (1971).

[3] G. M. Whitesides and D. W. Lewis, *ibid.*, **93**, 5914 (1971).

[4] R. R. Fraser, M. A. Petit, and J. K. Saunders, *Chem. Commun.*, **1970**, 1450.

[5] R. L. Pecsok, "Principles and Practices of Gas Chromatography," Chapman & Hall, London, 1959; Private communication from R. O. Brace at Beckman Instrument, Fullerton, California.

[6] a) K. Mislow, M. M. Green, P. Laur, J. T. Mellilo, T. Simmons, and A. L. Jernay, Jr., *J. Amer. Chem. Soc.*, **87**, 1958 (1965); b) K. K. Andersen, *J. Org. Chem.*, **29**, 1953 (1964).

the isomer of the R-configuration. In a chloroform solution, however, this method proved unsuccessful, as no difference between the methyl protons of enantiomers was observed. The attempted application of the present method to the methyl ester of a *p*-tolylsulfinic acid failed because of the samll separation of the enantiomeric signals.

Experimental

The NMR spectra were obtained on a 100 MHz instrument (Varian HA-100), using TMS as the internal standard. The optically-active sulfoxides were prepared from (−)-menthyl arylsulfinate and methylmagnesium iodide by the known method.[6] The optically-active complex **1** was obtained from *tert*-butylhydroxymethylene-*d*-camphor and europium(III) nitrate in the presence of sodium hydroxide.[1,7] The diketone was prepared from camphor and pivaloyl chloride by the following modified method.

A mixture of camphor (24 g, 0.16 mol) and sodium hydride (3.8 g, 0.16 mol) in hexamethylphosphoric triamide (150 m*l*) under N_2 was stirred at 70°C for 5 hr to give a dark brown carbanion solution. This solution was diluted with THF (30 m*l*), and then a solution of pivaloyl chloride (8.8 g, 0.08 mol) in THF (10 m*l*) was added under ice-cooling. The reaction mixture was then stirred at room temperature for 12 hr, poured into water (500 m*l*), acidified with 10% hydrochloric acid (50 m*l*), and extracted with benzene. The product was purified by chromatography on a silica-gel column, followed by distillation; bp 130°C/2 mmHg. The 3-*t*-butylhydroxymethylene-*d*-camphor thus obtained (11%) formed white crystals; mp 65—67°C. We could find no suitable recrystallization solvent. The IR, NMR, the mass spectrum, and the analyses supported the structure.

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[7] K. J. Eisentraut and R. E. Sievers, *J. Amer. Chem. Soc.*, **87**, 5254 (1965).