A Simple Allylic Amination Procedure and the Metathesis of *N*-Sulfinylcarbamates

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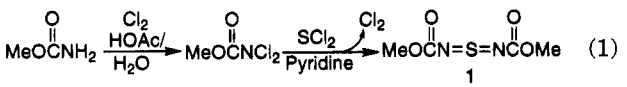
This note describes a procedure, related to one developed by Kresze et al.,[1] that appears to be the simplest and least expensive for introducing amino functions into the allylic positions of alkenes. It shows how *N,N'*-bis(alkoxycarbonyl)sulfur diimides can be prepared easily, and it analyzes how to overcome the enormous variability in the yields of alkyl *N*-sulfinylcarbamates obtained when alkyl carbamates are combined with thionyl chloride in pyridine.

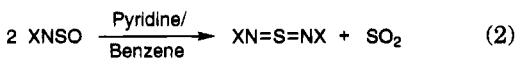
The problem considered is that while *N,N'*-bis(methoxycarbonyl)sulfur diimide (**1**) has considerable benefit as a reagent to effect allylic aminations, e.g. Scheme 1,[1] its preparation (eq 1), which calls for the manipulation of



(1)

chlorine in both steps, is troublesome.[1b,2] Thus if diimide **1** could be obtained more easily, its usefulness for synthesis would increase significantly. The benefit of Scheme 1 is the facility with which aqueous base removes residual groups from the nitrogen that is introduced, a virtue shared with a more lengthy procedure of Whitesell and Yaser that uses *N*-sulfinylcarbamates[3] but not with those that effect allylic aminations by using reagents such as TsN=Se=NTs,[4] TsN=S=NTs,[5] $PhSO_2NSO$,[6] $CH_3OCON{=}NCOOCH_3$ plus $SnCl_4$,[7] AcNO,[8] and PhNHOH combined with transition-metal catalysts.[9] These leave groups attached to nitrogen ($ArSO_2$, $NHCO_2CH_3$, or OH plus either Ac or Ph) that hydrolysis does not readily remove.

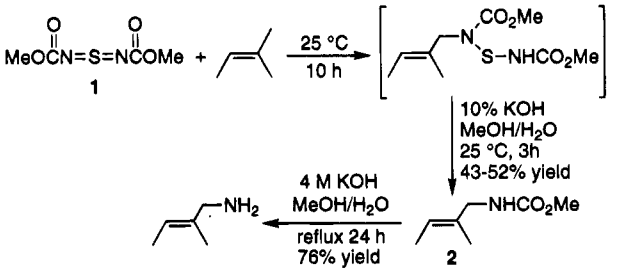
The question considered in this paper is whether **1** can be obtained by the same procedure (eq 2) that converts



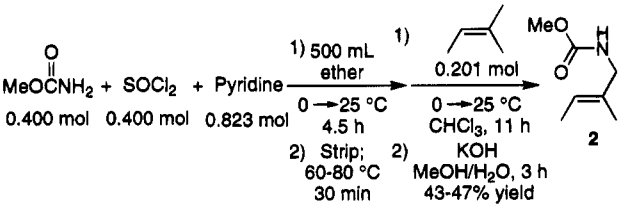
(2)

TsNSO into TsN=S=NTs.[10,11] If so, the only reagents required to effect an allylic amination, such as that in

Scheme 1

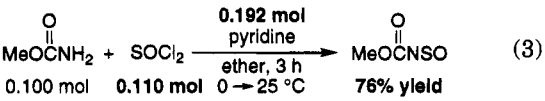


Scheme 2



Scheme 1, would be methyl carbamate, thionyl chloride, and pyridine.[13] It turns out that this combination (Scheme 2) does indeed bring about the amination, and more easily and efficiently than when Scheme 1 follows eq 1 .[1,14] Moreover, minute amounts of pyridine at 60–80 °C (and at room temperature more slowly) do convert MeOCONSO into $MeOCON{=}S{=}NCOOMe$ (eq 2, X = CO_2Me).

This conversion has another previously unrecognized consequence. It explains why the yields obtained in reported *N*-sulfinylations vary mysteriously and what must be done to obtain yields that are consistently satisfactory. Since pyridine catalyzes the conversion of MeOCONSO into $MeOCON{=}S{=}NCOOMe$, to obtain MeOCONSO in good yield (eq 3), it is essential that



(3)

pyridine, a reagent in the preparation, not be present in excess.[15] Equations 4 and 5 demonstrate the difference that is observed when methyl carbamate, thionyl chloride, and pyridine are combined in ca. 1:1:2 molar ratios, but with just a bit less than 2 mol of pyridine in the one case and just a bit more in the other. If there is 5% too much pyridine, the yield of *N*-sulfinylcarbamate is essentially nil. No wonder that Ichimura et al.[16] and sub-

(1) (a) Kresze, G.; Münsterer, H. *J. Org. Chem.* **1983,** *48,* 3561. (b) Kresze, G.; Braxmeier, H.; Münsterer, H. *Organic Syntheses*; Wiley: New York, 1993; Collect. Vol. 8, p 427.

(2) Levchenko, E. S.; Bal'on, Ya. G.; Kirsanov, A. V. *J. Org. Chem. USSR (Engl. Transl.)* **1967,** *3,* 2014.

(3) Whitesell, J. K.; Yaser, H. K. *J. Am. Chem. Soc.* **1991,** *113,* 3526.

(4) Sharpless, K. B.; Hori, T.; Truesdale, L. K.; Dietrich, C. O. *J. Am. Chem. Soc.* **1976,** *98,* 269.

(5) (a) Sharpless, K. B.; Hori, T. *J. Org. Chem.* **1976,** *41,* 176. (b) Singer, S. P.; Sharpless, K. B. *J. Org. Chem.* **1978,** *43,* 1448.

(6) Deleris, G.; Dunogues, J.; Gadras, A. *Tetrahedron* **1988,** *44,* 4243.

(7) Brimble, M. A.; Heathcock, C. H. *J. Org. Chem.* **1993,** *58,* 5261.

(8) Keck, G. E.; Webb, R. B.; Yates, J. B. *Tetrahedron* **1981,** *37,* 4007.

(9) Johannsen, M.; Jørgensen, K. A. *J. Org. Chem.* **1994,** *59,* 214 and references cited therein.

(10) (a) Wucherpfennig, W.; Kresse, G. *Tetrahedron Lett.* **1966,** 1671. (b) Kresze, G.; Wucherpfennig, W. *Angew. Chem., Int. Ed. Engl.* **1967,** *6,* 149 (see p 165). (c) Bussas, R.; Kresze, G. *Liebigs Ann. Chem.* **1980,** 629.

(11) Pyridine also converts PhCONSO into PhCONSNCOPh,[12a] while metal alkoxides and other strong bases similarly convert aryl-NSO's.[12b–e] Piperidine condenses aryl-NSO's with aldehydes.[12b]

(12) (a) Levchenko, E. S.; Dorokhova, E. M. *J. Org. Chem. USSR (Engl. Transl.)* **1972,** *8,* 2573. (b) Hörhold, H.-H. *Z. Chem.* **1972,** *12,* 41. (c) Hörhold, H.-H.; Flossmann, K.-D. *Z. Chem.* **1967,** *7,* 345. (d) Minami, T.; Miki, H.; Matsumoto, H.; Ohshiro, Y.; Agawa, T. *Tetrahedron Lett.* **1968,** 3049. (e) Hörhold, H.-H.; Beck, J. *J. Prakt. Chem.* **1969,** *311,* 621, and later papers.

(13) *N*-Sulfinylcarbamates are prepared by combining carbamates with $SOCl_2$ in pyridine. (a) Hancock, J.; Markert, A. R. *Tetrahedron Lett.* **1966,** 6157. (b) Reference 10b, p 149ff.

(14) The yield of **2** in Scheme 1 is based on the amount of dichlorocarbamate used to make **1**. That dichlorocarbamate was made from the carbamate in 63–73% yield.

(15) The best yields of distilled *N*-sulfinylcarbamate (73%), contaminated (as all samples seemingly are) by 10% recovered methyl carbamate, were obtained repeatedly by using a small deficiency of pyridine and a small excess of thionyl chloride.

(16) Ichimura, K.; Ichikawa, S.; Imamura, K. *Bull. Chem. Soc. Jpn.* **1976,** *49,* 1157. They report that yields are poor when $SOCl_2$ is added to the carbamate and pyridine but good when $SOCl_2$ and pyridine are added in drops to the carbamate.

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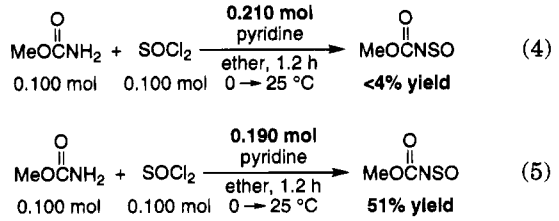

sequently Bussas and Kresze[17] recorded the need for modified procedures, and that Hanson and Stockburn, whose recipe calls for 2–6% less pyridine than required by the other reagents, obtained a yield of 75%,[18] while Hancock and Markert (who did not specify how much pyridine they used) obtained a yield of only 20%.[13a] Nevertheless, the essential principle remained obscure.[19,21,22]

The experiments reported here demonstrate three points: that pyridine catalyzes the conversions of alkyl *N*-sulfinylcarbamates to *N,N'*-bis(alkoxycarbonyl)sulfur diimides (eq 2, X = CO_2R), that in consequence very simple reagents can be used to aminate alkenes in their allylic positions (Scheme 2), and that excess pyridine must be avoided if *N*-sulfinylations of carbamates are to give high yields (eqs 3–5).

Experimental Section

Amination of 2-Methyl-2-butene (Scheme 2). Pyridine (65.0 g, 0.823 mol) was added in drops during a period of 0.5 h to a solution of methyl carbamate (30.0 g, 0.400 mol) and $SOCl_2$ (47.6 g, 0.400 mol) in 500 mL of ether that was cooled in an ice bath and stirred. The bath was removed, and stirring was continued for 4 h. After the pyridine hydrochloride had been filtered and washed quickly with ether, the solvent was evaporated, and the residue was heated at 60–80 °C for 30 min. Any *N*-sulfinylcarbamate present was then removed by evacuating the flask to a pressure of 0.5 mmHg for 10 min. (In a repetition of the experiment, the yield of methyl *N*-sulfinylcarbamate that could be distilled from the product was <4%.) The reaction with 14.1 g (0.20 mol) of 2-methyl-2-butene was carried out exactly as in ref 1b. The yield of distilled **2** was 12.4 g (43% yield). A similar experiment that started with 7.5 g of methyl carbamate gave 3.38 g of **2** (a 47% yield). Its NMR spectra match those reported:[1] ^{13}C NMR (75 MHz, $CDCl_3$) δ 13.2, 14.0, 48.6, 52.0, 120.5, 132.7, 157.3; ^1H NMR (400 MHz, $CDCl_3$) δ 1.59 (d, q, J = ca. 6.5, 1.1 Hz, 3H), 1.61 (bs, 3H), 3.67 (s, 3H), 3.69 (d, J = 5.8 Hz, 2H), 4.68 (bs, 1H), 5.39 (q, J = 6.4, 1H); MS (EI) *m/z* (rel intensity) 143 (30), 135 (100), 128 (26), 102 (20), 76 (100), 69 (42), 59 (78), 42 (34); HRMS (EI) calcd for $C_7H_{13}NO_2$ 143.0946, found 143.0940.

Preparation of Methyl *N*-Sulfinylcarbamate. Pyridine (15.2 g, 0.192 mol) in 50 mL of ether was added in drops during a period of 1.5 h to a stirred solution of 7.5 g (0.100 mol) of methyl carbamate and 13.1 g (0.110 mol) of $SOCl_2$ in 250 mL of ether, and the mixture was stirred for another 1.5 h. After the pyridine hydrochloride had been filtered and washed quickly with ether, the solvent was stripped, and the residue was distilled (ca. 31 °C/2 mmHg) to a receiver cooled in dry ice–acetone. Obtained was 9.5 g of colorless liquid, analyzed by its proton NMR spectrum to be a mixture of 8.8 g of methyl *N*-sulfinylcarbamate (a 76% yield) and 0.76 g (a 10% recovery) of methyl carbamate. ^1H NMR spectra in $CDCl_3$: methyl *N*-sulfinylcarbamate, δ 3.95; methyl carbamate, δ 3.69.

When the amounts of methyl carbamate, thionyl chloride, and pyridine were 7.50 g (0.100 mol), 11.90 g (0.100 mol), and 15.01 g (0.190 mol), the distillate obtained consisted of 5.9 g of methyl *N*-sulfinylcarbamate (a 51% yield) and 0.5 g of recovered methyl carbamate. The same experiment, but using 16.59 g of pyridine (0.210 mol), gave only 0.5 g of distillate, which ^1H NMR analysis showed to be a mixture of methyl carbamate (δ 3.69), **1** (δ 3.87), methyl *N*-sulfinylcarbamate (δ 3.95), and pyridine [δ 8.05 (t), 8.50 (t), and 8.94 (d)]. The yield of methyl *N*-sulfinylcarbamate was thus <0.5 g (4%). In these experiments, the reaction mixture was cooled in an ice bath while the pyridine was added, then the solution was stirred for 1–1.5 h at room temperature and worked up as before.

Conversion of Methyl *N*-Sulfinylcarbamate into *N,N'*-Bis(methoxycarbonyl)sulfur Diimide (1). Samples in $CDCl_3$ of methyl *N*-sulfinylcarbamate (1 g) stirred with pyridine (40 mg) were analyzed by ^1H NMR spectroscopy (starting material, δ 3.95; product sulfur diimide, δ 3.87 (reported,[1a] δ 3.88). After 1 h at 60–80 °C, the conversion was 67%, and after 3 h, 83%. After 4 h at room temperature, the conversion was 50%, and after 14 h, 64%. The spectra are displayed in the supplementary material.

Acknowledgment. We acknowledge the support of the NSF (CHE 92-24634).

Supplementary Material Available: ^1H NMR spectra analyzing the conversion in eq 1 (X = CO_2Me) (2 pages). This material is contained in libraries on microfiche, immediately follows this article in the microfilm version of the journal, and can be ordered from the ACS; see any current masthead page for ordering information.

(17) Bussas, R.; Kresze, G. *Liebigs Ann. Chem.* **1982**, 545.

(18) Hanson, P.; Stockburn, W. A. *J. Chem. Soc., Perkin Trans. 2* **1985**, 589. Their reported yield, 94%, was miscalculated.

(19) Other recipes also call for a deficiency of pyridine and its addition last,[20] although one is accompanied by a preparation in which the pyridine is added first.[20b] Whitesell and Yaser used an excess of $SOCl_2$.[3]

(20) (a) Garigipati, R. S.; Freyer, A. J.; Whittle, R. R.; Weinreb, S. M. *J. Am. Chem. Soc.* **1984**, *106*, 7861. (b) Wald, L.; Wucherpfennig, W. *Liebigs Ann. Chem.* **1971**, *746*, 28. (c) Niclas, H.-J.; Habisch, D.; Martin, D. *Tetrahedron* **1979**, *35*, 2353.

(21) It is interesting that the preparation of TsNSO from $TsNH_2$ and $SOCl_2$ requires no pyridine, although the reaction time can be very long: (a) ref 10b, p 151. (b) Hori, T.; Singer, S. P.; Sharpless, K. B. *J. Org. Chem.* **1978**, *43*, 1456.

(22) The puzzle is reminiscent of that presented by the synthesis of cyanohydrins before 1903, when it was not recognized that an extra drop of H_2SO_4, beyond that needed to neutralize the cyanide salts, is deleterious.[23]

(23) Lapworth, A. *J. Chem. Soc.* **1903**, *83*, 995: "It is probably a general experience that in preparing cyanohydrins ... the speed of the reaction and the yield ... obtained may vary in an extraordinary manner, even when the experimental conditions are apparently constant...".