Synthetic Methods and Reactions; 77[1]. Dimethyl Sulfoxide/Chlorosulfonyl Isocyanate: An Extremely Mild Reagent for Oxidation of Alcohols to Carbonyl Compounds

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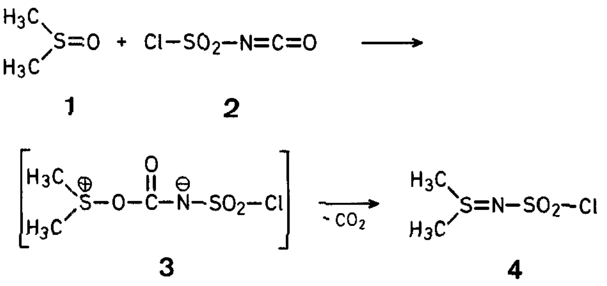
Oxidation of alcohols to carbonyl compounds by "activated" dimethyl sulfoxide has been studied by a number of research groups in recent years. As a result, a number of electrophiles, such as acetic anhydride, pyridine/sulfur dioxide, *N*-chlorosuccinimide, cyanuric chloride, benzoyl chloride, methanesulfonyl chloride, *p*-toluenesulfonyl chloride, and trifluoroacetic anhydride, have been reported[2] to be capable of activating dimethyl sulfoxide for use in the oxidation of alcohols. Our continued interest[3] in developing new reagents for organic synthesis has led us recently to report[4] the use of chlorosulfonyl isocyanate (**2**) as a mild and effective dehydrating agent. The well-known strongly electrophilic nature of **2** prompted us to also examine its behavior towards dimethyl sulfoxide (**1**) and thus the possibility of using this system in the oxidation of alcohols.

The reaction of **1** with **2** has been reported[5] to form *N*-chlorosulfonyl-dimethylsulfimide (**4**).



1 **2** **3** **4**

The formation of **4** proceeds via an intermediate Zwitterion **3**, which readily loses carbon dioxide to form **4**. Although the reaction of **2** with **1** in dichloromethane is extremely vigorous at room temperature, it was found to proceed slowly at 0 °C or at −25 °C, but still with the loss of carbon dioxide. At −78 °C, however, a white complex is formed, which does not lose carbon dioxide unless warmed up to 0 °C. The ^{13}C-N.M.R. spectrum of this complex at −78 °C shows a singlet at $\delta_C = 125.83$ ppm corresponding to carbonyl carbon and a quartet at $\delta_C = 41.51$ ppm ($J_{CH} = 138$ Hz) corresponding to methyl groups of the intermediate **3**. In comparison, the carbon absorption in **2** appears at $\delta_C = 131.07$ ppm and in **1** at 35.71 ppm. The peak at $\delta_C = 125.83$ ppm disappears when the temperature of the solution is brought up to 0 °C, and a methyl carbon absorption corresponding to complex **4** appears at $\delta_C = 39.07$ ppm with $J_{CH} = 142.9$ Hz. The Zwitter-ionic complex **3** containing an electrophilic sulfur atom was expected to combine exceedingly readily with the alcohols **5** to give **6**, which in turn, upon treatment with a base, should be converted into the corresponding carbonyl compound **7**.

We have, indeed, found that a broad variety of alcohols **5** react readily with equimolar mixtures of **1** and **2** in dichloromethane solution in the presence of triethylamine at −78 °C to give the corresponding carbonyl compounds **7** in high yields (see Table).

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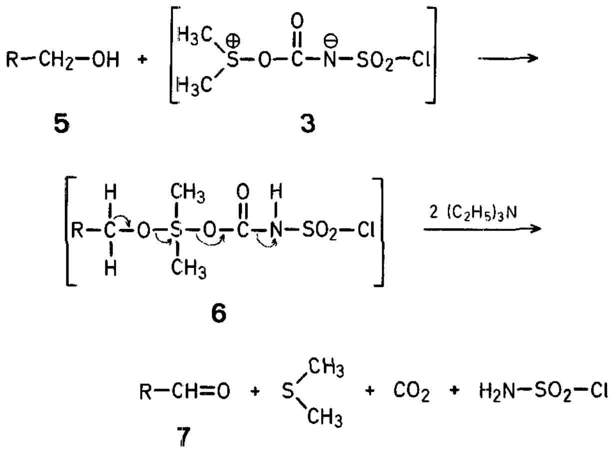
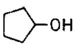
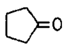
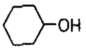
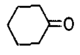
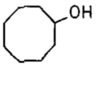
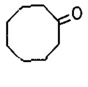
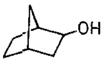
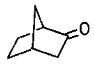
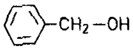
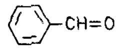
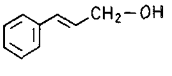
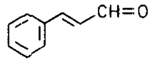
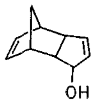
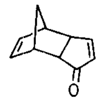
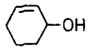
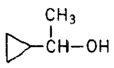
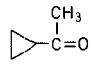


Table. Oxidation of Alcohols to Carbonyl Compounds with Dimethyl Sulfoxide/Chlorosulfonyl Isocyanate

Alcohol	Ketone	Yield[a] [%]	m.p. or b.p./torr	
			found	reported[7]
		81	128–129 °C/760	130 °C/760
		85	45–46 °C/15	47 °C/15
		79	89 °C/22	195–197 °C/760
		86	94.8 °C	93–95 °C
		90	60–61 °C/10	62 °C/10
		69	125–126 °C/18	130 °C/20
		70	58.5 °C	59–59.5 °C[8]
		71	55–56 °C/12	169–171 °C/760
		70	112–113 °C/760	114 °C/760

[a] Yield of isolated product of ≥99% purity as determined by I.R. and ^{1}H-N.M.R. spectroscopy and by T.L.C. (silica gel, 2:1 hexane/benzene) and G.L.C. (6 ft × 1/8 in stainless steel column, SE-30, 200 °C) analysis.

Although olefinic compounds are known to react[6] with **2** to form β-lactams, we have found that unsaturated alcohols are also smoothly oxidized without the intervention of any side reactions of the double bonds as is shown, for example, in the conversion of cinnamyl alcohol to cinnamaldehyde. Further, the reagent system is equally applicable to the oxidation of sterically hindered alcohols, such as norborneol. The present reagent system is considered to be one of the mildest and most effective ways for the oxidation of alcohols giving high yield conversions at temperatures as low as −78 °C.

Oxidation of Alcohols to Carbonyl Compounds with Dimethyl Sulfoxide/Chlorosulfonyl Isocyanate; General Procedure:

To a stirred solution of **2** (2.12 g, 15 mmol) in dichloromethane (10 ml, dried with phosphorus pentoxide) is added a solution of **1** (1.56 g, 20 mmol) in dichloromethane (15 ml) at −78 °C forming a white complex. A solution of the alcohol **5** (10 mmol) in dichloromethane (10 ml) is then added dropwise with good stirring to the above mixture and stirring is continued for 1.5 h at −78 °C. At the end of this period, triethylamine (1.5 g, 15 mmol) dissolved in dichloromethane (10 ml), is added and the reaction mixture stirred for 0.5 h at room temperature. The solution is then diluted with water (20 ml) and the organic layer separated. The aqueous layer is extracted with dichloromethane (2 × 15 ml). The combined organic extracts are washed with water (2 × 20 ml), followed by brine (15 ml), and dried with anhydrous sodium sulfate. Evaporation of the solvent gives the crude product, which, upon chromatography on silica gel column with hexane/benzene (2:1) eluent furnishes pure carbonyl compound **7**. All the carbonyl compounds were known from the literature and their identity and purity were confirmed by the comparison of their physical and spectral data.

Support of our work by the National Institutes of Health and the National Science Foundation is gratefully acknowledged.

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[1] Part 76, G. A. Olah, Y. D. Vankar, M. Arvanaghi, *Synthesis* **1979**, 984.

[2] For a detailed account of all the methods, see K. Omura, D. Swern, *Tetrahedron Lett.* **34**, 1651 (1978).

[3] G. A. Olah, *Acc. Chem. Res.*, in press.

[4] G. A. Olah, Y. D. Vankar, A. Garcia-Luna, *Synthesis* **1979**, 227.

[5] R. Graf, *Angew. Chem.* **80**, 179 (1968); *Angew. Chem. Int. Ed. Engl.* 7, 172 (1968).

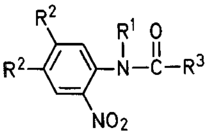
[6] (a) J. K. Rasmussen, A. Hassner, *Chem. Rev.* **76**, 389 (1976).
(b) W. A. Szabo, *Aldrichimica Acta* **10**, 23 (1977).

[7] *Dictionary of Organic Compounds*, 4th Ed., Oxford University Press, New York 1965.

[8] M. Rosenblum, *J. Am. Chem. Soc.* **79**, 3179 (1957).

Errata and Addenda 1980

V. N. R. Pillai, *Synthesis* **1980** (1), 1–26;
The structure of compound **86** (p. 12) should be:

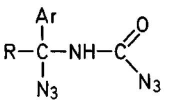


86

V. I. Cohen, *Synthesis* **1980** (1), 60–63;
The alternative name (in brackets) for compounds **1** (p. 62, first experimental procedure) should be ***S*-Methylpseudothiourea Hydroiodides.**

J. R. Mahajan, H. C. de Araújo, *Synthesis* **1980** (1), 64–66;
The authors have erroneously stated that "exaltolide" is a trivial name for pentadecanolide. In fact "exaltolide" is a trademark registered in the name of Firmenich SA, Geneva and should be designated as Exaltolide®.

V. I. Gorbatenko, L. I. Samarai, *Synthesis* **1980** (2), 85–110;
The structure of compound **97** (p. 99) should be:



97

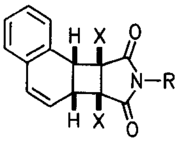
M. Mikołajczyk, P. Bałczewski, S. Grzejszczak, *Synthesis* **1980** (2), 127–129;
The correct name for compound **5a** (first procedure, p. 129) is **Diethyl 1-Phenylthioethanephosphonate.**

G. A. Olah, Y. D. Vankar, M. Arvanaghi, *Synthesis* **1980** (2), 141–142;
The correct name for compound **4** is ***N*-(Chlorosulfonyl)-dimethylsulfilimine.**

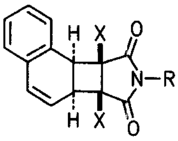
Abstract 5692, *Synthesis* **1980** (2), 159;
The title should be: **Phenols from Aryl Ethyl Ethers.**

Abstract 5698, *Synthesis* **1980** (2) 161;
The title should be: **Enals and Enones from Ketones.**

T. Wagner-Jauregg, *Synthesis* **1980** (3), 165–214;
The structures of compounds **90** (p. 175) should be:



90 (*syn*)



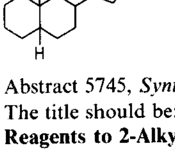
90 (*anti*)

The correct name for compound **251** (p. 188) is **2*H*-Cyclohepta[*gh*]pyrrolizin-Derivat.**

Abstract 5724, *Synthesis* **1980** (3), 254;
The title should be: **Carbamates, Thiocarbamates, and Carbonates from Alcohols or Thiols.**
The first line under the formula scheme should be: Y = O, S.

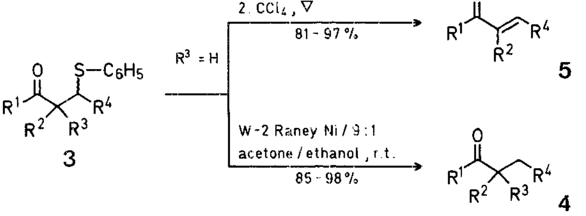
Abstract 5728, *Synthesis* **1980** (3), 256;
The title (and name for compound **3**) should be: ***N*-Sulphenylimines Derived from Amino Acids.**

C. R. Harrison, P. Hodge, *Synthesis* **1980** (4), 299–301;
The 3rd group in the Table, part B (p. 300) should have the structure:



Abstract 5745, *Synthesis* **1980** (4), 334;
The title should be: **Stereocontrolled *cis*-Addition of Organocopper Reagents to 2-Alkynals, 1-Alkynyl Ketones, 2-Alkynoic Acids, and 2-Alkynoic Esters.**

Abstract 5752, *Synthesis* **1980** (4), 336;
The title should be: **α-Alkylation and α-Alkylidenation of Carbonyl Compounds.**
The formula scheme for the conversion **3**→**4** or **5** should be:



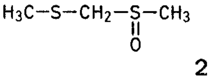
$R^4 = CH_3, i\text{-}C_3H_7, t\text{-}C_4H_9$.

Abstract 5770, *Synthesis* **1980** (4), 342;
The title should be: **Claisen Rearrangement of Ketene Allyl Ethyl Acetals.**

M. A. Alkhader, R. K. Smalley, B. Mohajerani, *Synthesis* **1980** (5), 381–383;
The correct name for compound **6** is **Indazolo[3,2-*b*]naphtho[2,3-*d*]-[1,3] oxazin-6-one.**

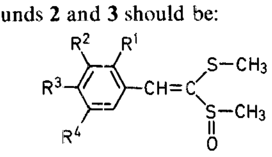
Abstract 5782, *Synthesis* **1980** (5), 418;
The formula scheme should be:

Abstract 5799, *Synthesis* **1980** (5), 424;
The structures of compounds **2** and **3** should be:



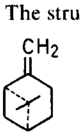
$H_3C{-}S{-}CH_2{-}\underset{\underset{O}{\|}}{S}{-}CH_3$

2



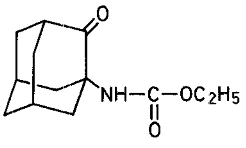
3

L. M. Harwood, M. Julia, *Synthesis* **1980** (6), 456–457;
The structure of compound (−)-**7** should be:



(−)-**7**

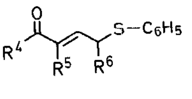
T. Sasaki, S. Eguchi, T. Okano, *Synthesis* **1980** (6), 472–475;
The structure of compound **5** should be:



5

Abstract 5804, *Synthesis* **1980** (6), 498;
The title should be: **Allylic Funtionalisation of Exomethylene Compounds.**

Abstract 5817, *Synthesis* **1980** (6), 503;
The structure of compound **5** should be:



5