J. Org. Chem. **1999,** *64,* 4509−4511

Trimethylsilylnitrate−Chromium Trioxide and Trimethylsilylnitrate−DMSO: Novel Reagent Systems for One Step Conversion of Olefins into α-Nitro Ketones and Cyclic Ethers into Lactones[1]

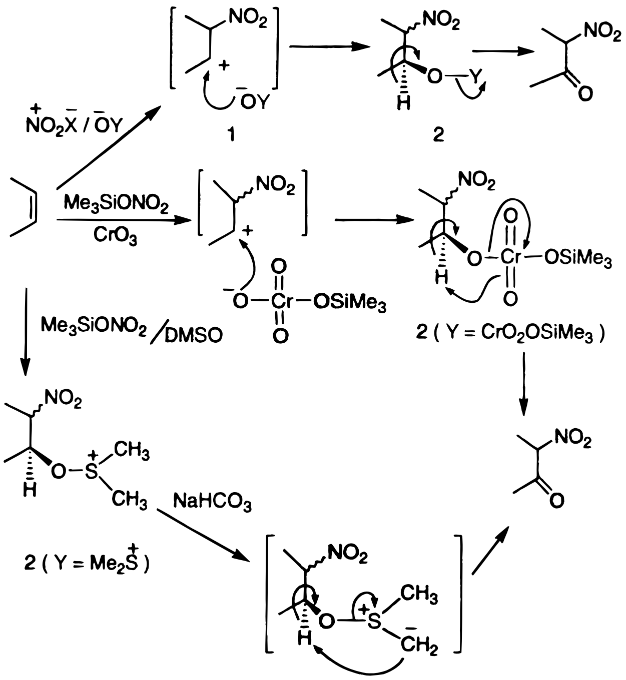
Shatrughan P. Shahi, Anuradha Gupta,
Sangeeta V. Pitre, M. Venkat Ram Reddy,
R. Kumareswaran, and Yashwant D. Vankar*

Department of Chemistry, Indian Institute of Technology, Kanpur 208 016, India

Received January 29, 1998

α-Nitro ketones are useful intermediates in organic synthesis.[2] This is mainly because the proton α to the nitro group is fairly acidic and can be easily removed under mild conditions, thus permitting C−C bond formation.[3] After C−C bond formation, the nitro group can be reductively[4] removed using *n*-Bu_3SnH, thereby leading to the formation of nitro-free compounds. On the other hand, the NO_2 group can either be converted into an amino functionality[5] by reduction or to a carbonyl group via the well-known Nef reaction.[5,6] Additionally, the original keto group of an α-nitro ketone can also be transformed into a variety of other functional groups. As a result, several approaches toward the preparation of these intermediates have been reported.[7] Some of the most commonly employed methods to prepare cyclic α-nitro ketones involve treatment of an enol acetate, a potassium enolate, or an enol silyl ether with nitric acid,[8] pentyl nitrate,[9] or nitronium tetrafluoroborate,[10] respectively. Reaction of an enol acetate with trifluoroacetic anhydride and ammonium nitrate has been found[11] to be a better alternative over nitric acid, with improved yields and milder reaction conditions. Recently, Kochi et al.,[12] during studies related to electron transfer processes, found that tetranitromethane reacts readily with enol silyl ethers to form the corresponding α-nitro ketones. Olefins also are known to react with dinitrogen tetroxide in the presence of oxygen to yield α-nitro ketones.[13] Oxidation of nitroaldols[14] and C-acylation of nitroalkanes[15] are generally utilized for the synthesis of acyclic α-nitro ketones. Although these methods are useful, there is still a need for newer, general approaches for the preparation of acyclic as well as cyclic α-nitro ketones, particularly from olefins. Recently, in a preliminary communication, we have reported[16] a new reagent system comprised of trimethylsilylnitrate−chromium trioxide for converting cyclic as well as acyclic olefins into the corresponding α-nitro ketones. In this paper, we wish to report the details of our studies using this reagent system, as well as its modifications and scope.

Scheme 1



It was expected that when a nitronium ion (NO_2^+ X^-) in conjunction with an oxidant (OY^-) comes in contact with an olefin, electrophilic addition[17] would result in an intermediate such as **2** (Scheme 1), leading to an α-nitro ketone. The OY portion of the intermediate **2** is crucial: Y must act as a leaving group. Toward this end, we considered an OY portion derived from chromium-[18] or sulfur-based[19] reagents so that intermediates analogous to the ones involved in chromium-based[18] or Moffat-type[19b] oxidations of alcohols would be formed. Thus, Me_3SiONO_2 (prepared[20] in situ from $AgNO_3$ and $ClSiMe_3$) was reacted with chromium trioxide hoping to form a

---

[1] Chemistry of Nitro Compounds. 9. Part 8: Gupta, A.; Haque, A. Vankar, Y. D. *J. Chem. Soc., Chem. Commun.* **1996**, 1653.

[2] (a) Fischer, R. H.; Weitz, H. M. *Synthesis* **1980**, 261. (b) Ono, N.; Kaji, A. *Synthesis* **1986**, 693. (c) Rosini, G.; Ballini, R. *Synthesis* **1988**, 833. (d) Rosini, G.; Ballini, R.; Petrini, M.; Marotta, E.; Righi, P. *Org. Prep. Proced. Int.* **1990**, *22,* 707.

[3] (a) Stach, H.; Hesse, M. *Helv. Chim. Acta* **1986**, *69,* 1614. (b) Ono, N.; Hamamoto, I.; Kaji, A. *J. Org. Chem.* **1986**, *51,* 2832.

[4] (a) Tamura, R.; Kamimura, A.; Ono, N. *Synthesis* **1991**, 423. (b) Chen, Y.-J.; Lin, W.-Y. *Tetrahedron Lett.* **1992**, 33, 1749. (c) Feuer, H.; Nielson, A. T. *Nitro Compounds*; VCH Verlagsgesellschaft mbH: Weinheim, Germany 1990.

[5] Seebach, D.; Colvin, E. W.; Lehr, F.; Teller, W. *Chimia* **1979**, *33,* 1.

[6] Larock, R. C. *Comprehensive Organic Transformations*; VCH: New York, 1989; p 603.

[7] (a) Cushman, M.; Mathew, J. *Synthesis* **1982**, 397. (b) Ashwell, M. A.; Jackson, R. F. W. *Synthesis* **1988**, 229. (c) Rene, L.; Royer, R. *Synthesis* **1988**, 878.

[8] Elfehail, F.; Dampawan, P.; Zazac, W. W., Jr. *Synth. Commun.* **1984**, *10,* 929.

[9] Elfehail, F.; Zazac, W. W., Jr. *J. Org. Chem.* **1966**, *31,* 3152.

[10] Shvarts, I. S. *Izv. Akad. Nauk SSSR, Ser Kim.* **1976**, 1674; *Chem. Abstr.* **1976**, *85,* 176926.

[11] Dampawan, P.; Zazac, W. W., Jr. *Synthesis* **1983**, 545.

[12] Rathore, R.; Lin, Z.; Kochi, J. K. *Tetrahedron Lett.* **1993**, *34,* 1859.

[13] Yamada, S.; Sasak, H.; Tanaka, T. Toyo Soda Man Co. *German Auslegeschrift (DAS) 2*, 2210, 344, 1974; *Chem. Abstr.* **1973**, *78,* 4737.

[14] Rosini, G.; Ballini, R.; Sorrenti, P.; Petrini, M. *Synthesis* **1984**, 607 and references therein.

[15] Ono, N.; Fuji, M.; Kaji, A. *Synthesis* **1987**, 532.

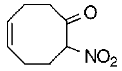
[16] Reddy, M. V. R.; Kumareswaran, R.; Vankar, Y. D. *Tetrahedron Lett.* **1995**, *36,* 7149.

[17] Electrophilic nitration of olefins has been reported using acetyl (and trifluroacetyl) nitrate. See: Kogan T. P.; Gaeta, F. C. A. *Synthesis* **1988**, 706. Bloom, J. A.; Mellor, J. M. *Tetrahedron Lett.* **1986**, *27,* 873. Holzapfel, C. W.; van der Merwe, T. L. *Tetrahedron Lett.* **1996**, *37,* 2307.

[18] Smith, M. B. *Organic Synthesis*; McGraw-Hill International Editions, New York, 1994; p 223 and references therein.

10.1021/jo980167z CCC: $18.00

Table 1. Conversion of Olefins into α-Nitro Ketones with Me_3SiONO_2−CrO_3 or Me_3SiONO_2−DMSO Reagent Systems

			Me_3SiONO_2/CrO_3		Me_3SiONO_2/DMSO	
entry	olefin	α-nitro ketone	yield (%)	time (h)	yield (%)	time (h)
1	cyclopentene	2-nitrocyclopentanone[24a]	27	24		*a*
2	cyclohexene	2-nitrocyclohexanone[24b]	61	24	70	3
3	cycloheptene	2-nitrocycloheptanone[24b]	70	24	73	3
4	cyclooctene	2-nitrocyclooctanone[24a]	65	24	45	6
5	cyclododecene	2-nitrocyclododeca-none[24b]	72	24	64	5
6	1-hexene	1-nitro-2-hexanone[24c]	88	24	68	6
7	1-octene	1-nitro-2-octanone[24d]	70	24	52	10[a]
8	2-octene	2-nitro-3-octanone[24e] + 3-nitro-2-octanone	60[b]	24		*a*
9	1-dodecene	1-nitro-2-dodecanone[24f]	94	20	65	6
10	1-tridecene	1-nitro-2-tridecanone	81	20	72	8
11	α-methylstyrene	α-nitro-2-phenyl-2-ethanone[7b]	76	10		*a*
12	trans-stilbene	1-nitro-1,2-diphenyl-2-ethanone[24g]	76[c]	10		*a*
13	1,2-dimethylstyrene	acetophenone + nitroethane				*a*
14	1,5-cyclooctadiene		45	2		*a*

[a] No reaction occurred. [b] 1:1 ratio of the two nitro ketones was formed that could not be separated. [c] A small amount (7%) of benzaldehyde was formed in this reaction.

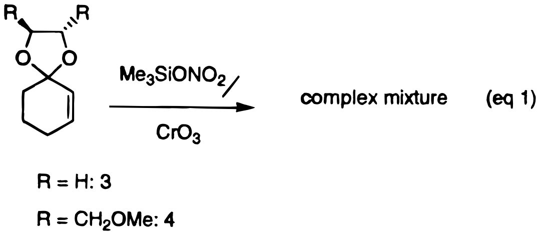
species $NO_2OCrO_2SiMe_3$, which can function both as a source of $^+NO_2$ as well as the oxidant $^-OCrO_2OSiMe_3$.

When olefins are reacted with this species, intermediate **2** (Y = CrO_2OSiMe_3, Scheme 1) should form, eventually to result in the corresponding α-nitro ketone. It is, however, possible that the intermediate **2** forms via a radical pathway,[21] akin to N_2O_4[22] or NO_2Cl[23] addition to olefins.

In practice, a variety of cyclic disubstituted as well as acyclic mono- and disubstituted olefins react with this reagent system to yield α-nitro ketones in good to excellent yields (Table 1). Among cyclic olefins, cyclopentene gave a relatively poor yield (27%) of α-nitrocyclopentanone.[24a] The reaction exhibits remarkable Markovnikov-like regioselectivity with terminal olefins, giving the α-nitro ketones exclusively (entries 6, 7, 9, and 10). Unfortunately, the reaction leads to C−C bond cleavage with trisubstituted olefins[25] (entry 13), and with unsymmetrical internal olefins no regioselectivity is observed (entry 8). It is, therefore, clear that the reaction is most suitable for terminal olefins and symmetric cyclic olefins unsubstituted at the double bond.

The success of this reagent system led us to explore the use of DMSO as an oxidant. It was expected that a Kornblum-type[19b] intermediate **2** (Y = $^+SMe_2$) should form, which under basic conditions would give an α-nitro ketone. Thus, the reagent system Me_3SiONO_2−DMSO readily reacted with several olefins (Table 1) to give the corresponding α-nitro ketones in fair yields (45−73%). Unfortunately there was no reaction with cyclopentene, 2-octene, *β*-methylstyrene, stilbene, 1,2-dimethylstyrene, and 1,5-cyclooctadiene possibly due to lower nucleophilicity of DMSO (Table 1). On the other hand, regioselectivity was similar to that found with the Me_3SiONO_2−CrO_3 reagent. These results clearly indicate that these new reagent systems are excellent in situ sources of $^+NO_2$ associated with chromium- and sulfur-based oxidants. They are convenient to handle and are useful for both cyclic as well as acyclic olefins. We anticipate that these reagent systems will find application[26] in organic synthesis.

To further explore the scope of these reagent systems, we reacted them with olefinic acetals **3** and **4** (eq 1).[27]



Neither of these compounds gave a clean product, though the IR spectra of the crude reaction mixtures indicated a lactone group instead of the expected NO_2 group. This led us to explore the possibility of converting cyclic ethers

---

(19) (a) This intermediate **2** (Y = $^+SMe_2$) is similar to the one obtained in Moffat oxidation (see: Pftitzner, K. E.; Moffatt, J. G. *J. Am. Chem. Soc.* **1965**, *87*, 5661. Moffatt, J. G. In *Oxidation*; Augustine, R. L., Trecker, D. J., Eds.; Marcell Dekker: New York, 1971; Vol. 2, p 12) or Swern oxidation (Mancuso, A. J.; Huang, S.-L.; Swern, D. *J. Org. Chem.* **1978**, *43*, 2480) of alcohols. (b) Replacement of a halide, tosylate, or mesylate by DMSO was originally reported by Kornblum involving similar intermediates. See: Kornblum, N.; Jones, W. J.; Anderson, G. J. *J. Am. Chem. Soc.* **1959**, *81*, 4113.

(20) Kimura, M.; Kajita, K.; Onoda, N.; Morosawa, S. *J. Org. Chem.* **1990**, *55*, 4887.

(21) We thank one of the reviewers for pointing out the possibility of radical reactions.

(22) Shechter, H.; Conrad, F.; Daulton, A. I.; Kaplin, R. E. *J. Am. Chem. Soc.* **1952**, *74*, 3052.

(23) Hassner, A.; Kropp, J. E.; Kent, J. E. *J. Org. Chem.* **1969**, *34*, 2628.

(24) (a) It is known in the literature (see: Feuer, H.; Pivawer, P. M. *J. Org. Chem.* **1966**, *31*, 3152 and ref 11 above) that α-nitrocyclopentanone is prone to undergo ring cleavage, and hence, it is not surprising that in the present study we have a low yield of this compound. (b) Bischoff, C.; Schroden, E. *J. Prakt. Chem.* **1972**, *314*, 891. (c) Shvedov, V. I.; Altukhova, L. B.; Ermakov, Yu. I. U.S.S.R. 398,104 (C1. C07C); *Chem. Abstr.* **1976**, *84*, 17980f. (d) Lachowickz, D. R.; Kreuz, K. L. *Am. Chem. Soc., Div. Petrol. Chem*., preprints **1967**, *12*, 85; *Chem. Abstr.* **1967**, 67, 43367a. (e) Ono, N.; Miyake, H.; Fuji, M.; Kaji, A. *Tetrahedron Lett.* **1983**, *24*, 3477. (f) Simmons, T.; Kreuz, K. L. *J. Org. Chem.* **1968**, *33*, 836. (g) Saito, I.; Takami, M.; Konoike, T.; Matsuuro, T. *Bull. Chem. Soc. Jpn.* **1973**, *46*, 3198.

(25) Other trisubstituted olefins such as limonene, α-pinene, and Δ^3-carene gave a complex mixture of products.

(26) Langlois et al. (see: Chassaing, C.; Haudrechy, A.; Langlois, Y. *Synth. Commun.* **1997**, *27*, 61) have made use of the Me_3SiONO_2−CrO_3 reagent system in their studies related to the synthesis of Huperzine A, a *Lycopodium* alkaloid.

(27) Vankar, Y. D.; Bawa, A.; Kumaravel, G. *Tetrahedron* **1991**, *47*, 2027. Vankar, Y. D.; Chaudhuri, N. C. *Synth. Commun.* **1991**, *21*, 885.

(28) (a) Sasidharan, M.; Suresh, S.; Sudalai A. *Tetrahedron Lett.* **1995**, *36*, 9071 and references therein. (b) Smith, A. B.; Scarborough, R. M., Jr. *Synth. Commun.* **1980**, *10*, 205. (c) Booker-Milburn, K. I.; Cowell, J. K. *Tetrahedron Lett.* **1996**, *37*, 2177. (d) Hobbs, P. D.; Magnus, P. D. *J. Am. Chem. Soc.* **1976**, *98*, 4594. (e) Shiori, T.; Ninomiya, K.; Martin, V. S.; Sharpless, K. B. *J. Org. Chem.* **1981**, *46*, 3936.

Scheme 2

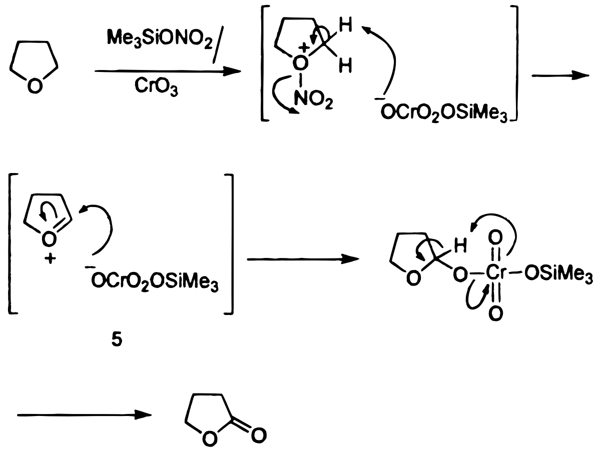
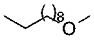
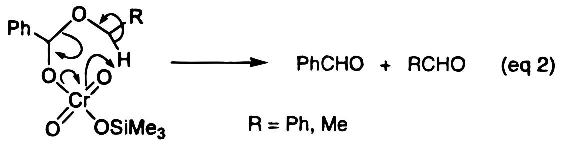


Table 2. Conversion of Cyclic Ethers into Lactones and Cleavage of Benzyl Ethers

entry	ether	product	% yield
1	tetrahydrofuran	γ-butyrolactone	65
2	3,4-dihydro-2*H*-pyran	δ-valerolactone	50
3	1,4-dioxane	2-oxo-1,4-dioxane[31]	52
4	cyclohexanone ethylene acetal	*a*	*a*
5	dibenzyl ether	benzaldehyde	45
6	benzyl methyl ether	benzaldehyde	44
7		*a*	*b*

[a] Complex mixture of products. [b] No reaction.

into lactones.[28] The use of $^+NO_2\ BF_4^-$ for ether cleavage has been reported.[29] We, therefore, believe that with the $TMSONO_2-CrO_3$ reagent system ethers react with the $^+NO_2$ species leading to an intermediate **5**[29] (Scheme 2), which reacts[30] with $^-OCrO_2OSiMe_3$ leading to lactones. Our results are summarized in Table 2. Surprisingly, 3,4-dihydro-2*H*-pyran gave δ-valerolactone. Although there is some precedent[28a] for such a conversion, the exact course of this reaction is not yet clear. Benzyl ethers underwent C–C bond cleavage, a case often encountered[28a,b] in such reactions. It is likely that such a cleavage occurs as shown in eq 2. Under these conditions,



however, ether cleavage does not occur with aliphatic ethers (entry 7). In light of the fact that conversion of cyclic ethers into lactones is an important reaction[28c,d,e] in organic synthesis, we believe that the present reagent system is a useful addition to the various reagents used for such a transformation. The Me_3SiONO_2-DMSO reagent system does not bring about this transformation.

In summary, the new reagent systems $Me_3SiONO_2-CrO_3$ and Me_3SiONO_2-DMSO are useful for converting olefins into α-nitro ketones. The former reagent system is also useful for converting cyclic ethers into lactones and cleaving benzyl ethers.

Experimental Section

Dichloromethane and acetonitrile were distilled from P_2O_5 prior to use. Chlorotrimethylsilane was distilled over CaH_2 and stored over 4 Å molecular sieves. DMSO was stored over activated CaO, distilled, and stored over 4 Å molecular sieves.

General Procedure for Converting Olefins into α-Nitro Ketones using $Me_3SiONO_2-CrO_3$ and Me_3SiONO_2-DMSO Reagent Systems. Using $TMSONO_2$-CrO_3. Silver nitrate (187 mg, 1.1 mmol) was added under N_2 atmosphere at 0 °C to a stirred solution of $ClSiMe_3$ (110 mg, 1 mmol) in 2 mL of dry CH_3CN and the resultant mixture stirred for 1 h. The resulting CH_3CN solution of $TMSONO_2$ was decanted from the precipitated AgCl and was added to a stirred mixture of CrO_3 (150 mg, 1.5 mmol) in 1 mL of CH_3CN. After 15 min, an olefin (1 mmol) dissolved in 1 mL of CH_3CN was added very slowly to this reaction mixture (fast addition led to exothermic and vigorous reaction) with occasional cooling with cold water. After the addition was complete, the reaction mixture was stirred for the time indicated in Table 1. Addition of H_2O followed by usual workup with ether gave crude α-nitro ketones. These were further purified by column chromatography.

Using $TMSONO_2-DMSO$. The acetonitrile solution of Me_3SiONO_2, obtained as described above, was added to a solution of an olefin (1 mmol) in 1 mL of CH_3CN at −10 °C, and the reaction mixture was stirred for 10 min. DMSO (156 mg, 2 mmol) was then added, and the reaction mixture was allowed to warm to room temperature slowly. On completion of the reaction (TLC monitoring), a solution of $NaHCO_3$ (84 mg, 1 mmol) in 3 mL of H_2O was added and the reaction thoroughly extracted with CH_2Cl_2. The combined organic layer was washed with brine solution and dried over anhydrous Na_2SO_4. Evaporation of the solvent afforded the crude α-nitro ketone, which was purified by column chromatography.

The known[7b,24] α-nitro ketones were characterized by comparison with their spectral data.

1-Nitro-2-tridecanone (entry 10, Table 1): mp 84 °C; IR ($CHCl_3$, cm^{-1}) 1550, 1720; ^1H NMR ($CDCl_3$, 60 MHz) δ 0.8–1.5 (m, 21H), 2.2–2.5 (t, $J = 6$ Hz, 2H), 5.18 (s, 2H); MS *m/z* 244 $(M + 1)^+$, 243 (M^+), 197 $(M^+ - 46)$. Anal. Calcd. for $C_{13}H_{25}NO_3$: C, 64.16; H, 10.35; N, 5.76. Found: C, 64.21; H, 10.29; N, 5.81.

2-Nitro-5-cylcoocten-1-one (entry 14, Table 1): thick oil; IR ($CHCl_3$, cm^{-1}) 1535, 1630, 1710; ^1H NMR ($CDCl_3$, 300 MHz) δ 5.68–5.96 (m, 2H), 5.3 (dd, $J = 5.6$ Hz, 1H), 1.78–1.92 (m, 2H), 2.14–2.78 (m, 6H); ^{13}C NMR ($CDCl_3$, 75 MHz) δ 207.4, 130.8, 129.7, 84.7, 43.9, 29.7, 27.3, 21.1; MS *m/z* 139 $(M^+ - 30)$, 127 $(M^+ - 42)$, 97 $(M^+ - 72)$, 81 $(M^+ - 88)$.

General Procedure for the Oxidation of Ethers with $Me_3SiONO_2-CrO_3$ Reagent System. As described above, the mixture of Me_3SiONO_2 and CrO_3 after having been stirred for 15 min was treated dropwise with a solution of an ether (1 mmol) in 1 mL of CH_3CN while the reaction mixture was cooled with ice-cold water. After 24 h of stirring at room temperature, the reaction mixture was filtered through a pad of Celite and washed with dry CH_2Cl_2 and the solvent evaporated to give a crude product that was purified by column chromatography to obtain a pure lactone or benzaldehyde.

These lactones are known compounds and were characterized by IR and ^1H NMR spectral comparisons.

Acknowledgment. We thank the Department of Science and Technology and Council of Scientific and Industrial Research [Grant No. 01(1544)/98/EMR-II], New Delhi, for financial assistance. Two of us (A.G. and S.P.S.) thank the University Grants Commission, New Delhi, for Senior Research Fellowships.

JO980167Z

---

(29) Ho, T.-L.; Olah, G. A. *J. Org. Chem.* **1977**, *42*, 3097.

(30) For addition of nucleophiles to pyrylium salts at poisiton 2, see: Furber, M.; Taylor, R. J. K *J. Chem. Soc., Chem. Commun.* **1985**, 782.

(31) (a) Mitsubishi Petrochemicals Co. Ltd. *Jpn. Kokai Tokkyo Koho JP* 58 99,476 [83 99, 476] (C1. C 07 D 319 112) 1983; *Chem. Abstr.* **1983**, *99*, 158443a. (b) Kronich, I. G.; Dobrovlskii, S. V.; Nikolaev, Yu. T.; Shikunov, B. I.; Dyumaev, K. M. (USSR). *Khim. Prom. St. (Moscow)* **1982**, 653; *Chem. Abstr.* **1983**, *98*, 91383q.