Synthesis of Cyclic *N*-Nitrourethanes by the Simultaneous Oxidative Desulfurization and Nitration of Cyclic Thiourethanes

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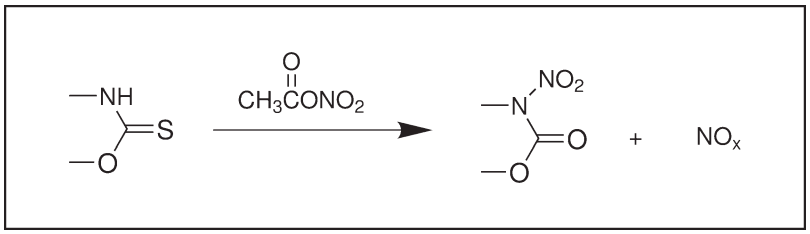

The reaction of five- and six-membered cyclic thiourethanes with acetyl nitrate results in a vigorous reaction that generates copious amounts of red–brown nitrogen oxide fumes and produces the corresponding cyclic *N*-nitrourethanes in high yields (>95%). The overall yield of the cyclic *N*-nitrourethanes starting from an aminoalcohol using the ''thiourethane'' route is superior to the conventional route going through the cyclic urethane.

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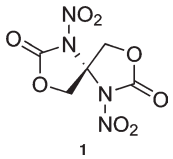
INTRODUCTION

Cyclic *N*-nitrourethanes (*N*-nitrocarbamates) are well known compounds. First reported by Franchimont and Lubin in 1902 [1], they were originally synthesized by the nitration of the corresponding cyclic urethanes with fuming nitric acid. These compounds were extensively studied by White et al. [2] in the mid-1960s, and they introduced the use of acetyl nitrate as the nitrating agent [2]. Modern syntheses of cyclic *N*-nitrourethanes involve reaction of the trimethylsilyl derivatives of the cyclic urethanes with dinitrogen pentoxide in methylene chloride [3]. In the course of our work on energetic compounds, we selected 3,8-dinitro-1,6-dioxa-3,8-diazaspiro[4.4]nonane-2,7-dione, **1**, as a target molecule, because it is calculated to be dense ($d = 1.88$ g/cc) and energetic [4]. Herein we report a new synthetic approach to **1** and related compounds involving simultaneous oxidative desulfurization and nitration of cyclic thiourethanes using acetyl nitrate.



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RESULTS AND DISCUSSION

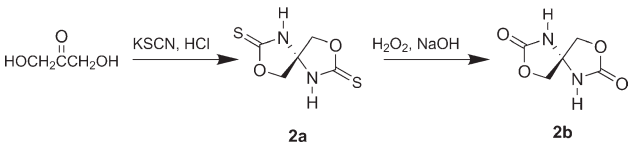
The standard approach to **1** would be nitration of the known 1,6-dioxa-3,8-diazaspiro-[4.4]nonane-2,7-dione [5], **2b**, with acetyl nitrate. Compound **2b** has been synthesized from the analogous spirodithiourethane, **2a**, using basic hydrogen peroxide desulfurization [5] (Scheme 1). The yield for the conversion of **2a** to **2b** is very poor (44%) and the procedure is somewhat lengthy [5].

There is limited literature precedence describing the nitration chemistry of cyclic thiourethanes. Thus, we examined the reaction of **2a** with an acetyl nitrate solution at -10°C as a possible alternative. Surprisingly, a vigorous reaction occurred with the evolution of copious amounts of nitrogen oxides. Upon work-up, the product was identified as the desired spirodinitrourethane, **1**, based on ^{1}H NMR, ^{13}C NMR, FT-IR, and high resolution mass spectroscopy data (Fig. 1). The structure was confirmed by X-ray crystallography [6]. The yield of **1** was greater than 95%.

We examined the scope of this tandem process by studying the reaction of the four monocyclic thiourethanes, **3–6** (Scheme 2), with acetyl nitrate. The cyclic thiourethanes were synthesized using a procedure similar to that reported by Li and Ohtani [7]. Reaction of these four compounds with an acetyl nitrate solution produced high yields (>95%) of the corresponding cyclic *N*-nitrourethanes, **7–10**. Formation of high yields of **10** did require a increase of the reaction temperature to 0°C.

The synthesis of both the monocyclic urethanes and thiourethanes starts from the corresponding aminoalcohols (Scheme 2). Typical yields reported for the synthesis of the five- and six-membered cyclic urethanes from the aminoalcohol and diethyl carbonate range from 40 to 70% [2]. The yields reported by Li and Othani (and

Scheme 1. Synthesis of **2a** and **2b**.



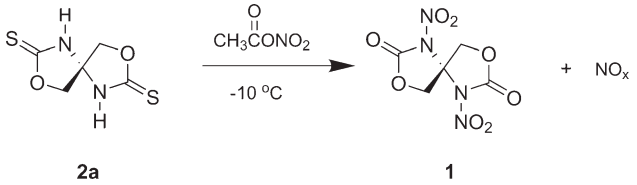


Figure 1. Reaction of **2a** with acetyl nitrate.

confirmed by this work) for the corresponding thiourethanes are in the range of 80–95%. It can be easily seen that the ''thiourethane'' route to the cyclic *N*-nitrourethanes appears to be superior to the ''conventional'' urethane route.

EXPERIMENTAL

Materials. Reagents and all specialty solvents (anhydrous, NMR) were purchased from Aldrich Chemical Co. and used without further purification. Routine solvents were purchased from Fisher Scientific.

Instrumentation. FT-IR spectra were obtained on a Bruker Equinox 55 spectrometer as KBr pellets or films. High resolution mass spectroscopy (HR MS) analyses were conducted at The University of Iowa HRMSF. ^{1}H NMR and ^{13}C NMR spectra were obtained using a Varian Mercury NMR spectrometer operating at a frequency of 300.13 MHz for proton and 75.5 MHz for carbon. DSCs were obtained on a TA Instruments Model Q200 using hermetically sealed Al pans under a nitrogen purge. They were run from ambient to 300°C at 3°C/min.

1,6-Dioxa-3,8-diazaspiro[4.4]nonane-2,7-dithione, 2a. This compound was made by the procedure of Köll and coworkers [5]. The melting point (mp) was 205–206°C (ref. 5; 206°C).

General procedure for 2-thioxo-1,3-*O,N*-heterocycles, 3–6 (cyclic thiourethanes). Modified Li and Ohtani procedure [7]. The 2-aminoalcohol (0.1 mol), triethylamine (0.1 mol), and methanol (100 mL) are placed in a two-neck 250-mL flask equipped with a stir bar [7]. The solution is stirred at 0°C, while carbon disulfide (7.62 g, 0.10 mol) is added dropwise. The solution is stirred at room temperature for 30 min. Hydrogen peroxide (30%, 16–20 mL, 0.15–0.2 mol) is then added at such a rate that reflux of the solvent was observed and until the upper solution of the reaction mixture no longer becomes cloudy by addition of extra hydrogen peroxide. The reaction is cooled to room temperature and then filtered. The methanol and water are removed by reduced pressure. The residue is extracted with methylene chloride (2 × 100 mL). The combined methylene chloride extracts are washed with water (2 × 50 mL) and then dried over $MgSO_4$. The organic layer is filtered and then evaporated to dryness under reduced pressure.

1,3-Oxazolidine-2-thione, 3. The compound was recrystallized from benzene to give colorless crystals, mp 97–98°C (ref. 7; 97–99°C).

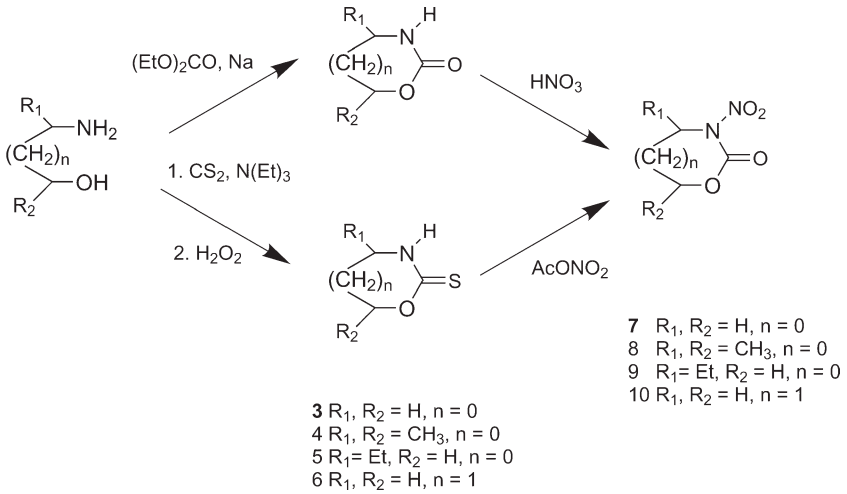
5-Methyl-1,3-oxazolidine-2-thione, 4. The compound was recrystallized from benzene to give colorless crystals, mp 73–74°C (ref. 7; 74.5–75°C).

4-Ethyl-1,3-oxazolidine-2-thione, 5. The compound was recrystallized from water to give colorless crystals, mp 74–75°C (ref. 8; 74–75°C).

Tetrahydro-1,3-oxazine-2-thione, 6. The compound was recrystallized from benzene to give colorless crystals, mp 127–128°C (ref. 7; 128–129°C).

General procedure for the reaction of cyclic thiourethanes with acetyl nitrate. A dry 50-mL round-bottom flask maintained at −10°C (brine/ice bath) and under a nitrogen atmosphere is charged with 4.08 g (4.0 mL) of acetic anhydride. Slow addition of 2.52 g (1.60 mL) of 100% nitric acid forms the acetyl nitrate solution. The temperature is raised to

Scheme 2. Synthesis of cyclic *N*-nitrourethanes via the urethane and thiourethane routes.



10°C for 10 min and then lowered back to −10°C. The cyclic thiourethane (5.0 mmol) is added in two portions, resulting in the immediate generation of a red/brown gas. The reaction is stirred for 1 h and allowed to come to 0°C. The volatiles are removed under high vacuum at room temperature. The crude product is washed with cold distilled water, collected, and dried. The crude products were dissolved in a minimum amount of acetone, filtered, and the acetone allowed to evaporate overnight to give the crystalline product.

In the cases of the liquid compounds (**8** and **9**), the crude compounds were taken up in 20 mL of ethyl acetate and washed with saturated sodium bicarbonate solution until neutral. The ethyl acetate solution was dried over $MgSO_4$, filtered, and the solvent removed to give the compounds.

3,8-Dinitro-1,6-dioxa-3,8-diazaspiro[4.4]nonane-2,7-dione, 1. Caution: This compound calculates to be a moderate explosive [4] and should be handled with due caution until adequate safety data are available! DSC: Strong exothermic decomposition at 187°C.

^{1}H NMR(acetone-d_6): δ = 4.92(d, J = −11.1 Hz, 1H), 5.29(d, J = −11.1Hz, 1H) ppm. ^{13}C NMR(acetone -d_6): δ = 67.27($C_{4,6}$), 76.37(C_5), 145.16($C_{2,7}$) ppm. FT-IR(KBr) = 3048(w), 2986(w), 2915(w), 1836(vs), 1816(vs), 1598(vs), 1471(m), 1407(m), 1392(m), 1319(s), 1277(s), 1245(s), 1200(s), 1184(s), 1164(s), 1130(s), 1118(s), 1097(s), 1067(s), 1054(s), 976(m), 850(m), 828(m), 786(m), 753(m), 729(s), 707(m), 634(m) cm^{-1}. HR MS (EI); $C_5H_4N_4O_8$ $[M]^+$: calcd. 248.0029; found 248.0034 amu.

3-Nitro-1,3-oxazolidine-2-one, 7. The compound was recrystallized from acetone to give colorless crystals, mp 110–111°C (ref. 1; 111°C).

3-Nitro-5-methyl-1,3-oxazolidine-2-one, 8. This compound is a liquid.

^{1}H NMR(CD_3CN): δ = 1.42(d, J = 7.0 Hz, 3H, —CH_3), 3.95(t, J = 7.0 Hz, 1H, H_4), 4.40(t, J = 7.0 Hz, 1H, H_4), 4.78 (hex, J = 7.0 Hz, 1H, H_5) ppm. ^{13}C NMR(CD_3CN): δ = 19.37(CH_3), 51.82(C_4), 70.43(C_5), 148.30(C_2) ppm. FT-IR(film) = 2990(w), 2940(w), 1809 (vs), 1573(vs), 1479(m), 1456(m), 1392(m), 1357(sh), 1337(sh), 1285(s), 1171(s), 1056(s), 955(m), 880(m), 827(m), 727(sh), 742(m) cm^{-1}. HR MS (EI) ; $C_4H_6N_2O_4$: calcd. 146.0328; found 146.0324 amu.

3-Nitro-4-ethyl-1,3-oxazolidine-2-one, 9. This compound is a liquid.

^{1}H NMR(CD_3CN): δ = 0.95(t, J = 7.5 Hz, 3H, —CH_3), 1.85(p, J = 7.5 Hz, 2H, —CH_2) 4.14(dxd, J = 9.0 Hz, J = 7.5 Hz, 1H, H_5), 4.52(t, J = 9.0 Hz, 1H, H_5), 4.69(m, 1H, H_4) ppm.^{13}C NMR(CD_3CN)): δ = 7.67(CH_3), 24.08(CH_2), 57.96(C_4), 66.07(C_5), 149.01(C_2) ppm. FT-IR(film) = 2976(w), 2884(w), 1817(vs), 1577(s), 1285(s), 1262(sh), 1163(s), 1120(sh), 1057(w), 1015(w), 832(m), 760(w), 738(w), 740(sh) cm^{-1}. HR MS (EI); $C_5H_8N_2O_4$: calcd. 160.0484; found 160.0478 amu.

3-Nitro-tetrahydro-1,3-oxazine-2-one, 10. The compound was recrystallized from methanol to give colorless crystals, mp 75–76°C (ref. 1; 75°C).

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