



Synthesis of unsaturated silyl nitronates *via* the silylation of conjugated nitroalkenes

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ABSTRACT

A new method for the synthesis of conjugated silyl nitronates from nitroalkenes is described. The procedure has wide substrate scope and is compatible with *in situ* generation of the substrates from 2-nitroalcohols or 2-chloro-nitroalkanes. A cascade transformation to give 3,4,5,6-tetrahydropyridine *N*-oxide derivatives was disclosed.

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Silyl nitronates are well-known intermediates in organic synthesis [1], which are widely used as 1,3-dipoles for cycloadditions [2] and as precursors to functionalized nitro compounds [3] and carbonyl compounds (Scheme 1) [4]. However, silyl nitronates **1** possessing conjugated C=N and C=C double bonds are nearly unknown. Such conjugation could open the way to new transformations, in the same manner that α,β -unsaturated carbonyl compounds show wider chemistry than saturated ones. Usually, silyl nitronates are obtained by the silylation of aliphatic nitro compounds. Thus, the scarce literature examples for the synthesis of nitronates **1** rely on the use of 3-nitro-1-propene derivatives, *i.e.* β,γ -unsaturated nitro compounds **2** (Scheme 2) [2d,e,5]. Examples of the silylation of conjugated nitroalkenes **3** are even rarer [6]. However, in many cases nitronates **1** were generated *in situ* and used without isolation. [5b–f,6] Moreover, Seebach and co-workers reported that the simplest unsubstituted conjugated nitronate **1** ($R^1 = R^2 = R^3 = H$, SiAlk₃ = TBS) polymerized upon standing [5a].

Herein, we report the synthesis of nitronates **1** *via* the silylation of conjugated nitroalkenes **3** (Scheme 3). Firstly, typical silylation conditions were employed. Treatment of **3** with the mixture of NEt₃ and trialkylsilyl chloride at ambient temperature gave the

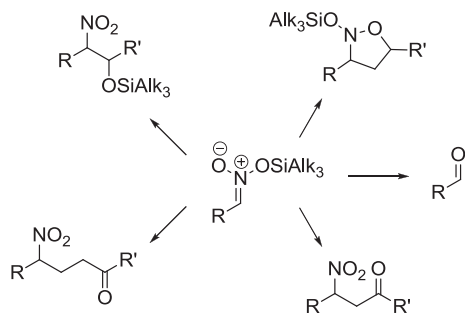
target nitronates **1** [7]. The procedure allowed the synthesis of nitronates **1a–k** possessing various substituents in the α -, β - and γ -positions.

To further expand the scope of the described procedure, silylation was combined with the *in situ* preparation of nitroalkenes **3** (Scheme 4). Indeed, nitroalkenes **3** may often be unstable and prone to anionic oligo/polymerization which reduces the reaction yield [8,9]. Two nitroalkene precursors were chosen. 2-Nitroalcohols **4** are readily available *via* the Henry reaction and undergo elimination when treated with MsCl/NEt₃ [10]. In turn, 2-chloronitroalkanes **5** can be obtained by the chloro-nitration of alkenes [8]. It is noteworthy that in both cases NEt₃ is used for the generation of substrates **1**, which makes it compatible with the presented nitroalkene silylation. Both approaches provided high yields of the target nitronates **1**. Overall, the appropriate precursor of the nitroalkene can be chosen depending on the substituents desired for each particular case.

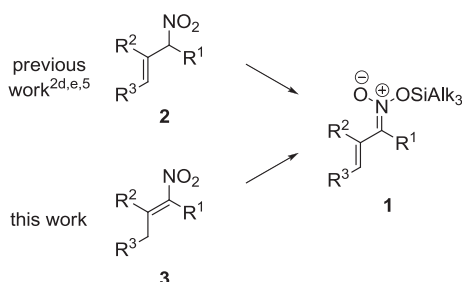
Two mechanisms for the silylation can be proposed (Scheme 5). In path (a) deprotonation of the γ -position of nitroalkene **3** occurs as the first step [11]. Subsequent reaction of the resulting anion **A** with the trialkylsilyl chloride leads to the target nitronates **1**. In path (b), triethylamine acts not only as a base but also as a nucleophilic catalyst [12]. Its addition to the nitroalkene leads to zwitterion **B**. Silylation of **B** and elimination of the amine catalyst ultimately leads to nitronate **1**. In any case, either **A** or **B** is trapped by the trialkylsilyl chloride, thus preventing their interaction with

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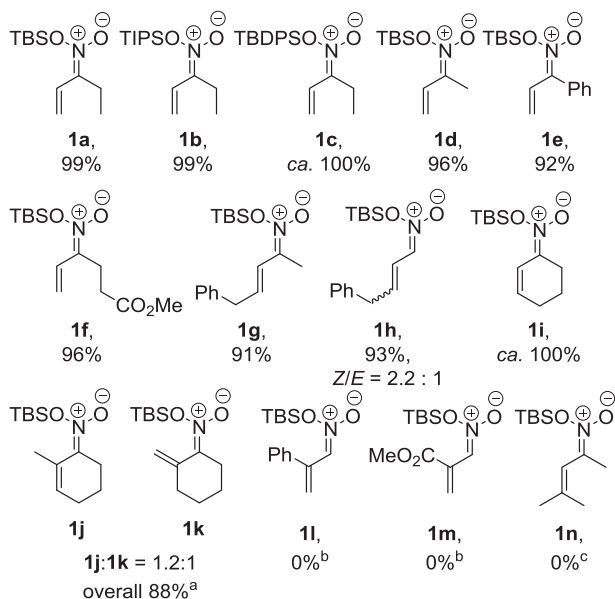
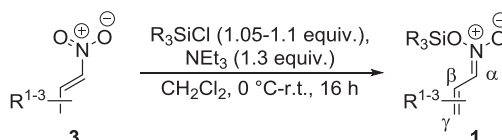
E-mail address: tabolin87@mail.ru (A.A. Tabolin).



Scheme 1. Representative chemistry of silyl nitronates.



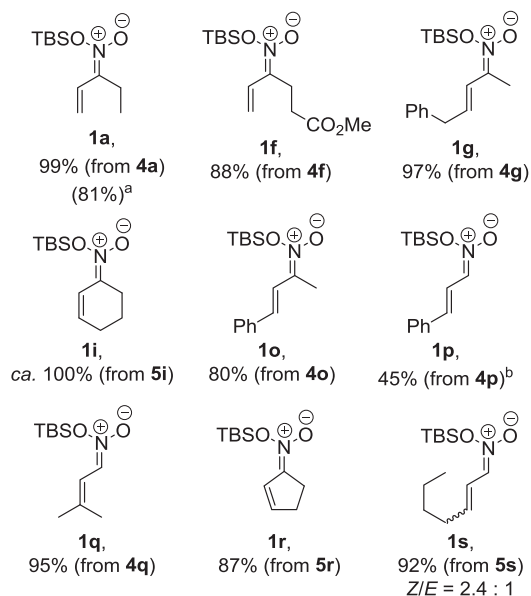
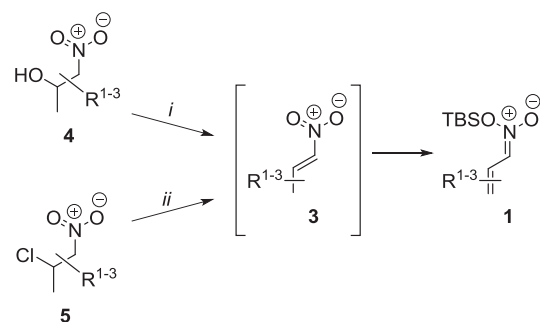
Scheme 2. Two approaches for the synthesis of conjugated silyl nitronates **1**.



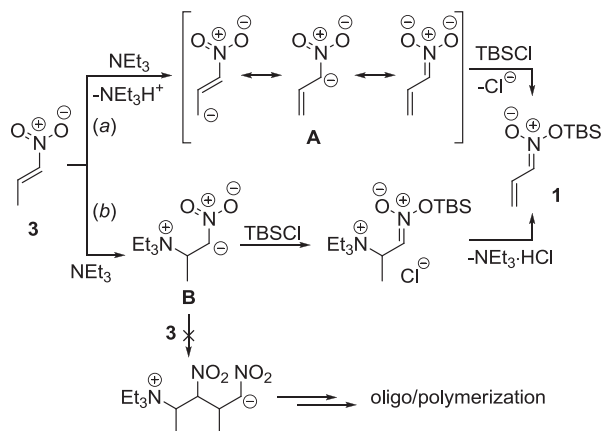
Scheme 3. Synthesis of conjugated silyl nitronates **1** by the silylation of nitroalkenes **3**. ^a72 h; ^bcomplex product mixtures (NMR); ^conly the starting nitroalkene **3n** was observed by ¹H NMR spectroscopy.

another molecule of nitroalkene **3** that propagates oligomerization [12a,b,13].

Nitronates **1** were sufficiently pure after standard work up (dilution with petroleum ether, filtration, evaporation). If desired, they can be distilled *in vacuo*, as was demonstrated for nitronate **1a** (see Scheme 4) with some loss in yield (99% → 81%). The



Scheme 4. One-pot synthesis of conjugated silyl nitronates **1** from nitroalcohols **4** or nitroalkylchlorides **5**. *i*: MsCl (1.1 equiv.), TBSCl (1.05–1.1 equiv.), NEt₃ (3.5 equiv.), CH₂Cl₂, 0 °C-r.t., 16 h; *ii*: TBSCl (1.1 equiv.), NEt₃ (2.2 equiv.), CH₂Cl₂, r.t., 16 h; ^ayield after distillation; ^byield determined by ¹H NMR spectroscopy.



Scheme 5. Proposed mechanism for the formation of nitronates **1**.

structures of the nitronates **1** were confirmed by ¹H and ¹³C NMR spectroscopy, as well as by HRMS data. For nitronates **1h** and **1s** 2D NMR was also used. The regioselectivity for the formation of the C=C double bond was expectedly not high (nitronates **1j** and **1k**). Nitronates **1h** and **1s** possessing a 1,2-disubstituted C=C double bond were obtained as *E,Z*-mixtures. Moderate *Z*-selectivity in these cases is in accordance with the known preferences for the elimination of quaternary ammonium salts

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