# Synthesis and Characterization of Chiral Nitronic Esters via *O*-Alkylation of (4*S**,5*R*)-(+)-4-(1′-Nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone with Alkyl Halides

Fu-An Kang and Cheng-Lie Yin*

*Department of Chemistry, Beijing Normal University, Beijing 100875, PRC*

Shi-Wang She

*Sino-German Joint Institute (Jiangxi-OAI), Jiangxi 330047, PRC*

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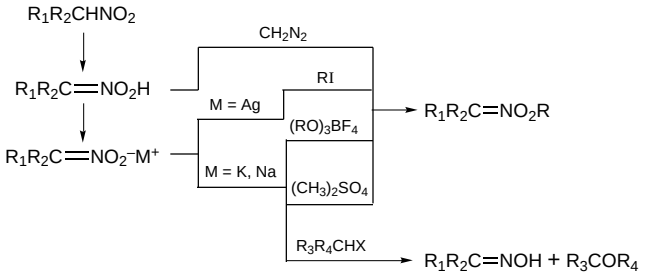
A series of stable and enantiomerically pure alkyl nitronic esters are synthesized in good to excellent yields via *O*-alkylation of (4*S**,5*R*)-(+)-4-(1′-nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (**4a**) with alkyl halides in the presence of $K_2CO_3$ and DMF at room temperature. Thus, nitronic esters are obtained for the first time from the alkali metal salt of a nitro compound and various alkyl halides, which refutes the traditionally held view that the reaction of alkyl halides with alkali metal derivatives of nitro compounds gives a carbonyl compound and an oxime, rather than a nitronic ester. Secondary alkyl nitronic esters are found to partially decompose into *O*-alkyloximes. The configurations of the nitronic esters and *O*-alkyloximes were assigned to be *Z* on the basis of the NOE experiments. The synthesis of the nitro furanone **4a** and its enolization to form a six-membered intramolecular hydrogen bond structure are described.

## Introduction

Nitronic esters are a relatively little studied group of compounds formally derived from *aci*-nitro compounds (or nitronic acids). Nitronic esters have been obtained mainly by three methods: (1) reaction of nitro compounds that are comparatively strong acids with diazomethane,[1] (2) treatment of the silver salts of nitro compounds with alkyl iodides,[2] utility being strained due to the observed instability of these silver salts,[3] and (3) alkylation of the alkali metal salts of nitro compounds with trialkyloxonium fluoroborates[4] and dimethyl sulfate[1a,5] (Scheme 1). In addition, two special approaches are used for the preparation of nitronic esters from 2,6-di-*tert*-butyl-4-nitro phenol[6] and trinitro methyl iodide.[7]

Given the scarcity of silver and the inconvenience of using diazomethane, trialkyloxonium fluoroborates, and dimethyl sulfate, it seems ideal to prepare nitronic esters from alkali metal salts of nitro compounds and alkyl halides. The application of alkyl halides to this alkylation has thus been a matter of considerable research. Unfortunately, it seems that all of the attempts have failed to produce a nitronic ester but rather gave an oxime and a carbonyl compound,[8] or a *C*-alkylated product.[9] Indeed, this is a widely accepted method for the synthesis of aldehydes and ketones[10] (Scheme 1).

**Scheme 1**[a]




[a] $R_1$, $R_2$, $R_3$, $R_4$ = H, alkyl, aryl.

Recently, during the study of an asymmetric synthesis of a natural product, we synthesized a key intermediate, the nitro furanone **4a**, which is obtained by a three-step procedure from furfural (Scheme 2).

In an attempt to obtain a chiral nitro compound (*C*-alkylated product), we treated **4a** with 1-bromobutane in the presence of $K_2CO_3$ and DMF. A white crystalline substance was eventually afforded, which to our surprise was not the expected tertiary nitro compound but was characterized as a butyl nitronic ester of **4a** (*O*-alkylated product) by its IR, $^1$H NMR, $^{13}$C NMR spectra and elemental analysis (Figure 1).

We thus obtained an enantiomerically pure nitronic ester, which was the first example of a nitronic ester produced via *O*-alkylation of the alkali metal salt of a nitro compound with an alkyl halide. Subsequently, we prepared a series of chiral nitronic esters of **4a**. The yields ranged between 63 and 96% (Table 1).

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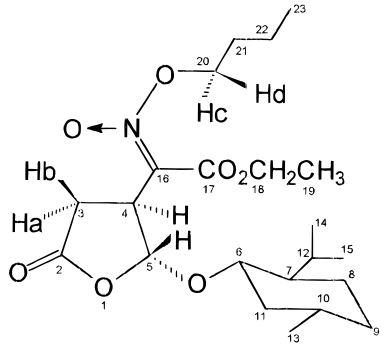

**Figure 1.**

**Table 1**

| nitronic ester | alkyl halide | time,[a] d | yield,[b] % | config[c] |
|---|---|---|---|---|
| **6a** | $CH_3I$ | 1.5 | 96 | *Z* |
| **6b** | $C_2H_5I$ | 2 | 96 | *Z* |
| **6c** | *n*-$C_3H_7Br$ | 2 | 85 | *Z* |
| **6d** | *n*-$C_4H_9Br$ | 2 | 74 | *Z* |
| **6e** | $C_6H_5CH_2Cl$ | 2.5 | 86 | *Z* |
| **6f** | *n*-$C_9H_{19}Br$ | 4 | 72 | *Z* |
| **6g** | *n*-$C_{12}H_{25}Br$ | 3.5 | 70 | *Z* |
| **6h** | c-$C_5H_9Br$ | 2.5 | 66 | *Z* |
| **6i** | c-$C_6H_{11}Br$ | 5 | 63 | *Z* |
| **7a**[d] | c-$C_5H_9Br$ | 2.5 | 12 | *Z* |
| **7b**[d] | c-$C_6H_{11}Br$ | 5 | 6 | *Z* |

[a] Reaction was generally run once and no optimization was made. [b] Isolated yield. [c] On the basis of the NOE experiments. [d] *O*-Alkyloxime.

## Results and Discussion

5-Hydroxy-2(5*H*)-furanone (**2**) was readily prepared by sensitized photo-oxidation of furfural.[12] By employing (−)-menthol as a chiral auxiliary, 5-[(1*R*)-menthyloxy]-2(5*H*)-furanone (**3**) was formed via esterification.[11] It was a mixture of two diastereoisomers, **3a** and **3b** (60:40 ratio). Crystalline, enantiomerically pure **3a** was obtained after three recrystallizations from light petroleum ether (30−60 °C), and its absolute configuration at the acetal center has been assigned to be *R* on the basis of X-ray analysis.[11b]

The nitro furanone **4a** was successfully synthesized via Michael addition to the furanone **3a** by ethyl nitroacetate. On the basis of the fact that **3a** underwent $\pi$-face selective cycloadditions with a variety of dienes,[11] nitrones, nitrile oxides, and azides[13] and Michael additions with such Michael donors as amines and mercaptans,[14] we deduced that a similar enantioselective Michael addition resulting in an asymmetric carbon−carbon bond formation also took place here. This was confirmed by the $^1$H NMR and $^{13}$C NMR spectra. A six-membered intramolecular hydrogen bond structure (or a chelating nitronic acid) was inferred by characteristic spectroscopic data such as IR 3225 cm$^{-1}$ (O−H), 1680 cm$^{-1}$ (C═O), and 1635 cm$^{-1}$ (C═N) and $^1$H NMR 9.70 ppm (O−H). It was soon found that the state and structure of the Michael adduct depended on the method of workup. When the reaction mixture was extracted with a solvent, a colored polar oil of **4b**[15] was ultimately obtained. However, when it was quenched with ice and water, a white solid of the completely enolized isomer **4a** was isolated. It was also observed that **4a** spontaneously reverted to **4b** when it was left in a solvent for a period of time.[16]

In the presence of $K_2CO_3$, **4a** was converted to the potassium nitronate **5**; then a nucleophilic substitution occurred when **5** was treated with RX, yielding the nitronic ester **6**, whose IR spectrum as compared to that of **4a** showed a strong absorption at 1640 cm$^{-1}$ (C═N), with the absence of the absorption at 3225 cm$^{-1}$ (O−H) (Scheme 3). During the course of the reaction and after the workup, we noticed that there were in fact two close spots on our TLC plates, with the upper spot being moderately weak for secondary alkyl nitronic esters (**6h** and **6i**) and very weak for primary alkyl nitronic esters (**6a**−**g**). Careful column chromatography of crude **6h** and **6i** gave a colorless oil as the first species and white crystals as the second species, while recrystallization of crude **6a**−**g** afforded white crystals. The purity of the products was demonstrated by TLC. The crystalline nitronic esters **6** gave a satisfactory elemental analysis and $^1$H NMR and $^{13}$C NMR data consistent with their structures. The carbon of nitronate was first observed to resonate at *ca*. 103 ppm. In principle, two stereoisomers could be obtained considering the resonance of the nitronate anion **5**, upon attack by RX. Indeed, stereoisomerism in nitronic esters has been noticed previously,[4] but the designation of the two isomers could not be made. The configuration of the nitronic esters obtained herein was confirmed to be *Z* by means of NOE experiments. In the case of cyclohexyl nitronic ester **6i**, when irradiated at the frequency of the $C_{18}$ methylene proton signal ($\delta$ 4.33), a notable NOE decrease (16%) was observed in the $H_{20}$ signal ($\delta$ 5.19). On the other hand, irradiation of the $H_{20}$ frequency showed an NOE decrease (18%) of the $C_{18}$ methylene proton signal and NOE enhancement (6%) of the $C_{19}$ methyl proton signal ($\delta$ 1.35).

The reason that the nitronic esters **6** were obtained exclusively as *Z* stereoisomers is probably that there is a considerable difference in the chemical surroundings in which the two delocalized N−O bonds of the nitronate anion reside (Scheme 3). Conformational analysis made it clear that the N−O bond *trans* to the carbethoxy is highly blocked by the plane of the furanone ring and the hydrogen atoms linked to it, leaving the other N-O bond to be attacked preferentially by RX.[17]

The oily products mentioned above were at last identified as *O*-alkyloximes **7** by elemental analyses. They probably resulted from the partial decomposition of the nitronic esters, an assumption that is in agreement with previous observations.[18] Although they had $^1$H NMR patterns similar to those of the nitronic esters, a striking difference was seen in their $^{13}$C NMR spectra, where the signal at *ca*. 103 ppm for **4a** and nitronic esters **6** shifted downfield to *ca*. 153 ppm, which just falls in the range (145−165 ppm) for oximes.[19] The configuration of the *O*-alkyloximes **7** was also assigned to be *Z* on the basis of the NOE experiments. In the case of *O*-cyclopentyl-

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(15) In principle, it should be comprised of two stereoisomers and an effort to isolate and characterize them is underway at present.

(16) There seems to be no such an equilibrium of a nitro compound and its enolized isomer in solution since the latter tends spontaneously to tautomerize to the former. Kohler, E. P.; Stone, J. F. *J. Am. Chem. Soc.* **1930**, *52*, 761.

(17) Further evidences including X-ray analysis to strengthen this conclusion are in progress.

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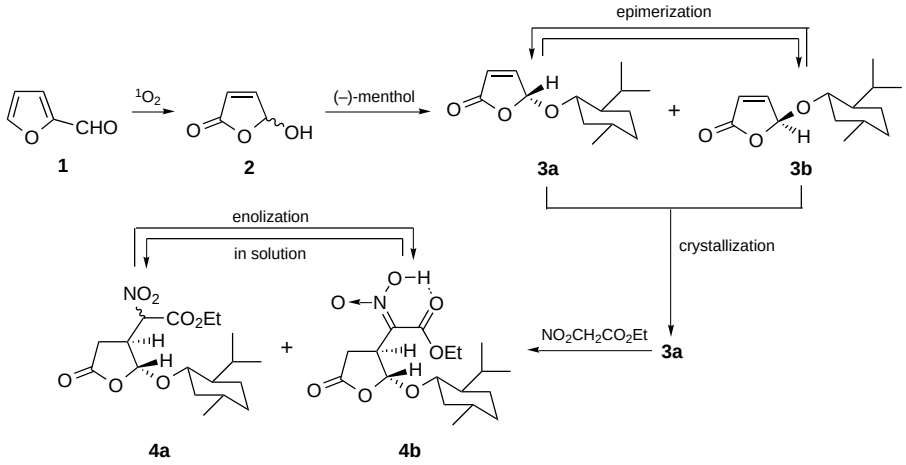
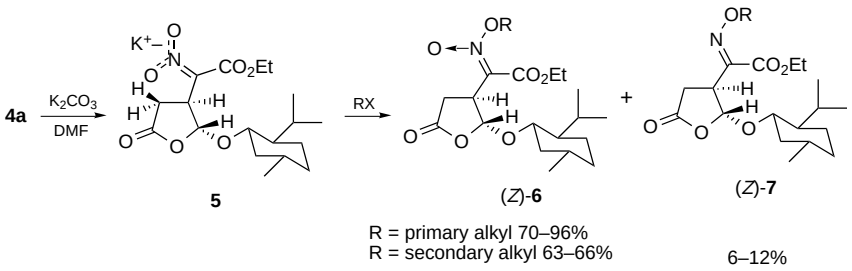
**Scheme 2**




**Scheme 3**




oxime **7a**, upon irradiation at the $C_{18}$ methylene proton frequency ($\delta$ 4.36), notable NOE decrease (33%) was observed in the $H_{20}$ signal ($\delta$ 5.18). On the other hand, irradiation at the $H_{20}$ frequency showed considerable NOE decrease (46%) of the $C_{18}$ methylene proton signal and NOE enhancement (11%) of the $C_{19}$ methyl proton signal ($\delta$ 1.38).

Two geminal couplings at $C_3$ and $C_{20}$ were observed in the $^1$H NMR spectra of most of the nitronic esters **6** and *O*-alkyloximes **7**, with the coupling constants $^2J_{3a,3b}$ = 16.6 Hz and $^2J_{20c,20d}$ = 1.5−2.0 Hz (Figure 1). Interestingly, the small coupling constant characteristic of a *trans* relationship between $H_4$ and $H_5$ varied slightly from J = 0 Hz (for **4a** and nitronic esters **6**) to *J* = 1.8 Hz (for *O*-alkyloximes **7**). Moreover, the signals for the α and α′ carbons of $C_{20}$ in the cycloalkyl nitronic esters (**6h** and **6i**) and the *O*-cycloalkyloximes (**7a** and **7b**) were unusually differentiated at *ca*. 32.6 ppm with 0.08 ppm in between, with a 200 MHz spectrometer, revealing their unequivalent chemical environments.

From the literature,[1,2,4] it is apparent that nitronic esters are usually unstable and there is no defined relationship between structure and stability. Most of the reported nitronic esters decompose within minutes to weeks upon storage at room temperature. Therefore, it is noteworthy that the nitronic esters prepared in the present study showed a remarkable stability. All turned out to be quite stable for prolonged periods at ambient temperature, and it made no difference if they were in pure state or in solution.

In conclusion, using a very mild and versatile procedure, stable chiral alkyl nitronic esters were synthesized for the first time via asymmetric *O*-alkylation of the alkali metal salt of the nitro furanone **4a** with various alkyl halides. *O*-Alkyloximes were obtained as byproducts in concert with the production of secondary alkyl nitronic esters. The molecular structures of the new compounds were assigned and identified by means of NMR analyses and NOE experiments. The carbon signal for nitronate was first observed at *ca*. 103 ppm by $^{13}$C NMR spectroscopy. Application of this methodology to other nitro compounds and the use of the chiral nitronic esters obtained herein in asymmetric synthesis are currently under investigation.

## Experimental Section

**Materials.** All reagents were the best commercial grades available and were not purified further unless otherwise indicated. Ethyl nitroacetate was prepared according to S. Sifniades′ method[20] (bp 78−80°C/6 mmHg, lit.[20] bp 70 °C/1.5 mmHg). $^1$H and $^{13}$C NMR spectra were performed at 200 MHz in $CDCl_3$ with chemical shifts in ppm downfield from TMS and coupling constants (*J*) in hertz. Melting points were measured using a micro melting point apparatus and are uncorrected.

**5-Hydroxy-2(5*H*)-furanone (2).** A solution of freshly distilled furfural (200 mL, 2.4 mol) and rose bengal (5 g, 4.9 mmol) in 95% ethanol (2000 mL) was exposed to a tungsten−iodine lamp for 42 h, with the internal temperature maintained at 25 °C, while oxygen was bubbled through the reaction vessel with effective stirring.[11b,13b] The mixture was concentrated by rotary evaporation to a red residue, which solidified in a freezer to give a light pink solid (164 g, 68%) of **2** that was used directly in the next step. Recrystallization from methanol generated white crystals of **2**: mp 55−56 °C (lit.[12,11b,21,22] mp 49−53, 55, 57.3−59.2, 58−60 °C).

**(*R*)-(−)-5-[(1*R*)-Menthyloxy]-2(5*H*)-furanone (3a).** (1*R*,2*S*,5*R*)-(−)-Menthol (39 g, 0.25 mol) and compound **2** (25 g, 0.25 mol) were added to benzene (170 mL) followed by a drop of concentrated $H_2SO_4$. The resulting mixture was stirred and refluxed for 22 h with continuous removal of water by

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azeotropic distillation.[11b,13b] Removal of solvent gave a residue which solidified on standing. Recrystallization three times from light petroleum ether led to white crystals (33 g, 56%) of **3a**: mp 79.5−80.5 °C (lit.[11b,13b] mp 70.5−70.7, 76−77 °C); $[\alpha]^{25}_{578}$ −139.5° (*c* 1.0, $CHCl_3$) [lit.[11b] $[\alpha]_D$ −136.4° (*c* 1.0, absolute ethanol)]; IR (KBr) 3110, 1795, 1765, 1610 $cm^{-1}$.

**(4*S**,5*R*)-(+)-4-(1′-Nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (4a).** To a well-stirred solution of ethyl nitroacetate (0.6 mL, 5.5 mmol) in DMF (4 mL) was added 2 N NaOEt (0.8 mL). To this white emulsion was then added **3a** (1.2 g, 5 mmol) dissolved in DMF (4 mL). The stirring was continued at rt for 24 h. Soon after the completion of the reaction, the mixture was quenched with ice and water (80 mL) and a white solid was precipitated on standing. Recrystallization from ether and acetone afforded white crystals (1.7 g, 92%) of **4a**: mp 146−147 °C (dec); $[\alpha]^{25}_{578}$ +52.3° (*c* 1.0, $CHCl_3$); IR (KBr) 3225, 1745, 1725, 1680, 1635 $cm^{-1}$; $^1$H NMR $\delta$ 0.71−1.23 (m, 14H), 1.33 (t, 3H, *J* = 7.1), 1.62 (m, 2H), 2.14 (m, 2H), 2.64 (dd, 1H, *J* = 17.4, 11.5), 2.94 (dd, 1H, *J* = 17.4, 3.3), 3.38 (ddd, 1H, *J* = 10.5, 4.3), 3.73 (dd, 1H, *J* = 11.5, 3.3), 4.31 (q, 2H, *J* = 7.1), 5.37 (s, 1H), 9.70 (br s, 1H); $^{13}$C NMR $\delta$ 14.3, 16.1, 21.0, 22.2, 23.1, 25.5, 31.8, 33.0, 34.2, 43.1, 46.9, 48.3, 62.0, 82.3, 103.4, 109.3, 158.7, 176.5. Anal. Calcd for $C_{18}H_{29}NO_7$: C, 58.21; H, 7.87; N, 3.77. Found: C, 57.99; H, 8.15; N, 3.83.

**General Procedure for Preparation of Alkyl Nitronic Esters 6.** Compound **4a** (0.74 g, 2 mmol) and finely ground anhydrous $K_2CO_3$ (0.28 g, 2 mmol) were mixed in DMF (9 mL). To this well-stirred suspension was added an alkyl halide (2 mmol). The progress of the reaction was monitored by TLC. After being stirred at rt for the indicated time, the reaction mixture was dissolved in ether and washed with water and brine and then dried ($Na_2SO_4$). Removal of solvent furnished the corresponding alkyl nitronic ester, which was further purified by recrystallization from light petroleum ether or by column chromatography on silica gel using a mixture of light petroleum ether and ethyl acetate (8:1) as the eluent.

**(*Z*)-(+)-Methyl nitronic ester of (4*S**,5*R*)-4-(1′-nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (6a):** white crystals; mp 93−94 °C; $[\alpha]^{25}_{578}$ +63.8° (*c* 1.0, $CHCl_3$); IR (KBr) 1750, 1725, 1640 $cm^{-1}$; $^1$H NMR $\delta$ 0.78−1.28 (m, 14H), 1.35 (t, 3H, *J* = 7.1), 1.65 (m, 2H), 2.18 (m, 2H), 2.58 (dd, 1H, *J* = 16.6, 11.5), 2.86 (dd, 1H, *J* = 16.6, 3.4), 3.41 (ddd, 1H, *J* = 10.5, 4.2), 3.79 (s, 3H), 3.80 (dd, 1H, *J* = 11.5, 3.4), 4.33 (q, 2H, *J* = 7.1), 5.39 (s, 1H); $^{13}$C NMR $\delta$ 14.2, 16.1, 21.0, 22.1, 23.1, 25.4, 31.6, 33.1, 34.1, 43.0, 47.1, 48.2, 52.1, 61.9, 82.0, 103.2, 109.6, 158.5, 170.4. Anal. Calcd for $C_{19}H_{31}NO_7$: C, 59.22; H, 8.05; N, 3.64. Found: C, 59.04; H, 7.94; N, 3.47.

**(*Z*)-(+)-Ethyl nitronic ester of (4*S**,5*R*)-4-(1′-nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (6b):** white crystals; mp 71.5−72.5 °C; $[\alpha]^{25}_{578}$ +68.0° (*c* 1.0, $CHCl_3$); IR (KBr) 1750, 1725, 1640 $cm^{-1}$; $^1$H NMR $\delta$ 0.77−1.20 (m, 14H), 1.32 (quintet, 6H, *J* = 7.1), 1.66 (m, 2H), 2.16 (m, 2H), 2.55 (dd, 1H, *J* = 16.6, 11.2), 2.83 (dd, 1H, *J* = 16.6, 3.4), 3.41 (ddd, 1H, *J* = 10.7, 4.4), 3.75 (dd, 1H, *J* = 11.2, 3.4), 4.18 (dddd, 2H, *J* = 7.1, 1.5), 4.33 (q, 2H, *J* = 7.1), 5.39 (s, 1H); $^{13}$C NMR $\delta$ 14.1, 14.2, 16.1, 21.0, 22.1, 23.0, 25.4, 31.6, 33.3, 34.1, 43.0, 47.1, 48.1, 61.1, 61.8, 81.9, 103.2, 109.7, 158.5, 170.0. Anal. Calcd for $C_{20}H_{33}NO_7$: C, 60.15; H, 8.27; N, 3.51. Found: C, 60.07; H, 8.01; N, 3.33.

**(*Z*)-(+)-*n*-Propyl nitronic ester of (4*S**,5*R*)-4-(1′-nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (6c):** white crystals; mp 81−82 °C; $[\alpha]^{25}_{578}$ +66.3° (*c* 1.0, $CHCl_3$); IR (KBr) 1750, 1730, 1640 $cm^{-1}$; $^1$H NMR $\delta$ 0.77−1.28 (m, 17H), 1.35 (t, 3H, *J* = 7.1), 1.65 (m, 4H), 2.15 (m, 2H), 2.57 (dd, 1H, *J* = 16.6, 11.2), 2.84 (dd, 1H, *J* = 16.6, 3.4), 3.41 (ddd, 1H, *J* = 10.6, 4.4), 3.74 (dd, 1H, *J* = 11.2, 3.4), 4.08 (ddd, 2H, *J* = 6.8, 1.5), 4.33 (t, 2H, *J* = 7.1), 5.39 (s, 1H); $^{13}$C NMR $\delta$ 10.2, 14.1, 16.0, 20.9, 21.8, 22.0, 22.0, 23.0, 25.4, 31.6, 33.3, 34.1, 43.0, 47.1, 48.1, 61.8, 66.7, 81.9, 103.2, 109.7, 158.5, 170.0. Anal. Calcd for $C_{21}H_{35}NO_7$: C, 61.02; H, 8.47; N, 3.39. Found: C, 61.25; H, 8.61; N, 3.46.

**(*Z*)-(+)-*n*-Butyl nitronic ester of (4*S**,5*R*)-4-(1′-nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (6d):** white crystals; mp 89−90 °C; $[\alpha]^{25}_{578}$ +60.9° (*c* 1.0, $CHCl_3$); IR (KBr) 1760, 1730, 1650 $cm^{-1}$; $^1$H NMR $\delta$ 0.77−1.28 (m, 17H), 1.35 (m, 5H), 1.63 (m, 4H), 2.17 (m, 2H), 2.56 (dd, 1H, *J* = 16.6, 11.2), 2.83 (dd, 1H, *J* = 16.6, 3.6), 3.41 (ddd, 1H, *J* = 10.6, 4.4), 3.75 (dd, 1H, *J* = 11.2, 3.6), 4.12 (ddd, 2H, *J* = 6.6, 1.7), 4.33 (q, 2H, *J* = 7.1), 5.38 (s, 1H); $^{13}$C NMR $\delta$ 13.7, 14.2, 16.1, 19.1, 21.0, 22.1, 23.1, 25.5, 30.6, 31.7, 33.3, 34.1, 43.0, 47.2, 48.2, 61.9, 65.1, 81.9, 103.2, 109.7, 158.6, 170.1. Anal. Calcd for $C_{22}H_{37}NO_7$: C, 61.83; H, 8,67; N, 3.28. Found: C, 61.58; H, 8.66; N, 3.20.

**(*Z*)-(+)-Benzyl nitronic ester of (4*S**,5*R*)-4-(1′-nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (6e):** white crystals; mp 97−98 °C; $[\alpha]^{25}_{578}$ +48.4° (*c* 1.0, $CHCl_3$); IR (KBr) 1755, 1725, 1640 $cm^{-1}$; $^1$H NMR $\delta$ 0.75−1.25 (m, 14H), 1.33 (t, 3H, *J* = 7.1), 1.64 (m, 2H), 2.17 (m, 2H), 2.61 (dd, 1H, *J* = 16.6, 11.0), 2.89 (dd, 1H, *J* = 16.6, 3.4), 3.39 (ddd, 1H, *J* = 10.6, 4.2), 3.78 (dd, 1H, *J* = 11.0, 3.4). 4.31 (q, 2H, *J* = 7.1), 5.16 (d, 2H, *J* = 2.0), 5.39 (s, 1H), 7.36 (s, 5H); $^{13}$C NMR $\delta$ 14.2, 16.1, 21.0, 22.1, 23.1, 25.5, 31.7, 33.3, 34.1, 43.0, 47.2, 48.2, 61.9, 67.0, 82.0, 103.2, 109.7, 128.4, 128.5, 128.7, 135.3, 158.5, 169.9. Anal. Calcd for $C_{25}H_{35}NO_7$: C, 65.08; H, 7.59; N, 3.04. Found: C, 65.05; H, 7.54; N, 2.95.

**(*Z*)-(+)-*n*-Nonyl nitronic ester of (4*S**,5*R*)-4-(1′-nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (6f):** white crystals; mp 54−55 °C; $[\alpha]^{25}_{578}$ +52.5° (*c* 1.0, $CHCl_3$); IR (KBr) 1750, 1730, 1640 $cm^{-1}$; $^1$H NMR $\delta$ 0.77−1.15 (m, 16H), 1.18−1.50 (m, 16H), 1.63 (m, 4H), 2.16 (m, 2H), 2.57 (dd, 1H, *J* = 16.6 11.2), 2.84 (dd, 1H, *J* = 16.6, 3.5), 3.41 (ddd, 1H, *J* = 10.3, 4.2), 3.75 (dd, 1H, *J* = 11.2, 3.5), 4.11 (ddd, 2H, *J* = 6.8, 2.0), 4.33 (q, 2H, *J* = 7.1), 5.39 (s, 1H); $^{13}$C NMR $\delta$ 14.1, 14.2, 16.1, 21.0, 22.1, 22.7, 23.1, 25.5, 25.7, 28.6, 29.2, 29.5, 31.7, 31.9, 33.4, 34.1, 43.0, 47.2, 48.2, 61.9, 65.5, 82.0, 103.3, 109.9, 158.6, 170.2. Anal. Calcd for $C_{27}H_{47}NO_7$: C, 65.19; H, 9.46; N, 2.82. Found: C, 65.06; H, 9.58; N, 2.72.

**(*Z*)-(+)-*n*-Dodecyl nitronic ester of (4*S**,5*R*)-4-(1′-nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (6g):** white crystals; mp 53.5−55.5 °C; $[\alpha]^{25}_{578}$ +49.8° (*c* 1.0, $CHCl_3$); IR (KBr) 1750, 1720, 1635 $cm^{-1}$; $^1$H NMR $\delta$ 0.77−1.00 (m, 17H), 1.00−1.50 (m, 21H), 1.64 (m, 4H), 2.17 (m, 2H), 2.56 (dd, 1H, *J* = 16.6, 11.3), 2.83 (dd, 1H, *J* = 16.6, 3.4), 3.41 (ddd, 1H, *J* = 10.6, 4.4), 3.75 (dd, 1H, *J* = 11.3, 3.4), 4.10 (ddd, 2H, *J* = 6.8, 1.7), 4.33 (q, 2H, *J* = 7.1), 5.39 (s, 1H); $^{13}$C NMR $\delta$ 14.1, 14.2, 16.1, 21.0, 22.1, 22.7, 23.1, 25.4, 25.9, 28.5, 29.2, 29.3, 29.5, 29.6, 29.6, 31.7, 31.9, 33.3, 34.1, 43.0, 47.2, 48.2, 61.8, 65.4, 81.9, 103.2, 109.7, 158.5, 170.1. Anal. Calcd for $C_{30}H_{53}NO_7$: C, 66.79; H, 9.83; N, 2.60. Found: C, 66.57; H, 10.01; N, 2.54.

**(*Z*)-(+)-Cyclopentyl nitronic ester of (4*S**,5*R*)-4-(1′-nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (6h):** white crystals; mp 80−81 °C; $[\alpha]^{25}_{578}$ +65.8° (*c* 1.0, $CHCl_3$); IR (KBr) 1750,1725, 1640 $cm^{-1}$; $^1$H NMR $\delta$ 0.77−1.23 (m, 13H), 1.35 (t, 3H, *J* = 7.1), 1.5−2.0 (m, 13H), 2.16 (m, 2H), 2.56 (dd, 1H, *J* = 16.6, 10.7), 2.76 (dd, 1H, *J* = 16.6, 3.6), 3.41 (ddd, 1H, *J* = 10.6, 4.4), 3.75 (dd, 1H, *J* = 10.7, 3.6), 4.33 (q, 2H, *J* = 7.1), 5.19 (m, 1H), 5.38 (s, 1H); $^{13}$C NMR $\delta$ 14.2, 16.1, 21.0, 22.1, 23.1, 23.7, 25.5, 31.7, 32.6, 32.7, 33.7, 34.1, 43.0, 47.2, 48.2, 61.8, 78.0, 81.9, 103.1, 109.8, 158.6, 169.8. Anal. Calcd for $C_{23}H_{37}NO_7$: C, 62.87; H, 8.43; N, 3.19. Found: C, 62.47; H, 8.13; N, 3.03.

**(*Z*)-(+)-Cyclohexyl nitronic ester of (4*S**,5*R*)-4-(1′-nitro-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (6i):** white crystals; mp 73−75 °C; $[\alpha]^{25}_{578}$ +64.2° (*c* 1.0, $CHCl_3$); IR (KBr) 1750, 1725, 1640 $cm^{-1}$; $^1$H NMR $\delta$ 0.77−1.25 (m, 14H), 1.35 (t, 3H, *J* = 7.1), 1.5−2.0 (m, 12H), 2.17 (m, 2H), 2.56 (dd, 1H, *J* = 16.6, 10.7), 2.78 (dd, 1H, *J* = 16.6, 3.4), 3.42 (ddd, 1H, *J* = 10.6, 4.4), 3.75 (dd, 1H, *J* = 10.7, 3.4), 4.33 (q, 2H, *J* = 7.1), 5.19 (m, 1H), 5.38 (s, 1H); $^{13}$C NMR $\delta$ 14.2, 16.1, 21.0, 22.1, 23.1, 23.7, 25.5, 31.7, 32.6, 32.7, 33.7, 34.1, 43.0, 47.3, 48.2, 61.8, 78.0, 81.9, 103.1, 109.8, 158.6, 169.8. Anal. Calcd for $C_{24}H_{39}NO_7$: C, 63.58; H, 8.61; N, 3.09. Found: C, 63.49; H, 8.33; N, 2.97.

**(*Z*)-(+)-*O*-Cyclopentyloxime of (4*S**,5*R*)-4-(1′-nitroso-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (7a):** a colorless oil; $[\alpha]^{25}_{578}$ +104.0° (*c* 2.18, hexane); IR (neat) 1796, 1724, 1582 $cm^{-1}$; $^1$H NMR $\delta$ 0.65−1.32 (m, 13H), 1.38 (t, 3H, *J* = 7.1), 1.67 (m, 11H), 2.20 (m,

2H), 2.36 (dd, 1H, $J$ = 16.0, 10.8), 2.76 (dd, 1H, $J$ = 16.0, 3.7), 3.45 (ddd, 1H, $J$ = 10.4, 4.2), 3.60 (dddd, 1H, $J$ = 10.8, 3.7, 1.8), 4.36 (q, 2H, $J$ = 7.1), 5.18 (m, 1H), 5.53 (d, 1H, $J$ = 1.8); $^{13}$C NMR $\delta$ 14.0, 16.0, 20.9, 22.0, 23.0, 23.5, 25.3, 31.5, 32.4, 32.5, 32.8, 34.1, 42.8, 48.1, 49.6, 61.9, 77.8, 81.5, 110.6, 153.4, 159.9, 169.7. Anal. Calcd for $C_{23}H_{37}NO_6$: C, 65.25; H, 8.75; N, 3.31. Found: C, 65.65; H, 9.03; N, 3.28.

**(*Z*)-(+)-*O*-Cyclohexyloxime of (4*S**,5*R*)-4-(1′-nitroso-1′-carbethoxymethyl)-5-[(1*R*)-menthyloxy]-3,4-dihydro-2(5*H*)-furanone (7b):** a colorless oil; $[\alpha]^{25}_{578}$ +94.2° (*c* 0.72, hexane); IR (neat) 1795, 1720, 1580 cm$^{-1}$; $^1$H NMR $\delta$ 0.70−1.30 (m, 14H), 1.37 (t, 3H, $J$ = 7.1), 1.71 (m, 12H), 2.19 (m, 2H), 2.36 (dd, 1H, $J$ = 16.0, 10.8), 2.76 (dd, 1H, $J$ = 16.0, 3.7), 3.45 (ddd, 1H, $J$ = 10.6, 4.4), 3.60 (dddd, 1H, $J$ = 10.8, 3.7, 1.8), 4.35 (q, 2H, $J$ = 7.1), 5.18 (m, 1H), 5.53 (d, 1H, $J$ = 1.8); $^{13}$C NMR $\delta$ 14.1, 16.1, 21.0, 22.1, 23.1, 23.6, 25.4, 31.6, 31.8, 32.5, 32.6, 32.9, 34.2, 42.8, 48.2, 49.6, 62.0, 77.9, 81.5, 110.7, 153.5, 160.0, 169.8. Anal. Calcd for $C_{24}H_{39}NO_6$: C, 65.90; H, 8.92; N, 3.20. Found: C, 65.57; H, 9.28; N, 3.15.

**Caution.** Care should be exercised when handling nitronic acids or their salts, for they have been reported to explode when allowed to stand for a period of time or when heated.[10c,23]

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