JOC*Note*

Nitroalkanes in Aqueous Medium as an Efficient and Eco-Friendly Source for the One-Pot Synthesis of 1,4-Diketones, 1,4-Diols, δ-Nitroalkanols, and Hydroxytetrahydrofurans

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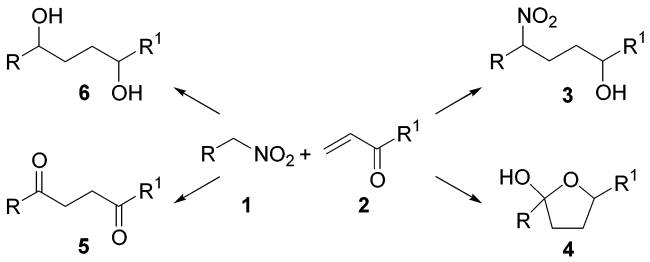
Abstract: The Michael addition of primary aliphatic nitro compounds to α,β-unsaturated enones, performed in aqueous media, provides the one-pot synthesis of 1,4-diketones, 1,4-diols, δ-nitroalkanols, and hydroxytetrahydrofurans, respectively, by the appropriate choice of the reaction conditions.

Aliphatic nitro compounds have proven to be valuable intermediates, and the chemical literature continuously reports progress in their utilization for the synthesis of a variety of target molecules. Moreover, these compounds are very powerful synthetic tools because they facilitate the carbon−carbon bond-forming processes and they can be easily converted into many other functionalities.[1]

The synthesis of complex molecules is traditionally performed by a chain of separate reaction steps, each step requiring its own conditions, reagents, solvent, catalyst, and purification step. Now, environmental and economic pressure are forcing the chemical community to search for more efficient ways of performing chemical transformations, and in this context, a goal in present organic synthesis is to perform more synthetic steps by "one-pot" methods.[2]

Recently, there has been increasing recognition that organic reactions carried out in water may offer advantages over those occurring in organic solvents because water is cheap and safe, it allows a precise control of the pH, and the reactivity and/or the selectivity of the reaction can be dramatically influenced when carried out in water.[3]

SCHEME 1



With the aim to develop more efficient synthetic processes, reduce the number of separate reaction steps, and minimize byproducts, and in continuation with our studies devoted to the chemistry of nitro compounds, we have now found an interesting synergy between nitroalkanes and aqueous medium[4] for the one-pot synthesis (Scheme 1) of the following compounds: (i) δ-nitroalkanols **3**, which have proven to be the key building blocks for the synthesis of tetrahydrofurans and spiroacetals;[5] (ii) hydroxytetrahydrofurans (lactols) **4**, intermediates in the synthesis of cyclic ethers,[6] dihydrofurans,[7] zoapatanol derivatives (the menses and labor-inducing principle of the Mexican plant *Montonoa tormentosa*),[8] and nonactic acid,[9] a component of the macrolide antibiotic nonactin; the hydroxytetrahydrofuran unit is also present in natural products such as *seco*-furoeremophilane derivatives, which are characteristic constituents of the plants of genus *Euryops*;[10] (iii) 1,4-diketones **5**, which are important intermediates in the synthesis of cyclopentenones, furans, pyrroles, thiophenes, and pyridazines;[11−16] and (iv) 1,4-diols **6**, widely used molecules for the preparation of important heterocycles such as γ-lactones, pyrroles, and tetrahydrofurans,[7,17]

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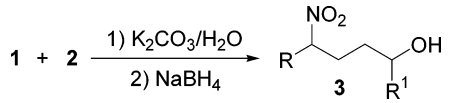
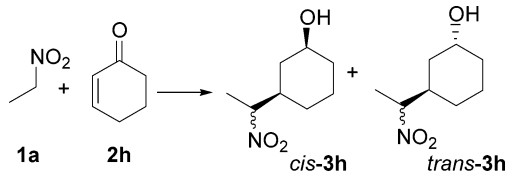
TABLE 1. δ-Nitroalkanols 3 Prepared

3	R	R^1	yield (%)	3	R	R^1	yield (%)
a	Me	Me	82	**e**	Et	Et	82
b	Et	Me	86	**f**	Pr	Et	78
c	Pr	Me	83	**g**	Ph	Et	79
d	Me	Et	94				

SCHEME 2



SCHEME 3



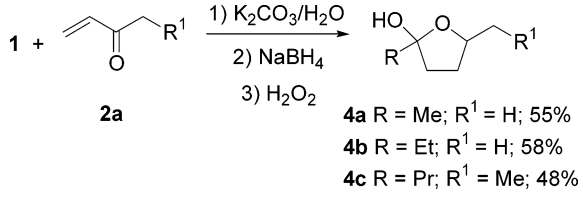
In the past, numerous methods have been reported for the synthesis of the compounds **3**,[18] **4**,[19] **5**,[20] and **6**;[21] however, they need a multistep sequence and most of them suffer from drawbacks such as the use of harsh conditions, employment of expensive chemical, and/or tedious, toxic procedures. Furthermore, no method is general for the synthesis of all these classes of molecules, so that other efficient, eco-friendly sources for their preparation are welcomed.

We have now found that the two- and three-step sequences needed for the preparation of compounds **3**−**6** could be reduced in a one-pot procedure by employing the aqueous medium and starting from nitroalkanes and α,β-unsaturated ketone, using K_2CO_3 and the appropriate combination of oxidative/reductive conditions.

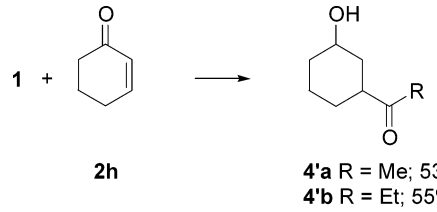
Preparation of δ-Nitroalkanols (3). The preparation of δ-nitroalkanols **3** was achieved in good yields (78−94%, Table 1) by reaction between the nitroalkanes **1** and the unsaturated ketones **2**, followed by in situ reduction with $NaBH_4$ (Scheme 2). The latter was chosen both because it can be used in water and because it does not reduce the nitro group. Another advantage of $NaBH_4$ is the absence of environmental effects of the byproducts (see the safety data sheet of sodium borate at http://msds.ehs.cornell.edu/msdsdoddata.asp).

The nitroalkanols were obtained as a 1:1 diastereoisomeric mixture. In the case of compound **3h** (Scheme 3, 86% yield), two of the four possible diastereomers were isolated. Further transformation of the diatereoisomeric mixture using the modified Nef reaction showed they were the cis and trans diastereoisomers in a 3:1 ratio (see compound **4′a**). On the basis of the NOESY spectrum, the configuration of the carbon bearing the nitro group could not be assigned.

SCHEME 4



SCHEME 5



Preparation of Hydroxytetrahydrofurans (Lactols) (4). Hydroxytetrahydrofurans **4** were obtained by in situ Nef reaction of the corresponding δ-nitroalkanols obtained as reported above, using a 30% water solution of H_2O_2 (Scheme 4). The conversion of a nitro group into a carbonyl can be accomplished by several alternative methods[22] although the use of H_2O_2/K_2CO_3 in a modified Nef reaction[23] appeared to us to be the most compatible with our effort to develop environmentally friendly processes.

The expected γ-hydroxyketones could not be isolated. They spontaneously cyclized to the corresponding lactols **4**, which were isolated as diatereomeric mixtures and identified on the basis of their ^{13}C NMR spectra (signals at about 110−115 ppm corresponding to the hemiketal-C).

When cyclohexenone was used as a Michael acceptor the cyclization could not happen and the expected γ-hydroxyketones **4′** were obtained (Scheme 5) in satisfactory yields. In the case of compound **4′a**,[24] the cis and trans diastereoisomers were isolated in a 3:1 ratio and their configuration was assigned on the basis of the NOESY experiment. For compound **4′b**, only the cis diastereo-

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SCHEME 6

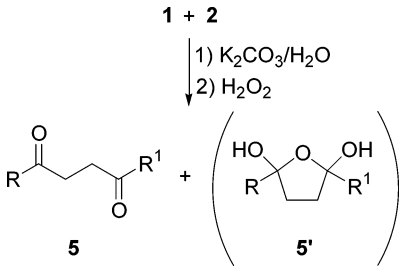

TABLE 2. 1,4-Diketones 5 Prepared

5	R	R^1	yield (%)	5	R	R^1	yield (%)
a[a]	Me	Me	73	**f**[27]	Pr	Et	70
d[25]	Me	Et	68	**i**[28]	Ph	Me	69
e[26]	Et	Et	72				

[a] Compound commercially available.

SCHEME 7

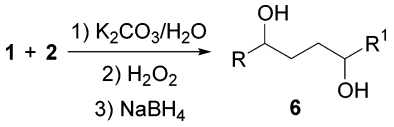

TABLE 3. 1,4-Diols 6 Prepared

6	R	R^1	yield (%)	6	R	R^1	yield (%)
a[29]	Me	Me	60	**i**[31]	Ph	Me	72
e[26,30]	Et	Et	64	**l**[21a]	Bu	Me	60
f	Pr	Et	61				

isomer could be isolated. Of great interest is the possibility of preserving the hydroxyl group under our oxidative conditions.

Preparation of 1,4-Diketones (5). Due to the good results obtained for the synthesis of γ-hydroxyketones, we successfully investigated the use of H_2O_2 for the one-pot preparation of 1,4-diketones. Thus, after reaction between the nitroalkanes (**1**) and the unsaturated ketones (**2**), the mixture was treated with a 30% water solution of H_2O_2, giving the corresponding diketone **5** (Scheme 6) in good yields (Table 2).

In the case of compounds **5a** and **5e**, an acidic workup of the reaction gave a mixture of the expected diketones and the corresponding 2,5-dihydroxytetrahydrofuran analogues **5′**. The cis/trans configuration of compounds **5′** was assigned on the basis of the −OH chemical shift, considering the higher downfield shift of the −OH protons due to the intramolecular hydrogen bonding in the case of the cis stereoisomer. For the product **5a** only the trans diastereoisomer was isolated, whereas for **5e** both diastereoisomers were isolated in a 1:1 ratio.

Preparation of 1,4-Diols (6). 1,4-Diols were prepared by in situ reduction of the 1,4-diketones obtained as reported above, using an excess of $NaBH_4$ as reducing agent (Scheme 7). For all the diols, the yields reported in Table 3 refer to the 1:1 diastereomeric inseparable mixture.

With our procedure, a variety of different building blocks can be easily prepared in one-pot starting from a common intermediate. Moreover, the method provides satisfactory to good overall yields using inexpensive and ecologically friendly conditions with evident environmental advantages for widespread industrial use. Moreover, by the obtained results it is evident that water shows a great versatility in order to assembly different methodologies for the one-pot transformations of the starting nitroalkanes and the conjugated enones into the title targets. Thus, our report clearly demonstrates the improved versatility of the nitroalkanes in aqueous media and enhances the importance of both nitroalkanes and aqueous media in current organic synthesis.

Experimental Section

General Procedure for the Preparation of the *δ*-Nitroalkanols (3). A 2 mL water solution of the nitroalkane **1** (1.5 mmol) and K_2CO_3 (3 mmol) was stirred at room temperature for 5 min, and then the conjugated enone **2** (1.5 mmol) was added. After the mixture was stirred at room temperature for 3 h, $NaBH_4$ (1,5 mmol) was added, and the reaction mixture was stirred at rt for 3 h and then extracted with AcOEt. The organic layer was dried over Na_2SO_4, filtered, and evaporated. The crude product **3** was purified by column chromatography (silica gel, cyclohexane/AcOEt = 4:1).

Compound 3a (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.21 (d, J = 6.6 Hz, 3H), 1.48 (m, 2H), 1.54 (d, J = 6.6 Hz, 3H), 1.98 (m, 2H), 3.82 (m, 1H), 4.60 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 19.4, 19.6, 23.8, 23.87, 31.4, 31.8, 34.9, 35.2, 67.1, 67.5, 83.6, 84.0. IR (neat): 3392, 2970, 2930, 1560, 1547, 1391, 1361. GC−MS (EI): m/z 132 (M − CH_3), 83, 55, 45 (100). Anal. Calcd for $C_6H_{13}NO_3$: C, 48.95; H, 8.91; N, 9.52. Found: C, 49.02; H, 8.89; N, 9.53.

Compound 3b (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.97 (t, J = 7.0 Hz, 3H), 1.20 (d, J = 5.8 Hz, 3H), 1.43 (m, 2H), 1.92 (m, 4H), 3.80 (m, 1H), 4.44 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 10.4, 10.5, 23.9, 24.1, 27.5, 27.6, 29.7, 30.3, 35.0, 35.4, 67.1, 67.8, 90.3, 90.9. IR (neat): 3391, 2973, 2933, 1560, 1548, 1372, 1334. GC−MS (EI): m/z 146 (M − CH_3), 97, 55 (100), 45. Anal. Calcd for $C_7H_{15}NO_3$: C, 52.13; H, 9.38; N, 8.69. Found: C, 52.22; H, 9.36; N, 8.68.

Compound 3c (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.94 (t, J = 7.0 Hz, 3H), 1.20 (d, J = 5.9 Hz, 3H), 1.23−2.20 (m, 8H), 3.81 (m, 1H), 4.52 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 13.6 (2C), 19.26, 19.28, 23.9, 24.0, 30.0, 30.6, 34.9, 35.4, 36.1, 36.2, 67.1, 67.7, 88.6, 89.2. IR (neat): 3400, 2965, 2933, 1558, 1551, 1377. GC−MS (EI): m/z 160 (M − CH_3), 131, 69 (100), 55. Anal. Calcd for $C_8H_{17}NO_3$: C, 54.81; H, 9.78; N, 8.00. Found: C, 54.69; H, 9.80; N, 7.99.

Compound 3d (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.93 (t, J = 7.3 Hz, 3H), 1.32−1.60 (m, 4H), 1.55 (d, J = 6.6 Hz, 3H), 1.73−2.28 (m, 2H), 3.54 (m, 1H), 4.61 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 9.9, 10.0, 19.35, 19.44, 30.3, 30.4, 31.4, 31.7, 32.5, 32.9, 72.2, 72.6, 83.6, 84.1. IR (neat): 3400, 2965, 2936, 1560, 1538, 1390, 1358. GC−MS (EI): m/z 132 (M − CH_2CH_3), 97, 85, 55 (100). Anal. Calcd for $C_7H_{15}NO_3$: C, 52.13; H, 9.38; N, 8.69. Found: C, 52.21; H, 9.40; N, 8.68.

Compound 3e (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.91 (t, J = 7.6 Hz, 3H), 0.95 (t, J = 7.6 Hz, 3H), 1.29−1.60 (m, 4H), 1.71−2.18 (m, 4H), 3.52 (m, 1H), 4.43 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 9.9, 10.0, 10.4 (2C), 27.4, 27.5, 29.6, 30.3, 30.5, 30.6, 32.6, 33.1, 72.2, 72.9, 90.3, 90.9. IR (neat): 3400, 2971, 2936, 1545, 1538, 1375. GC−MS (EI): m/z 146 (M − CH_2CH_3), 117, 99, 69 (100). Anal. Calcd for $C_8H_{17}NO_3$: C, 54.81; H, 9.78; N, 8.00. Found: C, 54.73; H, 9.80; N, 7.98.

Compound 3f (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.93 (t, J = 7.6 Hz, 3H), 0.94 (t, J = 6.9 Hz, 3H), 1.24−1.57 (m, 6H), 1.58−2.24 (m, 4H), 3.54 (m, 1H), 4.53 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 9.96, 10.05, 13.7 (2C), 19.3, 19.3, 29.9, 30.6, 30.7 (2C), 32.7, 33.2, 36.2, 36.3, 72.3, 73.0, 88.7, 89.3. IR (neat): 3391, 2964, 2935, 1548, 1538, 1379. GC−MS (EI) m/z 160 (M − CH_2CH_3), 95, 69, 55, 41 (100). Anal.

Calcd for $C_9H_{19}NO_3$: C, 57.10; H, 10.12; N, 7.40. Found: C, 57.18; H, 10.14; N, 7.41.

Compound 3g (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.22 (bd, J = 5.9 Hz, 3H), 1.46 (m, 2H), 2.22 (m, 1H), 2.59 (m, 1H), 3.87 (m, 1H), 5.51 (m, 1H), 7.44 (m, 5H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 23.8, 23.9, 30.3, 30.6, 35.2, 35.4, 67.3, 67.5, 91.4, 91.7, 127.8 (2C), 127.9 (2C), 129.2 (4C), 130.0 (2C), 134.7 (2C). IR (neat): 3391, 3092, 2969, 2930, 1560, 1547, 1538, 1364, 1304, 717, 696. GC−MS (EI): m/z 163 (M − NO_2), 145 (100), 117, 91. Anal. Calcd for $C_{11}H_{15}NO_3$: C, 63.13; H, 7.23; N, 6.70. Found: C, 63.30; H, 7.25; N, 6.68.

Compound *cis*-3h. Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.83−1.39 (m, 4H), 1.52 (d, J = 6.6 Hz, 3H), 1.67 (m, 2H), 1.94 (m, 3H), 3.61 (m, 1H), 4.42 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 16.5, 23.5, 27.2, 35.2, 38.7, 40.9, 70.1, 88.0. IR (neat): 3390, 2975, 2930, 1560, 1547, 1370, 1334. GC−MS (EI): m/z 126 (M − HNO_2), 109 (100), 67, 55. Anal. Calcd for $C_8H_{15}NO_3$: C, 55.46; H, 8.73; N, 8.09. Found: C, 55.41; H, 8.71; N, 8.11.

Compound *trans*-3h. Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.88−1.36 (m, 4H), 1.52 (d, J = 6.6 Hz, 3H), 1.64 (m, 2H), 1.92 (m, 3H), 3.63 (m, 1H), 4.41 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 16.5, 23.3, 28.6, 35.4, 37.3, 40.9, 70.3, 88.2. IR (neat): 3390, 2976, 2930, 1561, 1548, 1370, 1334. GC−MS (EI): m/z 126 (M − HNO_2) 109 (100), 67, 55. Anal. Calcd for $C_8H_{15}NO_3$: C, 55.46; H, 8.73; N, 8.09. Found: C, 55.45; H, 8.70; N, 8.10.

General Procedure for the Preparation of the γ-Hydroxyketones and Hydroxytetrahydrofurans (4). A 2 mL water solution of the nitroalkane **1** (1.5 mmol) and K_2CO_3 (3 mmol) was stirred at room temperature for 5 min, and then the conjugated enone **2** (1.5 mmol) was added. After the mixture was stirred at room temperature for 3 h, $NaBH_4$ (1,5 mmol) was added, and the resulting mixture was stirred at rt for 3 h. A 30% aqueous solution of H_2O_2 (4 mL) was then added, and the reaction mixture was stirred overnight at rt and then acidified with 6 N HCl and extracted with AcOEt. The organic layer was dried over Na_2SO_4, filtered, and evaporated. The crude product **4** was purified by column chromatography (silica gel, cyclohexane/AcOEt = 4:1).

Compound 4a (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.28 (d, J = 5.9 Hz, 3H), 1.35 (d, J = 5.9 Hz, 3H), 1.52 (s, 3H), 1.56 (s, 3H), 1.40−2.20 (m, 10H), 4.30 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 20.9, 21.0, 22.7, 23.4, 32.88, 32.93, 35.75, 35.83, 75.7, 76.3, 112.1, 113.2. IR (neat): 3326, 2973, 1540, 1375, 1159. GC−MS (EI): m/z 99 (M − OH), 43 (100). Anal. Calcd for $C_6H_{12}O_2$: C, 62.02; H, 10.42. Found: C, 62.15; H, 10.40.

Compound 4b (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.94 (t, J = 7.3 Hz, 3H), 0.95 (t, J = 7.3 Hz, 3H), 1.27 (d, J = 6.6 Hz, 3H), 1.35 (d, J = 6.6 Hz, 3H), 1.30−2.20 (m, 14H), 4.31 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 8.8, 8.9, 20.7, 22.3, 28.0, 28.2, 32.4, 32.7, 32.8, 33.6, 76.2, 77.9, 115.6, 115.8. IR (neat): 3342, 2973, 1560, 1380, 1154. GC−MS (EI) m/z 113 (M − OH), 57 (100). Anal. Calcd for $C_7H_{14}O_2$: C, 60.97; H, 11.95. Found: C, 60.83; H, 11.97.

Compound 4c (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (300 MHz, $CDCl_3$): δ 0.93 (m, 12H), 1.21−2.20 (m, 22H), 4.51 (m, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 9.9, 10.0, 13.7, 14.5, 19.3, 19.3, 29.9, 30.4, 32.6, 32.7, 36.1, 36,3, 37.5, 38.2, 72.5, 73.2, 110.2, 110.6. IR (neat): 3342, 2975, 1558, 1380, 1156. GC−MS (EI) m/z 141 (M − OH), 71 (100). Anal. Calcd for $C_9H_{18}O_2$: C, 68.30; H, 11.47. Found: C, 68.17; H, 11.50.

Compound *trans*-4′a. Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.20−1.97 (m, 8H), 2.16 (s, 3H), 2.83 (m, 1H), 4.15 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 19.9, 27.8, 28.2, 32.8, 34.7, 45.8, 66.0, 212.5. IR (neat): 3400, 2935, 2860, 1708. GC−MS (EI) m/z 142 (M), 124, 81, 67, 43 (100). Anal. Calcd for $C_8H_{14}O_2$: C, 67.56; H, 9.93. Found: C, 67.70; H, 9.91.

Compound *cis*-4′a. Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.12−1.40 (m, 4H), 1.82 (m, 2H), 1.93 (m, 1H), 2.10 (m, 1H), 2.13 (s, 3H), 2.41 (m, 1H), 3.61 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 23.4, 27.6, 28.2, 35.1, 37.0, 50.0, 69.9, 211.3. IR (neat): 3394, 2933, 2858, 1702. GC−MS (EI): m/z 142 (M), 124, 81, 67, 43 (100). Anal. Calcd for $C_8H_{16}O_3$: C, 59.96; H, 10.07. Found: C, 59.79; H, 10.06.

Compound *cis*-4′b. Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.05 (t, J = 7.3 Hz, 3H), 1.13−1.45 (m, 4H), 1.87 (m, 4H), 2.09 (m, 1H), 2.45 (m, 1H), 2.48 (q, J = 7.3 Hz, 2H), 3.64 (m, 1H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 8.0, 23.5, 27.8, 34.0, 35.3, 37.2, 49.1, 70.1, 213.6. IR (neat): 3402, 2936, 2859, 1708. GC−MS (EI): m/z 156 (M), 138, 127, 109, 81 (100). Anal. Calcd for $C_9H_{16}O_2$: C, 69.18; H, 10.33. Found: C, 69.31; H, 10.35.

General Procedure for the Preparation of the 1,4-Diketones (5). A 2 mL water solution of the nitroalkane **1** (1.5 mmol) and K_2CO_3 (3 mmol) was stirred at room temperature for 5 min, and then the conjugated enone **2** (1.5 mmol) was added. After the mixture was stirred at room temperature for 3 h, 4 mL of a 30% aqueous solution of H_2O_2 was added and the reaction mixture was stirred overnight at rt. The mixture was then extracted with AcOEt, and the organic layer was dried over Na_2SO_4, filtered, and evaporated. The crude product **5** was purified by column chromatography (silica gel, cyclohexane/AcOEt = 4:1).

Compound 5′a. Amorphous solid. ^{1}H NMR (200 MHz, $CDCl_3$): δ 1.49 (s, 6H), 1.64 (m, 2H), 1.88 (m, 2H), 8.34 (bs, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 19.3, 26.6, 108.3. IR (neat): 3338, 2997, 1378, 1120. GC−MS (EI): m/z 115 (M − OH), 99, 88, 71, 43 (100). Anal. Calcd for $C_6H_{12}O_3$: C, 54.51; H, 9.16. Found: C, 54.46; H, 9.15.

Compound *cis*-5′e. Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.94 (t, J = 7.3 Hz, 6H),1.64−2.20 (m, 8H), 9.09 (bs, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 8.6, 28.2, 31.6, 116.8. IR (neat): 3340, 2995, 1375, 1124. GC−MS (EI): m/z 142 (M − H_2O), 113 (100), 57, 29. Anal. Calcd for $C_8H_{16}O_3$: C, 59.96; H, 10.07. Found: C, 60.08; H, 10.08.

Compound *trans*-5′e. Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.98 (t, J = 7.3 Hz, 6H),1.78 (m, 2H), 2.10 (m, 6H), 7.98 (s, 2H). ^{13}C NMR (75 MHz, $CDCl_3$): δ 8.8, 28.9, 32.2, 116.8. IR (neat): 3338, 2994, 1378, 1120. GC−MS (EI): m/z 142 (M − H_2O), 113 (100), 57, 29. Anal. Calcd for $C_8H_{16}O_3$: C, 59.96; H, 10.07. Found: C, 59.91; H, 10.05.

General Procedure for the Preparation of the 1,4-Diols (6). A 2 mL water solution of the nitroalkane **1** (1.5 mmol) and K_2CO_3 (3 mmol) was stirred at room temperature for 5 min, and then the conjugated enone **2** (1.5 mmol) was added. After the mixture was stirred at room temperature for 3 h, 4 mL of a 30% aqueous solution of H_2O_2 was added and the reaction mixture was stirred overnight at rt. The mixture was then treated with an excess of $NaBH_4$ (180 mg), stirred at rt for 2 h, and then extracted with AcOEt. The organic layer was dried over Na_2SO_4, filtered, and evaporated. The crude product **6** was purified by column chromatography (silica gel, cyclohexane/AcOEt = 7:3).

Compound 6f (Diastereomeric Mixture). Yellow oil. ^{1}H NMR (200 MHz, $CDCl_3$): δ 0.94 (t, J = 6.9 Hz, 3H), 0.95 (t, J = 7.3 Hz, 3H), 1.33−1.78 (m, 10H), 2.35 (bs, 2H), 3.61 (m, 2H). ^{13}C NMR (50 MHz, $CDCl_3$): δ 10.2 (2C), 14.3 (2C), 19.1 (2C), 30.3, 30.7, 32.8, 33.4, 33.8, 34.3, 39.8, 40.1, 71.7, 72.2, 73.4, 73.9. IR (neat): 3306, 2928, 1456. GC−MS (EI): m/z 131 (M − CH_2-CH_3), 113, 95, 55, 43 (100), 29. Anal. Calcd for $C_9H_{20}O_2$: C, 67.44; H, 12.59. Found: C, 67.32; H, 12.60.

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