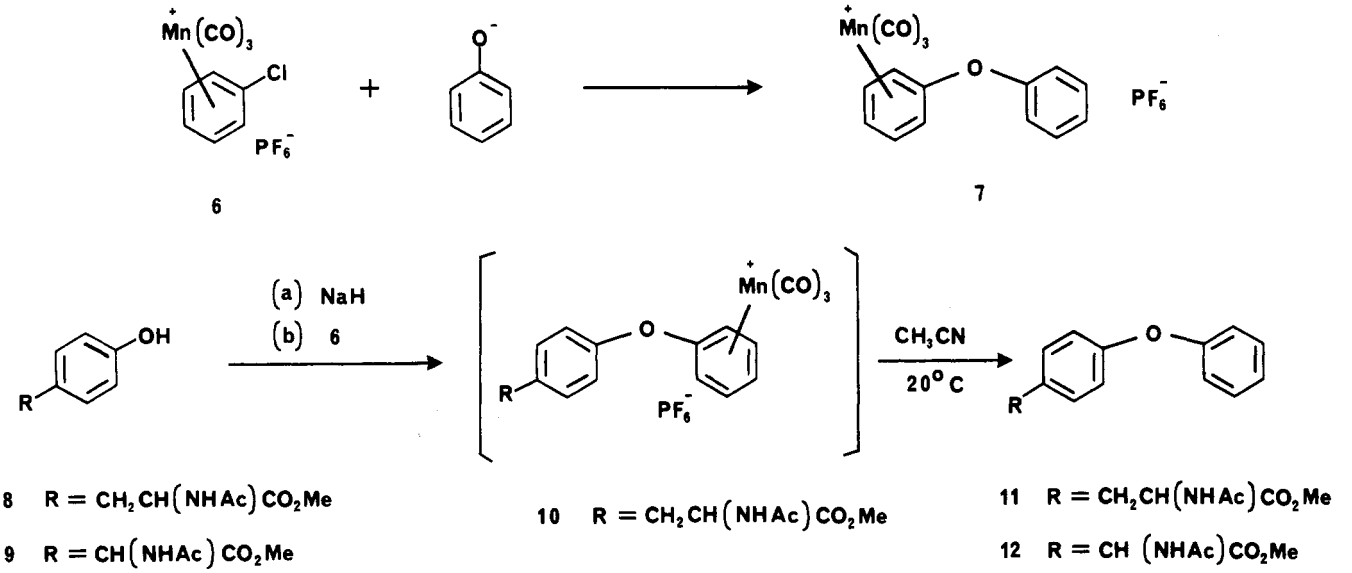

8 R = $CH_2CH(NHAc)CO_2Me$

9 R = $CH(NHAc)CO_2Me$

10 R = $CH_2CH(NHAc)CO_2Me$

11 R = $CH_2CH(NHAc)CO_2Me$

12 R = $CH(NHAc)CO_2Me$

s), 3.13 and 3.09 (2 H, ABX, J_{AB} = 12, J_{AX} = 2.8, J_{BX} = 2.7 Hz), 2.01 (3 H, s); $[\alpha]^{20}_D$ +91.6° (c 0.50 in $CHCl_3$, l = 1.0 dm, α = 0.458). Anal. C, H.

D-(-)-*N*-Acetyl-4-(phenyloxy)phenylglycine Methyl Ester (12). The procedure was identical with that described for the preparation of 11, using *N*-acetyl-4-hydroxyphenylglycine methyl ester (223 mg, 1 mmol), sodium hydride (44 mg), and (chlorobenzene)manganesetricarbonyl hexafluorophosphate (401 mg, 1.01 mmol). Extractive workup, followed by flash chromatography (silica gel, ethyl acetate), gave the product 12 as a hygroscopic white foam (194 mg, 65%): IR ($CHCl_3$) ν_{max} 3435, 1743, and 1682 cm^{-1}; NMR ($CDCl_3$, 200 MHz) δ 7.39–6.95 (9 H, m), 6.46 (1 H, br d, J = 7.2 Hz), 5.56 (1 H, d, J = 7.2 Hz), 3.75 (3 H, s), 2.05 (3 H, s). The optical rotation was measured immediately upon isolation of the vacuum-dried sample: $[\alpha]^{20}_D$ - 70.6° (c 0.50 in acetone, l = 1.0 dm, α = -0.353). Due to the hygroscopic nature of this compound, satisfactory combustion analysis was not obtained. Anal. Calcd for $C_{17}H_{17}NO_4$ M^+ = 299.1158, found M^+ = 299.1149.

Determination of Enantiomeric Purity. (1) Racemic tyrosine was commercially available and was used to prepare authentic samples of racemic 8 and 11. (2) *N*-acetyl-D-(-)-*p*-hydroxyphenylglycine methyl ester was converted to its *N,O*-diacetyl derivative by standard procedure (acetic anhydride, pyridine, CH_2Cl_2, 20 °C, 1.5 h) due to its poor solubility in most commonly used NMR solvents for the chiral lanthanide shift reagent study. A partially racemized sample was prepared as follows.[9] D-(-)-*p*-hydroxyphenylglycine was treated with 2.5 N NaOH and acetic anhydride at 20 °C for 2 h, followed by extractive workup, to give *N,O*-diacetyl-D-(-)-*p*-hydroxyphenylglycine, which was then partially racemized with acetic anhydride and glacial acetic acid at reflux for 15 min. The racemized compound was isolated in the usual way and converted to its methyl ester by treatment with dimethyl sulfate and potassium carbonate in acetone at reflux for 7 h, to provide a partially racemic sample of *N,O*-diacetyl-*p*-hydroxyphenylglycine methyl ester. The *N,O*-diacetyl derivatives were used to establish that no racemization had occurred during the preparation of 9. Mild hydrolysis of the racemized diacetate[10] (MeOH, H_2O, saturated $NaHCO_3$, 0.75 h, room temperature) gave partly racemic *N*-acetyl-*p*-hydroxyphenylglycine methyl ester. Racemized and nonracemized materials prepared in this study were identical, apart from optical rotation. The partially racemic sample of 9 was converted to partially racemic diaryl ether 12 by using the procedure described above: $[\alpha]^{20}_D$ -45.2° (c 0.5 in acetone). (3) The enantiomeric purity of each chiral compound described in this paper was determined by using the chiral lanthanide shift reagents tris[3-[heptafluorobutyryl]-*d*-camphorato]europium(III), [Eu(hfbc)$_3$], or tris(*d,d*-dicampholylmethanato)europium(III), [Eu(dcm)$_3$], at a defined molar ratio. The appropriate shift reagent for each compound was determined by using racemic or partially racemic samples of that compound. Optimum conditions were as follows: compound 8 (rac) showed separation of ar*H* and CO_2CH_3 peaks in $CDCl_3$ (solution) by using a molar ratio of Eu(hfbc)$_3$:8 of 0.11. Compound 9 (rac) showed separation of Ar*H*, CO_2CH_3, and $NHCOCH_3$ peaks in $CDCl_3$ solution by using a molar ratio of Eu(dcm)$_3$:9 of 0.23. Compound 11 (rac) showed separation of CO_2CH_3 and $NHCOCH_3$ peaks in $CDCl_3$ solution by using a molar ratio Eu(dcm)$_3$:11 of 0.17. Compound 12 (rac) showed separation of Ar*H* and CO_2CH_3 in $CDCl_3$ solution by using a molar ratio (Eu(dcm)$_3$:12 of 0.22. By using the same ratios of shift reagent:substrate, no racemization could be detected for the compounds 8, 9, 11 and 12, and the results for the latter are shown in Figure 1.

Acknowledgment. We are extremely grateful to the National Institutes of Health and the donors of the Petroleum Research Fund, administered by the American Chemical Society, for partial support of this work. The Varian XL 200 NMR spectrometer used in this work was purchased in part with funds provided by the National Institutes of Health (RR-01689). High resolution mass spectra were measured at the Midwest Center for Mass Spectrometry, University of Nebraska, Lincoln, NE. Combustion analyses were determined by Galbraith, Inc., Knoxville, TN.

Registry No. 6, 57812-91-6; 8, 2440-79-1; 9, 72691-40-8; 10, 101630-79-9; 11, 101630-75-5; 12, 101630-76-6; *O*-benzyl-L-tyrosine methyl ester hydrochloride, 34805-17-9; D-(-)-*p*-hydroxyphenylglycine, 22818-40-2; D-(-)-*p*-hydroxyphenylglycine *p*-toluenesulfonate, 101630-77-7; *N*-acetyl-*O*-benzyl-L-tyrosine methyl ester, 39613-68-8.

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Preparation of a New Type of Electron-Deficient Olefins: β-Phenylthio Nitro Olefins, β-Sulfinyl Nitro Olefins, and β-Sulfonyl Nitro Olefins

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Electron-deficient olefins substituted with nitro, sulfinyl, or sulfonyl groups are very important in the Michael addition reactions and cycloaddition reactions. In fact, ni-

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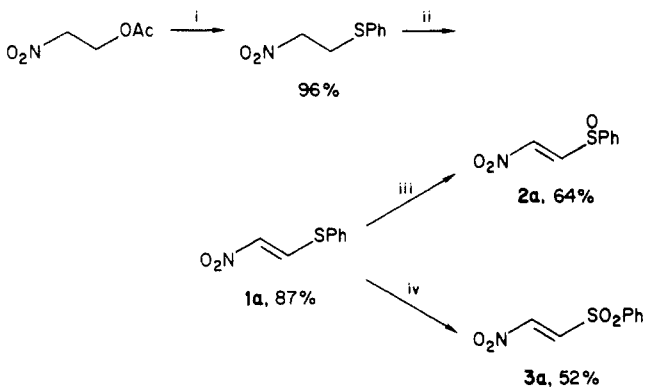
Scheme I[a]



[a] (i) PhSH, Et_3N (1 equiv), 0 °C, 2 h; (ii) SO_2Cl_2, CH_2Cl_2, 0 °C, 3 h; (iii) *m*-CPBA (1 equiv), CH_2Cl_2, 0 °C, 3 h; (iv) *m*-CPBA (2 equiv), CH_2Cl_2, 20 °C, 38 h.

Table I. Preparation of β-Phenylthio Nitro Olefins 1 and β-Phenylsulfonyl Nitro Olefins 3

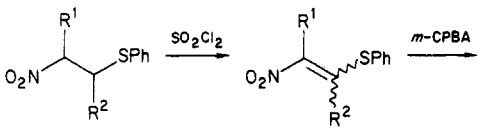
		1	3
R^1	R^2	yield, %	yield, %
Me	H	**1b** 95	**3b** 88
H	Me	**1c** 83	**3c** 87
Et	H	**1d** 88	**3d** 86
n-C_5H_{11}	H	**1e** 88	**3e** 87

[a] Yields refer to pure isolated products as a 1:1 mixture of *E* and *Z* isomers. They were separated by column chromatography, and the structure was assigned.

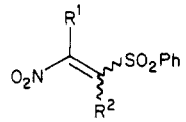
troethylene[1] vinyl sulfoxide,[2] and vinyl sulfone[3] have been used frequently in recent years as excellent Michael acceptors or dienophiles, and their utility is well documented. On the other hand, there are a few reports on the reaction of olefins substituted with two of these groups.[4] Olefins substituted with the nitro and the sulfur groups at the vicinal positions would be very useful for organic synthesis, because they should be very reactive as the Michael acceptors or dienophiles and the nitro and sulfur functional groups can be used for further transformations.[5] However, only one report is available for the preparation of such olefins, in which β-ethylthio nitro olefins are prepared by the reaction of α-nitro ketones with ethanethiol in the presence of a Lewis acid.[6] Although this method can be applied to α-nitro ketones, it cannot be applied to α-nitro aldehydes because of their instability. Moreover, it is impossible to prepare β-(alkylthio)nitroethylene by this method.

In this paper we wish to report the first synthesis of 1-nitro-2-(phenylthio)ethylene (**1a**) and the oxidation products, 1-nitro-2-(phenylsulfinyl)ethylene (**2a**) and 1-nitro-2-(phenylsulfonyl)ethylene (**3a**) as shown in Scheme I.

1-Nitro-2-(phenylthio)ethane was obtained in 96% yield on treatment of 1-acetoxy-2-nitroethane with thiophenol in the presence of triethylamine. This reaction is very useful to prepare general β-nitro sulfides, because isolation of intermediates of nitro olefins is not necessary. The sulfide was converted to olefin **1a** by treating with sulfuryl chloride and triethylamine. Oxidation of **1a** with *m*-chloroperbenzoic acid (*m*-CPBA) gave **2a** and **3a** in 64% and 52% yield, respectively, depending on the amount of *m*-CPBA. This method can be extended to the general synthesis of these types of olefins. The results are summarized in Table I. Substituted derivatives of **1** and **3** are more readily prepared than the parent compounds. Compound **1a** was formed as a mixture of *E* and *Z* isomers in the ratio of 95:5, and the pure *E* isomer was separated and was used for further reactions. Other β-phenylthio nitro olefins were obtained as 1:1 mixture of *E* and *Z* isomers. Both isomers were separated by column chromatography. As vinylic protons of (*E*)-**1** were strongly deshielded by anisotropic effect of the nitro group[7] the ratio of *E*/*Z* was readily determined by ^1H NMR.



1



3

Table II. Diels–Alder Reactions of 1a, 2a, and 3a with Cyclopentadiene

olefins	*n*	conditions	adducts	yield, %	endo/exo[a]
1a	0	toluene, 110 °C, 1 h	**4**	75	96/4
2a	1	20 °C, 3 h	**5**	97	86/14
3a	2	20 °C, 30 min	**6**	85	75/25

[a] Concerning the nitro group.

These new electron deficient olefins are good dienophiles in the Diels–Alder reaction. For example, **1a**, **2a**, and **3a** react with cyclopentadiene rapidly to give the adducts in good yield. Compound **3a** is especially reactive due to activation by both the nitro and the sulfonyl groups. The results are summarized in Table II The endo/exo ratio was determined by ^1H NMR using the chemical shift of H-6 and the coupling constant between H-1 and H-6 in compound **6**. Adducts of **1a** and **2a** with cyclopentadiene were converted into the sulfone with *m*-CPBA and the endo/exo ratio was then determined. Thus, the nitro groups are oriented at the endo position preferentially.

The Diels–Alder reaction of (*E*)-1,3-pentadiene with **1a**, **2a**, and **3a** was carried out by heating a solution of these

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(4) 1,2-Bis(phenylsulfonyl)ethylene: Lucchi, O. D.; Lucchini, V.; Pasquato, L.; Modena, G. *J. Org. Chem.* **1984**, *49*, 596. 1,4-Benzodithiin 1,1,4,4-tetraoxide: Nakayama, J.; Nakamura, Y.; Hoshino, M. *Heterocycles* **1985**, *23*, 1119. 1,1-Bis(phenylsulfonyl)ethylene: Lucchi, O. D.; Pasquato, L.; Modena, G. *Tetrahedron Lett.* **1984**, 3463, 3467.

(5) Reduction of β-nitro sulfones or β-nitro sulfides gives olefins, see: Ono, N.; Kawai, S.; Tanaka, K.; Kaji, A. *Tetrahedron Lett.* **1979**, 1733. Ono, N.; Tamura, R.; Nakatsuka, T.; Hayami, J.; Kaji, A. *Bull. Chem. Soc. Jpn.* **1980**, *53*, 3295. Ono, N.; Miyake, H.; Tamura, R.; Hamamoto, I.; Kaji, A. *Chem. Lett.* **1981**, 1139. Ono, N.; Kamimura, A.; Kaji, A. *Tetrahedron Lett.* **1984**, 5319.

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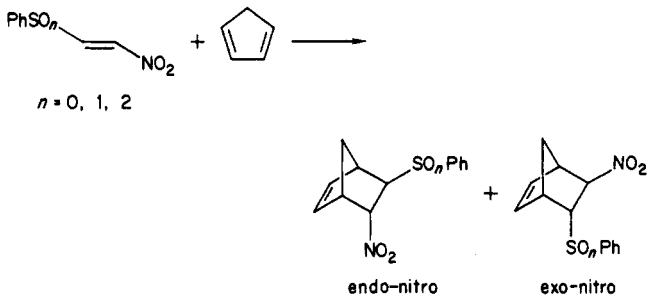
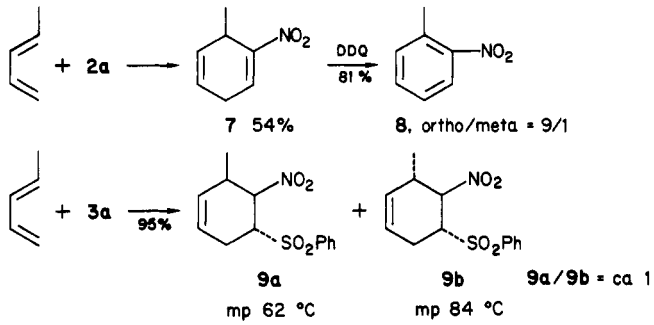
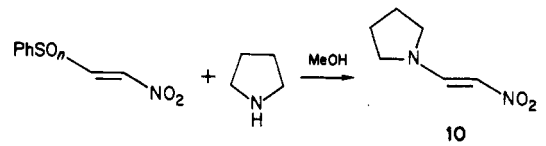


olefins and the diene in toluene at 100 °C for 4 h. When **1a** was used, the reaction did not take place under these conditions. The reaction of **3a** with (*E*)-1,3-pentadiene gave the adduct **9**, but that of **2a** gave the nitro olefin **7** (54%), which was formed by the addition and subsequent elimination of PhSOH. The structure of this compound was determined by the conversion of **7** to nitrotoluene on treatment with 2,3-dichloro-5,6-dicyanobenzoquinone (DDQ). GLC analyses revealed that *o*-nitrotoluene (the ratio of ortho/meta is 9/1) was obtained regioselectively. The structure of **9** was determined by ^{1}H NMR. Two isomers were separated by column chromatography, whose mps are 62 and 84 °C, respectively. As the α-hydrogen of the nitro group in both isomers appeared as d,d by NMR, the nitro group should locate at the vicinal position of the methyl group. The coupling constants of this proton are observed to be 6 and 8 Hz (isomer of mp 62 °C) and 10 and 12 Hz (isomer of mp 84 °C). On basis of these facts, the structure of the isomer of low mp and the isomer of high mp are assigned as **9a** and **9b**, respectively.



These olefins are also good Michael acceptors, and they react with various nucleophiles. For example, the reaction of **1a**, **2a**, and **3a** with pyrrolidine gave the nitroenamine **10** in 81%, 89%, and 71% yield, respectively.

Thus, the orienting effect of the nitro group in the Diels–Alder reaction and the Michael addition prevails over that of the sulfur functional groups.



n	yield of 10, %
0	81
1	89
2	71

Experimental Section

(*E*)-1-Nitro-2-(phenylthio)ethylene (1a). To a solution of 1-acetoxy-2-nitroethane (5.32 g, 40 mmol) and thiophenol (4.40 g, 40 mmol) in acetonitrile (100 mL) was added dropwise a solution of triethylamine (4.10 g, 40.4 mmol) in 20 mL of acetonitrile at 0 °C during 30 min. The resulting solution was stirred further 30 min at 0 °C poured into 200 mL of 1 N HCl, and then extracted with hexane–benzene (1:2). The organic layer was washed with water and dried with magnesium sulfate. Removal of the solvent gave 1-nitro-2-(phenylthio)ethane, 7.05 g (96%), which was pure enough to use the next step: NMR ($CDCl_3$) δ 2.44 (t, J = 8 Hz, 2 H), 4.55 (t, J = 8 Hz, 2 H), 7.56 (m, 5 H). To a solution of 1-nitro-2-(phenylthio)ethane (6.30 g, 34 mmol) in 30 mL of methylene chloride was added a solution of sulfuryl chloride (2.9 mL, 36 mmol) at 0 °C, and the mixture was stirred at 0 °C for 5 min. Then the volatile materials were evaporated. The residue was dissolved in 50 mL of methylene chloride, a solution of triethylamine (3.50 g, 36 mmol) was added at 0 °C, and the mixture was stirred for 30 min at 0 °C. The reaction mixture was then poured into water, and the organic layer was washed with dilute HCl. After evaporation of the solvent, the residue was subjected to column chromatography (silica gel/hexane) to give **1a** (oil), 5.4 g (87%): IR 1550 cm^{-1}; NMR ($CDCl_3$) δ 6.66 (d, J = 12 Hz, 1 H), 7.24–7.56 (m, 5 H), 8.18 (d, J = 12 Hz, 1 H). Anal. Calcd for $C_8H_8NO_2S$: C, 53.02; H, 3.89; N, 7.73. Found: C, 53.02; H, 3.96; N, 7.67.

(*E*)-1-Nitro-2-(phenylsulfinyl)ethylene (2a). A mixture of **1a** (1.82 g, 10 mmol) and *m*-CPBA (80%, 2.2 g, 10 mmol) in 100 mL of methylene chloride was stirred at 0 °C for 3 h. The mixture was washed with water, dilute aqueous sodium acetate, and brine, and then the organic layer was dried with magnesium sulfate. Evaporation of the solvent gave a yellow solid, which was recrystallized from ethanol to give **2a**, 1.27 g (64%): mp 100–115 °C; IR 1060, 1550 cm^{-1}; NMR ($CDCl_3$) δ 7.36–7.90 (m, 7 H); Ms, m/e (M^+) calcd for $C_8H_7NO_3S$ 197.0147, found 197.0186. Anal. Calcd for $C_8H_7NO_3S$: C, 48.72; H, 3.58; N, 7.10. Found: C, 48.32; H, 3.62; N, 6.70.

(*E*)-1-Nitro-2-(phenylsulfonyl)ethylene (3a). A mixture of **1a** (4.91 g, 27 mmol) and *m*-CPBA (12.11 g, 56 mmol) in 300 mL of methylene chloride was stirred at room temperature for 38 h. After the same workup as in preparation of **2a**, recrystallization of the crude product from ethanol gave **3a**, 2.98 g (52%): mp 148–150 °C; IR 1160, 1350, 1550 cm^{-1}; NMR ($CDCl_3$) δ 7.50–7.96 (m, 7 H); MS, m/e (M^+) calcd for $C_8H_7NO_4S$ 213.0095 found 213.0061.

The following compounds were prepared by these procedures. **1b**: yellow oil (E/Z = ca. 1/1); IR 1370, 1570 cm^{-1}; NMR ($CDCl_3$) δ 2.22 (s, 3 H), 7.30–7.50 (m, 5 H), 7.32 (s, (*Z*)-**1b**), 8.10 (s, (*E*)-**1b**); MS, m/e (M^+) calcd for $C_9H_9NO_2S$ 195.0355 found 195.0356.

1c: yellow oil (E/Z = ca. 1/1); IR 1380, 1580 cm^{-1}; NMR ($CDCl_3$) δ 1.80 (s, (*Z*)-**1c**), 2.51 (s, (*E*)-**1c**), 6.30 (s, (*E*)-**1c**), 7.20 (s, (*Z*)-**1c**), 7.20–7.50 (m, 5 H); MS, m/e (M^+) calcd for $C_9H_9NO_2S$ 195.0355, found 195.0340.

1d: yellow oil (E/Z = ca. 1/1); IR 1370, 1580 cm^{-1}; NMR ($CDCl_3$) δ 1.16, 1.14 (t, J = 8 Hz, 3 H), 2.48–2.78 (m, 2 H), 7.33, 8.10 (s, 1 H), 7.36–7.48 (m, 5 H); MS, m/e (M^+) calcd for $C_{10}H_{11}NO_2S$ 209.0510, found 209.0498.

1e: yellow oil (E/Z = ca. 1/1); IR 1370, 1580 cm^{-1}; NMR ($CDCl_3$) δ 0.70–0.98 (m, 3 H), 1,10–1.60 (m, 6 H), 2.40–2.80 (m, 2 H), 7.20, 8.10 (s, 1 H), 7.30–7.50 (m, 5 H); MS, m/e (M^+) calcd for $C_{13}H_{17}NO_2S$ 251.0979; found 251.0950.

Compounds **3b–e** were obtained as a mixture of *E* and *Z* isomers; each isomer was readily separated by column chromatography (silica gel/hexane–ethyl acetate).

(*E*)-**3b**: mp 44–47 °C; NMR ($CDCl_3$) δ 2.62 (s, 3 H), 7.50–7.72 (m, 4 H), 7.86–7.98 (m, 2 H); MS, m/e (M^+) calcd for $C_9H_9NO_4S$ 227.0252, found 227.0249.

(*Z*)-**3b**: mp 72–78 °C, NMR ($CDCl_3$) δ 2.31 (s, 3 H), 6.28 (s, 1 H), 7.56–8.00 (m, 5 H); MS, m/e (M^+) calcd for $C_9H_9NO_4S$ 227.0252, found 227.0247.

(*E*)-**3c**: mp 66–68 °C; NMR ($CDCl_3$) δ 2.28 (s, 3 H), 7.50–7.98 (m, 6 H); MS, m/e (M^+) calcd for $C_9H_9NO_4S$ 227.0252, found 227.0220.

(*Z*)-**3c**: mp 75–76.5 °C; NMR ($CDCl_3$) δ 2.02 (s, 3 H), 6.96 (s, 1 H), 7.50–8.04 (m, 5 H); MS, m/e (M^+) calcd for $C_9H_9NO_4S$ 227.0252, found 227.0208.

(*E*)-**3d**: mp 42–44 °C; NMR ($CDCl_3$) δ 1.16 (t, J = 7 Hz, 3 H), 3.12 (q, J = 7 Hz, 2 H), 7.40 (s, 1 H), 7.40–7.96 (m, 5 H); MS, m/e (M^+) calcd for $C_{10}H_{11}NO_4S$: 241.0407, found 241.0387; m/e ($M^+ - NO_2$) calcd for $C_{10}H_{11}O_2S$ 195.0479, found 195.0478.

(*Z*)-**3d**: mp 47 °C; NMR ($CDCl_3$) δ 1.11 (t, J = 7 Hz, 3 H), 2.60 (q, J = 7 Hz, 2 H), 6.16 (s, 1 H), 7.52–7.96 (m, 5 H); MS, m/e (M^+) calcd for $C_{10}H_{11}NO_4S$ 241.0407, found 241.0412.

(*E*)-**3e**: yellow oil; NMR ($CDCl_3$) δ 0.92 (t, J = 7 Hz, 3 H), 1.20–1.60 (m, 6 H), 3.15 (3 H, J = 7 Hz, 2 H), 7.44 (s, 1 H), 7.58–8.04 (m, 5 H); MS, m/e (M^+) calcd for $C_{13}H_{17}NO_4S$ 237.0948, found 237.0942.

(*Z*)-**3e**: yellow oil; NMR ($CDCl_3$) δ 0.82 (t, J = 8 Hz, 3 H), 1.20–1.60 (m, 6 H), 2.56 (t, J = 8 Hz, 2 H), 6.22 (s, 1 H), 7.56–8.04 (m, 5 H). Anal. Calcd for $C_{13}H_{17}NO_4S$: C, 55.11; H, 6.05; N, 4.94. Found: C, 55.03; H, 5.88; N, 4.92.

Diels–Alder Reaction of 1a with Cyclopentadiene. A mixture of **1a** (0.37 g, 2.04 mmol) and cyclopentadiene (1.0 g, 15 mmol) in toluene was heated at 110 °C for 1 h. The solvent was evaporated, and the residue was subjected to column chromatography (silica gel/benzene–hexane) to give **4** 0.38 g (75%): NMR ($CDCl_3$) δ 1.5–2.1 (m, 1 H), 3.80 (t, J = 2 Hz, 1 H), 4.78 (d,d, J = 4,2 Hz, 1 H, H-6), 5.82 (d,d, J = 3, 6 Hz, 1 H), 6.28 (d,d, J = 3, 6 Hz, 1 H), 7.3 (m, 5 H). Minor isomer: NMR δ 4.20 (t, H-6). Compound **4** was converted into the corresponding sulfone on treatment with *m*-CPBA (2 equiv) in $CHCl_3$, and the structure was confirmed by comparison with spectral data of **6**, which was prepared by the Diels–Alder reaction of **3a**.

Diels–Alder Reaction of 2a with Cyclopentadiene. A mixture of **2a** (0.30 g, 1.55 mmol) and cyclopentadiene (0.90 g, 13.6 mmol) in 1 mL of methylene chloride was stirred at 20 °C for 3 h. Column chromatography (silica gel/benzene–hexane) gave **5**, 0.39 g (97%): NMR ($CDCl_3$) δ 1.5–2.4 (m, 2 H), 3.2–4.1 (m, 3 H), 5.18 (t, J = 4 Hz), 5.30 (d,d, J = 4, 3 Hz), 6.1–6.6 (m, 2 H), 7.5 (m, 5 H). NMR spectra of **5** were very complicated due to the presence of chiral center of the sulfoxide. The structure was further confirmed by conversion to the sulfone by oxidation with *m*-CPBA (1 equiv).

Diels–Alder Reaction of 3a with Cyclopentadiene. A mixture of **3a** (0.26 g, 1.22 mmol) and cyclopentadiene (0.49 g, 7.42 mmol) in 7 mL of methylene chloride was stirred at 20 °C for 30 min. Pentane (30 mL) was poured into the reaction mixture, and the mixture was cooled at −70 °C. The precipitated solid was collected, 0.28 g (82%), mp 145–152 °C, which was pure **6**. Anal. Calcd for $C_{13}H_{13}NO_4S$: C, 55.90; H. 4.69: N, 5.01. Found C, 55.61; H, 4.74; N, 4.94. NMR ($CDCl_3$) δ [of endo-nitro isomer] 1.73 (d, J = 10 Hz, 1 H), 2.29 (d, J = 10 Hz, 1 H), 3.52 (d, J = 4 Hz, 1 H), 3.69 (d, J = 4 Hz, 1 H), 3.70 (d, J = 4 Hz, 1 H), 5.33 (t, J = 4 Hz, 1 H), 6.13 (d,d, J = 2.8, 5.6 Hz), 6.47 (d,d, J = 3.4, 3.5 Hz), 7.4–8.1 (m, 5 H), [of exo-nitro isomer] 1.76 (d, J = 10 Hz, 1 H), 1.88 (d, J = 10 Hz, 1 H), 3.37–3.60 (m, 2 H), 4.37 (t, J = 4 Hz, 1 H), 4.71 (d,d, J = 1.5, 4.3 Hz), 6.53 (d,d, 1 H, J = 3, 4 Hz), 7.4–8.1 (m, 5 H).

Diels–Alder Reaction of 2a with (*E*)-1,3-Pentadiene. A mixture of **2a** (0.60 g, 3.04 mmol) and (*E*)-1,3-pentadiene (1.38 g, 30 mmol) in 4 mL of toluene was heated at 100 °C for 4 h. Column chromatography (silica gel/benzene–hexane) gave **7** (oil), 0.21 g (54%): NMR ($CDCl_3$) δ 1.20 (d, J = 8 Hz, 3 H), 2.90–3.20 (m, 2 H), 3.40–3.80 (m, 1 H), 6.78 (m, 2 H), 7.28 (m, 1 H). The structure of this compound was confirmed by conversion into *o*-nitrotoluene. A mixture of **7** (0.10 g, 0.72 mmol) and DDQ (0.24 g, 1.06 mmol) in 2 mL of toluene was refluxed for 2 h. Column chromatography (silica gel/benzene–hexane) gave 0.08 g (81%) of *o*-nitrotoluene. GLC analyses showed that the product consisted of 90% of *o*-nitrotoluene and 10% of *m*-nitrotoluene.

Diels–Alder Reaction of 3a with (*E*)-1,3-Pentadiene. A mixture of **3a** (0.43 g, 2.02 mmol) and (*E*)-1,3-pentadiene (0.40 g, 6 mmol) in 10 mL of toluene was heated at 100 °C for 4 h. Column chromatography (silica gel/benzene–hexane) gave two products, **9a**, 0.26 g (46%), mp 61.5–62.5 °C, and **9b**, 0.28 g (49%), mp 83–84 °C.

9a: NMR ($CDCl_3$) δ 1.01 (d, J = 8 Hz, 3 H), 2.60–2.63 (m, 2 H), 3.05 (m, 1 H), 4.04 (m, 1 H), 5.21 (d,d, J = 6, 8 Hz, 1 H), 5.62–5.73 (m, 2 H), 7.58–7.90 (m, 5 H). Anal. Calcd for $C_{13}H_{15}NSO_4$: C, 55.50; H, 5.37; N, 4.98. Found: C, 55.37; H, 5.30; N, 4.89.

9b: NMR ($CDCl_3$) δ 1.11 (d, J = 7 Hz, 3 H), 2.45–2.63 (m, 2 H), 2.83 (m, 1 H), 4.02 (q, 1 H), 4.52 (d,d, J = 10, 12 Hz, 1 H), 5.63 (m, 2 H), 7.58–7.91 (m, 5 H). Anal. Calcd for $C_{13}H_{15}NSO_4$: C, 55.50; H, 5.37; N, 4.98. Found: C, 55.47; H, 5.39; N, 4.73.

Michael Addition of 1a, 2a, and 3a. A mixture of **1a** (0.22 g, 12 mmol) and pyrrolidine (0.10 g, 14 mmol) in 5 mL of methanol was stirred at 20 °C for 2 h. After evaporation of the solvent, the residue was subjected to column chromatography (silica gel/benzene–hexane–ethyl acetate) to give **10**, 0.14 g (81%): mp 78 °C (lit.[8] mp 77–78 °C); NMR ($CDCl_3$) δ 1.9–2.2 (m, 4 H), 3.1–3.3 (m, 2 H), 3.6–3.8 (m, 2 H), 6.62 (d, J = 12 Hz, 1 H), 8.38 (d, J = 12 Hz, 1 H). The reaction of other olefins was carried out in the same way and the same product, **10**, was obtained in 89% and 71% yields from **2a** and **3a**, respectively.

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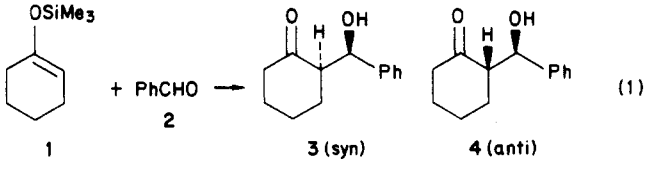
Communications

Water-Promoted Organic Reactions: Aldol Reaction under Neutral Conditions

Summary: The trimethylsilyl enol ether of cyclohexanone adds to benzaldehyde in aqueous solution at room temperature and atmospheric pressure without a catalyst to give good yields of condensation products with a selectivity that is the reverse in comparison with the acid-catalyzed reaction.

Sir: The Mukaiyama variant[1] of the aldol reaction, that is, the condensation of silyl enol ethers with aldehydes (eq 1), has become a popular tool in organic synthesis as it is relatively easily carried out, with readily available starting materials. However, acid-sensitive substrates may raise a problem, because stoichiometric amounts of $TiCl_4$ must be used. More recently,[2] it has been shown that the reaction could be conducted without catalyst, but under high pressure (10 kbars), to give good yields of products, with a selectivity that is the reverse in comparison with the acid-catalyzed reaction (Table I, entries 1 and 2). While these experiments gave some insight into mechanistic problems, their preparative developments may suffer at present from the scarcity of high-pressure equipment.



(1)

As part of a program of using water-soluble glyco-organic substrates[3] for aqueous organic reactions, we were led naturally to address the following questions:

(1) Mukaiyama, T.; Banno, K.; Narasaka, K. *J. Am. Chem. Soc.* **1974**, *96*, 7503.

(2) Yamamoto, Y.; Maruyama, K.; Matsumoto, K. *J. Am. Chem. Soc.* **1983**, *105*, 6963.

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