J_{gem} = 12.2 Hz, C14-H_A), 3.22 (1 H, d, C14-H_B), 4.73 (1 H, br dd, ΣJ = 7 Hz, C4-H), 6.89 (1 H, m, C2a-H), 6.93 (1 H, m, C2c-H), 7.20 (1 H, m, C2b-H), 7.45 (1 H, d, J = 10.4 Hz, C13-H), 7.50 (1 H, m, C2d-H), 12.02 (1 H, br d, J = 10.4 Hz, NH); ^{13}C NMR ($CDCl_3$) see Figure 1.

Reduction of 7. A solution of **7** (0.50 g, 1.62 mmol) in THF (30 mL) was dropped to a suspension of $LiAlH_4$ (0.50 g, 13.2 mmol) in THF (20 mL) within 20 min. The reaction mixture was stirred at room temperature for 10 min, then cooled, and decomposed with 10% NaOH (5 mL). The organic layer was separated, and the inorganic part was extracted with THF (30 mL). The combined extracts were dried and evaporated in vacuo. The residue was treated with Et_2O to give **14** (0.32 g, 63.6%) as white powder: mp 195–198 °C dec; IR (KBr) ν 3280–3200 (OH, indole NH), 2300 cm^{-1} (CN); MS, m/z (relative intensity) *311* (100), 294 (29), 293 (42), 282 (13), 264 (29), 250 (24), 177 (40), 163 (42), 147 (37), 144 (17), 124 (59), 110 (35), 96 (46); ^{1}H NMR ($CDCl_3$ + DMSO-d_6, 2:1) δ 0.91 (3 H, t, J = 7.3 Hz, CH_2CH_3), 4.32 (1 H, br s, C8a-H), 4.78 (1 H, br s, NH), 6.5–7.3 (4 H, m, Ar); ^{13}C NMR (DMSO-d_6 + $CDCl_3$, 3:1) δ 7.63 (CH_2CH_3), 46.38 (C2), 50.92 (C4 + C14), 122.61 (C13), 128.60 (C11), 149.20 (C9a).

Dehydration of 14. (a) A solution of **14** (30 mg, 0.10 mmol) in pyridine (6 mL) was refluxed for 6 h and then evaporated in vacuo. The remaining oil was crystallized from MeOH to give **3** (26 mg, 92.0%).

(b) Compound **14** (100 mg, 0.32 mmol) was dissolved in MeOH (15 mL) saturated with HCl at 0 °C. The solution was allowed to stand at 0 °C for 30 min, then treated with 25% NH_4OH, and extracted with CH_2Cl_2. The organic layer was dried and evaporated in vacuo. The residue was crystallized from MeOH to give **3** (90 mg, 95.5%).

Selective Acetylation of 14. To a solution of **14** (0.18 g, 0.58 mmol) in THF (25 mL) were added anhydrous K_2CO_3 (0.7 g) and Ac_2O (0.5 mL). The reaction mixture was stirred at reflux for 75 min, then cooled to room temperature, and filtered. The filtrate was evaporated, and the residue was treated with 5% $NaHCO_3$ to give **15** (0.11 g, 53.8%) as white powder: mp 208–210 °C (MeOH); IR (KBr) ν 3270 (OH), 2300 (CN), 1640 cm^{-1} (amide C=O); MS, m/z (relative intensity) *353* (100), 338 (85), 337 (25), 336 (24), 293 (16), 264 (21), 250 (22), 117 (38), 164 (35), 130 (26), 110 (38), 96 (52); ^{1}H NMR ($CDCl_3$) δ 0.85 (3 H, t, J = 7.3 Hz, CH_2CH_3), 2.37 (3 H, s, $COCH_3$), 3.34 (2 H, s, C8-H + OH), 5.47 (1 H, br s, C8a-H), 7.0–7.45 (4 H, m, Ar); ^{13}C NMR ($CDCl_3$) δ 7.15 (CH_2CH_3), 21.98 (C5), 23.99 ($COCH_3$), 28.68 (CH_2CH_3), 31.84 (C1 + C6), 40.54 (C7), 42.00 (C8), 46.33 (C2), 50.94* (C4), 51.50* (C14), 71.97 (C8a), 77.33 (C13b), 115.24 (C10), 118.45 (CN), 123.41† (C12), 124.47† (C13), 130.01 (C11), 137.60 (C13a), 140.58 (C9a), 168.73 ($COCH_3$) [*,† may be interchanged].

Oxidation of 2. CrO_3 (0.2 g, 2.0 mmol) in Ac_2O (20 mL) was dropped to a solution of **2**[2] (200 mg, 0.74 mmol) in a mixture of CH_2Cl_2 (40 mL) and AcOH (10 mL). The reaction mixture was stirred at room temperature for 3 h, then treated with concentrated NH_4OH (80 mL) at 0 °C, and extracted with CH_2Cl_2 (100 mL). The organic layer was dried and evaporated in vacuo. The remaining oil was purified by TLC to afford **17** (25 mg, 11.2%) as white crystals: mp 150–151 °C (MeOH); IR (KBr) ν 1690–1680 cm^{-1} (C=O); MS, m/z (relative intensity) *300* (100), 285 (12), 271 (4), 243 (7), 147 (15), 146 (18), 138 (8), 124 (44), 123 (55), 110 (16); ^{1}H NMR ($CDCl_3$) δ 0.94 (3 H, t, J = 7.5 Hz, CH_2CH_3), 2.13 (1 H, d, J_{AB} = 13 Hz, C12-H_AH_B), 2.76 (1 H, d, C12-H_AH_B), 7.06 (1 H, ddd, ΣJ = 7.5 + 7.0 + 1.0 Hz, C2c-H), 7.18 (1 H, ddd, ΣJ = 7.5 + 2.1 + 0.6 Hz, C2d-H), 7.41 (1 H, ddd, ΣJ = 8.1 + 7.0 + 2.1 Hz, C2b-H), 8.26 (1 H, ddd, ΣJ = 8.1 + 1.0 + 0.6 Hz, C2a-H), 9.81 (1 H, br s, NH); ^{13}C NMR ($CDCl_3$) see Figure 1.

Oxidation of 4. A solution of CrO_3 (0.10 g, 1.0 mmol) in Ac_2O (10 mL) was dropped to a solution of **4** (100 mg, 0.32 mmol) in a mixture of CH_2Cl_2 (20 mL) and AcOH (5 mL). The reaction mixture was stirred at room temperature for 1 h, then treated with concentrated NH_4OH (40 mL) at 0 °C, and extracted with CH_2Cl_2 (100 mL). The organic layer was dried and evaporated in vacuo. The remaining oil was crystallized from MeOH to give **16b** (18 mg, 17.1%) as white powder: mp 219–222 °C dec; IR (KBr) ν 3300 (OH), 1645 cm^{-1} (amide C=O); MS, m/z (relative intensity) *327* (100), 310 (75), 283 (23), 251 (64), 125 (66), 124 (59), 110 (46); ^{1}H NMR (DMSO-d_6 + $CDCl_3$, 2:1) δ 0.86 (3 H, t, J = 7 Hz, CH_2CH_3), 4.30 (1 H, s, C8-H), 6.3 and 7.7 (2 H, br s, $CONH_2$), 7.1–7.5 (4 H, m, Ar); ^{13}C NMR (DMSO-d_6 + $CDCl_3$, 3:1) see Figure 1.

Acknowledgment. We express our sincere thanks to Dr. Péter György, Anna Korcsog-Kassa, and Magdolna Tóth for their valuable help. The financial support of the Richter Gedeon Pharmaceutical Co. and the Hungarian Academy of Sciences is gratefully acknowledged.

Registry No. (±)-**2**, 97720-63-3; (±)-**3**, 97720-62-2; (±)-**4**, 111324-81-3; (±)-**6**, 111324-82-4; **7**, 111324-83-5; (±)-**8**, 111324-84-6; **10**, 111324-85-7; **11**, 111324-86-8; (±)-**12**, 111324-87-9; **13**, 111324-88-0; **14**, 111324-89-1; **15**, 111324-90-4; **16b**, 111324-91-5; (±)-**17**, 111324-92-6.

Efficient Conjugate Alkylation of α,β-Unsaturated Nitro Olefins by Triorganoalanes

Angelo Pecunioso*† and Rita Menicagli†,‡

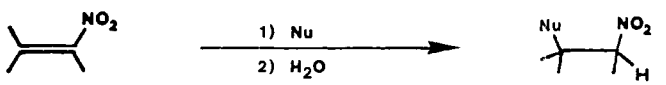
Dipartimento di Chimica e Chimica Industriale and Centro di Studio del CNR per le Macromolecole Stereordinate ed Otticamente Attive, 56100 Pisa, Italy

Received April 2, 1987

Both trialkylaluminum (AlR_3; R = Et, *i*-Bu) and triorganoaluminum etherates (AlR_3·OEt_2; R = Et, *i*-Bu, Ph) rapidly react with α,β-unsaturated nitro olefins to give only 1,4-monoalkylated products in high yield. The natures of substrates, the reaction conditions as well as the reagents molar ratio, do not cause significant variations on the recovered products.

Reactions involving nitro compounds in carbon–carbon bond-forming processes are of increasing importance owing to the remarkable versatility of the nitro group.[1]

Scheme I



α-Nitro olefins are unique synthetic intermediates[2] because a wide class of nucleophiles adds, in a Michael-type

† Dipartimento di Chimica e Chimica Industriale.
‡ Centro di Studio del CNR per le Macromolecole Stereordinate ed Otticamente Attive.

0022-3263/88/1953-0045$01.50/0

Table I. Reactions of Nitro Olefins 1a–e with Triorganoalanes (AlR_3, $AlR_3 \cdot OEt_2$)

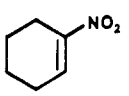
run	compd	AlR_3, R	ligand	hydrolysis	yield, %[a] 2	yield, %[a] 3
1	1a	Et		A	80 (75)	20 (16)
2				B	4	96 (86)
3			Et_2O	A	74 (67)	26 (21)
4				B	6	94 (83)
5		*i*-Bu		A	96 (87)	4
6				B	5	95 (82)
7			Et_2O	A	88 (73)	12
8		Ph		A	92 (87)	8 (6)
9	1b	*i*-Bu		A	94 (86)	6
10				B	35 (21)	65 (58)
11	1c			A	100 (96)	
12				B	42 (38)	58 (50)
13				C	7	93 (86)
14	1d	Et	Et_2O	A	94 (87)	6
15				B	19	81 (48)
16		*i*-Bu		A	93 (87)	7
17				C	5	95 (86)
18	1e			C	4	96 (85)
19		Ph	Et_2O	A	100 (76)	

[a] Determined by GLC analyses; the numbers in parentheses are isolated yields in chemically pure compounds.

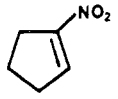
reaction, to the double bond to form the corresponding saturated nitro compounds[1a,2] (Scheme I).

When dialkylcuprates,[3] Grignard reagents,[4] and alkyllithium derivatives[5] are used to alkylate α-nitro olefins, unsatisfactory yields are generally obtained owing to both the high reactivity and the basic properties of these organometallic reagents.

To the best of our knowledge no data have been reported on the reactivity of α-nitroalkenes toward trialkylaluminum reagents, therefore, in connection with our studies on the reactivity of heterosubstituted unsaturated compounds with alanes,[6] we have investigated the behavior of substrates **1a–e** toward some aluminum derivatives.

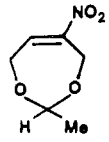


1a

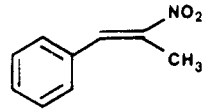


1b

1c



1e

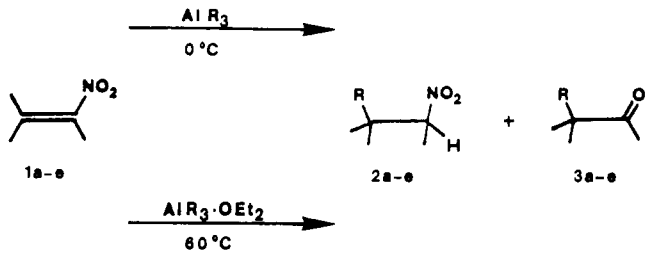


1d

Results and Discussion

Compounds **1a–e** were reacted in *n*-hexane either with trialkylaluminum derivatives (AlR_3; R = *i*-Bu, Et) at 0 °C or with trialkylaluminum etherates ($AlR_3 \cdot OEt_2$; R = Et, *i*-Bu, Ph) at 60 °C (Scheme II). The yields, the product distributions, and the hydrolysis procedure adopted are reported in Table I. The structures of the reaction

Scheme II



products, established by IR, ^1H and ^{13}C NMR, and mass spectroscopy, and, whenever pertinent, the diastereoisomeric ratios are shown in Tables II and III.

Nitroalkenes readily react at 0 °C with AlR_3 to give the immediate formation of a brown coloration that quickly disappears.[7] The reaction affords only 1,4-addition products (Scheme II) independently of the mixing order of the reagents and of the nitro olefin/AlR_3 molar ratio (0.5, 1, and 2). No traces of 1,2-addition products were detected, and only monoalkylated adducts are isolated even in the presence of an excess of AlR_3, in contrast with the results obtained when Grignard reagents were used.[4]

Such a selectivity is quite surprising, in fact both 1,2- and 1,4-additions usually occur in reactions of triorganoalanes with other α,β-unsaturated compounds, and dialkylated products can be formed when an excess of AlR_3 is employed.[8]

Moreover even though α,β-unsaturated ketones are reduced[9] by Al-*i*-Bu_3, no appreciable amounts of reduction products were observed when **1a–d** were reacted with this organometallic reagent (Table I; runs 5, 6, 9–13, and 16–18).

Under the adopted experimental conditions (see Experimental Section) compounds **1**, reacted with a slight excess (1.3 molar equiv) of AlR_3, give, after hydrolysis, mixtures of the corresponding products **2** and **3**. Even compounds **1c** and **1d**, which usually do not give satisfactory results with alkyllithium derivatives,[3,5] were successfully alkylated with AlR_3 (Table I; runs 11–13, 16, and 17).

(1) (a) Seebach, D.; Colvin, E. W.; Lehr, F.; Weller, T. *Chimia* **1979**, *33*, 1. (b) Rosini, G.; Petrini, M.; Sorrenti, P. *Synthesis* **1985**, 515 and references cited therein. (c) Ono, N.; Kaji, A. *Ibid.* **1986**, 693.

(2) (a) Yoshikoshi, A.; Miyashita, M. *Acc. Chem. Res.* **1985**, *18*, 284. (b) Barrett, A. G. M.; Graboski, G. G. *Chem. Rev.* **1986**, *86*, 751. (c) Denmark, S. E.; Cramer, C. J.; Sternberg, J. A. *Helv. Chim. Acta* **1986**, *69*, 1971 and references cited therein.

(3) Bowlus, S. B. *Tetrahedron Lett.* **1975**, 3591.

(4) (a) Buckley, D. G. *J. Chem. Soc.* **1947**, 1494. (b) Buckley, D. G.; Ellery, E. *Ibid.* **1947**, 1497.

(5) Knochel, P.; Seebach, D. *Tetrahedron Lett.* **1981**, 3223.

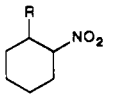
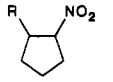
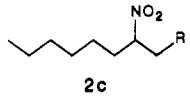
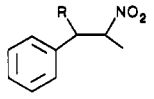
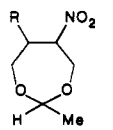
(6) (a) Menicagli, R.; Malanga, C.; Lardicci, L. *J. Org. Chem.* **1982**, *47*, 2288. (b) Menicagli, R.; Malanga, C.; Guidi, M.; Lardicci, L. *Tetrahedron* **1987**, *43*, 171. (c) Menicagli, R.; Malanga, C.; Dell'Innocenti, M.; Lardicci, L. *J. Org. Chem.*, in press.

(7) This coloration is persistent if the reaction is performed at −78 °C.

(8) Eisch, J. J. In *Comprehensive Organometallic Chemistry*, 1st ed.; Pergamon: New York, 1982; Vol. 1, p 555.

(9) Caporusso, A. M.; Giacomelli, G.; Lardicci, L. *J. Org. Chem.* **1982**, *47*, 4640.

Table II. Spectroscopic Data and Stereochemical Ratios of 2a–e

compd	R	formula[a] (mol wt)	m/e (rel intensity)	IR, cm^{-1} [b]	^1H NMR, δ[c,d]	^{13}C NMR, δ[c,d]	cis/trans ratio[e]
 2a	Et	$C_8H_{15}NO_2$ (157.2)	111 (45, $M^+ - NO_2$), 81 (2), 68 (100), 67 (27), 56 (63)	1545	4.74–4.46 (m, 1); 2.27–0.8 (m, 1); 0.97 (m, 3)[f]	90.93,* 86.20, 40.69, 27.30, 26.47, 22.15, 22.08, 21.92, 11.55	75/25
	i-Bu	$C_{10}H_{19}NO_2$ (185.2)	139 (18, $M^+ - NO_2$), 113 (34), 97 (27), 83 (100), 69 (63), 55 (72)	1546	4.67–4.68 (m, 0.9); 4.15 (dt, J = 11.0, 5.1 Hz, 0.1),* 2.10–0.75 (m, 12); 0.85 (dd, J = 6.0, 4.0 Hz, 6)	91.39,* 86.20, 39.43, 37.92, 29.05, 29.01, 26.88, 25.19, 24.19, 24.15, 23.87	90/10
	Ph	$C_{12}H_{15}NO_2$ (205.3)	205 (6, M^+), 159 (15), 158 (10), 129 (7), 117 (10), 115 (11), 91 (100)	1546 1372	7.29–7.15 (m, 5); 4.97–4.90 (m, 1); 3.04 (dt, J = 12.0, 4.2 Hz, 1); 2.53–1.60 (m, 8)	140.47, 128.47, 127.30, 127.18, 87.21, 45.22, 30.24, 25.07 (2 C), 20.11	100/0
 2b	*i*-Bu	$C_9H_{17}NO_2$ (171.2)	125 (9, $M^+ - NO_2$), 109 (6), 83 (22), 81 (24), 69 (54), 55 (34), 41 (100)	1548	4.92 (dt, J = 6.0, 3.2 Hz, 0.15);* 4.48 (q, J = 6.5 Hz, 0.85); 2.45–0.80 (m, 10); 0.89 (dd, J = 4.8, 1.3 Hz, 6)	91.94, 90.70,* 44.50, 43.08, 31.56, 31.21, 25.91, 23.41, 22.46, 21.47	85/15
 2c	*i*-Bu	$C_{12}H_{25}NO_2$ (215.3)	169 (7, $M^+ - NO_2$), 146 (5), 111 (9), 97 (15), 85 (27), 69 (52), 57 (100)	1549	4.42 (m, 1); 2.45–0.92 (m, 15); 0.92–0.84 (m, 9)	89.27, 34.80, 33.96, 31.88, 31.47, 28.66, 27.65, 25.80, 22.45 (2 C), 22.17, 13.96	
 2d	Et	$C_{11}H_{15}NO_2$ (193.2)	147 (8, $M^+ - NO_2$), 146 (37), 131 (5), 117 (18), 105 (51), 91 (100)[g]	1547[g]	7.37–7.07 (m, 5); 4.70 (dq, J = 10.0, 6.7 Hz, 1); 2.97 (dt, J = 10.0, 7 Hz, 1); 1.63 (q, J = 7.0 Hz, 2); 1.26 (d, J = 6.6 Hz, 3); 0.71 (t, J = 7.0 Hz, 3)[g]	138.40, 128.72, 128.15, 127.34, 88.10, 52.15, 25.62, 18.06, 11.56[g]	
			177 (12), 162 (13), 146 (27), 131 (8), 117 (16), 105 (35), 91 (100)[i]		7.38–7.10 (m, 5); 4.73 (dq, J = 10.0, 6.6 Hz, 1); 2.95 (dt, J = 10.0, 7.2 Hz, 1); 1.66 (q, J = 7.0 2); 1.45 (d, J J = 6.6 Hz, 3); 0.74 (t, J = 7.0 Hz, 3)[i]	138.56, 128.42, 127.95, 127.19, 87.91, 51.73, 23.48, 16.98, 11.73[i]	65/35[h]
	i-Bu	$C_{13}H_{19}NO_2$ (221.3)	175 (5, $M^+ - NO_2$), 174 (30), 132 (17), 119 (21), 105 (68), 91 (100)[g]	1551[g]	7.40–7.09 (m, 5); 4.65 (dq, J = 10.0, 6.7 Hz, 1); 3.17 (dt, J = 10.0, 4.0 Hz, 1); 1.88–1.10 (m, 3); 1.26 (d, J = 6.7 Hz, 3); 0.81 (d, J = 3.0 Hz, 6)[g]	138.72, 128.81, 128.23, 127.41, 88.65, 48.44, 41.55, 25.06, 23.83, 20.76, 18.18[g]	
			175 (6, $M^+ - NO_2$), 174 (29), 132 (16), 119 (20), 105 (59), 91 (100)[i]		7.37–7.09 (m, 5); 4.68 (dq, J = 10.0, 6.7 Hz, 1); 3.22 (dt, J = 10.0, 3.5 Hz, 1); 1.90–1.10 (m, 3); 1.57 (d, J = 6.6 Hz, 3); 0.82 (d, J = 3.0 Hz, 6)[i]	139.00, 128.45, 127.92, 127.28, 88.70, 48.09, 39.40, 25.06, 23.89, 20.91, 17.06[i]	60/40[h]
 2e	Ph	$C_{12}H_{15}NO_4$ (237.3)	190 (3, $M^+ - HNO_2$), NO_2), 177 (8), 133 (17), 117 (100), 91 (22)	1550	7.300–7.100 (m, 5); 4.984 (q, J = 5.2 Hz, 0.3); 4.958 (q, J = 5.2 Hz, 0.7); 4.801 (ddd, J = 10.01 Hz, J = 9.04 Hz, J = 3.42 Hz, 1); 4.370–3,530 (m, 5); 1.264 (d, J = 5.2 Hz, 2.1); 1.255 (d, J = 5.2 Hz, 0.9)[h]	137.05,* 136.46, 128.92, 127.94, 127.43, 99.84, 99.57,* 90.55, 90.11,* 68.36, 66.09,* 63.18,* 62.06, 49.76, 49.62,* 19.57, 19.43*[k]	0/100[j]

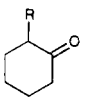
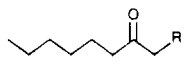
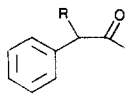
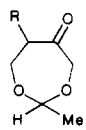
[a] All isolated products gave satisfactory C, H, and N elemental analyses (±0.4%). [b] Liquid film, 20 μm. [c] All spectra were measured in $CDCl_3$ (TMS as internal standard) at 100 MHz unless otherwise stated; s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet. [d] Marked (*) values are referred to the signals of the minor component. [e] GLC and ^1H NMR analyses. [f] 60 MHz. [g] Erythro isomer. [h] Erythro/threo. [i] Threo isomer. [j] 70/30 diastereomeric mixture. [k] 300 MHz.

Since the etherate triorganoalanes (AlR_3·OEt_2) are more easily available than the corresponding non-etherate compounds, it could be of interest to test their reactivity toward the α-nitro olefins **1**.

Although it is well-known that complexation of AlR_3 with Lewis bases often results in a drastic change in reactivity, the reagents employed (AlR_3·OEt_2; R = Et, *i*-Bu, Ph) were able, once again, to convert nitroalkenes **1** into the corresponding alkylation products in satisfactory yield (Table I; runs 3, 4, 7, 8, 14, 15, and 19).

The main difference found with respect to the reactions performed with AlR_3 was a slower reaction rate, and, in fact, comparable conversions can be obtained by heating the reaction mixtures at 60 °C for 30 min (Scheme II).

Table III. Spectroscopic Data of 3a–e

compd	R	formula[a] (mol wt)	m/e (rel intensity)	IR, cm^{-1} [b]	^1H NMR, δ[c,d]	^{13}C NMR, δ[c,d]
 **3a**	Et	$C_8H_{14}O$ (126.2)	126 (32, M^+), 111 (10), 98 (100), 83 (37), 67 (18), 55 (58)	1711	2.60–1.10 (m, 11); 0.96 (m, 3)[e]	212.55, 52.39, 41.95, 33.46, 28.04, 24.89, 22.55, 11.71
	i-Bu	$C_{10}H_{18}O$ (154.24)	111 (5), 98 (100), 83 (14), 70 (22), 55 (18)	1710	2.55–0.95 (m, 12); 0.85 (d, J = 5.5 Hz, 6)[e,f]	207.71, 49.44, 43.07, 39.79, 35.79, 29.77, 27.12, 26.67, 24.87, 24.19
	Ph	$C_{12}H_{14}O$ (174.2)	174 (30, M^+), 145 (3), 130 (100), 117 (49), 115 (24), 104 (35), 91 (30), 77 (13), 65 (8), 51 (11)	1715	7.37–7.08 (m, 12); 3.60 (dd, J = 11.0, 5.6 Hz, 1); 2.50–1.10 (m, 8)	209.54, 140.37, 128.40, 128.22, 126.75, 57.35, 42.13, 35.03, 27.81, 25.29
 **3b**	*i*-Bu	$C_9H_{16}O$ (140.2)	140 (6, M^+), 97 (5), 84 (100), 69 (12), 55 (34), 41 (72)	1739	2.95–0.90 (m, 10); 0.88 (d, J = 6.0 Hz, 6)	220.79, 47.39, 39.17, 37.89, 30.25. 26.34, 23.37, 21.69, 20.81
 **3c**	*i*-Bu	$C_{12}H_{24}O$ (184.3)	184 (21, M^+), 165 (4), 141 (26), 138 (58), 113 (100), 99 (62), 85 (33), 81 (53), 71 (69)	1715	2.40 (t, J = 7.2 Hz, 4); 1.57–1.24 (m, 11); 1.11–0.83 (m, 9)	210.6, 42.79, 40.80, 32.86, 31.72, 29.05, 27.85, 24.00, 22.55, 22.36 (2 C), 13.97
 **3d**	Et	$C_{11}H_{14}O$ (162.2)	162 (16, M^+), 133 (4), 119 (46), 91 (100)	1715	7.33–7.05 (m, 5); 3.40 (t, J = 7.0 Hz, 1); 2.15–1.35 (m, 2); 1.97 (s, 3); 0.82 (t, J = 7.2 Hz, 3)[f]	207.99, 138.92, 128.72, 128.15, 127.06, 61.62, 29.91, 24.98, 12.03
	i-Bu	$C_{13}H_{18}O$ (190.3)	17 (1, M^+ – COMe), 134 (24), 105 (24), 91 (100), 43 (25)	1713	7.36–7.15 (m, 5); 3.71 (t, J = 7.0 Hz, 1); 2.05 (s, 3); 1.90–0.95 (m, 3); 0.87 (dd, J = 6.0, 1.1 Hz, 6)	207.07, 139.15, 128.65, 128.03, 126.91, 57.59, 40.76, 28.65, 25.61, 22.93, 22.16
 **3e**	*i*-Bu	$C_{10}H_{18}O_3$ (186.2)	186 (0.4, M^+), 156 (5), 142 (10), 130 (29), 113 (23), 99 (42), 84 (96), 69 (44)	1716	4.880 (q, J = 5.2 Hz, 0.6); 4.683 (q, J = 5.3 Hz, 0.4);* 4.325–4.006 (m, 2); 3.988–3.342 (m, 2); 3.297–3.207 (m, 0.4);* 3.047–2.960 (m, 0.6); 1.428 (d, J = 9.0 Hz, 1.2);* 1.373 (d, J = 9.0 Hz, 1.8); 1.817–0.922 (m, 3); 0.901 (dd, J = 6.4, 4.2 Hz, 6)[g,h]	212.626, 211.688,* 104.174,* 103.203, 75.323,* 72.554, 68.13,* 67.860, 51.159,* 50.565, 36.602, 35.422,* 25.740, 25.730, 22.894,* 22.685, 22.465 (2 C + 2 C*), 20.856,* 20.503[g,h]

[a] All isolated products gave satisfactory C, H, and N elemental analyses (±0.4%). [b] Liquid film, 20 μm. [c] All spectra were measured in $CDCl_3$ (TMS as internal standard) at 100 MHz unless otherwise stated; s, singlet; d, doublet; t, triplet; q, quartet; m, multiplet. [d] Marked (*) values are referred to the signals of the minor component. [e] 60 MHz. [f] CCl_4. [g] 300 MHz. [h] 60/40 diastereoisomeric mixture.

In all the investigated cases (Table I) the ratio of the recovered products **2** and **3** strongly depends on the hydrolysis procedure: nitro compounds **2** predominate when the reaction mixtures are hydrolyzed with cold 0.1 N HCl while ketones **3** can be recovered in good overall yields by using 3 N HCl; alternatively an alkaline $KMnO_4$ solution[10] can be used to obtain compounds **3** (Table I; procedures A, B, and C, respectively; see Experimental Section).

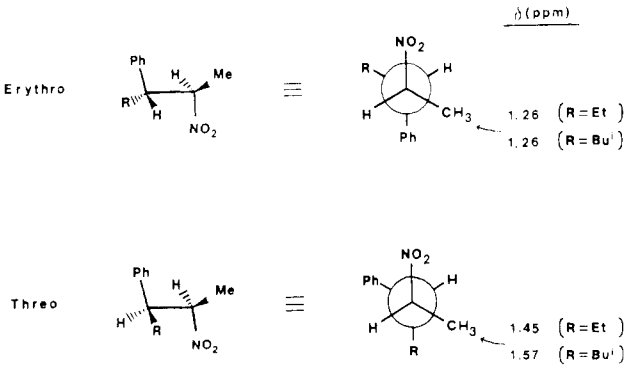
Alkylation of nitro compounds **1a,b,d,e** resulted in diastereoisomeric cis/trans or erythro/threo mixtures (Table II) as determined by GLC analyses.

Alkylation of the **1d** system occurs with a low degree of diastereoselectivity (erythro/threo = 2/1): on the contrary starting from cyclic systems **1a,b,e** higher cis/trans selectivities were found (Table II).

Pure samples of each isomer of compounds **2d** were obtained by means of flash chromatography, and the anisotropy, introduced by the aromatic group, leading to specific upfield shift of the gauche CH_3 group signal (Scheme III), was used to attribute the *erythro* configuration to the main isomer showing the highest R_f on silica gel.

Compound **2e** was isolated as a 2/1 diastereoisomeric mixture, due to the presence of a chiral center on the C_2.

Scheme III



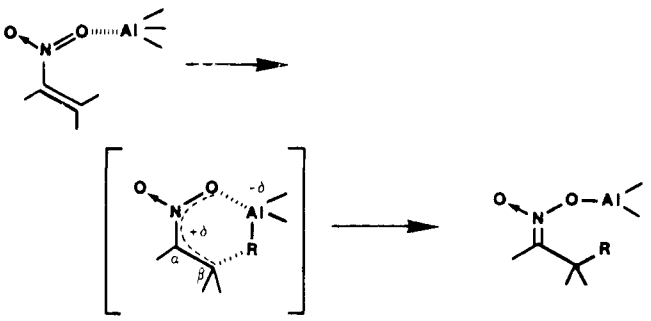
In accordance, the inspection of the ^1H NMR spectrum allowed us to determine that the NO_2 and the phenyl group are arranged in trans[11] configuration only; in fact the values of the coupling constants of the $CHNO_2$ (10.0, 9.0, and 3.4 Hz, Table II) are consistent with the proposed structure.

The cis configuration of the predominant isomer of **2a** and **2b** was established on the basis of either ^1H NMR coupling pattern of $CHNO_2$ signal or ^{13}C NMR upfield shift of the CNO_2 signal. It is to be stressed that the increase of the steric hindrance of the R group in **2a** results

(10) (a) Shechter, H.; Williams, F. T., Jr. *J. Org. Chem.* **1962**, *27*, 3699. (b) Kornblum, N.; Erickson, A. S.; Kelly, W. J.; Henggeler, B. *J. Org. Chem.* **1982**, *47*, 4534.

(11) For cis/trans configurational assignment in 2-substituted cycloheptanols, see: Bauman, A.; Mohrle, H. *Tetrahedron* **1968**, *24*, 6941.

Scheme IV



5

in an increase of the selectivity in the formation of the less stable cis isomer.

The cis preference observed in the formation of **2a** products well agrees with the previously reported data;[12] this preference was attributed to a kinetically controlled addition of protons to nitronate intermediates in which the steric hindrance of the neighboring alkyl group plays a main role.[13]

The regioselective 1,4-alkylation of **1a–e** can be rationalized on the basis of the mechanistic pathway proposed for the reaction of α,β-unsaturated ketones with AlR_3.[8] Accordingly the reaction of AlR_3 and $AlR_3{\cdot}OEt_2$ with α-nitro olefins should proceed through the coordination of AlR_3 to the oxygen of the nitro group followed by the regiospecific transfer of an alkyl group, via the transition state **5**, from the aluminum to the carbon atom in the β-position to NO_2 (Scheme IV).

The reported results clearly indicate that AlR_3 as well as $AlR_3{\cdot}OEt_2$ are very satisfactory reagents to perform the conjugate addition of unstabilized[1a] carbanions to nitro olefins in high yields and under mild reaction conditions.

This reaction, followed by acid or oxidative workup, is therefore synthetically equivalent to a completely regioselective α-alkylation or α-arylation of ketones.

Experimental Section

Material and Instrumentation. Triethyl- and triisobutylaluminum (Fluka A.G.Co) as well as their etherate complexes were distilled under argon and stored in sealed capillary glass vials in weighed amounts. Triphenylaluminum etherate,[14] 1-nitrocyclohexene,[15] 1-nitrocyclopentene,[15] 2-nitro-1-octene,[15] 2-methyl-5-nitro-4,7-dihydro-2*H*-1,3-dioxepin,[15] 1-phenyl-2-nitropropene[16] were prepared according to reported procedures. Hexane was purified by standard methods and redistilled from $LiAlH_4$ before use.

GLC analyses were performed on a Perkin Elmer F-30 instrument (XE-60, 2 m × 0.29 cm columns) equipped with flame ionization detectors and N_2 as carrier gas.

IR spectra were obtained on a Perkin Elmer FT IR 1750 spectrophotometer using liquid films (20 μm).

^1H NMR spectra were recorded on Varian T 60 (60 MHz), Varian XL-100 (100 MHz), and Varian VXR 300 (300 MHz) spectrometers; ^{13}C NMR spectra were recorded on Varian XL-100 (25.2 MHz) and Varian VXR 300 (75.4 MHz) spectrometers. All NMR data were obtained in $CDCl_3$ solution, unless otherwise stated, and chemical shifts are reported as δ values referred to Me_4Si (TMS) as internal reference.

Mass spectra were taken on VG-Analytical 7070 GC–MS instrument.

Analytical TLC was performed on silica gel (Merck, SiO_2 60); all crude products were purified by flash chromatography on silica gel column (Merck SiO_2 60, 230–400 mesh) using ethyl acetate/light petroleum (10/90) or ethyl ether/light petroleum (5/95).

General Procedure. Reaction with AlR_3. All reactions were carried out in dry apparatus, under argon atmosphere, and chemically pure products were isolated, from the crude reaction mixtures, by flash chromatography. In a typical run, the nitro olefin (10 mmol) was portionwise added to a cooled (0 °C) solution of triorganoalane (13 mmol) in hexane (40 mL). The resulting clear solution was stirred at 0 °C for additional 30 min and then hydrolyzed according to the following (A, B, or C) procedures.

Reaction with $AlR_3{\cdot}OEt_2$. Nitro olefin (10 mmol) was added, as described above, to the triorganoaluminum etherate (13 mmol). As soon as the reagents were mixed, a red-brown coloration arose and disappeared when the mixture was heated at 60 °C (30 min). The resulting mixture was hydrolyzed according to one of the following (A, B, or C) procedures.

Hydrolysis. Procedure A: Diethyl ether (100 mL) was added, under argon, to the reaction mixture, and the resulting solution, cooled at 0 °C, was poured into a separatory funnel containing cold 0.1 N HCl solution (100 mL). The mixture was shaken until all solid was dissolved, and then the aqueous phase was extracted with ether (4 × 50 mL).

Organic extracts were washed with diluted $NaHCO_3$ and brine and then dried (Na_2SO_4). The solvent was removed under vacuum (20 mmHg) to give the crude reaction products.

Procedure B. Diethyl ether (100 mL) was added to the reaction mixture, and the resulting solution was added, dropwise, to a solution (50 mL) of 3 N HCl. The mixture was vigorously stirred at room temperature for 2 h, and then the organic products were recovered as reported in procedure A.

Procedure C. The reaction mixture was cautiously hydrolyzed with 0.2 N NaOH solution (50 mL) and then poured into a flask containing a cold (0 °C) stirred mixture of hexane (400 mL) and water (400 mL). $KMnO_4$ (10 g) was added portionwise over 2 h, and then sodium bisulfite (18 g) and 10% H_2SO_4 (50 mL) were added; NaCl (100 g) was added to the resulting clear mixture, and the organic products were extracted into ether (4 × 100 mL) and recovered as reported above.

Acknowledgment. This work was supported in part by the Ministero della Pubblica Istruzione Roma.

Registry No. **1a**, 2562-37-0; **1b**, 22987-82-2; **1c**, 2783-14-4; **1d**, 705-60-2; **1e**, 110774-53-3; *cis*-**2a** (R = Et), 110774-54-4; *cis*-**2a** (R = Bu-*i*), 110774-55-5; *cis*-**2a** (R = Ph), 17448-50-9; *trans*-**2a** (R = Et), 110774-62-4; *trans*-**2a** (R = Bu-*i*), 110774-63-5; *cis*-**2b** (R = Bu-*i*), 110774-56-6; *trans*-**2b** (R = Bu-*i*), 110774-64-6; **2c** (R = Bu-*i*), 110774-57-7; *erythro*-**2d** (R = Et), 110774-58-8; *erythro*-**2d** (R = Bu-*i*), 110774-59-9; *threo*-**2d** (R = Et), 110774-65-7; *threo*-**2d** (R = Bu-*i*), 110774-66-8; **2e**-(isomer 1) (R = Ph), 110774-60-2; **2e**-(isomer 2) (R = Ph), 110849-62-2; **3a** (R = Bu-*i*), 4668-64-8; **3a** (R = Et), 4423-94-3; **3a** (R = Ph), 1444-65-1; **3b** (R = Bu-*i*), 4668-65-9; **3c** (R = Bu-*i*), 50639-02-6; **3d** (R = Et), 1528-39-8; **3d** (R = Bu-*i*), 103392-12-7; *cis*-**3e** (R = Bu-*i*), 110774-61-3; *trans*-**3e** (R = Bu-*i*), 110774-67-9; $Al(Bu\text{-}i)_3$, 100-99-2; $Al(Et)_3$, 97-93-8; $Al(Et)_3{\cdot}OEt_2$, 15221-30-4; $Al(Bu\text{-}i)_3{\cdot}OEt_2$, 14263-25-3; $Al(Ph)_3{\cdot}OEt_2$, 58482-37-4.

(12) (a) Zimmerman, H. E.; Nevins, T. E. *J. Am. Chem. Soc.* **1957**, *79*, 6559. (b) Trager, W. E.; Vincenzi, F. F.; Huitric, A. C. *J. Org. Chem.* **1962**, *27*, 3006.
(13) Angyal, S. J.; Luttrell, B. M. *Aust. J. Chem.* **1970**, *23*, 1485.
(14) Mole, T. *Aust. J. Chem.* **1963**, *16*, 794.
(15) Corey, E. J.; Estreicher, H. *J. Am. Chem. Soc.* **1978**, *100*, 6294.
(16) Gairaud, C. B.; Lappin, G. R. *J. Org. Chem.* **1953**, *18*, 1.