Selective Homologation of Ketones and Aldehydes with Diazoalkanes Promoted by Organoaluminum Reagents

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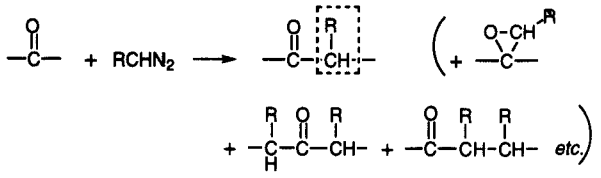
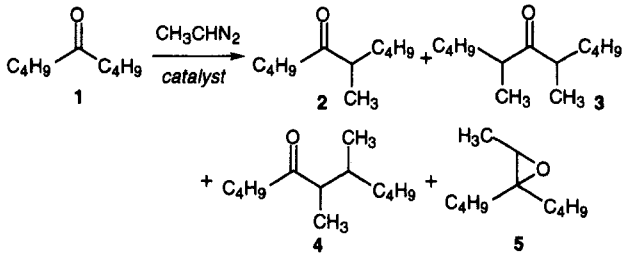
Abstract: Organoaluminum-promoted single homologation or ring expansion of ketones and aldehydes with diazoalkanes has been described, and among various organoaluminum reagents, exceptionally bulky methylaluminum bis(2,6-di-*tert*-butyl-4-methylphenoxide) (MAD) is found to be highly effective for the selective homologation of various ketones and aldehydes.

The single carbon chain homologation or ring expansion of aliphatic and aromatic carbonyl compounds is a frequently encountered synthetic transformation and constitute a challenging task in organic synthesis. The most effective approach is obviously the direct insertion of an alkylidene unit from diazoalkane to carbonyl substrates.[1] This reaction,



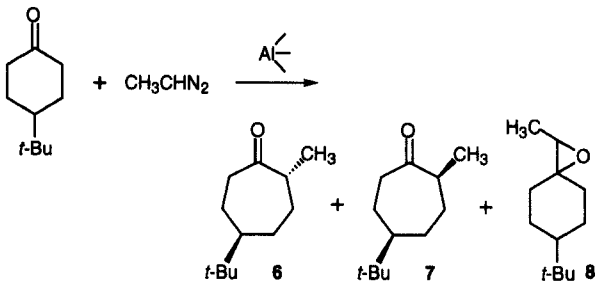
however, has severe experimental limitations, the most serious of which include the low reactivity, multiple homologation, and oxirane formation, depending on the nature of alkyl substituents of carbonyl substrates and diazoalkanes, and catalytic influences. The rate of the homologation reaction can be somewhat accelerated by the use of protic solvents such as alcohols and water, which are not generally applicable to less reactive ketones.[2,3] Protic acids and Lewis acids usually decompose diazoalkane.[4-6] Accordingly, various alternative procedures have been developed with limited success. In this context, we have been interested in the possibility that certain bulky, oxygenophilic organoaluminum reagents might be highly useful for the single homologation or ring expansion of carbonyl substrates with diazoalkane because of their carbonyl activation ability without affecting the interaction of diazoalkane. Here we wish to report a new technique for single carbon chain homologation or ring expansion of carbonyl compounds promoted by organoaluminum reagents.

We examined the reaction of 5-nonanone (**1**) with diazoethane in the presence of various activation catalysts, which gave homologation products **2-4** and epoxide **5**. This system is preferrable for our purpose because of the low reactivity of acyclic ketones towards diazoalkane under the influence of conventional activators. Indeed, the previously known catalysts such as alcohols and lithium chloride are totally ineffective for the less reactive 5-nonanone substrate **1**.[1a] An ordinary Lewis acid, $BF_3{\cdot}OEt_2$ afforded only trace amounts of the homologation products.[5] However, trialkylaluminum (Me_3Al or *i*-Bu_3Al) gave quite satisfactory results in chemical yield and product selectivity. This is rather surprising since organoaluminums are reported to react easily with diazoalkanes to give insertion products with the evolution of nitrogen.[7]

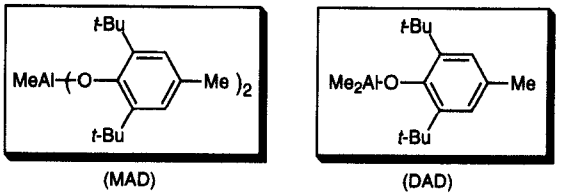


Me_3Al, CH_2Cl_2, -78 °C, 1 h : 52% (92 : 0 : 0 : 8)
Me_3Al, CH_2Cl_2, 0 °C, 1 h : 60% (91 : 1 : 0 : 8)
i-Bu_3Al, CH_2Cl_2, -78 °C, 1 h : 65% (92 : 1 : 0 : 7)
Et_2AlCl, CH_2Cl_2, -78 °C, 1 h : 74% (63 : 30 : 7 : 0)
$BF_3{\cdot}OEt_2$, ether, -20~0 °C : 2%

In the homologation of 4-*tert*-butylcyclohexanone with Me_3Al/diazoethane, the isomeric ratio of *trans*- and *cis*-5-*tert*-butyl-2-methylcycloheptanone, (**6**) and (**7**), is ~3:2. Since 5-substituted 2-methylcycloheptanones constitute an important framework for the synthesis of guaiazulene sesquiterpenes,[8] we continued our search for more superior organoaluminum catalysts for stereoselective ring expansion of 4-*tert*-butylcyclohexanone with diazoethane. Exceptionally bulky methylaluminum bis(2,6-di-*tert*-butyl-4-methylphenoxide) (MAD) has been found to be highly effective for this transformation.[9] Dimethylaluminum 2,6-di-*tert*-butyl-4-methylphenoxide (DAD) is less selective. Noteworthy is the fact that diazoethane should be added to the organoaluminum-ketone complex, and attempted reaction of ketone with a mixture of diazoalkane and organoaluminum at -78 °C gave none of the homologation products.



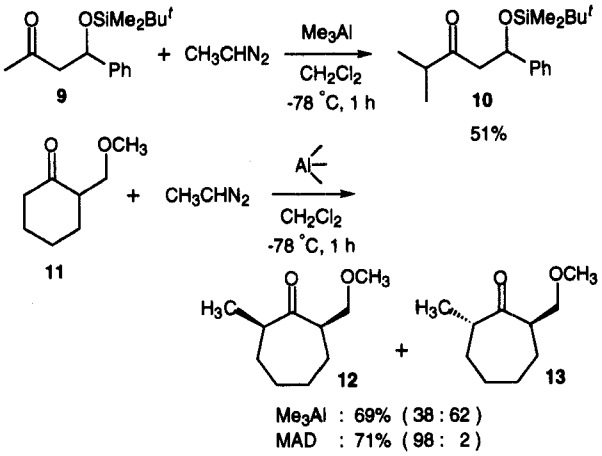
20% EtOH/ether : 91% (43 : 43 : 14)
Me_3Al, CH_2Cl_2 : 81% (54 : 32 : 14)
i-Bu_3Al, CH_2Cl_2 : 85% (67 : 20 : 13)
DAD, CH_2Cl_2 : 84% (80 : 10 : 10)
MAD, CH_2Cl_2 : 87% (94 : 3 : 3)



(MAD) (DAD)

Other examples are listed in Table I, which illustrates the generality of our organoaluminum-promoted homologation of ketones with diazoalkanes. (1) The homologation of cyclopentanone with R_3Al (R = Me or *i*-Bu)/diazoethane resulted in predominant formation of cycloheptanones at the expense of the intermediary 2-methylcyclohexanone (entries 2 and 3). This is because the reactivity of cyclic ketones is in the order of cyclohexanone > cyclopentanone > cycloheptanone.[2] In contrast, use of MAD exhibited moderate selectivity for the single homologation of cyclopentanone (entry 1). Here, thermodynamically stable isomers of 2,7- and 2,3-dimethylcycloheptanones are formed exclusively.[10] (2) The organoaluminum-promoted single homologation of cyclopentanone has been effected with trimethylsilyldiazomethane,[6] where the single-homologated cyclohexanone is successfully trapped as its trimethylsilyl enol ether (entry 5).[12] (3) The advantage of MAD over other organoaluminums is also seen in the selective homologation of 4-*tert*-butylcyclohexanone with diazomethane (entry 7 vs. 8-10). (4) Another characteristic feature is the reaction of acetophenone, where three methods showed totally different selectivity (entries 18-20), and where MAD has proved to be effective for the regioselective single homologation (entry 18). (5) The MAD-promoted homologation of unsymmetrical ketone exhibited good regioselectivity on the insertion mode of the trimethylsilylmethylidene moiety (entry 21).

Even more interesting is the application of this method for the regio- and stereocontrolled homologation of aldol derivatives, **9** and **11** with diazoalkanes as illustrated below.



Since a variety of diazoalkanes including functionalized ones are readily accessible from the corresponding amines in 3-step sequences,[11] the present technique has a broad applicability in selective organic synthesis. For example, use of diazopropene permits α-vinylation of cyclic ketones with ring enlargement (entry 11), hitherto difficult by

Table I. Homologation of Typical Ketones and Aldehydes with Diazoalkanes [a]

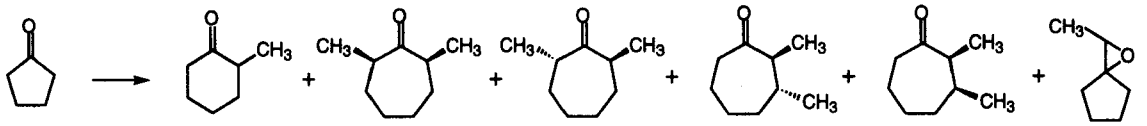
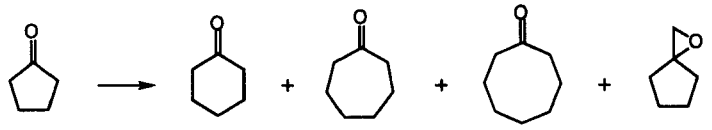
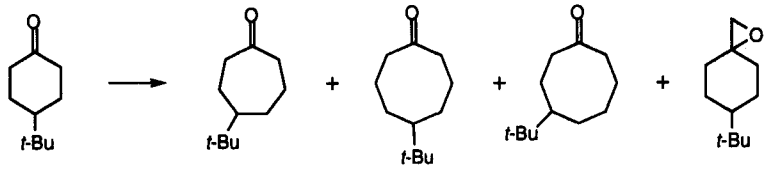
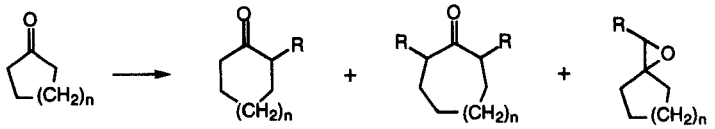
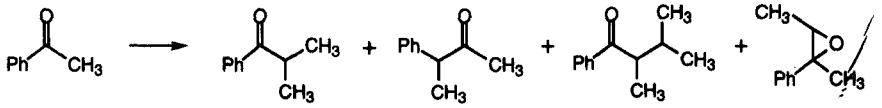
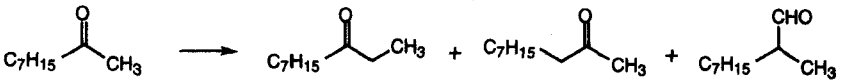
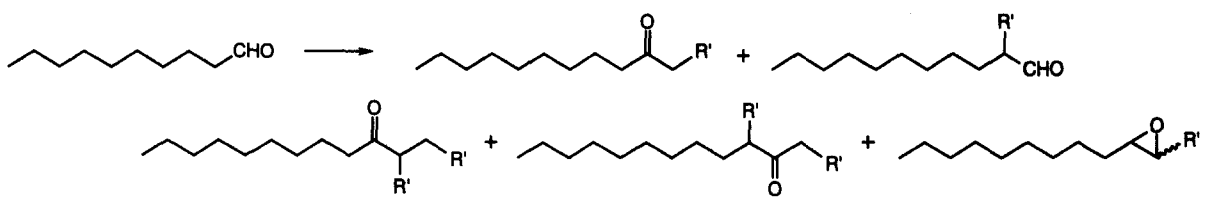
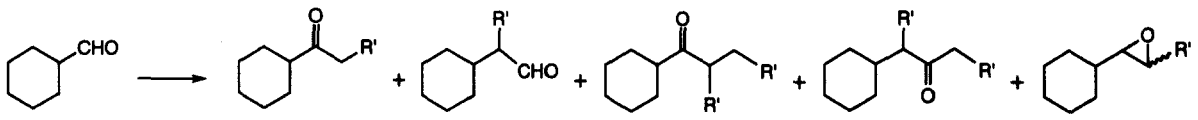
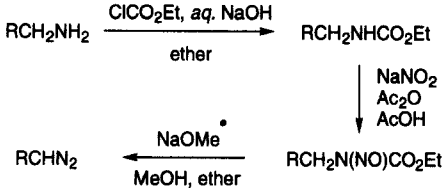
entry	diazoalkane	promotor/solvent	condition (°C, h)	products	% yield [b] (ratio) [c]
					
1	CH_3CHN_2	MAD / CH_2Cl_2	-78, 1		62 (70 : 16 : 0 : 14 : 0 : 0)
2		Me_3Al / CH_2Cl_2	-78, 1		45 (4 : 50 : 22 : 12 : 5 : 7)
3		*i*-Bu_3Al / CH_2Cl_2	-78, 1		46 (3 : 52 : 11 : 18 : 4 : 12)
4		MeOH/ether	0, 2		16 (45 : 16 : 11 : 28 : 0 : 0)
					
5	Me_3SiCHN_2	Me_3Al / CH_2Cl_2	-20, 1; 0, 1		68 (96 : 2 : 0 : 2)
6		$BF_3{\cdot}OEt_2$ / CH_2Cl_2 [d]	-20, 3		35 (64 : 23 : 10 : 3)
					
7	CH_2N_2	MAD / CH_2Cl_2	-78, 1		95 (84 : 3 : 3 : 10)
8		Me_3Al / CH_2Cl_2	-78, 1		70 (66 : 15 : 15 : 4)
9		*i*-Bu_3Al / CH_2Cl_2	-78, 1		68 (54 : 22 : 22 : 2)
10		MeOH/ether	0, 2		63 (50 : 25 : 25 : 0)
					

Table 1. (continued)

entry	diazoalkane	promotor/solvent	condition (°C, h)	products	% yield [b] (ratio) [c]
11	CH_2=$CHCHN_2$	Me_3Al / CH_2Cl_2	-78, 1	(n = 2; R = vinyl)	51 (100 : 0 : 0)
12		MeOH/ether	0, 2		0
13	CH_3CHN_2	MAD / CH_2Cl_2	-78, 1	(n = 4; R = Me)	56 (100 : 0 : 0)
14		Me_3Al / CH_2Cl_2	-78, 1		60 (98 : 1 : 1)
15		MeOH/ether	0, 2		0
16	$CH_3(CH_2)_4CHN_2$	Me_3Al / CH_2Cl_2	-78, 1	(n = 4; R = pentyl)	88 (100 : 0 : 0)
17		MeOH/ether	0, 2		0
					
18	CH_3CHN_2	MAD / CH_2Cl_2	-78, 1		85 (80 : 0 : 3 : 17)
19		Me_3Al / CH_2Cl_2	-78, 1		83 (36 : 0 : 40 : 24)
20		MeOH/ether	0, 2		18 (57 : 43 : 0 : 0)
					
21	Me_3SiCHN_2	MAD / CH_2Cl_2	-78, 8		75 (85 : 15 : 0)
22		Me_3Al / CH_2Cl_2	-20, 2		92 (31 : 36 : 33) [f]
23		BF_3·OEt_2 / CH_2Cl_2 [d]	-20, 3		87 (51 : 40 : 9) [f]
					
24	CH_3CHN_2	Me_3Al/CH_2Cl_2	-78, 1	(R' = CH_3)	69 (80 : 2 : 16 : 1 : 1)
25		MAD/CH_2Cl_2	-78, 1		77 (90 : 1 : 7 : 0 : 2)
26		MAD/CH_2Cl_2 [e]	-78, 1		47 (76 : 8 : 13 : 0 : 3)
27		MeOH/ether	0, 1.5		80 (59 : 24 : 10 : 5 : 2)
28	Me_3SiCHN_2	Me_3Al/CH_2Cl_2	-78, 1; -40, 1	(R' = H)	98 (99 : 0 : 0 : 1 : 0)
29		MeOH/CH_2Cl_2	25, 16		90 (79 : 0 : 1 : 5 : 15)
30	CH_2N_2	MAD/CH_2Cl_2	-78, 1	(R' = H)	66 (53 : 0 : 6 : 1 : 40)
31		ATPH/CH_2Cl_2	-78, 1		87 (1 : 0 : 2 : 0 : 97)
32		MeOH/ether	0, 2		96 (86 : 0 : 1 : 3 : 10)
					
33	CH_3CHN_2	MAD/CH_2Cl_2	-78, 1	(R' = CH_3)	62 (75 : 2 : 9 : 1 : 13)
34		MeOH/ether	0, 2		62 (71 : 10 : 12 : 5 : 2)
35	Me_3SiCHN_2	Me_3Al/CH_2Cl_2	-78, 1; -40, 1	(R' = H)	80 (94 : 1 : 0 : 5 : 0)
36		MeOH/CH_2Cl_2	25, 18		68 (66 : 11 : 5 : 1 : 17)
37	CH_2N_2	MAD/CH_2Cl_2	-78, 1	(R' = H)	97 (21 : 0 : 0 : 1 : 78)
38		ATPH/CH_2Cl_2	-78, 1		83 (1 : 0 : 1 : 0 : 98)
39		MeOH/ether	0, 2		82 (61 : 9 : 2 : 1 : 27)

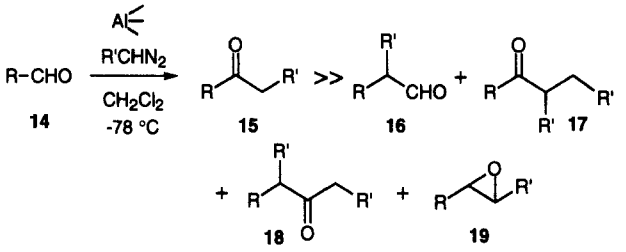
[a] Unless otherwise noted, 1.2 equiv of organoaluminum reagents and 1.1~1.5 equiv of diazoalkanes were utilized under the given reaction conditions. [b] Isolated yield. [c] The product ratio was determined by capillary GLC analysis. [d] Ref. 6. [e] Use of 0.5 equiv of MAD. [f] 2-Methylnonanal was obtained via the Lewis acid-catalyzed rearrangement of 2-methylnonene oxide.

other chemical transformations. Organoaluminum-promoted insertion of long-chain diazoalkane appears feasible (entry 16).

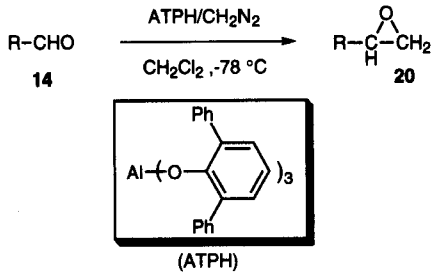


(52~68% overall yield)

In addition to the ketone homologations, the direct conversion of aldehydes to the homologous ketones can be effected with diazoalkanes and organoaluminum catalysts. Selected examples are also included in Table I. For example, treatment of decanal **14** (R = C_9H_{19}) with diazoethane (1.2 equiv) in CH_2Cl_2 in the presence of Me_3Al at -78 °C for 1 h yielded the mixture of single homologated 3-dodecanone **15** (R = C_9H_{19}; R' = CH_3) and 2-methylundecanal **16** (R = C_9H_{19}; R' = CH_3), double homologated 3-methyl-4-tridecanone **17** (R = C_9H_{19}; R' = CH_3) and 4-methyl-3-tridecanone **18** (R = C_9H_{19}; R' = CH_3), and 2-dodecene oxide **19** (R = C_9H_{19}; R' = CH_3) in a ratio of 80:2:16:1:1 in careful comparison with authentic samples (entry 24). However, switching the aluminum reagents from simple trialkylaluminums to MAD (1.2 equiv) has been found to be highly effective for the selective transformation to the homologous ketone **15** (R = C_9H_{19}; R' = CH_3) [ratio of **15~19** (R = C_9H_{19}; R' = CH_3) = 90:1:7:0:2] (entry 25). Attempted use of smaller amounts of MAD (0.5 equiv) lowered the yield and selectivity [ratio of **15~19** (R = C_9H_{19}; R' = CH_3) = 76:8:13:0:3] (entry 26). It should be noted that attempted reaction of decanal **14** (R = C_9H_{19}) with diazoethane (1.2 equiv) in MeOH/ether (volume ratio, 4:1) at 0 °C resulted in formation of several reaction products **15~19** (R = C_9H_{19}; R' = CH_3) in a ratio of 59:24:10:5:2 in 80% combined yield (entry 27).



Insertion of diazomethane to aldehydes is not always selective in the absence or presence of organoaluminum catalysts. Cyclohexanecarboxaldehyde on treatment with MAD/CH_2N_2 afforded oxirane **20** (R = cyclohexyl) as a major product (entry 37). This selectivity was further enhanced by the choice of aluminum tris(2,6-diphenylphenoxide) (ATPH)[12] as catalyst (entry 38). A similar tendency is also observed in decanal (entry 31). On the other hand,



selective introduction of methylene moieties to aldehydes is attainable using trimethylsilyldiazomethane[13] (entries 28 and 35) in the presence of organoaluminum catalysts.

Experimental Section

Infrared (IR) spectra were recorded on a Shimadzu FTIR-8100 spectrometer. ^1H NMR spectra were measured on Varian Gemini-200 or Gemini-300 spectrometer. Analytical gas-liquid phase chromatography (GLC) was performed on Shimadzu GC-8A instruments equipped with a flame ionization detector and a capillary column of PEG-HT (0.25×25,000 mm) using nitrogen as carrier gas. All experiments were carried out under an atmosphere of dry argon. For thin-layer chromatography (TLC) analysis throughout this work, Merck precoated TLC plates (silica gel 60 F_{254}, 0.25 mm) were used. The products were purified by preparative column chromatography on silica gel E. Merck Art. 9385.

In experiments requiring dry solvents, anhydrous ether and tetrahydrofuran were purchased from Aldrich Chem. Co. Dichloromethane was stored over 4Å molecular sieves. Trimethylaluminum was obtained from Toso-Akzo Chem Co. Ltd., Japan. Trimethylsilyldiazomethane (2.0 M in hexane) was obtained from Aldrich Chem. Co. Other chemicals were purchased and used as such.

Preparation of Diazoethane. A solution of diazoethane in CH_2Cl_2 was prepared by a modification of the procedure of Arndt and Werner.[14] In a typical preparation, a mixture of 50% aqueous KOH (10 mL) and CH_2Cl_2 (40 mL) in a round-bottomed flask was cooled in an ice bath and solid *N*-ethyl-*N*-nitrosourea (5 g) was added in small portions over 15 min. The mixture was stirred for 30 min and cooled to -78 °C, thereby freezing the upper aqueous layer. The diazoethane solution was decanted into an Erlenmeyer flask containing KOH pellets. CH_2Cl_2 (10 mL) was added to the initial flask to rinse the remaining diazomethane and decanted into the flask.

For analysis, an aliquot portion (0.5 ml) of the solution was allowed to react at room temperature with accurately weighed benzoic acid (1.0 mmol) in 10 ml of dry ether. The unreacted benzoic acid was titrated with 0.2 *N* standard NaOH to the phenolphthalein end point. The solution was stored in the freezer.

Preparation of Diazopropene and Diazohexane. An ethereal solution of diazopropene and diazohexane were prepared by a modification of the procedure described by Brewbaker and Hart[11] from the corresponding ethyl alkylnitrosocarbamate by the reaction with methanolic NaOMe.

Preparation of MAD, DAD, and ATPH. To a solution of 2,6-di-*tert*-butyl-4-methylphenol (2 equiv) in CH_2Cl_2 was added at room temperature a 2 *M* hexane solution of Me_3Al (1 equiv). The methane gas (~2 equiv) evolved immediately. The resulting colorless solution was stirred at room temperature for 1 h and used as a solution of MAD in CH_2Cl_2 without any purification. Other modified organoaluminum reagents such as DAD and ATPH were prepared *in situ* from Me_3Al and the corresponding phenols in CH_2Cl_2 in a similar manner as described above.

General Method for the Organoaluminum-Promoted Homologation of Ketones with Diazoalkanes. To a solution of organoaluminum reagent (0.60 mmol) in CH_2Cl_2 (7.0 ml) was added a ketone (0.50 mmol) at -78 °C. Diazoalkane (0.55 mmol) in CH_2Cl_2 was added in one portion and stirred under the condition indicated in the text or the table. The reaction mixture was then poured into 1 *N* HCl and extracted with CH_2Cl_2. Evaporation of the solvent and purification of the residue by column chromatography gave several homologated ketones and epoxides.

Reaction of 5-Nonanone (1) with Diazoethane. According to the general procedure described above, 5-nonanone (1) was converted to homologation products, 6-methyl-5-decanone (2); 5,7-dimethyl-6-undecanone (3); 6,7-dimethyl-5-undecanone (4) and epoxide **5**. The ratio was established *via* GLC analysis by comparison with

authentic samples, which were isolated from the reaction products or independently synthesized: t_R(2) = 9.78 min, t_R(3) = 15.54 and 16.49 min, t_R(4) = 21.84 and 22.50 min, t_R(5) = 7.33 min at the column temperature of 110 °C.

6-Methyl-5-decanone (2): IR (neat) 2961, 2934, 2874, 1713, 1460, 1379, 1124 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.44 (1H, sextet, J = 6.8 Hz, CHC=O), 2.42 (2H, t, J =7.0 Hz, CH_2C=O), 1.12-1.76 (10H, m, $5CH_2$), 1.05 (3H, d, J = 6.8 Hz, CH_3-C-C=O), 0.91 (3H, t, J = 7.0 Hz, CH_3), 0.89 (3H, t, J = 7.0 Hz); MS: *m/z* (%) = 170 (M^+, 77), 141 (38), 127 (79), 114 (96), 113 (90), 85 (100), 72 (97), 57 (95), 43 (90), 41 (89), 27 (82). Anal. Calcd for $C_{11}H_{22}O$: C, 77.58; H, 13.02. Found: C, 77.66; H, 13.03.

5,7-Dimethyl-6-undecanone (3): ^1H NMR ($CDCl_3$) δ 2.63 (2H, sextet, J = 6.8 Hz, 2CHC=O), 1.08-1.77 (12H, m, $6CH_2$), 1.18 and 1.26 (6H, d, J = 6.8 Hz, diastereomeric $2CH_3$-C-C=O), 0.88 (6H, t, J = 6.8 Hz, $2CH_3$). Anal. Calcd for $C_{12}H_{24}O$: C, 78.20; H, 13.12. Found: C, 78.25; H, 13.13.

Epoxide 5: ^1H NMR ($CDCl_3$) δ 2.83 (1H, q, J = 7.6 Hz, CH-C-O), 1.17-1.67 (12H, m, $6CH_2$), 1.27 (3H, d, J = 7.6 Hz, CH_3-C-O), 0.81-1.20 (6H, m, $2CH_3$). Anal. Calcd for $C_{11}H_{22}O$: C, 77.58; H, 13.02. Found: C, 77.61; H, 13.06.

The authentic 6,7-dimethyl-5-undecanones (4) were prepared according to the literature procedure.[15]

6,7-Dimethyl-5-undecanones (4):[15] IR (neat) 2961, 2932, 2874, 1713, 1458, 1408, 1379, 1125, 1032, 729 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.41 (2H, t, J = 7.5 Hz, CH_2C=O), 2.34-2.50 (1H, m, CHC=O), 1.71-1.89 (1H, m, CH-C-C=O), 1.49-1.59 (2H, m, CH_2-C-C=O), 0.96 and 1.00 (3H, d, J = 6.9 Hz, diastereomeric CH_3-C-C=O), 0.78 and 0.92 (3H, d, J = 6.6 Hz, diastereomeric CH_3-C-C-C=O), 1.04-1.39 (11H, m, CH and $5CH_2$), 0.89 (6H, t, J = 6.6 Hz, $2CH_3$).

Reaction of 4-*tert*-Butylcyclohexanone with Diazoethane. Following the general protocol, 4-*tert*-butylcyclohexanone was converted to homologation products, *trans*- and *cis*-2-methyl-5-*tert*-butylcycloheptanones, (6) and (7), and 2-methyl-6-*tert*-butyl-1-oxaspiro[2.5]octane (8). The *cis*/*trans* configuration of 2-methyl-5-*tert*-butylcycloheptanones was established by equilibration in methanolic NaOMe[10] and the ratio was determined by GLC analysis: t_R(*trans*-isomer, 6) = 19.73 min, t_R(*cis*-isomer, 7) = 20.23 min, t_R(epoxide, 8) = 9.92 and 10.57 min at the column temperature of 110 °C.

2-Methyl-5-*tert*-butylcycloheptanone:[3] IR (neat) 2964, 2870, 1705, 1458, 1366, 1233, 1005, 926, 885 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.44-2.68 (3H, m, CH_2-C(=O)CH), 1.75-2.08 (3H, m, CH-CH_2), 0.94-1.48 (4H, m, $2CH_2$), 1.08 and 1.05 (3H, d, J = 7.0 Hz, *cis*- and *trans*-CH_3-C-C=O), 0.85 (9H, s, *t*-Bu); MS: *m/z* (%) = 182 (M^+, 59), 167 (100), 149 (59), 139 (29), 125 (92), 107 (85), 98 (90), 79 (86), 57 (95), 41 (83), 39 (54), 29 (54), 27 (44). Anal. Calcd for $C_{12}H_{22}O$: C, 79.06; H, 12.16. Found: C, 79.02; H, 12.28.

The authentic 2-methyl-6-*tert*-butyl-1-oxaspiro[2.5]octanes (8) were synthesized by treatment of a THF solution of 4-*tert*-butylcyclohexanone and 1,1-dibromoethane with *t*-BuLi at -78 to 0 °C.

2-Methyl-6-*tert*-butyl-1-oxaspiro[2.5]octane (8):[3] IR (neat) 2955, 2867, 1482, 1443, 1379, 1366, 1032, 995, 926, 887, 675 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.88 (1H, q, J = 5.6 Hz, CH-O), 1.04-1.87 (8H, m, $4CH_2$), 1.27 (3H, d, J = 5.6 Hz, CH_3-C-O), 0.89 (9H, s, *t*-Bu); MS: *m/z* (%) = 182 (M^+, 77), 167 (100), 164 (79), 149 (78), 125 (100), 107 (80), 98 (75), 79 (78), 67 (78), 57 (76), 55 (75), 39 (75), 27 (61). Anal. Calcd for $C_{12}H_{22}O$: C, 79.06; H, 12.16. Found: C, 79.12; H, 12.19.

Reaction of Cyclopentanone with Diazoethane. Following the general protocol, cyclopentanone was converted to homologation products, 2-methylcyclohexanone, *cis*-2,7-dimethylcycloheptanone, *trans*-2,7-dimethylcycloheptanone, *trans*-2,3-dimethylcycloheptanone, *cis*-2,3-dimethylcycloheptanone, and 2-methyl-1-oxaspiro[2.4]heptane. The *cis*/*trans* configuration of 2,3- and 2,7-dimethylcycloheptanones was established by equilibration in methanolic NaOMe[10] and the products ratio was determined by GLC analysis: t_R(2-methylcyclohexanone) = 7.46 min, t_R(*cis*-2,7-dimethylcycloheptanone) = 13.55 min, t_R(*trans*-2,7-dimethylcycloheptanone) = 11.74 min, t_R(*trans*-2,3-dimethylcycloheptanone) = 21.79 min, t_R(*cis*-2,3-dimethylcycloheptanone) = 17.07 min, t_R(2-methyl-1-oxaspiro[2.4]heptane) = 6.18 and 6.84 min at the column temperature of 70 °C.

2,7-Dimethylcycloheptanones: IR (neat) 2971, 2928, 2855, 1705, 1456, 1375, 1335, 1213, 1186, 1169, 1134, 1092, 1013, 963, 934, 816 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.63 (2H, m, 2CH-C=O), 1.74-1.96 (4H, m, $2CH_2$), 1.07 (6H, d, J = 6.9 Hz, $2CH_3$). Anal. Calcd for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 77.01; H, 11.50.

2,3-Dimethylcycloheptanones: IR (neat) 2961, 2932, 2872, 1705, 1456, 1321, 1246, 1161, 1055, 542 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.02-2.64 (3H, m, CH_2-C=O and CH-C=O), 1.18-1.96 (7H, m, CH and $3CH_2$), 1.10 (3H, d, J = 6.8 Hz, CH_3-CH-C=O), 1.02 (3H, d, J = 6.7 Hz, CH_3-CH-CH-C=O). Anal. Calcd for $C_9H_{16}O$: C. 77.09; H, 11.50. Found: C, 76.94; H, 11.65.

The authentic 2-methyl-1-oxaspiro[2.4]heptanes were synthesized by treatment of a THF solution of cyclopentanone and 1,1-dibromoethane with *t*-BuLi at -78 to 0 °C.

2-Methyl-1-oxaspiro[2.4]heptanes:[16] ^1H NMR ($CDCl_3$) δ 2.86 (1H, q, J = 5.6 Hz, CH-O), 1.51-1.92 (8H, m, $4CH_2$), 1.26 (3H, d, J = 5.6 Hz, CH_3-C-O).

Reaction of Cyclopentanone with Trimethylsilyl-diazomethane. Following the general protocol, Lewis acid-promoted homologation of cyclopentanone with trimethylsilyldiazomethane afforded cyclohexanone, cycloheptanone, cyclooctanone and 1-oxaspiro[2.4]heptane. The ratio was established *via* GLC analysis by comparison with authentic samples: t_R(cyclohexanone) = 6.72 min, t_R(cycloheptanone) = 12.49 min, t_R(cyclooctanone) = 22.98 min, t_R(1-oxaspiro[2.4]heptane) = 5.43 min at the column temperature of 60 °C.

Reaction of 4-*tert*-Butylcyclohexanone with Diazomethane. Following the general protocol, 4-*tert*-butylcyclohexanone was converted to homologation products, 4-*tert*-butylcycloheptanone,[17] 5-*tert*-butylcyclooctanone,[18] 4-*tert*-butylcyclooctanone,[19] and 6-*tert*-butyl-1-oxaspiro[2.5]octanes.[20] The product ratio was determined by GLC analysis: t_R(4-*tert*-butylcycloheptanone) = 14.85 min, t_R(5-*tert*-butylcyclooctanone) = 21.06 min, t_R(4-*tert*-butylcyclooctanone) = 18.89 min, t_R(6-*tert*-butyl-1-oxaspiro[2.5]octanes) = 6.34 and 7.21 min at the column temperature of 110 °C.

4-*tert*-Butylcycloheptanone:[17] IR (neat) 1703 cm^{-1} (C=O); ^1H NMR ($CDCl_3$) δ 2.45-2.71 (4H, m, CH_2-C(=O)CH_2), 1.33-1.98 (7H, m, CH and $3CH_2$), 0.88 (9H, s, *t*-Bu).

Reaction of Cyclohexanone with Diazopropene. Following the general protocol, cyclohexanone was converted to 2-vinylcycloheptanone, exclusively, in 51% yield: IR (neat) 3081, 2930, 2857, 1705, 1634, 1456, 1343, 1323, 1173, 1154, 992, 916 cm^{-1}; ^1H NMR ($CDCl_3$) δ 5.94 (1H, ddd, J = 7.5, 10, 17.4 Hz, CH=C), 5.12 (1h, d, J = 10 Hz, CH=), 5.08 (1H, d, J = 17.4 Hz, CH=), 3.12-3.26 (1H, m, CH-C=O), 2.46-2.57 (2H, m, CH_2-C=O), 1.30-2.02 (8H, m, $4CH_2$); MS: *m/z* (%) = 138 (M^+, 70), 123 (43), 110 (41), 95 (71), 81 (77), 67 (74), 54 (67), 32 (99), 28 (100). Anal. Calcd for $C_9H_{14}O$: C, 78.21; H, 10.21. Found: C, 78.19; H, 10.25.

Reaction of Cyclooctanone with Diazoethane. Following the general protocol, cyclooctanone was converted to 2-methylcyclononanone, 2,9-dimethylcyclodecanone and 2-methyl-1-oxaspiro[2.7]decane. The ratio was established *via* GLC analysis by comparison with authentic samples: t_R(2-methylcyclononanone) = 13.32 min, t_R(2,9-dimethylcyclodecanone) = 23.12 min, t_R(2-methyl-1-oxaspiro[2.7]decane) = 8.68 min at the column temperature of 110 °C. The authentic 2-methyl-1-oxaspiro[2.7]decane was synthesized by treatment of a THF solution of cyclooctanone and 1,1-dibromoethane with *t*-BuLi at -78 to 0 °C.

2-Methylcyclononanone: IR (neat) 2961, 2930, 1701, 1466, 1445, 1375, 1211, 1150, 1134, 1028, 797 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.56-2.76 (1H, m, CH-C=O),

2.33-2.65 (2H, m, CH_2-C=O), 1.19-1.98 (12H, m, $6CH_2$), 1.05 (3H, d, J = 6.8 Hz, CH_3). Anal. Calcd for $C_{10}H_{18}O$: C, 77.89; H, 11.76. Found: C, 77.81; H, 11.94.

Reaction of Cyclooctanone with Diazohexane. Following the general protocol, cyclooctanone was converted exclusively to a single homologation product, 2-pentylcyclononanone in 88% yield: IR (neat) 2930, 2856, 1701, 1468, 1447, 1377, 1360, 1341, 1221, 1159, 1090, 1040, 997, 727 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.48-2.66 (1H, m, CH-C=O), 2.31-2.52 (2H, m, CH_2-C=O), 1.15-1.98 (20H, m, $10CH_2$), 0.87 (3H, t, J = 6.8 Hz, CH_3); MS: *m/z* (%) = 210 (M^+, 77), 181 (45), 167 (47), 153 (48), 140 (82), 125 (64), 111 (80), 98 (100), 84 (83), 55 (83), 41 (76), 39 (63), 27 (61). Anal. Calcd for $C_{14}H_{26}O$: C, 79.94; H, 12.46. Found: C, 79.90; H, 12.52.

Reaction of Acetophenone with Diazoethane. Following the general protocol, acetophenone was converted to 2-methyl-1-phenyl-1-propanone, 3-phenyl-2-butanone,[21] 2,3-dimethyl-1-phenyl-1-butanone[22] and 2-phenyl-2-butene oxide.[23] The ratio was established *via* GLC analysis by comparison with authentic samples: t_R(2-methyl-1-phenyl-1-propanone) = 11.21 min, t_R(3-phenyl-2-butanone) = 12.50 min, t_R(2,3-dimethyl-1-phenyl-1-butanone) = 18.04 min, t_R(2-phenyl-2-butene oxide) = 6.05, 6.94 min at the column temperature of 110 °C.

2-Methyl-1-phenyl-1-propanone: ^1H NMR ($CDCl_3$) δ 7.89-8.04 (2H, m, Ph-H), 7.41-7.61 (3H, m, Ph-H), 3.57 (1H, heptet, J = 7 Hz, CH-C=O), 1.23 (6H, d, J = 7 Hz, $2CH_3$).

3-Phenyl-2-butanone:[21] ^1H NMR ($CDCl_3$) δ 7.18-7.45 (5H, m, Ph-H), 3.75 (1H, q, J = 7.2 Hz, CH-C=O), 2.04 (3H, s, CH_3-C=O), 1.39 (3H, d, J = 7.2 Hz, CH_3).

2,3-Dimethyl-1-phenyl-1-butanone:[22] ^1H NMR ($CDCl_3$) δ 7.86-8.06 (2H, m, Ph-H), 7.39-7.62 (3H, m, Ph-H), 3.29 (1H, quintet, J = 7 Hz, CH-C=O), 2.10 (1H, octet, J = 7 Hz, CH), 1.13 (3H, d, J = 7 Hz, CH_3-C-C=O), 0.94 (3H, d, J = 7 Hz, CH_3), 0.89 (3H, d, J = 7 Hz, CH_3).

(*E*)-2-Phenyl-2-butene oxide:[23] ^1H NMR ($CDCl_3$) δ 7.20-7.53 (5H, m, Ph), 2.96 (1H, q, J = 6.2 Hz, CH-O), 1.65 (3H, s, CH_3), 1.42 (3H, d, J = 6.2 Hz, CH_3).

(*Z*)-2-Phenyl-2-butene oxide:[23] ^1H NMR ($CDCl_3$) δ 7.20-7.53 (5H, m, Ph), 3.19 (1H, q, J = 6.2 Hz, CH-O), 1.64 (3H, s, CH_3), 0.99 (3H, d, J = 6.2 Hz, CH_3).

Reaction of 2-Nonanone with Diazoethane. Following the general protocol, 2-nonanone was converted to 3-decanone, 2-decanone, and 2-methylnonanal. The ratio was established *via* GLC analysis by comparison with commercially available 2- and 3-decanone, and authentic 2-methylnonanal:[24] t_R(3-decanone) = 9.97 min, t_R(2-decanone) = 8.53 min, t_R(2-methylnonanal) = 7.00 min at the column temperature of 100 °C.

3-Decanone: IR (neat) 2957, 2930, 2857, 1717, 1458, 1418, 1375, 1132, 1107, 723 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.41 (2H, q, J = 7.3 Hz, $CH_3C\underline{H}_2C$=O), 2.39 (2H, t, J =7.3 Hz, CH_2C=O), 1.57 (2H, quintet, J = 7.3 Hz, $C\underline{H}_2$-CH_2C=O), 1.27 (8H, m, $4CH_2$), 1.05 (3H, t, J = 7.3 Hz, CH_3-C-C=O), 0.88 (3H, t, J = 6.7 Hz, CH_3).

2-Decanone: IR (neat) 2957, 2928, 2857, 1721, 1466, 1412, 1360, 1163, 720, 596 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.41 (2H, t, J = 7.4 Hz, CH_2-C=O), 2.13 (3H, s, CH_3C=O), 1.49-1.66 (2H, m, CH_2-C-C=O), 1.27 (10H, m, $5CH_2$), 0.88 (3H, t, J = 6.7 Hz, CH_3).

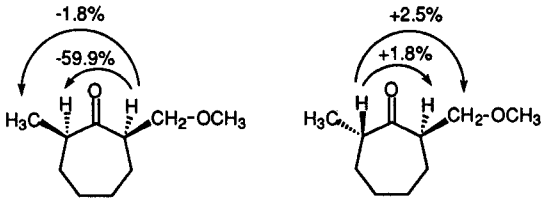
2-Methylnonanal:[24] IR (neat) 2959, 2928, 2857, 2809, 1702, 1528, 1460, 1397, 1377, 924, 723 cm^{-1}; ^1H NMR ($CDCl_3$) δ 9.62 (1H, d, J = 2.0Hz, CH=O), 2.33 (1H, d and sextet, J = 2.0, 6.9 Hz, CH-C=O), 1.40-3.58 (12H, m, $6CH_2$), 1.10 (3H, d, J = 6.9 Hz, CH_3), 0.89 (3H, t, J = 6.9 Hz, CH_3).

Reaction of 4-(*tert*-Butyldimethylsiloxy)-4-phenyl-2-butanone (9) with Diazoethane. Following the general protocol, the aldol derivative **9** was converted to 1-(*tert*-butyldimethylsiloxy)-1-phenyl-4-methyl-3-pentanone (**10**) in 51% yield: IR (neat) 2959, 2930, 2859, 1717, 1472, 1362, 1256, 1090, 1061, 1005, 938, 837, 779, 700 cm^{-1}; ^1H NMR ($CDCl_3$) δ 7.18-7.37 (5H, m, Ph), 5.22 (1H, dd, J = 4.0, 8.8 Hz, CH-OSi), 3.00 (1H, dd, J = 8.8, 15.4 Hz, C$\underline{H}$H-C=O), 2.50 (1H, dd, J = 4.0, 15.4 Hz, CH$\underline{H}$-C=O), 2.53 (1H, septet, J = 7.0 Hz, CH-C=O), 1.08 (3H, d, J = 7.0 Hz, CH_3), 1.03 (3H, d, J = 7.0 Hz, CH_3), 0.84 (9H, s, *t*-Bu), 0.01 (3H, s, CH_3-Si), -0.18 (3H, s, CH_3-Si). Anal. Calcd for $C_{18}H_{30}O_2Si$: C, 70.53; H, 9.86. Found: C, 70.50; H, 9.91.

Reaction of 2-(Methoxymethyl)cyclohexanone (11) with Diazoethane. Following the general protocol, the aldol derivative **11** was converted to *cis*- and *trans*-2-(methoxymethyl)-7-methylcycloheptanones, (**12**) and (**13**), in 69% and 71% yields using Me_3Al and MAD, respectively. The *cis/trans* configuration of 2-(methoxymethyl)-7-methylcycloheptanones was established by equilibration in methanolic NaOMe and the *cis/trans* ratio was determined by GLC analysis: t_R(*cis*-isomer, **12**) = 15.9 min, t_R(*trans*-isomer, **13**) = 17.9 min at the column temperature of 100 °C.

cis-2-(Methoxymethyl)-7-methylcycloheptanone (**12**): IR (neat) 2930, 2857, 2361, 1705, 1456, 1388, 1375, 1196, 1115, 980, 964 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.58 (1H, dd, J = 6.4, 9.2 Hz, C$\underline{H}$H-O), 3.38 (1H, dd, J = 6.2, 9.2 Hz, CH$\underline{H}$-O), 3.31 (3H, s, CH_3-O), 2.71-2.90 (1H, m, CH-C=O), 2.42-2.69 (1H, m, CH-C=O), 1.74-2.02 (4H, m, $2CH_2$), 1.17-1.48 (4H, m, $2CH_2$), 1.07 (3H, d, J = 7.0 Hz, CH_3-C-C=O); MS: *m/z* (%) = 170 (M^+, 98), 156 (15), 138 (85), 127 (100), 113 (99), 110 (90), 95 (87), 88 (99), 71 (89), 69 (89), 45 (91), 41 (89), 39 (71), 27 (66). Anal. Calcd for $C_{10}H_{18}O_2$: C, 70.55; H, 10.66. Found: C, 70.61; H, 10.73.

The *cis/trans* configuration of 2-(methoxymethyl)-7-methylcycloheptanones was further confirmed by 500 MHz ^1H NMR NOE experiments as shown below.



cis-isomer, **12** *trans*-isomer, **13**

Homologation of Decanal 14 (R = C_9H_{19}) with MAD/CH_3CHN_2 System. A 1 M hexane solution (1.2 mL, 1.2 mmol) of Me_3Al was added dropwise to a stirred solution of 2,6-di-*tert*-butyl-4-methylphenol (529 mg, 2.4 mmol) in CH_2Cl_2 (5 mL) at room temperature and the resulting colorless solution was stirred there for 1 h to furnish MAD in hexane/CH_2Cl_2. This solution was cooled to -78 °C and decanal (188 μL, 1 mmol) was added at this temperature, giving an decanal/MAD complex. Then, a 0.8 M CH_2Cl_2 solution (1.5 mL, 1.2 mmol) of CH_3CHN_2 was added in one portion at -78 °C. The whole mixture was stirred at -78 °C for 1 h. The reaction mixture was worked up with diluted HCl and extracted with CH_2Cl_2. The combined organic extracts were dried over Na_2SO_4, concentrated under reduced pressure, and purified by column chromatography on silica gel (ether/hexane = 1:20~1:10) to furnish a mixture of **15~19** (R = C_9H_{19}; R' = CH_3) (142 mg, 77% combined yield). The ratio was established *via* GLC analysis by comparison with authentic samples, which were independently synthesized: t_R(**15** (R = C_9H_{19}; R' = CH_3)) = 10.9 min, t_R(**16** (R = C_9H_{19}; R' = CH_3)) = 8.9 min, t_R(**17** (R = C_9H_{19}; R' = CH_3)) = 16.3 min, t_R(**18** (R = C_9H_{19}; R' = CH_3)) = 18.4 min, t_R(**19** (R = C_9H_{19}; R' = CH_3)) = 7.6 and 9.2 min at the column temperature of 120 °C.

3-Dodecanone **15** (R = C_9H_{19}; R' = CH_3): IR (neat) 2926, 2855, 1717, 1458, 1414, 1377, 1109, 722 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.42 (2H, q, J = 7.3 Hz, $CH_3C\underline{H}_2C$=O), 2.40 (2H, t, J =7.3 Hz, CH_2C=O), 1.58 (2H, m, $C\underline{H}_2$-CH_2C=O), 1.27 (12H, m, $6CH_2$), 1.06 (3H, t, J = 7.3 Hz, CH_3-C-C=O), 0.88 (3H, t, J = 6.7 Hz, CH_3); MS: *m/z* (%) = 184 (M^+, 20), 155 (89), 110 (16), 95(31), 85 (73), 72 (100), 57 (96), 43 (70), 27 (38). Anal. Calcd for $C_{12}H_{24}O$: C, 78.20; H, 13.12. Found: C, 78.21; H, 13.40.

2-Methylundecanal **16** (R = C_9H_{19}; R' = CH_3):[25] IR (neat) 2959, 2926, 2857, 1732, 1458, 924, 722 cm^{-1}; ^1H NMR ($CDCl_3$) δ 9.61 (1H, d, *J* = 2.0Hz, CH=O), 2.32 (1H, d and sextet, *J* = 2.0, 6.9 Hz, CH-C=O), 1.27-3.89 (16H, m, $8CH_2$), 1.08 (3H, d, *J* = 6.9 Hz, CH_3-C-C=O), 0.88 (3H, t, *J* = 6.8 Hz, CH_3); MS: *m/z* (%) = 184 (M^+, 4), 126 (23), 95 (13), 85 (17), 71 (46), 58 (100), 43 (62), 27 (11).

3-Methyl-4-tridecanone **17** (R = C_9H_{19}; R' = CH_3):[26] IR (neat) 2961, 2926, 2856, 1713, 1458, 1379, 722 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.43 (1H, sextet, *J* = 6.9 Hz, CH-C=O), 2.42 (2H, t, *J* = 7.1 Hz, CH_2-C=O), 1.20-1.78 (16H, m, $8CH_2$), 1.06 (3H, d, *J* = 6.9 Hz, CH_3-C-C=O), 0.88 (3H, t, *J* = 6.9 Hz, CH_3), 0.87 (3H, t, *J* = 7.2 Hz, CH_3); MS: *m/z* (%) = 212 (M^+, 30), 183 (9), 155 (52), 113 (17), 99 (45), 86 (100), 71 (77), 57 (95), 43 (67), 27 (27).

4-Methyl-3-tridecanone **18** (R = C_9H_{19}; R' = CH_3): IR (neat) 2926, 2855, 1716, 1458, 975, 771 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.54 (1H, quintet, *J* = 6.8 Hz, CH-C=O), 2.45 (2H, dq, *J* = 1.2, 7.3 Hz, CH_2-C=O), 1.63 (2H, m, CH_2-C-C=O), 1.18-1.39 (14H, m, $7CH_2$), 1.06 (3H, d, *J* = 7.3 Hz, $C\underline{H}_3$-CH-C=O), 1.05 (3H, t, *J* = 7.3 Hz, $C\underline{H}_3$-CH_2-C=O), 0.88 (3H, t, *J* = 6.7 Hz, CH_3); MS: *m/z* (%) = 212 (M^+, 31), 183 (6), 155 (84), 113 (14), 99 (24), 86 (98), 71 (73), 57 (100), 43 (63), 27 (21). Anal. Calcd for $C_{14}H_{28}O$: C, 79.18; H, 13.29. Found: C, 79.24; H, 13.31.

2-Dodecene Oxides **19** (R = C_9H_{19}; R' = CH_3):[27] IR (neat) 2926, 2856, 1471, 1458, 1390, 979, 829, 758, 725 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.04 (1H, dq, *J* = 1.2, 5.9 Hz, CH_3-C$\underline{H}$-O), 2.89 (1H, dt, *J* = 1.2, 6.4 Hz, CH_2-C$\underline{H}$-O), 1.18-1.59 (16H, m, $8CH_2$), 1.26 (3H, d, *J* = 5.6 Hz, CH_3-C-O), 0.88 (3H, t, *J* = 6.6 Hz, CH_3); MS: *m/z* (%) = 184 (M^+, 13), 168 (35), 155 (45), 111 (34), 69 (93), 57 (83), 43 (100), 27 (21).

Reaction of Decanal 14 (R = C_9H_{19}) with Me_3Al/Me_3SiCHN_2 System. Following the general protocol, decanal **14** (R = C_9H_{19}) was converted to 2-undecanone almost exclusively in 98% yield. The isomeric ratio was determined *via* GLC analysis by comparison with commercially available samples: t_R(**15** (R = C_9H_{19}; R' = H)) = 11.34 min, t_R(**16** (R = C_9H_{19}; R' = H)) = 10.26 min, t_R(**17** (R = C_9H_{19}; R' = H)) = 15.06 min, t_R(**18** (R = C_9H_{19}; R' = H)) = 11.49 min, t_R(**19** (R = C_9H_{19}; R' = H)) = 9.66 min at the column temperature of 110 °C.

Reaction of Decanal 14 (R = C_9H_{19}) with ATPH/CH_2N_2 System. Following the general protocol, decanal **14** (R = C_9H_{19}) was converted to 1-undecene oxide **20** (R = C_9H_{19}) almost exclusively in 84% yield.

1-Undecene Oxide **20** (R = C_9H_{19}): IR (neat) 3044, 2926, 2856, 1466, 1410, 1379, 1259, 916, 837 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.92 (1H, m, CH-O), 2.76 (1H, dd, *J* = 4, 5 Hz, C$\underline{H}$H-O), 2.47 (1H, dd, *J* = 2.7, 5 Hz, CH$\underline{H}$-O), 1.07-1.62 (16H, m, $8CH_2$), 0.90 (3H, t, *J* = 6.7 Hz, CH_3). Anal. Calcd for $C_{11}H_{22}O$: C, 77.58; H, 13.02. Found: C, 77.48; H, 13.03.

Reaction of Cyclohexanecarboxaldehyde 14 (R = cyclohexyl) with Diazoethane. Following the general protocol, cyclohexanecarboxaldehyde **14** (R = cyclohexyl) was converted to homologation products, cyclohexyl ethyl ketone **15** (R = cyclohexyl; R' = CH_3), 2-(cyclohexyl)propanal **16** (R = cyclohexyl; R' = CH_3),[28] *sec*-butyl cyclohexyl ketone **17** (R = cyclohexyl; R' = CH_3),[29] 2-cyclohexyl-3-pentanone **18** (R = cyclohexyl; R' = CH_3),[30] 1-cyclohexylpropene oxide **19** (R = cyclohexyl; R' = CH_3).[31] The products ratio was determined by GLC analysis: t_R(**15** (R = cyclohexyl; R' = CH_3)) = 15.44 min, t_R(**16** (R = cyclohexyl; R' = CH_3)) = 14.56 min, t_R(**17** (R = cyclohexyl; R' = CH_3)) = 26.08 min, t_R(**18** (R = cyclohexyl; R' = CH_3)) = 32.67 min, t_R(**19** (R = cyclohexyl; R' = CH_3)) = 9.47 and 10.84 min at the column temperature of 80 °C.

Cyclohexyl ethyl ketone **15** (R = cyclohexyl; R' = CH_3): IR (neat) 2932, 2855, 1713, 1451, 1414, 1375, 1347, 1148, 1115, 976, 891, 828 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.47 (2H, q, *J* = 7.3 Hz, CH_2C=O), 2.36 (1H, m, CH-C=O), 1.12-1.97 (10H, m, $5CH_2$), 1.05 (3H, d, *J* = 7.3 Hz, CH_3-C-C=O); MS: *m/z* (%) = 140 (M^+, 80), 111 (81), 83 (100), 55 (94), 41 (65), 27 (26). Anal. Calcd for $C_9H_{16}O$: C, 77.09; H, 11.50. Found: C, 77.00; H, 11.64.

2-(Cyclohexyl)propanal **16** (R = cyclohexyl; R' = CH_3):[28] IR (neat) 2926, 2855, 2699, 1725, 1449, 1399, 1375, 1003, 889, 822 cm^{-1}; ^1H NMR ($CDCl_3$) δ 9.66 (1H, d, *J* = 2.3 Hz, CH=O), 2.22 (1H, m, CH-C=O), 0.98-1.67 (11H, m, CH and $5CH_2$), 1.05 (3H, dd, *J* = 1.5, 7.0 Hz, CH_3-C-C=O).

sec-Butyl cyclohexyl ketone **17** (R = cyclohexyl; R' = CH_3):[29] IR (neat) 2965, 2932, 2857, 1709, 1451, 1379, 1144, 1059, 990, 893 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.60 (1H, sextet, *J* = 6.9 Hz, CH_3-C$\underline{H}$-C=O), 2.45 (1H, m, CH-C=O), 1.16-1.84 (12H, m, $6CH_2$), 1.03 (3H, d, *J* = 6.9 Hz, CH_3-C-C=O), 0.85 (3H, t, *J* = 7.5 Hz, CH_3).

2-Cyclohexyl-3-pentanone **18** (R = cyclohexyl; R' = CH_3):[30] IR (neat) 2977, 2928, 2853, 1715, 1449, 1375, 1356, 1109, 974, 891 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.43 (2H, q, *J* = 7.3 Hz, CH_2-C=O), 2.34 (1H, quintet, *J* = 7.2 Hz, CH-C=O), 1.07-1.79 (11H, m, CH and $5CH_2$), 1.04 (3H, t, *J* = 7.3 Hz, $C\underline{H}_3$-CH_2-C=O), 1.00 (3H, d, *J* = 7.0 Hz, $C\underline{H}_3$-CH-C=O).

1-Cyclohexylpropene Oxide **19** (R = cyclohexyl; R' = CH_3):[31] IR (neat) 2928, 2855, 1541, 1508, 980, 938, 858, 754 cm^{-1}; ^1H NMR ($CDCl_3$) δ 3.08 (1H, dq, *J* = 1.2, 5.5 Hz, $CH_3C\underline{H}$-O), 2.84 (1H, dq, *J* = 2.3, 5.2 Hz, diastereomeric $CH_3C\underline{H}$-O), 2.64 (1H, m, CH-C$\underline{H}$-O), 2.47 (1H, dd, *J* = 2.2, 6.5 Hz, diastereomeric CH-C$\underline{H}$-O), 1.32 (3H, d, *J* = 5.2 Hz, CH_3), 1.03-2.02 (11H, m, CH and $5CH_2$).

Reaction of Cyclohexanecarboxaldehyde 14 (R = cyclohexyl) with Me_3Al/Me_3SiCHN_2 System. Following the general protocol, cyclohexanecarboxaldehyde **14** (R = cyclohexyl) was converted to homologation products, cyclohexyl methyl ketone **15** (R = cyclohexyl; R' = H), cyclohexylethanal **16** (R = cyclohexyl; R' = H),[32] cyclohexyl ethyl ketone **17** (R = cyclohexyl; R' = H), cyclohexylacetone **18** (R = cyclohexyl; R' = H),[33] vinylcyclohexane oxide **19** (R = cyclohexyl; R' = H). The products ratio was determined by GLC analysis: t_R(**15** (R = cyclohexyl; R' = H)) = 11.07 min, t_R(**16** (R = cyclohexyl; R' = H)) = 10.50 min, t_R(**17** (R = cyclohexyl; R' = H)) = 16.28 min, t_R(**18** (R = cyclohexyl; R' = H)) = 18.85 min, t_R(**19** (R = cyclohexyl; R' = H)) = 9.13 min at the column temperature of 80 °C.

Reaction of Cyclohexanecarboxaldehyde 14 (R = cyclohexyl) with ATPH/CH_2N_2 System. Following the general protocol, cyclohexanecarboxaldehyde **14** (R = cyclohexyl) was converted to vinylcyclohexane oxide **20** (R = cyclohexyl) almost exclusively in 81% yield.

Vinylcyclohexane Oxide **20** (R = cyclohexyl): IR (neat) 3046, 2928, 2853, 1483, 1250, 1169, 1132, 943, 880, 858, 837, 803 cm^{-1}; ^1H NMR ($CDCl_3$) δ 2.74 (1H, m, CH-O), 2.73 (1H, dd, *J* = 1.9, 4.5 Hz, CH$\underline{H}$-O), 2.55 (1H, dd, *J* = 3.4, 4.4 Hz, C$\underline{H}$H-O), 1.04-2.02 (11H, m, CH and $5CH_2$). Anal. Calcd for $C_8H_{14}O$: C, 76.14; H, 11.18. Found: C, 76.19; H, 11.20.

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